Sustainable and optimal use of biomass for energy in the EU beyond 2020

Annexes of the Final Report

PricewaterhouseCoopers EU Services EESV's consortium

To

EC
Directorate General for Energy
Directorate C1 –
Renewables and CCS policy

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Annex A - Biomass supply potentials for the EU and biomass demand from the material sector by 2030

Annex B - Short summary BioSustain Stakeholder Workshop and Background paper for the stakeholder consultation workshop of the Biosustain project

Annex C - Modelling framework

Annex D - Results public consultation sustainable bioenergy policy

Annex E - Policy context and gap analysis

Annex F - Administrative cost analysis

Annex G - Price increases for Scenario Option 5

Table of Contents

Annex A - Biomass supply potentials for the EU and biomass demand from the material sector by 2030

Annex B - Short summary BioSustain Stakeholder Workshop and Background paper for the stakeholder consultation workshop of the Biosustain project

Annex D - Results public consultation sustainable bioenergy policy

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Biomass supply potentials for the EU and biomass demand from the material sector by 2030

Annex A

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Biomass supply potentials for the EU and biomass demand from the material sector by 2030

Technical Background Report of the "BioSustain" study: Sustainable and optimal use of biomass for energy in the EU beyond 2020

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Abbreviations

a	annum (year)
ARA	Antwerp, Rotterdam and Amsterdam region
bbl	Oil barrel (159 L)
BIT-UU	Biomass Intermodal Transportation model - Utrecht University
BU	Bottom-Up
CCL	Climate Change Levy
CH_4	Methane
CHP	Combined Heat and Power
CIF	Cost, Insurance and Freight
CO_2	Carbon dioxide
DECC	Department of Energy & Climate Change (UK)
dLUC	direct land use change
EC	European Commission
EJ	Exa joule (1 x $10^{\wedge 18}$ joule)
EU	European Union (EU28)
FAME	Fatty Acid Methyl Ester
FOB	Free on Board
GHG	Greenhouse gas
GIS	Geographic Information System
GJ	Giga joule (1 x $10^{\wedge 9}$ joule)
iLUC	indirect land use change
kt	kilotonne (1 x $10^{\wedge 6}$ kg)
LHV	Lower Heating Value
MJ	Mega joule (1 x $10^{\wedge 6}$ joule)
M m^3	Million cubic metre (sometimes also hm^3 is used)
Mt	Million tonne (1 x $10^{\wedge 9}$ kg)
Mtoe	million tonne of oil equivalent (41.868 PJ)
N_2O	Nitrous oxide
NG	Natural Gas
NGO	Non-governmental organization
NREAP	National Renewable Action Plans
NUTS2	Nomenclature of Territorial Units for Statistics
PJ	Peta joule (1 x $10^{\wedge 15}$ joule)
PV	Photovoltaics
RE	Renewable Energy
RED	Renewable Energy Directive
RES	Renewable Energy Sources
RES-E	renewable electricity
RES-H	renewable heat
RES-T	renewable transport
SWE	Solid Wood Equivalent
t	metric tonne (1000 kg)
toe	tonne of oil equivalent (41.868 GJ)
UK	United Kingdom
US	United States
wpe	wood pellet equivalent (17.6 MJ/kg)

Executive Summary

This report describes the current biomass uses and reviews current and future biomass supply potentials from EU feedstocks and extra-EU imports. The results will be used to support the design of plausible biomass supply scenarios to 2030 and update the existing biomass cost-resource curves used in the energy system model Green-X.

To assess the future potential of bioenergy, realistic 2030 biomass supply scenarios have been developed building on a review of the sustainable biomass potentials from agriculture, forests and waste that could be available for the EU, through domestic sustainable production or international markets. Secondly, competing demand in forest markets and novel material use and biochemistries are assessed in order to identify additional demand for biomass.

The sustainable supply of wood sources is not a fixed point but it is represented by a “corridor” of options society may take within given borders. The corridor describes the options for sustainable utilisation. It is quantified by the three realisable supply scenarios: **Restricted**, **Reference** and **Resource**. Extra-EU supply scenarios of liquid biofuels and solid biomass have been aligned to the forest supply scenarios. Biomass potentials from agriculture (i.e. energy crops and agricultural residues) and organic waste do not differ between the three supply scenarios.

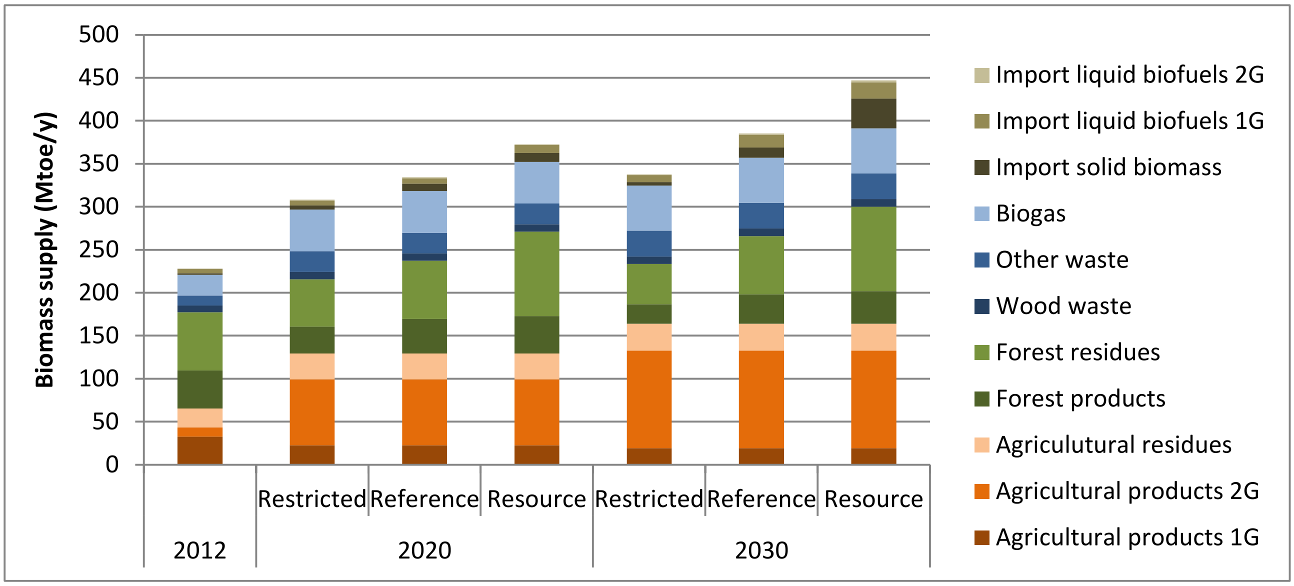
Total potential supply of biomass for energy use in the EU28 in 2012, 2020 and 2030

The estimated potential of biomass for bioenergy from forest, agriculture and waste sectors as well as import from outside the EU of today is well above today’s primary production of biomass for energy in the EU28 (123 Mtoe in 2013) and net imports from outside the EU (4.9 Mtoe in 2013).

Today, biomass use for energy purposes (bioenergy) contributes 1,342 Mtoe or about 10% to the global total primary energy supply (TPES) compared to 128 Mtoe in the EU28 or 8 % of gross inland consumption in 2013 and 105 Mtoe (10%) of final energy consumption. Heat is still the largest sector of final bioenergy consumption representing 75% of total final bioenergy in the EU28 and with its main end-use in the residential sector, followed by electricity (13 %) and transport fuels (12 %). Solid biomass, mainly from forest resources, represents the largest share (90.8 Mtoe gross inland renewable energy consumption), followed by liquid biomass (14.4 Mtoe), biogas (13.5 Mtoe) and organic waste (9.1 Mtoe).

However, it should be noted that part of this supply potential might be difficult to mobilize. In particular additional supply of stemwood and forest residues depends on forest management constrains. The domestic supply in the EU28 in 2030 ranges between 338 Mtoe in the Restricted scenario to 391 Mtoe in the Resource scenario. The future share of solid biomass and liquid biofuels supply from extra-EU sources ranges between 4% (13 Mtoe) in the Restricted scenario to 14% (56 Mtoe) in the Resource scenario compared to 4% in 2013 (4.92 Mtoe).

Figure 0-1. Overview of estimated biomass potential for bioenergy in the EU28 in 2010, 2020 and 2030 in terms of primary energy.



Biogas and liquid import of liquid biofuels are shown in final energy units.
1G: food-based energy crops/biofuels
2G: lignocellulosic energy crops/biofuels

Forest biomass

Forest biomass can be divided into biomass from primary forest products (stemwood, other industrial roundwood), primary forest residues (logging residues), secondary forest residues (wood processing industrial residues, like sawdust, bark and black liquor) and, wood wastes (construction and demolition wood, post-consumer wood).

The total growing stock of forest biomass in the EU is estimated around 21,000 Mm³ solid wood equivalent (swe) (or 4,400 Mtoe), with a theoretical annual increment of total biomass of 1,277 M m³ swe overbark[1] (268 Mtoe) in the EU. However, various technical, environmental and social constraints and conditions reduce the total achievable supply potential for all uses (energy and materials) to about 710 Mm³ swe.

Total material demand of primary forest products and residues is projected to increase from 310 Mm³ in 2010 to 365 Mm³ in 2030. As a consequence, 450 to 550 Mm³ swe are available for energy uses, depending on the scenario (Restricted, Reference, Resource). At least 350 Mm³ are already used for bioenergy in 2010 . Thus, the additional potential for bioenergy use lies roughly between 100 to 200 Mm³ in the period 2020 - 2030, mostly in the form of forest residues. However, mobilisation of these depends very much on technical solutions, because of the actual technical focus on the stem and high cost of manual collection. Furthermore, there can be quite high environmental restrictions on the use of

[1] Overbark is used when the volume of wood also includes bark. If bark is excluded, the qualification underbark is used.

residues. The environmental effects of residue utilization are discussed controversially in relation the extractions of nutrients and deadwood which may be solved in accordance to forest stands. The three supply scenarios Restricted, Reference and Resource, assess different strategies of forest biomass mobilisation and the associated corridor of sustainable biomass supply.

Coniferous stemwood (softwood) is almost completely used for material uses, leaving between 1.0 Mm^3 (Restricted) and 44 Mm^3 (Resource) available for energy in 2030. Non-coniferous stemwood (hardwood) is technically available (60-110 Mm^3), however, the mobilisation of high value assortments for energy use is likely to be problematic, because prices for high-grade hardwood are above the resource price level of biomass plants. Primary forest residues are the largest reserve for woody biomass for energy (29 – 265 Mm^3). Bark is harvested with stems and its potential is, therefore, directly connected with mobilisation of stemwood (42-49 Mm^3).

Landscape care wood has an interesting potential especially for communities who are often the owner of such resource. However, a large proportion is garden wood, often used by households as firewood. Post-consumer wood is a significant resource as well (45 Mm^3 in 2010, 26 Mm^3 in 2030). In countries with good collection systems, it is already widely used, while in other countries it is not yet available. Secondary forest residues, like black liquor is already completely used for energy today or like sawmill residues to some extend for energy, but mainly for material uses with 67 Mm^3 (82%) in 2010 increasing to 82 Mm^3 (88%) in 2030.

Energy crops

Energy crops are grown for the purpose of bioenergy production. They can be classified in annual crops and perennial crops or food and non-food energy crops. Non-food crops are unsuitable for food and/or feed consumption and are most often perennial (for example, miscanthus, switchgrass) and short rotation coppice (for example poplar, willow). Most food crops used for bioenergy purposes are annual crops (for example wheat, sugar beet or rapeseed).

The total Utilised Agricultural Area (UAA) in the EU28 adds up to 181 Mha in 2012 and decreased to 177 Mha in 2013. Arable land makes up the largest area (112 Mha in 2012, 106 Mha in 2013, permanent cropland cultivated with perennial crops covers 11 Mha and 12 Mha in 2012 and 2013 respectively and permanent grassland remained constant at 58 Mha between 2012 and 2013. In 2012, total arable land used for biofuel feedstock cultivation in the EU28 was 4.4 Mha. Furthermore, crops cultivated for co-digestion take up a significant share (1 Mha in Germany).

Future land available for bioenergy is projected to be 23 Mha in 2020 and 24 Mha in 2030 (18%-19% of total arable land, 12%-13% of utilized agricultural area). The total supply potential of dedicated energy crops in the EU is estimated to increase from 39 Mtoe in 2010 to 131 Mtoe in in 2030. In particular, high yield lignocellulosic crops (grassy crops, short rotation coppice) make up the largest potential, increasing from 11 Mtoe in 2012 to 113 Mtoe in 2030.

Agricultural residues and manure

Agricultural residues can be segmented into primary residues (or harvest residues) that are produced on the field (for example straw, prunings, cuttings), secondary agricultural residues that are produced from processing of harvested products (for example, bagasse or rice husks) and on-farm residues (manure).

Straw currently makes up the largest potential of agricultural residues. Its potential highly depends on the sustainable extraction rate to maintain soil quality and to the competitive uses of the residues (for example for animal bedding); both factors are varying per country. The potential for primary harvest residues is estimated to stay fairly constant in time.

The largest growth in terms of agricultural biomass potentials for energy is, however, projected in agriculture biogas, increasing from 15 Mtoe in 2010 to 40 Mtoe in 2030. Animal manure is the largest supply source of agriculture biogas (47%), followed by biogas from pasture residues (28%) and agriculture products such as maize (18%).

Organic waste

Next to forestry and agriculture, organic waste is the third main category of biomass that can potentially be used for energy generation. An important share of waste is of biological origin (paper, wood, food waste, garden waste).

The main waste categories, as reported in Eurostat, consisting partly or entirely of organic material are: (1) paper and cardboard wastes, (2) animal and mixed food waste, (3) vegetal wastes, (4) household and similar wastes, (5) common sludges and (6) wood wastes. Wood waste is not included in this assessment as it is already covered in the assessment of forestry biomass.

A substantial growth of bioenergy from waste is possible, from current levels around 11 Mtoe in 2012, up to around 25-30Mtoe in 2030, which is more than double current use. The main potential for waste biomass in the next decades still lies in the incineration (and energy recovery) of mixed household and similar waste in waste-to-energy plants (~14 Mtoe/y). The potential of other (separated) fractions generally varies between 3 and 5 Mtoe each. Used animal fats and vegetable oils can be important as feedstock for 'advanced' biodiesel. A substantial share (> 1 Mtoe/y) is already used for this application today; mind that used cooking oils are already traded between countries for this purpose.

Trends in waste management (waste generation, recycling targets, share of landfill) have a substantial impact on total potentials. These have been taken into account, both in the baseline scenarios and in sensitivity runs performed for this study by applying stronger waste management evolutions compared to the baseline scenario (reduced MSW generation, higher landfill reduction, higher waste separation, decoupling of sector waste from GDP growth). Some of these effects increase the energy potential (e.g. reduced landfill), other reduce the potential (e.g. reduced waste generation, higher waste separation). When combining the different effects, the energy potential could reduce by around 5 Mtoe (own calculations).

The potential for paper and cardboard is very low (about 3% of recovered material or 0.18 Mtoe in 2012, 0.33 Mtoe in 2030), as most of those fractions will go to recycling. Material recycling (e.g. paper recycling) is excluded from the energy potential. Recovery options for separated waste biomass fractions such as vegetal waste or mixed animal and food waste consist of a balance of material applications (e.g. oleochemicals, but also soil improvers such as compost) and energy applications. There may be a trend to convert current compost facilities to pre-digestion and post-composting.

Biomass demand for novel materials (biochemicals and bio-polymers) to 2030

Biomass demand for novel materials (biochemicals) has a higher priority over energy use and should therefore be subtracted from overall supply potentials to calculate the feedstock surplus available for bioenergy use.

There are different options of using biomass for the production of chemicals. Biobased surfactants and solvents (mostly based on vegetable oils/animal fats, sugar or starch) are currently the most important biobased applications in chemistry; however, highest growth rates (between 10 and 15% CAGR) are expected in biopolymers / biobased plastics.

The projected biobased raw material demand from chemistry in 2030 is estimated in the range of 5 to 10 Mtoe, which is still much lower than biofuels or bioenergy.

Biopolymer demand in the EU by 2030 is estimated in the range of 2 to 3 million tonnes. Current raw materials are mainly sugar and starch (and cellulose for some specific chemicals); this is expected to remain in the near future, although a shift to 2nd generation pre-treatment processes (producing sugars from lignocellulose) can be anticipated, although at a slower pace than for biofuels.

Under certain assumptions (80% sugar/starch input; 20% lignocellulose input), biopolymers would induce a resource demand of 4 million tonnes of sugar/starch and 1.5 to 2 million tonnes of lignocellulose.

Mind that these figures are in relation to the European market *demand* of bio-plastics which may evolve differently from production; with current evolutions it is very likely that a substantial part of the production will happen outside Europe (e.g. South America, Asia).

Another application of biomass resources in materials would be in biocomposites, which are around 50% biobased. A forecast indicates that more than half of EU composite production (of 2.4 million tonnes per year) could be bio-composites in 2030, which would require around 0.5 million tonnes of woody biomass and 0.2 million tonnes of natural fibres.

1 Introduction

I.1. Policy background

Biomass is a versatile energy source that can substitute fossil energy in the energy sectors electricity, heat and transport fuels as well as non-energy use of fossil resources, for example replacing cokes in steel industries or replacing petroleum based polymers with biobased polymers. As a result of increasing efforts to mitigate greenhouse gas (GHG) emissions and improve energy supply security by diversification and reducing dependencies on fossil energy carriers, the use of biomass for energy purposes (bioenergy) has grown exponentially in the last decade (Lamers, Marchal, et al. 2014a; Lamers, Rosillo-Calle, et al. 2014). In the European Union (EU), member states have agreed on binding targets to increase the share of renewable energy to 20 % of gross final energy consumption by 2020, as was set out in the Renewable Energy Directive (RED) 2009/EC/28 (EC, 2009). To meet this target, EU member states expect that bioenergy will increase with 44 % by 2020 compared to actual production in 2010 and with the largest growth anticipated in electricity and liquid transport fuels (van Stralen *et al.*, 2013).

Beyond 2020, the EU is committed to reduce GHG emissions with 40 % compared to 1990 levels by 2030 and at least 27 % renewable energy without country specific targets and 27 % energy saving compared to 2007 (COM(2014) 15 final (EC, 2014). In its communications on the Energy Union Strategy and the EU climate and energy framework for 2030, the European Commission announced that a new Renewable energy package for the post-2020 period will be presented in 2016-2017, including an improved bioenergy policy. The latter should "maximise the resource efficient use of biomass in order to deliver robust and verifiable GHG savings and to allow for fair competition between the various uses of biomass resources in the construction sector, paper and pulp industries and biochemical and energy production. This should also encompass the sustainable use of land, the sustainable management of forests in line with the EU's forest strategy and address indirect land use effects as with biofuels" (EC, 2014).

In context of the EU forest strategy (COM(2013) 659), the Commission undertook to develop objective, ambitious and demonstrable EU sustainable forest management criteria that can be applied in different policy contexts regardless of the end use of forest biomass. Under the EU bioeconomy strategy, the Commission will undertake research on biomass availability for all uses post-2020 and on good practice regarding optimal use of biomass.

I.2. Objectives

The BioSustain project ('*Sustainable and optimal use of biomass for energy in the EU beyond 2020 – An Impact Assessment*') aims to assess the environmental, economic and social impacts of plausible policy options to ensure the sustainable production and use of bioenergy in the EU beyond 2020, in respect to the increasing demand for biomass within the bioenergy sector and in other sectors like material use and biochemistry.

To this purpose, the consortium will develop realistic 2030 biomass supply scenarios building on a review of the sustainable biomass potentials from agriculture and forests that could be available for the EU, through domestic sustainable production or international markets. The review of biomass, presented in this report, builds on the methodological framework developed in the Biomass Energy Europe (BEE) project and extends this with new studies and insights.

Secondly, the consortium will develop realistic 2030 EU biomass consumption scenarios, not only for energy but also for other sectors of the biobased economy (material use and biochemistry). Potential competition for the biomass resources within the bioenergy sector and with other sectors will be addressed.

To ensure a sustainable production and use of bioenergy in the EU, the consortium will review existing risks related to biomass use post-2020, review relevant EU/MS measures related to biomass sustainability, assess the impacts of further development of possible mitigation options at EU level (particularly administrative costs for bioenergy operators and public authorities), and evaluate them against the principles of subsidiarity and proportionality.

I.3. Biomass feedstock categories

This study uses the existing classification of biomass feedstocks used in the Green-X model that are divided in three main types of biomass categories, consistent with BEE: (1) forest products and forests residues, (2) energy crops and agricultural residues and (3) organic wastes. Furthermore, imports of biomass from outside Europe are considered. The focus of the review in this report is on forest biomass (including post-consumer wood) and agriculture biomass (excluding manure); for organic wastes, reference is made to the on-going project Biomass Policies. For extra-EU supply, the focus is on solid biomass.

Forest biomass

- Primary forest products (stemwood, complementary fellings)
- Primary forest residues (logging residues, stumps)
- Secondary forest residues (wood processing industry by-products and residues, like sawdust, bark and black liquor)
- Construction and demolition wood (post-consumer wood)

Biomass from agriculture

Energy crops

- Conventional food crops (starch, sugar or oil seed crops)
- Non-food energy crops (perennial grasses, short rotation coppice)

Agriculture residues

- Primary or harvest residues (like straw, corn stover) produced in the field
- Secondary residues from the processing of harvested products (like bagasse, rice husks)
- Manure

Organic waste[2]

- Paper and cardboard waste
- Animal and mixed food waste (including used fats and oils)
- Vegetal wastes
- Biodegradable fraction of household and similar waste
- Common Sludges

Extra-EU supply[3]

- Wood pellets from forest products and residues
- Agripellets from agriculture residues
- Liquid biofuels

[2] Wood waste is included in forest biomass

[3] Solid biomass imports have been dominated by pellets from forestry products and residues. Pellets from forest residues and products will remain the largest source for import, but the supply scenarios will also include pellets from agriculture residues (agripellets) and palm kernel shells (PKS).

2 Method

2.1 General Overview

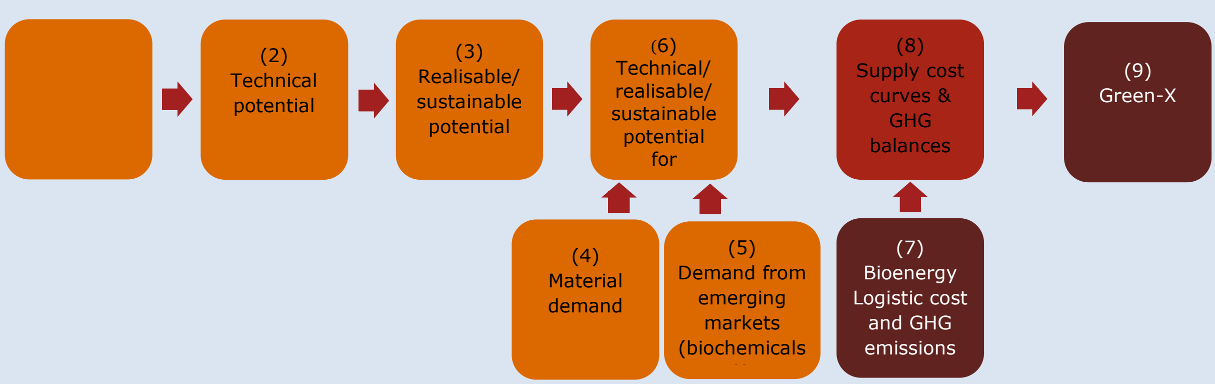
The potential for energy production from biomass is affected by biomass supply, but also demand dynamics in different sectors of the economy. In order to ensure sustainable production and supply of biomass for energy purposes, therefore, an insight is needed in the supply side of the market (forest, agriculture, waste) and associated sustainability constraints as well as demand for other purposes, including food, feed, fibre and biochemicals. The assessment undertaken in Task 1 (biomass supply potentials) and Task 2 (biomass consumption scenarios) of the BioSustain study aims at providing suitable consideration on both the complexity and the trade-offs between biomass supply, technical and sustainability constraints and demand across sectors.

This report helps introducing the outcomes of these analyses, providing the potentials of biomass that are available for the energy sector, i.e. the supply potentials for bioenergy, as a final outcome. The general approach of the analysis is outlined below in Box 1. Please note that, in this report, derived bioenergy potentials serve as input for the subsequent energy sector modelling and the related sustainability assessment.

Box 1. General approach to determine the biomass supply potential available for bioenergy

Based on an up-to-date review of available literature *(step 1)*, technical supply potentials of biomass are derived, indicating the (technical) upper boundary for the supply of biomass in Europe *(step 2)*. When constraints are taken into consideration (e.g. biomass management practices and sustainability concerns), technical potentials are reduced and, consequently, sustainable/achievable potentials can be indicated *(step 3)*. A biomass demand assessment from Materials sector *(step 4)* and from emerging market (biochemicals) *(step 5)* is then undertaken, complementing the previous one. In our analysis, such demand has a higher priority over energy use and, therefore, subtracted from overall supply potentials to calculate the feedstock surplus available for bioenergy use *(step 6)*. Finally, costs and GHG emissions concerning biomass feedstock supply are calculated taking intra-EU and extra-EU trade routes into account *(step 7 and 8)*. Supply cost curves and the associated GHG balances are input to the biomass trade module in the energy system model Green-X (9). A more detailed characterisation of Green-X is provided in Box 2.

Figure 2-1. General approach to determine the supply potential of biomass for bioenergy (adapted from BioTrade2020+)



Box 2. General approach to determine the biomass supply potential available for bioenergy

Brief characterization of the Green-X model:

The model Green-X has been developed by the Energy Economics Group (EEG) at the Vienna University of Technology under the EU research project "Green-X–Deriving optimal promotion strategies for increasing the share of RES-E in a dynamic European electricity market" (Contract No. ENG2-CT-2002-00607). Initially focussed on the electricity sector, this modelling tool, and its database on renewable energy (RES) potentials and costs, has been extended to incorporate renewable energy technologies within all energy sectors.

Green-X covers the EU-28 in full scope and has been extended recently to cover (with less detail) Turkey, the Western Balkans and Norway. It allows the investigation of the future deployment of RES as well as the accompanying cost (including capital expenditures, additional generation cost of RES compared to conventional options, consumer expenditures due to applied supporting policies) and benefits (for instance, avoidance of fossil fuels and corresponding carbon emission savings). Results are calculated at both a country- and technology-level on a yearly basis. The time-horizon allows for in-depth assessments up to 2030. The Green-X model develops nationally specific dynamic cost-resource curves for all key RES technologies, including for renewable electricity, biogas, biomass, biowaste, wind on- and offshore, hydropower large- and small-scale, solar thermal electricity, photovoltaic, tidal stream and wave power, geothermal electricity; for renewable heat, biomass, sub-divided into log wood, wood chips, pellets, grid-connected heat, geothermal grid-connected heat, heat pumps and solar thermal heat; and, for renewable transport fuels, first generation biofuels (biodiesel and bioethanol), second generation biofuels (lignocellulosic bioethanol, biomass to liquid), as well as the impact of biofuel imports. Besides the formal description of RES potentials and costs, Green-X provides a detailed representation of dynamic aspects such as technological learning and technology diffusion.

Through its in-depth energy policy representation, the Green-X model allows an assessment of the impact of applying (combinations of) different energy policy instruments (for instance, quota obligations based on tradable green certificates / guarantees of origin, (premium) feed-in tariffs, tax incentives, investment incentives, auctions, impact of emission trading on reference energy prices) at both country or European level in a dynamic framework. Sensitivity investigations on key input parameters such as non-economic barriers (influencing the technology diffusion), conventional energy prices, energy demand developments or technological progress (technological learning) typically complement a policy assessment.

Within the Green-X model, the **allocation of biomass feedstock** to feasible technologies and sectors is fully internalised into the overall calculation procedure. For each feedstock category, technology options (and their corresponding demands) are ranked based on the feasible revenue streams as available to a possible investor under the conditioned, scenario-specific energy policy framework that may change on a yearly basis. Recently, a module for **intra-European trade of biomass feedstock** has been added to Green-X that operates on the same principle as outlined above but at a European rather than at a purely national level. Thus, associated transport costs and GHG emissions reflect the outcomes of a detailed logistic model. Consequently, competition on biomass supply and demand arising within a country from the conditioned support incentives for heat and electricity as well as between countries can be reflected. In other words, the supporting framework at MS level may have a significant impact on the resulting biomass allocation and use as well as associated trade.

Moreover, Green-X was recently extended (within the BioBench study) to allow an **endogenous modelling of sustainability regulations for the energetic use of biomass**. This comprises specifically the application of GHG constraints that exclude technology/feedstock combinations not complying with conditioned thresholds. The model allows flexibility in applying such limitations, that is to say, the user can select which technology clusters and feedstock categories are affected by the regulation both at national and EU level, and, additionally, applied parameters may change over time.

2.2 Biomass supply potential by 2030 and scenarios

To define realistic 2030 biomass supply scenarios, an up-to-date review of studies is conducted that cover current and future (up to 2030) biomass resource potentials in the EU28 and potentials in key exporting regions outside the EU28. A starting point for the analysis are the different types of biomass potentials distinguished in the Biomass Energy Europe (BEE) project and the reduction in biomass potential as a result of applying technical, economic and ecologic constraints (see Appendix D for more details).

In the case of forest biomass, the wood use for energy will be calculated endogenously with the Green-X model, whilst the wood supply and use of biomass for materials will be exogenous scenario input to the model. The potential of wood biomass is closely linked with the development of wood industries, for example, wood residues from sawmills can be processed into wood pellets and wood disposal is closely linked with the purchase of new products. To address for the interdependencies of different wood markets, thus requires scenarios of material demand using a Wood Resource Balance approach similar to the EUwood study, but with updated scenarios. The available real utilization options of forest resource are calculated under different utilization cases. The result will be a corridor of utilizable woody biomass from forests. The calculations on forest resources from EUwood and EFSOS II with the forest resource model EFISCEN are used and partly actualized as explained in detail in Appendix B of this report.

The result is a corridor of sustainable utilization options for the following scenarios:

- ***Restricted***: EU wood availability under the condition of stronger utilization restrictions and larger set aside areas. Higher global competition for extra-EU solid biomass and lack of investments in infrastructure to mobilize alternative woody biomass. Low export capacity of liquid biofuels outside the EU.
- ***Reference***: EU wood availability is given under today’s circumstances. Extra-EU solid biomass development follows a business as usual trend. Medium export capacity of liquid biofuels to the EU.
- ***Resource***: maximum possible utilization of wood in the EU under long-term sustainable conditions. Strong development of supply and infrastructure of extra-

EU solid biomass, perennial crops cultivated for export markets. High export capacity of liquid biofuels to the EU.

Supply of agriculture biomass and organic waste changes in time, is assumed to be similar between the three different supply scenarios.

Next to the supply scenarios of wood, the availability of other woody biomass in the EU depends almost completely on the development of material uses of wood. This will be calculated on the basis of the wood industry scenarios. Forest growth potential is quite stable over time, because the yearly harvestable amount is roughly 3% of the standing volume and changes in today's management is hardly seen in the given time span until 2030. Thus, as long as fellings stay within the margin of the above cases the corridor will remain stable and interaction to demand scenarios are negligible.

2.3 Biomass cost and greenhouse gas emissions

2.3.1 Lifecycle GHG emission and cost calculation

The approach to calculate emissions will follow the Life Cycle Assessment methodologies of Annex V of the EU Renewable Energy Directive (EC 2009)[4] for biofuels:

$$E = e_{ec} + e_{l} + e_{p} + e_{td} + e_{u} - e_{sca} - e_{ccs} - e_{ccr} - e_{ee}$$

The method to calculate the cost is consistent with the method used to calculate GHG emissions. A description of the parameters and associated data sources for GHG emissions and cost are provided in Table 2-1. For the use of solid biomass for electricity, heat and cooling, the useful heat and electricity will be used in the calculations. For combined heat and power, allocation by energy will be applied as described in Annex I of COM2010(11)[5] and for biogas in SWD(2014)259[6]. Annualised positive or negative emissions from potential carbon stock changes in above and below ground biomass induced by land clearing for bioenergy production or conversion of marginal/degraded land are excluded because defining the exact height/range of C-footprint per type of feedstock and originating region is extremely difficult and proofed not feasible based on available literature and data sources.

[4] European Commission. Directive 2009/28/EC of the European Parliament and of the Council - on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC. Brussels, Belgium; European Commission. 2009. 62 p.

[5] European Commission. On sustainability requirements for the use of solid and gaseous biomass sources in electricity, heating and cooling - Report from the Commission to the Council and European Parliament. Brussels, Belgium; 2010, February. COM(2010)11 final.

[6] European Commission. State of play on the sustainability of solid and gaseous biomass used for electricity, heating and cooling in the EU - Commission Staff working document, Belgium; 2014. SWD(2014)259 final.

Table 2-1. Parameters and data sources used to calculate GHG emissions and cost of biomass supply chains

Parameter		GHG emissions*	Cost
E	Total emissions/cost from the use of the fuel	Calculated with the Green-X model.	Calculated with the Green-X model.
e_{ec}	Emissions from the extraction or cultivation of raw materials. Cost of cultivation/stumpage fee.	Solid and gaseous biomass: JRC (Giuntoli *et al.*, 2015), with country specific data from BioGrace II. Liquid biofuels: RED (2009/28/EC), future improvements to 2020 from COWI (2009)	Biomass cost database of the Green-X model.
e_l	Annualised emissions from carbon stock changes caused by land-use change	**Excluded**	N/A
e_p	Emissions from processing/pre-treatment Cost of processing/pre-treatment (chipping/pelletisation)	Solid and gaseous biomass: JRC (Giuntoli *et al.*, 2015), with country specific data from BioGrace II. Liquid biofuels: RED (2009/28/EC), future improvements to 2020 from COWI (2009)	Cost associated with energy consumption (electricity, natural gas, diesel) are made consistent with GHG calculations based on JRC (Giuntoli *et al.*, 2015).
e_{td}	Emissions from transport and distribution	Calculated with GIS tools for international supply chains including intermodal transport.	Calculated with GIS tools for international supply chains including intermodal transport.
e_u	Emissions from the fuel in use/cost of conversion	Calculated with the Green-X model.	Calculated with the Green-X model.
e_{sca}	Emission saving from soil carbon accumulation via improved agricultural management	**Excluded**	N/A
e_{ccs}	Emission savings from carbon capture and geological storage	N/A	N.A
e_{ccr}	Emission saving from carbon capture and replacement	N/A	N/A
e_{ee}	Emission saving from excess electricity from cogeneration	Calculated with the Green-X model.	N/A

*) *Including the latest EC values as published in SWD (2014) 259 and EUR26696EN*

GHG savings are calculated according to COM(2010)11:

$$GHG\ savings = \frac{FFC - GHG\ bioenergy}{Fcc} * 100$$

Where:

$FFC_{electricity}$ (fossil fuel comparator) = 186 g CO_2eq / MJ_{el}

FFC_{heat} = 80 g CO_2eq/MJ_{heat}

FFC_{fuel} = 83.8 g CO_2eq/MJ_{fuel}

2.3.2 Modelling of cost and emission from transport and distribution

In order to assess the potential supply of biomass from EU and non-EU sources and the expected logistic chains of biomass distribution, the Green-X database was extended to include feedstock specific costs and GHG emissions for cultivation, pre-treatment (for instance, chipping, pelletisation) and country-to-country specific transport chains.

To identify likely trade routes of solid biomass and to quantify the specific costs and GHG emissions of the logistic chains of solid biomass trade, a geospatial network model was developed in GIS by the Copernicus Institute at Utrecht University. The model includes an intermodal network with road, rail, inland waterways and short sea shipping in Europe. The networks are connected via transhipment hubs, where biomass can be transferred to other transport modalities (for instance, from truck to ship). Recently, the model was extended, incorporating also ocean shipping routes for extra-EU supply chains. The model optimises for least cost or GHG emissions from demand to supply regions. Total cost and GHG emissions depend on the routes taken, transport modes used and number of transfers between different transport modes.

Table 2-2 summarizes the assumed cost and performances per mode of transport used to calculate the cost of Extra-EU and Intra-EU supply chains of solid biomass. The empty trip factor, diesel consumption of truck, rail and ocean shipping (Handysize, Supramax) and design ratio[7] are made consistent with the reported values in EUR 26696 EN (Giuntoli *et al.*, 2015). Cost parameters are described in detail in Hoefnagels et al. (2014).

Table 2-2. Transport mode parameters for inland transportation and sea/ocean shipping (Hoefnagels et al., 2014).

Transport mode		Truck	Dry bulk railcars	Small, dry bulk	Middle, dry bulk	Large dry bulk	Large dry bulk 2	Large dry bulk push tug	>7,500 DWT	Handysize	Supramax
Labor (person/v)	Person/h	1.0		1.3	1.4	2.6	2.6	3.8			
Time cost	€/h	18.4		10.3	21.9	72.2	106.7	214.2	224.9	1557.5	2293.1
Variable cost	€/km	0.30	0.06	0.00	0.00	0.74	0.93	17.84	11.20		
Fuel type		Diesel	Diesel	MDO	MDO	MDO	MDO	MDO	HFO	HFO	HFO
Fuel consumption full	MJ/km	11	127	188	285	437	437	678	2150	1,389	1,837
Fuel consumption empty	MJ/km	11	127	177	272	425	425	661	2150	1,360	1,792
Maximum load	t	26	1,820	550	950	2,500	2,500	10,800	9,600	26,000	54,000
Maximum load	m^3	92	4,550	642	1,321	3,137	3,137	14,774	16,000	34,667	72,000
Speed (max)	km/h	80	80	5.42	5.80	6.71	8.64	9.00	31.50	26.48	26.67
Empty trip factor		100%	100%	37%	23%	34%	34%	54%	6%	43%	43%
Design ratio	t/m^3	0.282	0.400	0.857	0.719	0.797	0.797	0.731	0.600	0.750	0.750

[7] The design ratio determines if the volume or weight determines the maximum load of cargo. If the bulk density of goods (in t/m^3) is lower than the design ratio, the hold capacity is limited by its volume, otherwise, cargo weight is limited by the ship its deadweight (DWT), the maximum mass a ship can carry.

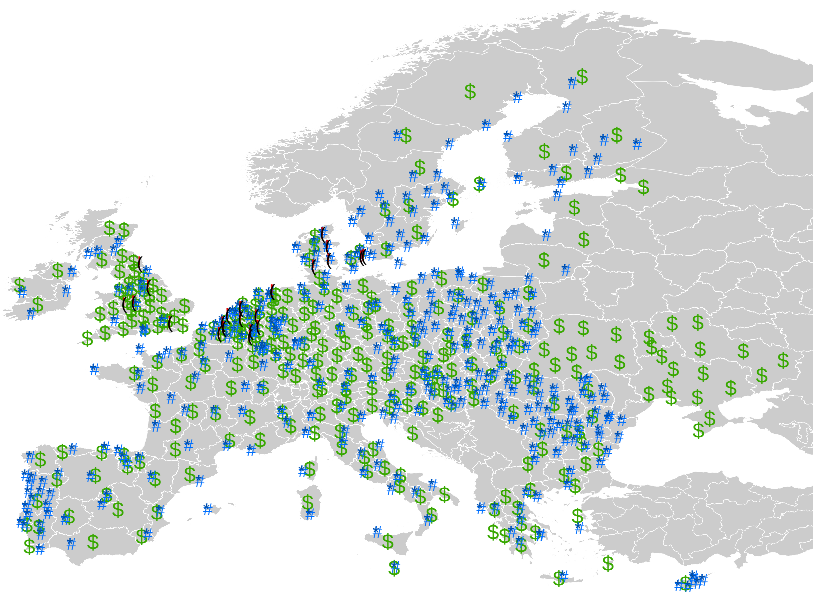
2.3.3 Intra-European supply chains

Transport cost are calculated between each supply node (the geographic centers of NUTS-2 regions) and each demand node. Demand nodes include coal fired power plants that can co-fire biomass or coal power plants that are fully converted to biomass, for example Drax in the UK, and major cities in Europe. Coal plants are included to represent the developed infrastructure in Northwest Europe to supply wood pellets. These power plants are often located near sea ports or inland waterways. Cities are considered representative for decentralized demand of biomass with more complex supply chains. The power plant capacity (MWe) and population per city were used to allocate demand per demand node.

The distribution of biomass in the EU is based on the geographic supply potential of biomass determined in the Biomass Policies project (Elbersen et al., 2015). Note that only the relative distribution per country is used to calculate the weighted average cost of biomass supply between EU member states and not the actual potentials.

Figure 2-2. Supply and demand nodes in Europe in the BIT model.

Supply and demand nodes in Europe



Legend

- ▲ Demand node (major city)
- ● Demand node (power plant)
- ⬟ Supply node (centroid Nuts-2 region)

Demand

Large scale electricity generation:

- Power plants in Northwest Europe nodes
    - Belgium
    - Denmark
    - Netherlands
    - United Kingdom
- Demand allocated based on plant capacity (MWe)

Other demand (mainly heat):

- Demand per member state is allocated to major cities based on its relative size (population)

Supply

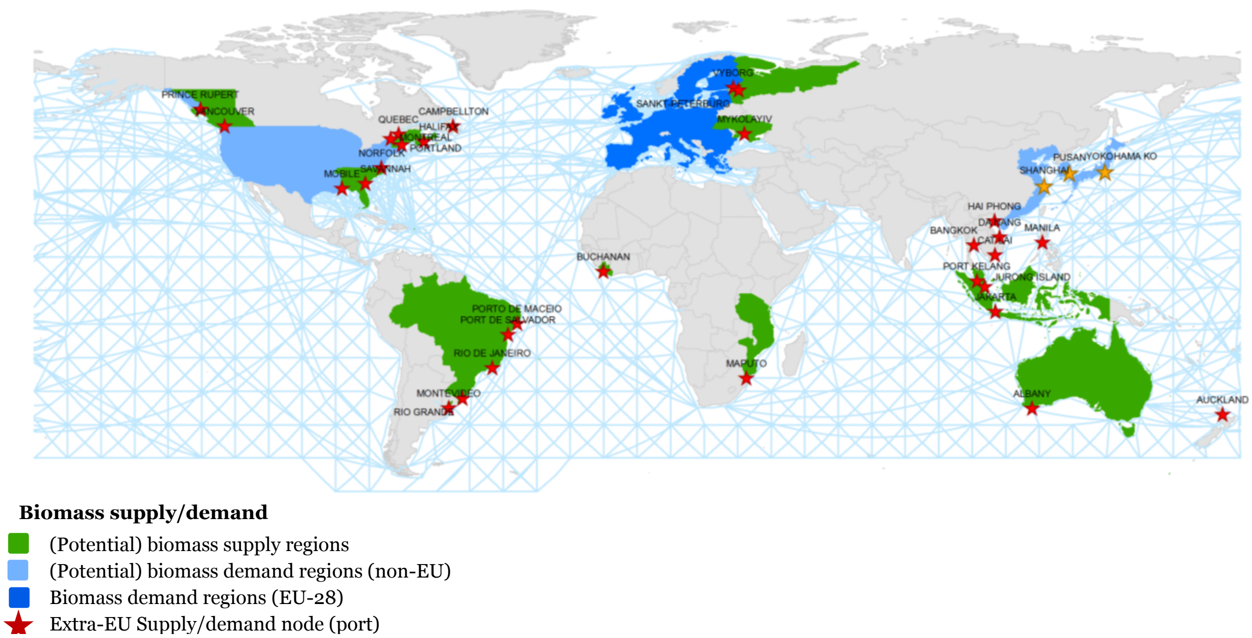
Geographic distribution of forest biomass, energy crops and agricultural residues per country based on Biomass Policies (Elbersen *et al.*, 2015).

2.3.4 Extra-EU supply chains

Similar to Lamers et al. (2014c), FOB[8] prices in Table 9-1 are used in combination with the location of export terminals in sea ports of exporting regions (

Figure 2-3.), to calculate the cost of pellet delivery to EU member states. By using this approach, the model takes into account the different characteristics of landlocked countries (for example Austria, Czech Republic) compared to countries with deep-seaports and hinterland infrastructure, for example the Netherlands. Future changes in fossil fuel prices are addressed taking into account the consumption of fossil transport fuels consistent with EUR 26696 EN (Giuntoli *et al.*, 2015).

Figure 2-3. Extra-EU supply regions and ports and ocean shipping network. Competing import regions are only shown for illustrative purposes.



[8] Free on Board (FOB) is defined by Inconterm 2010 rules (International Chamber of Commerce): all cost and risk of freight are covered by the seller up to the point that freight is loaded on board of a vessel in an export port.

3 State of play of bioenergy

3.1 Introduction

In recent years, biomass demand in the EU has grown exponentially. This section provides an overview of the current supply and demand of biomass in the EU for energy. The use of biomass for non-energy purposes are described in the relevant sections of agriculture, forest, waste. Given the increasing relevance of global biomass trade, this section also provides an overview of global biomass supply and trade. Results are based on a combination of statistical data (EUROSTAT, FAOSTAT) and specific studies on biomass demand, supply and trade including the results of IEA Bioenergy Task 40 and relevant reports and scientific publications.

For forest biomass, the consumption in the EU28 will be calculated on the basis of removals as well as on the basis of consumption sectors. Both calculations will be compared and an estimate on the order of magnitude of unregistered consumption is made. This is important to get a realistic view on current use of forest biomass[9] for energy and non-energy uses. To this purpose, existing studies (e.g. EUwood, EFSOS, INDUFOR, Solberg/Hetemäki) will be reviewed. Forest and wood and energy industry data will be updated for the year 2013 to include latest developments.

3.2 Bioenergy

3.2.1 Role of biomass in renewable energy production in the EU

Biomass is the dominant renewable energy source today, as around two third of current renewable energy production in the EU-28, expressed in terms of final energy, is produced from solid, gaseous and liquid biomass sources. Figure 3-1 shows the role of the different biomass types (in relation to overall renewable energy production) in the different EU Member States in 2013. Solid biomass represents the largest share at EU level (90.8 Mtoe gross inland renewable energy consumption), followed by liquid biomass (14.4 Mtoe), biogas (13.5 Mtoe) and the renewable part of MSW (9.1 Mtoe). A balance of bioenergy production and final demand at EU member state level is provided in the appendix, Table A 2.

The leading application with respect to biomass for energy is heat, representing around ¾ of total bioenergy and with its main end use in the residential sector (Figure 3-2). In 2013, biomass use in households was over 41 Mtoe. Electricity from biomass was second in the past, but in recent years biofuels for transport purposes took over – and it is expected that

[9] Forest biomass consumption is documented in two statistical sources. In a direct way, the registered removals of a country may be chosen. However, studies (Wood Resource Monitoring Germany) have shown that removals underestimate the real consumption (Germany by about 20%). The problem is that all sectors with many small entities underestimate the real production. This is also the case in the saw mill industry and in markets outside forestry and wood industries. In an indirect way, the consumption can be calculated from the consumer side. To produce a specific mass of pulp, the needed biomass can be calculated via conversion factors (4.5 m³ per t). However, to do this, one needs the resources mix, because pulp can be produced from pulpwood or from chips.

this will remain so in the (near) future. Generally, bioenergy experienced a strong growth (i.e. by about 6.9% per year for bioenergy in total) from 2005 to 2012. Further growth is still necessary to meet national renewable energy targets in 2020, although with somewhat lower growth rates than in the past. In 2012, net import (i.e. import minus exports) of bioenergy to the EU amounted 6.6 Mtoe with main imports of wood pellets and liquid biofuels.

Figure 3-1. Role of different biomass types in relation to overall renewable energy production in the different EU Member States in 2013. Source: EU policy landscape (Biomass Policies, 2014) updated to 2013 based on Eurostat.

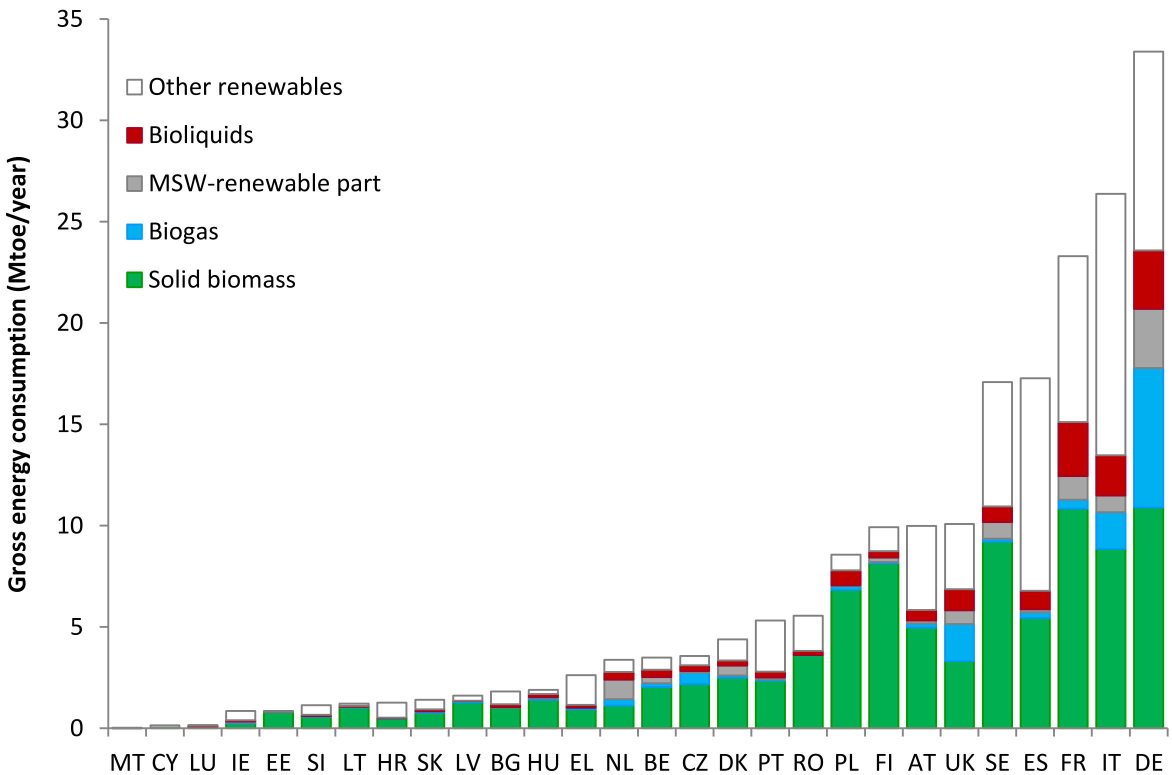
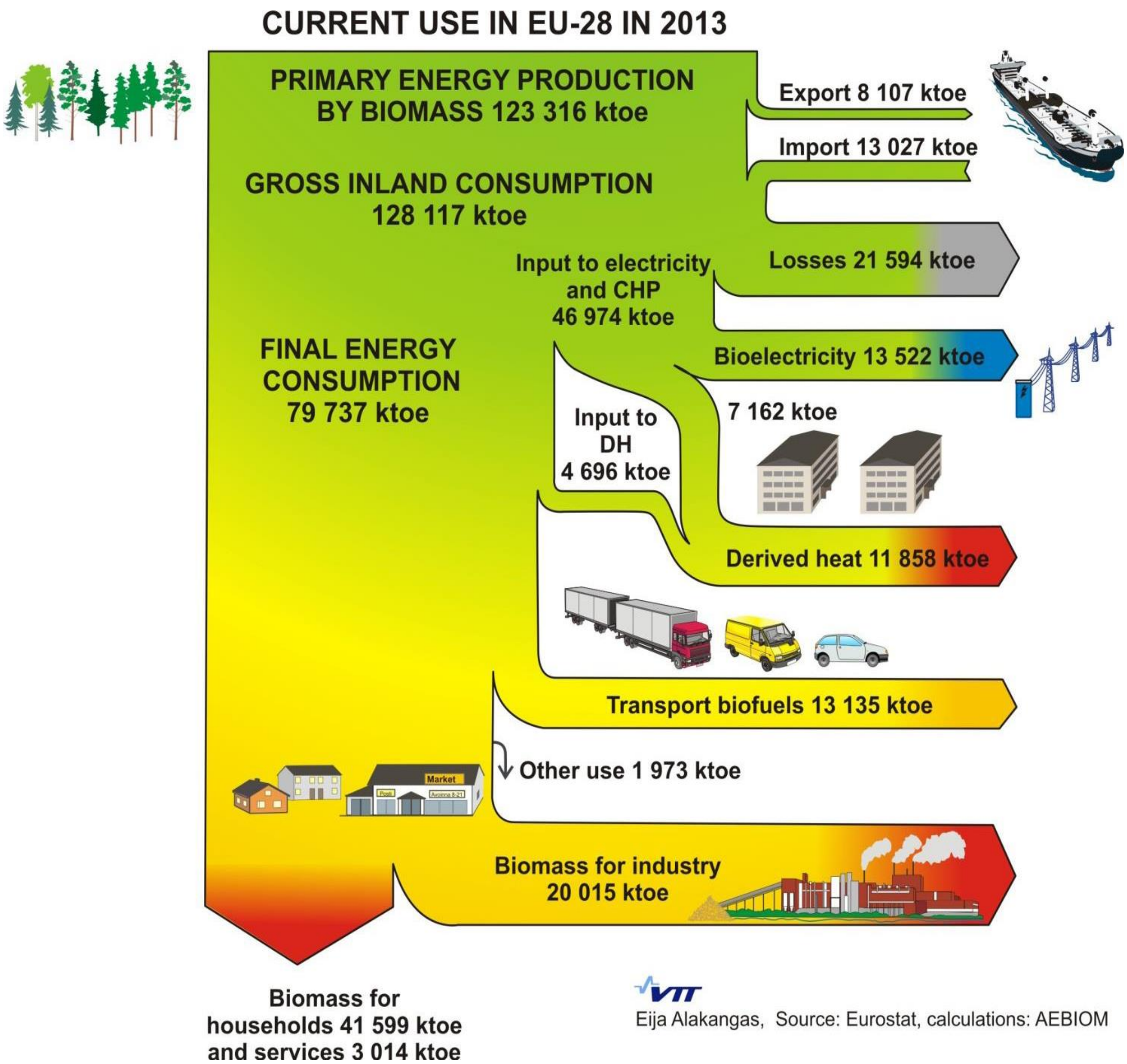


Figure 3-2. Current use of biomass in the EU28 in 2013 (AEBIOM, 2015)



Note: Exports and Imports include also intra-EU trade.

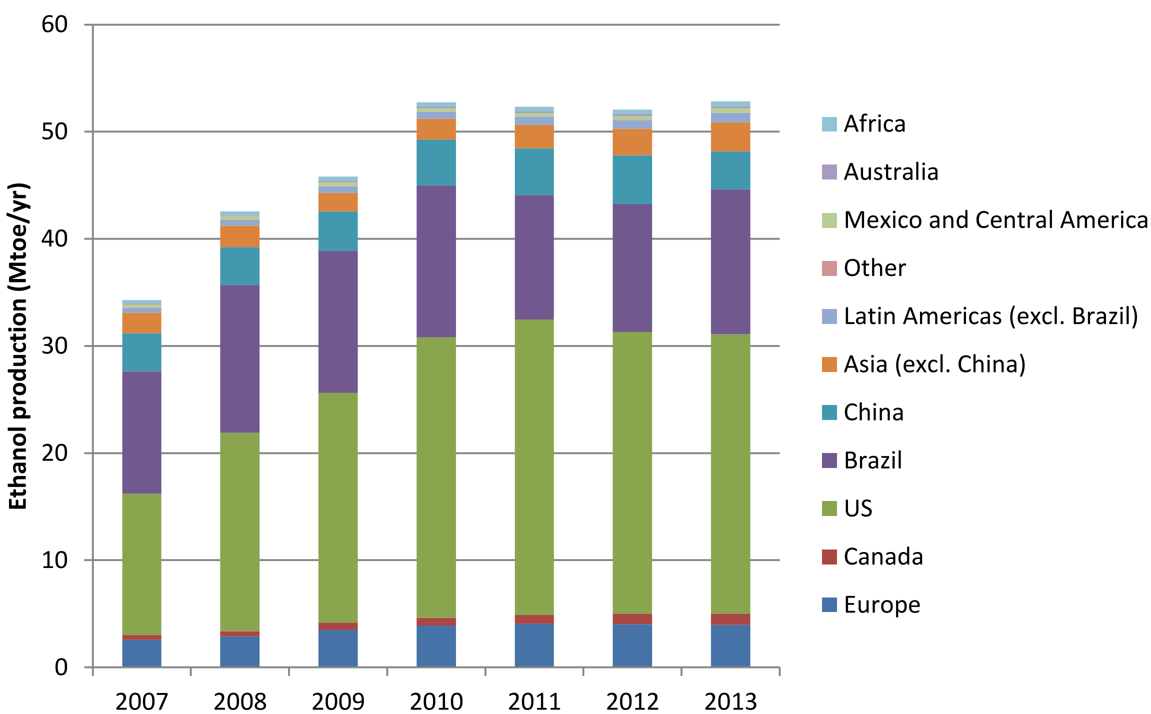
Source: Eurostat and AEBIOM calculations. Graph done by Eija Alakangas, VTT

3.2.2 Agricultural biomass use for energy

The most important application of agricultural biomass for energy is the production of biofuels, typically sugar and starch crops for bio-ethanol and oil crops for biodiesel. In some regions straw is used for the production of heat and/or electricity (mainly practiced in Denmark, typical use around 1.0-1.5 Mt per year). There are also agricultural digesters producing biogas from energy crops(predominantly maize) and manure, with Germany being the biggest player (using 1.16 Mha arable crops for biogas production in 2012[10]). In relation to data availability, we will focus the discussion on liquid biofuels from agricultural crops.

Global trends in biofuels

Global consumption of liquid transport fuels has seen exponential growth between 2000 and 2010 (Lamers *et al.*, 2014b), but after 2010, the increasing trend has slowed. Bio-ethanol consumption grew from 6.5 Mtoe in 2000 to 53 Mtoe in 2013 and biodiesel consumption went from only 0.4 Mtoe in 2000 to 15 Mtoe in 2010 and 20 Mtoe in 2013. The current global production of biofuels consists roughly of 72% bio-ethanol and 28% biodiesel. Mind that in the EU the balance of liquid biofuels consumption is completely different with 79% (10.7 Mtoe) biodiesel and 20% (2.7 Mtoe) ethanol in 2013 (EurObserv'er, 2014) as a result of the high share of diesel fuel in the European transport sector. For that reason Europe dominates global biodiesel production, whereas the US and Brazil dominate global ethanol production, as shown in Figure 3-4 .Development of global production of ethanol between 2007 and 2013 (Nakada et al., 2014)



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[10] German Renewable Energy Progress Report, 2013 & DBFZ, 2014: Stromerzeugung aus Biomasse (Vorhaben IIa Biomasse) - Zwischenbericht Juni 2014 - https://www.dbfz.de/fileadmin/user_upload/Referenzen/Berichte/Monitoring_ZB_Mai_2014.pdf

The contribution of lignocellulosic biofuels is currently small. Janssen et al. (2013) identified a number of demonstration and pilot projects in Europe and North America of mainly biochemical plants making up about 1-2% of the fuel ethanol market. With the exception of production capacity of the BioMCN facility in the Netherlands (200 kton methanol/year), thermochemical biofuel production has not entered the market yet (Janssen *et al.*, 2013).

Figure 3-3. Development of global production of biodiesel between 2006 and 2013 (Nakada et al., 2014)[11]

[11] Energy content biodiesel: 33.3 MJ/L

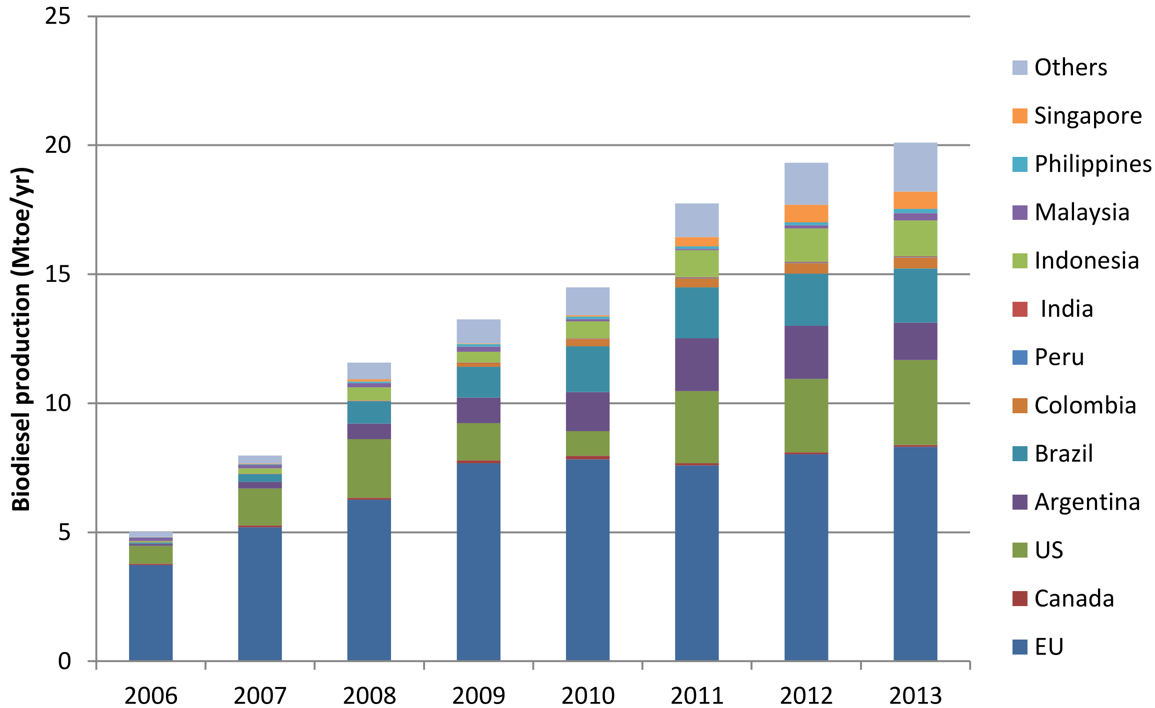
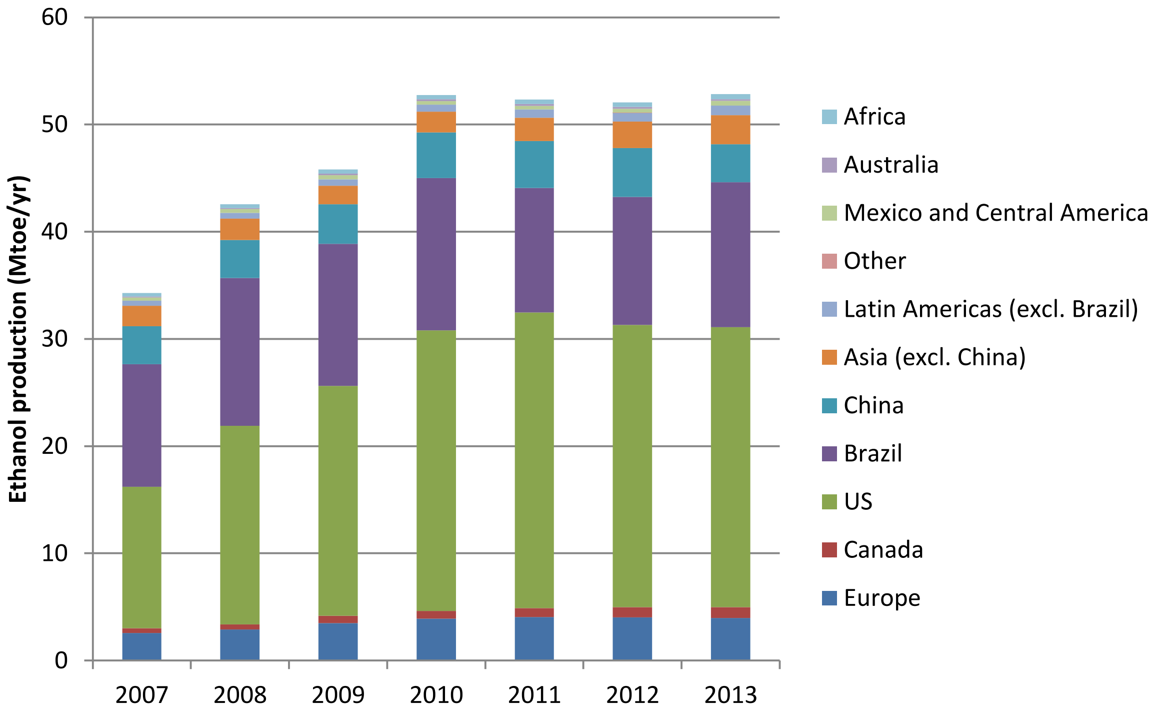


Figure 3-4 .Development of global production of ethanol between 2007 and 2013 (Nakada et al., 2014)[12]

[12] Energy content ethanol: 21.3 MJ/L



Feedstock and land use for liquid biofuels

Given the small volume of advanced biofuels from lignocellulosic biomass produced today, and the so far limited role of waste and residues for biofuels, the majority of liquid biofuels are produced from agriculture crops. The FAO Agricultural Outlook 2014-2030 (FAO 2014) provides average figures for 2011-2013 on global ethanol and biodiesel production and the share of specific crops used for biofuel production.

Bio-ethanol:

Coarse grain (mainly corn) is the main global source for ethanol (53%), followed by sugar crops, mainly sugar cane (25%), molasses (8%), wheat (3%) and others (12%). Land use for global ethanol production is estimated as follows:

- Wheat: 692 Mt wheat produced on 222 Mha: 0.9% (6.6 Mt) used for biofuels;
- Coarse grains: 1207 Mt coarse grains produced on 332 Mha: 11% (139 Mt) used for biofuels;
- Sugar beet: 266 Mt sugar beet produced on 4.8 Mha: 5.3% (14 Mt) used for biofuel;
- Sugar cane: 1828 Mt sugarcane produced on 26.2 Mha: 15.5% (283 Mt) used for biofuel.

Biodiesel:

World biodiesel production is based on 82% vegetable oil, 2% jatropha and 16% other (mainly used cooking oil and animal tallow). The global vegetable oils production was 163 Mt (of which 63 Mt palm and palm kernel oil) of which 11.7% (19 Mt) was used for biofuel.

The most recent quantification of land use for EU biofuels is provided for 2012 by Hamelinck et al. (2013) based on statistical analysis.

Hamelinck et al. based their analysis on feedstock origins combined with crop production and yield data from FAO. Co-products, for example soybean meal, were accounted for by allocation by energy content consistent with the RED. The implication of this approach is that the nutritional or economic value correctly leads to an overestimation of land use for biofuels according to the authors. In 2012, total land use for EU biofuel consumption was estimated to be 7.8 Mha of which 4.4 Mha within the EU27 and 3.5 Mha outside the EU.

In most of the non-EU countries, the land dedicated to the production of feedstock for EU biofuels is minimal (less than 5%). The crops usually have another main 'purpose' for which it is produced. Within the EU, land used for EU biofuels can be substantial as is the case in Slovakia, France, Germany, Czech Republic and Poland (Hamelinck *et al.*, 2013). In Germany, total land use for energy crops was estimated at 18% of arable land (2.1 Mha) in 2012 of which 0.79 Mha were used for rapeseed oil and 0.20 Mha for ethanol. A large share of land (1.16 Mha) was also used the for cultivation of energy crops for biogas production (co-digestion)[13](AEBIOM, 2014).

Table 3-1 and Table 3-1 show primary production, net import and gross inland consumption of biodiesel and bio-ethanol between 2009 and 2013. For 2009 to 2012, also feedstock use for domestic production is provided. European biodiesel is mainly produced from domestic rapeseed with fluctuating imports of soybean oil, mainly from Argentina, and crude palm oil, mainly imported from Indonesia and Malaysia. EU ethanol production is mostly based on sugar beet and wheat. Main feedstocks of imported ethanol are corn (US) and sugar cane (Brazil).

These figures show a remarkable downturn of biofuel imports from 2013. According to Eurobserv'ER (2015) this could be linked to the introduction of additional import taxes and anti-dumping taxes both for biodiesel and bio-ethanol.

Table 3-1. Biodiesel: primary production, net import and gross inland consumption (EUROSTAT) and feedstock use in European biodiesel production 2009 - 2012 as estimated by AEBIOM (2014)

[13] German Renewable Energy Progress Report, 2013. Available at http://ec.europa.eu/energy/en/topics/renewable-energy/progress-reports

	2009	2010	2011	2012	2013	2014**
Primary production (ktoe)	8013	8935	8494	9210	9868	10450
Share (%)						
Rapeseed oil	68.1%	70.4%	77.6%	74.6%		
Soybean oil	13.5%	11.5%	5.7%	4.1%		
Crude palm oil	4.9%	6.2%	0.1%	0.2%		
Refined palm oil	3.8%	2.1%	0.8%	1.6%		
Sunflower oil	2.8%	1.0%	0.7%	0.6%		
Used cooking oils/recycled fats	2.5%	4.8%	9.7%	10%*		
Other	1.7%	0.9%	0.3%	0.2%		
Animal by-products	2.7%	3.2%	5.1%	8.3%		
High oleic sunflower oil	0.0%	0.0%	0.0%	0.4%		
Net import (ktoe)	1659	1589	2517	2659	916	700
Gross inland consumption (ktoe)	9681	10511	10903	11932	10700	11158
Import share (to gross inland consumption)	17%	15%	23%	22%	9%	

) 0.1% in AEBIOM, assumed to be 10%.

Table 3-2. Ethanol: primary production, net import and gross inland consumption (EUROSTAT) and feedstock use in European ethanol production 2009 - 2012 as estimated by AEBIOM (2014)

	2009	2010	2011	2012	2013	2014**
Ethanol, primary production (ktoe)	1719	1991	1764	2056	2581	2855
Share (%)						
Wheat	14.2%	19.9%	22.9%	25.3%		
Corn	14.1%	13.5%	15.1%	15.8%		
Rye	5.9%	6.0%	5.1%	4.7%		
Barley	3.9%	3.3%	3.8%	3.6%		
Sugar beet	61.9%	57.2%	53.0%	50.6%		
Net import (ktoe)	590	855	1176	822	151	180
Gross inland consumption (ktoe)	2298	2843	2917	2899	2732	2674
Import share (to gross inland consumption)	26%	30%	40%	28%	6%	7%

*** first estimates by Eurobserv'ER (Biofuel Barometer, 2015)*

4 Forest biomass supply: state of play and scenarios to 2030

4.1 Feedstocks and typical uses

Woody biomass can be segmented into biomass from forests, from other wooded land, from industrial residues and from recycling processes. The availability and use of these forest biomass sources for materials and energy are intertwined with forest industry and energy sectors. These interactions need to be taken into account in determining the potential of forest biomass for bioenergy. The potential of the primary biomass is dependent on the natural production, while the other woody biomass potential depends on the production and consumption of wood products. Since disposal of wood products is closely linked with the purchase of new products, recycling is closely associated with the production as well. Thus, the availability of industrial residues and recycling products is closely linked with the development of the wood industry. This study uses the wood resource balance approach to assess total wood use for energy and materials. Table 4-1 provides an overview of wood sources and use sectors. A more detailed description is provided in Mantau et al. (2010; 2014).

Table 4-1. Wood resources balance (sources and uses)

woody biomass			
resources		uses	
Primary forest products and residues	stemwood, coniferous	saw mill industry	**wood industry (material uses)**
	stemwood, con-coniferous	veneer and plywood industry	
	forest residues	pulp industry	
	bark	panel industry	
Other primary woody biomass	landscape care wood	other traditional uses	
	short rotation plant.	other innovative uses	
Secondary forest (industrial) residues	saw mill by-products	biomass power plants	**energy end user**
	other industrial resid.		
	black liquor	private households	
Recycled wood	post-consumer wood	liquid biofuels	
solid wood fuels	pellets and other	pellets and other	**solid wood fuels**
total			**total**

4.2 Wood supply and demand in the EU

4.2.1 Wood flows in the EU[14]

In total all woody biomass use in the EU equals about 200 Mtoe. 63% comes directly from forests (stemwood, forest residues), 37% from other sources (e.g. industrial residues, post-consumer wood, landscape care wood).

Wood is the main resource for the wood industry and the pulp and paper industry. Next to that woody biomass is used for heat and electricity production. Figure 4-1 shows a schematic overview of wood flows in the EU27 in 2010 from resource to the end user in **million m^3 solid wood equivalent** (M m³ swe). For comparison with energy uses, a conversion factor of 1 M m^3 = 8.81 PJ = 0.21 Mtoe was used in this report.

Total growing stock of forest biomass in the EU is estimated around 21000 M m³ swe (4400 Mtoe), with a yearly increment of 1277 M m³ swe (268 Mtoe). An estimated 731 M m³ swe (154 Mtoe) (around 57% of annual increment) is harvested and 544 M m³ swe (114 Mtoe) is removed from the forest.

When considering the total biomass used for energy (341 M m^3 swe, 72 Mtoe in 2010), about half of this amount is consumed for residential heating (households), a quarter for energy production in the wood and paper industries themselves and the remaining quarter in biomass power plants. The difference between total biomass use for households in Figure 3-2 (39 Mtoe in 2012) and Figure 4-1 (168.6 M m3 swe, 35 Mtoe) can be explained by different statistical data sources and conversion factors used, the exclusion of non-woody biomass in Figure 4-1 and the different reporting years and regions (EU27, EU28).

Primary forest resources and residues make up the largest supply of wood for energy in 2010 (208 M m^3 swe, 44 Mtoe), followed by industrial residues (104 M m^3 swe, 22 Mtoe), and post-consumer wood (21 M m^3 swe, 4 Mtoe) (Mantau, 2012). Wood pellets contributed 7 Mtoe in 2010 (32 M m^3 swe). It should be noted however that the use of wood pellets for energy has increased substantially since 2010. In 2013, total wood pellet consumption in the EU was 8.2 Mtoe of which 2.9 Mtoe was imported from outside the EU.

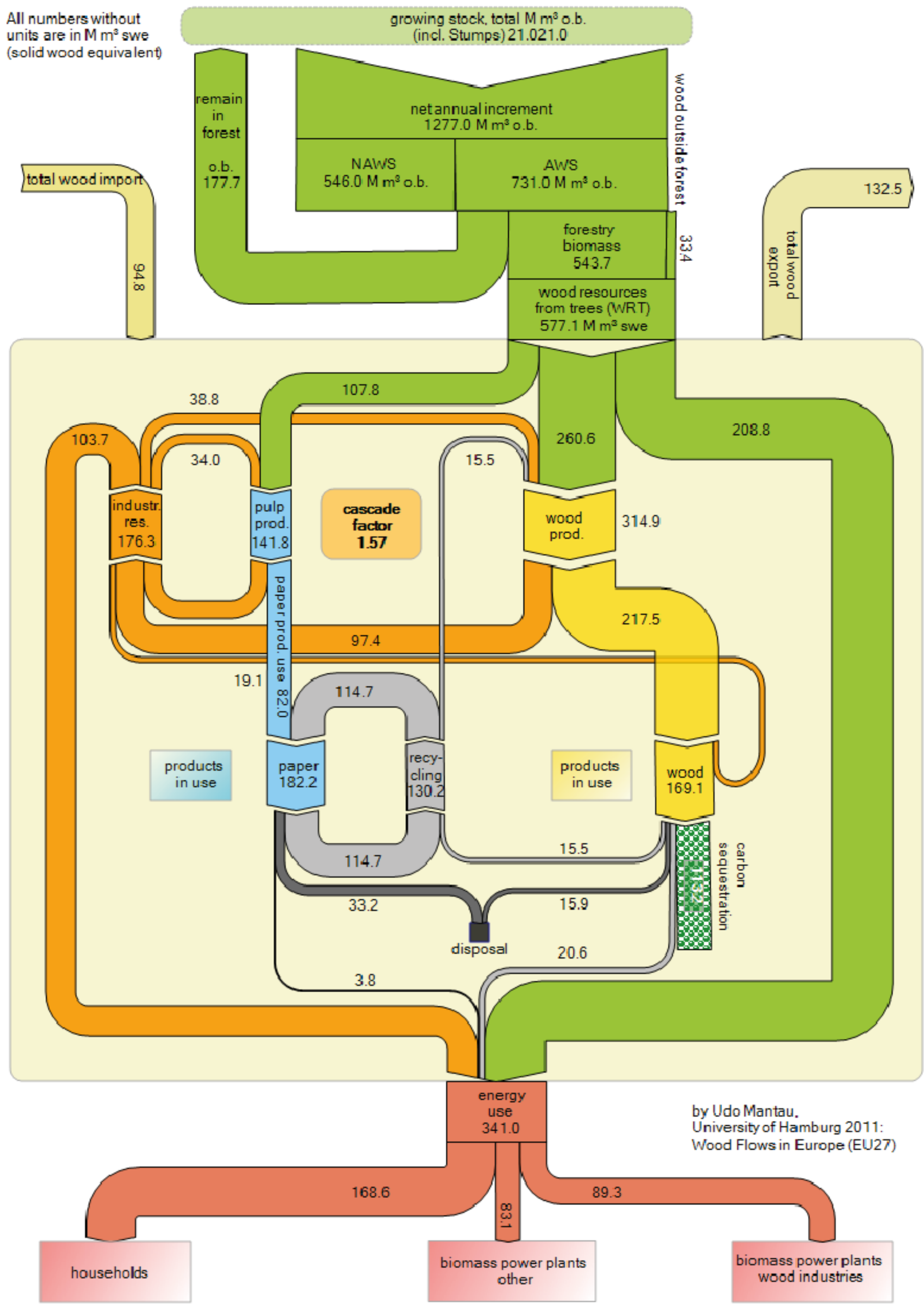
Saw mill industry and veneer and plywood industry fully rely on stemwood. Stemwood is also the most important resource for the pulp industry. The wood panel industry uses the broadest variety of woody biomass. Other material uses (e.g. dissolving pulp/viscose, poles, sleepers, mulch) are very much based on stemwood as well. Only mulch production is based on bark.

The forest industry internal power and heat plants utilize mainly their own residues as resource while other biomass plants have a broader variety of resources. In recent years industrial pellets may have gained a stronger market share. The main energy user is the private household sector and their dominant resource is split wood that comes from stemwood.

[14] Summary of Mantau (2012)

In absolute numbers (solid wood equivalents) the EU27 was using 836.8 M m^3 of wood in the year 2010 including cascade uses. 576.7 M m^3 or 68.9 % come from primary sources (forest, landscape care wood). Black liquor (59.8 M m^3) is a special resource. It is hardly available on the market, it is mainly used in the pulp industry for energy purposes and may be a resource for future bio-refinery products, most likely also in integrated pulp mills. In this concern, there will be a shift from the energy sector towards a new bio-refinery sector. Calculations have been started for Task 2 of this study.

Figure 4-1. Wood flows in the EU27 (2010) from resource to end-user (condensed version) (Mantau, 2012)



4.2.2 Trade of wood in the EU

The overall trade volume of all EU27 countries is quite high due to their high internal trade volume. For the purpose of this study only the extra-EU trade is considered (between EU and countries outside the EU). All trade data from EUROSTAT are reported in value, weight (100 kg) and a supplementary quantity. The conversion factors were calculated on the basis of existing conversion factors (UNECE, 2010)[15] and further assumptions. One should bear in mind that in the calculations of the wood resource balance, the transformation from 1 m³ of a product fibre board (MDF) into solid wood equivalents (1.799) is different from the calculation from traded tons into m³. A heavy product with a condensed wood density (MDF) has a lower conversion factor than a product with a normal density (sawnwood, 1.770) which represents more cubic meter per ton. In contrast, the conversion factor for sawnwood in the wood resource balance would be 1.000. It is an expansion factor from mass to volume.

As a result of these calculations, the EU27 imports of **roundwood** are estimated at 1.391 Mtoe (6.611 M m³ swe) and the exports are estimated at 0.532 Mtoe (2.530 M m³). The net imports from outside the EU27 are 0.859 Mtoe (4.081 M m³ swe). Thus, trade of primary resources in the form of roundwood is relatively low compared to other traded forms.

Table 4-2. Extra-EU trade from EU27 of roundwood in M m³ swe and Mtoe

Resources - roundwood		converted volume in swe			converted in Mtoe		
2010		import	export	net trade	import	export	net trade
		M m³ swe	M m³ swe	M m³ swe	Mtoe	Mtoe	Mtoe
fuelwood (stem)	4401 10 00	1.490	0.230	-1.260	0.314	0.048	-0.265
industr. roundw.	4403	5.121	2.300	-2.821	1.078	0.484	-0.594
total roundwood		6.611	2.530	-4.081	1.391	0.532	-0.859

Source: Mantau (2012) Wood Flows in Europe

The following table shows the trade of semi-finished products. Trade in semi-finished products is very high. 29.3 Mtoe (139.0 M m³) are exported form the EU and 17.4 Mtoe (82.5 M m³) are imported. Thus, the net trade balance is positive by 11.9 Mtoe (56.5 M. m³). Plywood products and pulp have a net trade deficit. The highest export sectors are recovered paper, paper and further processed paper products. Sawnwood and panels contribute as well to the trade surplus. To calculate semi-finished and finished products into energy content does not really make sense, because nobody would first start a production process to this type of (semi)-finished product to convert it to energy. Nevertheless, we include Mtoe value in the table for comparison with wood flows traded for energy.

[15] UNECE (2010): Forest product conversion factors for the UNECE region, Geneva Timber and forest discussion paper 49.

Table 4-3. Extra-EU trade from EU27 of semi-finished products in M m³ swe and Mtoe (Mantau, 2012, Wood Flows in Europe)

SEMI-finished products 2010		converted volume in swe			converted in Mtoe		
		import M m³ swe	export M m³ swe	net trade M m³ swe	import Mtoe	export Mtoe	net trade Mtoe
sawnwood	4407	9.216	16.223	7.007	1.939	3.414	1.474
veneer+plywood	4408	0.442	0.116	-0.326	0.093	0.024	-0.069
particl + OSB *)	4410	0.814	3.402	2.588	0.171	0.716	0.545
Fibreboard	4411	0.523	3.383	2.861	0.110	0.712	0.602
plyw. Panel	4412	3.091	0.443	-2.648	0.650	0.093	-0.557
wood products		14.086	23.567	9.481	2.964	4.959	1.995
pulp	4701-06	34.837	9.223	-25.614	7.330	1.941	-5.390
recov. paper	4707	4.636	34.775	30.139	0.976	7.318	6.342
paper	48	28.934	71.451	42.518	6.088	15.035	8.947
paper products		68.407	115.449	47.043	14.394	24.293	9.899
semi-finished total		82.493	139.016	56.524	17.358	29.252	11.894

The level of aggregation of different resources normally increases with the production level. On the other hand, almost no conversion factors are available for the extremely high variety of finished products. A very simple assumption was taken for the product categories in the following table: the conversion factor of finished wooden products is based on the conversion factor of sawnwood (1.770). "Strips" are made from sawnwood and are not mixed with other materials (1.770). "Packaging" is very similar to sawnwood. The proportion of panels leads to a lower conversion factor as well as the mixture with other materials. This is also the case for all other finished products but with a higher proportion of other materials. Therefore, the conversion factor of sawnwood is decreased by 15% for "packaging", by 25% for "building materials" and by 35% for furniture and other.

Based on these calculations, the trade balance of finished products is as well positive with almost 4.2 Mtoe (19.8 M m³). The highest contribution comes from building products with 3.2 Mtoe (15.4 M m³). The packaging sector has a net export of almost 1 Mtoe (4.5 M m³).

Table 4-4. Extra-EU trade from EU27 of finished products, in M m³ swe and Mtoe Mtoe (Mantau, 2012, Wood Flows in Europe)

FINISHED products 2010		converted volume in swe			converted in Mtoe		
		import M m³ swe	export M m³ swe	net trade M m³ swe	import Mtoe	export Mtoe	net trade Mtoe
strips	4409	0.885	2.447	1.562	0.186	0.515	0.329
building mat.	4418+9406	0.980	16.385	15.405	0.206	3.448	3.242
packaging	4415	0.390	4.909	4.519	0.082	1.033	0.951
furniture	94	2.875	1.930	-0.946	0.605	0.406	-0.199
other	4420/21	0.698	0.000	-0.698	0.147	0.000	-0.147
finished		5.829	25.671	19.841	1.227	5.402	4.175

The following table summarizes the trade activities of the different production sectors. The trade of wood products (materials) is strongly focused on semi-finished products and finished products. The trade of resources of traditional wood products is relatively small. Only 1.4 Mtoe (6.6 M m³) are imported and 0.5 Mtoe (2.5 M m³) of round wood are exported. Less than a quarter of registered imports (0.3 Mtoe) are used for energy.
As (unprocessed) biomass from forest only stemwood is traded. The low values of forest residues as well as their high moisture content are high trade barriers. Even round wood is of low quantitative relevance and fuelwood imports are marginal. Most imported roundwood is supposed to be of higher quality.

Table 4-5. overview of traded wood products

Total wood products 2010	converted volume in swe			converted in Mtoe		
	import M m³ swe	export M m³ swe	net trade M m³ swe	import Mtoe	export Mtoe	net trade Mtoe
raw wood	6.611	2.530	-4.081	1.391	0.532	-0.859
semi-finished products	82.493	139.016	56.524	17.358	29.252	11.894
finished products	5.829	25.671	19.841	1.227	5.402	4.175
Total wood products	94.933	167.217	72.284	19.976	35.186	15.210

4.3 Wood supply scenarios by 2030

4.3.1 Global wood supply

The available worldwide statistics on forest resources is documented in the Forest Resources Assessment study from FAO (FRA 2010[16]) and include many data gaps. For the UNECE region the net annual increment (NAI) or average yearly growth is available. Many other countries report only forest land area and standing volume. Net annual increment or real available yearly potential is hardly known. A report on the "Global Wood Production - Assessment of industrial round wood supply from forest management systems in different global regions (Arets et al. 2011[17]) present most valuable information on worlds forest, but no consistent data on NAI in world regions. A comprehensive summary on all forest resource assessment are given by Gold et al. (2006). However, the conclusion is that the inconsistencies of international resource data are large and data on net annual increment are not available.

The following Table 4-6 summarizes the data relevant for wood availability worldwide. The total forest area is estimated at 4 033 Mha whereof almost 200 Mha or five percent are in the geographical area of Europe without Russia. The forest cover in Europe is slightly higher (34%) than in the world (31%).

[16] Food and Agriculture Organization of the United Nations (2010): Global Forest Resources Assessment 2010. Main report. Rome 2010. FAO Forestry Paper 163
[17] Arets E, Meer P, Verwer G, Hengeveld G, Tolkamp G, Nabuurs G, Oorschot M (2011): Global Wood Production. Assessment of industrial round wood supply from forest management systems in different global regions. Alterra Report 1808. 2011.

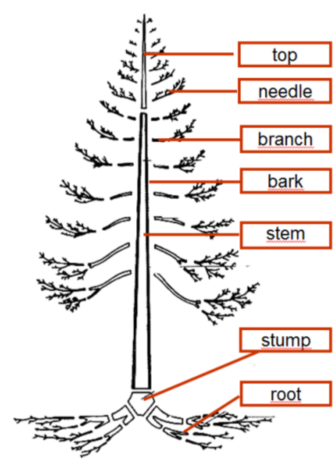
The growing stock (the living tree component of the standing volume) worldwide is 527,203 M m³ whereof 61% of growing stock or 321,000 M m³ belong to commercial species. Growing stock is documented relatively clearly on an international level.

Table 4-6. Available statistics from worldwide wood availability

World regions	Forest area area in 1.000 ha	Forest land cover in%	Growing stock in hm³	Growing stock (m³/ha	Commercial species in %	hardwood in %	softwood in %
Eastern and Southern Africa	267,517	27	13,697	51	16.5	96.6	3.4
Northern Africa	78,814	8	1,346	17	71.8	60.7	39.3
Western and Central Africa	328,088	32	61,908	189	21.6	100.0	0.0
Total Africa	674,419	23	76,951	114	20.5	98.9	1.1
East Asia	254,626	22	21,337	84	32.4	48.8	51.2
South and Southeast Asia	294,373	35	29,031	99	28.8	86.5	13.5
Western and Central Asia	43,513	4	3,316	76	53.9	42.0	58.0
Total Asia	592,512	19	53,685	91	32.9	59.9	40.1
Russian Federation	809,090	49	81,523	101	99.6	24.2	75.8
Europe excl. Russian Federation	195,911	34	30,529	156	99.3	41.1	58.9
Total Europe	1,005,001	45	112,052	111	99.8	28.6	71.2
Caribbean	6,933	30	584	84	75.0	91.0	9.0
Central America	19,499	38	2,891	148	17.1	89.1	10.9
North America	678,961	33	82,941	122	91.5	26.9	73.1
Total North and Central America	705,393	33	86,416	123	89.8	28.5	71.5
Total Oceania	191,384	23	20,885	109	16.5	100.0	0.0
Total South America	864,351	49	177,215	205	36.0	98.8	1.2
World	4,033,060	31	527,203	131	61.2	61.2	38.8

4.3.2 Total potential of forest biomass in the EU

In the studies EUwood and EFSOS II the EFISCEN model, a forest resource projection model, was applied to assess the biomass supply from European forests. Total growing stock of forest biomass in the EU is estimated around 21,000 Mm³ swe (4,400 Mtoe), with a theoretical annual increment of total biomass of 1,277 Mm³ swe overbark (268 Mtoe) in the EU. According to projections with EFISCEN, the potential is expected to decrease by 1.8% to 1,254 M m^3 in 2030, but in general remains rather stable.



The biggest proportion does not come from stemwood (hardwood and softwood) but from residues. While this could theoretically be extracted from EU forests, the theoretical biomass of forest residues includes roots, stumps, branches, tops and leaves and needles. Most of the biomass from forest residues is not utilisable due to technical, environmental and economic restrictions, while the biomass of stems is almost completely utilisable. Therefore, the proportions of biomass assortments differ a lot between the theoretical potential and real utilisation scenarios.

Table 4-7. Total theoretically available forest biomass in the EU28

	in Mtoe	in PJ	in M m³	in %
Hardwood	41.8	1749	198	15.9
Softwood	80.4	3365	382	30.7
Residues	127.7	5350	607	48.7
Bark	12.3	514	58	4.7
Total	262.1	10978	1246	100.0

4.3.3 Real utilisation scenarios

The sustainable utilizable potential of forest biomass is based on forest inventories and forest growth models. Furthermore, there are restrictions/constraints (technical, environmental, social) to utilize the theoretical potential. These calculations have recently been carried out by two studies (EUwood, EFSOS II) and will also be applied in this study. The development of natural resources within different intensities of utilization/mobilization is sufficiently characterized by these calculations. The concept of the EUwood study is used (high, medium, low utilization/mobilization scenarios) and actualized on the basis of the EFSOS-Study. This will characterize the sustainable, possible utilization of woody biomass from forests in the form of a **development corridor** in total or in assortments (stemwood, forest residues, bark). Sustainable utilization may only occur within the corridor. Between the medium and low utilization scenario no negative effect of wood utilization is assumed. Depending on the amount of wood consumed above the medium utilization scenario some environmental targets may be affected, but forest management is still sustainable. Thus the corridor safeguards sustainability and is an indicator of sustainability pressure. Sustainability itself is not a fixed point but represents a corridor of options society may take within given borderlines. Those have been defined with the above described scenarios and are used for the present study as described below.

Biomass use for bioenergy will be calculated endogenously with the Green-X model, whilst the supply of biomass and use of biomass for materials will be exogenous scenario input to the model. To determine the net availability of biomass for energy purposes, scenarios of biomass supply will be combined with scenarios of material demand. The development of scenarios of biomass supply will partly be based on existing scenarios for forest biomass. Scenarios for agriculture biomass will be aligned with these scenarios as described below. It is important to note that the scenarios for agriculture biomass are first suggestions and subject to change and improvement in the course of this study.

For forest biomass as well as for agricultural biomass a corridor approach is used based on three supply scenarios. The forest biomass scenarios are based on EUwood/EFSOS II and slightly actualized and adapted for this study. A detailed description of the constraints in these scenarios is provided in Appendix B of this report. Biomass from organic waste is assumed to remain constant in the scenarios. The EUwood-study (Mantau *et al.*, 2010) calculated low, medium and high utilization scenarios as explained in detail in Verkerk et al.

(2010). The European Forest Sector Outlook Study II (EFSOS II) (2011) calculated reference (medium) and energy (high) utilization scenarios (Verkerk, H., Schelhaas, 2013). EFSOS II used partly more actual inventory data (e.g. Poland, Germany 2002). For the consolidated scenarios in this study the EFSOS II calculated the restricted scenario (low) on basis of the relation between low and medium utilization scenarios in the EUwood study.

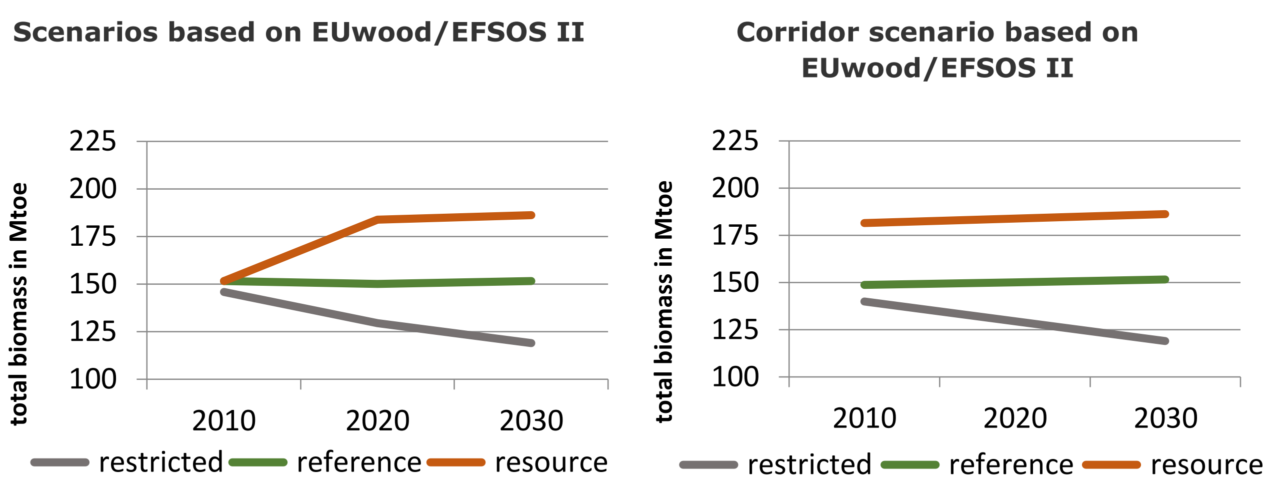
Table 4-8. Forest resource supply scenarios, a detailed description is provided in Appendix B.

Restricted	Reference	Resource
Recommendations do not have the desired effect, because the use of wood for producing energy and for other uses is subject to strong environmental concerns. Possible negative environmental effects of intensified use of wood are considered very important and lead to strict biomass harvesting guidelines. Application of fertiliser to limit detrimental effects of logging residue and stump extraction on the soil is not permitted. Forests are set aside to protect biodiversity with strong limitations on harvest possibilities in these areas. Furthermore, forest owners have a negative attitude towards intensifying the use of their forests. Mechanisation of harvesting is taking place, leading to a shift of motor-manual harvesting to mechanised harvesting, but with little effect on the intensity of resource use. For these, data from literature is used to estimate average costs. A premium of 1 €/MWh primary feedstock (corresponding to about 5 €/Mt in mass terms) is identified as suitable, representing a relatively high but reasonable estimate to reflect the associated burden for a biomass producer.	Recommendations are not all fully implemented or do not have the desired effect. New forest owner associations or co-operations are established throughout Europe, but this does not lead to significant changes in the availability of wood from private forest owners. Biomass harvesting guidelines that have been developed in several countries are considered adequate and similar guidelines are implemented in other countries through improved information exchange. Mechanisation of harvesting is taking place, leading to a further shift of motor-manual harvesting to mechanised harvesting. To protect biodiversity forests are being protected, but with medium impacts on the harvests that can take place. Application of fertiliser is permitted to limited extent to limit detrimental effects of logging residue and stump extraction on the soil.	There is a strong focus on the use of wood for producing energy and for other uses. Recommendations have been successfully translated into measures that lead to an increased mobilisation of wood. This means that new forest owner associations or co-operations are established throughout Europe. Together with existing associations, these new associations lead to improved access of wood to markets. In addition, strong mechanisation is taking place across Europe and existing technologies are effectively shared between countries through improved information exchange. Biomass harvesting guidelines will become less restricting, because technologies are developed that are less harmful for the environment. Furthermore, possible negative environmental effects of intensified use of forest resources are considered less important than the negative effects of alternative sources of energy (i.e. fossil fuels) or alternative building materials (e.g. steel and concrete). Application of fertiliser is permitted to limit detrimental effects of logging residue and stump extraction on the soil.

The three above utilisation scenarios for EU forest biomass are based on EUwood and EFSOS II: restricted (low), reference (medium) and resource (high). As shown in Table 4-9, the technical available potential is about 110 Mtoe lower in the reference scenario than in the theoretical scenario.

EUwood and EFSOS II started with an actual value (2010), based on the average consumption of the years 2003 to 2007, which was a very good proxy for the year 2010. However, in this study the data will be actualized on the basis of the UNECE data (flat-file) up to 2013. Furthermore, Croatia is added and results of the new inventory in Germany (2012) are proportionally included. From there growth rates on the long-term scenarios of EUwood/EFSOS will be chosen. Thus, this project is based on the existing scenarios, but will actualize them significantly. Especially the structural changes of the financial crises (starting values) can be captured. The potential of other woody biomass will be calculated on a result of wood industry development via conversion/technical factors.

Figure 4-2. Scenarios on biomass from forests, based on EUwood/EFSOS II and applied to the corridor approach of the BioSustain project.



4.3.4 Primary forest biomass

About 52% of the total potential lies in stems (including bark). Logging residues and stumps represent 26% and 21%, respectively. Other biomass like stem and crown biomass from early thinnings, represent only 1% of the total potential. The proportion stemwood increases to 76% when the technical potential is chosen as basis. Logging residues account for only 16% and bark accounts for 8%.

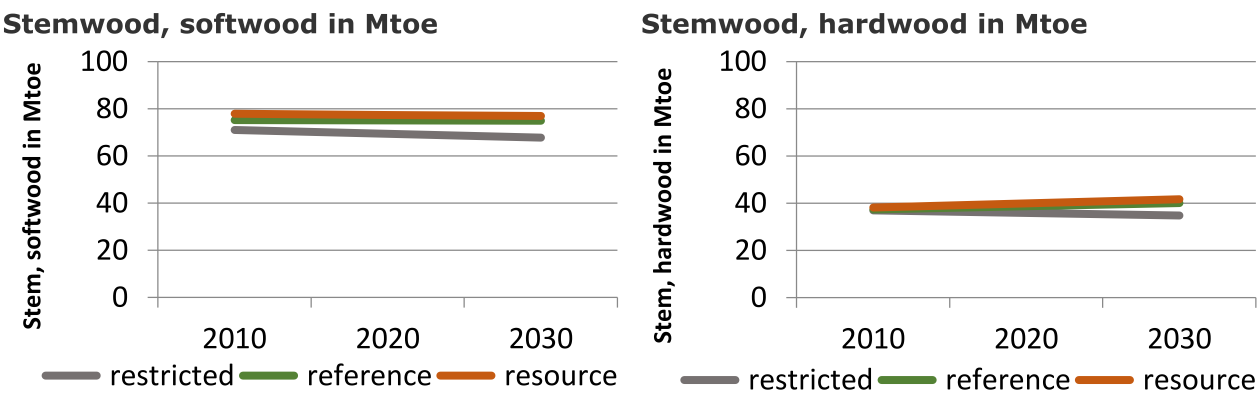
Table 4-9. Total technical available forest biomass

Total forest biomass in Mtoe			
EU28	**Restricted**	**Reference**	**Resource**
2010	140.0	148.7	181.4
2020	129.5	150.1	183.9
2030	119.0	151.5	186.3

The differences between the scenarios for stemwood are quite low because stemwood has always been the main production target of forestry. The technique is still targeting for a maximum share of stemwood. It is still the assortment that can be harvested most efficiently per unit and has the highest value per unit [m³ or ton]. Unless clearcut, the extraction of stemwood (including bark) is seen as less environmentally harmful than the extraction of residues.

Two third (67%) of all available stemwood in the EU is softwood (362 M m³). Hardwood (182 M m³) accounts only for 33% of all stemwood.

Figure 4-3. Availability of forest biomass assortments (stemwood)



The spread between the high and low mobilization scenario of stemwood is 16 Mtoe (76 Mm³), which is quite low. In contrast, the spread of the residues is 50 Mtoe (236 Mm³), which corresponds to twice the reference scenario. There are three main reasons. On the one hand, stemwood has always been the goal of harvesting and management is focused on it. On the other hand, the use of residuals is very much dependent on the interpretation of the restrictions. Finally, the figures represent the technical potential. Economic restrictions do not affect stemwood as strong as residuals.

The technical potential of marketable bark depends completely on the harvest of stemwood. Bark is not harvested on its own, but always with the stemwood, as it also provides a good protection. Therefore, the bark does not appear as a special forest product. It goes to the buyer with the stemwood and he may consume it with the stem or debark the stem and sell or consume the bark separately.

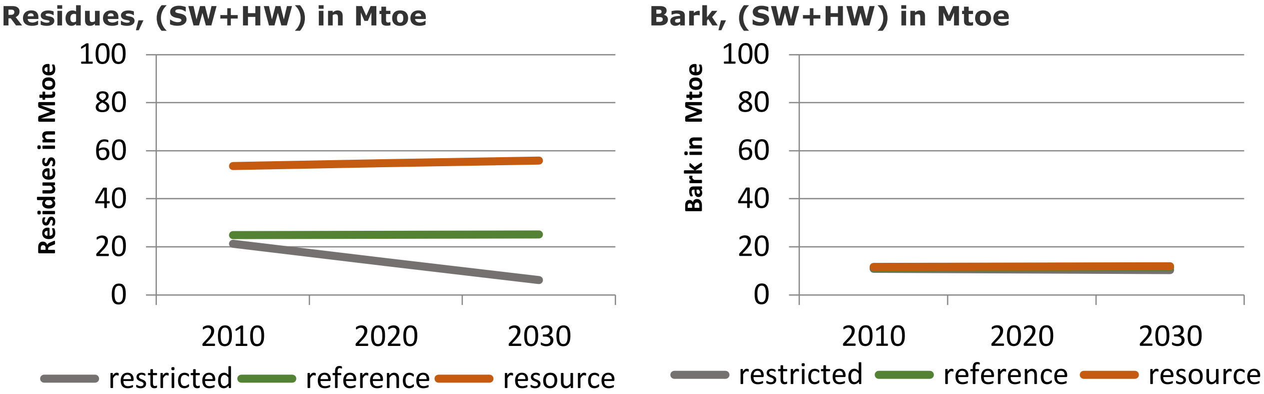


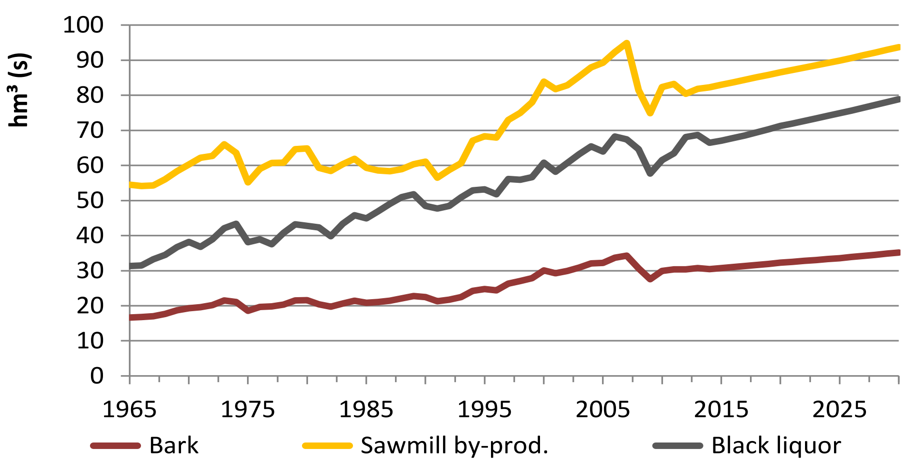
Figure 4-4. Availability of forest biomass assortments (residues and bark)

Forest utilizable potential under sustainable conditions is about 700 Mm³ (150 Mtoe) and quite stable over time. The difference between a strongly restricted and a resource oriented energy utilisation is about 300 M m³ (63 Mtoe). The greatest variability lies in the use of residuals, but they have also the highest sensitivity with respect to restrictions and cost.

4.3.5 Secondary forest residues

Industrial residues are sawmill by-products, other wood residues from wood processing and black liquor from chemical pulp production. Thus, the availability of these by-products depends totally on the development of wood and paper industries. The following figure depicts how much industrial residue will be available, if the wood processing industry develops similar to historic trends. The current developments show that wood industry will grow less than in the in the period 1990 to 2007. Other industrial restudies from wood processing have been used on the basis of EUwood studies.

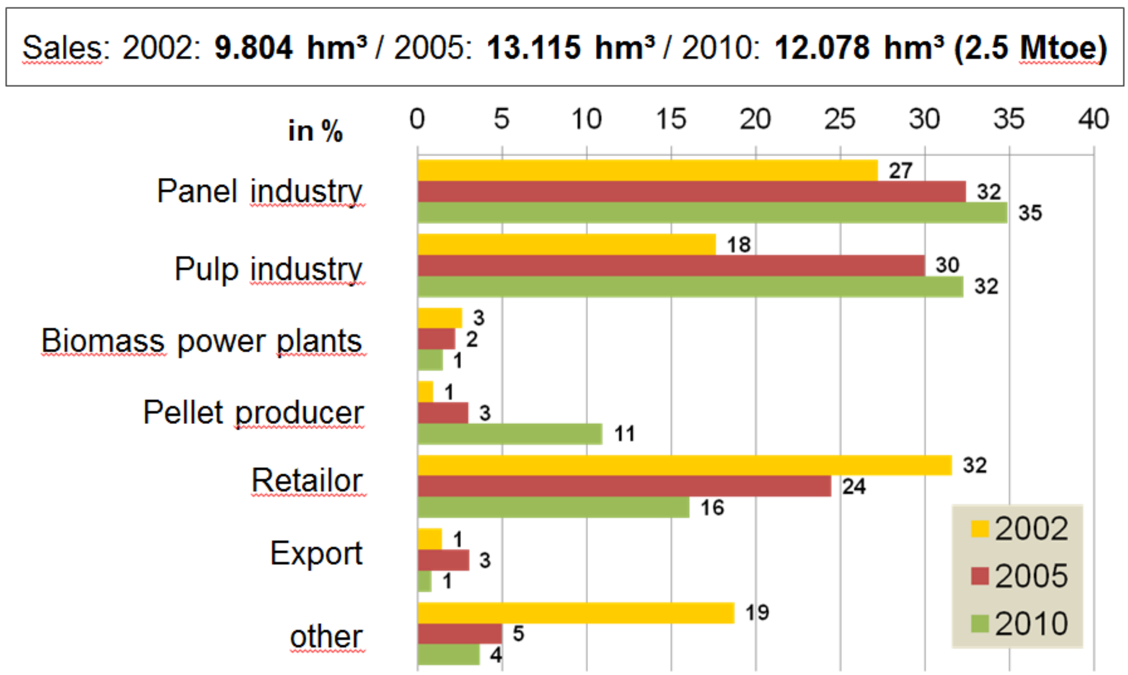
Figure 4-5. Scenario of total potential wood residue volumes – 2010 -2030 in Mtoe



Source: Saal (2010), Industrial residues and by-products, 2010 based on Jonsson, Econometric modelling, 2010

The amount of residues is not equal to market availability. For Germany three studies have analysed the distribution of sawmill by-products: 15.7% of the available residues are used internally; two third of the distributed sawmill by-products are delivered to panel and pulp industry; only 12% are distributed directly to energy producers (11% pellets, 1 % directly to power plants). Pellet producers are to a large proportion sawmill industries. The decreasing relevance of retailors may be explained with the higher margins which can be earned with sawmill by-products. Black liquor for example is more or less fully used by the pulp industry. Other industrial residues are quite often reused in the production process (particle board) or in wood industry owned power plants or for heat production.

Figure 4-6. Distribution channels of saw mill by-products in Germany



The availability of industrial wood residues depends completely on the production of traditional wood industry. All industrial residues add up to 17.3% of the wood potential in the year 2010. Wood and paper industries may evolve to bio-refineries, most likely using 100% of the raw wood, without being a source of available residues themselves. Thus the availability of industrial wood residues may lose market shares.

4.3.6 Wood waste

Post-consumer wood (PCW) includes all kinds of wooden material that is available at the end of its use as a wooden product ("post-consumer" or "post-use" wood). Post-consumer wood mainly comprises packaging materials, demolition wood, timber from building sites, and fractions of used wood from residential (municipal waste), industrial and commercial activities. (Leek 2010b)

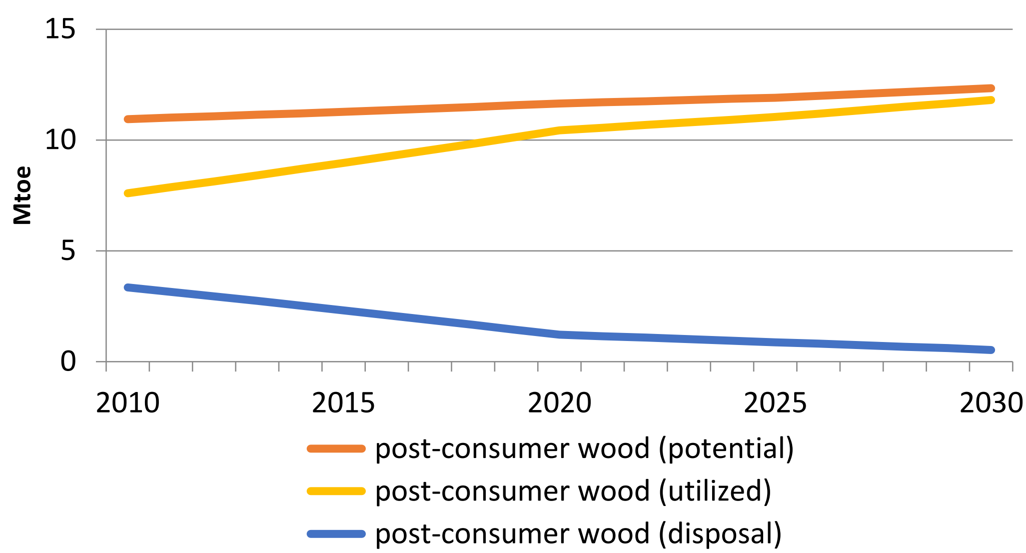
The primary sources for post-consumer wood are:

- Municipal solid wood waste mainly from households
- Construction waste and demolition wood
- Fractions of used wood from industrial and commercial activities (primarily packaging materials, including pallets).

There is a lack of empirical studies on post-consumer wood. The EUwood study based its figures on the COST Action E31 (2005) and later studies in the Netherlands and Germany. A comprehensive model was derived from these data. Later studies are based on EUwood/EFSOS II data.

The relation between the solid wood consumption per capita and the share of post-consumer wood in the total national solid wood consumption in 2007 was used for the prediction of the future post-consumer wood supply in the EU27 countries. The national solid wood consumption (sawn wood and panel consumption) was calculated for the years 2010, 2015, 2020, 2025 and 2030 from the data sets of econometric modelling (Future Forest, Jonsson), both for the EUwood scenarios A1 and B2 (Mantau *et al.*, 2010). The total potential of post-consumer wood for each country of the EU 27 in 2010 and 2030 is shown in Figure 4-7 (Leek, 2010a).

Figure 4-7. Potential, use (energy and materials) and disposal of PCW for the EU 27 countries– scenario A1 in in Mtoe



Source: Leek (2010a): Post-consumer Wood EUwood

The potential of post-consumer wood was estimated at 12 Mtoe (52 Mm³) in 2010 which is five percent of the total woody biomass and it was assumed that it will increase to almost 15 Mtoe (70 Mm³) in 2030. However, this development was based on the assumption that consumption of sawn wood and panels will increase as well. The linkage between post-consumer wood based on the effect, that old furniture or demolition wood occur when new products are bought or houses are built. “Nobody brings his living room cabinet to the disposer, because of rising post-consumer wood prices.” Only the intensity of disposal may be affected. For the future two developments are possible. A decreasing volume because of a decreasing demand for furniture and housing may be assumed. In contrast, an increasing effect of GHG emission policy or a change in consumer preferences towards CO2 sequestering products is possible.

There is still some potential for additional post-consumer wood by improving the collection systems. The EU directive 2008/98/EC on waste (Waste Framework Directive) and circular economy package (COM/2014/0398) will lead to less disposed quantity of biodegradable municipal waste (BMW) as assumed in the above scenarios. However, the post-consumer wood depends very much on the consumption of wood products (sawn wood, panels).

4.3.7 Landscape care wood

Landscape care wood includes plants or plant components, which accumulate within landscape care activities. It refers to woody residues from landscape care such as:

- Maintenance operations, tree cutting and pruning activities in agriculture and horticulture industry,
- Other landscape care or arboricultural activity in parks, cemeteries, etc.,
- Maintenance along roadsides and boundary ridges, rail- and waterways, orchards,
- Gardens.

Wood based solid biomass from agriculture, such as from short rotation plantations, are not considered in this section.

The estimated potential of landscape care wood within the EU 27 is 86.7 million m^3 each year (see Table 4-10) (Mantau *et al.*, 2010). Large changes in this potential are not expected before 2030. The major changes will occur in the share of the potential that is actually used for energy production or possibly also in the wood based industry. In 2010 45% of the potential is (mainly) used as fuelwood, 20% goes to composting and the remaining 35% is unused. The use of 11.8 Mtoe (56.3 M m^3) landscape care wood in 2010 (8.2 Mtoe fuelwood and 3.6 Mtoe composting) accounts for more than 7% of the total supply of primary woody biomass in the Wood Resource Balance for 2010.

Table 4-10. Landscape care wood potential in the EU 27 and EU 27 sub regions (Oldenburger, J., 2010, EUwood)

Region	Total potential [Mtoe]	Fuel use [Mtoe]	Compost. [Mtoe]	Unused [Mtoe]
EU 27 North	2.462	1.094	0.484	0.863
EU 27 West	7.891	3.556	1.578	2.757
EU 27 East	3.935	1.768	0.779	1.368
EU 27 South	3.956	1.789	0.800	1.389
EU 27 Total	**18.244**	**8.207**	**3.640**	**6.376**

In order to give some insight into the share of different segments within the landscape care wood potential three of these segments are presented in this paragraph. These segments are: wood from horticulture, wood from urban areas and wood harvested from other wooded land. Due to the lack of data it was impossible to calculate the potential for the other segments separately and for this reason they are presented as the category other (see Table 4-11).

Table 4-11. Landscape care wood potential divided by segments (Oldenburger, J., 2010, EUwood)

Segment	Total potential [Mtoe]	Share [%]
Horticulture	3.367	18.5
Urban areas	4.629	25.4
Other wooded land	0.484	2.7
Other	9.764	53.5
EU 27 Total	**18.244**	**100.0**

With 18.2 Mtoe (86.7 Mm^3) landscape care wood represents a relevant potential of woody biomass. There are still reserves to activate. 3.6 Mtoe (17 M m^3) is composted and 6.4 Mtoe (30 M m^3) remain unused. In most cases economical restrictions prevent utilization. For the future, it should be kept in mind that this may as well be an assortment used in bio-refineries and even material uses.

4.4 Material demand of forest biomass by 2030

The best-known scenarios of wood industry and energy consumption may be those from EUwood (2010) and EFSOS II (2012) which was based on EUwood. However, the main purposes of the EUwood project were to explain the new market situation and to assess whether the political targets regarding material and energy consumption are realistic. The scenarios were therefore not meant to forecast the future development but were instead meant to answer three questions:

1. How much wood is needed if the wood industry remains and develops as it has in the past?
2. How much wood is needed if the National Action Plans for renewable energy of EU Member States (in March 2010) will be fulfilled (20% efficiency achieved and a reduction in biomass proportion from 50% to 40%)?
3. Is there enough wood to achieve scenarios 1 and 2 at the same time?

This was helpful for the important questions in 2010 but will not be a suitable scenario analysis of the remaining wood for energy purposes because EUwood was a gap model. In a gap model supply and demand may differ largely. This means that the consumption may be higher or lower than the available biomass. In this case it was shown that all the utilisation targets were much larger than the availability of wood. Furthermore, the EUwood scenarios were built on the basis of FAO data up to 2007. For this project FAO/UNECE data will be available up to 2013 which will make it easier to assess the consequences of the financial crises. New scenarios will be created in order to analyse different developments of cascading uses.

The first step was to develop a new flexible modelling tool. Data from FAO and UNECE were compared so that more suitable data could be used. UNECE data are partly of higher quality, sometimes more up to date because of additional checks but FAO data reach back to 1961. The model allows choosing between the data sets.

In the next step five different scenarios are calculated:

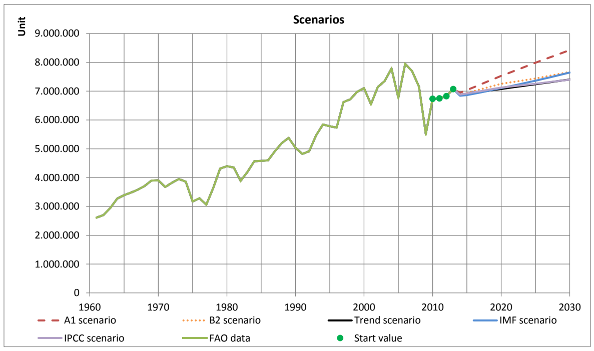
1. A1 Scenario: It assumes the development of the A1 scenario of EUwood (Johnsson R. 2010) and applies it to the latest data set until 2013.
2. B2 Scenario: as A1. The scenarios are based on IPCC projections for GDP. The main quantitative difference is that A1 assumes an average GDP growth rate of +2.5% and B2 of +1.0%.
3. Trend-Scenario: Linear trend over a chosen time period.
4. IPCC-Scenario: The B2 IPCC-Scenario is chosen but the elasticities between wood consumption and the GDP are recalculated.
5. IMF-Scenario: The GDP projection of the International Monetary Fund is chosen. However, the forecast includes data until the year 2019. Thus, thereafter IPCC growth rates were chosen.

The result is a bundle of projections as shown in

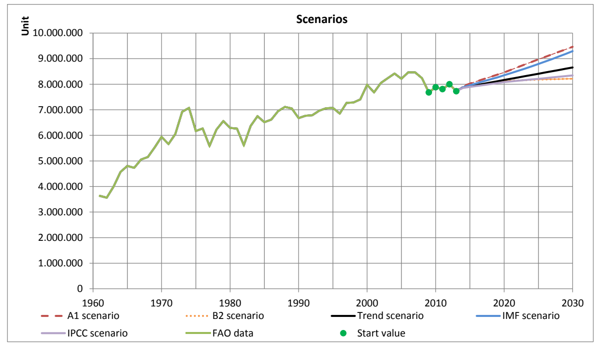
Figure **4-8** for Finland and Sweden.

Figure 4-8. Raw wood consumption of the chemical wood pulp industry in M m³(swe) (Mantau, 2012)

Finland



Sweden

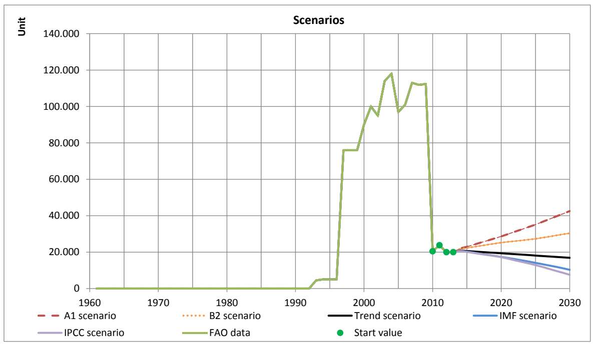


The figure shows as well that the dramatic decline of Scandinavian pulp industry, projected by Hetemeki/Solberg (2014), did not occur. The financial crisis caused a strong downturn and future growth rates might be smaller, but a complete breakdown of the whole industry is unlikely.

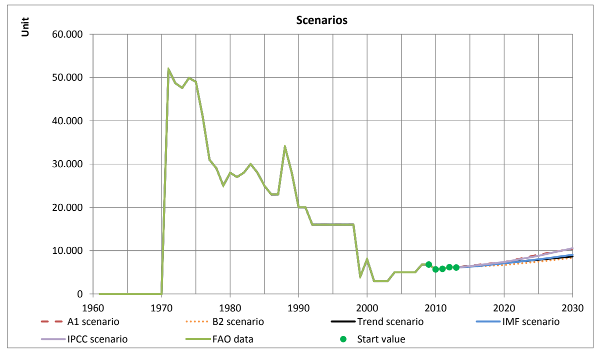
In the next step a scenario is chosen. In most cases the more conservative scenario B2 (Johnsson R. 2010) was chosen. The decision was taken based on the mathematical calculation but as well on a qualitative approach because the modeller sees the long-term development as well as different growth phases. This is a much more realistic approach than black box projections. However, there is the disadvantage that 12 products for 28 countries means that 336 evaluations have to be made. But this is very important because statistical data do not always develop in the continuous way as in Finland and Sweden. Especially products with small quantities tend to have high fluctuations, as illustrated in Figure 4-9. In these cases the already existing scenarios A1 or B2 may be applied or in the case of Bulgaria only the time period between 2000 and 2013 is chosen for the regression analysis. The model allows choosing the time span of regression depending on structural developments.

Figure 4-9. Raw wood consumption of the semi-chemical wood pulp industry in M m³(swe) (Mantau, 2012)

Slowakia



Bulgaria



However, the actual year is not always the best starting year for a scenario, because it may be extremely high or low. The starting timespan may be chosen (green dots). In general it is a five-year period (2009-2013) but can be shorter or longer, depending on its plausibility. Maximum and minimum values can be assumed if the regressions produce unrealistic numbers. In that case the GDP projection is capped and bowed by a saturation function. However, this option was only used in very few cases in countries with small quantities where the statistical data fluctuate unrealistically. This is not always caused by economic developments but by reporting problems.

Finally, one scenario was chosen. Based on this scenario the resource mix of products is calculated. The coefficients for the resource mix are derived from the reports of paper industries (CEPI) and panel industries (EPF). Sawnwood is, of course, easy to calculate (100% stemwood (C or NC)).

A similar calculation sheet is included for the provision of by-products. Sawnwood industry uses stemwood and produces roughly 55% of sawnwood and 45% of sawmill by-products. In this way the availability of residues was calculated.

For an overview of the results the following regions have been defined which are the same as in the EUwood-study, additionally including Croatia in region "East".

Table 4-12. Regional aggregations by country

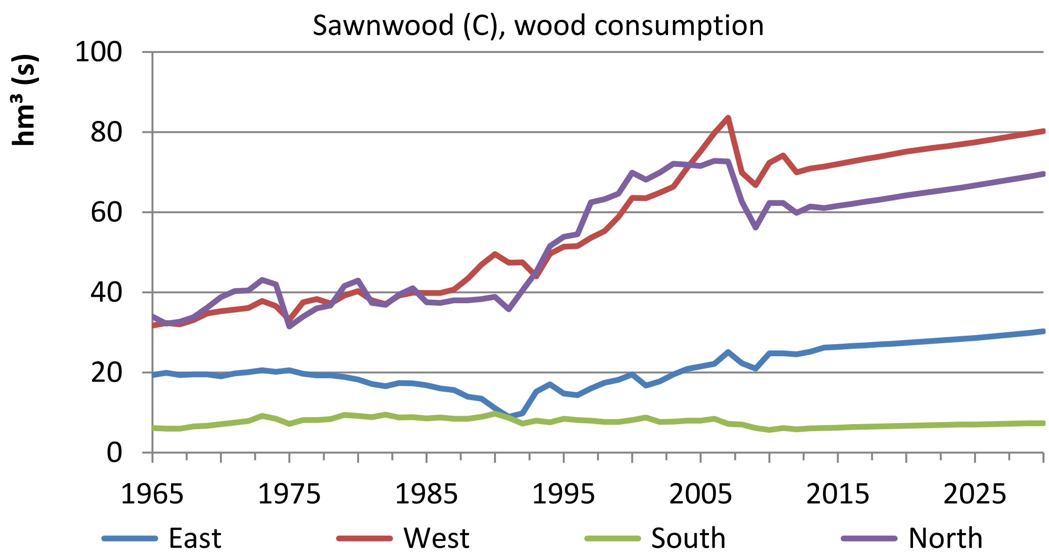
East		West		South		North	
Czech Republic	CZ	Austria	AT	Cyprus	CY	Estonia	EE
Hungary	HU	Belgium	BE	Greece	GR	Finland	FI
Poland	PL	Germany	DE	Spain	ES	Lithuania	LT
Romania	RO	France	FR	Italy	IT	Latvia	LV
Slovakia	SK	United Kingdom	GB	Malta	MT	Sweden	SE
Bulgaria	BG	Ireland	IE	Portugal	PT		
Croatia	HR	Luxembourg	LU				
Slovenia	SI	Netherlands	NL				
		Denmark	DK				

The developments shown in this chapter are all presented in M m³ (swe) [million cubic meter solid wood equivalent].

The **softwood sawnwood** production may be separated in three development phases. Between 1965 and 1990 the industry remains in small size classes and grows slowly. With globalization and the high growth rates after 1990 up to 2007 the industry expands and large units develop. The following developments show aggregated coniferous and non-coniferous sawnwood production. During this time, the sawmill industry gains economic support from increasing material and energy demand because sawmill by-products can be sold at higher prices. The financial crisis leads to a break in the development.

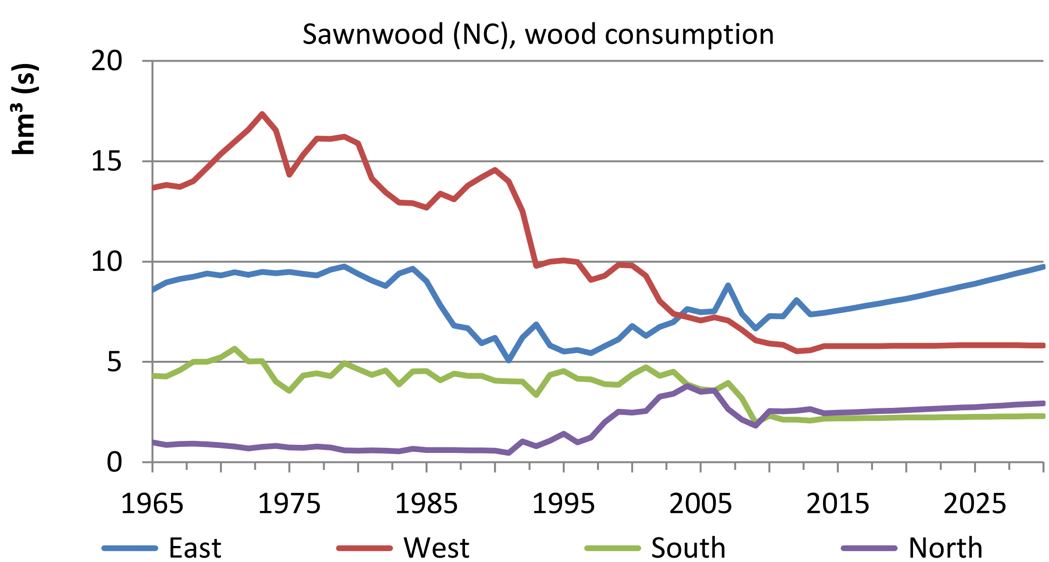
Meanwhile, the industry has stabilized. It has a stronger competitive structure than in the first development phase. The growth rates for the period 2003 to 2007 will not be repeated, but a moderate upward trend is very plausible. Initially the development in Eastern Europe takes a different course due to the collapse of the Warsaw Pact but has now embarked on a relative strong and parallel growth trend.

Figure 4-10. Wood consumption of softwood sawnwood industry by regions in M m³(swe)



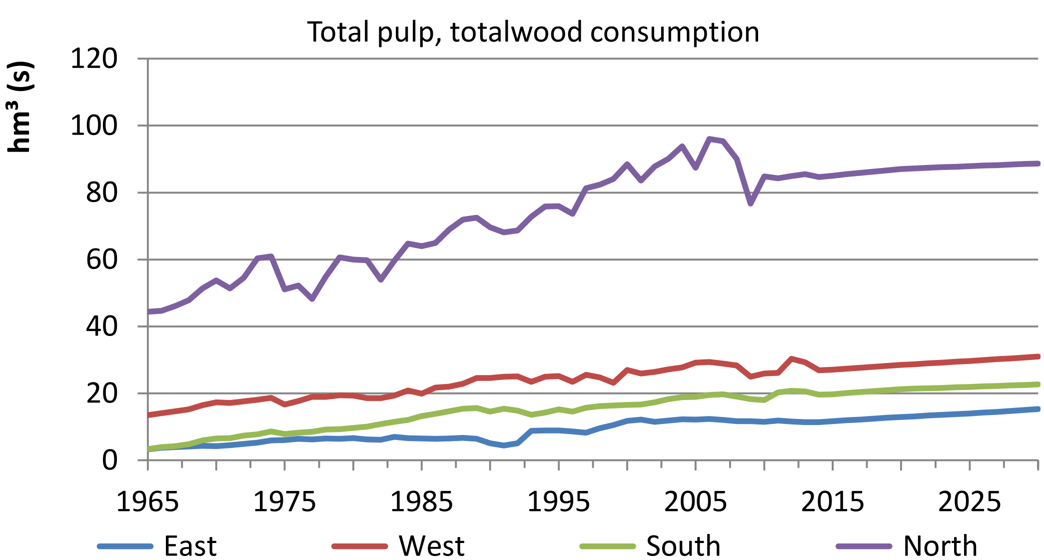
Hardwood sawnwood develops completely different from softwood sawnwood. The markets are declining over the largest part of the period. Part of decline is due to changes in the statistical cut-off limit. 1995 the cut-off limit was increased from 1,000 m³ to 5,000 m³. From 2006 to 2007 the cut-off limit was set from 5.000 m³ to 10 employees which is equivalent to 12,000 m³ in softwood and 7,500 m³ in hardwood. Thus the statistical numbers decline, while the market remains stable. As mentioned before, production statistics for hardwoods are not very reliable.

Figure 4-11. Wood consumption of hardwood sawnwood industry by regions in M m³(swe)



The **pulp industry** is mainly located in Scandinavia. Since 1965 it was characterized by a strong growth that continued until the financial crisis of 2008. The financial crisis represents a turning point here as well. In addition, the growth opportunities are limited by the growing competition of electronic media. Scenarios of a collapsing pulp industry in Scandinavia as described recently cannot be confirmed by recent developments. However, it is an industrial sector in transition to bio-economy with new chances in the sector of new bio-based products. However, such products would be calculated in the sector 'other new bio-based uses'. In other regions, the development is also characterized by growth. The developments in Figure 4-12 represent the aggregated wood consumption of chemical, mechanical and semi-chemical pulp production.

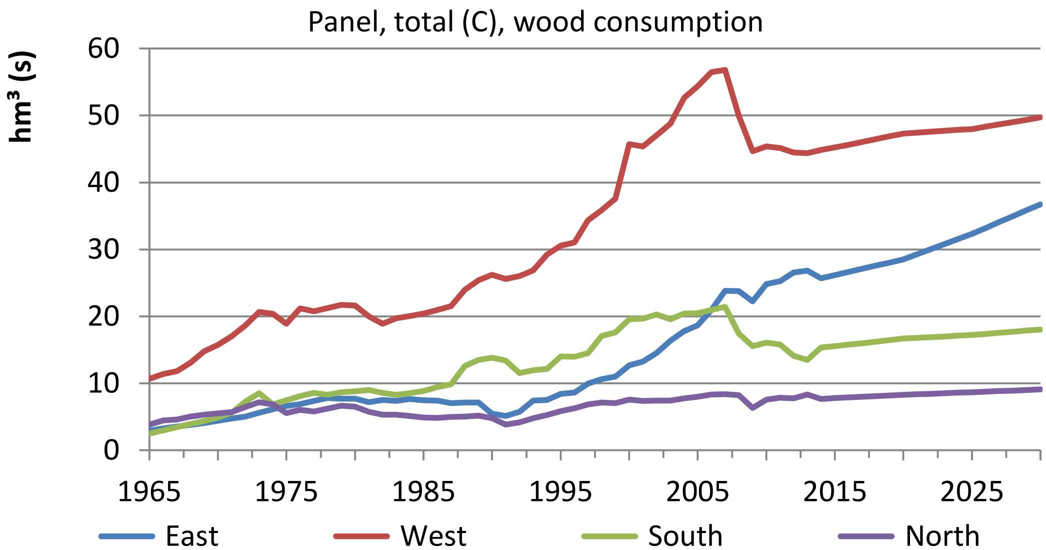
Figure 4-12. Wood consumption of pulp industry by regions in M m³(swe)



For Northern Europe much slower growth rates are assumed than in the past, but the pulp industry will still remain. In other regions the slightly higher growth rate is also supported by a new minor capacity expansion in regions with no or small capacities so far.

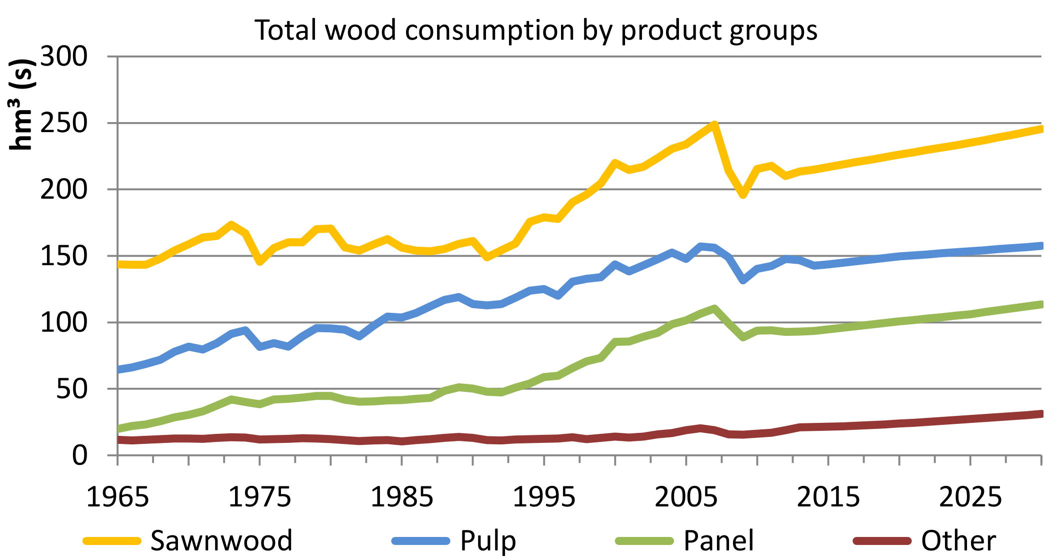
The **panel industry** is mainly located in Western Europe. It "furnished" the nations after World War II and then turned into a phase of stagnation until around 1990. The re-construction of the Eastern bloc countries gave the industry a comeback with strong growth rates. Judging by the year's production, capacities were built up strongly in the Eastern European countries. While in Western Europe growth rates will turn down, countries in Eastern Europe have still some prosperous years ahead. The developments in Figure 4-13 represent the aggregated wood consumption of particle board, oriented strand board (OSB) and all kinds of fibre boards (HDF, MDF, LDF) characterized by their density high (HDF), medium (MDF) and low (LDF). Veneer and plywood production is included as well.

Figure 4-13. Wood consumption of panel industry by regions in M m³(swe)



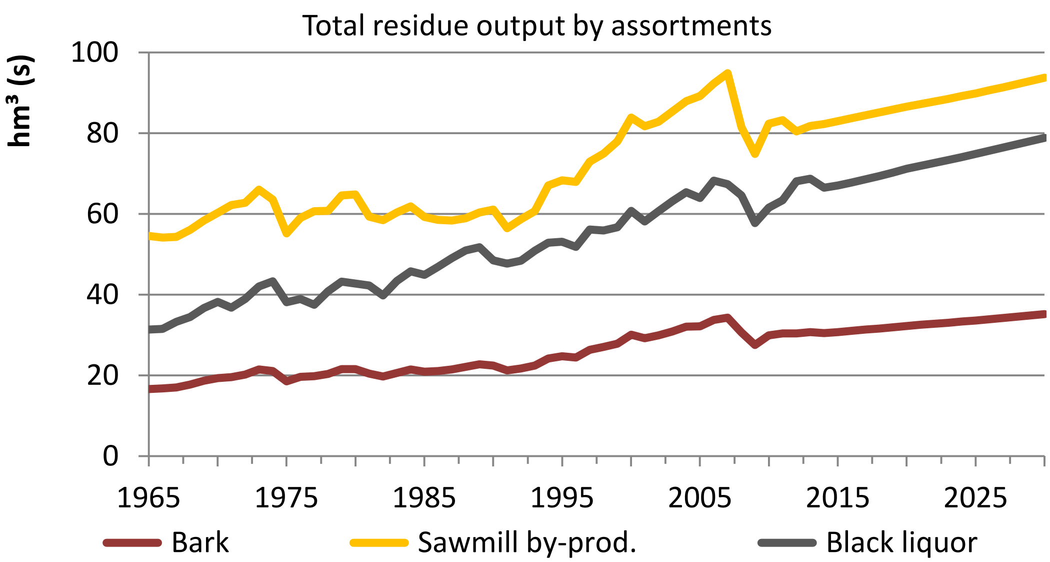
In total, wood industry will develop more moderately in the upcoming time period than in the growth years 1995 to 2007, but it is still expected to grow. There may be even further positive effects on the demand for wood. The positive CO2-effects of wood consumption may even lead to higher growth rates than shown, when policy incentives strengthen the competitiveness of material uses of wood. The sector of new bio-based products is not yet visible in quantities but may gain economic and political support in the future. Generally speaking, this reference scenario is a more carefully defined assessment of the wood material demand up to 2030. Even if the pulp industry may be threatened more than others the resource quantities will be needed for the build-up of new bio-based industries.

Figure 4-14. Wood consumption of wood industry by product groups in M m³(swe)



Industrial by-products are very much linked to the developments of wood industries. If the sawmill industry drops by ten percent, the availability of sawn-wood by-products drops by the same dimension. Bark is a very special assortment. Its availability is normally overvalued. Bark is a perfect wrapping for wood. Wood is not anymore debarked in the forest. Thus, bark is where the stem is. When split wood is burned in households, that proportion is not available anymore on the market for energy use as well as bark on other wood assortments. Marketable bark can mainly be found in industries which debark wood before processing. This proportion is shown in. It is up to those industries, if they sell it e.g. to mulch industry or burn it in their own mills.

Figure 4-15. Availability of industrial by-products by assortments in M m³(swe)



4.5 Forest biomass supply scenarios

A "Wood Resource Balance" (WRB) summarizes all flows from forest to wood industry and wood energy. It summarizes all the underlying material wood flows. The left side of the balance sheet shows the raw material volume and the right side of the balance sheet show in which sectors wood is used. The Wood Resource Balance can describe the resource situation in different ways. Table 4-13 shows only the material use in $Mt_{o.d.}$ (oven dry tons; dry matter). On the right side the total wood consumption by wood industries is shown and on the left side the resources that have been used. In this case, the balance sum is even. It answers the question: How much wood is used by different consumers and what kinds of resources were used?

Table 4-13. Wood resource balance for material uses only (Source: Wood resource balance approach, see Mantau 2010)

Wood Resource Balance - EU28							
Utilisation	**2010 M m³**	**2020 M m³**	**2030 M m³**	**2010 M m³**	**2020 M m³**	**2030 M m³**	**Consumption**
stemwood, conifers	277.1	296.2	321.4	183.2	192.3	208.2	sawmill industry
stemwood, non-con.	68.4	74.6	82.3	12.1	13.0	14.7	veneer plywood
stemwood, total	345.5	370.8	403.7	140.3	149.7	157.6	pulp industry
forest residues	0.4	0.5	0.5	81.7	87.5	98.1	panel industry
bark	7.7	7.6	7.7	17.3	18.0	19.0	other traditional
landscape care wood	0.0	0.0	0.0	3.3	10.0	16.2	other new bio-based
sawmill residues	67.4	74.1	82.5				energy consumption
other industrial res.	0.0	0.0	0.0				
black liquor	0.0	0.0	0.0				
post consumer wood	16.8	17.5	19.4				
balance clearing							balance clearing
total	**437.8**	**470.5**	**513.8**	**437.8**	**470.5**	**513.8**	**total**
(c) INFRO							

As mentioned before the WRB is a condensed form of all flows between resource and consumption sectors. Instead of the utilisation on the left side and the consuming sectors on the right side it is possible to compare the potential of all resources and the utilisation of resources. In this case the right side of the balance shows the pre allocated resources for material use. Table 4-14 compares the material used by wood industries with the reference potential. The term potential is understood as technical potential. Therefore it should be borne in mind, that this material is not necessarily available on the market. The market availability depends on actual prices and mobilisation by forest land owners. Furthermore, some statistical values are underestimated. At the end of this chapter an estimation of data uncertainties is provided.

Table 4-14. Comparison of reference scenario and material use of wood

Wood Resource Balance							
Potential Reference	**2010 M m³**	**2020 M m³**	**2030 M m³**	**2010 M m³**	**2020 M m³**	**2030 M m³**	**Materially used**
stemwood, conifers	357,4	356,7	356,0	277,1	296,2	321,4	stemwood, conifers
stemwood, non-con.	177,7	183,9	190,1	68,4	74,6	82,3	stemwood, non-con.
stemwood, total	535,1	540,6	546,1	345,5	370,8	403,7	stemwood, total
forest residues	118,1	118,7	119,2	0,4	0,5	0,5	forest residues
bark	53,6	54,2	54,8	7,7	7,6	7,7	bark
landscape care wood	87,0	87,0	87,0	0,0	0,0	0,0	landscape care wood
sawmill residues	82,4	86,6	93,7	67,4	74,1	82,5	sawmill residues
other industrial res.	29,8	32,6	34,8	0,0	0,0	0,0	other industrial res.
black liquor	61,5	71,3	78,9	0,0	0,0	0,0	black liquor
post consumer wood	36,3	49,9	56,5	16,8	17,5	19,4	post consumer wood
solid wood fuels							solid wood fuels
total	**1.004,0**	**1.040,8**	**1.071,1**	**437,8**	**470,5**	**513,8**	**total**
(c) INFRO							

The difference between the technical potential and the quantities used for materials in Table 4-14 is the available biomass for other purposes (primarily energy). Table 4-15 compares the technical potential with the available biomass for non-material purposes. It answers the question how much is technically available for other uses under the reference potential and the given material utilization scenarios.

Table 4-15. Comparison of reference scenario and resources available for non-material purposes

Wood Resource Balance							
Potential	2010	2020	2030	2010	2020	2030	Not materially
Reference	M m³	M m³	M m³	M m³	M m³	M m³	used
stemwood, conifers	357.4	356.7	356.0	80.3	60.5	34.6	stemwood, conifers
stemwood, non-con.	177.7	183.9	190.1	109.3	109.3	107.8	stemwood, non-con.
stemwood, total	535.1	540.6	546.1	189.6	169.8	142.4	stemwood, total
forest residues	118.1	118.7	119.2	117.7	118.2	118.7	forest residues
bark	53.6	54.2	54.8	45.9	46.6	47.1	bark
landscape care wood	87.0	87.0	87.0	87.0	87.0	87.0	landscape care wood
sawmill residues	82.4	86.6	93.7	14.9	12.5	11.3	sawmill residues
other industrial res.	29.8	32.6	34.8	29.8	32.6	34.8	other industrial res.
black liquor	61.5	71.3	78.9	61.5	71.3	78.9	black liquor
post consumer wood	52.3	55.7	59.0	35.6	38.2	39.6	post consumer wood
solid wood fuels							solid wood fuels
total	**1,020.0**	**1,046.6**	**1,073.6**	**582.1**	**576.1**	**559.8**	**total**
(c) INFRO							

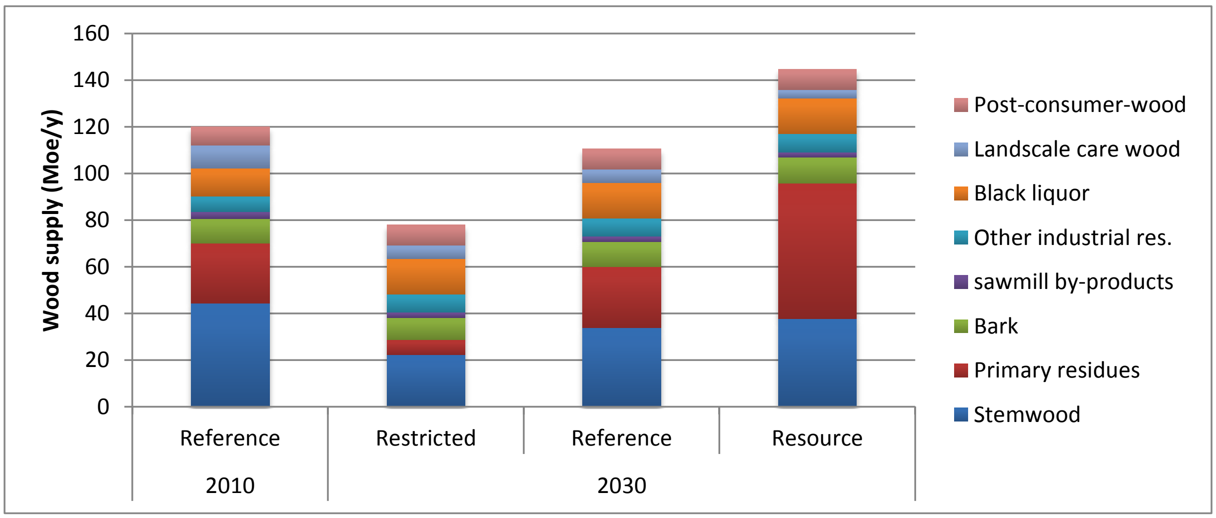
Table 4-16 shows on the left side the resource scenario with high mobilisation of resources and on the right hand side the technically available potential of the different assortments for non-material purposes. Thus, these values are higher because the material uses remain on the same level. It answers the same question as Table 4-15 for the resource scenario.

Table 4-16. Comparison of resource scenario and resources available for other purposes

Wood Resource Balance							
Potential	2010	2020	2030	2010	2020	2030	Not materially
Resource	M m³	M m³	M m³	M m³	M m³	M m³	used
stemwood, conifers	370.4	368.0	365.5	93.3	71.7	44.2	stemwood, conifers
stemwood, non-con.	181.4	189.6	197.8	113.0	115.0	115.5	stemwood, non-con.
stemwood, total	551.8	557.6	563.3	206.3	186.7	159.6	stemwood, total
forest residues	255.1	260.3	265.5	254.6	259.8	264.9	forest residues
bark	55.3	55.9	56.6	47.6	48.3	48.9	bark
landscape care wood	87.0	87.0	87.0	87.0	87.0	87.0	landscape care wood
sawmill residues	82.4	86.6	93.7	14.9	12.5	11.3	sawmill residues
other industrial res.	29.8	32.6	34.8	29.8	32.6	34.8	other industrial res.
black liquor	61.5	71.3	78.9	61.5	71.3	78.9	black liquor
post consumer wood	52.3	55.7	59.0	35.6	38.2	39.6	post consumer wood
solid wood fuels							solid wood fuels
total	**1,175.3**	**1,206.9**	**1,238.9**	**737.5**	**736.4**	**725.0**	**total**
(c) INFRO							

Under current management practices (Reference scenario), the total supply potential of wood biomass available for bioenergy in 2030 is projected to decrease by 11% compared to 2010, mainly as a result of increased demand for stemwood from the material sector (Figure 4-16). On the other hand, it could also substantially increase when a strong focus on wood mobilisation for producing energy and materials is pursued, using maximum sustainable biomass (Resource scenario).

Figure 4-16. Total supply of wood sources for bioenergy and novel biomaterials (not materially used wood supply) in the EU28 in 2010 and 2030



4.5.1 Uncertainties in wood mobilization and consumption registration

The available technical potential does not reflect in which resource areas the mobilization problem is economically almost impossible to solve and in which consumer sectors the officially registered consumption is underestimated. In this chapter these areas of uncertainty are discussed and an expert guess is given for their dimension.

Resources

Wood industry is to a large extent based on **coniferous stemwood** (softwood). This assortment is almost completely used because not all of the technically available potential can be economically mobilized. Between technical and economic potential are structural barriers that cause an under exploitation of the technical potential even at high prices. Not all millions of small forest land owners follow market incentives. They earn their income in other areas or simply have other preferences. Furthermore, the last part of the technical potential is always hard to mobilize. It is assumed that most likely 10% of the technical available potential cannot be mobilized because of these structural barriers.

Non- coniferous stemwood (hardwood) still shows some reserves because it has limited market demand in many areas of utilisation. In construction 85% of timber is softwood (Germany 2013, Mantau, Döring, Hiller 2013). Panels (80%) and pulp (90%) are mainly produced from softwood and even biomass heat and power plants use 70% softwood, with pellets composed of 95% softwood (Mantau 2012b). Hardwood logs are most cost intensive to process given their shape and the impact hardwoods have on machinery, as opposed to softwoods. The production of hardwood logs is normally more cost intensive (capital cost of longer rotation time). The producer (forest land owner) expects a higher price and is not motivated to harvest when market prices for softwood are equal or even higher than for hardwood. As a result of these examples, hardwood mobilisation has many more structural barriers than softwood mobilisation. It is assumed that most likely 20% of the technical available potential of hardwoods cannot be mobilised.

Forest residues are the main reserve for energy uses. All forest potential data are based on calculations of EFI (European Forest Institute) in the EUwood / EFSOS II studies and have been updated. Thus, the volumes represent technically realistic volumes. However, forest residues face a severe mobilisation problem. Harvesting technique is based on stemwood and labour costs are high. It will take some time to overcome these structural barriers. On the other hand environmental NGOs propose stronger restrictions on the use of forest residues which may become a stronger barrier in the future. It is assumed that the mobilization barriers are at least as high as for hardwood (>20% cannot be mobilized).

As mentioned before, **bark** is a special resource. It is either delivered to the wood industry, burned with energy wood or still remaining in forests with unused potential (standing trees). It obviously cannot be harvested on its own. Thus the mobilisation barrier of bark is the weighted average of soft- and hardwood (87%).

The **landscape care wood** volumes are taken from the EUwood study. No further assumptions are made. It is assumed that the technical potential can be mobilised. The proportion of short rotation plantations in the year 2010 was quite low. Further assumptions for short rotation plantations will be undertaken in the chapter of agricultural biomass.

As mentioned before the availability of **industrial residues** depends very much on the development of traditional industries. It may be mentioned that it is unlikely that new bio-based products based on bio-refineries will produce a lot of residues. Furthermore, new bio-based products may be seen as a new competitor for energy use of wood because they normally would not need high quality stemwood. The assortment "other industrial residues" occurs by further processing of wood in construction, furniture, packaging and other wood processing activities. They are generally internally used for energy in factory driven heating installations or sold directly to energy producers. When other industrial residues are transferred to the disposal system they become by definition post-consumer wood. Post-consumer wood is so far only used for materials in the particle board industry. It is assumed that the technical potential of these assortments are available.

Consumption statistics

Reporting of the sawmill industry is limited to companies with more than 10 employees. Broadly undertaken analysis in Germany shows for the sawmill industry, that the cut-off limit of 10 employees and reporting errors causes an underestimation of 22.2% for softwood (C) and 57.3% for hardwood (NC (Döring/Mantau (2012). The underestimation in the sawnwood industry for hardwood is higher than for softwood because hardwood sawmills are generally smaller. Therefore a larger amount of mills fall under the cut-off limit. For these calculations a very conservative underestimation factor was chosen (C 20%; NC 40%). As Germany has a sawmill industry with many large sawmills it can be assumed that the underestimation in other countries may be higher. However, not all stemwood is used in sawmills. Therefore, the underestimation is smaller for the total stemwood quantities (1.094 for softwood and 1.085 for hardwood). There is another side to this as well. When sawnwood production is higher than registered in official statistics, then the amount of sawmill-by products is higher as well. Thus, the net effect is just about 60% because roughly 40% sawmill- by products occur on the left hand side as higher potential. Table 4-17 summarizes all uncertainties and where they occur in the wood flow. It is a sensitivity analysis for data uncertainties. The factor for sawmill-by products (1.26) is higher because the basis is just sawn wood logs and not all stemwood.

Table 4-17. Uncertainties of wood mobilisation and wood consumption registration

Wood Resource Balance							
Uncertainty	**2010**	**2020**	**2030**	**2010**	**2020**	**2030**	**Uncertainty**
Rates	**Correction factor**			**Correction factor**			**Rates**
stemwood, conifers	0,90	0,90	0,90	1,094	1,094	1,094	stemwood, conifers
stemwood, non-con.	0,80	0,80	0,80	1,085	1,085	1,085	stemwood, non-con.
stemwood, total							stemwood, total
forest residues	0,80	0,80	0,80				forest residues
bark	0,87	0,87	0,87				bark
landscape care wood							landscape care wood
sawmill by-products	1,26	1,26	1,26				saw mill by products
other industrial res.							other industrial res.
black liquor							black liquor
post consumer wood							post consumer wood
solid wood fuels							solid wood fuels
total							**total**
(c) INFRO							

If these uncertainties are applied, the available wood for non-material use is of course smaller. The economic potential of softwood is practically fully used (even overused). That does not necessarily mean that it is used unsustainably. Depending on age-classes or silvicultural activities longer yearly fluctuations are possible. Even natural sustainability is more complex than the difference of two numbers.

The largest reserves of primary biomass are found in non-coniferous stemwood, forest residues and landscape care wood. In secondary biomass the largest proportion is black liquor which is almost completely used in the pulp industry for heat and energy. By-products sum up to more than 50 $Mt_{o.d.}$ biomass. Post-consumer wood is most likely to be activated, but in total a maximum of 20 $Mt_{o.d.}$ post-consumer wood is not used for materials. If policy targets put a strong incentive on cascade use material use of post-consumer wood may even increase higher.

Table 4-18. Comparison of reference scenario and resources available for non-material use assuming data uncertainties

	Wood Resource Balance						
Potential	**2010**	**2020**	**2030**	**2010**	**2020**	**2030**	**Not materially**
Reference	**M m³**	**M m³**	**M m³**	**M m³**	**M m³**	**M m³**	**used**
stemwood, conifers	321.7	333.4	320.4	32.2	22.6	-16.7	stemwood, conifers
stemwood, non-con.	142.2	147.1	152.1	67.9	66.2	62.7	stemwood, non-con.
stemwood, total	463.8	480.5	472.5	100.1	88.7	46.0	stemwood, total
forest residues	94.5	94.9	95.3	94.1	94.5	94.8	forest residues
bark	46.6	47.2	47.7	38.9	39.5	40.0	bark
landscape care wood	87.0	87.0	87.0	87.0	87.0	87.0	landscape care wood
sawmill residues	103.8	109.1	118.1	36.4	35.0	35.6	sawmill residues
other industrial res.	29.8	32.6	34.8	29.8	32.6	34.8	other industrial res.
black liquor	61.5	71.3	78.9	61.5	71.3	78.9	black liquor
post consumer wood	36.3	49.9	56.5	19.6	32.5	37.1	post consumer wood
solid wood fuels							solid wood fuels
total	**923.5**	**972.4**	**990.9**	**467.4**	**481.0**	**454.3**	**total**
(c) INFRO							

Under the assumption of a resource scenario with high mobilisation the remaining woody biomass for non-material uses is assumingly higher. Softwood is almost used at its full potential. The largest reserves of primary biomass in this scenario are in forest residues. The resource scenario assumes that there is a societal common sense that resources mobilization is of a high value. Forest still grows sustainably under this scenario (See Section 4.3.3) but conflicts to other targets are higher. Landscape care wood remains the same because it is not part of forest growth modelling and not used for materials. Secondary biomass remains the same as well, because it depends on developments in the wood industry.

Table 4-19. Comparison of resource scenario and resources available for other purposes assuming uncertainties

	Wood Resource Balance						
Potential	**2010**	**2020**	**2030**	**2010**	**2020**	**2030**	**Not materially**
Resource	**M m³**	**M m³**	**M m³**	**M m³**	**M m³**	**M m³**	**used**
stemwood, conifers	333.4	331.2	329.0	43.9	20.4	-8.1	stemwood, conifers
stemwood, non-con.	145.1	151.7	158.2	70.9	70.7	68.9	stemwood, non-con.
stemwood, total	478.5	482.9	487.2	114.7	91.1	60.8	stemwood, total
forest residues	204.1	208.2	212.4	203.6	207.8	211.8	forest residues
bark	48.1	48.7	49.2	40.4	41.0	41.5	bark
landscape care wood	87.0	87.03	87.03	87.0	87.0	87.0	landscape care wood
sawmill residues	103.8	109.1	118.1	36.4	35.0	35.6	sawmill residues
other industrial res.	29.8	32.6	34.8	29.8	32.6	34.8	other industrial res.
black liquor	61.5	71.3	78.9	61.5	71.3	78.9	black liquor
post consumer wood	52.3	55.7	59.0	35.6	38.2	39.6	post consumer wood
solid wood fuels							solid wood fuels
total	**1065.2**	**1095.3**	**1126.7**	**609.1**	**603.9**	**590.1**	**total**
(c) INFRO							

5 Agriculture biomass supply: state of play and scenarios to 2030

5.1 State of play

The most important application of agricultural biomass for energy is for the production of biofuels, typically sugar and starch crops for bio-ethanol and oil crops for biodiesel. In some regions straw is used for the production of heat and/or electricity (mainly practiced in Denmark, typical use around 1.0-1.5 million tonnes per year). There are also agricultural digesters producing biogas from energy crops(predominantly maize) and manure, with Germany being the biggest player (using 1.16 Mha arable crops for biogas production in 2012). In relation to data availability, we will focus the discussion on liquid biofuels from agricultural crops.

5.1.1 Land use and availability

Global land use

The amount of land area available for bioenergy production depends on the amount of land needed for other purposes, as well as the suitability of the theoretically available land for energy crop production. Demand for land for different purposes include food, feed, fibre and energy production, land for humans to live and build, as well as land for recreational purposes. In addition, land is required for regulating services such as carbon sequestration and the provision of clean air and water, as well as for the protection of biodiversity (Kretschmer *et al.*, 2013).

According to the FAO, the world total land area is approximately 13 billion hectares (ha), of which:

- 4.92 billion ha agricultural area,
    - 1.40 billion ha arable land
    - 0.16 billion ha permanent crops
    - 3.36 billion ha permanent meadows and pastures
- 4.02 billion ha forest area,
- 4.07 billion ha other land.

A distribution of land, forest land per region is provided in Table 5-1.

Table 5-1. Distribution of agricultural land, forest land and other land in worldwide regions (source: FAOstat). Figures are for 2012 (in 1000 ha).

Regions	Agricultural area	*Arable land*	*Permanent crops*	*Permanent meadows and pastures*	Forest area	Other land
EU28	186 459	*108 281*	*11 692*	*66 485*	159 621	76 652
Europe, non-EU	67 217	*46 719*	*1 866*	*18 633*	37 703	47 831
Russian Federation	214 350	*119 750*	*1 600*	*93 000*	809 210	614 127
Eastern Asia	637 724	*115 287*	*16 750*	*505 687*	259 739	255 754
South and South-eastern Asia	440 406	*283 534*	*61 813*	*95 058*	304 817	328 860
Western and Central Asia	554 582	*68 103*	*6 633*	*479 846*	31 342	287 261
Eastern and Southern Africa	506 552	*80 867*	*8 394*	*414 530*	206 245	196 442
Northern Africa	218 587	*44 000*	*6 040*	*168 547*	78 500	512 419
Western and Central Africa	452 614	*112 268*	*19 381*	*320 965*	382 874	422 890
South America	613 441	*133 768*	*14 174*	*465 499*	857 188	275 482
North and Central America	611 201	*235 073*	*13 966*	*362 161*	705 431	816 360
Oceania	419 076	*48 245*	*1 584*	*369 247*	189 240	240 366

EU land use

A high share of European land is covered by forested land, followed by arable land and permanent crops and pastures and mosaics. The artificial area between 2000 and 2006 has increased and a survey based on LUCAS 2012 land cover data suggests that this area has continued to increase between 2009 and 2012 (Allen *et al.*, 2014). According to that survey, woodland has increased significantly in that same period, while the other land cover types decreased on European level (Allen *et al.*, 2014).

Total utilized agricultural land (UUA) in EU-28 declined from 187 Mha in 2006 to 177 Mha in 2013 (Eurostat 2015). Share of arable land (60%) and permanent grassland (33%) of UUA stays fixed over time (Figure 5-1).

More than half of the arable land in EU-28 is cultivated with cereal crops (Figure 2). The crop category industrial crops is mainly consisting of oilseed crops (approximately 10% of the total arable land), with rapeseed as the main oilseed crop cultivated. About half of the area cultivated with 'root crops' consists of sugar beet production. The category 'plants harvested green' include all 'green' crops grown on arable land and are mainly intended for animal feed, a small part of this category is however used for energy production such as green maize (European Commission, 2014). A decline in fallow land is observed from 2008 as the requirement of fallow land under the Common Agricultural Policy was abolished in that year.

Hamelinck et al. (2014) calculated the total amount of agricultural land required for the EU biofuel consumption in 2012 to be 7.8 Mha, of which 4.4 Mha (56%) is within EU-28 and 3.5 (44%) outside the EU. The amount of arable land used for biofuel feedstock production corresponds to 3.9% for 2012.

Figure 5-1. Shares of arable land, permanent grassland and permanent cropland of the Utilized Agricultural Area in EU-28 between 2006-2013 (EUROSTAT, 2015a, 2015b)

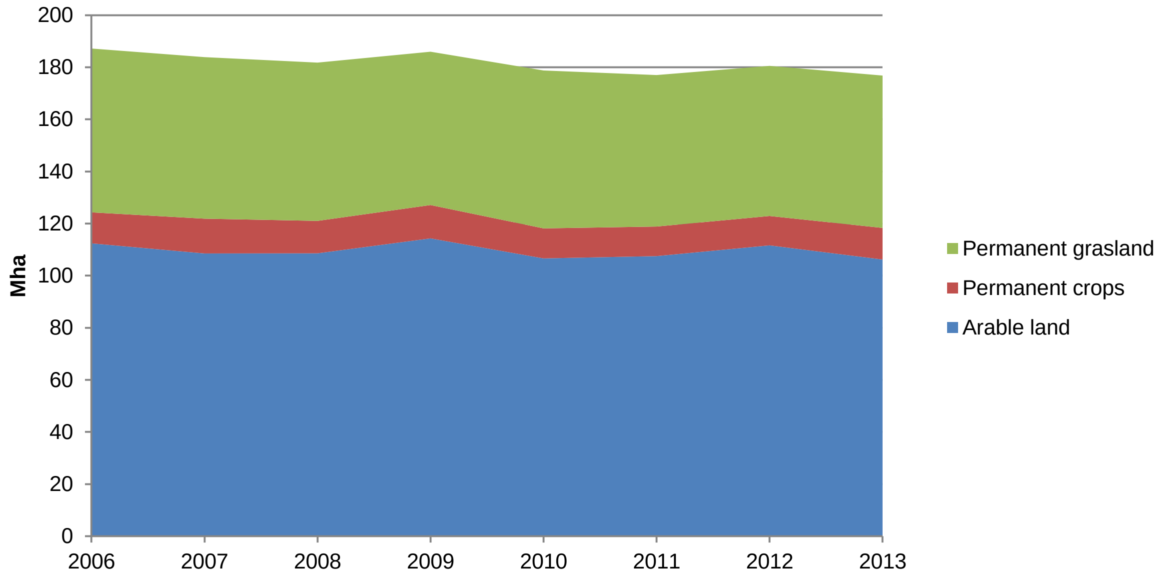
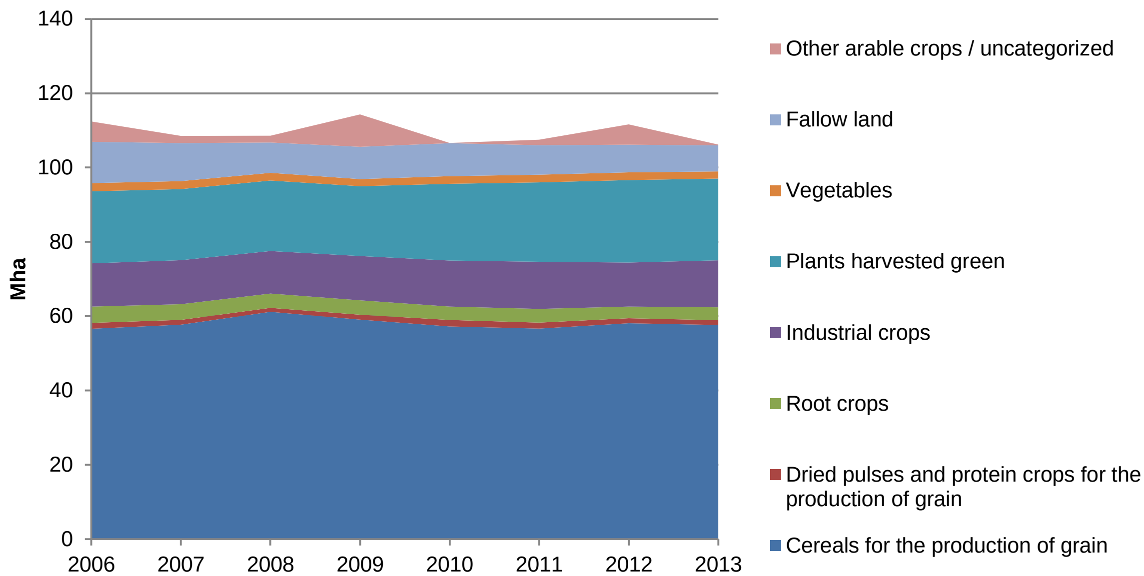


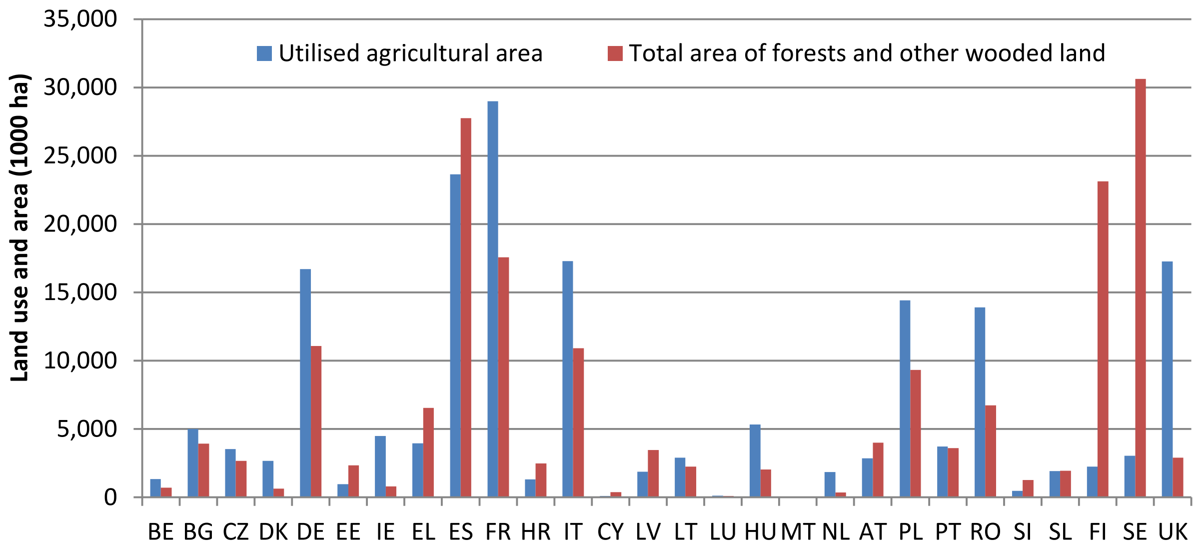
Figure 5-2. Crop cultivation on arable land in EU-28 between 2006-2013 (EUROSTAT, 2015a, 2015b)



In the EU28, France has the largest area of utilized agricultural area (29 Mha) and arable land (18 Mha) whereas Sweden has the largest area of forests and other wooded land (31

Mha) and forests available for wood supply (21 Mha) as shown in Figure 5-3. A detailed table is also provided in the Appendix (Table A 1).

Figure 5-3. Utilised agricultural area (2013) and total area of forests and other wooded land (2010) in the EU28 (EUROSTAT 2015).



5.1.2 Current consumption, production and trade of agricultural commodities

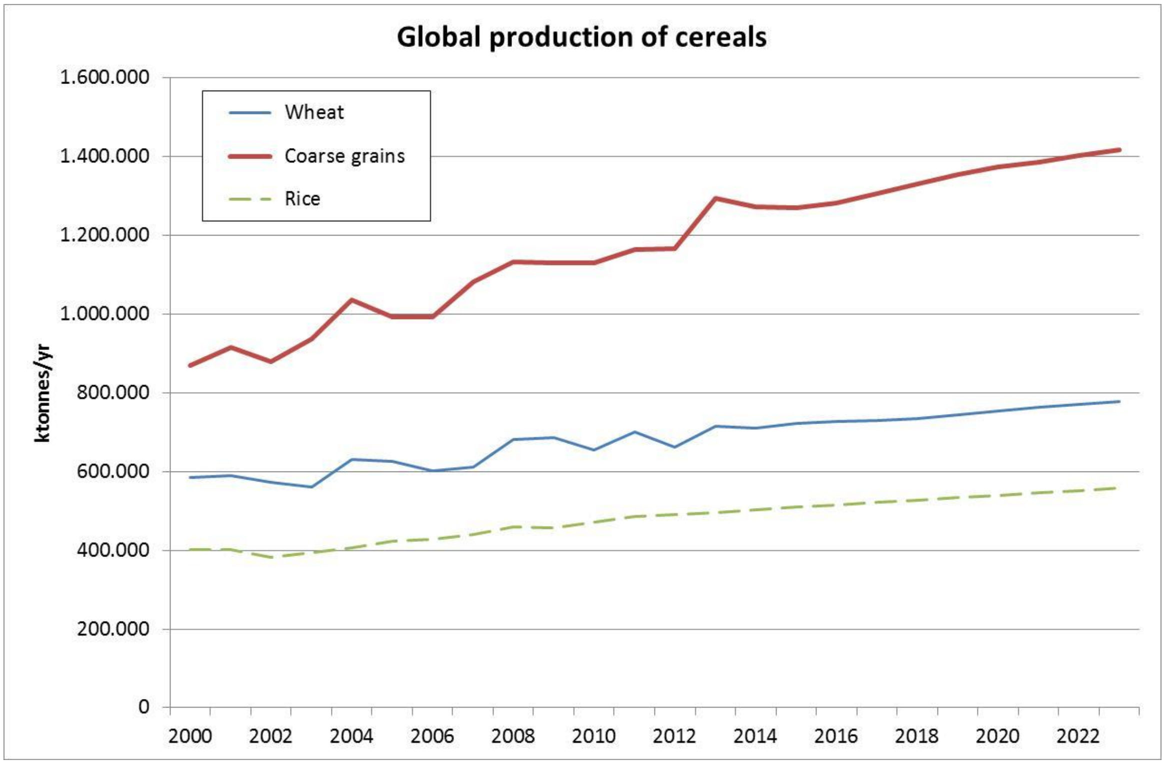
To sketch the overall picture of agricultural biomass on a global level, we build on data derived from the OECD-FAO Agricultural Outlook 2014-2023. Data up to 2012 are reported values, data for 2013 are provisional, data from 2014 to 2023 are forecast values. For current consumption, production and trade, the average figures of 2011-2013 are considered.

We focus on land based crops, in particular cereals, oil crops and sugar crops that are already relevant for energy production, in particular biofuels (bioethanol or biodiesel).

Cereals

FAO (2014) classifies cereals into wheat, coarse grains and rice. In 2011-2013 these crops accounted for 720 Mha of arable land, producing 700 Mt of wheat, 1200 Mt of coarse grains and 490 Mt of rice per year. There is a clear increasing trend of global production of cereals in the past decade (linked to world population growth and changing diet patterns) and FAO expects this trend to continue.

Figure 5-4: Global production of cereals (derived from FAO, 2014)



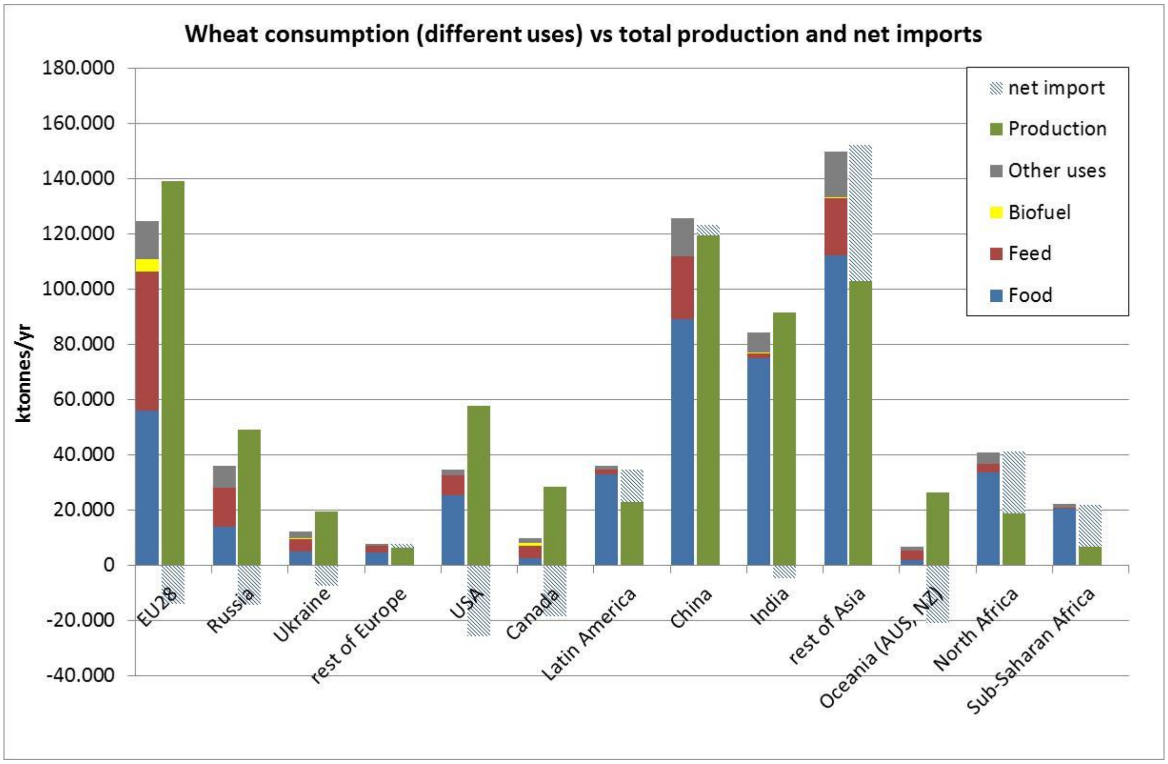
Wheat

Global production of wheat is 690 Mt (average 2011-2013 in Figure 5-4). The main producers of wheat are Asia (41%), Europe & Russia (31%) and North America (13%) as shown in Figure 5-5. The EU28 by itself accounts for 20% of global wheat production (139 Mt). 90% of that amount (125 Mt) is consumed within the EU, 10% (14Mt) is exported outside the EU.

The main export countries/regions for wheat are the US, Canada, Australia, the EU, Russia and Ukraine. In the case of Canada and Australia, more than two third of their production is destined for export. The main import regions are Latin America, Asia and Africa.

At the global level 67% of total wheat is used for food purposes, 18% for feed, 0.9% for biofuels and 10% for other uses. Only at EU level the use of wheat for biofuels reaches a significant level (3.5% of wheat consumption).

Figure 5-5. Wheat consumption (different uses) and production/imports in different world regions (derived from FAO, 2014)



Coarse grains

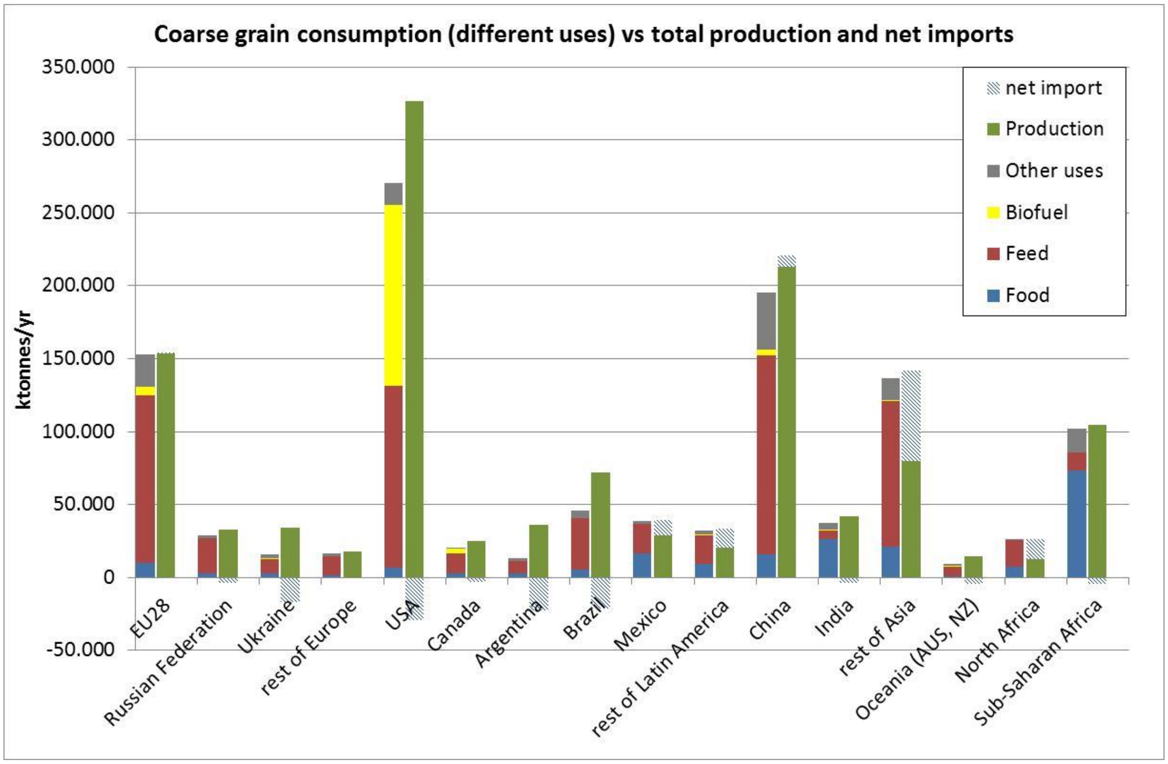
The term 'coarse grains' generally refers to cereal grains other than wheat and rice. It contains barley, maize, oats, sorghum and other coarse grains, but around ¾ is corn.

Global production of coarse grains was 1.2 billion tonnes (average 2011-2013). The USA is the biggest producer of coarse grains, with 27% of global production. The EU28 accounts for 13% of global production. Production and consumption in the EU are more or less in balance.

When looking at the global overview 16% of total coarse grains are used for food purposes, 55% for feed, 11% for biofuels and 11% for other uses. Mind that 89% of biofuel production from coarse grains is situated in the USA (based on corn).

The main export countries/regions for coarse grains are the USA, Argentina, Brazil and Ukraine. The main import regions are Asia (excl. China and India), Latin America (excl. Argentina and Brazil) and North Africa.

Figure 5-6. Coarse grain consumption (different uses) and production/imports in different world regions (derived from FAO, 2014)

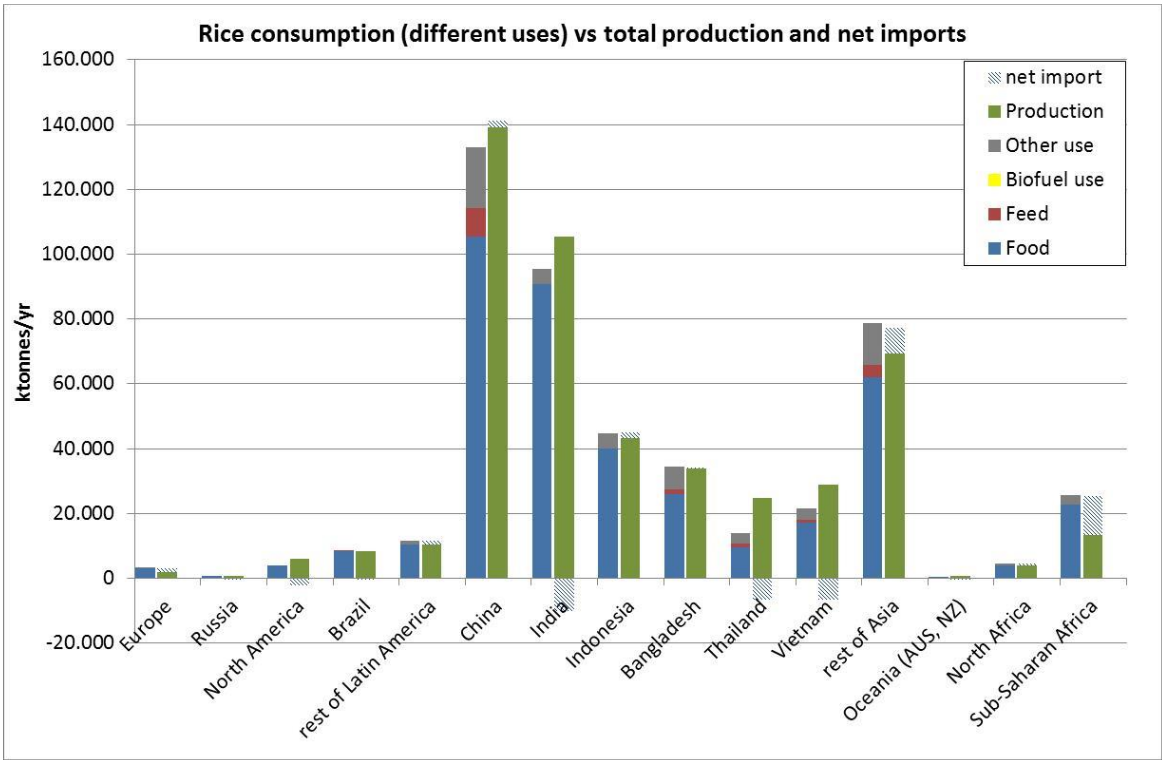


Rice

Global rice production in 2011-2013 was 490 Mt per year on 162 Mha of land. 91% of production is situated in Asia (more than half of that in China and India).

Most rice (84%) is used for food. Some fractions are used for feed (3.5%) and other uses (12%), but this is mainly the case in Asia and Africa. Rice is not used for biofuels.

Figure 5-7. Rice consumption (different uses) and production/imports in different world regions in 2011-2013 (derived from FAO, 2014)



Oil crops and derivatives

FAO (2014) considers oilseeds, protein meals and vegetable oils. Mind that the oilseeds category contains rapeseed (canola), soybeans and sunflower. It does not include oil palm fruits, coconut, cotton, olive or peanuts which are also used to produce vegetable oils.

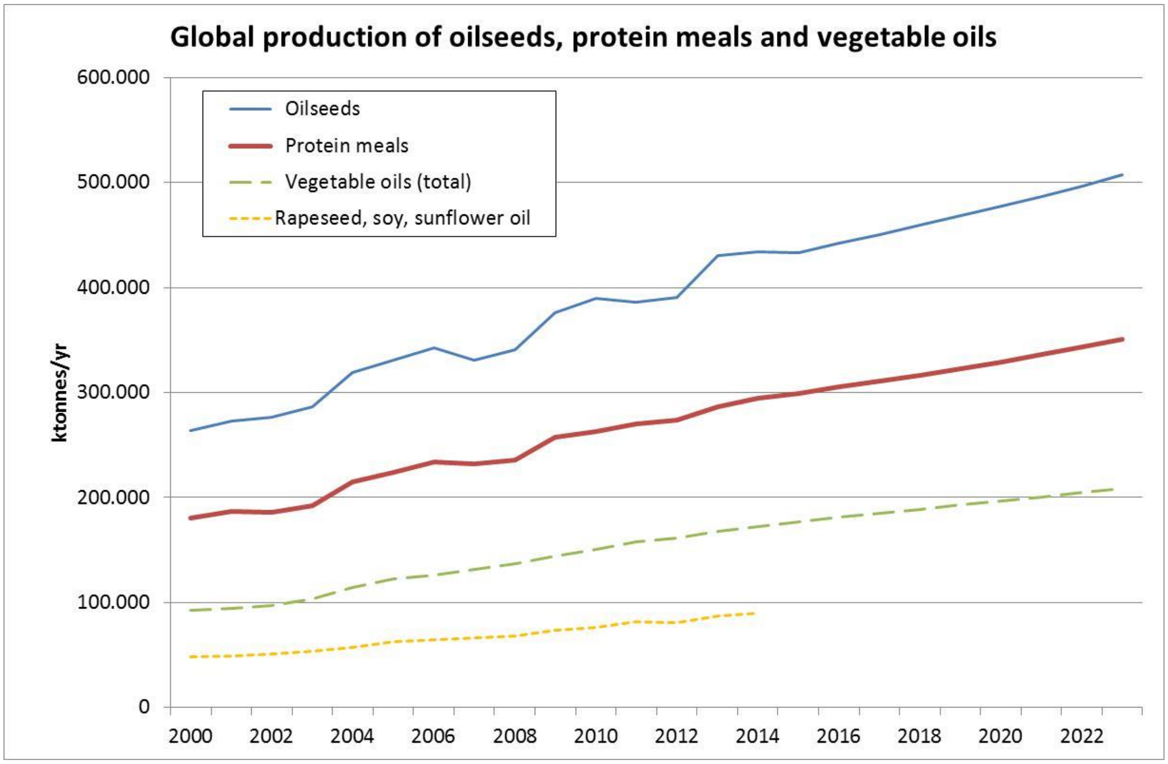
Protein meals are defined as oilseed meals, coconut meal, cotton meal and palm kernel meal. Mind that 2/3 of produced protein meals (and ¾ of traded protein meals) are derived from soybeans.

In 2011-2013 oilseeds accounted for 190 Mha of arable land, producing 402 Mt of oilseeds per year, from which 277 Mt of protein meals were produced and 83 Mt of vegetable oil (25 Mt rapeseed oil, 44 MT soybean oil and 15 Mt sunflower oil).

Next to vegetable oil from oilseeds, 63 Mt of palm and palm kernel oil were produced, and 17 Mt of other vegetable oils (coconut, cotton, olive, peanut) (source: USDA-FAS).

There is a clear increasing trend in production in the past decade, linked to world population growth, changing diet patterns and also the introduction of biodiesel. The FAO (2014) expects this trend to continue as shown in Figure 5-8.

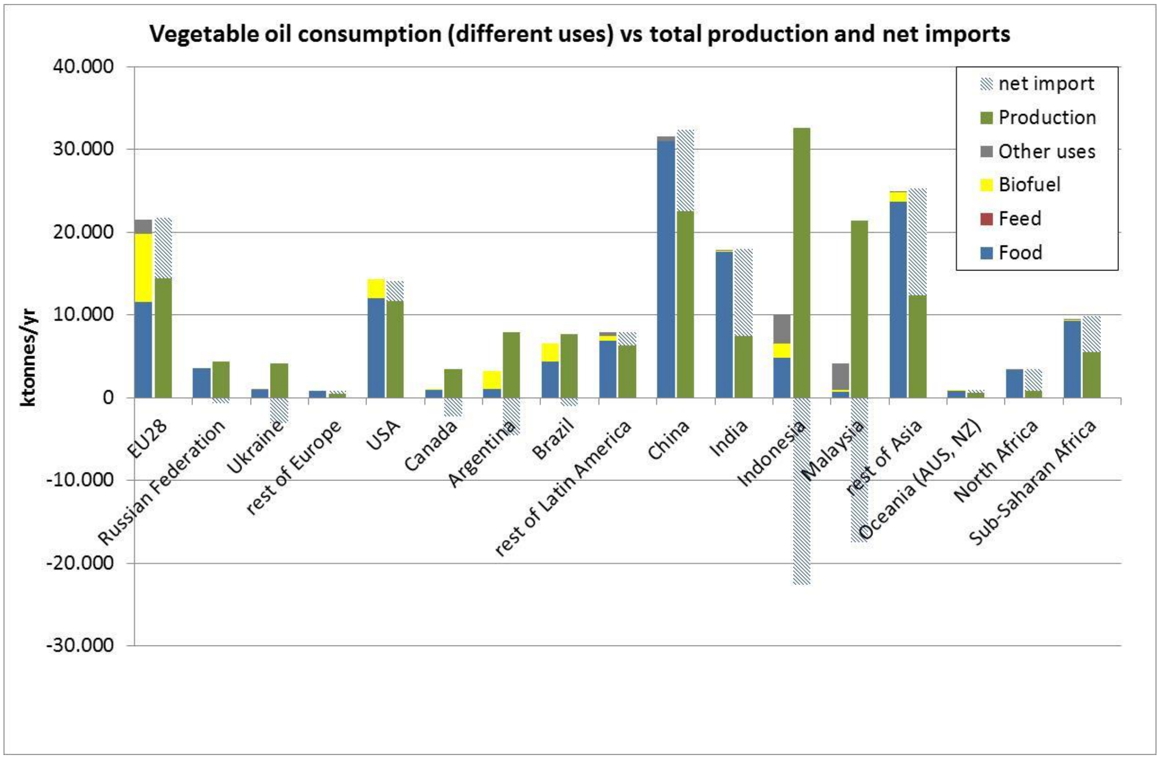
Figure 5-8. Global production of oilseeds, protein meals and vegetable oils (derived from FAO, 2014). Total production of rapeseed oil, soybean oil and sunflower oil are also displayed (derived from USDA-FAS).



When looking at the global distribution, Indonesia and Malaysia are the biggest producers of vegetable oil, in particular palm oil. Most of their production is destined for exports. Countries/regions mainly producing for domestic consumption are China, India, rest of Asia (excl. Indonesia and Malaysia), EU, USA and Brazil. Countries producing substantial amounts but mostly for export are Argentina, Canada and Ukraine. The main import regions are China, India, other Asian countries, the EU and Africa.

On global level 82% of total vegetable oils are used for food purposes, 12% for biofuels and 6% for other uses (FAO, 2014). The EU uses around 38% of its vegetable oil (own production and imports) for biodiesel. Other regions producing significant amounts of biodiesel from vegetable oils are Argentina, Brazil, the USA and Indonesia.

Figure 5-9. Vegetable oil consumption (different uses) and production/imports in different world regions in 2011-2013 (derived from FAO, 2014)



In several ways the EU depends on imports for oil crops and its derivatives. 35% of the oilseeds used to produce vegetable oils and protein meals in the EU are already imported. So in fact only 43% of EU vegetable oil consumption is based on domestic oilseeds. Moreover, another 2.7 Mt biodiesel is imported from outside the EU (based on extra-EU vegetable oil).

Protein meals (soybean meal, rapeseed meal) are an important source of animal feed in the EU. About half is imported and 1/3 of the domestically produced is derived from imported oilseeds.

Table 5-2. EU import dependency for oil crops and its derivatives (FAO, 2014)

EU28 (MT/yr) ***Average 2011-2013***	**Oilseeds**	**Protein meals**	**Vegetable oil**	**Biodiesel**
Application	*Vegetable oil & protein meals*	*Animal feed*	*Food, biodiesel & other uses*	*Transport fuel*
EU consumption	43.8	49.9	21.5	13.0
Production in EU	28.6	25.6	14.4 (35% based on	10.3 (8.2 Mt from vegetable oils, the

			imported oilseeds)	rest from used oils and fats)
Net imports	15.2	24.3	7.3	2.7

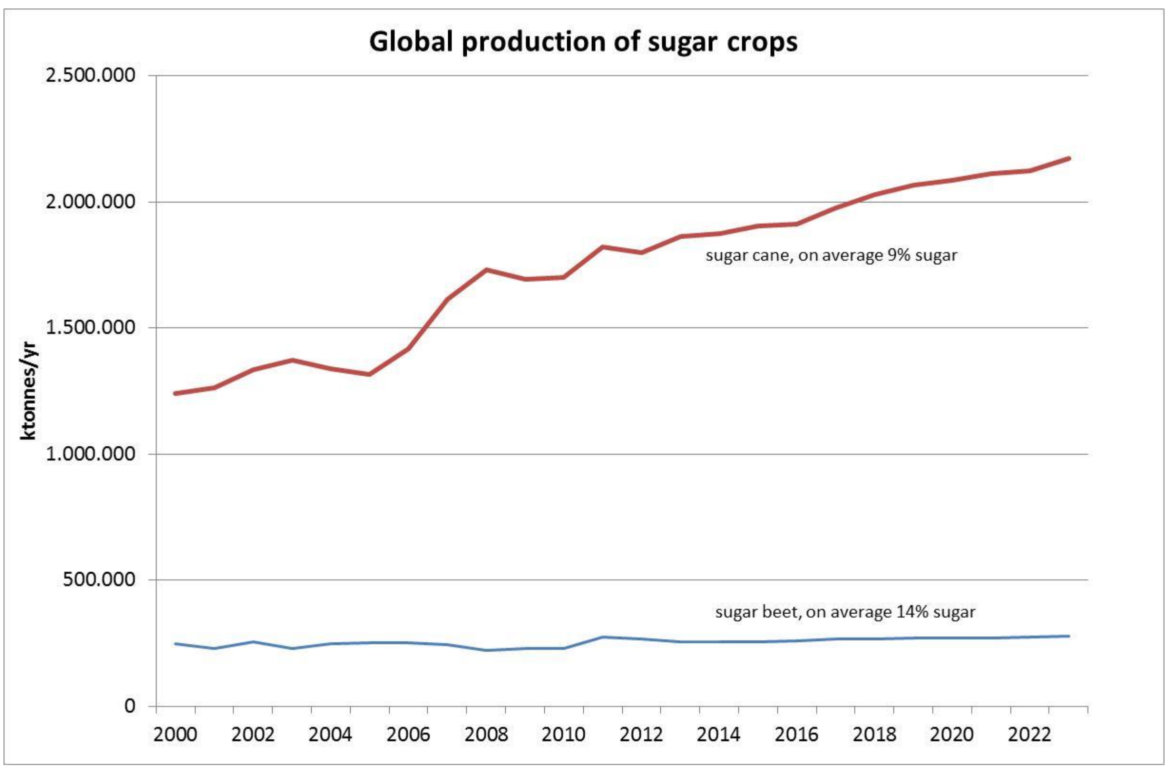
Sugar crops and derivatives

Worldwide 26 Mha of arable land is used to produce sugar cane, most in Latin America (Brazil) and Asia (India, China, Thailand, Pakistan). 15.5% of sugar cane is used for bio-ethanol production (94% of that in Brazil), 84.5% of sugar cane is used for sugar and molasses. A substantial part of the molasses in South America and Asia is also used for bio-ethanol production.

4.8 Mha are used for sugar beet production, most in the EU, Russia, Ukraine and the USA. 5.3% of sugar beets are used for bio-ethanol production, all of that situated in the EU. 94.7% of sugar beets is used for sugar and molasses.

Sugar cane production has grown substantially in the past decade, and a further growing trend is expected by FAO. Sugar beet production is stable and is expected to remain around the same level.

Figure 5-10. Global production of sugar cane and sugar beet (derived from FAO, 2014).



Globally 180 Mt of sugar are produced. Brazil is the biggest producer of sugar worldwide (22%), followed by India (15%) and the EU (10%). The main sugar exporters are Brazil, Thailand, Australia, Mexico and India. The main import regions are Asia (excl. Thailand, India), Africa, North America and Europe.

When looking at molasses, from the global production of 64 Mt, around 50% is used for biofuels, 24% for feed and 26% for other uses. Biofuels from molasses is common practice in Latin America (especially Brazil) and Asia (especially India). The EU is an important importer of molasses, but mainly for feed and other uses.

Figure 5-11. Sugar consumption and production/imports in different world regions (derived from FAO, 2014)

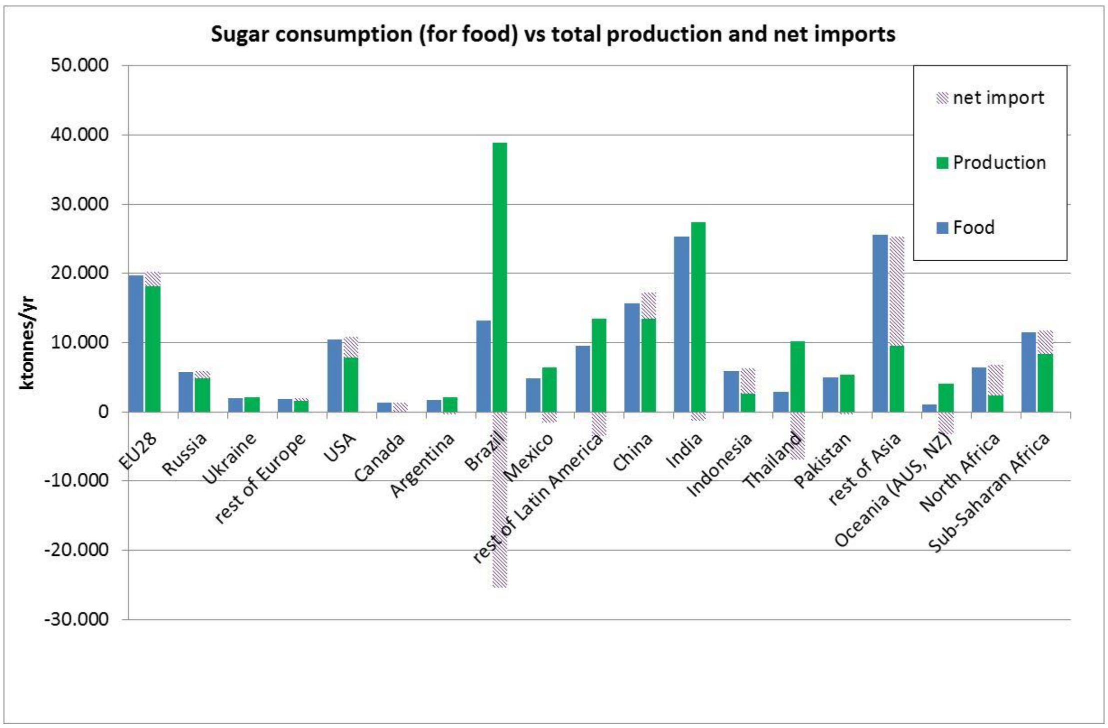
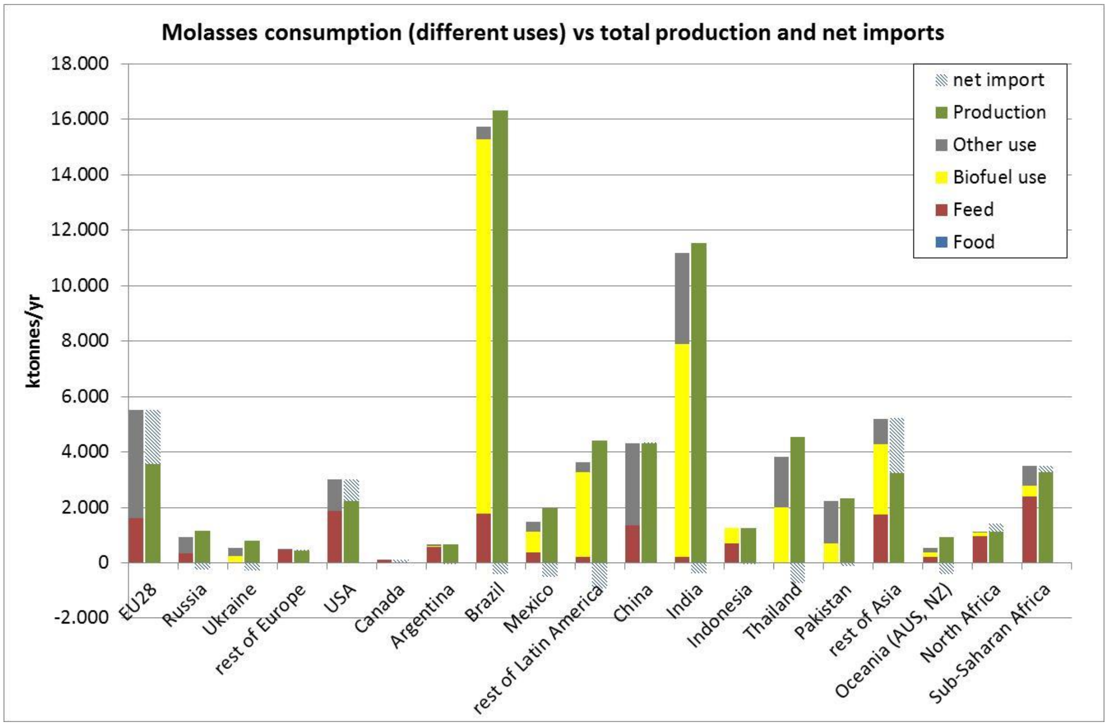


Figure 5-12. Molasses consumption (different uses) and production/imports in different world regions (derived from FAO, 2014)



5.2 Review of agriculture biomass supply potentials

5.2.1 Land availability

As mentioned before, the focus will be on surplus land, so the amount of land area available for bioenergy production depends on the amount of land needed for other purposes, such as nature, food production and urban areas, as well as the suitability of the theoretically available land for energy crop production. This section elaborates on the approaches applied in the reviewed studies to estimate the area excluded for 1) food production and 2) biodiversity protection and carbon stock changes leading to high GHG emissions. Finally, the estimated land area and land categories for bioenergy production in the reviewed studies are assessed. A detailed list of the reviewed studies is provided in the Appendix (Table C 1).

Exclusion of land areas for food production

Productive land areas designated for food production should be excluded from the land available for energy crop cultivation. All studies reviewed (Table C 1), except the spatially explicit illustration case of Böttcher et al. (2010), restrict energy crop cultivation to so-called 'surplus' land, i.e. land not needed for other purposes including food production. The use of only surplus land for energy crop cultivation is important to ensure food security and to avoid indirect land use change, which could lead to high greenhouse gas emissions. The land area available for energy crop cultivation therefore depends on the land reserved for nature protection and total land needed for food production, which in turn depends on the projected food demand, level of agricultural intensification, self-sufficiency ratio and the use of by-products of bioenergy production.

The future food demand highly depends on projections on population, GDP and food consumption per capita. Projections by the FAO on future food demand are used by Beringer et al. (2011) and Böttcher et al. (2012), while EEA (2013a) and Elbersen et al. (2012a) use projections by The Royal Society (2009). Not all studies explicitly mention the land area needed for food production (Table 5-3). The agricultural area used for food production in 2030 in the EU is in the range of 105-120 Mha (de Wit & Faaij, 2010; Fischer *et al.*, 2010; Beringer *et al.*, 2011). The biomass demand from other sectors than food, such as the chemical sector, is not considered in any of the studies. The total potential should therefore be considered as the total biomass availability for energy and material purposes.

The land area needed to supply future food production highly depends on the level of intensification of food crop and livestock production. All studies estimating future energy crop potential consider increases in crop yields, but not all studies explicitly mention projected crops. Stated projected crop yield increases vary from 0.2% per year to 2% per year (Table 5-3). Fischer et al (2010) projected yields in the EU-15 to increase by 0.2-0.5% per year till 2030, while assuming higher rates of annual crop yield increases (up to 2%) for the other EU27 member states in order to reach 80% of the level achieved in EU-15 by 2030. Böttcher et al. (2012) used the GLOBIOM model for their study in which crop yield increases consist of two elements: the first is an autonomous crop yield increase of 0.5% per year caused by technological progress; the second element consists of regional average yield changes which are caused by management systems changes and re-allocation of crops to more productive areas (Böttcher *et al.*, 2012).

Exclusion of high biodiverse areas and high carbon stock areas

All studies excluded certain areas from biomass production for bioenergy purposes. However, the definition and datasets vary among studies. The RED (EC, 2009) defined two types of areas which should be excluded for bioenergy feedstocks: high biodiversity areas (i.e. primary forest and other wooded land, legally protected areas, natural and non-natural highly biodiverse grassland) and high carbon stock areas (i.e. wetland including peatland and continuously forested areas as defined in the RED).

Forests were excluded for agricultural crops in all studies, except in the statistical and spatially-explicit approaches applied by Böttcher et al. (2010). The datasets used to quantify the European forest area differ among the studies. The distribution of the current forests is based on the following databases: the HYDE (Klein Goldewijk *et al.*, 2011), GEO-BENE (Skalsky *et al.*, 2008), FRA2000 (FAO, 2001), and Global Forest Cover (Schmitt *et al.*, 2009) are used by Beringer et al. (2011), Böttcher et al. (2012), De Wit & Faaij (2010), and Schueler et al. (2013), respectively. The exclusion of wetland is based on the Global Lakes and Wetlands Database (GLWD) (Lehner & Döll, 2004) in the studies of Beringer et al. (2011) and Schueler et al. (2013), both using the model LPJmL, and on Schleupner (2007) in the model EUFASOM used by Böttcher et al. (2010) in the integrated modelling approach.

Legally protected areas are excluded by Schueler et al. (2013) and Beringer et al. (2011). Both studies use the global LPJmL model and identify the legally protected areas based on the World Database on Protected Areas (WDPA) (IUCN & UNEP-WCMC, 2009).

The distribution of anthropogenic grasslands to exclude these from energy crop cultivation is determined by using the HYDE database (Klein Goldewijk *et al.*, 2011) in the studies of Beringer et al. (2011) and Schueler et al. (2013). Böttcher et al. (2010) exclude permanent meadows and pasture areas from energy crop cultivation, while De Wit & Faaij (2010) consider pastures not used for food production or nature protection and which are economically accessible to be available for energy crop production. However, for suitability reasons, pastures could only be used for the production of herbaceous lignocellulosic crops.

A different approach was applied in the Biomass Futures project (Böttcher *et al.*, 2012; Elbersen *et al.*, 2012a) and by the same authors conducted for the EEA (2013a). Instead of quantifying each area separately, they used high nature value (HNV)-farmland as a proxy for both high biodiverse and high carbon stock areas. HNV-farmland are areas in Europe where agriculture is a major land use, and where this agriculture maintains or contributes to high biodiversity (EEA/UNEP, 2004). Both the Biomass Futures study as well as the EEA study used the HNV-farmland spatial distribution map developed by Paracchini et al. (2008a). The Biomass Policies project (Elbersen *et al.*, 2015) used the results from the EEA study and Biomass Futures project.

Table 5-3. Incorporation of aspects in the quantification of surplus land in the reviewed studies (✓= included; ☓= not included; n.a.=not applicable)

	Approach	Competing demand **Food, feed and fibre**	**Biomaterials**	Intensification **Food crop production**	**Livestock production**
Allen et al. (2014)		✓Arable land in rotation (excl. fallow land) and grassland under agricultural management are excluded.	☓	n.a.	n.a.
Beringer et al. (2011)		✓Current agricultural land is excluded (F2 scenarios), and expanded by 120 Mha in 2030 (F1 scenarios) (Bruinsma, 2003). 70% increase of global food production by 2050 compared to 2005/07 (FAO, 2009).	☓	✓1.2% annual crop yield increase globally	☓
Böttcher et al. (2010)	Statistical method	✓Current land needed for food and feed production based on grain equivalent excluded. 86-100 Mha (security factor 1.33 and 2, resp.)	☓	n.a.	n.a.
	Spatially-explicit method	☓	☓	n.a.	n.a.
	Integrated modelling	✓not explicitly mentioned	☓	Not specified. Crop yields are based on EPIC results.	☓
Böttcher et al. (2012)		✓exogenously to model, derived from changes over time in GDP, population and food consumption per capita	☓	✓0.5% annual crop yield increase and regional average yield changes are caused by management systems changes	✓Management system changes

		(projections according to FAO (Alexandratos & Bruinsma, 2012))		and re-allocation of crops to more productive areas.	
EEA (2013); ETC/SIA (2013)		✓50% increase of food production by 2050 (The Royal Society, 2009). CAPRI estimates for land use	✗	✓	✓-CAPRI estimates
Elbersen et al. (2012)		✓50% increase of food production by 2050 (The Royal Society, 2009). CAPRI estimates for land use	✗	✓	✓-CAPRI estimates
Fischer et al. (2010)**; de Wit & Faaij (2010)**		✓land needed for food excluded. 105-107 Mha in 2030 (Fischer *et al.*, 2010)	✗	✓distinction between EU-15 (0.2-0.5% annual crop yield increase) and EU-12 (around 2% annual crop yield increase)	✓livestock feed conversion efficiency increases
Schueler et al. (2013)		✓areas for food, feed and fodder production are excluded based on HYDE grass- and cropland data (Klein Goldewijk *et al.*, 2011)	✗	n.a.	n.a.

Estimates of land availability for bioenergy crops in the EU

The estimated land area available for bioenergy crop production from the different studies is shown in Table 5-4. Not all studies explicitly stated the land area available for energy crops. The percentage of agricultural land (i.e. the sum of areas under arable land, permanent crops and permanent meadows and pastures in 2011) dedicated to energy crops ranges from 3.8-39%. According to the Institute for European Environmental Policy (IEEP), total land available for non-food lignocellulosic crop cultivation in the EU is between 1 and 1.5 Mha and could generate between 7.7 and 16.7 Mt dry biomass annually (3.3 – 7.2 Mtoe) (Allen *et al.*, 2014). Highest land potential is estimated by De Wit & Faaij (2010), also including a high potential in Ukraine. They base the land potential on the approach presented by Fischer et al. (2010), but most likely assume higher crop yield increases (this is however not explicitly stated in the article). The land potential estimated by Elbersen et al. (2012a) is considered a conservative estimate since land abandoned before 2004 is not taken into account, while this is expected to be considerable especially in Eastern Europe and the Mediterranean region. In addition, the decline in land estimated by Elbersen et al. (2012a) is caused by a higher demand for arable land in 2030 compared to 2020.

Scenarios with (stricter) sustainability criteria lead to lower estimated land area available for energy cropping. This is caused by a higher share of land reserved for nature reservation. For example, countries with a large share of HNV-farmland have a much smaller land potential in the sustainability scenario (Elbersen *et al.*, 2012a) and set-aside areas in 2000 were reserved for nature conservation leading to a lower potential in the environment scenario (Fischer *et al.*, 2010). In addition in demand-driven studies[18], stricter sustainability criteria lead to more regions where the GHG mitigation requirements are not reached (Elbersen *et al.*, 2012a).

Table 5-4. Estimated land area for bioenergy crops in Europe in 2020 and 2030 in the reviewed studies

Study	Scenario or potential	Available land area 2020 in Mha (% of agricultural land)	Available land area 2030 in Mha (% of agricultural land)	Remark
Allen et al. (2014)		1.35 (0.7%)		Extra land available for dedicated energy crops, no timeframe specified
Böttcher et al. (2010)	Economic potential Sustainable potential	8.5 (4.5%) 7.8 (4.1%)	8.3 (4.4%) 7.3 (3.8%)	Subsidy level zero Subsidy level zero
De Wit and Faaij (2010)	Baseline	67 (29%)	90 (39%)	Arable land + pasture land for LC crops. Including Ukraine,

[18] In the demand driven approach, the competitiveness of biomass is compared with alternative sources of renewable energy (wind, PV, hydro) and the fossil and/or nuclear based energy system, thus the amount that is determined to be used under scenario conditions (Vis & van den Berg, 2010).

				Switzerland and Norway
EEA (2013a)	Market first Climate focus Resource efficiency	17 (8.9%) 11 (5.8%) 7 (3.7%)	n.a. n.a. n.a.	Demand-driven approach
Elbersen et al. (2012a)	Reference scenario	22 (12%)	19 (10%)	Land released between 2004-2020
	Sustainable scenario	18 (9.4%)	16 (8.4%)	Land released between 2004-2030
Fischer et al. (2010)	Base scenario	n.a.	31 (16%)	Arable land. Excluding Ukraine (23 Mha)
	Environment scenario	n.a.	22 (12%)	Arable land. Excluding Ukraine (22 Mha)
	Energy scenario	n.a.	46 (24%)	Arable land + pasture land for LC crops. Excluding Ukraine (27 Mha)
Krasuska (2010)		21 (11%)	26 (14%)	Surplus land potentially available for non-food crops
Green-X	Scenario 1 Scenario 2	35 (18%) 38 (20%)	38 (20%) 48 (25%)	EU-28 EU-28

Different types of land are considered suitable for bioenergy production (Table 5-5). Two main categories could be distinguished, namely *unused agricultural land* and *low productive land* that is not suitable for conventional crop production (Batidzirai *et al.*, 2012). Unused agricultural land, or surplus agricultural land, is the land area available after subtracting the land area used for food and feed production, built areas, and nature areas. Also abandoned agricultural land and released agricultural land fall under this main category. In addition, fallow land could be considered as unused land, although agricultural land that is left fallow for a period could be part of crop rotation and is therefore not necessarily available for bioenergy production. Low productive land includes marginal land, which could be marginal from an economic or environmental perspective, or both. In addition, degraded land is considered as low productive land. Degraded land areas are those areas where soil functions are largely depleted, for example through soil erosion or salinization.

Table 5-5. Land categories considered for bioenergy production in the reviewed studies.

Land category	Terms used	Studies
Unused agricultural land	Surplus land	Beringer et al. (2011), Böttcher et al.(2010), Schueler et al. (2013), de Wit & Faaij (2010)
	Recently abandoned arable land	Allen et al. (2014), EEA (2013a)
	Recently abandoned grassland	Allen et al. (2014)
	Fallow land in agricultural crop rotation	Allen et al. (2014), EEA (EEA, 2013a)
	Released agricultural land (between 2004 and 2020/2030)	EEA (EEA, 2013a), Elbersen et al. (2012a)

Low productive land	Marginal land Degraded land contaminated land	Allen et al. (2014) Allen et al (2014)
Other	Other underutilised land	Allen et al. (2014)

Note: Böttcher et al. (2010) and Böttcher et al. (2012) did not explicitly state the land categories included. The latter is based on the technical potential provided by Elbersen et al. (2012a), therefore it could be assumed that both studies consider the same land categories.

5.2.2 Agriculture products

The energy crop potential is constrained by environmental, economic, market, implementation and other factors. This section first focuses on ecological sustainability constraints, i.e. biodiversity loss prevention, GHG emissions from the cultivation phase, land use change, and soil, water and air protection (Table 5-6), followed by social sustainability constraints and market and logistic constraints.

Sustainability constraints to agricultural biomass

Biomass potential studies show a wide variety in estimated land available for energy cropping and subsequently energy potential. This variety is caused by differences in definitions, datasets, method and assumptions (Torén et al. 2011; Batidzirai et al. 2012). In addition, the potential varies due to the sustainability constraints included in the various studies. The biomass potential studies were reviewed on the inclusion of the key sustainability factors, and if the factors were taken into account, it was evaluated how these factors were included, which assumptions were made and which datasets were used. The criteria constraining the biomass potential are based on the BEE Methods Handbook (Vis *et al.*, 2010):

1) Environmental sustainability
    a. Biodiversity
    b. Climate change
    c. Soil (quality and quantity)
    d. Water (quality and quantity)
    e. Air quality
    f. Resource use
2) Social sustainability
    a. Competition with the demand for food, feed and fibres
    b. Labour conditions
    c. Social acceptance
3) Economic sustainability
    a. Business case
    b. Profitability

Although this review focuses on the GHG emissions from the cultivation phase, GHG savings should be calculated along the whole life cycle as will be applied in this project. Criteria for soil, water and air protection are the adaptation of local management practices to local bio-physical conditions, especially for rain-fed agriculture, as well as the prevention of soil erosion. Societal sustainability criteria include the avoidance of competition with food and biomaterial production and the compliance to international labour standards.

The review of agricultural biomass supply starts with a review of land availability for bioenergy production and the land categories considered. The amount of land available for energy crop production depends on the competing use for land for food and feed production, nature preservation and other uses. A preference for **surplus land** is desired to ensure food security (Vis *et al.*, 2010), avoid undesirable land use change and a loss of biodiversity. This preference means that a **food first paradigm** should be applied. The amount of land needed for food production highly depends on the level of intensification of crop and livestock production.

Prevention of biodiversity loss

The BEE Methods handbook (Vis *et al.*, 2010) describes different parameters to prevent biodiversity loss due to energy crop production, namely the exclusion of high biodiverse areas for energy crop cultivation (see section 4.2), prevention of land use change by excluding certain nature areas, the implementation of buffer zones in sensitive areas, diversity within the cropping area (e.g. by a minimum number of crop species and varieties as well as structural diversity), and the adaptation of management practices in high biodiverse areas, areas under agro-environmental support, extensive or organic farming.

The implementation of buffer zones between cultivated land and areas of high biodiversity value is only considered by Allen et al. (2014), by excluding these areas from the land potential to produce energy biomass. None of the studies considered a minimum number of crop species and structural diversity within cropping areas for bioenergy purposes. According to the BEE Methods Handbook (Vis et al. 2010), the implementation of buffer zones as well as a structural diversity should be taken into account in the estimation of the biomass potential in spatially-explicit, cost-supply and integrated assessment studies. This is done through the adaptation of crop choices and related yields and production costs to the specific crop yields in spatially explicit and cost-supply methods, respectively. Only De Wit & Faaij (2010) explicitly state a yield reduction factor for areas under organic farming.

Table 5-6. Incorporation of environmental aspects in the selected biomass potential studies estimating the potential from energy crops (✓= included; ✗= not included)

	Scenario	Biodiversity			GHG emission savings [b]	Soil protection	Water protection	Air protection
		Buffer zones in sensitive areas	Diversity within cropping area	Adaptation of management practices [a]				
Allen et al. (2014)		✓	✗	✗	✗	✗	✗	✗
Beringer et al. (2011)		✗	✗		✗	✓	✓Irrigation only possible if excess surface runoff is available after water allocation to food production and natural ecosystems	
Böttcher et al. (2010)	Statistical method	✗	✗	✗	✗	✗	✗	✗
	Spatially-explicit method	✗	✗	✗	✗	✗	✗	✗
	Integrated modelling	✗	✗	*Not explicitly stated*	✗	✗	*Not explicitly stated*	*Not explicitly stated*
Böttcher et al. (2012)	Reference	✗	✗	*Not explicitly stated*	✓50% for biofuels only	✗	*Not explicitly stated*	*Not explicitly stated*
	Sustainability	✗	✗	*Not explicitly stated*	✓70% and 80% for all bioenergy in	✗	*Not explicitly stated*	*Not explicitly stated*

	Scenario	Biodiversity			GHG emission savings [b]	Soil protection	Water protection	Air protection
		Buffer zones in sensitive areas	Diversity within cropping area	Adaptation of management practices [a]				
					2020, and 2030, resp. (incl. ILUC)			
EEA (2013); ETC/SIA (2013)	Market first	✗	✗	✗	✗	✗	✗	✗
	Climate focus	✗	✗	✗	✓50% for biofuels only(incl. ILUC)	✗	✗	✗
	Resource efficiency	✗	✗	✗	✓50% for all bioenergy (incl. ILUC)	✓Apt selection of energy crop mixes and rotation to local conditions.	✓No irrigation for dedicated energy crops	✓Apt selection of energy crop mixes and rotation to local conditions.
Elbersen et al. (2012)	Reference	✗	✗	✗	✓50% for biofuels only	✗	✗	✗
	Sustainability	✗	✗	✗	✓80% for all bioenergy (incl. ILUC)	✗	✗	✗
Schueler et al. (2013)		✗	✗	✗	✓restricted to areas where compensation time for C-emissions is	✗	✗	✗

	Scenario	Biodiversity			GHG emission savings [b]	Soil protection	Water protection	Air protection
		Buffer zones in sensitive areas	Diversity within cropping area	Adaptation of management practices [a]				
					<5 years			
de Wit & Faaij (2010)		✗	✗	✓Organic farming yields 20% lower than standard	✗	✗	✗	✗

[a] Adaptation of management practices in Natura2000 areas, other areas with high biodiversity, areas under agro-environmental support, extensive or organic farming.
[b] Certain reduction of GHG emissions compared to fossil alternatives.

Soil, water and air protection

To minimise negative impacts on soil, water and air, management practices of energy cropping should be adapted to local bio-physical conditions, in particular for rain fed agriculture.

Agricultural production, whether for food, feed or energy, affects different aspects of soil function and quality and can lead to soil degradation in case of unsustainable production. Soil degradation processes includes erosion, decline of soil organic matter, compaction, salinisation and sodification, pollution, and decline of soil biodiversity. The risk of soil degradation is highly variable to local environmental, biophysical and climatic conditions, as well as to crop type cultivated and management practices applied (Diaz-Chavez *et al.*, 2013). Management practices with high risk of soil erosion are for example intensive tillage and the continuous cropping systems with reduced crop rotations (Diaz-Chavez *et al.*, 2013). The BEE Methods Handbook (Vis et al. 2010) therefore states that biomass potential studies need to consider only perennial crops on sites susceptible to soil erosion, since annual crops require regular tillage operations, whereas perennial crops do not. The assessment of the soil degradation risk in the three storylines of the EEA (2013a) study revealed that the storyline with the lowest risk on soil erosion (i.e. storyline 2 'climate focus') has the highest share of perennial crops instead of rotational or row crops (ETC/SIA, 2013). Areas with high erosion risks should be completely excluded from the land area potential by the consideration of a maximum slope limit for energy crop cultivation. Beringer et al. (2011) assume that energy cropping is impossible on the most severely degraded soils, and that achievable yields on highly degraded soils are decreased by 50%. The GLASOD world map (Oldeman *et al.*, 1991) is used to identify the areas with degraded soils within the LPJmL model. Other reviewed studies do not exclude highly degraded areas from the land potential (or do not explicitly state this).

Limitations to irrigation are taken into account in Beringer et al. (2011) and in the resource-efficiency scenario of the EEA (2013a) study. The latter also takes into account that the selection of energy crops and their management has to follow environmental guidance regarding the adaptation to regional bio-physical constraints and ecological values and an appropriate mix of crops and crop rotation (ETC/SIA, 2013). The implementation of these requirements is not explicitly stated in the documentation of the study.

Avoidance of competition with food and biomaterial production and compliance with labour standards

The societal sustainability constraints mentioned in the BEE Methods handbook are the avoidance of competition of energy crop production with food production and biomaterial production, and the compliance with international labour standards. None of the reviewed studies include compliance with labour standards as a constraint to the EU biomass supply potential from energy crops.

Market and logistic constraints

Logistic and market factors further constrain the potential from energy crops. Some of these factors are listed below. Logistic factors are further elaborated on in Task 2.

- Increased risk for farmers: the risk associated with producing perennial crops instead of annual crops is higher since economic returns on perennial crops are only until a few years after planting while annual crops are sold within the same year. Moreover farmers are not familiar with these crops and it creates a long-term commitment (perennial crops generally remain for 20 years on the same field), while markets are new and unproven. A higher gross margin is needed to attract farmers to overcome the greater risks associated with changes in the market, this however increases the relative price of the perennial crops (Sims *et al.*, 2006).
- High collection and transportation costs: the majority of the estimated surplus lands available for energy cropping are small patches of land dispersed across the EU, resulting in large transport distances from feedstock production sites to processing sites. These large distances combined with the low energy density of feedstock results in often resource-intensive logistics for collecting and transporting the feedstock (Sims *et al.*, 2006; ETC/SIA, 2013; Allen *et al.*, 2014). This particularly constrains the potential in countries with a centralized power generation infrastructure, e.g. in Western Europe (Sims *et al.*, 2006).
- Variability in feedstock supply due to natural and climatic conditions: the supply might vary between seasons and years resulting in the use of different feedstock sources and qualities at the conversion plants. This is one of the factors restricting the achievement of economies of scale (Sims *et al.*, 2006).
- Low maturity of conversion technology, especially second-generation technology. Second-generation conversion technologies are assumed to be economically viable around 2020-2025, varying in scenarios depending on incentives for technological development and the deployment of novel bioenergy products (Elbersen *et al.*, 2012a; EEA, 2013a).

EU biomass supply from energy crops

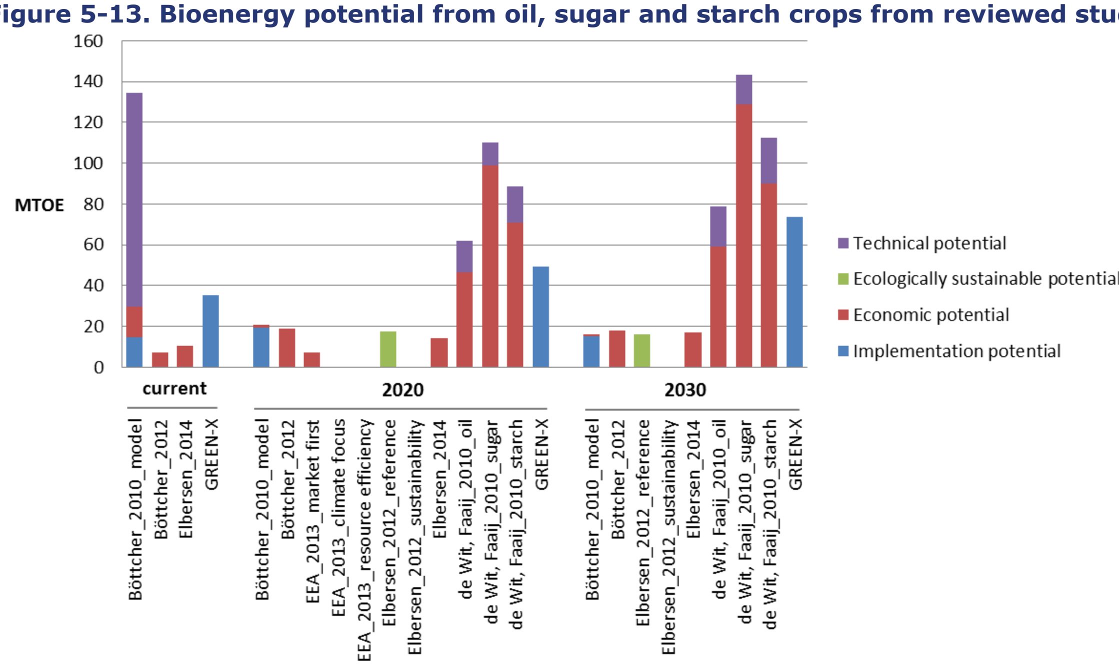
A review of biomass potential studies was carried out within the BEE project (Rettenmaier *et al.*, 2010). The review resulted in a considerably large range of technical potential from energy crops; 12-351 Mtoe (0.5-14.7 EJ) in 2020 and 48-439 Mtoe (2.0-18.4 EJ) in 2030 for the EU27.

Potentials from crops estimated by the studies included in the present review are shown in Figure 5-13, Figure 5-14 and Figure 5-15. Three studies (Böttcher *et al.*, 2010; de Wit & Faaij, 2010; Allen *et al.*, 2014) included in the present review estimated the technical potential of energy crops without additional environmental constraints other than the exclusion of nature areas. This technical potential varies between 17-136 Mtoe (0.7-5.7 EJ) currently (Böttcher *et al.*, 2010), to 64-289 Mtoe (2.7-12.1 EJ) in 2020 and 79-377 Mtoe (3.3-15.8 EJ) in 2030 (de Wit & Faaij, 2010), depending on the energy crop cultivated and land considered for production. Allen et al. (2014) estimated an additional potential on current ‘spare land’ of 2-7 Mtoe (0.1-0.3 EJ) from lignocellulosic crops only. Elbersen et al. (2012a) estimated an ecologically sustainable potential varying between in 53-76 Mtoe (2.2-3.2 EJ) in 2020 and 36-64 Mtoe (1.5-2.7 EJ) in 2030. De Wit & Faaij (2010), Böttcher et al. (2010), Elbersen et al. (2015), Böttcher et al. (2012), and EEA (2013a) estimated economic potentials, of which the latter two studies considered environmental constraints in varying extent. The economic potentials found by de Wit & Faaij (2010) are considerably larger than the economic potentials found in the other studies. This is mainly caused by the choice of energy crop cultivated on the land available and the assumed high yield increases in Eastern Europe.

The studies included in this review lead to a wide range of potentials, as was also the case in the review performed in the BEE project. However, if excluding the study of de Wit & Faaij (2010) a smaller range could be considered. De Wit & Faaij (2010) estimated the potentials by dedicating the whole land area available to one specific crop group (i.e. oil crops, sugar crops, starch crops, lignocellulosic crops, or herbaceous lignocellulosic crops). Their results show the importance of crop selection on the total potential. The potentials estimated by Elbersen et al. (2012a), Böttcher et al. (2012), EEA (EEA, 2013a) and Elbersen et al. (2015) are in the same range, as they all use the same approach but vary in scenario assumptions and the inclusion of sustainability criteria.

Although the demand for 1st generation crops will remain large until 2020, it is expected that increasing amounts of lignocellulosic biomass will be used for the production of biofuels and for the electricity and heat demand. Lignocellulosic crops and agricultural residues are therefore expected to play a key role in the future biomass potential, in particular in scenarios in which stricter sustainability criteria are applied (Figure 5-14 and Figure 5-15). The estimated potential derived from oil, sugar and starch crops is reduced to zero in the scenarios considering stricter sustainability criteria in the studies of the Biomass Futures project ((Böttcher et al. 2012; Elbersen et al. 2012) and EEA (2013), due to the avoidance of bioenergy production with high ILUC impacts in these scenarios (Figure 5-14). These studies use a demand-driven approach including exogenous set targets on GHG savings, whereas other studies focus on the agricultural biomass resource base and the competition between the different uses of these resources (i.e. resource-focused approach).

Figure 5-13. Bioenergy potential from oil, sugar and starch crops from reviewed studies



Short rotation plantations are defined as plantings established and managed under short rotation intensive culture practices. They can be established with fast growing tree species like poplar, willow, black locust (Robinia *pseudoacacia* L.) and eucalypt. These species have rotation cycles of 10 to 15 years or can be managed as a coppice system with 2 to 4 year rotation. Plantations with rotations from 10 to 15 years are mainly used for fibre production for the pulp and paper industry. This management system includes most often replanting. For energy purposes short rotations of 2 to 4 year with coppice management are more favourable with respect to total production.

An exception can be made for the area of short rotation coppice, especially because these plantations are more or less established as an energy producing crop system. A first analysis of literature shows that the existing area of SRC is estimated to be about 30,000 hectares (2010) in the EU (Leek, 2010b). Since 2010, efforts were made to expand the area. But even if it was more than tripled, it would not be more than 100,000 ha. With an annual growth capacity of 20 m^3 per ha, the full potential in Europe would add up to 0.420 Mtoe (2 M m^3(s)).

Leek (2010b) showed that in recent years different studies have been made for the EU Commission on modelling the future area of bioenergy crops in Europe. The results of these studies show great variations in the area, which could become available from agriculture and used for bio-energy crops in the next two decades.

The current volume of energy wood from fast growing plantations is between 1 and 2 M m^3 (s) or significantly less than 0.5 Mtoe. The land use studies say little to estimate the amount of wood from short rotation plantations. However, developments in recent years show that it is obviously more profitable for farmers to grow non-woody agricultural energy plants.

Figure 5-14. Bioenergy potential from lignocellulosic crops from reviewed studies

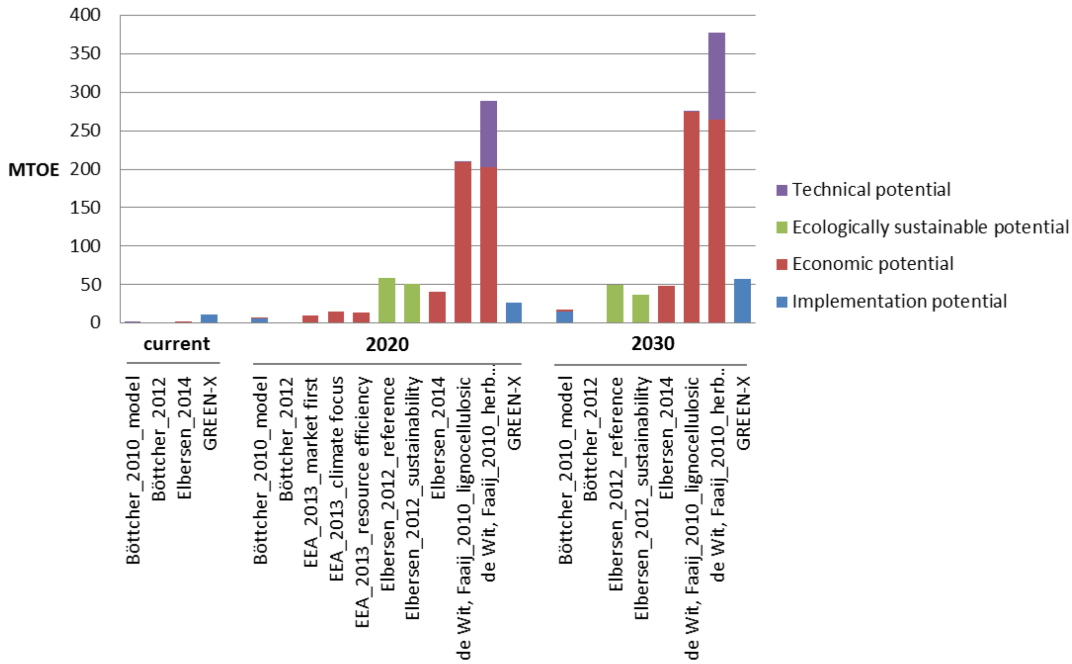
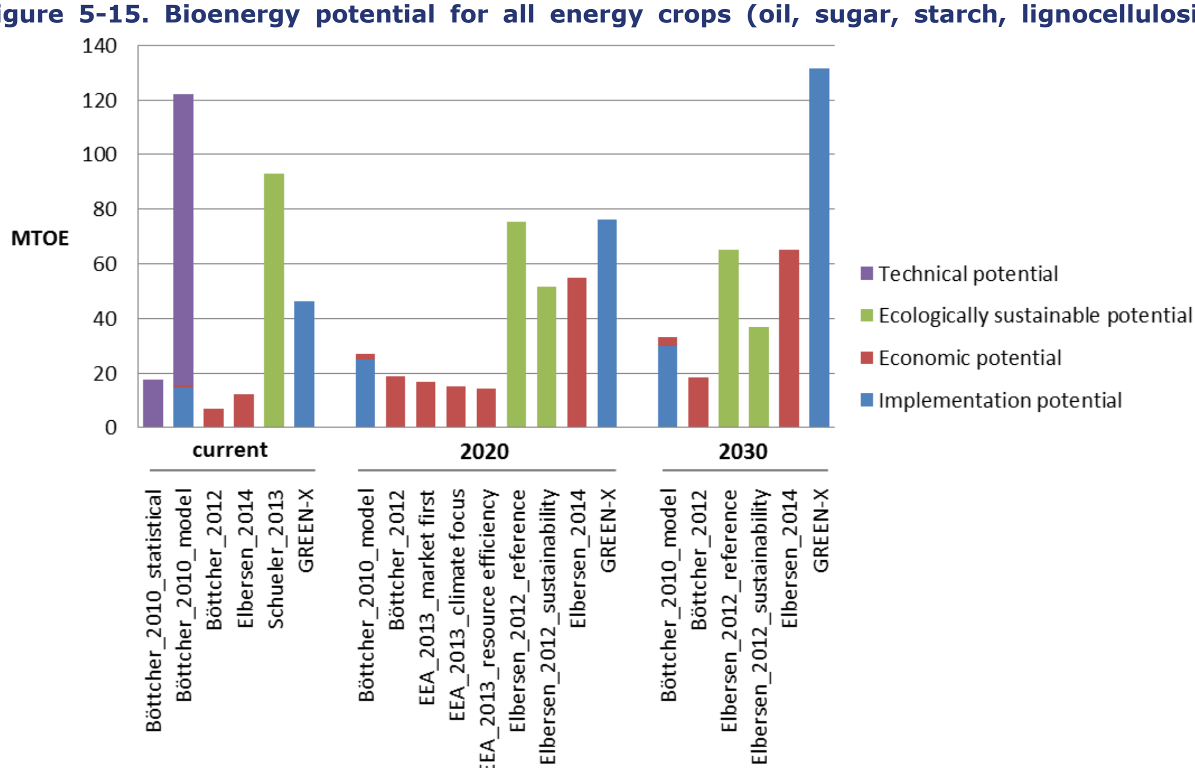


Figure 5-15. Bioenergy potential for all energy crops (oil, sugar, starch, lignocellulosic)



Notes to Figure 5-13, Figure 5-14 and Figure 5-15:

- Economic potentials are calculated with the following feedstock prices:
- Böttcher et al. (2010), integrated modelling approach: not stated, but the baseline economic potential values for the different biomass types are boundary conditions from the PRIMES model
- Böttcher et al. (2012): not stated
- EEA (2013a): Market focus scenario feedstock prices < 3 €/GJ; climate focus and resource efficiency scenarios feedstock price < 6 €/GJ.
- De Wit & Faaij (2010), moderate production cost levels: Oil crops < 10 €/GJ; starch crops < 8.5 €/GJ; sugar crops < 7.5 €/GJ; lignocellulosic crops < 4 €/GJ; herbaceous lignocellulosic crops < 4.5 €/GJ.
- The final crop mix in the study of Elbersen et al. (2014) is by giving priority to the cheapest crop mix per region, in terms of production cost levels per ton harvested biomass.
- The shown potentials corresponds with a subsidy level of zero in the integrated modelling approach performed by Böttcher et al. (2010).
- The potentials estimated by de Wit & Faaij (2010) are the potentials if the whole land area would be cropped with the specific energy crop groups (i.e. oil crops, sugar crops, starch crops, lignocellulosic crops, or herbaceous lignocellulosic crops).

5.2.3 Agriculture residues

Constraints to primary agricultural residues potential

This section is limited to the constraints to straw potential as this is the main primary agricultural residue. Table 5-7 provides an overview of the sustainable removal rate and competitive uses applied in the reviewed studies to estimate the biomass potential from agricultural residues.

Sustainable extraction rates for primary agricultural residues

Straw incorporation in the soil has several ecological functions relating to soil quality, namely maintaining and improving soil organic matter (SOM) and soil organic carbon (SOC), providing a source of organic nutrients, protection from soil erosion and improving water retention (Spöttle *et al.*, 2013). The removal of all straw from the field could lead to a decline of these ecological functions. Therefore, a maximum sustainable extraction for straw should be considered in estimating the ecologically available potential. Although the sustainable removal rate is location specific and is affected by farming practices, harvesting equipment, local site conditions and climate conditions (Scarlat *et al.*, 2010), general sustainable removal rates are assumed.

Scarlat et al. (2010) estimated sustainable removal rates through an extensive literature review. These removal rates are also used in other studies (Elbersen et al. 2012; Monforti et al. 2013; Elbersen et al. 2014) (Table 5-6). Spöttle et al. (2013) base the removal rates on Scarlat et al. (2010), and adjust these rates to country-specific conditions in ten selected countries based on expert consultation. Lower removal rates for Germany (34%) and Hungary (33%) are assumed, while a removal rate of 50% is assumed for France (Spöttle *et al.*, 2013). Higher maximum removal rates, up to 70%, are assumed by Pudelko et al. (2013). Daioglou et al. (*submitted*) assume a constant residue cover of 2 tonne ha^{-1} independent of crop type, region and time, resulting in an average sustainable removal rate of 50-60% in Central and Western Europe.

Competitive uses of primary agricultural residues

Besides incorporation into the soil, straw is also used in the livestock sector for animal bedding and feed, in the horticulture sector, mainly for mushroom production, and in very small quantities in the industrial sector (Spöttle *et al.*, 2013).

The amount of crop residues used for competitive uses varies widely across countries. In particular, Ireland and the Netherlands use a higher share of the collectable crop residues for animal bedding (Monforti *et al.*, 2013). Mushroom production mostly takes place in the Netherlands, France, Spain and Poland, currently utilising approximately 5% to 31% of available straw in these countries (Scarlat *et al.*, 2010; Spöttle *et al.*, 2013). The low bulk density of straw limits the use of straw to regional or country level. Therefore, most studies restrict the subtraction of straw from neighbouring regions in case of deficits. For example, the Netherlands has a low straw potential for bioenergy purposes, because of low production and high competitive use from the livestock and horticulture sectors (Monforti *et al.*, 2013; Spöttle *et al.*, 2013). The reviewed studies assume different percentages of the available residues dedicated to competitive uses (Table 5-7). Böttcher et al. (2010), applied an availability factor of 30% for all crops, no clear distinction is made between the amount of residues left on the land and for other competitive uses.

Table 5-7. Sustainable removal rates and competitive use factors applied in selected biomass potential studies

	Sustainable removal rate		Competitive uses (% of available residues to competitive uses)
	Cereal crops (wheat, barley, rye, oats)	*Maize, rice, rapeseed, sunflower*	
Daioglou et al. (*submitted*)	50-60%		32-50% (global average)
EEA (2013)**; ETC/SIA** (2013)	*Not stated*	*Not stated*	*Not stated*
Elbersen et al. (2012)	40%	50%	Competing uses for crop residues estimated by CAPRI (animal bedding and feed)
Elbersen et al. (2015)	40%	50%	Competing uses for cereal crop residues estimated by CAPRI; other crops 50-70% (animal bedding and feed, mushroom production)
Fischer et al. (2010)	50%		*Not included*
Monforti et al. (2013)	40%	50%	16% (animal bedding)
Pudelko et al. (2013)	max. 70%	50% (maize); 60% (rice)	*not explicitly stated* (animal bedding and feed)
Scarlat et al. (2010)	40%	50%	25% (EU average) (animal bedding and feed, mushroom production)
Spöttle et al. (2013)	33-50%	30% (maize)	70% (animal bedding and feed, mushroom production, industrial uses)
De Wit & Faaij (2010)	50%		*Not included*

Constraints to mobilization

Different barriers concerning the mobilisation of the agricultural residue resources exist (Kretschmer *et al.*, 2012). The bioenergy produced from the available agricultural residues as estimated in the reviewed studies could therefore be considered lower. Kretschmer et al. (2012) identified the following additional barriers:

- Lack of appropriate infrastructure, in particular on-farm machinery and infrastructure for straw bailing to meet the requirements of the processing facilities.
- Variability in residue availability due to natural and climatic conditions.

- Economic factors, particularly relating to the value of straw resulting from competitive uses in other sectors. In addition, financial support to use straw for certain purposes exists in some MS. For example the incorporation of straw is incentivised through payments under the agri-environment measure of the CAP.
- Underdeveloped markets and lack of market information: The use of straw for bioenergy purposes is in most EU Member States not an established practice, resulting in the lack of supply chains and high investment costs for establishment.

EU biomass supply from agricultural residues

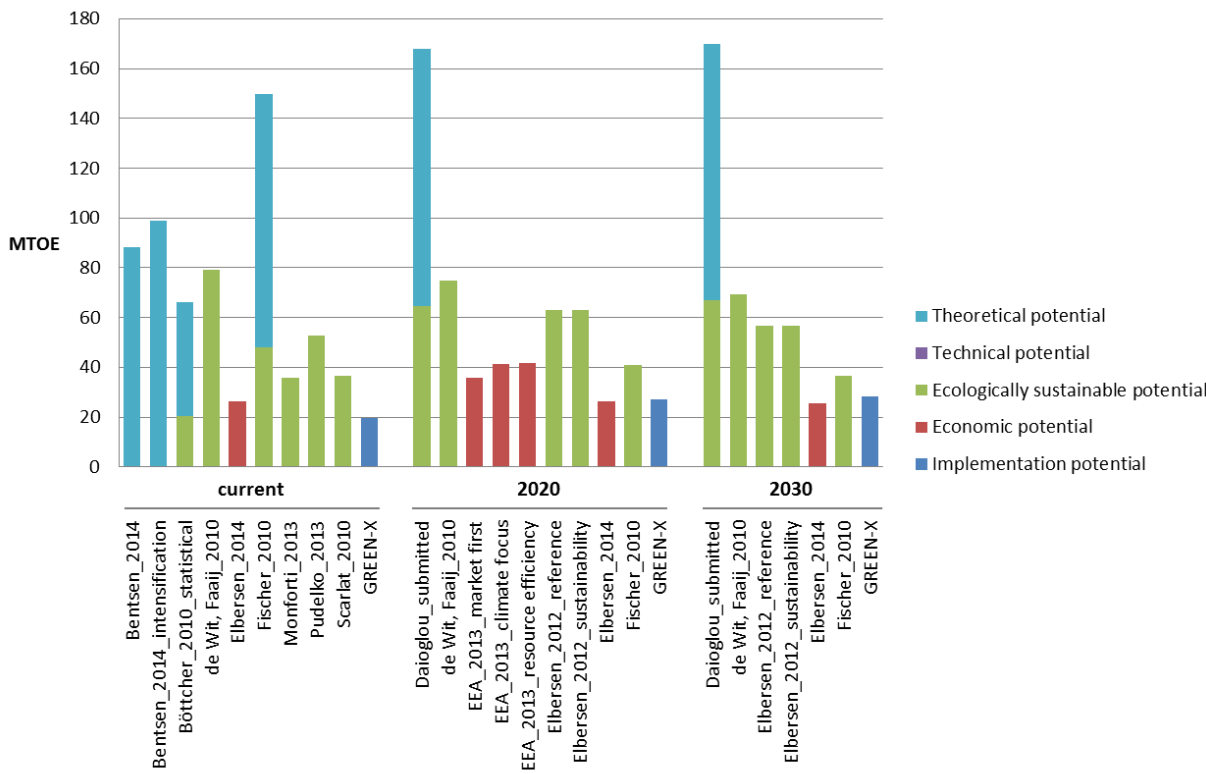
The review of biomass resource assessment of the BEE project (Rettenmaier *et al.*, 2010) estimated the agricultural residue potential to be in the range of 24-84 Mtoe (1.0-3.5 EJ) in 2020 and 26-74 Mtoe (1.1-3.1 EJ) in 2030. Estimates of agricultural residues theoretically available, found in the included studies in this review, are in the range of 67-98 Mtoe (2.8-4.1 EJ) currently, 36-167 Mtoe (1.5-7.0 EJ) in 2020 and 170 Mtoe (7.1 EJ) in 2030 (Figure 5.4). The ecologically sustainable potential remains fairly constant and is estimated at 41-96 Mtoe (1.7-4.0 EJ) in 2020 and 36-979 Mtoe (1.5-4.1 EJ) in 2030. De Wit & Faaij (2010) estimate the ecologically sustainable potential at 79 Mtoe (3.3 EJ) and 69 Mtoe (2.9 EJ) in 2020 and 2030, respectively, but this also includes the potential from Ukraine, Norway and Switzerland (8 and 7 Mtoe (0.35 and 0.28 EJ) in 2020 and 2030, respectively) and competitive uses are not yet accounted for. The estimated potential by Daioglou et al. (*submitted*) includes both Western and Central Europe as used in the IMAGE 3.0 model (PBL Netherlands Environmental Assessment Agency, 2014). Daioglou et al. (*submitted*) find that the ecologically sustainable potential is 56% of the theoretical potential, and by considering competitive uses the available potential decreases to 33-45% of the theoretical potential.

Two studies (Böttcher *et al.*, 2010; Bentsen *et al.*, 2014) consider both primary and secondary agricultural residues in the potential, whereas the other studies only consider straw (Monforti et al. 2013; Scarlat et al. 2010; Fischer et al. 2010; de Wit & Faaij 2010; Daioglou et al. *submitted*) or straw, cuttings, and pruning residues (Elbersen *et al.*, 2012a; EEA, 2013a; Pudelko *et al.*, 2013). The total contribution of secondary agricultural residues, including processing residues such as sunflower and rice husks and bagasse, remains small. Overall, wheat straw contributes most to the total share of primary agricultural residues (dry matter) (42%), followed by barley and maize (both 19%) (Scarlat *et al.*, 2010). All reviewed studies estimating the potential on country level, identify France and Germany as the countries with the highest crop residue availability, currently and in the future.

A decrease of approximately 10%-15% per decade in agricultural residue potential is projected because of assumed yield increases which lowers the residue to product ratio (RPR) (de Wit & Faaij, 2010; Fischer *et al.*, 2010; Elbersen *et al.*, 2012a). Crop breeding aims at improving yields by increasing the share of the harvestable component of the crop. Daioglou et al. (*submitted*) report a decrease in residue intensity (measured in GJ km^{-2}) caused by a decrease in RPR as crop yields increases, the theoretically and ecologically available agricultural residue potential between 2020 and 2030 slightly increases, however, due to an increase in agricultural production (Figure 5.4). Bentsen et al. (2014), on the other hand, estimate a 12% increase in agricultural residues theoretically available through agricultural intensification in Western, Northern and Southern Europe. No timeframe is defined for this intensification. The increase in agricultural residue production through agricultural intensification is low for these European regions compared to other regions, since high input agriculture is already applied.

Only, a few studies (Böttcher *et al.*, 2010; de Wit & Faaij, 2010; Elbersen *et al.*, 2012a; EEA, 2013a) estimated the energy crop potential and the agricultural residues potential using the same scenario assumptions. Other studies only estimated the energy crop potential or the residue potential. A consistent use of assumptions and approach is important to harmonise results of the different potentials.

Figure 5-16. Bioenergy potential from agricultural residues from reviewed studies



Notes to Figure 5-16:

- Daioglou et al. (*submitted*) include the regions Western and Central Europe.
- Bentsen et al. (2014) include the regions Western, Northern and Southern Europe. The potential of Eastern Europe is not incorporated as this is dominated by Russia.
- The potentials estimated by Bentsen et al. (2014) and Böttcher et al. (Böttcher *et al.*, 2010) includes both primary and secondary agricultural residues in the potential
- The potentials estimated by EEA (2013a) , Elbersen et al. (2012a), and Pudelko et al. (2013) include straw, cuttings and pruning residues.

- The potentials estimated by Daioglou et al. (*submitted*), de Wit & Faaij (2010), Fischer et al. (Fischer *et al.*, 2010), Monforti et al. (2013), and Scarlat et al. (2010) only include straw.
- De Wit & Faaij (2010) and Fischer et al. (2010) used the same approach and data, leading to the same amount of crop residues in tonne of dry matter (D.M.) available. However, different conversion factor were used namely 16 GJ tonne^{-1} D.M. (de Wit & Faaij, 2010) versus 9.3 GJ tonne^{-1} D.M. (Fischer *et al.*, 2010), resulting in a higher energy potential estimated by de Wit & Faaij (2010). Conversion factors used in the other studies are in the range of 14-18.1 GJ/tonne (dm).

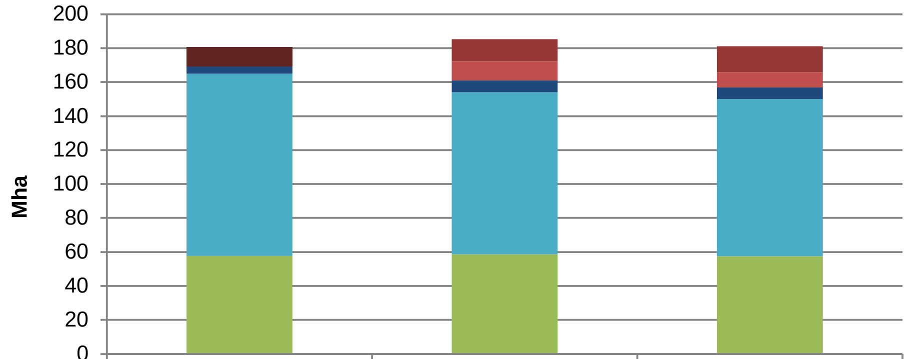
The primary agricultural residues potentially available for energy purposes highly depends on the sustainable extraction rate to maintain soil quality and to the competitive uses of the residues, both factors are varying per country. The agricultural residues potential is estimated to stay fairly constant among time. The ecologically sustainable agricultural residue potential is in the range of 36-98 Mtoe (1.5-4.1 EJ) in 2030, approximately 57 Mtoe (2.4 EJ) of this is available for energy purposes. Current and future highest availability of primary agricultural residues is found in Germany and France.

5.3 Agriculture biomass supply potentials in the Green-X model

The supply potential of agriculture residues as available in the Green-X model shows to be in range with the sustainable potential and economic potential in recent studies. An update of the supply potential of agriculture residues is therefore not considered to be required. To estimate future land supply for bioenergy crop cultivation, the approach used in the Biomass Futures project and Biomass Policies project (Elbersen *et al.*, 2015), was considered state-of-the-art. A similar approach was used to update land availability for dedicated energy crops including annual crops for liquid biofuels and co-digestion and perennial crops in the Green-X model.

The results of the agro-economic model CAPRI model baseline projections were used as a starting point. Because CAPRI is the only model available that can project agriculture market and production responses for the EU28 and neighbouring countries (western Balkans, Turkey and Norway) (Elbersen *et al.*, 2015). The CAPRI baseline scenario projections assume a status quo EU policy environment: "A continuation of the Common Agricultural Policy following the Health-Check decisions adopted by the Agricultural Council in November 2008" (EC, 2010). Furthermore, the RES 2020 targets of the RED are included for biofuels. Note that the amended RED and associated restrictions to 1st generation energy crops are not included in these projections. Beyond 2020, the bioenergy targets of the baseline run in the Trends to 2050 report (EC, 2013) are assumed to correspond. Demand for biofuels (both 1st generation and 2nd generation) used in CAPRI, are derived from PRIMES baseline, however the crop mixes, country distribution and conversion efficiencies are determined by the CAPRI model (Elbersen *et al.*, 2015). The projected agriculture land by CAPRI is depicted in Figure 5-17 and compared to current (2012) agriculture land use for food, feed, fibre and liquid biofuel production.

Figure 5-17. Current (Hamelinck et al., 2014; EUROSTAT, 2015a, 2015b) and future agricultural land use for food, feed, fibre and fuel production in EU-28 as projected by CAPRI (CAPRI, 2013)



	2012	2020	2030
Permanent cropland (PC)	11.3	24.2	24.2
PC: Lignocellulosic energy crops		13.0	15.2
PC: Other permanent crops		11.2	9.0
Arable land: Biofuel production	4.4	7.0	6.9
Arable land: Food, feed, fibre	107.2	95.4	92.5
Permanent grassland	57.6	58.6	57.5

Projections of land use for biofuel production on arable land (annual crops) was calculated as follows:

- 1st generation biofuel demand from domestic sources in 2020 and 2030 was derived from the CAPRI Reference scenario (CAPRI, 2013);
- Primary biomass demand was calculated based on conversion coefficients for 1st generation biofuels (Fonseca *et al.*, 2013) and biofuel production per feedstock (rape oil, sunflower oil, cereals, sugar) and country from CAPRI;
- Land use per country was calculated based on country specific yields (CAPRI, 2013) and primary biomass demand for 1st generation biofuel production.

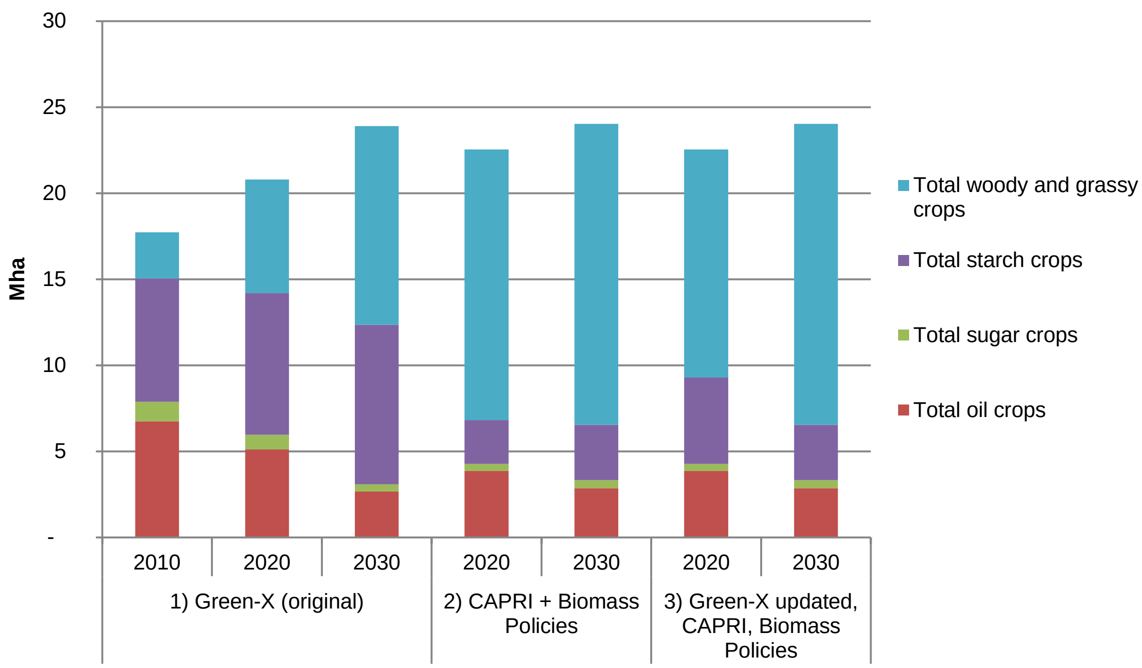
Further analysis of land supply for perennial, second generation biomass crops has been conducted based on post analysis of the CAPRI projections in the Biomass Policies project (Elbersen *et al.*, 2015). Perennial crops are assumed to be cultivated on land that is neither used for food, feed and liquid biofuel production. The released land, as calculated in the Biomass Policies project, was used in this study. Furthermore, the following assumptions were made to update the land supply database:

- The calculated released land for perennial crops does not take into account sustainability constraints. These will be applied in the second phase of the Biomass Policies project and were not available at the time of writing. Therefore a rough assumption was made that 15% of released agriculture land is under protected or High Nature Value (HNV) farmland based on the difference between the Reference and Sustainable scenario results of the Biomass Futures project (Elbersen *et al.*, 2012b)[19].

- A larger land supply for starch crops was assumed in 2020 to avoid the forced selection of 2nd generation biofuels only by restricted supply of 1st generation energy crops.

Figure 5-18 shows the total available land in the original Green-X model (1), 1st generation biofuels and released agriculture land for perennial crops (2) based on CAPRI and Biomass Policies in 2020 and 2030. These results are used to update the Green-X future land supply database (3).

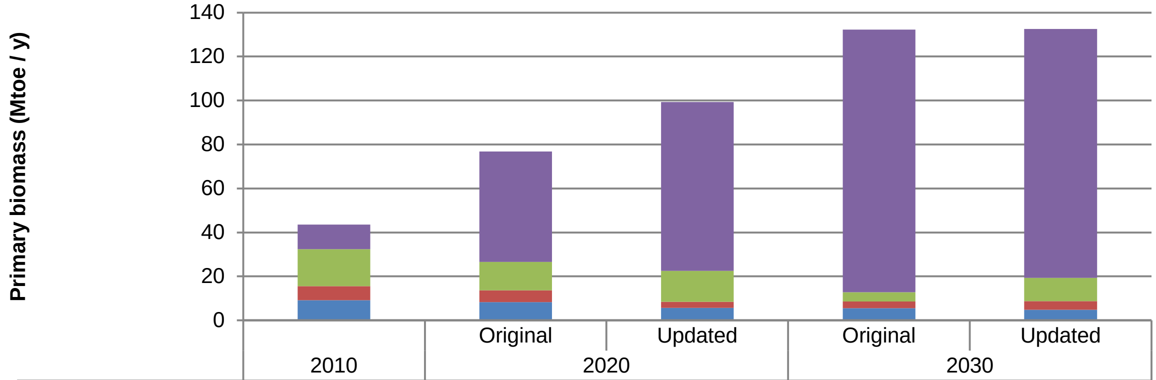
Figure 5-18. Land supply according to 1) Green-X (original), 2) 1st generation (starch, sugar, oil crops) according to CAPRI (CAPRI, 2013) and perennial crops (woody, grassy crops) according to Biomass Policies (Elbersen et al., 2015), 3) Green-X (updated) land supply.



Based on the updated land supply, Figure 5-19 shows the updated potential of dedicated energy crops in the Green-X model compared to the original supply potential.

[19] Total land released in Biomass Futures: Reference scenario: 21.7 Mha (2020), 18.8 Mha (2030). Sustainable scenario: 18.4 Mha (2020), 16.1 Mha (2030) (Elbersen *et al.*, 2012a).

Figure 5-19. Primary biomass supply potential in the EU to 2030 based on the original and updated land supply database of Green-X (in Mtoe/y).



	2010	2020 Original	2020 Updated	2030 Original	2030 Updated
Total	43.6	76.9	99.3	132.2	132.6
Lignocellulosic crops	11.1	50.2	76.8	119.4	113.2
Starch crops	16.8	13.0	14.1	4.2	10.5
Sugar crops	6.4	5.4	2.8	3.0	4.0
Oil crops	9.2	8.3	5.7	5.6	4.8

6 Organic waste supply: state of play and scenarios to 2030

Next to forestry and agriculture, waste is the 3rd main category of biomass which can potentially be used for energy generation. An important share of waste is of biological origin (paper, wood, food waste, garden waste).

6.1 Introduction

6.1.1 Approach

In this chapter we will indicate the potential supply of organic waste by 2030 in the EU28. A first step is a review of existing data and literature on **current amounts** of waste biomass. Various studies focus on municipal solid waste (MSW), which implies that industry/sector waste is only partly included.

The approach to define waste biomass volumes for different waste fractions is based on the methodology applied in the **Biomass Policies** project[20]. The starting base is to use the Eurostat waste generation and waste treatment data as input. Since 2004, data on waste generation and treatment are collected per EU member state. Information on waste generation is split by source (several business activities according to the NACE Rev. 2 classification and household activities) and by waste categories according to the *European Waste Classification for statistical purposes*. Mind that interpretations of waste categories (in the Eurostat reporting) may vary by Member State; in particular it is clear that reported wood waste figures sometimes include industry residues, which may lead to double counting of potential feedstocks. As wood waste and secondary (industrial) wood residues were already discussed in the chapter of forestry biomass, (separate) wood waste will not be included in this section.

Information on waste treatment is split by treatment type (recovery, incineration with energy recovery, other incineration, disposal on land and land treatment) and by waste categories. All values are measured in tonnes of waste.[21] Waste fractions going to material recovery are excluded from the potential available for energy production.

In order to calculate the **potential towards 2030** the following approach is followed as in Biomass Policies (Elbersen et al. 2015)):

- First the total waste generation per category of waste is taken;
- then the waste treatment categories are identified per type of waste.
- Waste treatment factors are applied to the total waste generated to identify which part is already going to alternative useful uses (e.g. compost, recycling) and which part of the waste is available for further conversion into energy or other future bio-economy

[20] B. Elbersen et al (2015) Outlook of spatial biomass value chains in EU28 - Deliverable 2.3 of the Biomass Policies project. September 2015

[21] http://ec.europa.eu/eurostat/web/waste/waste-generation-and-management

uses. So the part already going to energy is also perceived to be available as part of the potential.

- For future mobilisation potentials, specific evolutions in terms of waste generation, landfill share and separated collection are assumed, with sensitivity analysis.

6.1.2 Included waste categories

The main waste categories consisting partly or entirely of organic waste material are:

- **Paper and cardboard wastes** (W072): 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.
- **Animal and mixed food waste** (W091): animal and mixed wastes from food preparation and production (agriculture and manufacture of food and food products) and from separate collection of biodegradable kitchen and canteen waste, and edible oils and fats. Used animal fats and vegetable oils (UFO) are included in this category. Estimations from Biomass Policies (2015) will be used to provide separate figures for these UFO fractions.
- **Vegetal wastes** (W092): vegetal wastes from food preparation and products, including sludges from washing and cleaning, materials unsuitable for consumption and green wastes. They can originate from food and beverage production, and from agriculture, horticulture and forestry.
- **Household and similar wastes** (W101): 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. For calculation of the potential only the *organic fraction* of MSW is taken. The % organic fraction is different per country.
- **Common sludges** (W11): 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. The carbon contained in sludge is mostly organic.
- **Wood wastes** (W075): 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 buildings but can occur in all sectors in lower quantities due to wooden packaging. **Wood waste is not included in this assessment as it is already covered in the assessment of forestry biomass.**

Mind that the Waste Framework Directive defines the term 'bio-waste' as 'biodegradable garden and park waste, food and kitchen waste from households, restaurants, caterers and retail premises and comparable waste from food processing plants'. It does not include forestry or agricultural residues, manure, sewage sludge, or other biodegradable waste such as natural textiles, paper or processed wood.[22] This is more narrow than the fractions we include in this analysis. To avoid confusion we will use the term 'biogenic waste'.

6.2 Current situation of organic waste

6.2.1 Amounts

Many reports focus on **municipal solid waste (MSW)**, which in practice contains the waste from households and the 'household and similar wastes' from NACE activities. The share with biological origin is generally estimated to be around 35% of total MSW, representing around **90 million tonnes of organic waste** (Arcadis, 2009). This excludes separate paper & cardboard and waste wood collection.

Table 6-1. Ranges of bio-share compared to total municipal waste (EEA, 2013b).

% of biological origin in total municipal waste	Countries
Less than 20 %	Lithuania, Norway and Slovenia
Between 20 % and 30 %	Bulgaria, Denmark, Ireland, Hungary, Latvia and Switzerland
Between 30 % and 40 %	Germany, France, Italy, Sweden, United Kingdom, **European average**
Between 40 % and 50 %	Austria, Belgium, Czech Republic, Estonia, Finland, Luxembourg, the Netherlands, Poland, Romania and Spain
Between 50 % and 60 %	Greece, Portugal, Slovakia
Between 60 % and 80 %	Malta

In this report, also industrial and sectoral waste ('NACE') is taken into account. The following table shows the Eurostat data (in million tonnes, as received) for total generation of these waste categories for the EU28 in 2004, 2008, 2010 and 2012. Distinction is made between households (HH) and NACE activities (NACE).

Table 6-2. Total generation of the selected waste categories for the EU28 (derived from Eurostat)

EU28 (million tonnes)	2004	2006	2008	2010	2012
Total waste	*2564.8*	*2584.1*	*2426.5*	*2460.3*	***2515.1***
HH	*211.0*	*215.4*	*219.6*	*220.4*	***213.4***
NACE	*2353.9*	*2368.8*	*2207.0*	*2239.9*	***2301.7***
Paper and cardboard wastes	56.1	63.8	57.5	48.6	**46.9**
HH	16.3	16.8	17.7	17.4	**17.0**
NACE	39.9	47.1	39.8	31.2	**30.0**
Animal and mixed food waste	n.a.	n.a.	n.a.	36.5	**37.2**

[22] http://ec.europa.eu/environment/waste/compost/index.htm

HH	n.a.	n.a.	n.a.	5.2	**6.3**
NACE	n.a.	n.a.	n.a.	31.3	**30.9**
*of which used fats and oils**				***0.6***	***1.2***
Vegetal wastes	n.a.	n.a.	n.a.	54.1	**56.7**
HH	n.a.	n.a.	n.a.	21.1	**22.2**
NACE	n.a.	n.a.	n.a.	33.0	**34.5**
Household and similar wastes	214.5	207.9	200.0	178.9	**169.7**
HH	148.6	146.1	144.1	135.9	**129.3**
NACE	66.0	61.8	56.0	43.0	**40.3**
Common sludges	16.3	17.7	15.5	16.6	**21.5**
HH	0.16	0.17	0.13	0.25	**0.11**
NACE	16.2	17.5	15.4	16.4	**21.4**
Total municipal waste[23]	**252.4**	**259.0**	**260.7**	**253.7**	**246.2**

Source: Eurostat, accessed 3 July 2015
EUROSTAT reports sludges in dry matter content, and all other categories wet ('as received').
** used cooking oil from catering and food preparation. Source: Ecofys (2013). Potential by Biomass Policies (2015) estimated at 2.6 million tonnes per year.*

In 2012 around **47 million tonnes of paper and cardboard waste** are generated; most of that will be recycled (see further).

From NACE side, next to 'household and similar wastes', the following waste fractions containing organic material are generated: **animal and mixed food waste (30.9 MT)**, **vegetal wastes (34.5 MT)** and **common sludges (15.2 MT dry mass**)[24].

Weights are corrected to dry tonnes of organic fraction using estimates of dry matter content taken from Waste2Go (2014): paper/cardboard (92%), food waste (40%), and garden or park waste (50%). The organic fraction of mixed waste ('Household and similar wastes') typically consist of between 30 and 40% organic fraction (m/m), although it is country specific. According to Arcadis (2009), the average is 39%.

With these assumptions, and Lower Heating Values (LHV) as applied in Biomass Policies (2015), we get the following overview of generated organic waste, expressed in energy content (Mtoe).

[23] Definition of municipal waste (according to Eurostat (2012)): Municipal waste consists to a large extent of waste generated by households, but may also include similar wastes generated by small businesses and public institutions and collected by the municipality; this latter part of municipal waste may vary from municipality to municipality and from country to country, depending on the local waste management system.
[24] There seemed to be inconsistencies in Eurostat in the MS reporting on generated common sludge amounts (moisture included or not?). For 3 countries (BE, IE, IT) amounts were reduced to the amount reported in 'treated common sludge'.

Table 6-3. Overview of bio-waste categories, expressed in energy content

Type of waste	Organic fraction (% m/m)	Total organic fraction (Mton, dry mass)	Lower Heating Value organic fraction (MJ/kg dry mass)**	TOTAL in EU28 (Mtoe, LHV, 2012)
Paper and cardboard wastes	92%*	**43.2**	18.0	**18.6**
Animal and mixed food waste (excl. UFO)	40%*	**14.4**	15.9	**5.5**
Used animal fats & vegetable oils	100%	**1.2**	38.1	**1.1**
Vegetal wastes	50%*	**28.4**	18.1	**12.3**
Household and similar wastes	39% average (country dependent)	**66.9**	15.9	**25.4**
Common sludges	100% organic (totals reported in dry mass)	**15.2**	8.7	**3.2**
TOTAL		**169.3**		**66.0**

* the rest is moisture
** source Biomass Policies (Elbersen *et al.*, 2015), based on Phyllis database[25]

6.2.2 Current treatment of waste (including bio-fractions)

According to the Waste Framework Directive, the following priority order (waste management hierarchy) should be applied in waste prevention and management legislation and policy:

a. Prevention
b. Preparing for re-use
c. Recycling
d. Other recovery, e.g. energy recovery
e. Disposal

The following waste treatment options are reported in Eurostat:

- Other recovery (material recycling & composting, incl. anaerobic digestion)
- Incineration with energy recovery
- Incineration without energy recovery
- Landfill

[25] https://www.ecn.nl/phyllis2/

The reporting in Eurostat on waste treatment does not make distinction between composting, digestion and recycling in the ‘other recovery’ category.

Eurostat reports the following overview of treatment of the different waste fractions (HH and NACE together):

Table 6-4. Treatment of different waste fractions in the EU (derived from Eurostat)

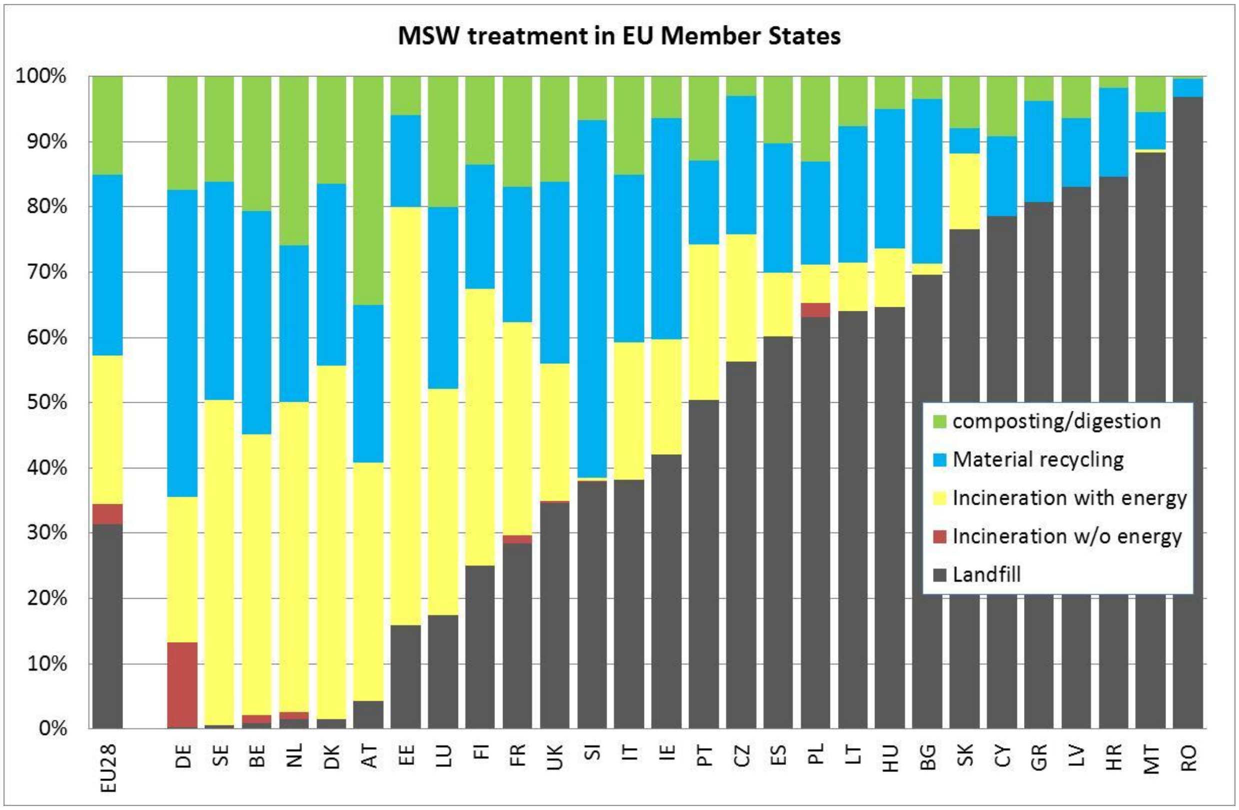
EU28, 2012	Other recovery	Incineration & energy recovery	Incineration & disposal	Landfill
Paper and cardboard wastes	98.7%	0.8%	0.1%	0.5%
Animal and mixed food waste	84.3%	5.7%	2.1%	7.3%
Vegetal wastes	93.4%	3.4%	0.4%	2.8%
Household and similar wastes	12.1%	23.0%	15.1%	49.7%
Common sludges	56.3%	12.7%	12.7%	11.1%

Source: derived from Eurostat, accessed July 2015

Specifically for **municipal waste**, which largely consists of household waste, but also similar wastes generated by small businesses and public institutions and collected by the municipality, Eurostat makes distinction between material recycling and composting/digestion.

Figure 6-1 shows the distribution of municipal waste treatment for the European member States in 2013.

Figure 6-1. Distribution of municipal waste treatment for the European member States in 2013



On average 31% of MSW is still landfilled, 3% incinerated without energy recovery, 23% incinerated with energy recovery, 28% is recycled and 15% (36 million tonnes) composted or digested. There are large differences between countries.

The EU Landfill Directive of 1999 (EC, 1999) introduced targets to reduce *biodegradable* municipal waste going to landfill, down to 35% of 1995 levels by 2016.

In December 2015, the Commission adopted a Circular Economy Package, which includes revised legislative proposals to amend the Waste Framework Directive and the Landfill Directive.[26] Key elements of the revised waste proposal include:

- A common EU target for recycling 65% of municipal waste by 2030;
- A binding landfill target to reduce landfill to maximum of 10% of all waste by 2030;
- A ban on landfilling of separately collected waste.

[26] http://ec.europa.eu/environment/circular-economy/index_en.htm

6.2.3 Current energy production from organic waste

In 2013, approximately 450 Waste-to-Energy (waste incineration with energy recovery) plants were operational in Europe[27]. According to Eurostat, the gross inland energy production from the renewable part of MSW in 2012 (through combustion/incineration) was **8744 ktoe**. This represented 7% of total biomass use for energy.

Also biogas production adds to the use of bio-waste for energy: in 2012 biogas production from sewage sludge amounted **1185 ktoe**; landfill gas production amounted **2842 ktoe**; 'other biogas'[28] represented 8000 ktoe, which is partly based on organic waste (EurObserv'Er).

In 2012 14490 ktoe of biofuels were consumed in the EU, of which 1790 ktoe were classified as 'advanced'; around 85% of that amount (1537 ktoe) is estimated to be based on used cooking oils and animal fats (Hamelink et al. 2014). Mind that part of the feedstock is imported from outside the EU. Hamelink et al. (2014) estimated that **932 ktoe** biodiesel was produced from EU **used cooking oil** and **481 ktoe** biodiesel from EU **animal fats**.

6.3 Potential supply of organic waste up to 2030

6.3.1 Methodology

In order to calculate the potential a similar approach is followed as in Biomass Policies (Elbersen *et al.*, 2015). This includes:

1. Total waste generation per category of waste;
2. Waste treatment categories distribution per type of waste;
3. Waste treatment *factors* are applied to the total waste generated to identify which part is already going to alternative useful uses (e.g. compost, recycling) and which part of the waste is available for further conversion into energy. So the part already going to energy is also perceived to be available as part of the potential.
4. For future mobilisation potentials, specific evolutions (in terms of waste generation, landfill share and separated collection) are assumed, with sensitivity analysis.

In terms of the waste treatment factors, the following waste treatment categories will be included in the current energy potential:

- Incineration with energy recovery: fully available (already going to energy)
- Incineration without energy recovery: available under the assumption that these amounts are shifted to incineration with energy recovery
- Disposal on or into land (landfill): available under the assumption that these amounts are shifted to incineration with energy recovery.

[27] http://www.cewep.eu

[28] This includes decentralised agricultural plants, organic waste digesters, centralized co-digestion plants.

- Other recovery: this category will in principle be excluded from the potential, as far as material recycling is concerned. The amount of recycled paper and cardboard will be excluded, as well as food and animal wastes recycled into animal feed and oleochemicals. However, other recovery of waste also includes operations such as **composting and anaerobic digestion,** producing biogas, the latter clearly being an energy carrier. So we can't exclude these from biomass potentials for energy. In fact, a large part of the fractions animal and food wastes, vegetal wastes and common sludges which are listed as 'other recovery' are being composted or digested. Combinations of anaerobic digestion and composting (e.g. pre-digestion of organic waste and post-composting of the digestate) are gaining interest, so waste which is currently being composted could also undergo an extra anaerobic digestion step.

    - Vegetal waste: As a rule of thumb, we assume that maximum 20% of the energy contained in vegetal waste in the category 'other recovery' will be available for energy (through anaerobic digestion) – the rest will end up in compost (including home composting) or soil improvers.
    - Animal and mixed food waste: Animal by-products from rendering will partly be valorised in animal feed, pet food, fish feed, oleochemicals and fertiliser production[29], some solid fractions are used as fuel in power stations and cement kilns, some animal fats are used for liquid biofuel (biodiesel). Substantial amounts of food waste will also go to anaerobic digestion, with the digestate serving as soil improver. Overall we assume that maximum 40% of the energy contained in animal and mixed food waste in the treatment category 'other recovery' will be available for energy.
    - Used animal fats and vegetable oils from catering and food preparation are largely (~90%) available for energy (biofuel); Ecofys (2013) estimates that 10% is used in oleochemistry.
    - Common sludge in the category 'other recovery' is assumed to be fully available for anaerobic digestion.

6.3.2 Current potential

When applying the methodology described above to the 2012 waste generation and treatment figures, this results in the following overview of organic waste potentials.

Table 6-5. Primary energy potential of organic waste for energy (Mtoe/yr)

EU28	Primary energy potential of organic waste for energy or bio-chemicals (Mtoe/yr)
Paper and cardboard wastes	0.3
Animal and mixed food waste	3.2
Used animal fats & vegetable oils	2.3*

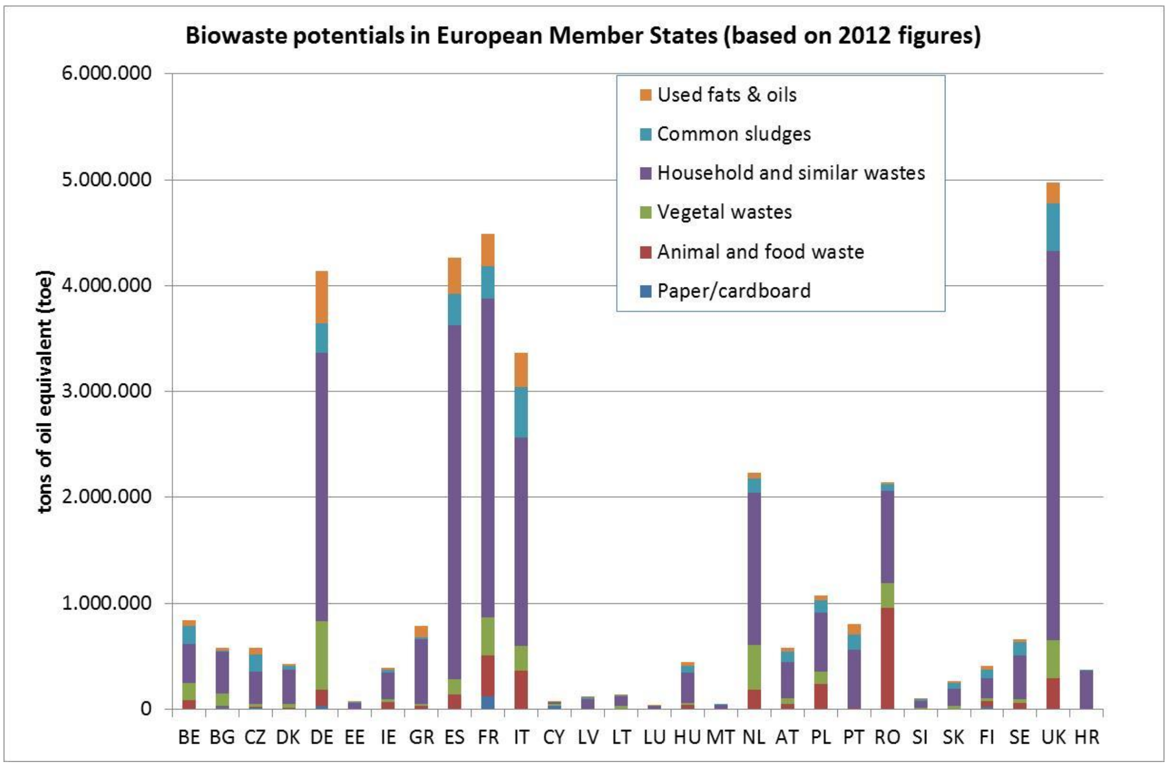
[29] EFPRA

Vegetal wastes	3.1
Household and similar wastes	22.4
Common sludges	3.2
TOTAL	**34.4**

* *potential of used cooking oil, estimated by Biomass Policies (2015)*

A similar calculation in Biomass Policies (Elbersen *et al.*, 2015) resulted in a potential of 1308 PJ (for 2010), which is equivalent to 31.2 Mtoe for organic waste (excluding wood waste or road side verge grass).

Figure 6-2. Organic waste potentials in European Member States (based on 2012 figures)



Landfill gas is not explicitly mentioned in this potential, as this is energy produced from historically landfilled waste. On the longer term it is assumed that landfill (and specifically landfill of biodegradable waste and recyclable fractions) will be outphased, as foreseen in the Landfill Directive and the Circular Economy Package.

6.3.3 Scenario background

For the scenario analysis (mobilisation potentials), we start from the currently used organic waste for energy, and include trends in terms of demography, waste generation, landfill reduction and waste separation. Waste generation and landfilling can be expected to decrease over the coming decades due to policies related to the EU Waste Framework

Directive (2008/98/EC), the Landfill Directive (1999/31/EC) and the Packaging and Packaging Waste Directive (94/62/EC). It is reasonable to expect that additional measures to reduce waste generation and landfilling will be adopted between now and 2020 (ICCT, 2015), also considering the recently adopted EU Circular Economy Package. According to EEA (2015) achieving the EU's long-term objective of establishing a circular economy will require far-reaching technological, behavioural and organisational change.

In this report, we have not attempted to separately characterize national waste and/or landfill reduction trajectories, and have instead adopted a single set of assumptions for the EU28 as a whole.

Demographic evolutions: population and GDP growth rates are derived from the 2013 reference scenario in the EC 'Trends to 2050' report[30].

MSW generation: Arcadis (2009) assumed in its baseline scenario that total MSW generation would be coupled to demographic evolutions, so MSW per capita would remain at current levels. EEA (2013) reviewed the period between 2001 and 2010, and found that there was little evidence of increased waste prevention. On the other hand EEA stated that the economic downturn that started in 2008 may have caused a reduction in municipal waste generation per capita. In the period from 2008 to 2013 MSW generation figures reported in Eurostat reduced from 520 kg per capita at EU level down to 481 kg per capita, which is equivalent to an average reduction of 1.6% per year.

In the baseline scenario we assume that MSW generation per capita remains constant up to 2030. For sensitivity analysis (*higher focus on reducing municipal waste generation*) an average reduction of total MSW generation per capita of 1% per year is considered, down from 488 kg/capita in 2012 to 407 kg/capita in 2030.

Recycling rates: average EU MSW recycling rate in 2013 amounted to 42%, with country performances varying between 5 and 65% (see Figure 6-1). The Waste Framework Directive (2008/98/EC) sets a target for 50% of municipal waste to be recycled by 2020 in individual countries. According to EEA (2013), five countries already reached this target in 2010, six countries will reach the target if they maintain the annual rate of increase in recycling from the period 2001-2010, while the other countries need to accelerate their shift to recycling. The Circular Economy Package mentions a common EU target for recycling 65% of municipal waste by 2030.

Although part of the recycling can be done through treatment of mixed waste, increasing recycling rates imply that **higher levels of separated waste collection** need to be reached. The Waste Framework Directive (Art 22) mentions that Member States should "*take measures to encourage the separate collection of bio-waste with a view to the composting and digestion of bio-waste*". A higher level of waste separation reduces the

[30] http://ec.europa.eu/transport/media/publications/doc/trends-to-2050-update-2013.pdf

amount of mixed waste and also implies a growth in separately collected vegetal waste and animal and food waste.

For the period 2004-2012, Eurostat reported a decrease of mixed (household and similar) waste from 435 to 336 kg per capita, which is equivalent to a decrease of 3% per year. In the baseline scenario we assume a slower trend towards 2030 with an average decrease of 2% per year, reducing mixed household and similar waste further down to 233 kg per capita in 2030 (47% of MSW); for sensitivity analysis we assume a *higher focus on separate collection of municipal waste,* reaching an average reduction of 4% per year, which would reduce mixed household and similar waste to 160 kg per capita in 2030 (33% of MSW). Mind that not only the separately collected fractions qualify for recycling as some mixed waste (currently 12%) is further recycled, e.g. through metal recovery or MBT.

Landfill**:** average landfill of EU MSW amounted 31% in 2013, with wide variation between countries ranging between 0.2% and 97% (see Figure 6-1). The EU Landfill Directive of 1999 (EC 1999) introduced targets to reduce biodegradable municipal waste going to landfill, down to 35% of 1995 levels by 2016 (*some countries were given a four-year derogation*). The Circular Economy Package mentions a ban on landfilling of separately collected waste, and a binding target to reduce landfill to maximum 10% of all waste by 2030.

The amounts which are landfilled are not available for energy (*only partly on the longer term through landfill gas recovery*). So the assumptions on landfill reduction have an important impact on energy potentials.

In the period 2000-2012, we saw a steady decrease of MSW landfill from 288 to 156 kg per capita (source: Eurostat), which is equivalent to a decrease of 5% per year. In the baseline scenario we assume a slightly slower trend towards 2030 with an average decrease of 4% per year, reducing MSW landfill from 156 kg per capita in 2012 to 75 kg per capita in 2030. For sensitivity analysis we assume a higher shift from landfill, reaching an average reduction of 6% per year, which would reduce MSW landfill to 50 kg per capita in 2030.

NACE (non-municipal) waste: Waste generation for non-municipal waste (NACE categories, with the exception of the NACE household and similar waste) is expected to evolve with GDP growth rates (around 1.5% per year). For sensitivity analysis we assume a decoupling of these waste fractions from GDP growth.

Landfill and incineration without energy recovery of separately available paper/cardboard, vegetal waste, animal and food waste and sludge is expected to be phased out by 2020.
The following table provides an overview of the main assumptions for the baseline scenario and sensitivity runs:

Table 6-6. Main assumptions for the baseline scenario and sensitivety runs

Factor	Baseline scenario to 2030	Sensitivity runs
MSW generation	constant per capita	-1% per year (per capita)
Mixed household and similar waste (for recycling targets)	-2% per year (per capita)	-4% per year (per capita)
MSW landfill	-4% per year (per capita)	-6% per year (per capita)
NACE waste	according to GDP growth	decoupled from GDP growth

6.3.4 Projected mobilisation potential to 2030

The following figure and table provide an overview of the calculations for the baseline scenario. The 2012 figures are an estimation of the current use of organic waste for energy. Note that the mobilisation potential in 2012 is larger than actual use explaining the relatively large growth between 2012 and 2020 in Figure 6-3.

Figure 6-3: Mobilisation potential of organic waste in the EU according to the baseline scenario (own calculations)

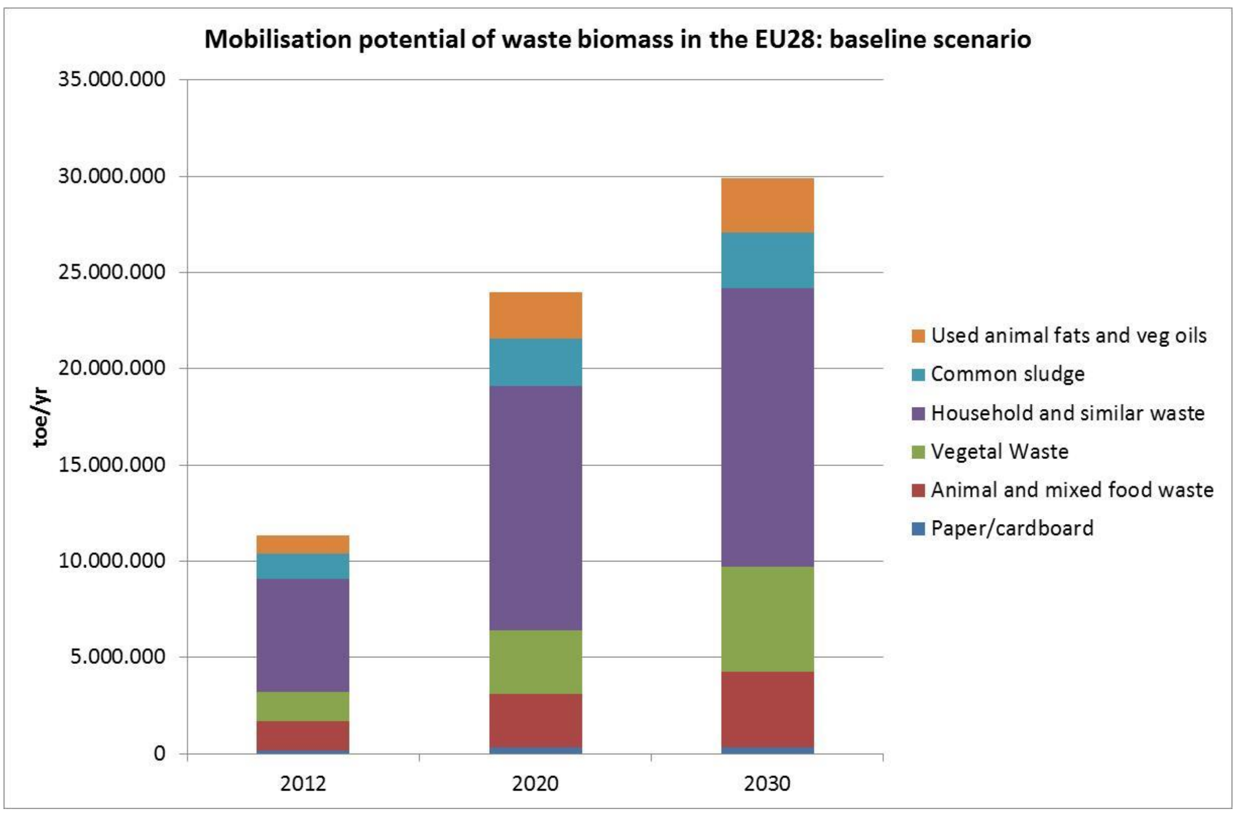


Table 6-7: Mobilisation potential of organic waste for energy in the EU according to the baseline scenario (own calculations)

Potential of organic waste in EU28 (Mtoe/yr)	2012	2020	2030
Paper and cardboard wastes	0.2	0.3	0.3
Animal and mixed food waste	1.5	2.8	3.9
Used animal fats & vegetable oils	1.0	2.4	2.9
Vegetal wastes	1.5	3.3	5.4
Household and similar wastes	5.8	12.7	14.5
Common sludges	1.3	2.5	2.8
TOTAL	**11.3**	**24.0**	**29.9**

In comparison to other studies, these results are in a similar range. For instance, ETC/SIA (2013) mentions a 'final energy potential from waste' in 2020 between 950 – 1250 PJ (23-30 Mtoe), including wood waste (around 5 -10 Mtoe). Biomass Policies (2015) comes to a 'total biomass potential from waste' in 2030 of 1617 PJ (38,6 Mtoe), including 417 PJ (10.0 Mtoe) of wood waste.

6.3.5 Sensitivity analysis

Four parameters were varied for sensitivity analysis, in relation to waste policy emphasis:

- Reduced MSW generation
- Higher landfill reduction
- Higher waste separation
- Decoupling of NACE waste from GDP growth

Reduced municipal waste generation in general reduces availability of municipal waste, including organic waste. Total energy potential from organic waste would reduce by 2.9 Mtoe in 2030 in case municipal waste generation would be reduced by 1% per year.

A **faster landfill reduction** would mainly increase the level of mixed waste that is available for incineration. Increasing landfill reduction from 4% per year to 6% per year would increase mixed waste for incineration (renewable share) by 1.8 Mtoe by 2030.

More **focus on waste separation** would reduce the mixed waste fraction and increase the shares of separated organic waste (animal and mixed food waste; vegetal waste). A 4% average yearly increase of waste separation compared to a 2% average increase would reduce the organic fraction of mixed waste by 2.4 Mtoe by 2030, and increase the energy potential of the separate organic waste fractions by 1.3 Mtoe. Mind that this would also imply an increase of compost production.

Decoupling waste generation in **NACE sectors** (non-municipal) from GDP growth, would reduce various fractions of waste, including organic waste (e.g. food waste). Total energy potential from organic waste would reduce by 2.9 Mtoe by 2030 in comparison to the baseline scenario.

Combining all four parameters together would reduce total energy potential from organic waste to 24.3 Mtoe in 2030 (compared to 29.9 Mtoe in the baseline scenario).

7 Global biomass supply available to the EU: state of play and scenarios to 2030

7.1 State of play of global biomass supply

7.1.1 Global biomass consumption

The global human annual harvest of biomass (agriculture, forest) for all uses including food, feed, materials and bioenergy is estimated to be about 5,374 Mtoe, or around 10% to 20% of global net primary production (NPP) of biomass (Slade *et al.*, 2011) Figure 7-1. Bioenergy makes up 25% of total annual human harvest of biomass, but also includes cascaded uses of biomass that were used first for material purposes. Bioenergy overall contributes about 10% to total primary energy supply (TPES) (Nakada *et al.*, 2014; REN21, 2014).

Figure 7-2 shows the breakdown of global bioenergy use per sector. IRENA estimated that 62% was used in the residential sector, mainly for traditional uses of bioenergy (heating in open fire stoves and cooking in developing countries). However, modern uses of bioenergy are growing rapidly since the last decade. These include mainly efficient heating systems in buildings, for example wood pellet stoves, large scale industrial uses of bioenergy in the manufacturing industry (14 %), transport (9 %) and power and district heating (8 %). Furthermore, (non-energy) use of biomass for the production of biobased chemicals and polymers adds 1 % (600 PJ, 14 Mtoe) to biomass use today (Saygin *et al.*, 2014).

Figure 7-1. Global energy content and total primary supply of fossil fuel, food, materials and bioenergy. Figure from Slade et al. (2011) updated with 2012 TPES (IEA, 2014) and bioenergy demand (Nakada et al., 2014).

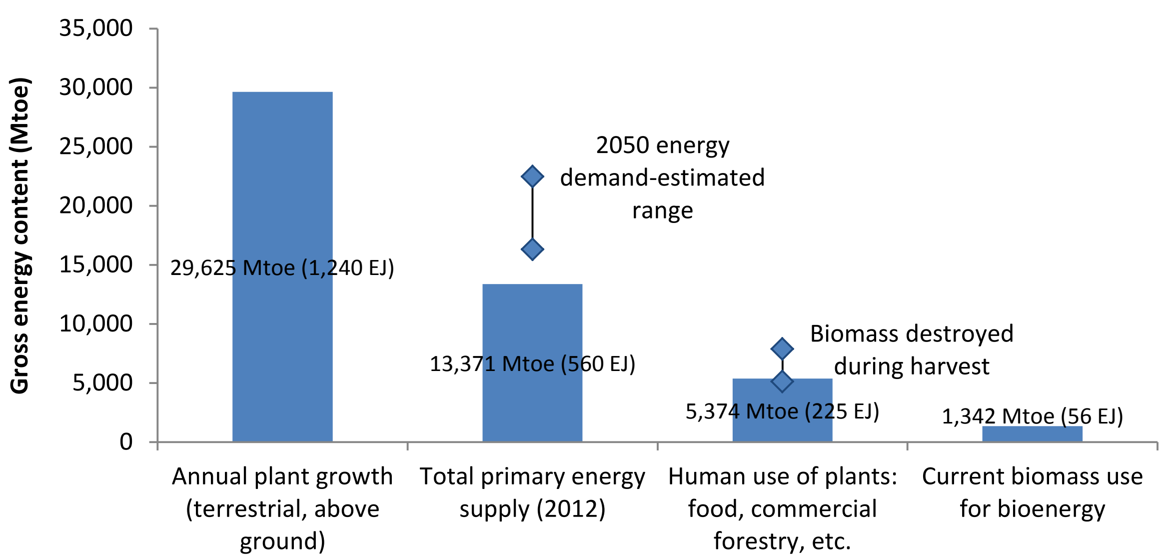
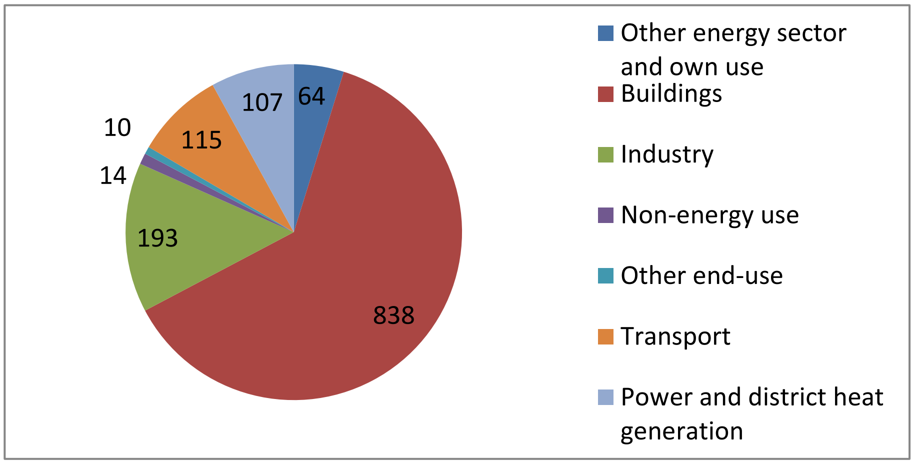


Figure 7-2. Traditional and modern uses of bioenergy in 2010 (Mtoe/yr) (Nakada et al., 2014)

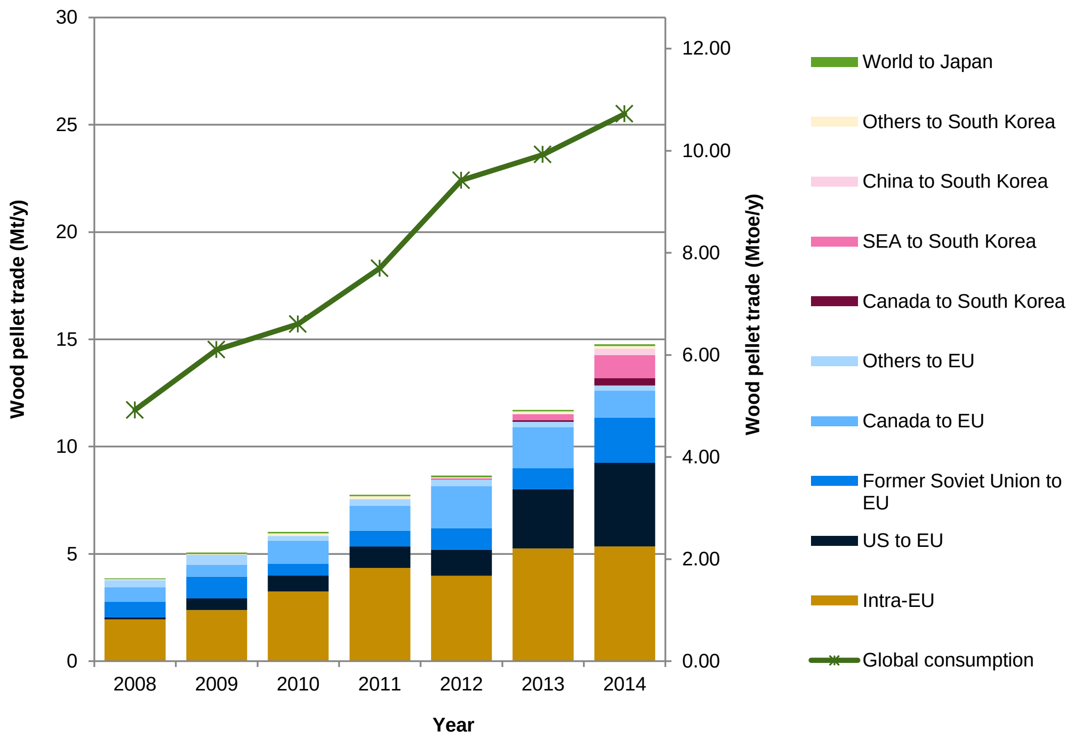


7.1.2 Production and trade of solid biomass for energy

To assess net trade of wood for bioenergy requires breaking down of statistics of commodity flows that are reported combined for energy and non-energy uses. In order to estimate trade flows of solid biomass for bioenergy purposes requires additional anecdotal information, for example from expert interviews, conferences etc. Wood pellets are almost solely used for bioenergy and are therefore easier to extract from statistics. Wood chips are mainly traded in small volumes in the Baltic sea region and Italy and fuelwood is mainly traded regionally and cross-border (Lamers *et al.*, 2014a).

Trade of unprocessed forest residues from outside the EU can be as good as excluded in the present as well as in the future, because of cost, moisture and phytosanitary reasons. Trade of raw wood is most likely focussed on higher quality stemwood for sawmills, veneer and plywood production. It may be questioned if import of raw wood will increase in the future. Under the actual legal framework of the EUTR (European Trade Regulation) only wood that is produced under compliance with national legal systems maybe imported. Furthermore, market actors more and more tend to also claim certified wood. The following table shows the potential global and regional supply of industrial roundwood from certified resources in the year 2014. The only world region with significant amounts of certified forest is the boreal zone (North America, Western Europe). The amount of certified roundwood in other areas of the world is less than 1 M m³ or 217.000 toe. Therefore, it is hardly to be expected that relevant quantities of raw wood from these regions will be imported. Furthermore, it is quite unrealistic that raw wood for energy will be imported from North America to Europe, because it is economically much more meaningful to convert them into pellets first and then transport it to Europe. Thus, we can assume that the only relevant import of biomass of wood for energy will be pellets. There are of course exceptions in border regions to Russia, but even in that case the imports of raw wood will focus on stemwood for pulp and sawnwood.

Figure 7-3. Global wood pellet production (in million tonnes) and trade between 2001 and 2014 (Lamers et al., 2012; EUROSTAT, 2015c; Goetzl, 2015; Junginger et al., 2015)



In 2013, the estimated production and consumption of wood pellets increased to 24.5 Mt (10.3 Mtoe) of which half (12.6 Mton, 5.3 Mtoe) was produced in the EU and 80% (19.5 Mt, 8.2 Mtoe) was consumed in the EU (AEBIOM, 2014). The US has become the largest producer of wood pellets with total production increasing to 5.8 Mt (2.4 Mtoe) in 2013 (Figure 7-3). Intra-EU trade of wood pellets increased from 1.9 Mt (0.8 Mtoe) in 2008 to 5.2 Mt (2.2 Mtoe) in 2013.

This strong growth in supply and demand of wood pellets in the EU is policy driven and is a result of both residential and industrial markets both growing at similar speeds. Residential heating markets are mainly found in Italy, Germany and Austria, district heating in Sweden and Denmark and large scale power generation in Belgium, Denmark, the Netherlands and the UK (Lamers *et al.*, 2014a). As a result of large scale conversion of coal fired units to biomass, the UK has become the largest consumer of wood pellets with consumption for power generation increasing to 3.5 Mt in 2013. Italy is the largest consumer for residential heating (3.3 Mt in 2013) (Figure 7-5) (AEBIOM, 2014).

Figure 7-4. Global wood pellet production per country in 2012 and 2013 (AEBIOM, 2014)

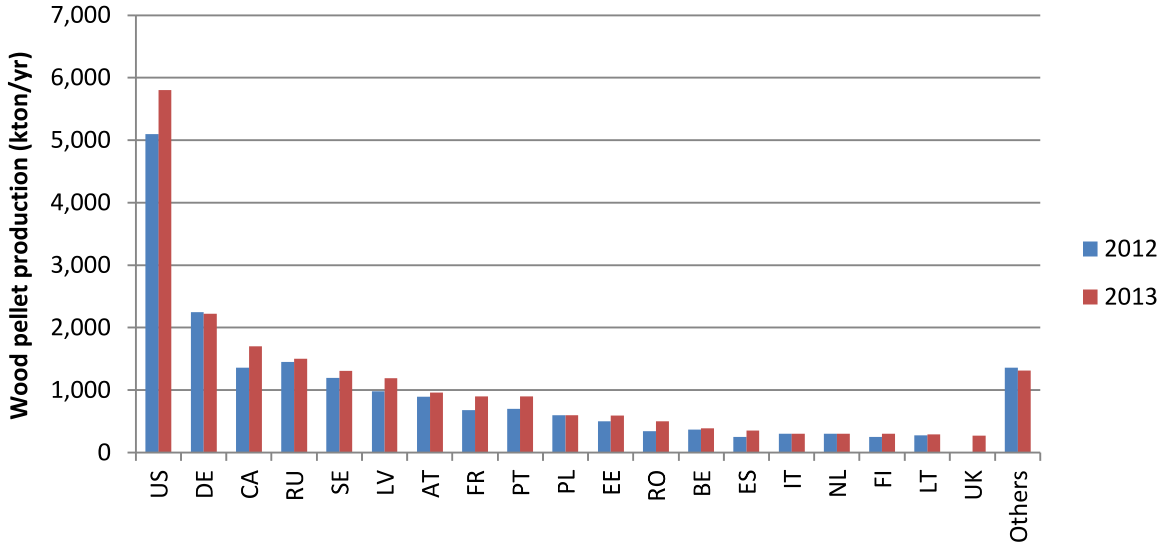
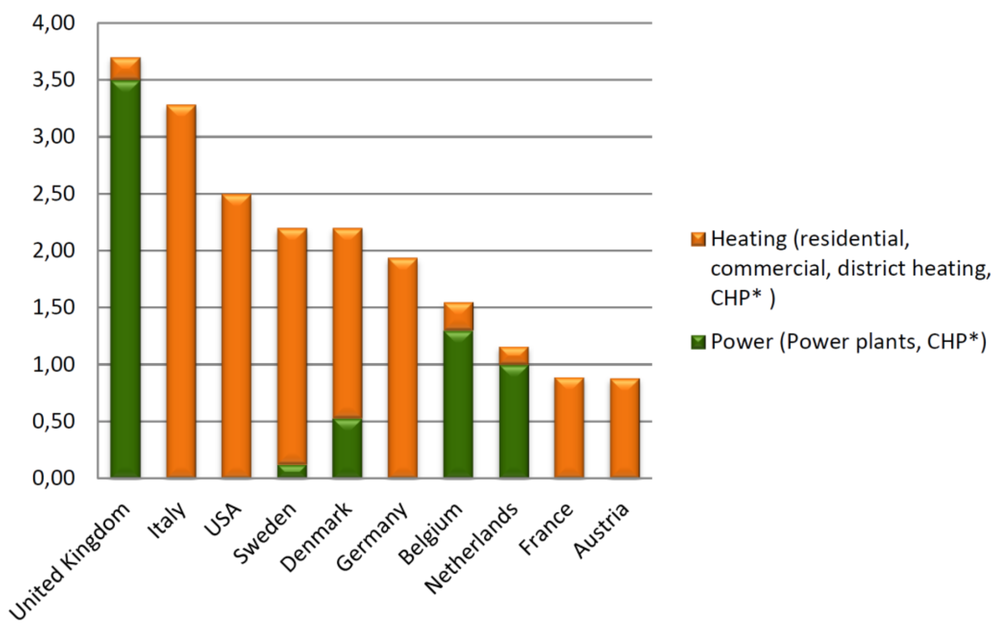


Figure 7-5. Wood pellet consumption for heat and power in top 10 countries EU in 2013 (AEBIOM, 2014)



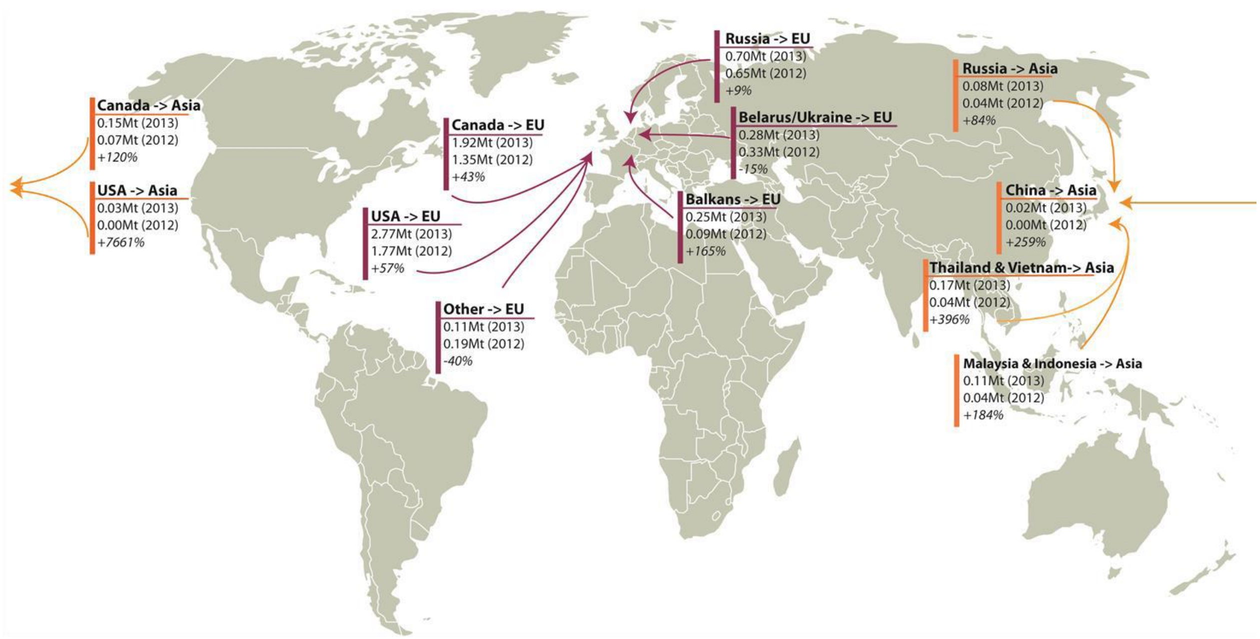
Source: Hawkins Wright, EPC Survey

*2/3 of the global CHP Pellet consumption is attributed to heating. 1/3 of the global CHP Pellet consumption is attributed to power.

While wood pellets for the residential pellet market are mainly sourced locally or from neighbouring countries, developments in the industrial pellet market (district heating, CHP and power plants) has been the key driver of international wood pellet trade (Lamers *et al.*, 2014a). With the strong increase in wood pellet production capacity, the US has overtaken Canada as the key exporting region of wood pellets.

Hawkins & Wright (2014) provide an overview of extra-EU wood pellet trade in 2012 and 2013 (Figure 7-6). Extra-EU imports of wood pellets increased from 4.4 Mt (1.8 Mtoe) in 2012 to 6.0 Mt (2.5 Mtoe) in 2013 mainly as a result of growing industrial markets in the UK. Next to EU markets, new markets in Asia are becoming increasingly relevant for international solid biomass trade. In 2013, wood pellet consumption in Asia was estimated to be 600 kt (0.252 ktoe) , mainly from imported sources (560 kt, 0.24 Mtoe in 2013) (AEBIOM, 2014). South Korea has set a target of 10 % power generation from renewable sources by 2020 whereas Japan has set a target of 35 % renewable energy and 25 % power generation from renewable sources by 2030 (Goetzl, 2015).

Figure 7-6. Global wood pellet trade strames in 2012 and 2013 (Mt) (Hawkins Wright, 2014)



7.1.3 Liquid biofuel trade31

Most recent status updates of global liquid biofuel trade are provided by IEA Bioenergy Task 40 (Lamers *et al.*, 2014b) for the year 2011.

Global trade of **ethanol** consists of three main trade routes between the EU, US and Brazil. Most imports to the EU were enabled via circumvention of EU's import tariffs in most EU member states for undenatured ethanol which is about twice as high as denatured ethanol.

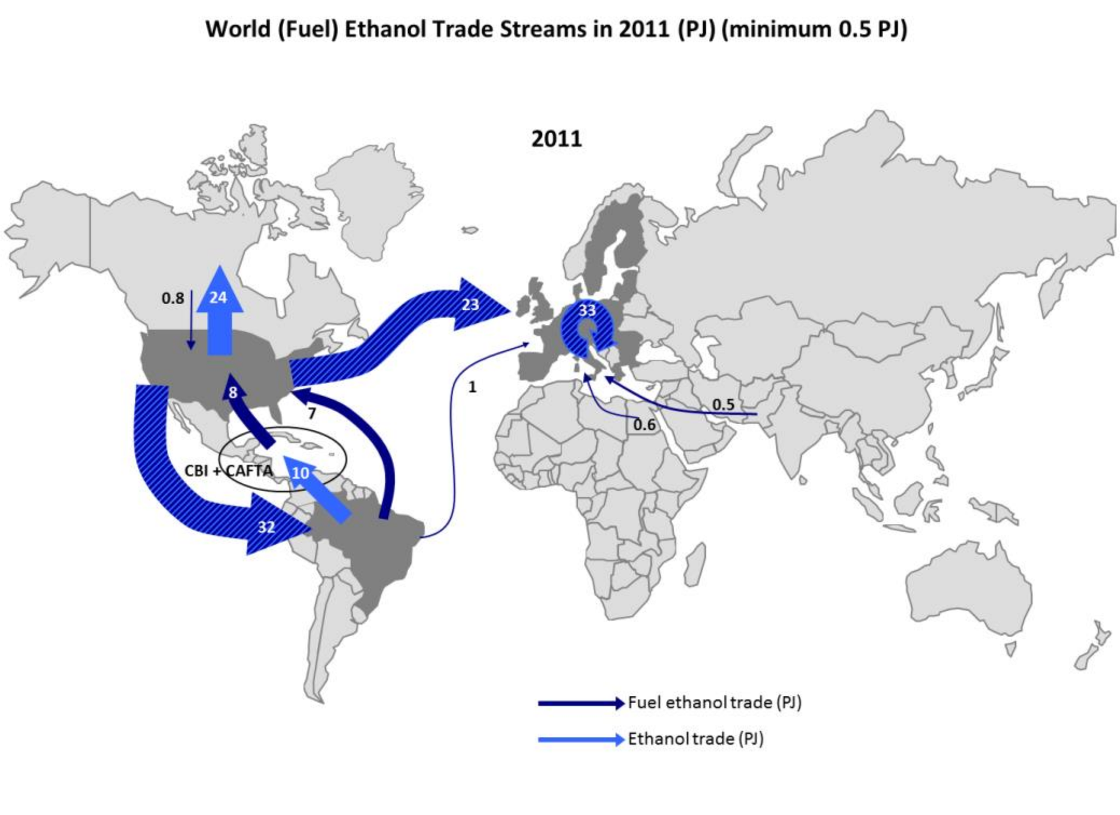
[31] Section mainly based on Lamers, Rosillo-Calle, et al. (2014).

Up to 2010, Brazil was the main exporting country to the EU, but was overtaken by the US in 2011 as shown in . In 2011, 1.1 billion litres (560 ktoe) were imported from the US under the low import tariff by importing in form of E90, classified as chemical compound. In 2012, new EU custom regulations targeted this loophole by increasing the minimum gasoline blend form 10% to 30% to be classified under the lower import tariff. This has resulted in a substantial reduction of extra-EU imports of ethanol. In 2014, the European Commission imposed anti-dumping taxes duties to US ethanol regardless of its transit country to prevent US exports of ethanol to Norway that re-exported the biofuels as blend with gasoline to the EU in 2013 (EurObserv'er, 2014).

According to FAO (2014), global production of ethanol is still expected to increase strongly (from 100 billion litres in 2012 up to 150 billion litres in 2020). EU demand would grow from 9 to 14 billion litres, with a trade balance stabilizing between 1.5 and 2.0 billion litres. Mind that non-biofuel use of ethanol (industrial applications) will be in the order of 2.2 billion litres.

On global level Brazil would remain the biggest exporter with around 10-12 billion litres per year. The USA would have an import need of around 6-8 billion litres, Japan between 1.2 and 1.4 billion litres.

Figure 7-7. Global (fuel) ethanol trade in 2011 (minimum 0.5 PJ) (Lamers et al., 2014b)

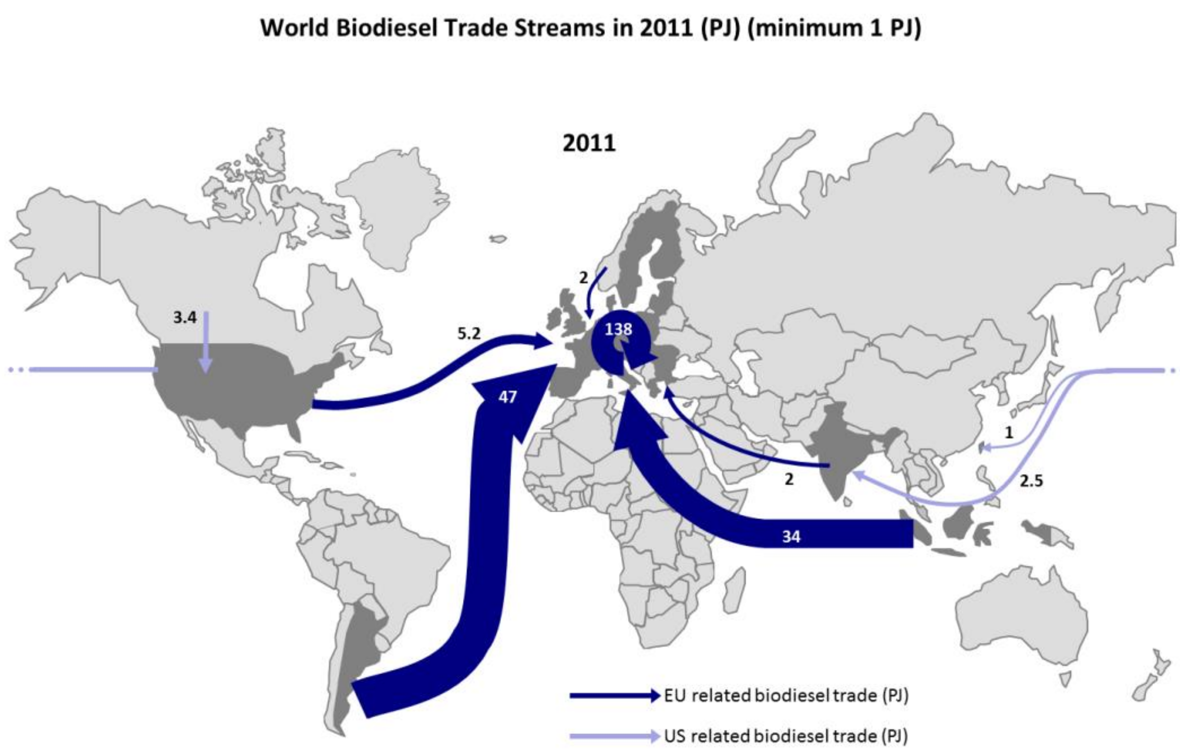


Biodiesel production started to become substantial with the introduction of the European Biofuels Directive (2003/30/EC). Trade of biodiesel was still practically zero in 2005, but was followed by an exponential increase to almost 2500 ktonnes (2.2 Mtoe) in 2011. Global trade of biodiesel is almost 100% driven by EU blending targets for biofuels with some minor trade flows, for example from the EU to Norway. Since 2010, palm oil from Indonesia and soybean oil from Argentina accounted for 90% of biodiesel imports to the EU (EurObserv'er, 2014). The production of drop-in diesel or Hydrotreated Vegetable Oils (HVO) has increased the demand for imports of vegetable oils in Europe as it uses imported palm oil, next to waste oils as a feedstock (Janssen *et al.*, 2013). The global production capacity of HVO increased to 3 billion liters (2.5 Mtoe) in 2013 with the largest capacity in Europe (1.8 billion liters, 1.5 Mtoe) followed by Singapore (0.9 billion liters, 0.7 Mtoe) and the US (0.3 billion liters, 0.2 Mtoe) (REN21, 2014).

Since November 2013, effective anti-dumping measures were taken against extra-EU imports of Indonesian and Argentinean biodiesel (between 120 and 250 €/t) reducing imports substantially. This has however also resulted in some imports from other regions including 400 million liters (203 ktoe) of ethanol import from Guatemala, Peru and Pakistan and some biodiesel imports from Malaysia and Brazil (Flach *et al.*, 2015). Given the current saturation of the EU biofuel market and the delayed decision on the iLUC directive, it is not expected that EU import of liquid biofuels will recover to the levels of before 2013 (EurObserv'er, 2014; Flach *et al.*, 2015).

According to FAO (2014), future biodiesel production will still reach over 40 bln liters (32 Mtoe) in 2023, with EU biodiesel demand to plateau at 19 bln liters (15 Mtoe) with about 3.2 bln liters (2.5 Mtoe) of import needed to meet the RED target, which is roughly 14% higher than total biodiesel trade to the EU in 2011.

Figure 7-8. Global biodiesel trade in 2011 (minimum 1 PJ) (Lamers et al., 2014b)



7.2 Global biomass supply and demand to 2030

Where traditional uses of biomass are mainly local within the production area, modern uses of bioenergy are often geographically remote from regions of biomass supply. The deployment of modern bioenergy today, about 270 Mtoe (11.3 EJ) (Chum *et al.*, 2011), has already created international bioenergy markets with countries becoming net suppliers of bioenergy. Up to 2030, primary biomass could increase from 1342 Mtoe (56 EJ) today to up to 2484 Mtoe (104 EJ) in 2030 in the IRENA Remap 2030 scenario. In this scenario, international trade increases to up to 549 Mtoe (23 EJ) (Nakada *et al.*, 2014). Similar ranges of trade have also been observed in global energy system models (TIMER, Poles) and the forest sector model GFM. In ambitious scenarios, interregional trade increases to 14%-26% of total primary biomass demand in 2030. Although international trade of solid and liquid biomass has increased exponentially in the last decade, most biomass is still sourced from local resources. Given the relatively small shares of trade today, liquid biofuel trade would increase with a factor 70 and solid biofuel trade would increase a factor 80 between 2010 and 2030 according to these ambitious scenarios. However, these models lack detailed characterization of the logistic infrastructure (collection, pre-processing, transport, handling, storage) and restrictions with respect to upscaling infrastructure in time. Given that the capacity to mobilize resources is considered a larger bottleneck than the supply potential itself, this is a key limitation (Fritsche & Iriarte, 2014). So far, challenges with respect to investments needed and feasibility of these expansions in logistic infrastructure (transport, handling pre-treatment, storage) are not simulated explicitly in the reviewed models (Matzenberger *et al.*, 2015).

Figure 7-9. Comparison of global biomass demand projections, 2030 (IEA primary energy definition)32 (Nakada et al., 2014).

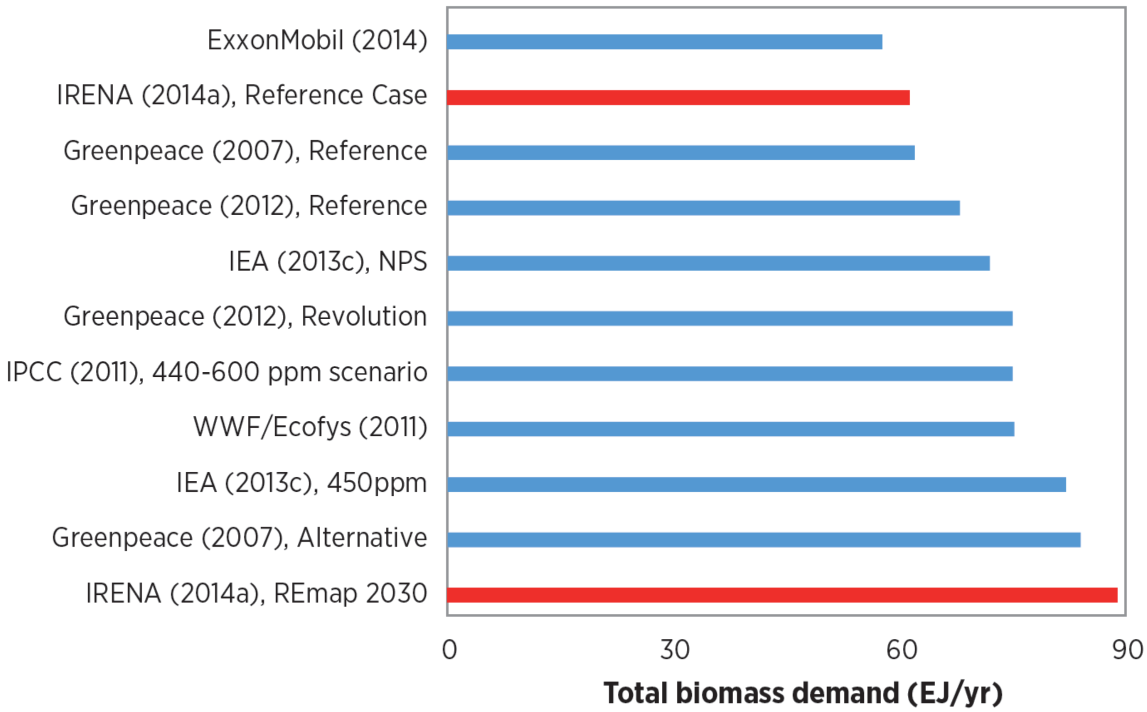
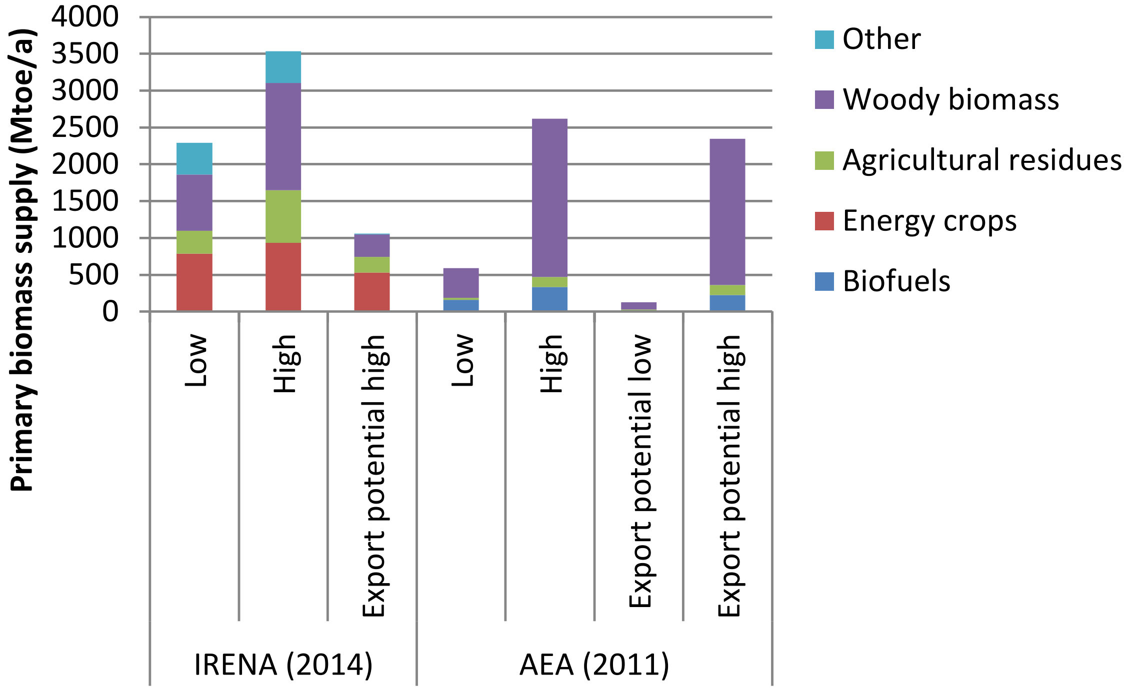


Figure 7-10 compares the total biomass potential estimated by IRENA in the Low and High scenarios (Nakada *et al.*, 2014) and the lowest (Low development 1st generation) and highest (BAU - high investment) potential found in the scenarios of the AEA (2011) in 2030. The export potential in both studies is determined by subtracting domestic demand from the domestic supply in the scenarios. Surplus of biomass are estimated to be around 80% by the AEA and about 26% by IRENA in 2030 in the high scenarios. In both studies, significant increases in plantations of energy crops are needed. Both IRENA and the AEA estimated that under a conservative scenario, supply and demand are in very close range.

[32] For liquid biofuels, the IEA considers the total energy content in liquid biofuels and not the primary biomass input to produce liquid transport fuels. A conversion efficiency is used to convert to primary bioenergy input of 50% by IRENA (Nakada *et al.*, 2014) and 60% by REN21 (REN21, 2014).

Figure 7-10. Comparison of estimated ranges of biomass supply and surplus of supply to determine the export potential of total biomass (solid and liquid biofuels) in 2030



7.3 Projected supply of solid biomass to the EU

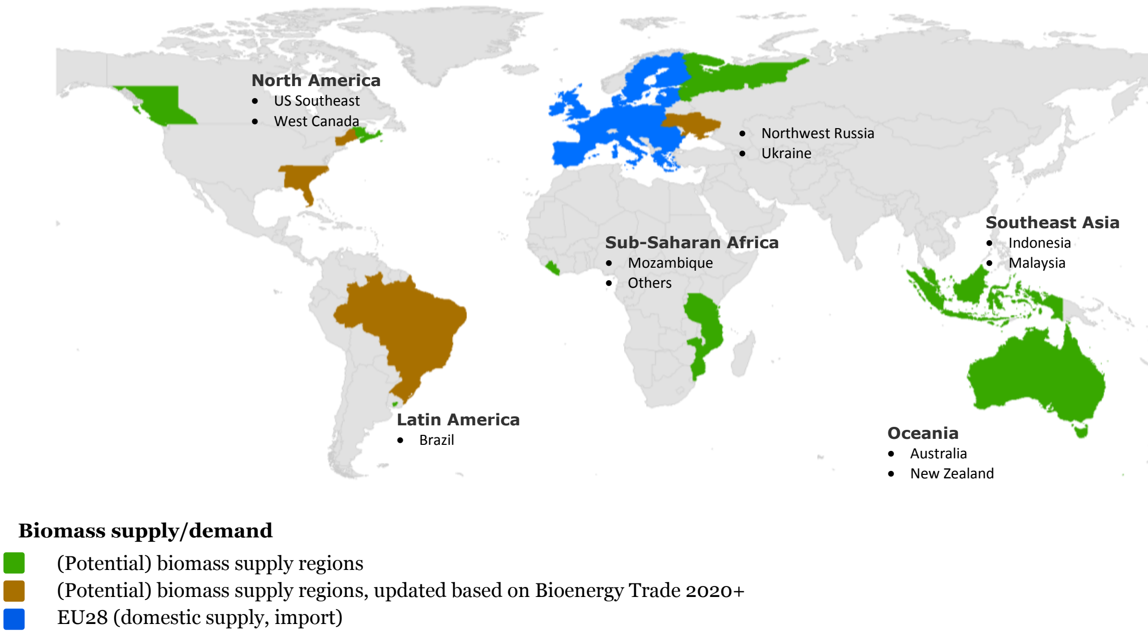
7.3.1 Method

Current key export regions of forest biomass include the US Southeast, Canada and northwest Russia. Beyond 2020, dedicated energy crops are expected to contribute to the supply potential of solid biomass. Additional key exporting regions of both residues and energy crops considered are Brazil and Ukraine and (to a smaller extent) countries in Sub-Saharan Africa (mainly Mozambique). The future export potential of these countries is however highly uncertain.

To determine the export potential of biomass, generally the geographic scope is limited to relevant supply regions that are already exporting or have the potential to become exporting regions of biomass for energy purposes. Figure 7-11 shows the regions that are included in this study. For Brazil, the US Southeast and Ukraine, intermediate results of the ongoing IEE project BioTrade2020+ are included. The main goal of this project is to provide guidelines for the development of a European Bioenergy Trade Strategy for 2020 and beyond[33].

[33] http://www.biotrade2020plus.eu/

Figure 7-11. Selected supply regions that are or are likely to become export regions of biomass.



In the Biotrade2020+ project, the current and future export potential is determined as follows:

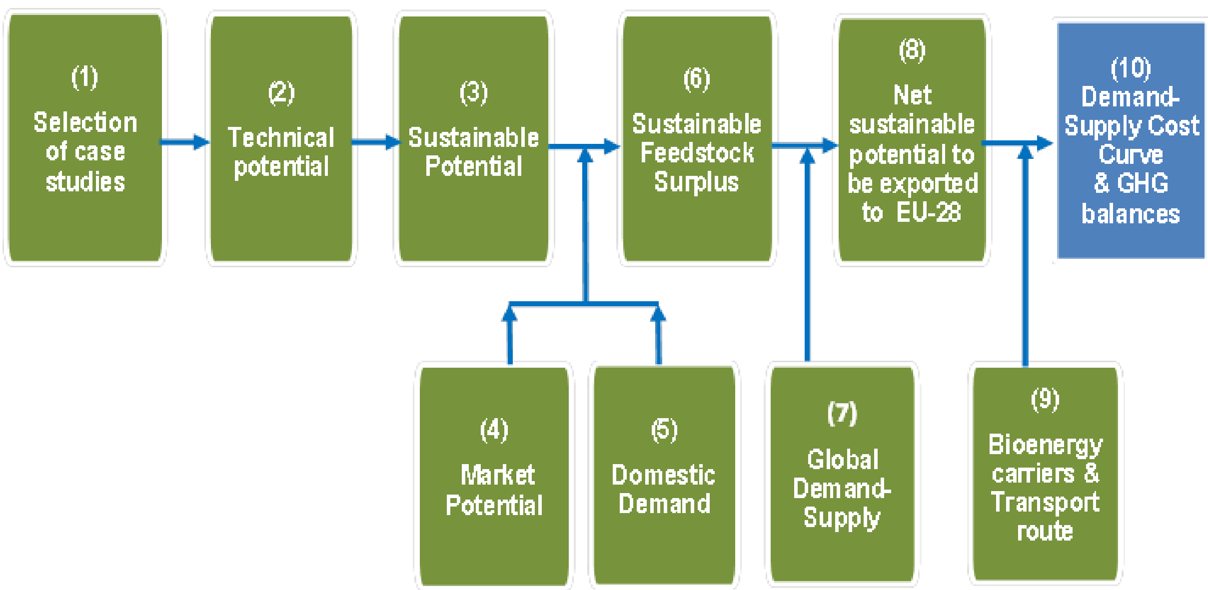
- As part of the selection of case study regions (step 1), based on a literature review, it is decided whether dedicated energy crops and/or forestry and agricultural residues are analyzed
- For these feedstock types, the technical potential is determined (step 2), e.g. how much corn stover might technically be available after harvest
- In step 3, the aim is to identify how much of the technical potential can be used taking into account various sustainability constraints. These are defined as a loose and strict set of criteria. The loose set of criteria do include the sustainability criteria as laid down in the RED (i.e. exclusion of highly biodiverse and carbon-rich lands, calculation of GHG footprints), and additional (specifically for residues) criteria regarding soil protection (erosion and soil organic carbon). The strict set of criteria includes various more environmental and also social sustainability criteria, but have not (yet) been applied for the intermediate results.
- Next, in step 4 & 5, the current local use for material and (traditional and modern) bioenergy uses determined and deducted from the sustainable potential. Also, an estimation is made whether the existing local markets and infrastructure could actually be sued to mobilize the net available biomass potential (e.g. the presence of mechanical harvesting machinery, presence of chipping/pelletisation plants, road and rail infrastructure etc.)
- An important intermediate outcome is then the net available export potential (step 6). After deducting an (already occurring) export of other world regions (step 7), and

after calculating the required costs of producing, harvesting, pretreating and transporting the biomass to an export hub (step 9), the cost-supply curves for the net available biomass potential to the EU is determined (step 10), including GHG footprints.

This procedure is carried out for the current situation (2015). For each case study, also two scenarios are devised: (1) a business as usual scenario, in which all current trends (e.g. agricultural yields, food demand, local biomass use etc.) are extrapolated until 2020 and 2030. In a High Trade (or optimistic) scenario, specific factors are identified that – if changed – could increase the net export potential (e.g. increasing agricultural yields by better management).

This bottom-up methodological approach is in line with the approach used in Green-X, as it also takes sustainability constraints into account, and results in dynamic cost-supply curves over time which then allows Green-X to choose whether it uses a feedstock or not based on cost (or e.g. a GHG emission constraint).

Figure 7-12. Assessment procedure of Sustainable Lignocellulosic Biomass Value Chains (BioTrade2020plus, 2014)



For the other regions, the current and future export potential is determined as follows (Vis & van den Berg, 2010; Fritsche & Iriarte, 2014):

$EP_{x,y} = THP_{x,y} - USW_{x,y} - U1_{x,y} \; ^{-} \; U2_{x,y}$

Where:

$EP_{x,y}$= net export availability under technical (and sustainability) constraints in country x, year y.

$THP_{x,y}$ = theoretical potential in country x, year y.

$USW_{x,y}$ = not available for harvest due to constraining factors (e.g. protection of biodiversity, soil, water, technical accessibility) in country x, year y.

$U1_{x,y}$ = non-energy uses of biomass (pulp, materials, feed, animal bedding, etc.) in country x, year y.

$U2_{x,y}$ = domestic energy uses (fuel wood, wood pellets, etc.) in country x, year y.

The type of constraints included determines the type of export potential (technical, sustainable or implementation/realisable).

Global biomass supply available for export to the EU

Although the EU-28 is still the main market for import of solid biomass, competing demand for traded biomass outside the EU-28 is becoming increasingly relevant. For the regional studies reviewed in this section two approaches are used to estimate the current and future share of global traded biomass available for the EU-28:

- Extension of the geographic scope with competing demand regions;
- Assuming a share available for the EU-28 or member state.

Lamers et al. (2014c) and Pöyry (Lechner & Carlsson, 2014) have extended the geographic scope by adding competing import regions in Asia including mainly Japan and South Korea. Both studies take into account the logistic cost of biomass delivered to different regions. Biomass is allocated by calculating the least cost of meeting total demand by Lamers et al. (2014) whereas Pöyry uses the actual wood paying capability to model global competition.

Fritsche et al. (2014) use a *per capita* approach to determine the share of extra-EU biomass sources available for the EU-28 based on current population statistics of countries that have similar paying capacities to the EU-28. These include Japan, 5 % of China, South Korea, the US and Canada. The share of bioenergy carriers available for export to the EU-28 is estimated to between 47 % and 49 % for 1^{st} and 2^{nd} generation biofuels respectively and 74 % for wood pellets. To estimate the share of bioenergy carriers for export to the UK, the AEA (AEA, 2011) assumes the share of energy demand in the UK to the EU (10 %) to be representative. Import regions outside the EU are not considered by the AEA.

7.3.2 Biomass export potentials per region34

The US Southeast

In recent years, the US Southeast has become the largest export region of wood pellets and, according to most studies, expected to remain one of the largest exporting regions .

[34] Based on DiaCore (Hoefnagels *et al.*, 2015)

According the Southern Environmental Law Center (SELC) (Sackett, 2015), 25 plants are currently in operation (5.3 Mt/y, 2.2 Mtoe/y), 25 plants are proposed (8.3 Mt/y, 3.5 Mtoe/y) and 2 plants are proposed but on hold (Figure 7-11). However, the average capacity utilization of pellet production facilities in the US has dropped significantly to under 60% in 2009 (Cocchi *et al.*, 2011; Walker, 2014).

To determine the sustainable export potential of solid biomass, intermediate results of the BioTrade2020plus project are used. Figure 7-14 summarizes the wood resource balance of the US Southeast[35] following the procedure of BioTrade2020plus. The technical potential of stemwood, primary forest residues and secondary forest residues (mainly sawdust) is based on harvesting inventory data and projections at subregional level. Domestic demand for material as well as energy purposes is subtracted to quantify total wood surplus.

The technical potential includes all wood harvested. The domestic use of wood biomass for material and domestic energy purposes is then subtracted. Suitability constraints are then applied to the surplus biomass potential in order to determine the amount of sustainable feedstock that could be exported. These constraints include the following:

- Land excluded for biomass supply if RED criteria are applied, based on Galik et al. (Galik & Abt, 2015) and biodiversity (based on rarity weighted index from Naturereserve);[36]
- All gum-cyprus and 50% of oak-pine forest and oak-hickory forest cannot be harvested for wood pellet production.

Based on these assumptions, the sustainable surplus of wood is estimated to be 7.8 Mtoe in 2015. In the Business as Usual scenario, the sustainable surplus is projected to decrease to 6.9 Mtoe in 2020 and 5.9 Mtoe in 2030 due to increased domestic demand and stable supply. Both domestic wood demand and supply are projected to increase in the High scenario. However, due to the stronger growth of wood supply in this scenario, the sustainable surplus of wood is projected to increase to 15.4 Mtoe in 2030.

Total pellet production potential shown in Figure 7-14 is based on the sustainable surplus, but takes into account wood required for drying and dry matter losses in the pelletization process based on JRC (Giuntoli *et al.*, 2015). The total export potential depends on actual pellet plant and infrastructure development as explained below.

[35] US Southeast region BioTrade2020plus: Alabama, Arkansas, Florida, Georgia, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee, Virginia.

[36] Exclusion of these lands hardly affects the results because most wood is produced from productive forests, not from reserves. The method and impact will be explained in more detail in the BioTrade2020plus case study report of the US Southeast.

Figure 7-13. Wood pellet production capacity in the US Southeast (Sackett, 2015) and capacity utilization (Walker, 2014)

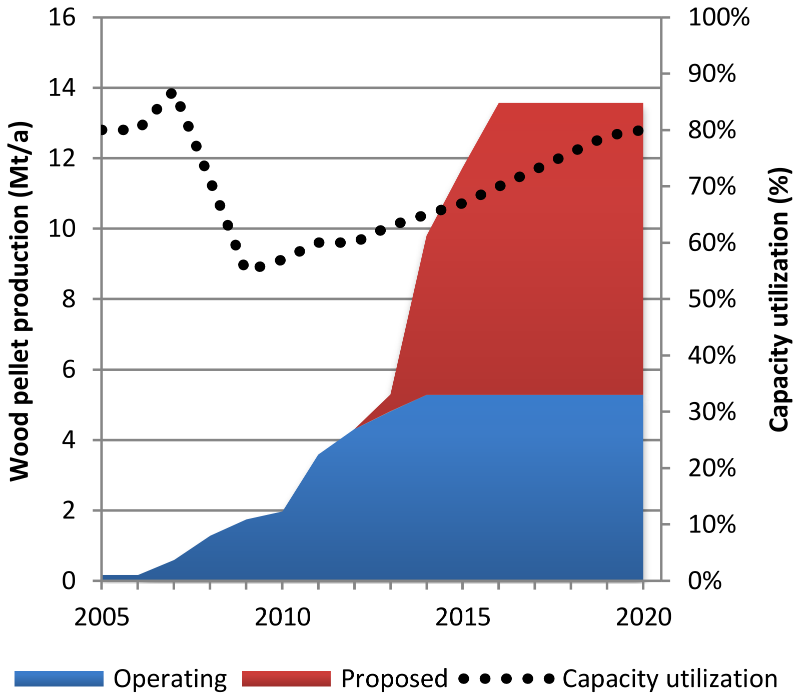
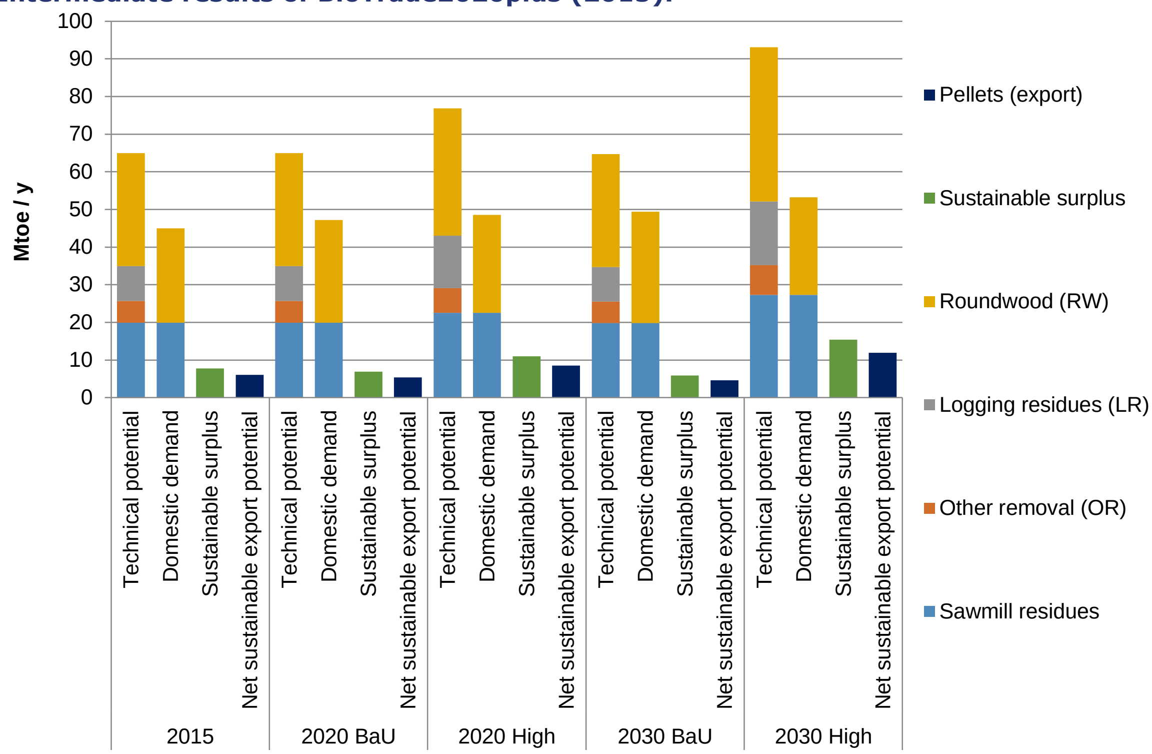


Figure 7-14. Wood balance and sustainable potential of wood pellets in the US Southeast. Intermediate results of BioTrade2020plus (2015).



The export potential of wood pellets is based on the planned and operational capacity of wood pellet plants and the following assumptions for planned or proposed capacity:

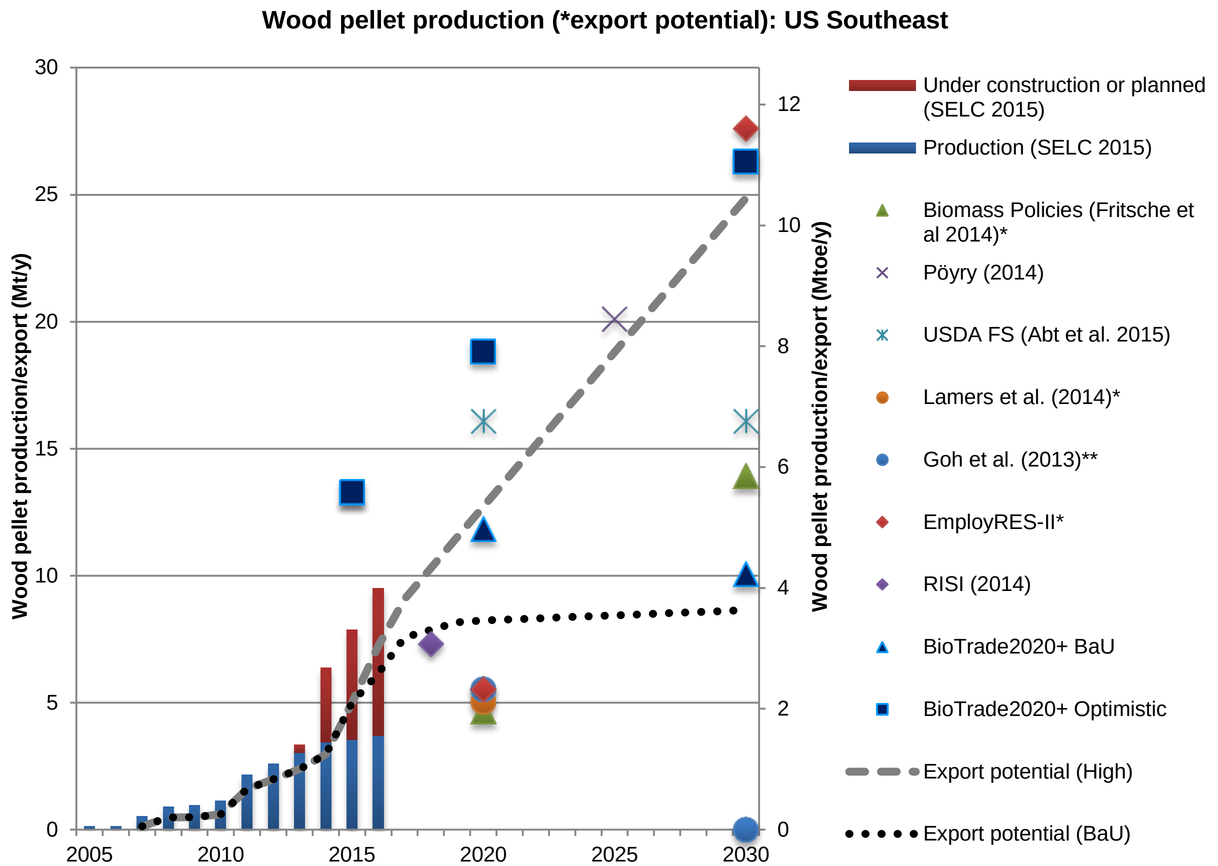
- A success rate of 75% for proposed plants in the Business as Usual scenario[37].
- A success rate of 100% for proposed plants in the High Trade scenario
- Proposed capacity is assumed to be delayed by one year, as a result of overcapacity (Lang, 2015).
- The Capacity utilization will increase again from 65% in 2015 to 80% in 2020 in both scenarios (Figure 7-13). According to RISI (Walker, 2014), capacity utilization of wood pellets for residential markets is expected to increase again to 80% by 2018. We assume a similar development for pellet plants that produce industrial pellets.
- The US Southeast mainly produces wood pellets for export markets with a relatively small share produced for domestic heat markets. The near term trend in production for domestic markets is based on RISI (Walker, 2014) and extrapolated to 2030 assuming a linear growth with 45 kt/a to 1.0 Mt in 2020 and 1.4 Mt in 2030.
- In 2030, the sustainable potential will be fully exploited to produce wood pellets in both the Business as Usual and High scenario. The export potential is slightly lower due to the domestic demand for wood pellets.

Figure 7-15 shows the resulting estimated export potential of wood pellets in the Business as Usual and High scenarios in comparison with other scenarios of wood pellet export found in literature for the US Southeast. It should be noted however that the US States included differ per study. The Business as Usual scenario is on the short term, to 2020, more optimistic compared to other studies. Many studies[38] have used similar assumptions and therefore determined almost similar wood pellet export potentials. However, these studies did underestimate recent developments in wood pellet production and the sharp increase in wood pellet export (already 3.9 Mt was exported to the EU in 2014, see Figure 7-3).

[37] Lamers et al. (2014) assumed a success rate of 50%, but has already proven to be too conservative.

[38] These include: (Goh *et al.*, 2013; Duscha *et al.*, 2014; Fritsche & Iriarte, 2014; Lamers *et al.*, 2014c).

Figure 7-15. Wood pellet supply and export scenarios in the US Southeast to 2030 compared to literature (Goh et al., 2013; Abt et al., 2014; Fritsche & Iriarte, 2014; Lamers et al., 2014c; Lechner & Carlsson, 2014; Walker, 2014; BioTrade2020plus, 2015).



The export potential as presented in Figure 7-15 for Abt et al. (2014)[39] is a demand driven potential based on expected wood pellet demand in the EU28. Potentially, Abt et al. have overestimated the demand for wood pellet from the US Southeast as they did not take into account other exporting regions, for example Western Canada. The High scenario shows to be consistent with Pöyry (20 Mt wood pellets in 2025) and estimated potential of the EmployRES-II study (27.6 Mt wood pellets in 2030) (Duscha *et al.*, 2014).

Brazil

Currently, Brazil is not exporting any solid biomass for energy. So far, however, developments in dedicated energy crops or forestry plantations for bioenergy purposes are lacking (Lamers *et al.*, 2014c), most likely because investments in e.g. ethanol production from sugarcane is deemed more profitable. Nevertheless, Brazil has a large potential for

[39] The wood pellet supply is not presented, but derived from the projected demand for bioenergy (20 Mt odt in 2020 and 2030), the amount of wood used for non-pellets bioenergy (5 Mt odt) and a net calorific value of 19.58 MJ/kg odt.

solid biomass export if substantial investments would be made and could become a large exporting region of solid biomass. This is also assumed by many energy and integrated assessment models.

The preliminary results from the Biotrade2020+ project so far only include the potential of agricultural and forestry residues. An assessment of the net sustainable export potential from energy crops will be included in the coming months. The technical potential for agricultural and forest residues from Brazil is large, considering the large production volumes. Even though only 7% of the country is used for agricultural, Brazil still has the world's 5th largest area under agricultural cultivation (CIA, 2012). In this analysis, the residues form crops with the largest technical potentials are included: Sugarcane, corn, soybean, cassava, oranges, rice, coffee, eucalyptus and pine. Especially sugarcane is interesting since the production of sugarcane outnumbers the other feedstocks by at least a factor 10 (IBGE, 2012).

The size of Brazil plays a large role in the potential. However, this also forms one of the main barriers for export. A large part of the potential was deemed not accessible In advance, because of the large distances from inland states to export harbours and the fact that the rail network in Brazil is underdeveloped. In the Biortade2020+ analysis, only the states located near harbours are included, namely: Bahia, Espirito Santo, Minas Gerais, São Paolo, Paraná, Santa Catarina and Rio Grande do Sol. Together, these states account for 70% of the agricultural production in Brazil (IBGE, 2012). The total technical potential based on agricultural was estimated to be at 92.2 Mtoe for 2015.

As only residues are assessed, only biomass form existing agricultural land is assessed, and any high carbon stock lands and high biodiversity areas such as the Amazonas or Pantanal regions are completely excluded from the analysis. The main sustainability criteria considered are soil erosion and prevention of soil organic carbon loss. Under these criteria, the sustainable feedstock surplus amounts to about 59.7 Mtoe.

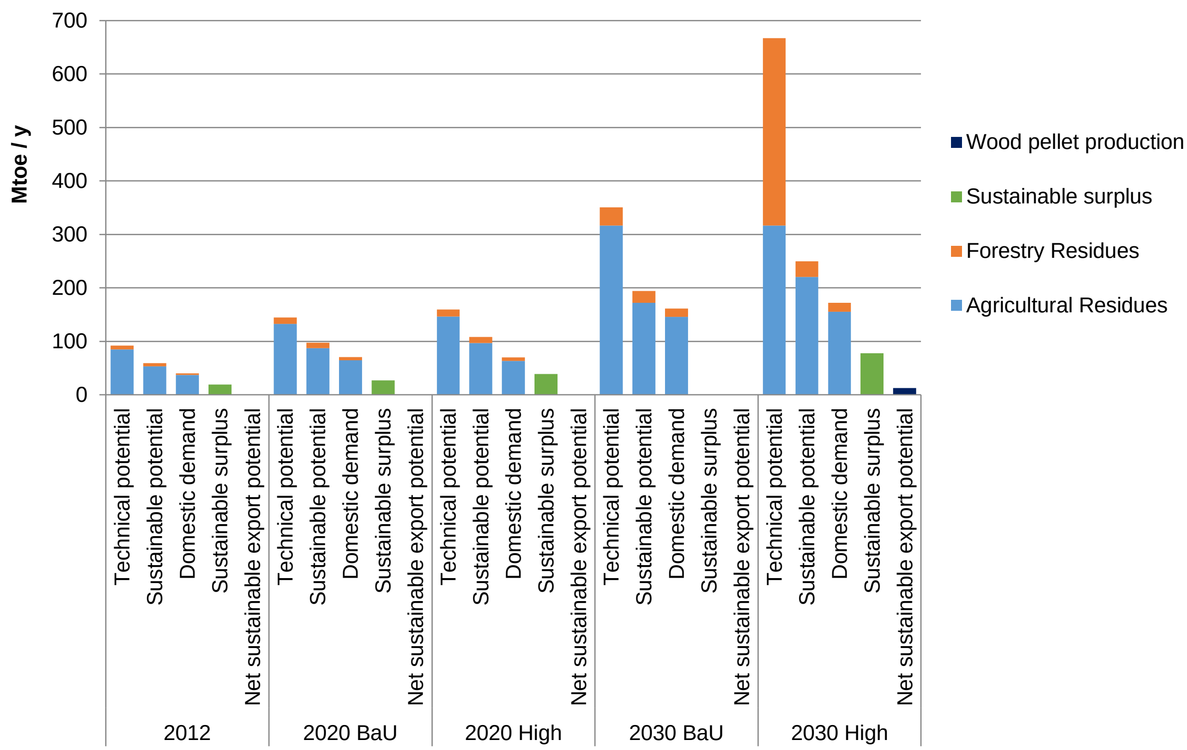
The local demand for biomass for energy and material uses is considerable; residues are mainly burned to provide industrial heat (e.g. bagasse) or used for bedding in chicken farms. After exclusion of the local demand, the remaining potential is 19.6 Mtoe in 2015.

With regard to woody biomass, there are 12 wood pellet production facilities in Brazil with the majority located in the South of Brazil (São Paulo and Paraná), close to the source of raw biomass used for the pellets, which is for most factories pine residues (ABIPEL, 2015b). Production scales vary between 3 kt/a to 37.5 kt/a, and a total capacity of 60 kt/a (Coelho & Escobar, 2013). Wood pellet production is mostly oriented towards domestic, residential markets.. Planned new pellet factories are scheduled to be built in São Paulo and several large projects in Santa Catarina and Rio Grande do Sul. Four plants with a production capacity of 400 kt each, which would become the largest plants in Brazil, are planned to be built in Minas Gerais, Espírito Santo, and Rio Janeiro (BBER, 2015).

The business as usual scenario assumes that agricultural- and forestry production and consumption evolves at the current pace, yield increases follow historic trends (based on time trends between 20000-2012, and differentiated by state) and current and proposed policies on, for example, agriculture and forestry, energy, infrastructure, and climate are considered. For the high trade scenario, the most important assumption is that agricultural productivity increases are about 20% higher than in the BaU scenario (e.g. 4.8% per year instead of 4%). These assumptions were based on optimistic ranges in existing Brazilian agricultural outlooks.

One crucial factor in both scenarios is the pelletisation capacity needed to pelletize agricultural residues (a necessity for export). This study assumes 910 kt/y (372 ktoe) capacity to be available for export in 2020 based on Lamers et al. (2014c) in the High Trade scenario. Beyond 2020, a compound annual growth rate of 42% was assumed, based on pellet mill capacity growth in the US Southeast between 2013 and 2013. In 2030, the total pellet production capacity increases to 30.5 Mt/y (12.5 Mtoe). It is important to point out that this is well below the sustainable surplus of biomass of 77.5 Mtoe in the High Trade scenario in 2030 (Figure 7-16), and thus is the most important limiting factor determining the export potential. In the Business as Usual scenario, pellet mill capacity is assumed to remain 910 kt/y beyond 2020 as a result of lacking investments.

Figure 7-16. Biomass resource balance and sustainable export potential of wood pellets and agripellets in Brazil. Based on intermediate results of BioTrade2020plus.



Ukraine

Agriculture has traditionally been a very important sector of the Ukrainian economy, the area which was nicknamed the Empire's breadbasket during Tsarist times produced 5.2% of the world's barley and 2.3% of the global output of wheat in 2012 (FAO). In large parts of the Ukraine, soils are fertile and the climate suitable for agricultural production. Furthermore, the low population density and lack of geographical features such as mountains result in a large availability of agricultural land.

The agricultural sector in Ukraine, like in other ex-Soviet republics, is characterized by a combination of large-scale commercial farms and a large number of family farms that were founded after the Soviet Union dissolution (FAO). The policy support for agriculture, is still very unstable and is based on short term needs instead of long-term priority setting. For instance, between 1997 and 2010, the annual monetary value of transfers from taxpayers to the agricultural sector arising from policy measures varied between 0.3% and 11.3% as a share in total gross farm receipts (FAO).

To determine the sustainable export potential of solid biomass the intermediate result of the BioTrade2020plus project are used.

The technical potential in Ukraine consists of primary agricultural residues, forest residues and the potential for dedicated energy crops (in the Biotrade 2020+ calculations, switchgrass was used to model potential biomass yields).

The technical potential is estimated to be 21.6 Mtoe in 2015, mainly consisting of agricultural residues.

The sustainable potential is calculated by considering the loose set of criteria as laid down in the RED, according to the following assumptions:

- Highly biodiverse and carbon-rich lands are excluded from the land available for energy crops. Calculations within the Biomass Futures project show that approximately 15% of reference land potential in Europe is High Nature Value (HNV) farmland (see Section 5.3). This average is applied to the potential for energy crops in Ukraine, this will be adjusted based on spatially explicit data in the BioTrade2020plus project.
- Exclusion of highly biodiverse and carbon-rich lands does not apply to existing agricultural areas.
- Additional criteria regarding soil protection are applied to the potential of agricultural residues. Soil Organic Carbon content is considered the greatest limitation in Ukraine. This is taken into account by calculations using the RothC Model, using input from the MITERRA-EUROPE model (Coleman *et al.*, 1997; Velthof *et al.*, 2007; Jenkinson & Coleman, 2008; Farina *et al.*, 2013). In the High Trade scenario (see below) it is assumed that moderate fertilizer use will increase the extraction potential of agricultural residues.
- For forest residues, soil type is used as indicator for the maximum extraction rate in analogy with the method as used by the European Environment Agency (European Environment Agency, 2009). Other criteria are not taken into account.

- Based on these assumptions, the sustainable potential in Ukraine that remains is 16.2 Mtoe in 2015. This remains unchanged in the BAU scenario and increases to 131.5 Mtoe in the High Trade scenario.

In the Biotrade2020+ project, local demand is given priority over export. This includes use of pellets as fodder, feed as well as local use of biomass pellets. This potential was estimated by local experts, different experts gave varying estimates, in a range of 69% - 100% of the technical potential being used locally. The following assumptions are made:

- For the current situation and in the Business As Usual scenario (see below), the average of the above estimations is domestically used, excluding 84.5% of the technical potential.
- In the high Trade scenario, the lower end of the range is considered not available, excluding 69% of the technical potential.
- Forest residues are not collected and therefore also not used locally. Therefore, all the potential that is collected would be available for pellet production. This is however not included in the surplus potential so far.
- The domestic demand is calculated per region, trade across regions of residues for domestic demand is not considered.

For the scenarios until 2030, the following assumptions are made in the calculation of the technical potential, these are in line with assumptions of Van der Hilst et al. (van der Hilst *et al.*, 2014).

- In the Business as Usual scenario, little improvements in yields and cropping intensity are expected. The yields in Ukraine have been fluctuating greatly in the past years (State Statistics Service of Ukraine, 2014). Furthermore the political and economic difficulties in the country reduce the likeliness of stable investments in the agricultural sector.
- In the High Trade scenario on the other hand, the assumption is made that investments will return, either from national or international investors, resulting in steady yield and cropping intensity improvements.
- Agricultural production will concentrate on most suitable land, resulting in increased potential for energy crops.
- Available land will be used for production of switchgrass from the moment the land becomes available

Based on these assumptions, in the High Trade scenario large areas of land will become available for production of energy crops, resulting in a potential of 155.6 Mtoe in 2030 in the High Trade scenario. The potential in the Business as Usual scenario remains unchanged.

The sustainable feedstock surplus is calculated by taking the pellet production capacity and the domestic demand for residues into account.

In 2013, 950 kt pellets were produced in the Ukraine, a mixture of straw and wood pellets (Ukrainian Pellet Union, 2013). However, most of this is produced in small scale pellet producing facilities, targeted at local markets (NL Agency - Ministry of Economic Affairs, 2012). This is the main limitation for the export of pellets in 2015, limiting the potential to 0.5 Mtoe in 2015. The following assumptions are used in the Biotrade2020plus methodology:

- In the Business as Usual scenario, pellet production is considered to increase according to existing growth trends.
- In the High Trade scenario the development of the US pellet market is used as an example of a possible rate of capacity building under favorable conditions. The pellet market in Ukraine is assumed to grow according the pellet market in the US.
- Forest residues are not yet collected in Ukraine. Collection of these residues could increase the sustainable feedstock surplus potential. However the availability of pellet mill capacity is such a severe limitation that the availability of more feedstock does not affect the market potential of biomass pellets.

This results in a potential of 1.5 Mtoe in the Business as Usual scenario in 2030 and a potential of 3.2 Mtoe in the High Trade scenario in 2030.

The availability of pellet plants is the largest limiting factor for the export potential; therefore, the excluded domestic demand of residues does hardly limit the potential any further.

One of the uncertainties however is the development of the local demand for biomass pellets in Ukraine. Following the political unrest in Ukraine the country desires to become independent of gas import from Russia. This could result in strong growth of the local demand for pellets, thereby reducing the potential for export.

Canada

Canada is the third largest producer of wood pellets and second largest supplier of wood pellets to the EU. Most of the supply is currently exported from Western Canada (British Columbia), but also Eastern Canada could become an exporting region of wood pellets. Given the shorter distance between Eastern Canada and the EU, Eastern Canada could have a competitive advantage over Western Canada due to reduced shipping costs. There are currently 19 wood pellet plants in operation in Eastern Canada with a total capacity of 1 Mt/a producing 270 kt/a wood pellets of which 120 kt is exported to the EU28 (Bradley *et al.*, 2014). The recent growth in timber industries might improve the availability of sawdust for wood pellet production, one of the main issues the Eastern Canadian pellet industry is facing today. Furthermore, supply chains are improving. According to Fritsche et al. (2014), the sustainable potential of wood pellet export from Eastern Canada could increase to 38 Mt wpe in 2020 and 28 Mt wpe in 2030. In this study, Eastern Canada is not included which might imply an underestimation of the Canadian wood pellet export potential. Supply growth from Western Canada in the export scenarios is based on Pöyry. According to Pöyry (Lechner & Carlsson, 2014), wood pellet production will increase moderately from 1.9 Mt/a today to 3.8 Mt in 2025. To 2025, Pöyry does not expect major exports from Eastern Canada.

Sub-Saharan Africa

To determine the export potential of Sub-Saharan Africa, results of the Biomass Policies project were used. Fritsche et al. (2014) determined the sustainable export potential for Mozambique as being one of the future potential exporting regions in Sub-Saharan Africa. The lack of actual investments in biomass supply as well as infrastructure to mobilize and export biomass, also for this region we assumed a delay of 5 years compared to the Biomass Policies study (Fritsche & Iriarte, 2014). In total the export potential of solid biomass was estimated to be 3.8 Mt in 2025/a increasing to 5.7 Mt/a in 2030.

Northwest Russia

Russia has vast underutilized forest resources and accounts for over 20% of global forest cover. However, the productivity of the Russian forest sector is 5 to 6 times lower compared to other developed countries as a result of lacking investments in infrastructure and equipment. Modernisation of the forest industry could mobilize substantial forest biomass for bioenergy (up to 75 M m^3, 75.8 Mtoe) in 2030 under preconditions that substantial investments are made (Nakada *et al.*, 2014). To increase the export potential, large investments are needed to upgrade facilities. Furthermore, the 6-month winter makes it difficult to mobilize resources and non-economic barriers need to be mitigated including bureaucracy, business culture and language barriers (Proskurina *et al.*, 2015). According to Pöyry, the wood pellet industry will not grow substantially in Northwest Russia with total pellet supply increasing moderately from 1.4 Mt in 2014 to 1.9 Mt in 2025. We used similar estimates in the export scenarios and assumed no further growth beyond 2025.

Southeast Asia and Oceania

The supply of solid biomass from agriculture residues, including palm kernel shells from Southeast Asia, and wood pellets from Australia and New Zealand in 2020 are based on Lamers et al. (2014c). We used similar estimates in the export scenarios and assumed that these potentials will remain constant between 2020 and 2030.

7.3.3 Global supply scenarios of solid biomass and comparison to other studies

Starting point of the supply scenarios of solid biomass are the intermediate results of the IEE project BioTrade2020+, which defines solid biomass trade potentials in six regions in the world. Intermediate results for Brazil, the US Southeast and Ukraine were considered. The Reference scenario and Resource scenario in this study are aligned to the 'Business as Usual'[40] and 'High Trade'[41] scenarios of BioTrade2020+. The Restricted scenario reflects

[40] The business-as-usual scenario reflects biomass production and consumption at national levels at current and predicted paces. They are built based on the reports and review of national statistics, FAO reports, scenarios presented in the World Energy Outlook 2012 and 2013 that set the normal development in the studied sectors in the studied countries The BAU scenarios are built on current and

higher competition for solid biomass and lack of investments in infrastructure to mobilize alternative sources. Some key assumptions are briefly explained below.

- **Restricted:** In Ukraine, no investments are made to increase the export potential of solid biomass. Due to growth in domestic demand, export of solid biomass will be phased out beyond 2020. In the US Southeast, the supply potential of forest products (pulpgrade roundwood) is projected to reduce similar to the Business as Usual scenario of BioTrade2020+. Domestic demand reduces the export potential of wood pellets from forest products. A similar trend was assumed for Eastern Canada. Similar volumes of forest residues that are already mobilized today are still available to 2030.
- **Reference (based on BaU of BioTrade 2020+):** similar to the Restricted scenario, the potential of pellets from forest products in the US Southeast is reduced. However, in contrast with the Restricted scenario, more forest residues are mobilized and processed into wood pellets for export markets. Furthermore, Sub-Saharan Africa is projected to become a supplier of solid biomass beyond 2020.
- **Resource (based on High Trade BioTrade2020+):** the US Southeast remains export oriented towards the EU, the total production of wood pellets increases to 26 Mt in 2030 compared to 3.9 Mt in 2014. In Brazil, investments in infrastructure and efficient mobilization of sustainable wood residues and agriculture residues make Brazil the largest supplier of solid biomass to the EU in 2030. In Ukraine, strong growth of export occurs after 2020 with a similar growth rate to the US Southeast between 2009 and 2013 (24%). Perennial crops are grown beyond 2025 to meet the growing demand for lignocellulosic biomass. In 2030, almost half of pellet production is produced from perennial crops.

Potential towards 2030

In 2014, total wood pellet imports to the EU were 7.5 Mt (3.1 Mtoe) of which the US Southeast supplied more than half. In the supply scenarios to 2030, the total potential increases t0 10 Mt (4 Mtoe), 29 Mt (12 Mtoe), and 86 Mt (34 Mtoe) in the Restricted, Reference and Resource scenario in 2030 (Figure 7-17). Compared to other studies, the export potential of solid biomass in the BioSustain scenarios of extra-EU supply of solid biomass appears to show a moderate range for 2020. For example, in the Biomass Policies study (Fritsche & Iriarte, 2014), the total export potential is estimated to be 29 Mtoe by

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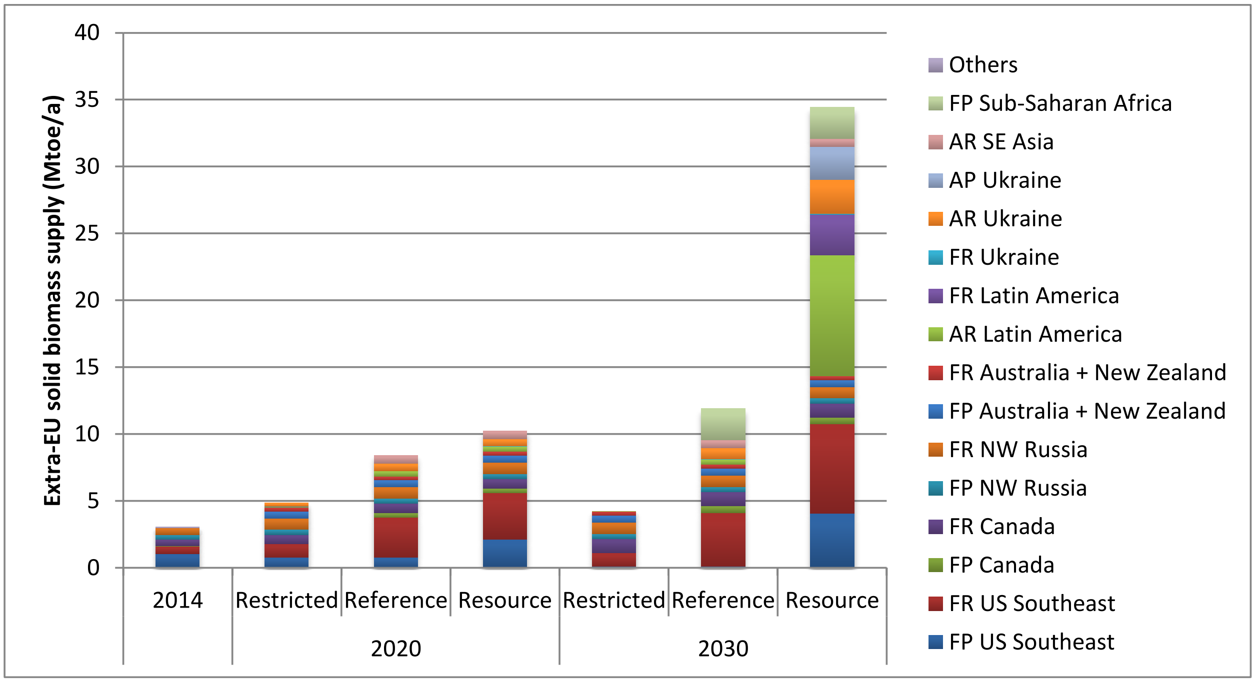
expected policies in energy, climate and environmental etc. which are already come into effect in the EU, in the sourcing regions and possible in other world regions. (BioTrade2020plus, 2014)

[41] The High scenario explores options under which larger volumes of sustainably produced biomass might become available for export. These may include an assessment of possibilities to increase the yields of both dedicated biomass production for energy, agricultural and forestry yields in general, effective land management and subsequent additional land availability for biomass production; it also envisages more vigorous policy developments in energy, climate and environment sectors. The High Trade scenarios are built amongst other inputs of national statistics, FAO reports, scenarios presented in the World Energy Outlook 2012 and 2013 that sets out an energy pathway consistent with the goal of limiting the global increase in temperature to 2°C by limiting concentration of greenhouse gases in the atmosphere to around 450 parts per million of CO2. (BioTrade2020plus, 2014)

2020 increasing to 40 Mtoe by 2030 (95 Mt wood pellet equivalent). The large range between the scenarios reflects the high uncertainty in cultivation of dedicated energy crops and investments in infrastructure to mobilize forest and agricultural residues.

Figure 7-17. Solid biomass supply scenarios to 2030



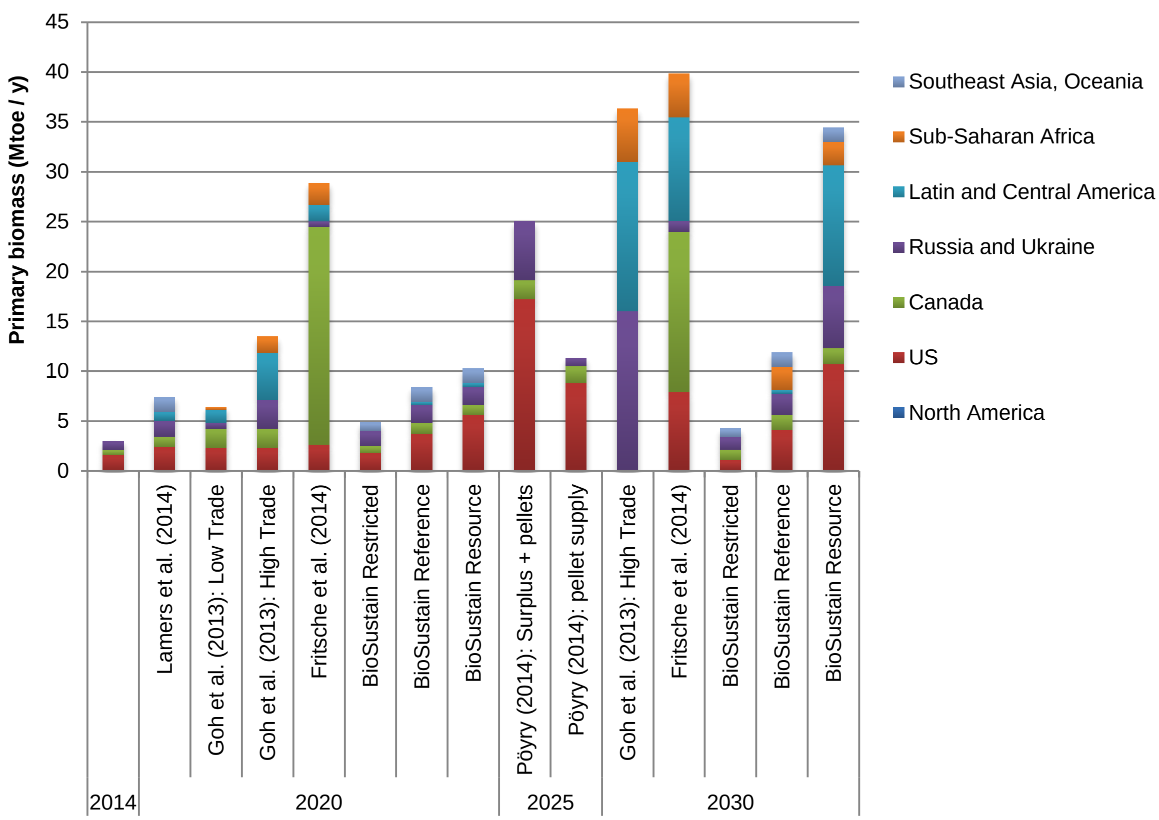
FP: forest products, FR: forest residues, AP: energy crops (SRC), AR: agriculture residues.

Compared to the export potential of solid biomass found in literature (see for an overview figure 7-17), the BioSustain BaU and High Trade scenarios of extra-EU supply of solid biomass appear to show a moderate range **for 2020**. There is a wide range for 2020 as a result of the large potential estimated for Canada by Fritsche et al. (2014) (21.8 Mtoe). Otherwise, the estimated export potentials are in the range of between 6.4 and 13.4 Mtoe in all studies included in this overview and the BioSustain scenarios (8.1 to 10.6 Mtoe) that include more up-to-date information regarding export capacity developments in the US Southeast and Brazil.

In this study, the actual production capacity and expected increase in production capacity were used by Lamers et al. (2014c) to estimate the total export potential in 2020. Key assumptions were that only 50 % of additional announced capacity will be actualized by 2o20 and that the utilization factor of new pellet plants will be on average 50%. According to AEBIOM (2014), actual wood pellet production in the US already increased to 2.4 Mtoe (5.8 Mt) in 2013 increasing the average utilization rate to 67% in 2013. RISI expects that the utilization rate of US pellet plants will further increase to 80 % in 2018 (Walker, 2014). It is therefore possible that the export potential for the US in 2020 is underestimated compared to recent market developments. Lamers et al. (2014) also included agripellets from the US and Ukraine (agripellets) and palm kernel shells from Indonesia and Malaysia, contributing 1.2 Mtoe to the total export potential in 2020 (7.4 Mtoe).

By 2030, the BioSustain scenarios show large increases in export from Brazil, Ukriane and the US Southeast increasing the total export potential to 36.6 Mtoe in the High Trade scenario compared to 11.5 Mtoe in the Business as Usual scenario in 2030. This means that the sustainable potential for export in the US Southeast will be exploited (11.1 Mtoe). The export potential for 2025, by Pöyry shows a large growth in potential in the US Southeast (17 Mtoe surplus wood), of which 9 Mtoe is estimated to be exported mainly to the EU in their demand driven scenarios. Beyond 2025, energy crops start to become increasingly relevant. Goh et al. (2013)[42] assumed that domestic demand in the US will reduce the export potential of wood pellets from forest resources and increased supply of dedicated energy crops from Brazil, Ukraine and Sub-Saharan Africa. Similar scenario assumptions were used by Fritsche et al. (2014) increasing the total export potential to between 36.3 Mtoe and 39.8 Mtoe in 2030. Also the AEA (2011) and IRENA (2014) emphasize the need for cultivation of dedicated energy crops including woody biomass.

Figure 7-18. Comparison of the estimated export potentials of solid biomass (wood pellets, agri-pellets, palm kernel shells) in BioSustain with other studies for 2020, 2025, 2030



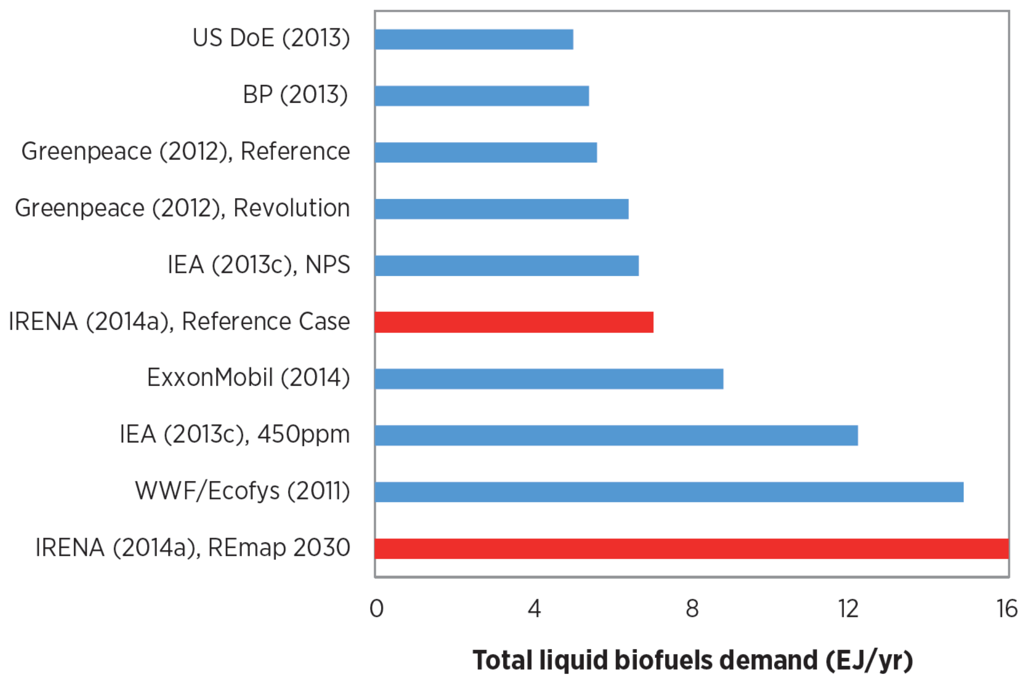
[42] Scenarios are only published to 2020, but have bene updated to 2030.

7.4 Future supply of liquid biofuels

7.4.1 Global supply and demand to 2030

Compared to current production levels of liquid biofuels of 43 Mtoe (3.1 EJ), the projected increase in demand for liquid biofuels differs widely. Recent studies and scenarios compared in Figure 7-19 show increases in global demand for liquid transport fuels ranging from a factor of between 1.6 fold to over 5 fold increase in more ambitious scenarios.

Figure 7-19. Comparison of global liquid biofuel demand projections (final energy), 2030 (Nakada et al., 2014)



7.4.2 Supply scenarios of liquid biofuels to the EU[43]

The supply potential of liquid biofuels for import to the EU is based on a quick assessment based on insights from selected literature sources. in the EmployRES-II project (Duscha *et al.*, 2014). Similar to solid biofuels, the potential for liquid biofuels depends on many (intertwined) factors including land required for food and feed and other non-energy uses, population, economic development and developments in agriculture and industry. Furthermore, scenarios of solid biomass and liquid biofuels overlap in case dedicated herbaceous or woody crops are cultivated or if liquid biofuels from lignocellulosic biomass are produced. The scenarios for solid biomass to 2030 however hardly include dedicated energy crops cultivated on agricultural land because most biomass is expected to be

[43] This section summarizes the scenarios of liquid biofuel supply as developed for the IEE EmployRES-II study. A detailed description is provided in the Duscha et al. (2014).

supplied from forest and agriculture residues. For the timeframe considered, possible double counting of land is therefore not to be significant.

Liquid biofuels

Global trade of biodiesel is almost 100% driven by EU blending targets for biofuels, with important roles for palm oil and soybean oil. One of the recent drivers for increased demand of imported palm oil is the production of drop-in diesel or Hydrotreated Vegetable Oils (HVO) as it uses palm oil next to waste oils as a feedstock (Janssen *et al.*, 2013). The production capacity of HVO in Europe is 1.8 billion litres (1.5 Mtoe). In 2012, total imports added up to 5.1 Mtoe (35% of total biofuel demand in the EU) with soy oil from Argentina and palm oil from Indonesia making up more than half of total import to the EU (Figure 7-20) (Hamelinck et al. 2014)[44].

Potential towards 2030

The starting point of the future supply scenario of liquid biofuels from extra-EU countries is the recent E4Tech study 'A harmonised auto-fuel biofuel roadmap for the EU to 2030' (Bauen *et al.*, 2013), containing four scenarios A, B, C and D that address key uncertainties in the future supply of liquid biofuels[45]. E4Tech's scenarios A, B and C are considered representative for the Restricted, Reference and Resource scenarios respectively:

- **Restricted (B):** low export capacity to the EU; medium demand from competing markets other than food/feed. Furthermore, an average yield improvement and high water scarcity are assumed.
- **Reference (C):** medium export capacity to the EU; medium demand from competing markets other than food/feed. Furthermore, an average yield improvement and medium water scarcity are assumed.
- **Resource (A):** high export capacity to the EU, low demand from competing markets other than food/feed. This scenario is however relatively conservative with respect to technology progress and yield improvements.

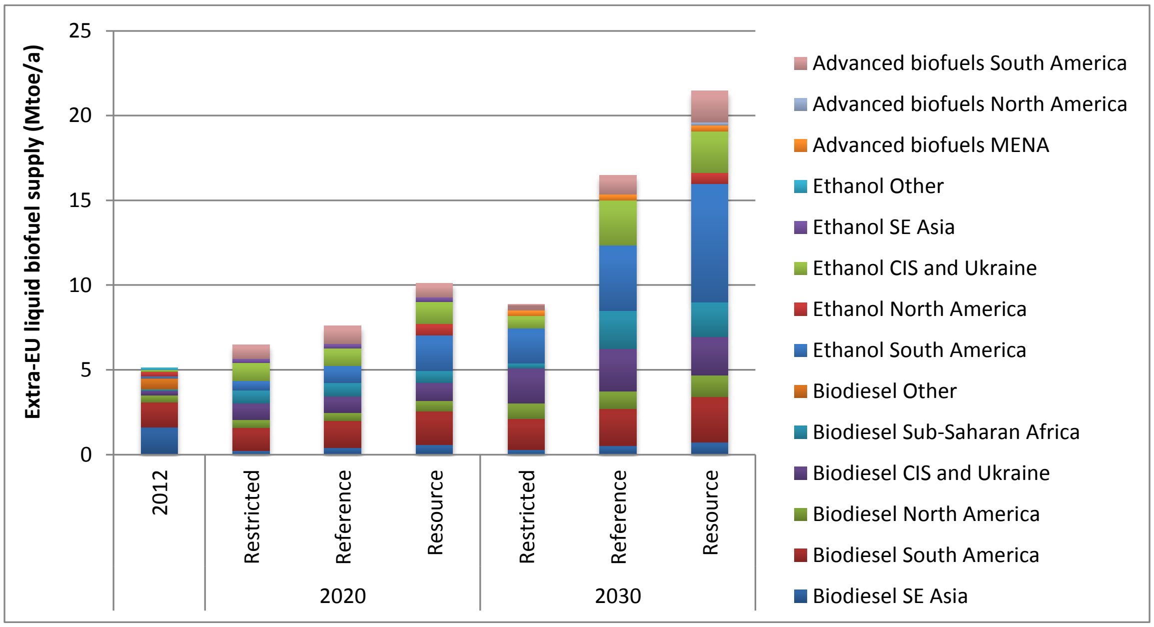
Scenario D assumes high conservation efforts, but also high yield and efficiencies. In terms of biofuel supply, this scenario is between B and C. Effects of saturation of the EU biofuel

[44] However, since November 2013, effective anti-dumping measures were taken against extra-EU imports of Indonesian and Argentinean biodiesel (between 120 and 250 €/t) reducing imports substantially. Although this has resulted in some imports from other regions, taking the current saturation of the EU biofuel market and decisions on the iLUC directive into account, it is not expected that EU import of liquid biofuels will recover to the levels of before 2013 (EurObserv'er, 2014; Flach *et al.*, 2015).

[45] The E4Tech study was selected for its detailed approach of 200 separate fuel chains (region specific feedstock, conversion combinations) and it addresses key uncertainties in its scenarios as explained below. In all four E4Tech scenarios, the amount of biomass that can be supplied to the EU is constrained by a GHG threshold value of 50% in 2020 and 60% in 2030. Furthermore, an environmental constraint is applied by restricting land used for energy crop cultivation to maximum 10% of agricultural land. Crop yields are assumed to be ~10% lower in regions that are likely to be affected by physical water scarcity.

market and other constraints, including the share of food-based biofuels, are expected to reduce the demand of liquid biofuel imports to the EU. These effects are not shown in the supply scenarios, but are assessed with the Green-X model.

Figure 7-20: Liquid biofuel feedstock supply in 2012 and supply scenarios to 2030



MENA = Middle East and North Africa; CIS = Commonwealth of Independent States (ex-Soviet Union states)

7.4.3 Sustainability requirements

First generation ethanol crops (mainly sugar cane) and biodiesel (mainly soy oil) make up the largest supply and trade of liquid biofuels (Lamers *et al.*, 2014b). Based on development trends in 2nd generation biofuel technologies, the availability of advanced biofuels is expected to be limited up to 2030 (Bauen *et al.*, 2013). In total, advanced biofuels (ethanol from lignocellulosic biomass and microalgae) make up 8% in 2020 and 10% in 2030 of the export supply potential. The production of advanced biofuels from imported biomass could also increase if production takes place at demand locations in the EU.

Sustainability criteria are taken into account in determining the supply modelling of liquid biofuels by E4Tech. These include (Bauen *et al.*, 2013):

- A GHG saving threshold value of 50% by 2020 and 60% by 2030.
- A conservation policy (land used for energy crop cultivation is restricted to maximum 10% of agricultural land).
- Crop yields are ~10% lower in regions that are likely to be affected by physical water scarcity.

Measures to reduce ILUC will be modelled based on policy scenario assumptions that will restrict the supply of food-based biofuel crops. These are part of the policy scenarios.

8 Scenarios for novel materials (biochemical and bio-polymers) to 2030

8.1 Approach

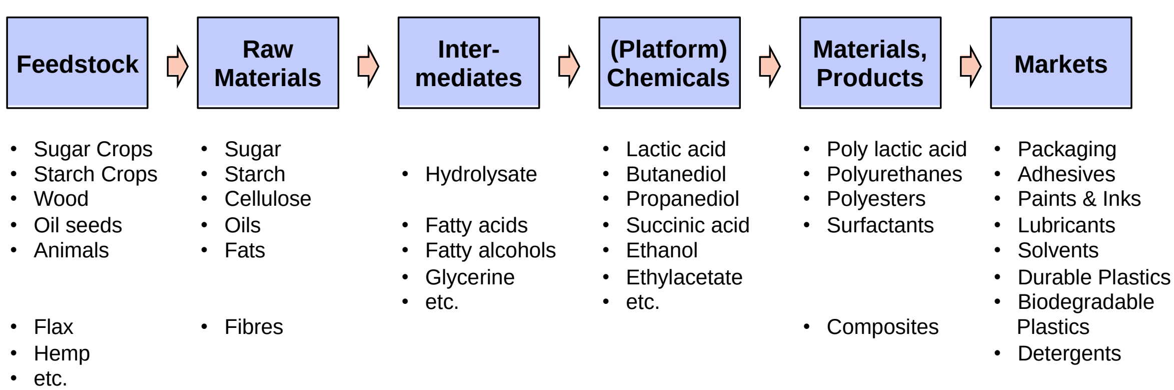
In this chapter we will indicate the potential role of biobased chemicals by 2030 in terms of market demand and biomass resource requirements. The analysis will be based on a review of recent studies in terms of long term market projections. Some examples are JRC (2005), BREW (2006), PRO-BIP 2009, BIOCHEM (2010), Nova-Institut (2013, 2015), BIO-TIC (2015),S2Biom (2015, on-going work) and JRC (Scarlat *et al.*, 2015). The focus will be on emerging materials, in particular biopolymers which have largest growth projections. The market demand will be translated in potential biomass resource requirements.

A large share of current products of the chemical industry can in principle be made from bio-based feedstock, such as starch, sugars, vegetable oils, animal fats or lignocellulosic material. Often, the appropriate biomass feedstock to use depends on the function of the desired product. From a technical point of view and based on the applications, the potential for substitution of fossil-based materials with their bio-based counterparts is significant. In some cases, the same chemical can be made either via a bio-based route, or via a petrochemical based route. In other cases, new chemicals can be made via a bio-based route, providing alternative carbon sources and potentially new applications. (IEA Bioenergy Task 42, 2012).

From an economic point of view, the bio-based route is currently only for a limited share of the chemicals produced the preferred choice.

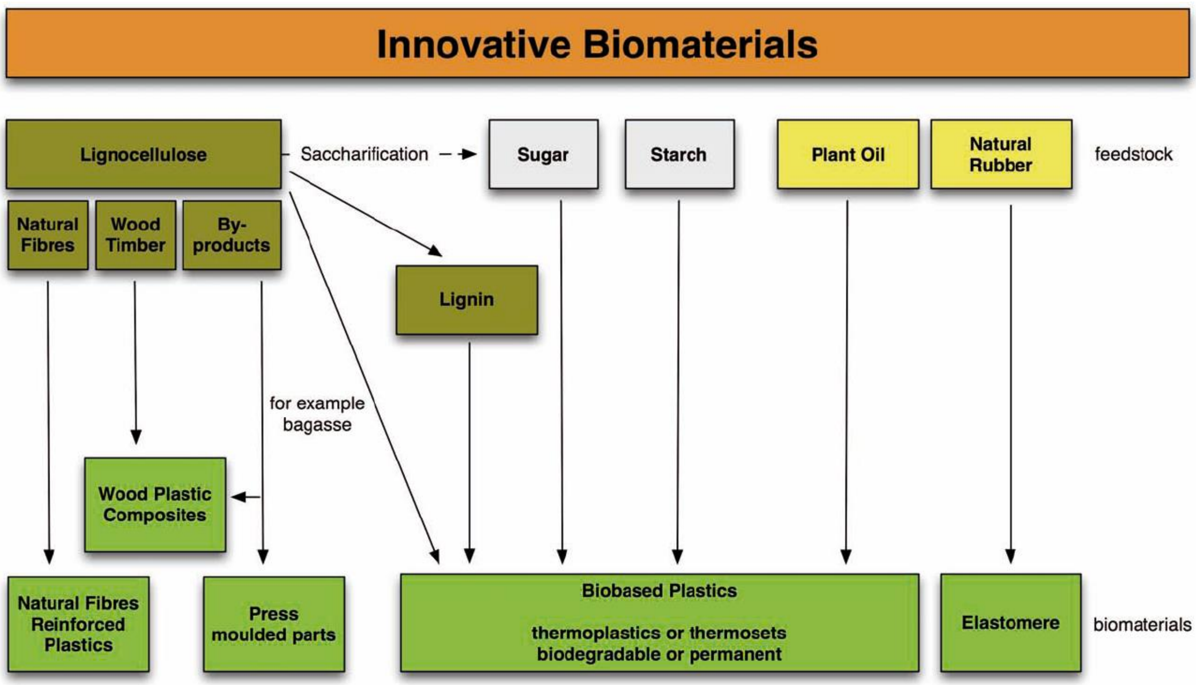
The following figure shows a schematic overview of the pathways from feedstock to markets.

Figure 8-1. biobased biochemical pathways (Busch & Wittmeyer, 2015)



We will focus our analysis on innovative material production, i.e. bioplastics/polymers and biocomposites (see figure). Biobased inputs for solvents, lubricants and surfactants are also significant and will shortly be highlighted, although growth perspectives are expected to be smaller than for biopolymers (BIOCHEM 2010).

Figure 8-2. Innovative pathways for biomaterials production (Jering et al., 2010)



8.2 Current situation

8.2.1 Biomass use for industrial applications

On global level, Piotrowski et al. (2015) estimated the volume of biomass used for materials and chemicals in 2011 at 1260 million tonnes (dry mass). The most important application areas were:

- construction and furniture with 522 million tonnes, mainly lignocellulose;
- 444 million tonnes for animal bedding, mainly by-products from agriculture and forestry (lignocellulose);
- pulp and paper with 201 million tonnes, mainly cellulose, hemicellulose and starch;
- chemical-technical industry (including polymers) with 59 million tonnes, mainly plant oils, starch and sugar and rubber;
- textile fibres with 35 million tonnes, mainly cotton and man-made cellulose fibres.

Nova-Institut (2015a) estimates the use of biomass for industrial material use in the EU27 in 2011 at **42 million tonnes of agricultural biomass** and **123 million tonnes of**

woody biomass. The last figure includes traditional uses of wood for timber products and paper.

According to the FAO Agricultural Outlook (2014), in the EU28 in 2012 the following amounts of agricultural feedstocks were used for industrial applications (non-food or feed, non-biofuel):

- Wheat: 13.6 million tonnes
- Coarse grains: 22.5 million tonnes
- Vegetable oils: 1.7 million tonnes
- Molasses: 3.9 million tonnes

Apart from wood or paper processing, the main uses of biomass for industrial applications at the moment are (Nova-Institut, 2015a):

- Vegetable oil and animal fats (though oleochemistry) for surfactants, lubricants, coatings/colours, additives for plastics;
- Starch for paper and textile;
- Sugar/starch for ethanol as solvent, or as fuel oxygenate (*although in this application it is counted as biofuel*);
- Natural rubbers for elastomers (tyres);
- Chemical pulp (from pulp and paper industry) for cellulosic fibres (for textiles);

The European Chemical Industry Council (CEFIC, 2014) estimated the use of renewable raw materials in the chemical industry in 2011 at 8.5 million tonnes (see Table). This is expressed in volume input to the chemical industry, in the form of starch, sugar, oil/fats, chemical pulp, ethanol, glycerol and rubber, so not expressed as agricultural or woody raw material. The following table shows an overview of biobased feedstocks compared to other organic raw materials in the chemical industry, and their typical applications.

Table 8-1. Organic raw material use in the EU chemical industry in 2011 (CEFIC, 2014)

EU 28 – Chemical Industry Input organic raw materials	ktonnes/yr (net)	Typical applications
Mineral Oil derivatives (refinery products)	61,210	
Natural Gas	19,200	
Coal	1,340	
Renewable raw materials total	8,560	
Vegetable Oils	1,570	surfactants, lubricants, coatings/colours, additives for plastics
Animal Fats	500	
Chemical Pulp*	890	viscose, cellulose derivatives
Starch and Sugar**	1,560	paper & textile; pharma and chemicals
Bioethanol (industrial use)	590	solvent

Bioethanol (ETBE)	*1,000*	*Fuel oxygenate*
Natural Rubber	1,240	Elastomers
Glycerol	470	Soaps and detergents, resins
Others***	740	Vegetable waxes, natural resins, tanning agents, proteins, medicinal plants
Total organic	**90,310**	

** 560 kT for viscose production, 330 kT for cellulose derivatives*
*** excluding fermentation of yeast and fuel ethanol production*
**** Vegetable waxes, natural resins, tanning agents, proteins, medicinal plants*

8.2.2 Oleochemistry

Oleochemicals are defined as fatty acids, glycerine, fatty alcohols, metallic soaps, fatty nitriles & their derivatives and fatty esters. Oleochemicals are made of vegetable and animal oils and fats and/or petrochemicals feedstocks. These oleochemicals feedstocks are converted into a wide range of chemical products for use in lubricants, soaps and detergents, cosmetics, pharmaceuticals, food additives, leather, paints and coatings, printing inks, rubber, plastics, metal-working and many other industries (APAG[46]).

The majority of fatty acid derivatives are used as surface active agents in soap, detergents and personal care products. Their most important sources are coconut, palm and palm kernel oil, which contain many C12 to C18 saturated and mono-unsaturated fatty acids. Multiple unsaturated oils such as soybean, sunflower and linseed oil serve the production of alkyd resins, linoleum and epoxidised oils. Rapeseed oil, which is high in oleic acid (unsaturated C18 fatty acid), is used in bio-lubricants. For lubricants and hydraulic fluids, plant oils usually only require minor chemical modification to fully replace fossil oils.

Industrial use of vegetable and animal oils and fats in the EU (2012) was estimated at 928 kT in the form of fatty acids, 235 kT as fatty esters, 615 kT as alcohols, 93 kT as metallic soaps and 207 kT as glycerine (source: Busch & Wittmeyer (2015), based on APAG).

8.2.3 Starch

In 2014 the European starch industry processed 23 million tonnes of raw materials (maize, wheat, potatoes) into 10.5 million tonnes of starch products. Total market in the EU was 9 million tonnes, of which 61% went to food, 1% to feed and 38% to industrial applications, primarily paper making (Starch Europe, 2015[47]). Around 2000 kT went to the paper industry, 500 kT to corrugating and adhesives, 400 kT to pharma and chemicals and 400 kT to other non-food (incl. textiles) (Busch & Wittmeyer, 2015).

[46] http://www.apag.org/oleo/index.htm
[47] http://www.starch.eu/european-starch-industry/

CelluloseSConsumption of cellulose in the EU (2012) is dominated by the paper and board sector (42.3 million Tonnes), but also 376 kT are going to fibres and 1091 kT to chemicals (source: Busch & Wittmeyer (2015), based on CEPI).

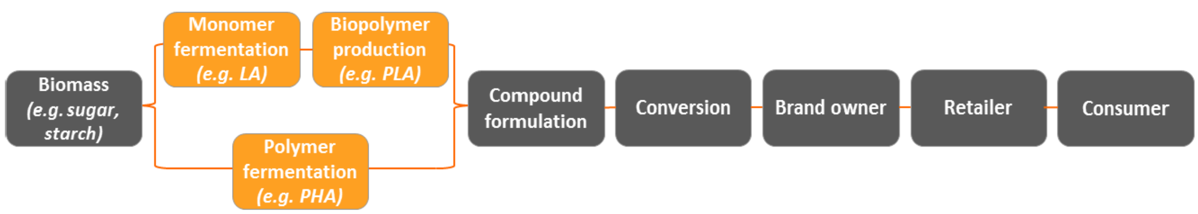
8.2.4 Biobased polymers and plastics

Polymers and plastics are often mixed as terms. A polymer is a chemical compound consisting of repeating structural units (monomers) synthesized through a polymerisation or fermentation process, whereas a plastic material constitutes a blend of one or more polymers and additives. (Nova Institute, 2015b).

According to PlasticsEurope (2015), plastics production of European industry was 57 million tonnes in 2013 (compared to a global production of 299 million tonnes). 39.6% of plastics are used for packaging, 20.3% for building and construction, 8.5% in automotive, 5.6% in electrical and electronic applications and 4.3% in agriculture.

The bio-based plastics value chain starts with a feedstock supplier and continues either directly with polymer production (e.g. PHA) or through an intermediate step where a monomer, i.e. a chemical building block (e.g. PLA) is formed. Polymer production is followed by compound formulation, where plastic properties are modified, and by conversion into a product.

Figure 8-3. The value chain for bio-based plastics (BIO-TIC, 2015)



The following table shows an overview of global production capacities of biobased structural polymers in 2013. Overall structural polymer production at global level is around 256 million tonnes, so with 5.1 million tonnes biobased polymers represent around 2%. In the remainder of the text the polymer abbreviations will be used.

Table 8-2. Biobased polymers, short names, current biobased carbon content and production capacities in 2013 (Nova-Institut, 2015b)

Biobased structural polymers		Current biobased carbon content*	Production capacities in 2013 (kT/yr)
Cellulose acetate	CA	50%	850
Epoxies/thermosets		30%	1210
Ethylene propylene diene monomer rubber	EPDM	50-70%	45
Polyamides (nylon)	PA	40-100%	85
Poly-butylene adipate-co-terephthalate	PBAT	Up to 50%**	75
Polybutylene succinate	PBS	Up to 100%**	100
Polyethylene	PE	100%	200
Polyethylene terephthalate	PET	20%	600
polyhydroxyalkanoates	PHA	100%	32
Polylactic acid	PLA	100%	195
Polytrimethylene terphthalate	PTT	27%	110
Polyurethanes	PUR	10-100%	1200
Starch blends***		25-100%	430
Polyethylene furanoate	PEF	100%	-
TOTAL			**5132**

** biobased carbon content, according to EN16575 Bio-based products*
*** currently still mostly fossil-based*
**** starch in plastic compound*

There are two groups in the bioplastics family, each with their own individual characteristics:

- Biobased or partially **biobased non-biodegradable** plastics such as biobased PE, PP, or PET (so-called drop-ins) and biobased technical performance polymers such as PTT;
- Plastics that are both **biobased and biodegradable**, such as PLA and PHA or PBS.

Another group of plastics are produced from **fossil** resources and are **biodegradable**, such as PBAT. Such plastics are sometimes also considered as bioplastics.
The fourth group is conventional, fossil based, non-biodegradable plastic, such as PE, PP or PET (source: European Bioplastics).

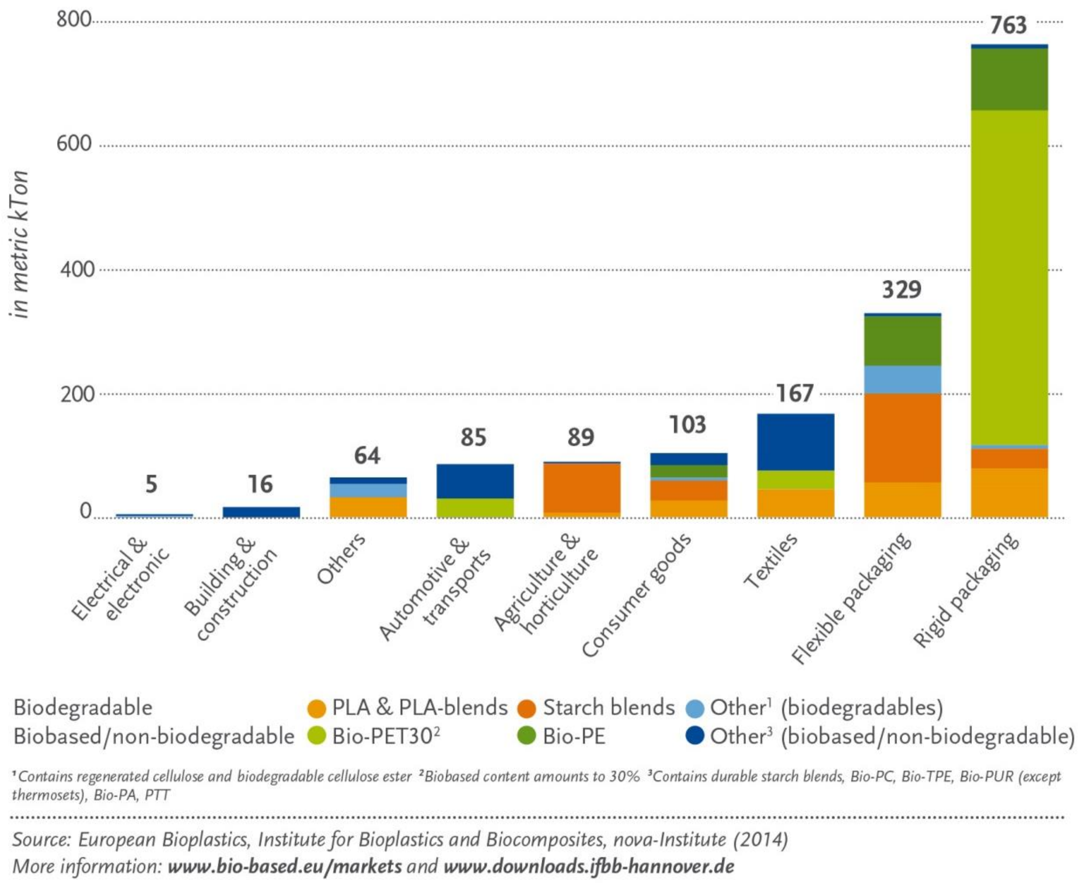
A large share of certified (EN13432) compostable plastic products available on the market contain a high portion of renewable raw materials. However, bio-based polymers are not in all cases biodegradable and compostable. It is important to note, that the property of biodegradation does not depend on the resource basis of a material, but is linked to its chemical structure.

Mind that most of the 'bio-plastics' in the above overview are only partly biobased. Considering the biobased shares of the different polymers, the total **biomass content** in the biopolymer production capacity at global level is estimated around **2 million tonnes** in 2013.

Biopolymers are used in an increasing number of markets – from packaging, catering products, consumer electronics, automotive, agriculture/horticulture and toys to textiles and a number of other segments. With growing numbers of materials, applications and products, the number of manufacturers, converters and end-users increases steadily. European Bioplastics provided an overview for 2013 of which sectors the bioplastics production capacities are aimed at (in total 1.6 million tonnes). Mind that epoxies, PUR and CA are not included in this overview (compared to the above table).

The packaging industry uses most (petro-based) plastics. For biobased plastics the same trend can be observed: the major part of this as rigid packaging (e.g. bottles), and the rest as flexible packaging (e.g. films). **Biobased PET** is one of the biggest biobased polymers in terms of capacity and is mostly used for the production of bottles.

Figure 8-4. Global production capacities of bioplastics in 2013 (European Bioplastics, 2015)



Currently 17.3% of global bioplastics production capacity is situated in Europe (mostly starch blends and some PLA). By 2018 it is expected that the European share will decrease to 7.6% and that most investments in new biobased polymer activities will take place in Asia (Nova-Institut, 2015a). Despite of the shift in production location Europe is expected to maintain its position as the main **consumer** of bio-based plastics.

8.2.5 Wood and fibres for biocomposites

Nova Institute (2015c) provided an overview of the production of biocomposites (Wood-Plastic Composites and Natural Fibre Composites) in the EU, also in relation to the total composite production. The most important application sectors for composites are construction (decking, siding and fencing) and automotive interior parts. Production of biocomposites is estimated around 350 kT per year, using around **180 kT of wood and natural fibres** (cotton, flax, kenaf, hemp). Around 15% of the total European composite market (of 2.4 million tonnes per year) is covered by biocomposites.

Table 8-3 Production of biocomposites in the EU in 2012 (source: Nova Institute, 2015c). Values are expressed in 1000 tonnes/yr.

Wood-Plastic Composites (WPC)	**260**
Decking	174
Automotive	60
Siding and fencing	16
Technical applications	5
Furniture & consumer goods	5
Natural Fibre Composites (NFC)	**92**
Automotive	90
Others	2
Total volume biocomposites (WPC and NFC)	**352**
Total composite production in the EU (glass, carbon, WPC, NFC)	2400

8.3 Projections up to 2030

8.3.1 Biobased chemicals

In this section we will compare the different literature sources containing long term projections of biobased chemicals.

The following table shows projections for biobased chemicals overall, up to 2050. The BREW study of 2006 provided a very wide range, from 4 to 50 MT in 2030. More recent analyses (CEFIC/Ecofys, 2013 and the on-going work of the S2Biom project) include biomass feed requirements for chemistry, with input requirements up to 10 Mtoe in 2030 in the EU. Mind that feedstocks will be a mix of lignocellulose, sugars, starch and oils. The S2BIOM project only considers lignocellulose.

Table 8-4. Projections of biobased chemicals (broad) up to 2050

Reference	Geo-graphy	Scenario	2020	2030	2050
BREW, 2006 / Dornburg et al., 2008: biobased chemicals	Global	Low: Medium: High:	2.4 MT 8.2 MT 26.7 MT	4.4 MT 11.9 MT 49.7 MT	4.8 MT 26.2 MT 113.1 MT
CEFIC/Ecofys, 2013 - biomass feed for chemistry	EU	4 scenarios		5 – 10 Mtoe	10 – 40 Mtoe
S2BIOM, 2015 - lignocellulose feed for chemistry*	*EU*	*Low:* *Medium:* *High:*	*0.4 Mtoe* *0.6 Mtoe* *0.7 Mtoe*	*1.5 Mtoe* *3.1 Mtoe* *5.0 Mtoe*	
*Nova-Institut, 2015d – total biomass demand for biobased chemicals and materials***	*Global*	*Low biomass supply:* *BAU:* *Biobased:* *Biobased high:*			*800 MT* *2400 MT* *4000 MT* *5700 MT*

Figures in green are expressed in biomass demand
** first draft; only lignocellulose; specific number of product-market combinations*
*** not limited to biobased chemicals. Current share of biomass to chemicals compared to chemicals and materials is around 5%.*

Busch & Wittmeyer (2012) (referenced in JRC, 2013) provided an overview of European biobased market development between 2010 and 2020 for different types of biobased products.

Table 8-5. Estimated market capacity development for several bio-based products in Europe (Busch & Wittmeyer, 2012, referenced in JRC, 2013)

Bio-product category	Bio-products	Market volume "Bio" 2010 (in tons)	Projected market volume "Bio" 2020 (in tons)
Bio-based plastics (European Bioplastics)	Short-life/disposable applications (PLA, PHA, Starch blends, cellulosics)	110.000	1.280.000
	Durable applications	150.000	
	Engineering polymers		740.000
	Modified PLA, Cellulosics		
	Polyolefines (2012)		530.000
	Starch based alloys	not marketed	260.000
	TOTAL	**260.000**	**2.810.000**
Biodegradable and bio-based plastics (BASF SE)	Waste & shopping bags	30.000	260.000
	Tableware	3.000	33.000
	Bio-mulch for agriculture	2.000	40.000
	TOTAL	**35.000**	**333.000**
Biolubricants (2008) (Fuchs Petrolub AG)	Hydraulic fluids	68.000	230.000
	Chainsaw lubricants	29.000	40.000
	Mould release agents	9.000	30.000
	Other oils	31.000	120.000
	TOTAL	**137.000**	**420.000**
Bio-composites (Nova-Institut, 2012)	Compression moulding:		
	- with natural fibres	40.000	120.000
	- with cotton fibres	100.000	100.000
	- with wood fibres	50.000	150.000
	Extrusion and injection moulding:		
	- Wood Plastic Composites	167.000	450.000
	- with natural fibres	5.000	100.000
	TOTAL	**362.000**	**920.000**
Bio-solvents (figures by Industries & Agro-Resources IAR)	**TOTAL (2012)**	**630.000**	**1.100.000** (BIOCHEM, 2010)
Bio-surfactants (figures by Industries & Agro-Resources IAR)	**TOTAL (2012)**	**1.520.000**	**2.300.000** (BIOCHEM, 2010)

Typical feedstocks are:

- biobased plastics: sugar[48], starch and cellulose;
- bio-lubricants: vegetable oils and animal fats;
- bio-composites: wood and natural fibres;
- bio-solvents: sugar[49] and starch (for production of ethanol); and
- bio-surfactants: vegetable oils and animal fats.

While most product types can be expected to grow, highest growth rates are expected for bioplastics. Projections of Busch & Wittmeyer (2012) would be equivalent to a CAGR of 27% per year for biobased plastics, although these projections have been reduced recently (Nova-Institut, 2015, see further).

The following paragraph will focus on projections for this product type.

8.3.2 Biopolymers

The following table show projections for biobased polymers and plastics up to 2030, as presented in different studies. Most studies focused on 2020; 2030 projections are very recent.

Table 8-6. Projections of biobased polymers/plastics up to 2030

reference	Geography	Scenario	2020	2030
JRC, 2005	Global	No P&M: With P&M:	2.2 MT 4.2 MT	
JRC, 2005	EU15	No P&M: With P&M: High growth:	0.9 MT 1.7 MT 3.0 MT	
PRO-BIP 2009	Global	Low: BAU: High:	1.5 MT 3 MT 4.4 MT	
PRO-BIP 2009	EU	Low: BAU: High:	0.4 MT 0.8 MT 1.1 MT	
BIOCHEM, 2010	EU		0.9 MT	
Busch & Wittmeyer, 2012	EU		3.1 MT	
Nova-Institut, 2015b Production *capacity*	Global	Partly biobased	*17 MT*	
	EU	Partly biobased*	0.9 MT*	
BIO-TIC, 2015** - Demand	EU	Low Reference	2 B€ (~1MT)	4.3 B€ (~2.0 MT)

[48] in future, sugars may be derived from lignocellulose (equivalent to 2nd generation ethanol production).
[49] see previous footnote.

		High		5.2 B€ (~2.5 MT) 6.7 B€ (~3.2 MT)
*S2BIOM, 2015** - first draft*	*EU*	*Low:* *Medium:* *High:*	*0.4 MT* *0.5 MT* *0.6 MT*	*1.3 MT* *2.7 MT* *5.0 MT*

P&M = policies and measures
** Without thermosets and cellulose acetate*
*** only biobased fraction*

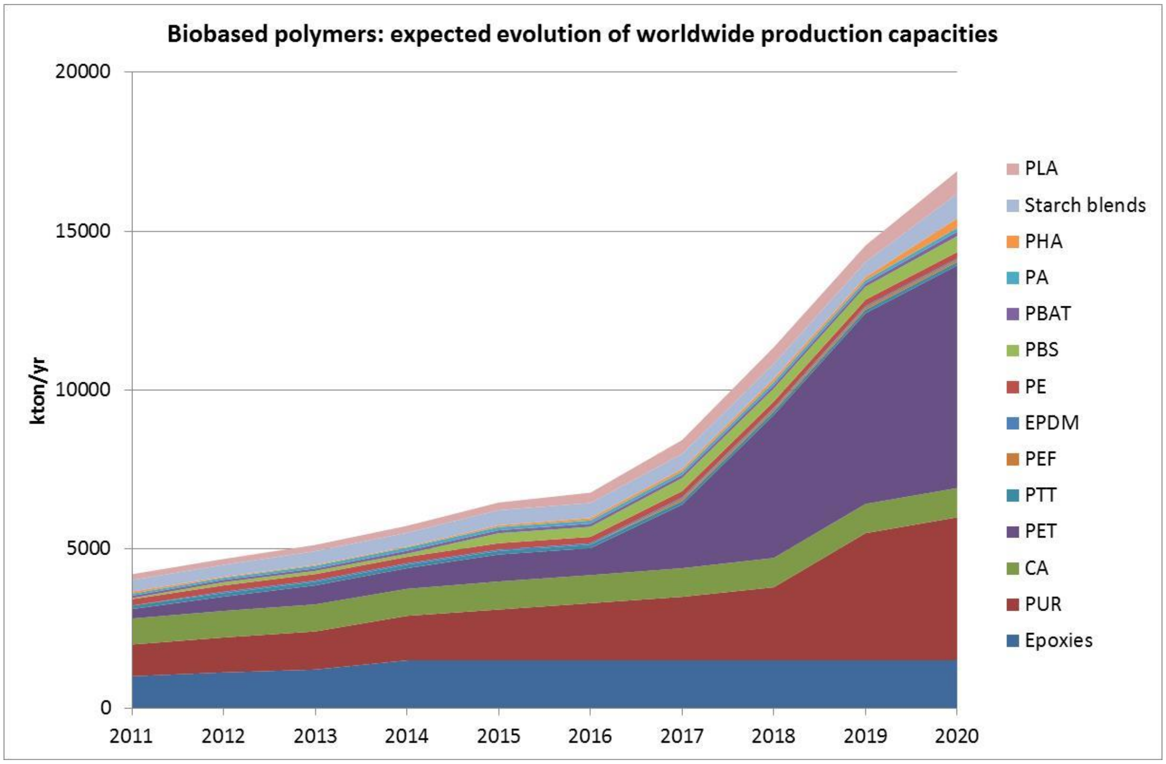
When looking at these different sources, there are some issues in terms of comparability:

- Projections may either be about production, demand or production capacity. In the latter, sometimes also fossil capacity is included, assuming that it could switch to biobased raw materials.
- Some bioplastics are only partly biobased (e.g. Bio-PET is on average 20% biobased).
- There may be differences in which types of polymer types are included.

Nova-Institut (2015b) made detailed projections of global biobased polymer production capacities up to 2020. High annual growth rates (CAGR) of almost 20% would be achieved, in comparison to petrochemical polymers, which have a CAGR between 3-4%.

Biobased PET dominates in this growth, with a production capacity of 600 kT in 2013, projected to reach about 7 million tonnes by 2020 (containing 30% biobased carbon), using bioethanol from sugar cane. This expansion is largely due to the Plant PET Technology Collaborative (PTC) initiative, launched by the Coca-Cola Company. Other polymers like PHA, PLA and bio-based PUR also show impressive growth rates.

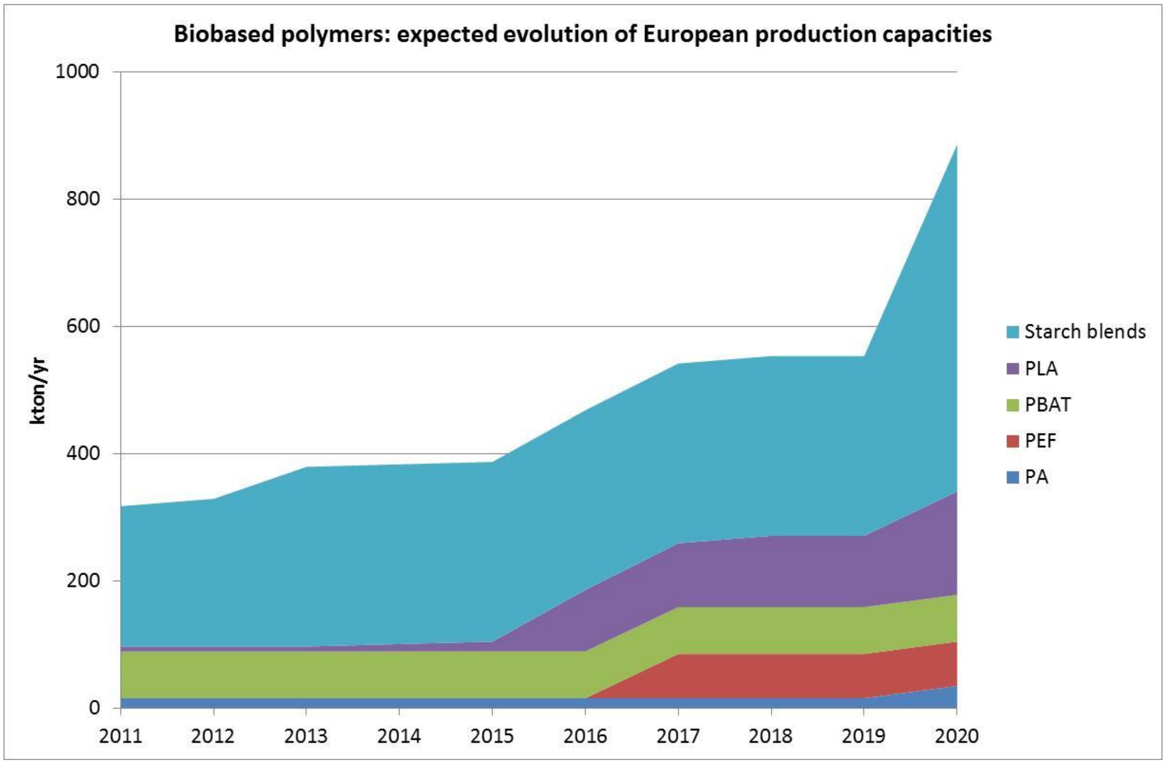
Figure 8-5. Expected evolution of worldwide production capacities for biobased polymers (based on Nova-Institut, 2015b)



** In partially bio-based plastics, the renewable carbon content ranges between 20% and 100%.*

The situation in Europe is somewhat different, as the main growth (e.g. biobased PET) is expected in other regions. Europe has so far established a solid position mainly in the field of starch blends, reaching around 380 kT production capacities of biopolymers in 2013, with biomass content around 150 kT. Growth is expected for starch blends, PLA and PEF. Capacities for PBAT (which are now fully fossil based) could increasingly be used for biobased precursors.

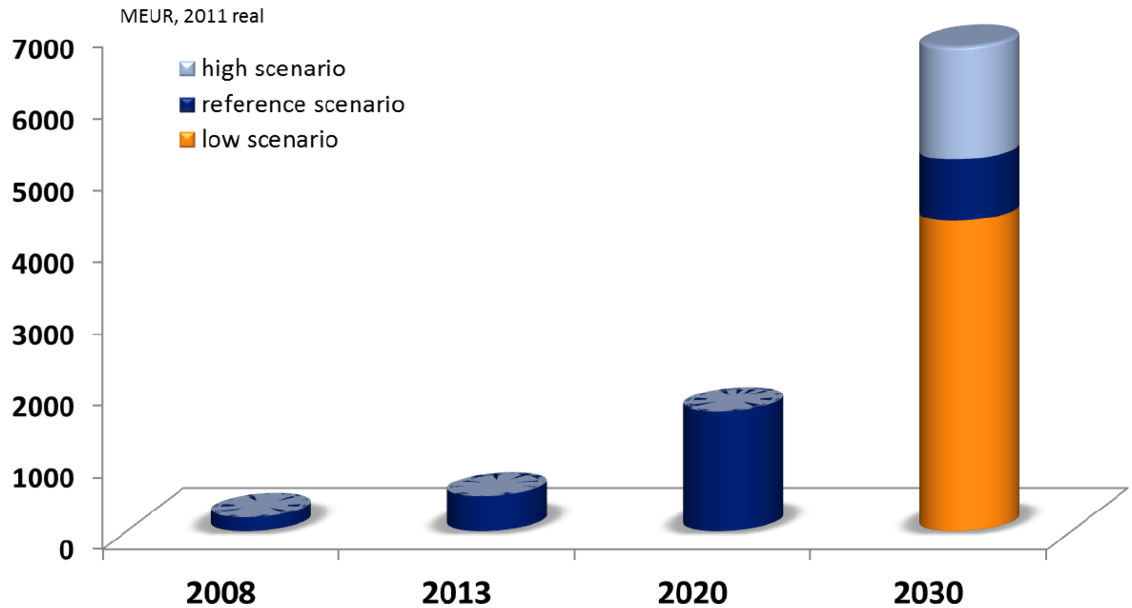
Figure 8-6. Expected evolution of European production capacities for biobased polymers (excluding thermosets and cellulose acetate) (based on Nova-Institut, 2015b)



BIO-TIC is a European project which recently presented its final results. Their projections are based on extensive stakeholder consultations.

BIO-TIC (2015) estimated EU demand for biobased plastics at 485 MEUR in 2013, representing a CAGR of 20% between 2008 and 2013. After 2013 BIOTIC applies growth rates of 10%, 12% and 15% for the low, reference, and high scenarios. With these growth rates, the biobased plastics market value is expected to reach approximately 5.2 billion Euros in 2030 in the reference scenario, and 4.3 billion Euros and 6.7 billion Euros in the low and high scenarios, respectively.

Figure 8-7. Estimated market demand for biobased plastics in the EU (BIOTIC, 2015)



The main growth is expected in the specialty polymers and packaging applications. Market adoption in all applications is dependent on the adoption of mandates (for example supermarket plastic bags), biobased plastic cost competitiveness compared to conventional plastics and on consumer willingness to pay a bio-premium. (BIOTIC, 2015).

Assuming an average market value of 2 Euro/tonne for biopolymers, the reference scenario would be equivalent with a **biopolymer** consumption of around **2.5 million tonnes** in Europe (with a spread between 2 and 3 million tonnes depending on the scenario).

8.3.3 Biomass feed for biopolymers

Current raw materials for bio-based plastics in the EU are largely based on 1st generation raw materials like sugar and starch, with exception of cellulose based biopolymers like CA. Similarly to other applications, there may be a shift to 2nd generation raw materials for bio-plastics in 2030, albeit at a slower rate than for biofuels.

Assuming that in 2030 an indicative share of 80% of bioplastics will be derived from sugar/starch and 20% from lignocellulose, this will require around ***4 million tonnes of sugar/starch*** and ***1.5 to 2 million tonnes (dry mass) of lignocellulose.***

Mind that these figures are in relation to the European market *demand* of bio-plastics; with current evolutions it is very likely that a substantial part of the *production* will happen outside Europe (e.g. South America, Asia).

8.3.4 Bio-composites

The following table shows a projection of Nova-Institut (2015c) on the different applications of WPC and NFC. A major expansion of biocomposites in the automotive sector is foreseen, especially when policy incentives would be provided. Applications in the construction sector are foreseen to include a much higher share of biocomposites by 2020, even in the reference scenario.

Table 8-7. Production of biocomposites (WPC and NFC) in the European Union in 2012 and forecast 2020 (in ktonnes) (nova 2015)

Biocomposites	Production in 2012	Forecast production in 2020 (without incentives for biobased products)	Forecast production in 2020 (with strong incentives for biobased products)
WPC	**265**	**580**	**>950**
Construction, extrusion	190	400	450
Automotive	60	80	300
Technical applications, furniture & consumer goods	15	100	>200
NFC	**92**	**130**	**>370**
Automotive	90	120	350
Granulates	2	10	>20

The overall demand of biomass by 2020 in the reference scenario would then be around 300 kT woody material and 65 kT/yr natural fibres. In the progressive scenario this could amount to **500 kT woody** and **200 kT/yr natural fibres**. In the reference scenario, we assume that these amounts may be reached by 2030.

9 Biomass cost and greenhouse gas emissions

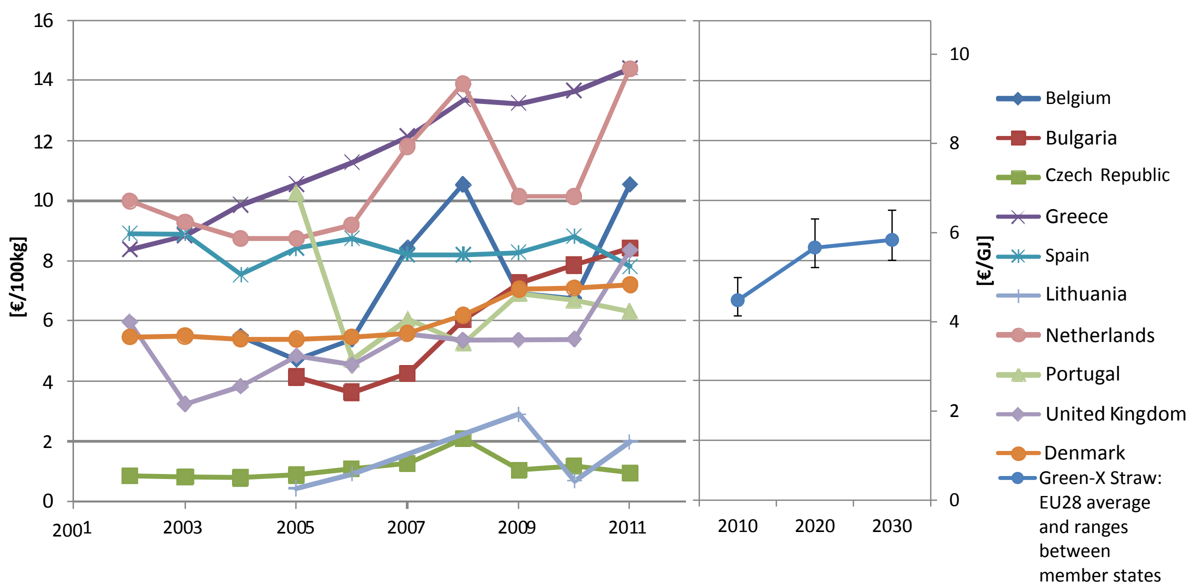
9.1 Biomass supply cost and market prices

9.1.1 Agricultural residues

The cost for straw comprises a grower payment, which is the equivalent of a stumpage price of forest biomass and includes the cost of production, production and a compensation for soil nutrient removal (Langholtz *et al.*, 2012) and the cost of harvesting , baling, bale collection and queuing of bales on field side (Kühner, 2013).

The cost of straw can vary substantially as a result of fuel and fertilizer cost, wages, straw density and average field size. The EU average cost of fertilizer replacement, baling, collection and stacking are calculated at 31.86 €/t on an EU average for the BioBoost project compared to 14.85 – 44.70 €/t calculated in other projects (Kühner, 2013). Furthermore, prices can be substantially higher than cost due to the quality (moisture content, grey leached out versus yellow), difference between supply and demand and stock levels. Grey straw has a lower value for non-energy markets, but is preferred for energy uses because part of potassium and chloride are leached out by rain (Kühner, 2013). Figure 9-1 compares actual price development of straw between 2002 and 2011 with the assumed cost of straw in Green-X. The cost estimates in Green-X are comparable with straw prices in Denmark that already uses straw for energy purposes at large scale. In 2013, straw bales delivered to district heating plants in Denmark were 76 €/t (5.1 €/GJ) (Stelte *et al.*, 2015). The assumed cost of straw in Green-X is therefore considered representative for straw delivered to end-users if used domestically.

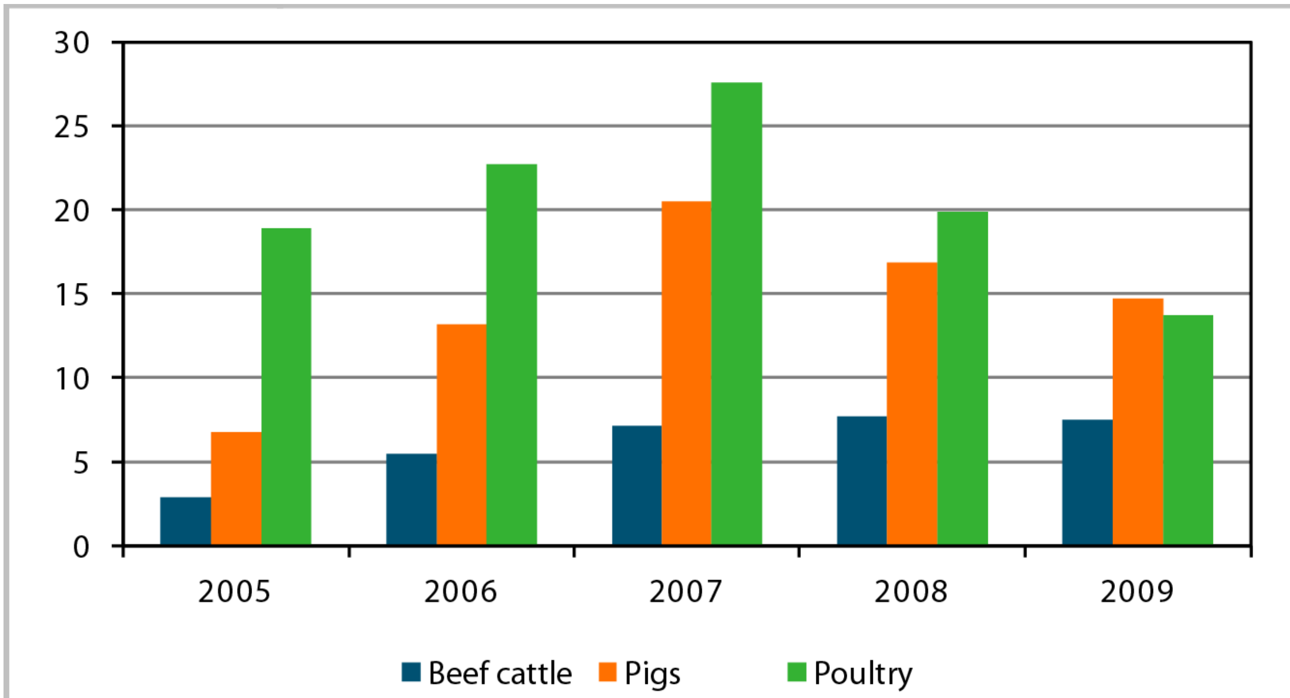
Figure 9-1. Left: straw price development 2002 - 2011 (in €/100 kg) (Kühner, 2013) compared to Right: EU28 average and ranges between member states in Green-X



Other agriculture residues and manure
This category combines various of location specific sources biomass such as such as pruning, cuttings, olive pits. A more detailed analysis of the cost and supply of these biomass sources can be found in the Biomass Policies study (Elbersen *et al.*, 2015)**.** In the Green-X database, other agricultural residues are assumed to have similar cost to straw.

Co-digestion is the main process to convert manure into biogas (AEBIOM, 2014). The cost of feedstock input to the co-digester is for a large extent determined by the cost of co-substrate. Furthermore, manure is expensive to transport as a result of the high moisture content. At the source of production, manure is often provided at negative cost. As an example, Figure 9-2 shows the disposal cost of manure from cattle, pigs and poultry in the Netherlands. Disposal cost of poultry manure in the Netherlands have increased after changes in policies that regulate consumption and processing of manure in 2006, but decreased after 2007 when a new power plant came online fuelled by chicken manure (Moerdijk). The disposal cost of pig manure reduced after 2008 as a result of decreased competition (Kühner, 2013).

Figure 9-2. Development of the average disposal cost of manure from cattle, pigs and poultry in the Netherlands. De Koeijer et al. 2011 in BioBoost (Kühner, 2013)



Source: Farm Accountancy Data Network

9.1.2 Energy crops

Figure 9-3 shows the weighted average cost development between 2010 and 2030 of energy crops per feedstock category (oil, starch/sugar, woody, grassy) in Green-X. The error bars show the difference between member states. In general, feedstock cost are lower in Eastern Europe compared to Western Europe as a result of labour cost and land prices. Oil crops are the most expensive feedstock, but the additional cost to produce biodiesel from vegetable oil are relatively low. SRC crops (willow, poplar) and grassy crops (miscanthus and switchgrass) are cheapest, but its economic potential depend for a large extend on the development of second generation conversion technologies.

Compared to the cost-supply curve, based on the REFUEL project shown in

Figure 9-4, the cost of SRC crops and grassy crops appear to be high. Note however, the cost-supply curves in

Figure 9-4 are production cost, available at roadside cost. Cost induced by logistic operations can add substantially to the total cost of feedstock supply to end-users (Chum *et al.*, 2011). The cost of energy crops in Green-X are therefore considered representative for energy crops delivered to end-users if used domestically.

Figure 9-3. Cost of energy crops on European average by feedstock type in 2010, 2020 and 2030 in €/GJ in Green-X. Error bars represent the ranges in cost found between different

EU member states.

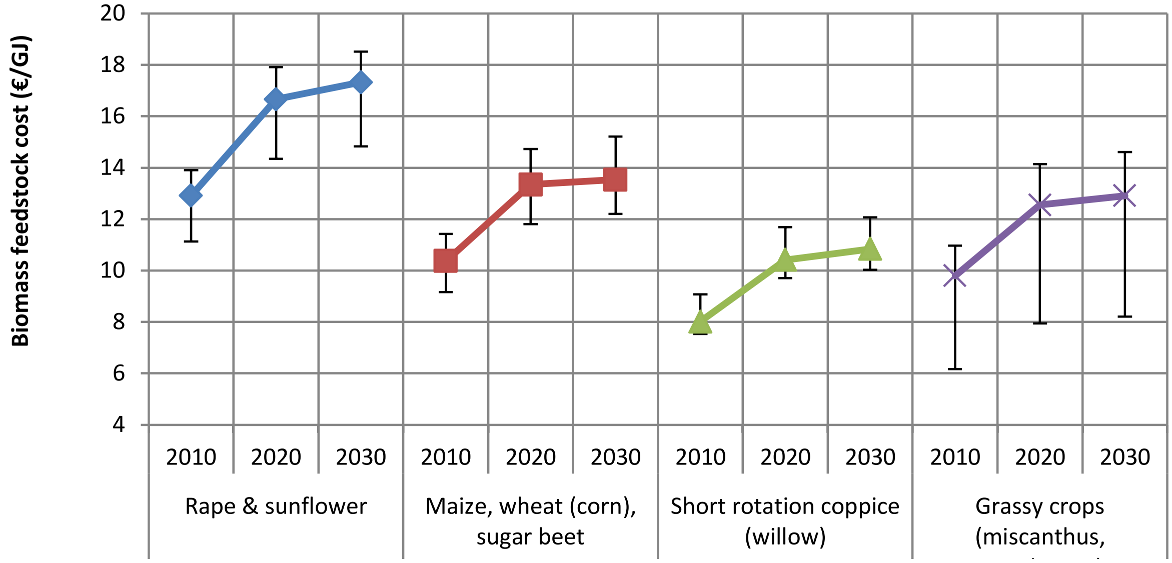
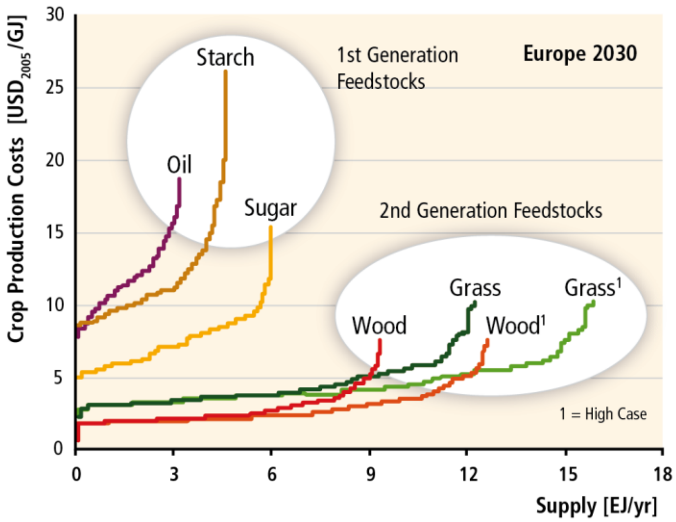


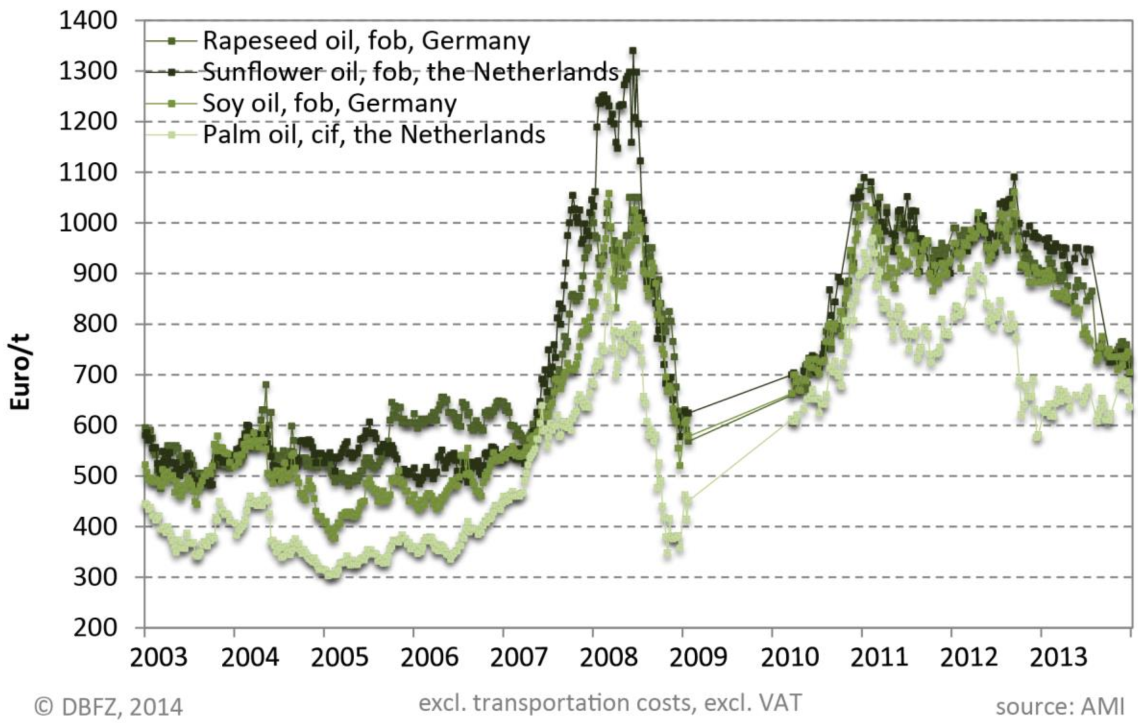
Figure 9-4. Feedstock cost-supply curve for European countries in the 2030 (Chum et al., 2011) based on de Wit et al. (2010) in USD2005/GJ (av. exchange rate 2005: 1.24 USD/Euro)



9.1.3 Market prices of vegetable oils

Most first generation feedstocks are global traded commodities for which market conditions can have a larger effect on prices than actual cost-prices discussed in the previous section. For example, the development of vegetable oils have remained relatively constant from 2003 to 2007, but started to become more erratic in the period 2007/2008 as a result of increased demand followed by a sharp decrease in the second half of 2008. There are many underlying reasons that could explain recent fluctuations in vegetable oil prices. According to Thrän et al. (2015), demand changes for biodiesel and the halt of support for combined heat and power from vegetable oils are the underlying reasons for the recent decreasing price trends after 2010. Prices of rapeseed oil were around 540 €/t (15 €/GJ) excl. VAT to 2007, but increased sharply to over 900 €/t (25 €/GJ) in 2008. In 2013, prices of rapeseed oil dropped from 920 €/t (26 €/GJ) to 725 €/t (20 €/GJ). In comparison, cost-prices assumed in Green-X are assumed to be 11-14 €/GJ in 2010 (400-500 €/t) increasing to 15-19 €/GJ (534-666 €/t) in 2030 (Figure 9-3).

Figure 9-5. Price development of vegetable oil (rapeseed oil sunflower oil, palm oil) in Germany and the Netherlands from 2003 to 2013 (Thrän et al., 2015)



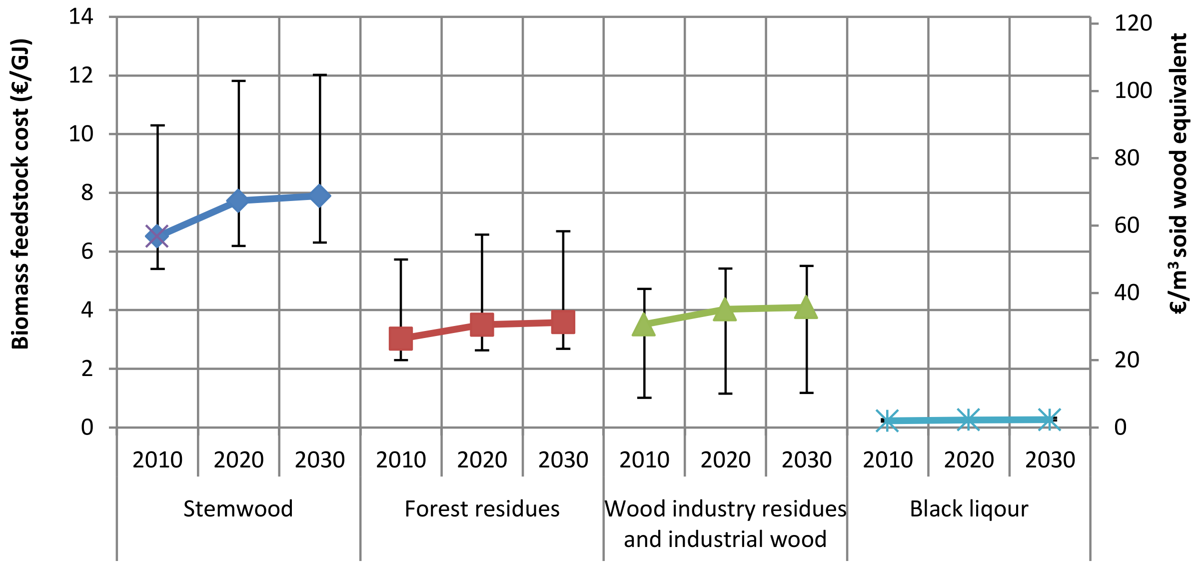
9.1.4 Forest biomass and wood industry residues

Wood cost in Green-X

Figure 9-6 summarizes the average cost and ranges of wood for bioenergy as assumed in the Green-X model if used domestically. If wood is exported (Intra-EU trade), the specific cost of transport are added, but not shown here. Stemwood (forest products) is divided in three subcategories resulting in the large rage of cost shown in Figure 9-6: current uses, complementary fellings at moderate cost and complementary fellings at high cost. An example of expensive complementary fellings is non-coniferous stemwood (hardwood) of which relatively large amounts are still technically available (60 – 110 M m^3), but represent a high value and are often difficult to mobilize.

Current (2010) cost of forest residues and forest industry residues assumed in Green-X are within the price range of industrial wood chips between 2006 to 2010 as collected by the EUBIONET3 project (Section 0) and confirm the geographic variation between EU member states. Black liquor is a low value, wet by-product from chemical pulping (Kraft process). It is most commonly combusted in a recovery boiler to recover chemicals at the pulp mill.

Figure 9-6. Cost of forest biomass and wood industry residues on European average by feedstock type in 2010, 2020 and 2030 in €/GJ in Green-X. Error bars represent the ranges in cost found between different EU member states.



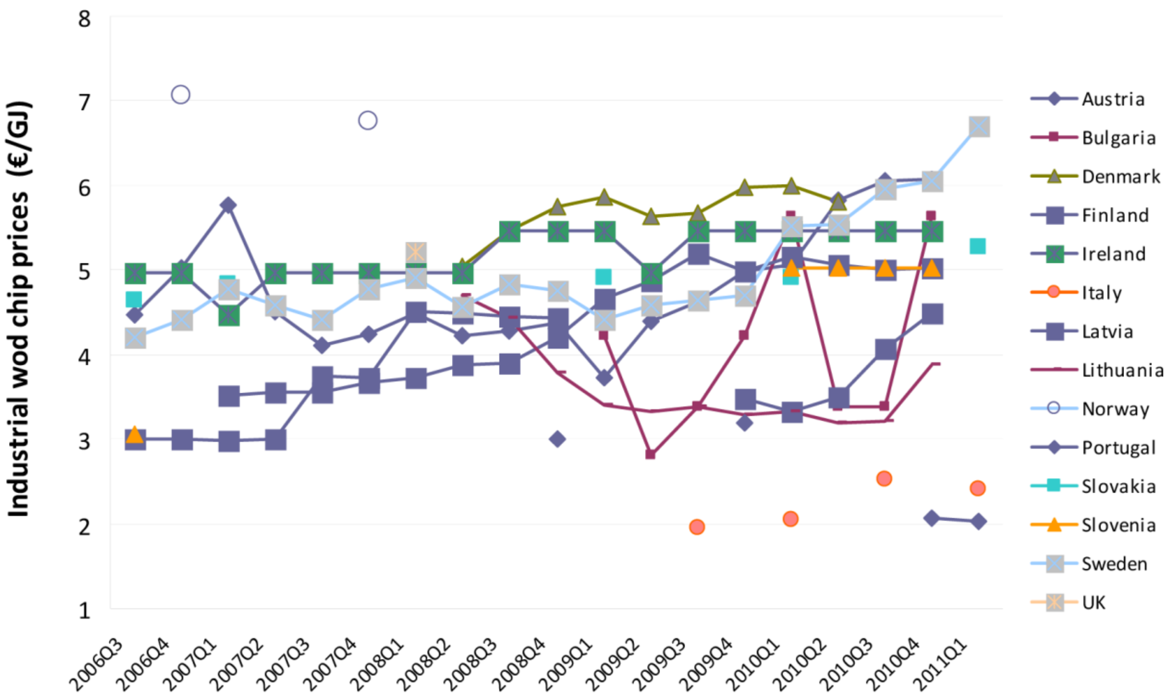
Wood fuel prices

In the EUBIONET3 project (EUBIONET3, 2011), prices of industrial wood chips were collected by project partners and harmonized for major European countries between the second half of 2006 to the end of 2010 (

Figure 9-7) varying between 2.0 - 6.7 €/GJ. In the same period, market prices of other wood energy products were in the following range (EUBIONET3, 2011), 2006 - 2010:

- Wood pellets (residential market, bulk delivery): 11-14 €/GJ
- Wood pellets (residential market, bags): 7.5-14.5 €/GJ
- Wood pellets (industrial market): 6-10 €/GJ
- Wood briquettes (residential market): 9-17 €/GJ
- Wood briquettes (industrial market): 6-10 €/GJ
- Wood chips (residential market): 3-6.5€/GJ
- Firewood (residential market, broadleaved): 3-13.8 €/GJ
- Sawmill by-products: 2.5-4 €/GJ

Figure 9-7 .Price development of industrial wood chips without VAT including logistic costs, €/GJ (EUBIONET3, 2011)



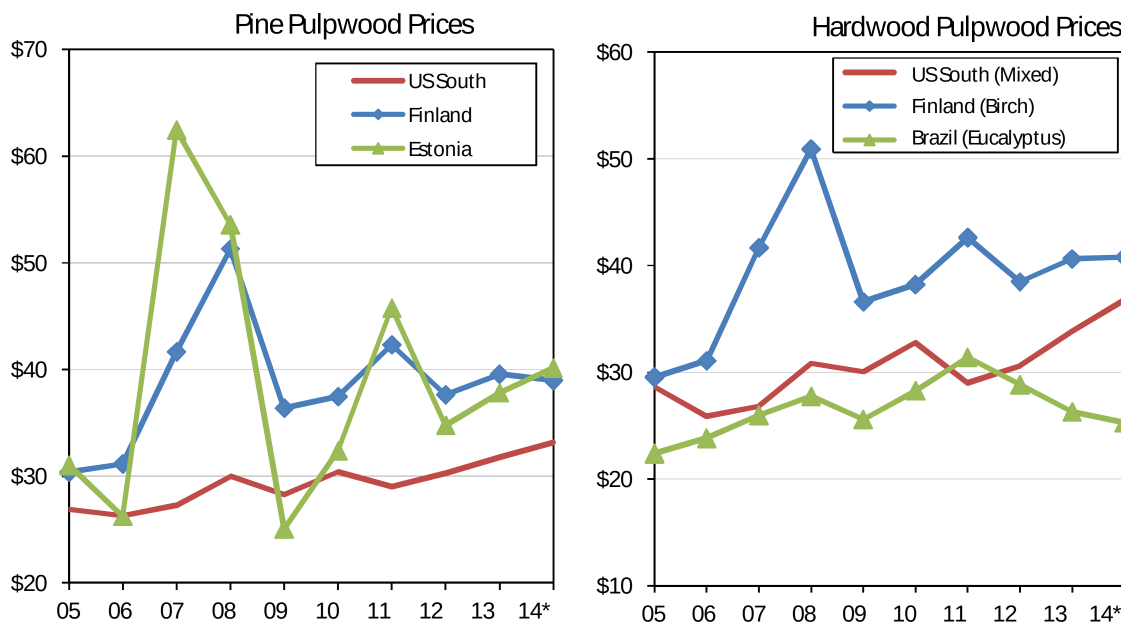
Wood product prices

The period covered by EUBIONET3 (2006-2010), covered the large peak and collapse in prices of wood prices that occurred in the last decade between 2008 and 2009. According to RISI (RISI, 2015), a construction bubble drove global sawlog demand upwards in the middle of the last decade. Global sawlog demand peaked in 2006 at 991 M m^3. Furthermore, European producers were affected by a strong Euro and import tariffs on timber. Due to the financial crisis, global timber demand collapsed in 2008-2009 and bottomed at 764 M m^3 in 2009. With the strong growth and collapse of timber demand, RISI also observed an inherent floor for sawlog prices on an global scale at around €58/m^3 (US$75/$m^3$) in real (2013) terms (RISI, 2015).

The two key sectors that do compete for raw material are pulp and paper and oriented strand board (OSB). According to Pöyry, pellet plants are at the lower end of the wood paying capability (WPC) in the Southeast of the US and are therefore not a real competitive threat to traditional industries. Increased demand for wood pellets might however tighten supply – demand resulting in regionally occurring price increases. Similar effects were identified by Abt et al. (2014). Pulpwood logs are still largely used for the production of pulp (82%) with the remaining 18% used for reconstituted panels and bioenergy, including wood pellets. The price of pulp is therefore still an important factor for the price of pulpwood.

Although pulpwood recently became the largest feedstock source for the production of wood pellets in the US Southeast, total pulpwood demand remained relatively flat and has actually declined in 2014. According to RISI, weather has been a factor in the recent upward trend in pulpwood prices. Due to high precipitation rates, access to forest stands became difficult, especially for lowland hardwoods (RISI, 2015). At €28/m^3 and 30 €/m^3 (€3.3/GJ - €3.5/GJ) for pine and spruce respectively, Finnish pulpwood prices remained within the same range since 2010.

Figure 9-8. Annual pine and hardwood pulp prices in US$/m3, 2005 – 2014 (RISI, 2015)



* Based on the average of the data available.

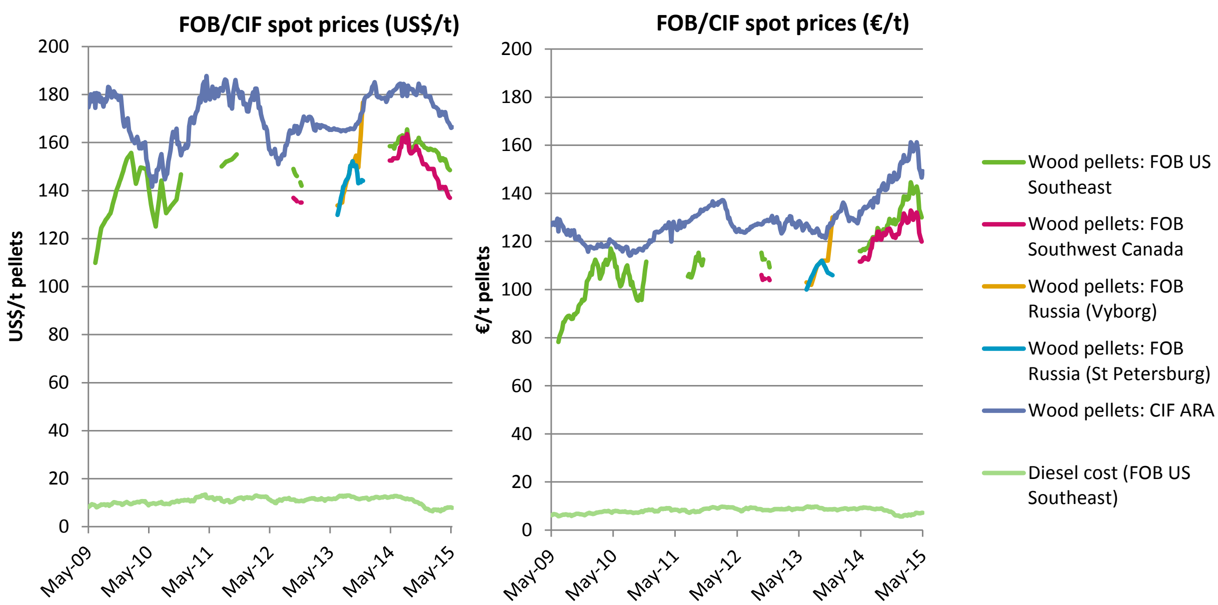
9.1.5 Wood pellets

FOB prices of industrial pellets are reported by companies such as Argus Media and FOEX (EUBIONET3, 2011). FOB prices of wood pellets from NW-Russia were 105 €/t to 119 €/t in 2013 (Proskurina *et al.*, 2016) and 78 to 145 €/t in the US Southeast (Figure 9-9). Spot prices of wood pellets delivered to the Antwerp-Rotterdam-Amsterdam region (CIF-ARA) were on average 129 €/t between May 2009 and May 2015, but have increased sharply in 2015 to up to 161 €/t, mainly due to an unfavorable development of the USD to Euro exchange rate. If expressed in US$/t, CIF ARA wood pellet prices in 2015 were almost identical to those in 2011.

According to a recent study from the U.S. Endowment for Forestry & Communities (Qian & McDow, 2013), wood pellets can be delivered to an export terminal in the US Southeast at 123 US$/t. Over the reported period in Figure 9-9, FOB prices of wood pellets in the US

Southeast were on average 147 US$/t resulting in an average profit margin of 16%, roughly half of the manufacturing industry in the US (30%) (Qian & McDow, 2013).

Figure 9-9. FOB and CIF ARA Spot price indices of industrial wood pellets and coal in US$/t (left) and €/t (right)50 for available time series (Qian & McDow, 2013; Argus Media, 2015; Proskurina et al., 2016) and diesel cost of FOB pellets in the US Southeast (diesel consumption 14 L/t pellets)51.

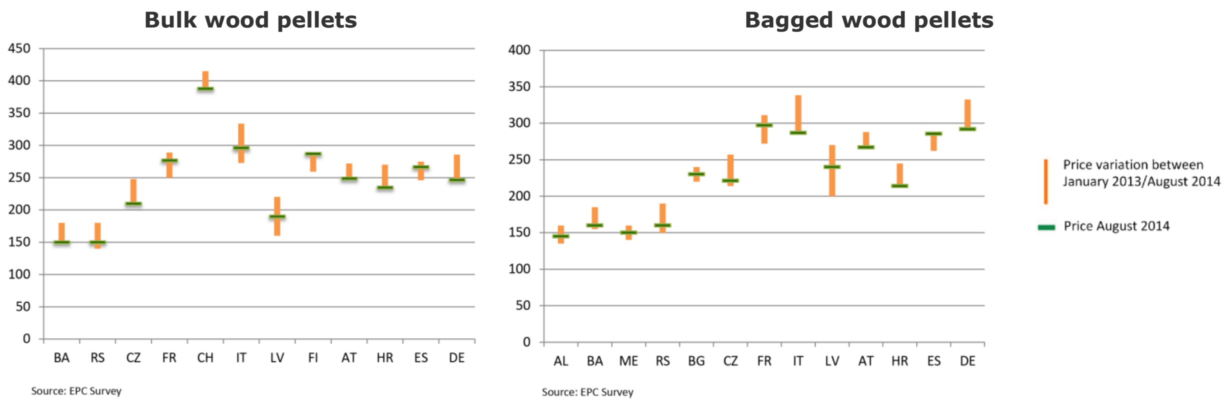


Wood pellet prices for heating markets are higher than industrial prices and also vary between countries as shown in Figure 9-10. VAT rates for wood pellets in Europe ranges between 5% in the UK (20% general VAT) and 27% in Hungary (general rate) resulting in different consumer prices (AEBIOM, 2014). Italy is heavily dependent on imports of wood pellets for heating markets (Rebiere, 2014) which could explain the higher price compared to other countries. VAT on wood pellets used to be relatively low (10%) in Italy, but has recently been increased to 22% with the Stability Act in 2015.

[50] Based on daily US Dollar (USD) / Euro exchange rate, https://www.quandl.com/data/CURRFX/EURUSD-Currency-Exchange-Rates-EUR-vs-USD

[51] The cost of diesel of pellets delivered to a port in the US Southeast are based on the average diesel consumption of wood pellets produced from forest and logging residues, stemwood and wood industry residues as calculated by JRC (Giuntoli et al. 2015) and supplied to a shipping terminal (for example Savannah, GA). Average diesel consumption of pellets was 14 L/t pellets, but exclude shipping to the EU28. Supply chains included: Pellets from forest logging residues and stumps (Pathway no 5), Pellets from wood industry residues (Pathway no 7), Pellets from stemwood (Pathway no 8), transport distance to export terminal: 150 km, transport by truck.

Figure 9-10. Variation in bulk (6t delivered, 100 km) and bagged (retailer price, 1 pallet) wood pellet prices in €/t pellets including VAT in Europe between January 2013 and August 2014 (AEBIOM, 2014). Note that the left and right charts have different scales.



With the assumed diesel consumption of pellet supply to export shipping terminals (14 L/t pellets), historic fluctuations in crude oil prices cannot explain the larger fluctuations in FOB market prices of wood pellets as shown in Figure 9-9. Future changes in diesel prices are however taken into account in calculating the prices of wood pellets as shown in Table 9-1. The average FOB prices of wood pellets are used as a proxy for the cost-supply of solid biomass at extra-EU supply nodes. FOB prices (in €/t) from Figure 9-9 (US Southeast, Southwest Canada and Russia) are assumed to implicitly represent cost structures of feedstock supply and hinterland logistics in extra-EU supply countries.

Table 9-1 Assumed FOB prices of solid biomass (pellets) in export countries

Supply country	Pellet price (€/t)[a]				
	2006	2010	2020	2025	2030
Southeast USA[b]	109.4	109.9	112.4	113.0	113.9
Southwest Canada	117.3	117.9	120.4	121.0	121.9
Russia (Vyborg)	108.0	108.5	111.0	111.6	112.5
Russia (St Petersburg)[c]	104.9	105.4	107.9	108.5	109.4

a) Assumed prices of solid biomass (pellets) at sea terminals in exporting countries. Prices in 2015 based on average reported FOB prices (Figure 9-9). Other years corrected for changes in diesel prices.

b) Assumed similar in Brazil, New-Zealand

c) Assumed similar in Australia, Sub-Saharan Africa, Ukraine

The resulting cost-supply curves of solid biomass are specific per EU member state, supply scenario and period in time. The average cost-supply curve of the Restricted, Reference and Resource scenarios are shown in Figure 9-11 (2020) and Figure 9-12 (2030) and compared to actual spot price variation of wood pellets delivered to Northwest Europe (CIF-ARA) between 2009 and 2015 of Figure 9-9.

Figure 9-11. Cost-supply curve of extra-EU solid biomass pellets delivered to the EU28 in the 2020 compared to the lowest and highest CIF-ARA spot prices of wood pellets between 2009 and 2015

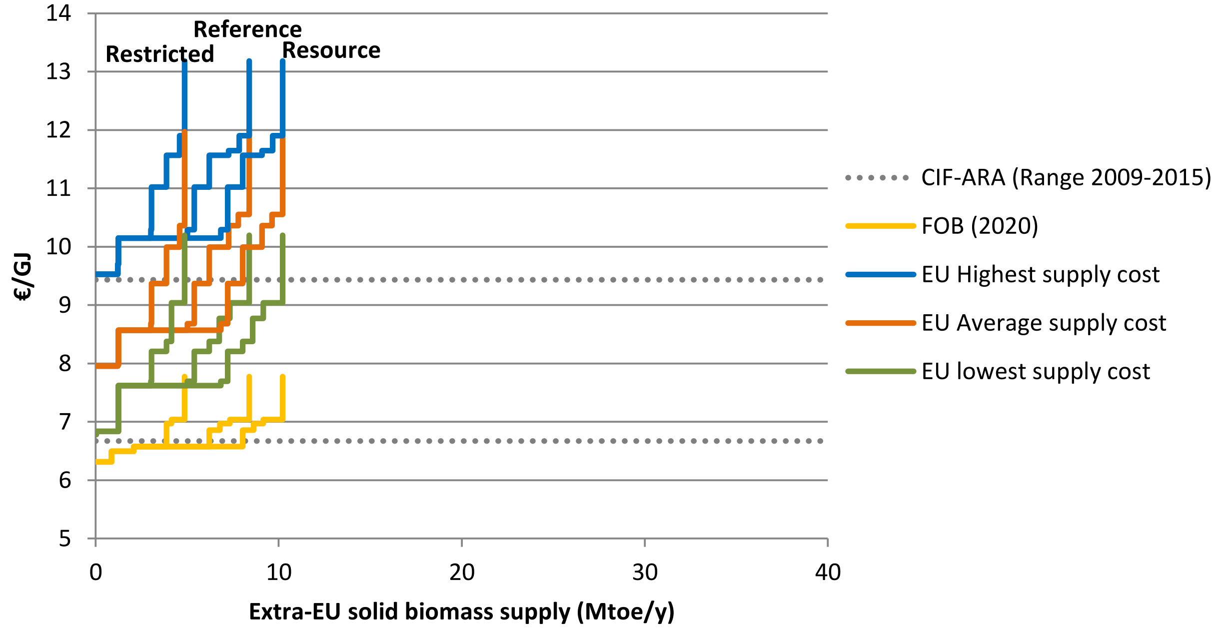
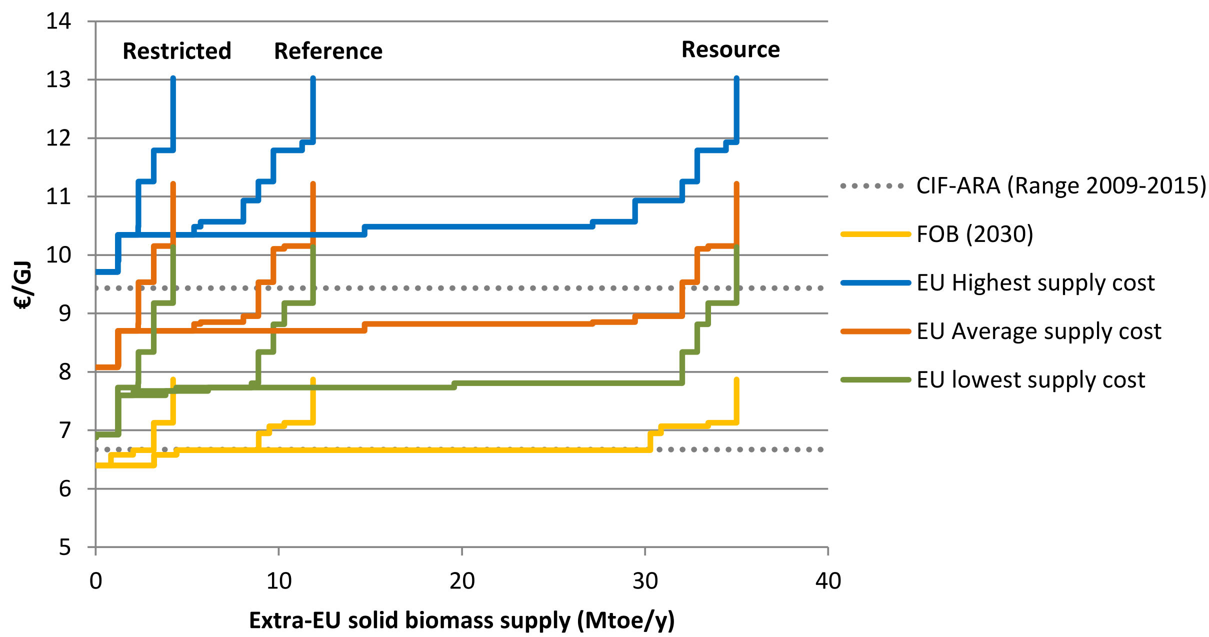


Figure 9-12. Cost-supply curve of extra-EU solid biomass pellets delivered to the EU28 in the 2030 compared to the lowest and highest CIF-ARA spot prices of wood pellets between 2009 and 2015



9.2 Greenhouse gas emissions

GHG emissions of liquid biofuels and solid and gaseous bioenergy pathways are calculated following the methodologies of Annex V of the EU Renewable Energy Directive (EC 2009), Annex I of COM2010(11) and in SWD(2014)259 as explained in Section **Error! Reference source not found.**. Defining the exact height/range of C-footprint per type of feedstock and originating region is extremely difficult and proofed not feasible based on available literature and data sources. Possible emissions or credits from carbon stock changes are therefore not included. Emissions of biomass supply chains are combined with conversion efficiencies to electricity, heat and fuels in Green-X to calculate total pathway emissions and to address for GHG criteria (threshold values).

9.2.1 Solid and gaseous biomass

GHG emissions and typical savings for electricity and heat are depicted in Figure 9-13 for European pathways and Figure 9-14 for imported solid biomass from Extra-EU countries. The results are calculated for trade between each individual member state per type of feedstock and as such implemented in the Green-X model. For readability, only the ranges are depicted here.

GHG savings are calculated assuming an efficiency of 85% for heat and 25% for electricity similar to the efficiencies assumed in COM(2010) 11 and SWD(2014) 259. Please note that the conversion efficiencies of electricity plants and CHP plants could be substantially higher resulting in more robust savings compared to the values shown below. These are calculated endogenously with the Green-X model. The pathways used in this study link to JRC's report on Solid and gaseous bioenergy pathways as follows (Giuntoli *et al.*, 2015):

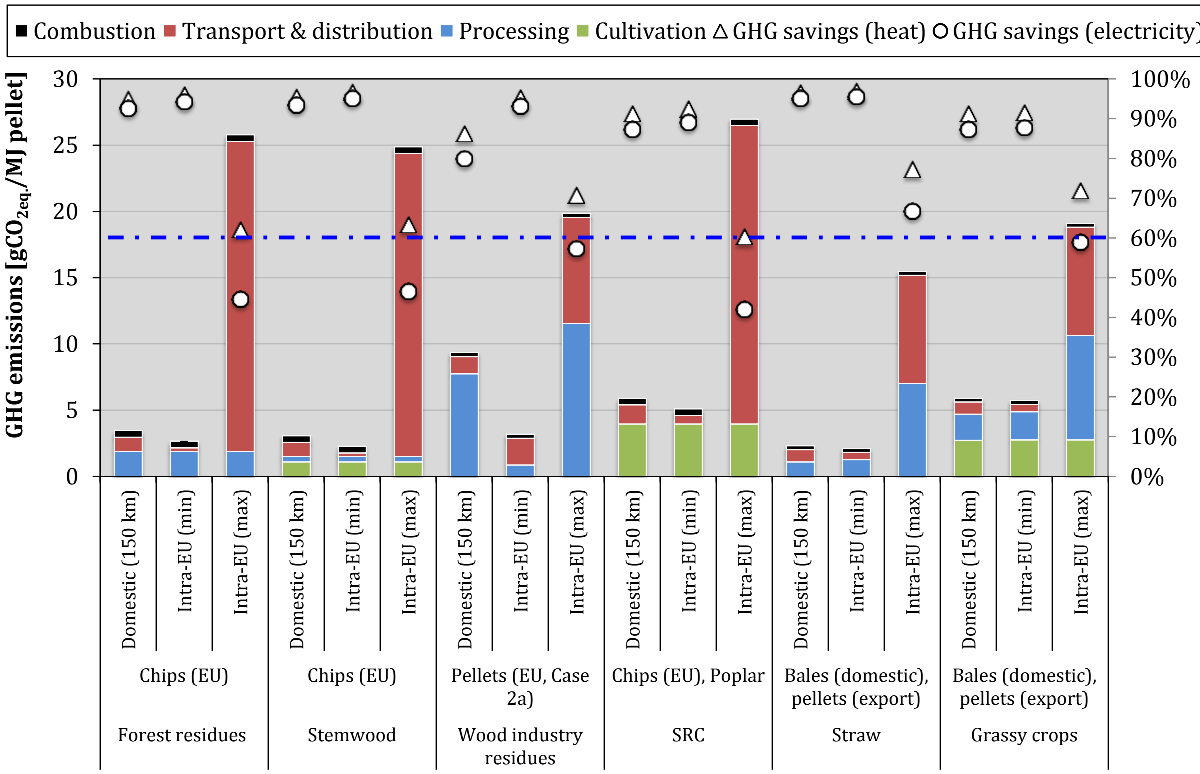
- EU/extra-EU Forest residues: A. Woodchips from forest logging residues (Pathway no 1)
- EU/extra-EU Stemwood: D. Woodchips from stemwood (Pathway no 4)
- EU/extra-EU Wood industry residues: C. Pellets from wood industry residues (Pathway no 7)
- Agricultural residues:
    - EU Straw, domestic: A. Agricultural residues with bulk density <0.2 tonne/m3 (Pathway no 11)
    - EU Straw, exported: C. Straw pellets (Pathway no 13)
    - Extra-EU Brazil: D. Bagasse pellets/briquettes (Pathway no 14)
    - Extra-EU Southeast Asia: F. Palm kernel meal (Pathway no 16) (open pond and closed pond)
- Grassy crops:
    - EU Domestic: E. Miscanthus bales
    - EU Export: E Miscanthus bales
- Short rotation coppice (SRC)
    - EU: B2. Woodchips from SRC – Poplar (pathway no 2b-c)
    - Extra-EU: B1. Pellets from SRC – Eucalyptus (Pathway no 6a)

Furthermore, the calculated emissions of solid bioenergy pathways are different from the reported values by JRC (Giuntoli *et al.*, 2015) for the following aspects:

- Country specific electric emission coefficients were used instead of the EU28 standard value. These were derived from the additional standard values from the BIOGRACE II tool (BIOGRACE II, 2015);
- Transport chains of international bioenergy pathways are calculated based on country-to-country specific trade routes as explained in Section **Error! Reference source not found.**.
- Grassy crops were eliminated from the JRC study due to lack of reliable data because the market of miscanthus cultivation is not yet well developed (Giuntoli *et al.*, 2015). For the purpose of the BioSustain project, the eliminated results are included because grassy crops are key feedstocks in the Green-X model.

Because of the low bulk density of straw and miscanthus bales, these feedstocks were assumed to be pelletized if exported. Due to handling difficulties, wood industry residues (sawdust) were assumed to be pelletized for domestic uses and exported. All other wood sources were assumed to be transported as wood chips. Due to the low bulk density of wood chips, this could lead to higher emissions if transported over long distances compared to transport of wood pellets. This is the main reason why the ranges between lowest and highest emissions from exported wood chips are higher than exported wood pellets or agri-pellets.

Figure 9-13. GHG emissions and typical GHG savings52 for domestic and ranges of intra-EU solid biomass, adapted from JRC (Giuntoli et al., 2015) with specific transport chains.

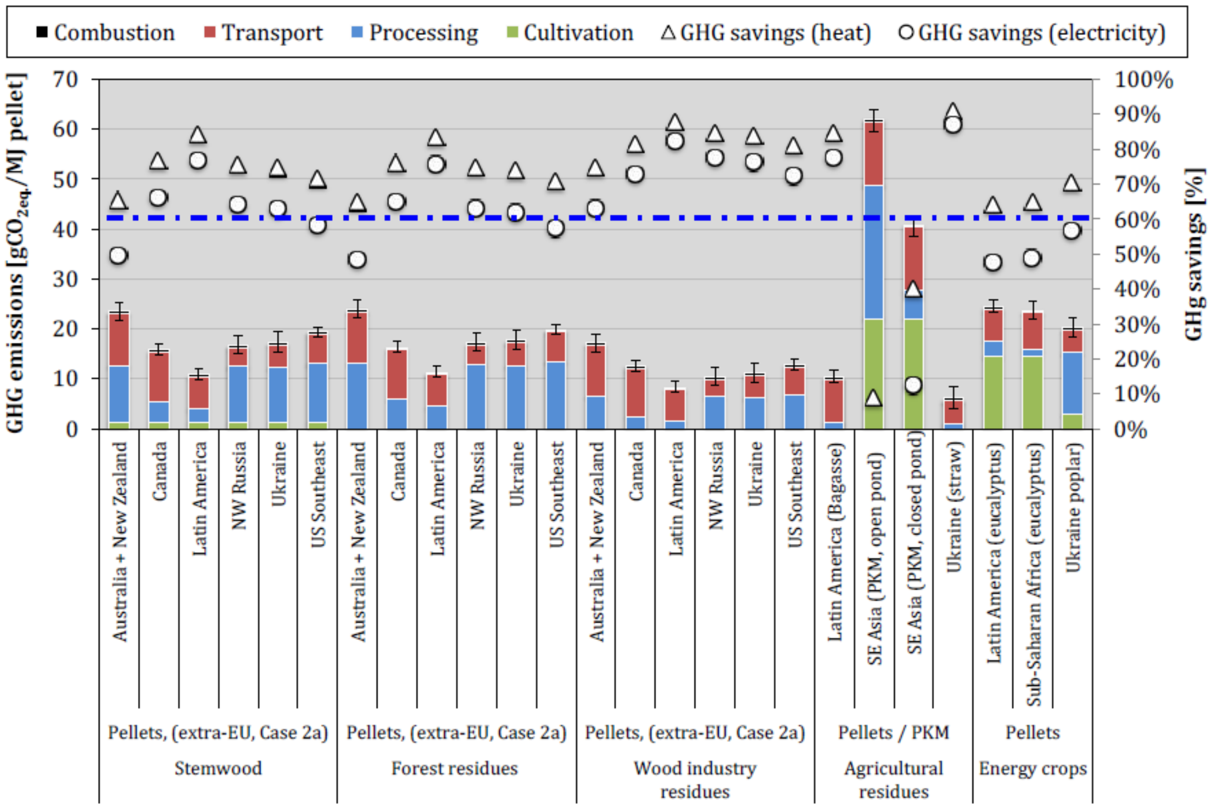


The GHG emissions of extra-EU imported solid biomass are in general higher than emissions of domestic sources of biomass. However, large bulk ocean carriers are relatively efficient compared to road or rail transport. In some cases, GHG emissions of overseas imported biomass pathways are therefore lower than solid biomass traded between EU member states.

Emission from palm kernel meal, a co-product from palm oil production are allocated according to the RED method (energy content, wet LHV). Waste water from palm oil processing results (palm oil mill effluent, POME) is often treated in open ponds leading to high methane emissions. These emissions can be reduced substantially if processed in a closed pond. Both pathways, as calculated by JRC, are depicted in Figure 9-14.

[52] GHG savings are calculated according to COM(2010)11: $GHG\ savings = \frac{FFC - GHG\ bioenergy}{Fcc} * 100$ where $FFC_{electricity}$ (fossil fuel comparator) = 186 g CO_2eq / MJ_{el} and FFC_{heat} = 80 g CO_2eq/$MJ_{heat.}$ Please note that GHG savings depend on the actual system efficiency, as calculated with the Green-X model.

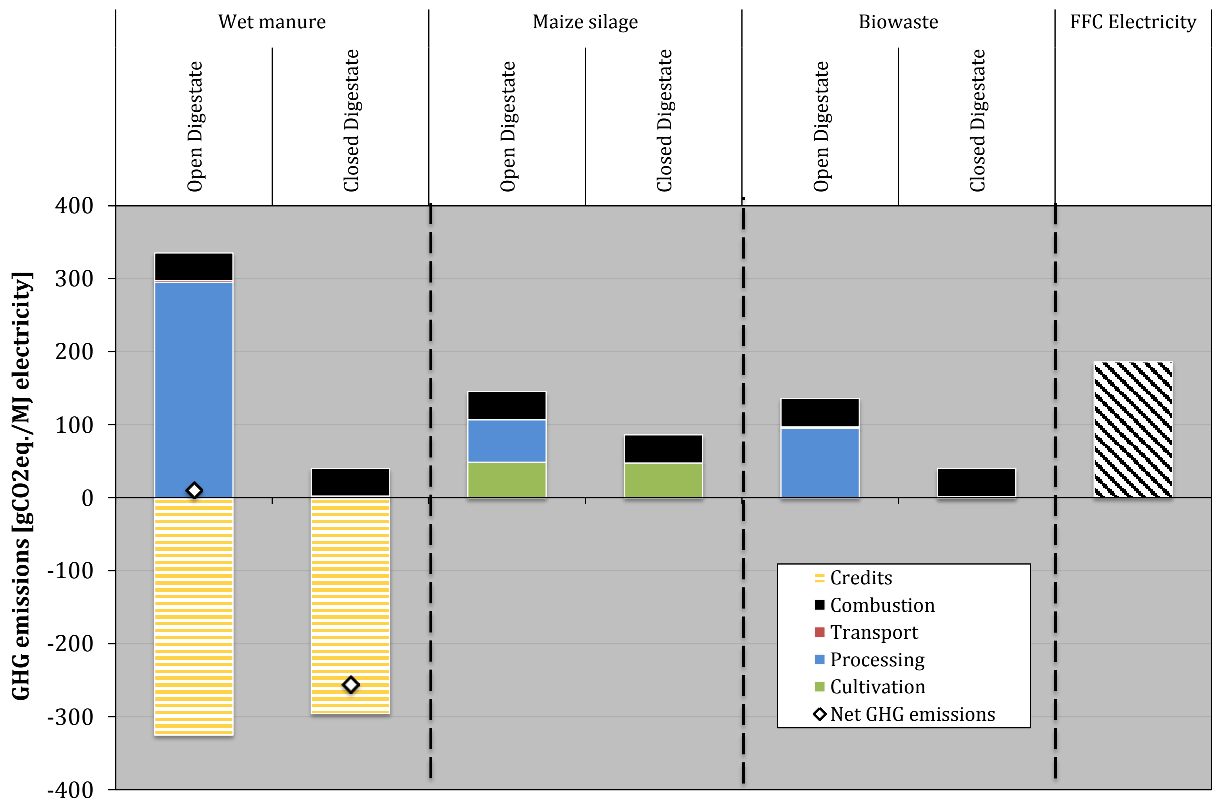
Figure 9-14. Average GHG emissions and typical GHG savings53 for extra-EU solid biomass, adapted from JRC (Giuntoli et al., 2015) with specific transport chains. Error bars show the ranges between EU member states



GHG emissions of gaseous bioenergy pathways from co-digestion (manure and maize) and waste do not entail international transport and are therefore directly derived from JRC as shown in **Error! Reference source not found.**. Note however that the typical values will be used. For the calculation of the default values shown below, emissions from processing, transport and fuel use are increased with 20% compared to the default values (Giuntoli *et al.*, 2015).

[53] GHG savings are calculated according to COM(2010)11: $GHG\ savings = \frac{FFC - GHG\ bioenergy}{Fcc} * 100$ where $FFC_{electricity}$ (fossil fuel comparator) = 186 g CO_2eq / MJel and FFC_{heat} = 80 g CO_2eq/MJ_{heat}.

Figure 9-15. Default GHG emissions for electricity production from non-upgraded biogas (Giuntoli et al., 2015)



9.2.2 Liquid biofuels

Emissions from liquid transport fuels are based used on JRC, as presented in the EU RED for current production systems. Future improvements and associated emissions and GHG savings are derived from COWI (COWI Consortium, 2009) as shown in

Table 9-2 and based on the following assumptions:

- N_2O Emissions from N-fertilizer plants will be reduced with 90% by application of end-of-pipe technologies;
- 25% reduction in CO_2 emissions from N-fertilizer production by 2020;
- 5% reduction in GHG emissions other than related to N-fertilizer consumption by 2020;
- 10% reduction in CO_2 emissions from biofuel processing by 2020.

Table 9-2. Typical biofuel GHG emissions and savings today, in 2017 and new installations in 2018 (COWI Consortium, 2009). Biofuel production systems that do not meet the GHG saving threshold value of 50% are colored red.

Biofuel, chain	GHG emitted (g CO_2eq/MJ)			Typical GHG saving (%)		
	2010	2017	>2018	2010	2017	>2018
Bioethanol (1st generation)						
Wheat						
lignite as process fuel in CHP plant	57	50	48	32%	40%	43%
natural gas as process fuel in conv. boiler	46	41	38	45%	51%	55%
natural gas as process fuel in CHP plant	39	34	31	53%	59%	63%
Corn (maize)						
natural gas as process fuel in CHP plant)	37	33	31	56%	61%	63%
Biodiesel						
Rape seed	46	39	37	45%	53%	56%
Soy bean	50	47	46	40%	43%	45%

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Appendix A: Background statistics

1. Agricultural land use and forest area in the EU28 (1000 ha)
2. Bioenergy balance in Europe
3. Use of woody biomass assortments in the consumer sectors (Mm^3)
4. Use of woody biomass assortments in the consumer sectors (Mtoe)

Table A 1 Agricultural land use and forest area in the EU28 (1000 ha) (Published in AEBIOM 2015, source Eurostat 2015)

Agricultural land use and forest area in the EU28 (1000 ha)

	Utilised agricultural area (UAA)[a]	Arable land[a]	Permanent grass land[a]	Permanent crops[a]	Total area of forests and other wooded land[b]	Forests[b]	Other wooded land[b]	Forests available for wood supply[b]
EU28	**180,528**	**111,622**	**56,969**	**9,257**	**179,477**	**159,113**	**20,364**	**134,968**
BE	1,339	818	498	18	706	678	28	672
BG	4,995	3,462	1,381	135	3,927	3,927	0	2,864
CZ	3,521	2,505	974	41	2,657	2,657	0	2,330
DK	2,664	2,435	216	6	635	587	48	581
DE	16,700	11,876	4,621	200	11,076	11,076	0	10,568
EE	966	628	325	3	2,337	2,203	134	2,013
IE	4,478	1,113	3,363	1	788	737	50	622
EL	3,959	1,514	1,081	1,211	6,539	3,903	2,636	3,595
ES	23,649	12,390	6,486	4,661	27,748	18,173	9,574	14,915
FR	28,976	18,373	9,439	1,015	17,572	15,954	1,618	15,147
HR	1,302	874	350	75	2,474	1,920	554	1,741
IT	17,277	12,885	2,461	:	10,916	9,149	1,767	8,086
CY	89	59	2	28	387	173	214	41
LV	1,878	1,208	663	6	3,467	3,354	113	3,138
LT	2,891	2,288	568	28	2,249	2,165	84	1,875
LU	131	63	67	2	88	87	1	86
HU	5,340	4,326	759	174	2,039	2,039	0	1,726
MT	12	9	0	1	0	0	0	0
NL	1,848	1,029	773	37	365	365	0	295
AT	2,862	1,354	1,441	65	3,991	3,857	134	3,343
PL	14,410	10,760	3,206	412	9,319	9,319	0	8,532
PT	3,721	1,167	1,817	722	3,611	3,456	155	1,822
RO	13,905	8,746	4,717	325	6,733	6,573	160	5,193
SI	479	174	277	27	1,274	1,253	21	1,175
SL	1,929	1,363	514	20	1,938	1,938	0	1,775
FI	2,259	1,969	31	3	23,116	22,084	1,032	19,869
SE	3,030	2,590	437	3	30,625	28,605	2,020	20,554
UK	17,259	6,272	10,940	36	2,901	2,881	20	2,411

a) In 2013, but with 2012 data for BG, DK, IT.

b) In 2010

Table A 2 Bioenergy balance in Europe in 2013 (ktoe) (AEBIOM, 2015)

	Primary energy Production	Import	Export	Gross inland consump-tion	Input to Power and CHP plants	Input to heating plants	Final energy consump-tion	Final use industry	Final use residential	Final use services	Final use transport	Final use other sectors[1]	Bio-electricity	Derived heat
EU28	123,316	13,027	8,107	128,116	42,278	4,696	105,116	20,015	41,599	3,014	13,135	1,973	13,522	11,858
BE	5,321	1,182	499	5,847	1,408	562	5,163	1,355	1,707	80	490	245	399	887
BG	2,335	667	111	2,895	1,167	4	2,188	685	611	37	329	48	4226	5
CZ	2,830	209	241	2,793	797	28	2,371	413	1,141	54	275	83	290	115
DK	2,183	1,170	38	3,302	1,487	48	3,052	187	855	36	223	58	382	1,311
DE	23,799	1,184	1,019	23,965	9,720	937	17,633	1,929	6,397	1,250	2,943	1	3837	1,276
EE	1,015	18	179	821	241	96	773	76	389	12	4	2	86	204
IE	320	79	0	397	112	0	346	154	28	23	104	-1	38	0
EL	1,213	167	24	1,356	73	0	1,335	191	909	24	124	69	18	0
ES	6,042	1,938	474	7,532	1,259	0	6,422	1,269	2,459	72	2,087	107	428	0
FR	13,785	437	116	14,106	2,072	314	12,825	1,245	7,389	291	2,694	62	451	693
HR	740	5	201	545	35	0	516	51	409	3	37	3	8	5
IT	6,568	2,762	56	9,306	3,969	95	6,927	235	3,576	46	1,368	51	1074	577
CY	23	14	0	37	7	0	41	3	3	1	16	13	4	1
LV	2,003	37	652	1,329	90	141	1,232	295	663	95	22	12	25	120
LT	1,111	151	203	1,075	99	220	1,016	86	561	35	61	11	19	243
LU	74	52	8	118	18	2.4	105	23	18	1	49	3	8	3
HU	1,764	79	270	1,571	478	20	1,292	63	724	125	155	15	142	68
MT	4	2	0	6	1	0	4	0	1	0	2	-1	1	1
NL	3,282	715	1,015	2,998	2,042	0	1,711	87	303	54	335	83	619	230
AT	5,408	917	445	5,890	1,631	529	5,013	1,255	1,680	69	479	253	399	878
PL	7,866	198	46	8,012	2,580	40	6,722	1,036	2,791	227	823	510	868	467
PT	2,757	25	271	2,771	645	0	2,377	1,047	759	1	275	41	254	0
RO	3,954	174	240	3,900	47	47	3,902	262	3,284	0	218	69	18	51
SI	599	55	4	649	69	10	623	46	471	2	51	1	23	29
SK	1,033	30	106	958	452	71	691	271	37	18	91	17	81	176
FI	8,437	270	256	8,452	2,835	595	8,430	3,182	1,334	81	266	179	961	2,427
SE	11,094	0	0	11,094	3,863	1,103	10,339	4,036	1,219	52	588	215	1,049	3,180
UK	4,700	1,518	230	5,991	3,975	84	3,240	398	390	91	882	121	1,307	51

1) Mainly Agricultural and forestry sectors Source: Eurostat September 2014, AEBIOM calculations

Table A 3 and Table A 4 show in more detail the use of woody biomass in the consumer sectors of material and energy uses. It should be born in mind, that data actualisation of consuming sectors is part of Task 2. This part will be actualised on the basis of Task 2 results. However, the relative distribution of the resource mix is quite stable.

Table A 3 Use of woody biomass assortments in the consumer sectors (in hm³) (Mantau et al., 2010)

in M m³	stemwood	forest residues	bark	landscape c.w.	saw mill by p.	other ind. res.	black liq.	post cons. Wood	solid wood fuels	short rotation plant.	out of balance	
resources -->	STW	FRES	BRK	LCW	SBP	OIR	BLL	PCW	SWF	SRP	OUT	
Consumer	2010 hm³	2010 hm³	2010 hm³	2010 hm³	2010 hm³	2010 hm³	2010 hm³	2010 hm³	2010 hm³	2010 hm³	2010 hm³	2010 hm³
sawmill industry	196.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	196.4
veneer plywood	11.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.4
pulp industry	102.1	5.7	0.0	0.0	34.0	0.0	0.0	0.0	0.0	0.0	0.0	141.8
panel industry	31.8	3.4	2.8	0.0	30.7	8.2	0.0	15.5	0.0	0.0	0.0	92.3
other material uses	9.6	0.0	5.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.8
forest sect. intern. use	0.0	5.1	19.7	0.0	0.0	0.0	59.8	0.9	0.0	0.0	0.0	85.5
biomass power plants	7.5	8.3	6.7	17.5	6.7	21.6	0.0	12.1	2.5	0.5	0.0	83.3
households (pellets)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	29.3	0.0	0.0	29.3
households (other)	85.0	13.9	15.5	15.5	1.5	0.0	0.0	7.7	0.0	0.0	15.5	154.5
liquid biofuels	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
producer of wood fuels	9.6	2.8	1.4	0.0	13.8	0.0	0.0	0.0	0.0	0.0	0.0	27.6
total	**453.4**	**39.2**	**51.1**	**32.9**	**86.7**	**29.8**	**59.8**	**36.1**	**31.8**	**0.5**	**15.5**	**836.8**

Table A 4 Use of woody biomass assortments in the consumer sectors (in Mtoe) (Mantau et al., 2010)

in Mtoe	stemwood	forest residues	bark	landscape c.w.	saw mill by p.	other ind. res.	black liq.	post cons. Wood	solid wood fuels	short rotation plant.	out of balance	
resources -->	STW	FRES	BRK	LCW	SBP	OIR	BLL	PCW	SWF	SRP	OUT	
Consumer	2010 Mtoe	2010 Mtoe	2010 Mtoe	2010 Mtoe	2010 Mtoe	2010 Mtoe	2010 Mtoe	2010 Mtoe	2010 Mtoe	2010 Mtoe	2010 Mtoe	2010 Mtoe
sawmill industry	41,3	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	41,3
veneer plywood	2,4	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	2,4
pulp industry	21,5	1,2	0,0	0,0	7,2	0,0	0,0	0,0	0,0	0,0	0,0	29,8
panel industry	6,7	0,7	0,6	0,0	6,5	1,7	0,0	3,3	0,0	0,0	0,0	19,4
other material uses	2,0	0,0	1,1	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	3,1
forest sect. intern. use	0,0	1,1	4,1	0,0	0,0	0,0	12,6	0,2	0,0	0,0	0,0	18,0
biomass power plants	1,6	1,8	1,4	3,7	1,4	4,6	0,0	2,5	0,5	0,1	0,0	17,5
households (pellets)	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	6,2	0,0	0,0	6,2
households (other)	17,9	2,9	3,3	3,3	0,3	0,0	0,0	1,6	0,0	0,0	3,3	32,5
liquid biofuels	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
producer of wood fuels	9,6	2,8	1,4	0,0	13,8	0,0	0,0	0,0	0,0	0,0	0,0	27,6
total resorces	**103,0**	**10,4**	**11,8**	**6,9**	**29,1**	**6,3**	**12,6**	**7,6**	**6,7**	**0,1**	**3,3**	**197,8**

Appendix B: Basic assumptions on biomass supply from forests and environmental constraints 2010-2030[54]

Each of the environmental and technical constraints was quantified separately for the type of biomass (i.e. stemwood, logging residues and stumps) and by type of felling activity (i.e. early thinning, thinnings and final felling).

The projections were based on detailed National Forest Inventory (NFI) data on species and forest structure and provided the theoretical biomass potentials from broadleaved and coniferous tree species separately from:

- Stemwood
- Logging residues (i.e. stem tops, branches and needles)
- Stumps
- Early thinnings (thinning in very young stands; also referred to as pre-commercial thinnings)

EUwood defined multiple environmental, technical, social and economic constraints that reduce the amount of biomass that can be extracted from forests. These constraints were quantified for three mobilisation scenarios. The forest following inventory data that were used in the EUwood/EFSOS II study

Table B 1 Forest inventory data sets used for EFISCEN model

Country	Year inventory	Country	Year inventory
Austria	2001-2002	Italy	2005-2008
Belgium	1997–1999	Latvia	2004-2008
Bulgaria	2000	Lithuania	2000
Croatia	1995	Luxembourg	1989
Czech Republic	2005	Netherlands	2001-2005
Denmark	2000	Poland	1993 (2010)
Estonia	1999–2001	Portugal	1997–1998
Finland	2004-2008	Romania	1985
France	1988–2000	Slovak Republic	1994
Germany	2001-2002 (2012)	Slovenia	2000
Greece	n.a.	Spain	1986–1995
Hungary	2005	Sweden	2004-2008
Ireland	2004-2005	United Kingdom	1995–2000

Detailed forest inventory data were not available for Cyprus, Greece and Malta. Instead, EUwood used aggregated data on forest area and net annual increment from MCPFE, UNECE and FAO (2007) and Meliadis et al. (2010). The new inventory in Germany (2012) is integrated in this study proportionally to the higher NAI (121 instead of 107 M m³).

Each of the environmental and technical constraints were quantified separately for the **type of biomass** and by type of felling activity:

- Stem biomass during early thinnings
- Crown biomass during early thinnings
- Logging residues from final fellings
- Logging residues from thinnings
- Stumps from final fellings
- Stumps from thinnings

Within each type of biomass environmental and technical constraints were quantified separately for the **type of constraint**:

- Site productivity
- Soil and water protection: Slope
- Soil and water protection: Soil depth
- Soil and water protection: Soil surface texture
- Soil and water protection: Soil compaction risk
- Biodiversity: protected forest areas
- Recovery rate
- Soil bearing capacity

For the **mobilization scenarios** the maximum extraction rates were calculated for:

- Current (2010) and medium mobilisation (BioSustain **Reference** scenario)
- High mobilisation (BioSustain **Resource** scenario)
- Low mobilisation (Biosustain **Resticted** scenario)

The types of constraints for stem biomass from **early thinnings** are not that relevant because of the selective harvesting method and the contribution to the stability and growth of the stand. However, for soils and water protection the utilization is 0% on slopes over 35%. No constrains were assumed for slopes up to 35%. The extraction rate was assumed by 95%.

Crown biomass during early thinnings is not utilized in the medium and low mobilization scenario. If early thinnings are not restricted additional restrictions are assumed for peatland (35% medium, 40% high, 0% low). If crown biomass utilization is not restricted the extraction rate was assumed by 80%.

More relevant for biomass availability from residues is their potential for final fellings. The maximum extraction rates for extracting logging residues from final fellings are shown in detail in the following table.

Table B 2 Maximum extraction rates for extracting logging residues from final fellings

Type of constraint	Current (2010) and medium mobilisation (Reference)	High mobilisation (Resource)	Low mobilisation (Restricted)
Site productivity	Not a constraining factor		35% extraction rate on poor soils; not a constraining factor on other soils
Soil and water protection: Slope	Not a constraining factor on slopes up to 35%; 0% on slopes over 35%, unless cable-crane systems are used		
Soil depth	0% on Rendzina, Lithosol and Ranker (very low soil depth)		
Soil surface texture	0% on peatlands	33% on peatlands	0% on peatlands
Soil and water protection: Soil compaction risk	0% on soils with very high compaction risk; 25% on soils with high compaction risk	0% on soils with very high compaction risk; 50% on soils with high compaction risk	0% on soils with high or very high compaction risk; 50% on soils with medium compaction risk
Biodiversity: protected forest areas	No utilization at all (0%); not a constraining factor in areas with high or very high fire risk		
Recovery rate	67% on slopes up to 35%; 0% on slopes over 35%, but 67% if cable-crane systems are used		
Soil bearing capacity	0% on Histosols, Fluvisols, Gleysols and Andosols. Not a constraining factor in Finland and Sweden in the high mobilization scenario		

The maximum extraction rates for extracting logging residues from thinnings are much more restricted. No residues at all are extracted in the low mobilisation scenario. In the medium mobilization scenario site productivity restrict the extraction to 0% on poor soils and to 33% on other soils. In the high mobilisation scenario it is restricted to 67% on all soils. Soil and water protection restricts the extraction on slopes up to 35%. Extraction on peatlands is only allowed in the high mobilisation scenario up to 33%. In case extraction is not restricted by the above mentioned circumstances the recovery rate is 67% on slopes up to 35%, 0% on slopes over 35%, but 47% if cable-crane systems are used.

Stumps from final fellings are not utilized in the low mobilization scenario. The differences between the medium and high mobilisation scenarios are shown in the following table.

Stumps from thinnings are not utilized in the medium and low mobilization scenario. The restrictions for the high mobilisation scenario are similar to the restrictions from final felling.

Table B 3 Maximum extraction rates for extracting stumps from final fellings

Type of constraint	Current (2010) and medium mobilisation (Reference)	High mobilisation (Resource)
Countries	Finland, Sweden, UK	All
Species	Conifers	All
Site productivity	15% on poor soils; 33% on other soils	33% on poor soils; 67% on other soils
Soil and water protection:	0% on slopes over 20%; not a	0% on slopes over 35%; not a

Slope	constraining factor on slopes up to 20%	constraining factor on slopes up to 35%
Soil and water protection: Soil surface texture	0% on peatlands	33% on peatlands
Soil and water protection: Soil depth	0% on soils < 40 cm (including Rendzina, Lithosol and Ranker); 33% on soils >40 cm	0% on soils < 40 cm (including Rendzina, Lithosol and Ranker); 67% on soils >40 cm
Soil and water protection: Soil compaction risk	0% on soils with very high compaction risk; 15% on soils with high compaction risk	0% on soils with very high compaction risk; 33% on soils with high compaction risk
Biodiversity: protected forest areas	0%	
Recovery rate	Not a constraining factor	
Soil bearing capacity	0% on Histosols, Fluvisols, Gleysols and Andosols; not a constraint in Finland and Sweden	

Table A 5 Maximum extraction rates for extracting logging residues from thinnings

Type of constraint	Current (2010) and medium mobilisation (Reference)	High mobilisation (Resource)	Low mob. (Restricted)
Site productivity	0% on poor soils; 33% on other soils	67%	0%
Soil and water protection: Slope	Not a constraining factor on slopes up to 35%; 0% on slopes over 35%, unless cable-crane systems are used	Not a constraining factor on slopes up to 35%; 0% on slopes over 35%, unless cable-crane systems are used	0%
Soil and water protection: Soil depth	0% on Rendzina, Lithosol and Ranker (very low soil depth)	0% on Rendzina, Lithosol and Ranker (very low soil depth)	0%
Soil and water protection: Soil surface texture	0% on peatlands	33% on peatlands	0%
Soil and water protection: Soil compaction risk	0% on soils with high compaction risk; 25% on soils with high compaction risk	0% on soils with very high compaction risk; 50% on soils with high compaction risk	0%
Biodiversity: protected forest areas	0%; not a constraining factor in areas with high or very high fire risk	0%; not a constraining factor in areas with high or very high fire risk	0%
Recovery rate	67% on slopes up to 35%; 0% on slopes over 35%, but 47% if cable-crane systems are used Cable cranes are applied in Austria, Italy, France, Germany, Czech Republic, Slovakia, Slovenia, Romania	67% on slopes up to 35%; 0% on slopes over 35%, but 47% if cable-crane systems are used Cable cranes are applied in Austria, Italy, France, Germany, Czech Republic, Slovakia, Slovenia, Romania, Bulgaria	0%
Soil bearing capacity	0% on Histosols, Fluvisols, Gleysols and Andosols	0% on Histosols, Fluvisols, Gleysols and Andosols ,not a constraint in Fennoscandia	0%

For further clarifications see: Verkerk, Eggers, Anttila, Lindner, Asikainen, (2010)

Table A 6 Maximum extraction rates for extracting stumps from final fellings

Type of constraint	Current (2010) and medium mobilisation (Reference)	High mobilisation (Resource)	Low mob. (Restricted)
Countries	Finland, Sweden, UK	All countries	0%
Species	Conifers	All species	0%
Site productivity	15% on poor soils; 33% on other soils	33% on poor soils; 67% on other soils	0%
Soil and water protection: Slope	0% on slopes over 20%; not a constraining factor on slopes up to 20%	0% on slopes over 35%; not a constraining factor on slopes up to 35%	0%
Soil and water protection:	0% on peatlands	33% on peatlands	0%
Soil and water protection: Soil depth	0% on soils < 40 cm (including - see right → 33% on soils >40 cm	0% on soils < 40 cm (including Rendzina, Lithosol and Ranker); 67% on soils >40 cm	0%
Soil and water protection: Soil compaction risk	0% on soils with very high compaction risk; 15% on soils with high comp. risk	0% on soils with very high compaction risk; 33% on soils with high compaction risk	0%
protected forest	0%	0%	0%
Recovery rate	Not a constraining factor	Not a constraining factor	0%
Soil bearing capacity	0% on Histosols, Fluvisols, Gleysols and Andosols	0% on Histosols, Fluvisols, Gleysols and Andosols;	0%

Table A 7 Maximum extraction rates for extracting stumps from thinnings.

Type of constraint	medium mob. (Reference)	High mobilisation (Resource)	Low mob. (Restricted)
Countries	0%	All countries	0%
Species	0%	All species	0%
Site productivity	0%	33% on poor soils; 67% on other soils	0%
Soil and water protection: Slope	0%	0% on slopes over 35%; not a constraining factor on slopes up to 35%	0%
Soil and water protection:	0%	33% on peatlands	0%
Soil and water protection: Soil depth	0%	0% on soils < 40 cm (including Rendzina, Lithosol and Ranker); 67% on soils >40 cm	0%
Soil and water protection: Soil compaction risk	0%	0% on soils with very high compaction risk; 33% on soils with high comp.risk	0%
protected forest areas	0%	0%	0%
Recovery rate	0%	Not a constraining factor	0%
Soil bearing capacity	0%	0% on Histosols, Fluvisols, Gleysols and Andosols;	0%

Appendix C: Selected studies for review

Selected studies for agriculture biomass potentials

The review builds upon the insights provided in the BEE project, therefore this review included studies published since 2010. The included studies cover global (including Europe as a world region), and European biomass resource potentials and take specifically into account sustainability targets. The studies estimate the potential from agriculture for different timeframes (i.e. current, 2020 and 2030). Table C 1 lists the reviewed studies and their general characteristics; in addition a short description of the studies is given below. The review focused on identifying the included sustainability constraints. Potential ranges were therefore not standardised for timeframe and area coverage. Where possible, the bioenergy potential was distinguished by feedstock: 1) oil, starch, and sugar (OSS) crops; 2) lignocellulosic (LC) crops; 3) agricultural residues, including straw, grassland cutting and harvest residues.

A short characterisation of the studies estimating the *energy crop* potential:

- Allen et al. (2014) focuses on the question of how much additional production of energy crops might be achieved in the European Union at this moment.
- The integrated assessment model LPJmL was used by Beringer et al. (2011) and Schueler et al. (2013). Beringer et al. (2011) assessed the global biomass potentials under environmental and agricultural constraints by using four scenarios varying on two criteria, namely (1) intensification of food production and (2) biodiversity and nature conservation. The article provides only global biomass potentials, the constraints applied in the study are however included in the discussion of ecological sustainability constraints section in this report. Schueler et al. (2013) quantify the effect of the RED sustainability criteria on the theoretical biomass potential.

A short characterisation of the studies estimating the *agricultural residues* potential:

- Daioglou et al. (2015) estimated the residue potential with the IMAGE 3.0 model for three scenario based on the Shared Socioeconomic Pathways (SSP) scenarios of the IPCC. The results included in this review are from the SSP2 scenario, including projections based on extrapolation of current trends.
- The studies of Scarlat et al. (2010) and Monforti et al. (2013) develop an approach to estimate the agricultural residue potential. This approach is often used in other studies (Elbersen et al. 2012; Bentsen et al. 2014; Elbersen et al. 2014) to estimate the agricultural residue potential.
- Spöttle et al. (2013) assesses the primary agricultural residue potentials in only ten selected EU Member State countries. This study provides key insights in sustainable removal rates and the competitive use of straw.

A short characterisation of the studies estimating both the *energy crop and agricultural residues* potential:

- Böttcher et al. (2010) demonstrates the harmonised methods for statistical, spatially-explicit and integrated assessment approaches developed in the BEE project in various illustration cases.

- The study done by ETC/SIA (2013), of which an analytical summary is provided by EEA (2013a), re-evaluates the bioenergy potential in the EU. The study builds upon previous work of the EEA (2006). Three alternative futures, so-called storylines, were developed differing in environmental, technological and policy developments. A detailed description of the different storylines can be found in EEA (2013a).
- A reference and a sustainability scenario are defined in the Biomass Futures project (Böttcher *et al.*, 2012; Elbersen *et al.*, 2012a). Stricter sustainability criteria regarding GHG mitigation targets and limitations on the use of land with high biodiversity and high carbon stocks apply to the sustainability scenario.
- The EEA (2013a) and Biomass Futures studies use the same modelling framework. Besides, for the estimation of minimal GHG emissions requirement the same approach was used, as well as for the estimation of high biodiverse and high carbon stock areas (Elbersen *et al.*, 2012a). In addition, EEA (2013a) based the estimated costs of supplying different forms of biomass in 2020 on data from the Biomass Futures project (Elbersen *et al.*, 2012a).
- The assessment of potential and related costs in the Biomass Policies project (Elbersen *et al.*, 2015) builds upon the results of the Biomass Futures project. The Biomass Policies project is ongoing. The report of Elbersen et al. (2015) included in this review presents the biomass potentials for the baseline scenario, which is considered as a business as usual scenario (Elbersen *et al.*, 2015).
- Fischer et al. (2010) estimate land and agricultural residues potentials for three scenarios, differing in land use and environmental policy preferences. De Wit & Faaij (2010) base their assessment on the work of Fischer et al. (2010), but use different yield data and conversion factors.

Table C 1 General characteristics of the included biomass potential studies

Reference	Objective of study	Spatial coverage	Spatial resolution	Timeframe	Method	Model(s)	Biomass categories						Type of potential
							OSS crops*	LC crops**	Agri residues	Forest	Forest residues	MSW	
Allen et al. (2014)	Estimation of additional production of dedicated energy crops within Europe, given land availability limitations.	EU-28	EU-28	Current	Statistical method			✓					Technical
Bentsen et al. (2014)	Estimation of agricultural residues potential and residue yields potentially achievable through agricultural intensification.	global	World regions (N, S, W Europe)	Current (2006-2008)	Statistical method				✓				Theoretical
Beringer et al. (2011)	Estimation of bioenergy potential from LC energy crops under a range of sustainability requirements to safeguard food production, biodiversity and terrestrial carbon storage.	global	Global	2050	Integrated modelling	LPJmL		✓					Ecologically sustainable
Böttcher et al. (2010)	Estimation of biomass potentials for bioenergy and demonstration of harmonised approaches developed within BEE.	EU-27	Member State / EU-27	2010, 2020, 2030	Statistical, spatially explicit, integrated modelling	EPIC, EUFASOM	✓	✓	✓	✓	✓		Theoretical, technical, economic (cost and supply), sustainable implementation
Böttcher et al. (2012)	Transformation of technical potentials from Elbersen et al. (2012) into economic potentials.	Global	Global, EU-27	2000, 2010, 2020, 2030	Integrated modelling	GLOBIOM	✓	✓					Economic
Daioglou et al. (*submitted*)	Assessment of the residues availability for advanced energy and material uses by investigating the mass flows of residues, accounting for ecological and current uses	Global	World regions (Western and Central Europe)	1971-2100 (yearly steps)	Integrated modelling	IMAGE			✓		✓		Theoretical, ecologically sustainable

de Wit & Faaij (2010)	Assessment of the European cost and supply potential for biomass resources.	EU+UA	NUTS-2	2030	Spatially explicit		✓	✓					Technical, economic (cost and supply)
EEA (2013); ETC/SIA (2013)	Review of the implications of resource efficiency principles for developing EU bioenergy production.	EU	EU	2020	Integrated modelling	CAPRI, MITERRA, GEMIS, GWSI, PRIMES, AGLINK-COSIMO	✓	✓	✓	✓	✓	✓	Ecologically sustainable
Elbersen et al. (2012)	Quantification of actual, 2020 and 2030 technically constrained biomass potentials according to scenarios.	EU-27	NUTS-2	2020, 2030	Integrated modelling	CAPRI, MITERRA, GLOBIOM, GEMIS	✓	✓	✓	✓	✓	✓	Ecologically sustainable
Elbersen et al. (Elbersen et al. 2014)	Assessment of biomass cost supply in EU-28 per MS and of the most suitable value chains to be developed in 11 focus countries.	EU-28	Member State / EU-28	2010, 2020, 2030	Integrated modelling	CAPRI, AGLINK-COSIMO	✓	✓	✓	✓	✓	✓	Economic (cost supply)
Monforti et al. (2013)	Geographical assessment of potential bioenergy production in the EU from agricultural residues.	EU-27	NUTS-2	Current	Spatially explicit method				✓				Ecologically sustainable
Pudelko et al. (2013)	Estimation of biomass potentials from agricultural and forest residues, and municipal waste.	EU-27+CH	NUTS-3	Current (2008-2011)	Statistical method				✓		✓	✓	Theoretical, technical
Scarlat et al. (2010)	Resource-based assessment of the available agricultural crop residues for bioenergy production in the EU.	EU-27	Member State	Current	Statistical method				✓				Ecologically sustainable
Schueler et al. (2013)	Quantification of the effect of EU sustainability criteria on theoretical biomass potential.	Global	World regions (OECD Europe)	2000	Integrated modelling	LPJmL	✓	✓					Ecologically sustainable
Spöttle et al. (2013)	*Assessment of the EU residues and waste potential with low ILUC risk that can be used for biofuel production.*	DK, DE, ES, FR, HU, IT, NL, PL, RO, UK	Country	Current (2002-2011)	Statistical method				✓		✓	✓	Ecologically sustainable
EUwood (2010)		EU27	Country	2030	Sector models and Gap projection					✓	✓		Theoretical, technical high, medium and low

EFSOS II (2013)		EFSOS regions	Country	2030	Sector models and Gap projection					✓	✓		Theoretical, technical baseline, energy
Hetemeki (editor (2014)		Europe	EU-regions	2030	Trend model + qualitative					✓	✓		No potentials, no energy analysed, wood industry focus

* OSS crops = oil, sugar and starch crops

** LC crops = lignocellulosic crop

Selected studies that determine Extra-EU export potentials of biomass

Assessments of biomass resources that have a global coverage mainly focus on determining the potential on the long-term in 2050 and few global studies present results for the short- to mid-term timeframe (2020 - 2030). This can be explained by the importance of this period in climate mitigation scenarios and modelling studies (Chum *et al.*, 2011; Slade *et al.*, 2011)[54]. Furthermore, the majority of global biomass resource studies lack geographic details and sector specific results that are needed to quantify the export potential of biomass.

The objective is not to determine the global biomass potential, rather, how the export potential is determined to support the development of up-to-date scenarios of extra-EU biomass supply available for import to the EU. The selection of studies for review in this section is therefore limited to studies that focus on the timeframe between 2020 and 2030 and do take international biomass trade into account. The selected studies for review are depicted in Table C 2.

[54] Of the 28 studies reviewed by the UK Energy Centre (UKEC) to provide insight in the sustainable potential of biomass taking sustainability concerns into account, 4 studies include results for the timeframe 2020 – 2030 (Slade *et al.*, 2011). Also the literature assessment in the IPCC Special Report on Renewable Energy Sources (Chum *et al.*, 2011) is mainly focused on the long-term to 2050.

Table C 2 General characteristics of the included studies for global biomass export

Reference	Method	Spatial coverage	Timeframe	Biomass categories	Type of potential
Pöyry (Lechner & Carlsson, 2014)	Demand-driven, based on technical supply potential, pellet mill capacity (growth) and wood paying capability in demand regions	US Southeast, Eastern Canada, Western Canada, Brazil, Northwest Russia	2014 - 2025	Pellets from forest products (pulp wood and other small roundwood), forest residues and unmobilized wood (sawlog and wood residues).	Economic-implementation (economic and market constraints)
Lamers et al. (2014c)	Supply based on past production and trade volumes, market expectations and expert interviews. Least cost supply - demand matching for resource allocation.	Supply: southeast and northeast USA, Canada (West and East coast), Northwest Russia, Brazil, Uruguay, Ukraine, Indonesia, Malaysia, Australia, and New Zealand	2010 - 2020	Pellets from forest products (pulp wood), forest residues and agriculture residues (agri-pellets). Palm kernel shells.	Economic-implementation (economic and market constraints). Sustainability constraints are applied by exclusion of resources (e.g. pulp grade roundwood)
Biomass Policies (Fritsche & Iriarte, 2014)	Cost supply curves, analysis based on literature review	Wood pellets: Russia (Northwest), US (Southeast), Canada (East), Brazil, Mozambique. EtOH: Brazil, Mozambique, 1G biodiesel: Argentina, Indonesia Biomethane: Russia (Northwest), Ukraine	2020 - 2030	Wood pellets, 1G biofuels, biomethane	Sustainable-implementation (sustainability and market constraints)
IEA Bioenergy Task 40 (Goh *et al.*, 2013)	Supply based on past production and trade volumes, market expectations.	Southeast and northeast USA, Canada (West and East coast), Northwest Russia, Brazil, Uruguay, Ukraine, Australia, and New Zealand	2010-2020, 2030 (high trade)	Pellets from forest products & residues, SRC.	Implementation (market constraints).
AEA (2011)	Forest biomass modeling (CARBINE) Agriculture biomass: literature review Demand outside based on IEA WEO projections (reference scenario)	Global supply. Focus on import potentials to the UK.	2010 - 2030	Forest products, forest residues, energy crops, agricultural residues. Liquid biofuels.	Sustainable-implementation (sustainability and market constraints). Sustainability constraints are applied by exclusion of resources (e.g. pulp grade roundwood).

IRENA (Nakada *et al.*, 2014)	Statistical method to determine the total potential. Surplus of domestic supply is considered exportable.	Global (demand based on 26 ReMAP countries)	2010-2030	Energy crops, forest products. Post-consumer waste, animal waste, forest products, forest residues	Economic potential.

Appendix D: Type of resource potentials

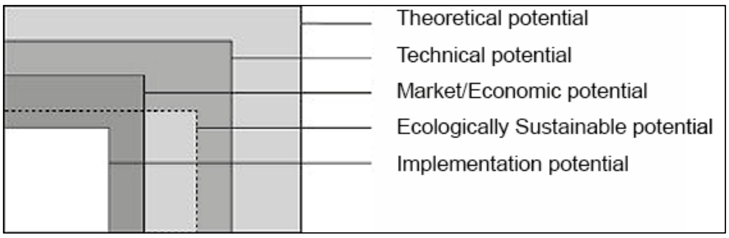
General constraints that determine the type of biomass potentials

A starting point for the analysis are the different types of biomass potentials distinguished in the Biomass Energy Europe (BEE) project (see Box 1) and the reduction in biomass potential as a result of applying technical, economic and ecologic constraints:

- The *theoretical potential* is defined as the overall maximum amount of terrestrial biomass which can be considered theoretically available for bioenergy production within fundamental bio-physical limits.
- The *technical potential* is defined as the fraction of the theoretical potential which is available under current technological possibilities, and taking into account spatial restrictions related to competition with other land uses (food, feed and fibre production), ecological (e.g. nature reserves) constraints and other non-technical constraints.
- The *economic potential* is defined as the fraction of the technical potential that meets criteria of economic profitability within the given framework conditions
- An *implementation potential* is defined, which refers to the fraction of the economic potential that can be implemented within a certain timeframe and under concrete socio-political framework conditions, including economic, institutional and social constraints and policy incentives.
- A *sustainable implementation potential*, integrating environmental, economic and social sustainability criteria which act like a filter on the different potentials leading in the end to a sustainable implementation potential.

Ecological constraints other than nature protection are not explicitly considered in the technical potential. By applying environmental constraints to the technical potential, the ecological potential can be determined. Additional economic and social criteria can be applied to the economic potential to quantify the sustainable-implementation potential. Most studies often consider other ecological constraints, such as soil, water and biodiversity preservation. As this review focuses on identifying those ecological constraints included we defined an additional potential, namely the *ecologically sustainable potential*. This potential refers to the fraction of the technical potential considering restrictions related to environmental criteria such as soil, water and biodiversity preservation (Batidzirai *et al.*, 2012). The criteria included for the estimation of the ecologically sustainable potential differ per study.

Figure 0-1 - Hierarchy and overlap between different types of biomass resource potentials (Batidzirai et al. 2012)



Box 1: Biomass Energy Europe (BEE)

- Research area: FP 7 - ENERGY-2007-3.7-01 Harmonisation of biomass resource assessment
- Project duration: March 2009 – November 2011
- BEE Partners: 16 partners from 9 European countries
- Website: http://www.eu-bee.eu/

The main goal of the IEE project Biomass Energy Europe (BEE) was to harmonize biomass resource assessments in Europe and neighbouring regions in order to improve consistency, accuracy and reliability of biomass assessments for energy. In total, 55 studies published were quantitatively analysed. The BEE project identified large variations in the results of biomass potentials for the same geographic region ranging between 2.8 EJ to 23.8 EJ (67 – 568 Mtoe). Key reasons were inconsistencies in definitions and lack of detailed data, methods used and assumptions on external factors including land use and biomass production for non-energy sectors (food, feed and fibre). Furthermore, 28 studies (from a database of 250 bioenergy potential assessments) were selected for detailed analysis on methods used and datasets included as well as the type of potential quantified to identify their strengths and weaknesses. Based on the results of the BEE study, a two-volume handbook has been published covering best practices and methods and data sources respectively. Secondly, the project provided recommendations to conduct new bioenergy assessments develop methods and improve datasets.

One of the key shortcomings identified by the BEE project was that sustainability aspects were inadequately taken into account in the studies assessed. They found that no study provided a comprehensive sustainability assessment taking all three pillars of sustainability (economic, social, and environmental) into account. Although environmental aspects were covered far more than social and economic aspects, none of the studies included covered all relevant environmental aspects (Torén *et al.*, 2011).

Appendix E: Overview on assessed bioenergy potentials

Below we provide a brief overview on the outcomes of our assessment of bioenergy potentials at EU level, indicating the domestically available supply potentials for energy use as well as the amounts of feasible biomass imports to the EU. The derived data has been incorporated in the database of the Green-X model and serves as basis for the development of detailed scenarios for bioenergy use within the EU.

Overview on domestic (EU28) bioenergy feedstock potentials by 2030: Assessment and model implementation

Agriculture and Biowaste

	Assessment categories	[Mtoe]		[Mtoe]	Green-X database categories
Agriculture	rapeseed and sunflower	5.8	=	5.8	AP1 - rapeseed and sunflower (for biodiesel)
	sugarbeet, maize, wheat, barley	16.1	=	16.1	AP2 - sugarbeet, maize, wheat, barley (for bioethanol)
	maize, wheat, barley - whole plant (excl. fruitcake)	5.3	=	5.3	AP3 - maize, wheat, barley - whole plant (excl. fruitcake) (for lignocellulotic bioethanol)
	short rotation coppice poplar, willow	29.4	=	29.4	AP4 - short rotation coppice poplar, willow
	miscanthus	22.5	=	22.5	AP5 - miscanthus
	switch grass, red canary	52.4	=	52.4	AP6 - switch grass, red canary
	sweet sorghum	18.5	=	18.5	AP7 - sweet sorghum
	straw, other agricultural residues	34.2	=	34.2	AR1 - straw, other agricultural residues
	energy crops (maize) for co-fermentation	34.2			
Biowaste	Animal and mixed food waste	4.4	=	42.8	BG - agricultural biogas - incl. animal, food, vegetal wastes and energy crops (maize for co-fermentation) (for digestion)
	vegetal waste	4.2			
	landfill gas	5.4	=	5.4	LG - landfill gas (digestion)
	sewage sludge gas	4.1	=	4.1	SG - sewage sludge gas (digestion)
	paper and cardboard wastes	0.3	=	15.1	BW1 - municipal solid waste - incl. cardboard, paper waste (for incineration)
	household and similar wastes (municipal waste - biodegradable fraction)	14.8			
	used fats and cooking oil	3.1	=	3.1	BW2(AR2) - used fats and cooking oil (for biodiesel)
	Subtotal (Agriculture and Biowaste)	**254.6**	=	**254.6**	**Subtotal (Agriculture and Biowaste)**

Overview on domestic (EU28) bioenergy feedstock potentials by 2030: Assessment and model implementation

Forestry

	Assessment categories	[Mtoe]				[Mtoe]			Green-X database categories
Forestry	black liquor	6,3	...	6,3	=	6,3	...	6,3	FR1 - black liquor
	post-consumer wood	8,8	...	8,8		15,7	...	16,5	FR4 - wood waste (post-consumer wood, industrial residues)
	other industrial residues	7,7	...	7,7					
	stemwood	27,2	...	43,6	=	38,1	...	45,9	FP1 - stemwood, bark, forestry residues for small-scale use (log wood, wood chips - dedicated use)
	bark	9,6	...	11,2		3,5	...	8,6	FP2 - stemwood, bark for small-scale use (additional potential) - low cost
	forestry residues	6,4	...	57,9		3,5	...	8,6	FP3 - stemwood, bark for small-scale use (additional potential) - high cost
	landscape care wood	5,7	...	3,8		4,3	...	7,3	FR2 - forestry residues for large-scale systems (dedicated use)
	sawmill by-products	6,6	...	6,6		2,5	...	48,3	FR3 - forestry residues (additional potential)
						4,4	...	4,5	FR5 - forestry residues and sawmill by-products (for pelletisation - dedicated use)
	Subtotal (Forestry)	**78,4**	**...**	**146,1**	=	**78,4**	**...**	**146,1**	**Subtotal (Forestry)**

Summary of domestic (EU28) bioenergy feedstock potentials by 2030 [Mtoe]

Subtotal (Agriculture)	218,3		
Subtotal (Biowaste)	35,3		
Subtotal (Forestry)	78,4	...	146,1
Total (Bioenergy)	**332,0**	**...**	**399,7**

Remark: For the forestry part ranges in the (residual) potential available for energy supply are indicated, steming from distinct scenarios on overall forestry availability (supply potentials) and trends on material use (demand). To summarise briefly these scenarios reflect different levels of competition between material and energy use, ranging from a "restricted", a "reference" to a "resource" case.

Overview on Extra-EU supply potentials of bioenergy by 2030 [Mtoe]

Liquid biofuels	21,3		
Solid biomass	4,2	...	34,4
Total (Extra-EU Bioenergy)	**25,5**	**...**	**55,7**

Short summary BioSustain Stakeholder Workshop

and

Background paper for the stakeholder consultation workshop of the Biosustain project

Annex B

VITO
Utrecht University
TU Wien
INFRO
Rütter Soceco
PwC

Short summary BioSustain Stakeholder Workshop

BioSustain – Study on the sustainable and optimal use of biomass for energy in the EU beyond 2020

Contract No ENER/C_1/2013-410/SI_2.685777

December 7th, 2015

Albert Borschette Congress Center
Rue Froissart 36, 1040 Brussels

Introduction

A consortium led by PwC, including VITO, Utrecht University, TU Vienna, INFRO and Rütter Soceco is conducting a technical assistance study for the European Commission, DG Energy. The objective is to develop plausible EU bioenergy supply and demand scenarios for 2030 and assess the environmental and socio-economic impacts of possible future EU action to ensure bioenergy sustainability post-2020. As part of this project, a stakeholder consultation workshop was held on 7 December 2015 in Brussels.

The workshop was hosted by the European Commission and was attended by 69 participants, including sector associations and actors in the field of agriculture, forestry, waste processing, bioenergy and biofuel production, wood processing industry, paper industry, as well as policy makers at national and EU level, academia, research organisations, NGOs and other organisations.

The objectives of the stakeholder consultation workshop were to:

- Present preliminary findings on biomass supply and demand scenarios for EU energy and non-energy use by 2030;
- Discuss and validate these findings by experts and stakeholders which have not been involved in the study so far;
- Introduce the next steps on identifying potential sustainability risks and map EU and national mitigation actions.

A background paper was distributed beforehand to give an overview of preliminary findings and topics to be discussed at the stakeholder consultation workshop. The presentations were also distributed to the participants after the workshop and comments were welcomed until one week after the workshop.

The results of the workshop will feed into the ongoing work under the study.

This summary highlights key points raised during the workshop. It is the consortium's interpretation of the discussions and questions (including written contributions and feedback after the workshop) and does not represent a commonly agreed position among participants at the workshop or by the European Commission.

More extended minutes are also available.

Short summary of the discussions

Opening remarks

Giulio Volpi (European Commission, DG Energy) welcomed the participants and introduced the background of the study at EC level. Given the growing share of renewable energy sources (RES) towards 2030 and the important role of biomass therein, the EC is reviewing evidence to base its post 2020 biomass policy upon, including sustainability risks to be managed. The BioSustain project is one of the studies providing input to this EC review.

Luc Pelkmans (VITO) presented the BioSustain project. The project starts with a review of supply potentials of biomass from agriculture, forestry and waste that could be available for the EU, either domestic, either through imports (bottom-up approach). Further, the consortium develops plausible baseline scenarios for EU biomass consumption beyond 2020, for energy use and for other sectors of the bio-economy. The current stakeholder workshop allows for validation of the modelling inputs and initial scoping of sustainability risks and possible additional action at EU level. The next step is to identify sustainability risks related to biomass use post 2020, and define possible options for EU action to address these risks. Finally, the study will assess the impacts of the identified options for EU action on availability and costs of biomass, GHG savings, energy security & administrative costs for public authorities and economic operators.

Biomass supply potentials and demand scenarios

Supply and demand scenarios of forest biomass

Udo Mantau (INFRO) presented an overview of potential forest biomass supply. He started with an overview of the potential of EU forest resources (for all applications together), for different assortments (stemwood, residues, bark, landscape care wood, sawmill and other industrial residues, black liquor), within different constraints (development corridors). Total wood consumption for materials was projected based on an analysis of long-term developments of the wood industry sector; a moderate growth is projected. Subtracting the use of wood for materials from the total forest biomass supply resulted in the technical potential for bioenergy in 2030, which is between 80 and 150 Mtoe/yr, depending on the development scenario. Mind that some potentials (logging residues, industrial residues, bark) are directly linked with material use of woody biomass. Forest data and materials demand are based on the EU wood study and EFSOS2. There are many constraints, also apart from environmental, such as accessibility, fragmentation of ownership. Mobilisation also depends on the use of improved technologies (with less environmental impacts).

There was some discussion on the assumptions behind the potentials and scenarios, e.g. the amount of residues that should be left in the forest, the growth projections of wood industries, and the amount of roundwood potential, which is quite stable. It was also stated that improved forestry practices could increase the amount of biomass that could sustainably be harvested from the forest – this is indeed part of one of the development variations (resource). There was a remark that current removals from forests are mostly underestimated in statistics and that there is a lot of conservatism in the forestry sector.

Supply potential for agricultural biomass

Ric Hoefnagels (Utrecht University) presented an overview regarding the EU agricultural land supply, the land available for bioenergy and the potential of dedicated energy crops and agricultural residues (harvest residues like straw or corn stover, or on-farm residues like manure). The availability of agricultural land for energy crops was based on up-to-date CAPRI projections and recent studies like Biomass Policies, based on 'surplus land' which is agricultural land not used for food or feed purposes. Total land available for bioenergy amounts around 24 Mha, leading to a supply potential for energy crops in the EU of up to 130 Mtoe in 2030. The potential of harvest residues was estimated around 28 Mtoe in 2030, while manure (in the form of biogas) may contribute up to 40Mtoe by 2030.

There were various questions and remarks on the amount of land for energy crops. It should be stressed that in theory, this potential may be there, but it is one of the more expensive bioenergy options. The Green-X model will show if this part is economically interesting to be used, but it is not likely to grow near the technical potential. Concerning growth of lignocellulosic crops, it should be accounted for that there is a time lag of several years between planting and harvesting. While this land may be considered as 'surplus', there are several feedback loops in economics, so this cannot be considered fully independent from other land use (non-linearities). Some participants stated that other land also has potential (e.g. through intermediate crops); the restriction between food crops and non-food crops (as in the iLUC Directive) may also be very artificial.

In terms of agricultural residues, some clarifying questions were asked on the assumptions of agricultural residues, e.g. the amount that should be left on the field, or how competing uses (like animal bedding) are taken into account.

Supply potential for biogenic waste

Nathalie Devriendt (VITO) gave a presentation regarding the potential of biogenic waste and the methodology to calculate these. The methodology applied in Biomass Policies was used, starting from Eurostat reporting on waste fractions and their treatment. To calculate potential supply of biogenic waste for energy, trends in waste management are taken into account (waste generation, the share of mixed waste, share of landfill), with sensitivity analysis, and material recovery is excluded from the energy potential. The overall potential of energy from biogenic waste by 2030 is estimated up to 25-30 Mtoe. Around half of that potential will still be in the combustion of mixed waste (in waste to energy plants); for the other fractions, anaerobic digestion can play an important role.

There were some questions on the evolution of waste potential towards 2030 (decreasing or not), in relation to the implementation of waste policies. Another participant mentioned some issues in relation to imported used cooking oil (UCO) for biodiesel to the EU. Concerning energy conversion of bio-waste, connection should be made to CHP and district heating.

Global biomass available to the EU

Martin Junginger (Utrecht University) made a presentation regarding the global biomass supply available to the EU from imported sources by 2030. Distinction was made between solid (lignocellulosic) biomass and liquid biofuels. The analysis of solid biomass was derived from the Biotrade2020+ project, which focused on Southeast US, Brazil and Ukraine as sourcing regions – next to these also Canada, Russia, Sub-Saharan Africa and

Oceania were included in the overview. Depending on the mobilisation scenario, the available amount for the EU could amount between 5 and 35 Mtoe. Figures for liquid biofuels were derived from a study performed by E4Tech. Depending on the scenario, between 9 and 22 Mtoe of liquid biofuels from outside the EU could be available for the EU.

It was asked whether demand from other (non-EU) countries was also taken into account and if local demand was considered. An indeed projection of local demand in the sourcing areas is considered. In terms of other demand areas, future importing countries are mainly OECD countries, which are located in North America, Europe and (East) Asia. The demand in the US was already accounted for, and Brazil and Ukraine are most likely to focus on the EU as trade partner. There were some remarks about US imports, whether residues or roundwood are used to produce pellets for the EU. Next to sawmill residues, thinnings, pulpwood and low quality roundwood are generally used for pellet production.

Demand for biochemicals up to 2030

Luc Pelkmans (VITO) made a presentation regarding the review of biomass demand of biomass for biochemicals up to 2030, including the methodology, the role of bio-based feedstocks in the EU chemical industry and growth projections for bio-product types. The focus was on emerging materials, in particular biopolymers/bioplastics. Biopolymer demand was estimated in the range of 2 - 3 MT in EU by 2030 (based on the BIOTIC project and Nova-Institute studies). Projected 2030 bio-based raw material demand from chemistry in EU is substantial (5-10 Mtoe), but still much lower than for biofuels/bioenergy. Mostly sugar, starch or oil-based feedstocks (except specific cellulose based chemicals) will be used; there may be a shift to 2nd generation raw materials (lignocellulose), but this will probably go slower than for biofuels.

There were some remarks on the potential interaction between bioenergy and biochemicals markets, e.g. when there are supporting mechanisms for bioenergy, but these are lacking for biochemicals. The BioSustain study will take into account demand projections for biochemicals, and prioritise those over bioenergy, but modelling these interactions is done in other studies. Inorganic chemistry could also be considered, e.g. biofertilisers from digestate. This would replace very energy-intensive mineral fertilisers.

Modelling of bioenergy demand up to 2030 through Green-X

Gustav Resch (TU Wien) made a presentation regarding the modelling approach for bioenergy demand up to 2030, including the features of the Green-X model and the MULTIREG model. The analysis will be based on the new PRIMES reference scenario, which is currently being revised at EC level (aimed to be available early 2016). Next to the reference scenario, a RES policy scenario will be calculated, aiming at 40% GHG reduction and (at least) 27% RES and energy efficiency by 2030. In these scenarios, sensitivity analyses will be performed with different availability of biomass feedstock (reference vs resource feedstock potential) and higher energy efficiency targets.

There was a question how materials production will be prioritised in practice, as in the real economy, prioritisation will not happen by itself. The supply analysis in BioSustain has looked at the projected demand of different sectors. Green-X is an energy model, with distinct scenarios at biomass supply level. Pre-allocation has been done in the scenarios presented before (on supply and material use), so we assume a certain demand scenario for materials, exogenous to the model. Green-X includes competition between energy technologies (e.g. heating, cooling, electricity, biofuels), also with other renewable energy options.

Panel debate and discussion with the floor on biomass supply potentials and demand scenarios

This part of the workshop concluded with a panel discussion on the presented biomass supply potentials and demand scenarios. Most remarks of the panellists on specific presentations are included in the above summaries. Policy related remarks are included in the summary of the second panel discussion.

Potential sustainability risks and EU mitigation actions

Identifying potential risks, related measures at national and EU level and possible EU mitigation actions

Luc Pelkmans (VITO) presented a first list of potential sustainability risks related to an increase use of biomass, and an overview of EU binding and non-binding measures trying to address these issues. In absence of binding EU sustainability criteria, a number of Member States introduced national sustainability schemes. Martin Junginger (Utrecht University) presented the sustainability regulation for solid biomass for energy in the UK, Belgium, Denmark and the Netherlands.

Presentation of a related study: Carbon impacts of EU bioenergy use post-2020

Robert Matthews (Forest Research) made a presentation on a related a study, also for DG Energy, on carbon impacts of EU bioenergy use post 2020. This study is recently concluded and results will be available in the coming months. There were several questions and comments on the modelling framework, the underlying assumptions and the interpretation of the results, which fall outside the scope of the BioSustain study.

Panel debate and discussion with the floor on potential sustainability risks and mitigation actions

Identified issues and risks/existing policies:

Forest owners have a **multifunctional** and sustainable approach. High value timber is the most important product from an economical perspective. Bioenergy is not a black or white story: there may be risks, but it can also lead to investments in **better forest management** and can lead to better forest growth and increase of the forest carbon stock (see Finland and Sweden). A sustained yield is important for foresters. Sustainability criteria have proven to improve overall forest management and can help against deforestation because it provides a higher value for forestry practices. We should also acknowledge that harvesting less wood from forests (far below increments) results in ageing forests, which have an increased risk for large-scale disturbances (forest fires, wind damage, infestation). Ageing forests also reduce the average growth rate and thus the sequestration of carbon.

NGOs do not consider biomass as a zero emission source. They stress the need for a comprehensive **carbon accounting system**, taking into account carbon debt, iLUC … NGOs are favouring other options like wind, solar and geothermal above biomass, particularly for electricity and heating, as bio-electricity would confirm (lock-in) the current baseload system instead of moving towards a new energy system based on intermittent supply. For transport purposes the NGOs considered biofuels useful for shipping and aviation, the other transport modes should focus on other options (mainly electrification).

Complexity and uncertainty is high around biomass. Sustainability definitions vary, leading to reduced investments. More **consistency/harmonisation** is needed between Member States requirements, e.g. in terms of soil issues, a consistent approach for residues and how to include carbon accounting. We should not overregulate (including administrative burdens) which mainly creates burdens for smallholders.

Targets or caps should be questioned if there is no differentiation between good or bad performing pathways. The focus should be on low carbon scenario.

High **efficiency** applications should be aimed at, e.g. CHP instead of electricity-only condensing plants.

Paper industry, wood processing industries and chemical industries argue that bioenergy is favoured above material use, creating an unlevel **competition**. Price developments should be followed closely to interfere when other markets are threatened. When considering the advantages of bioenergy in terms of climate change as reason to promote these, we should acknowledge that bio-materials can also have such advantages (replacing fossil intensive materials) and this should be reflected in support systems (or subsidies should be removed for all). The sectors are calling for a ‘clever, but no rigid’ way of cascading recognizing the long-term storage of carbon in these materials. Demand for wood products should also be stimulated (e.g. through public procurement), thereby substituting fossil-intensive materials.

In Finland there are mainly **synergies** between energy and materials sectors – also in the announced large investments - and not either/or forest harvesting for material, energy, chemicals. When mobilising more wood for materials, this automatically increases the availability of logging residues for energy.

Biochemicals production risks to move outside the EU, as there is a lack of promotion in the EU (see e.g. tax credits in the US); the chemical industry will only invest here if the **investment climate** is right.

Policy approach:

Existing national regulations (e.g. forest acts) should be the basis, instead of a total new set of regulations with extra bureaucracy. Carbon stock management and abatement of iLUC or carbon debt should be handled through environmental regulations, conservation laws and forest laws. We should learn from what was already developed for sustainable forestry management (process verification and certification) and the EU Forest Strategy. For agricultural biomass (EU level), there are already various requirements in regulations (Cross Compliance, Greening).
Mind that we should recognize that Member States and their **circumstances** are different (resource base, industry structure …).

Most actors were in favour of **common sustainability criteria** at EU level. Currently there are diverging rules and regulations, based on negotiations of limited groups. Common criteria are needed: they should not be too complicated, easy to understand and to live with for al partners; and similar or identical for all biomass users (materials, energy, chemicals). There is large variation in supply areas (including variable jurisdictions), so we need to move towards regional assessments, using a **risk-based approach** (decision tree).

Different actors emphasized the role of markets and that it would be unwise to steer cascading of high vs low value applications through policy (no detailed regulation on allocation of materials). Nevertheless, fossil fuels carry an environmental cost; EU **carbon pricing** would be a good framework to include environmental costs related to greenhouse gas impact in the pricing of different fuels and materials. This would create a level playing field, as this would apply both for bioenergy and for biomaterials. Energy taxation taking into account.

More efforts are needed in **mobilisation** of biomass resources, e.g. invest in infrastructure, mobilizing forest owners (producer groups), or increase agricultural productivity (especially in East Europe).

The restriction of food crops in the iLUC directive is counterproductive, considering the large amount of unused agricultural land projected by 2030. Instead of an arbitrary distinction between food vs non-food crops, the aim should be to grow the **most cost-effective energy crops**. The strategy should be to use available land area for optimal reduction of greenhouse gas emissions.

Concluding remarks

Conclusion remarks were made by Giulio Volpi (European Commission, DG Energy). Considering the large number of participants, broad representation over different sectors and active discussions this was a very successful workshop. Transparency will lead to a better understanding of the potential of biomass, different drivers for demand, risks and uncertainties. The presence and magnitude of uncertainties were made clear during the workshop and will be studied further. The consultants are called upon to help provide and improve insights in these uncertainties. The EC will collect a lot of evidence in the next months. The importance of understanding the drivers behind the risks was also stressed. With his presentation on the study on carbon impacts of EU bioenergy use post 2020, Robert Matthews (Forest Research) gave interesting and useful insights. The issue of the costs of various policy options will be valuable for the impact assessment.

Background paper for the stakeholder consultation workshop of the Biosustain project

BioSustain – Study on the sustainable and optimal use of biomass for energy in the EU beyond 2020

Contract No ENER/C_1/2013-410/SI_2.685777

December 7th, 2015

Albert Borschette Congress Center
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10 Introduction

10.1 The BioSustain project

A consortium led by PwC, including VITO, Utrecht University, TU Wien, INFRO and Rütter Soceco is carrying out a study committed by the European Commission - DG Energy with the objective of developing plausible EU bioenergy supply and demand scenarios for 2030 and assessing the environmental and socio-economic impacts of possible future EU action to ensure bioenergy sustainability post-2020.

The study includes the following tasks:

- *Task 1* performs a review of recent literature to identify updated 2030 ***biomass supply potentials*** from forestry, agriculture and waste that could be available for the EU, through domestic sustainable production or through international markets.
- *Task 2* develops realistic 2030 EU ***biomass consumption scenarios***, not only for energy, but also for other sectors of the bio-economy. These will form the baseline against which alternative options will be compared (in Task 5).
- *Task 3* is dedicated to the ***stakeholder consultation workshop***, allowing for validation of the modelling inputs and initial scoping of sustainability risks and possible additional action at EU level.
- Based on the previous tasks and findings of a further literature review, *Task 4* identifies ***sustainability risks*** related to biomass use post-2020 and assesses how existing EU and national energy-related sustainability measures address the identified risks. On this basis, ***possible options for EU action*** are developed in order to minimize these risks.
- *Task 5* will analyse the ***socio-economic and environmental impacts*** of a number of selected options for additional EU action. Impacts of each option will be compared against the baseline scenario in Task 2, and assessed according to a set of criteria, including environmental effectiveness, economic efficiency, and policy coherence.
- *Task 6* will summarize project findings and set out policy ***recommendations***.

10.2 Objectives of the workshop

The stakeholder consultation workshop shall provide an opportunity to:

- Present **preliminary findings on biomass supply and demand scenarios for EU energy and non-energy use by 2030**;
- Discuss and validate these findings by experts and stakeholders which have not been involved in the study so far;
- Introduce the **next steps on identifying potential sustainability risks and map EU and national mitigation actions**.

This background paper gives an overview of preliminary findings and topics to discuss at the stakeholder consultation workshop.

Information and views set out in this background paper are those of the authors and do not necessarily reflect the opinion of the European Commission.

11 Preliminary results of the review of biomass supply potentials, including demand of biomass for materials

11.1 Analytical approach

The potential for energy production from biomass is affected by biomass supply, but also demand and dynamics in different sectors of the economy. In order to ensure sustainable production and supply of biomass for energy purposes, therefore, an insight is needed in the supply side of the market (forest, agriculture, waste) as well as demand for other purposes, including food, feed, fibre and biochemicals. The assessment undertaken in Task 1 (biomass supply potentials) and Task 2 (biomass consumption scenarios) of the ongoing study aims at providing suitable consideration on both the complexity and the trade-offs between biomass supply and demand across sectors.

In the following sections, we present the outcomes of our assessments of supply potentials and non-energy use scenarios in further detail, considering the common sectorial classification concerning biomass supply: forest, agriculture and waste. Therein, the domestic EU biomass feedstock is assessed and supply potentials are derived, also including a reflection of demand for material use for the forestry part. A closer look at the demand triggered by emerging markets (biochemicals) is taken in Section 11.5. The global perspective is then added in the section 11.6.

11.2 Forest biomass

Forest biomass can be segmented into:

- biomass from primary forest products (stemwood, other industrial roundwood)
- primary forest residues (logging residues)
- secondary forest residues (wood processing industry by-products and residues, like sawdust, bark and black liquor) and wood wastes (construction and demolition wood, post-consumer wood).

The availability and use of forest biomass sources for materials and energy are intertwined with forest industry and energy sectors. These interactions shall be taken into account when determining the potential of forest biomass for bioenergy.

Calculations of forest potentials are based on EUwood and EFSOS II studies, which have been based on the EFISCEN-model (Verkerk 2010), a forest resource projection model. These were the first calculations using not only the net annual increment (NAI) or net yield, but real biomass availability. Calculations have been updated for this study by taking into account actualised new inventory results (based on up-to-date statistical data) and including Croatia (to extend EU27 to EU28).

Total growing stock of forest biomass in the EU is estimated around 21,000 Mm³ swe[55] (4,400 Mtoe), with a theoretical annual increment of total biomass of 1,277 Mm³ swe overbark (268 Mtoe) in the EU. However, various technical, environmental and social constraints and conditions reduce the total achievable supply potential. The sustainable

[55] Mm³ swe = million cubic metres of sawn wood equivalent

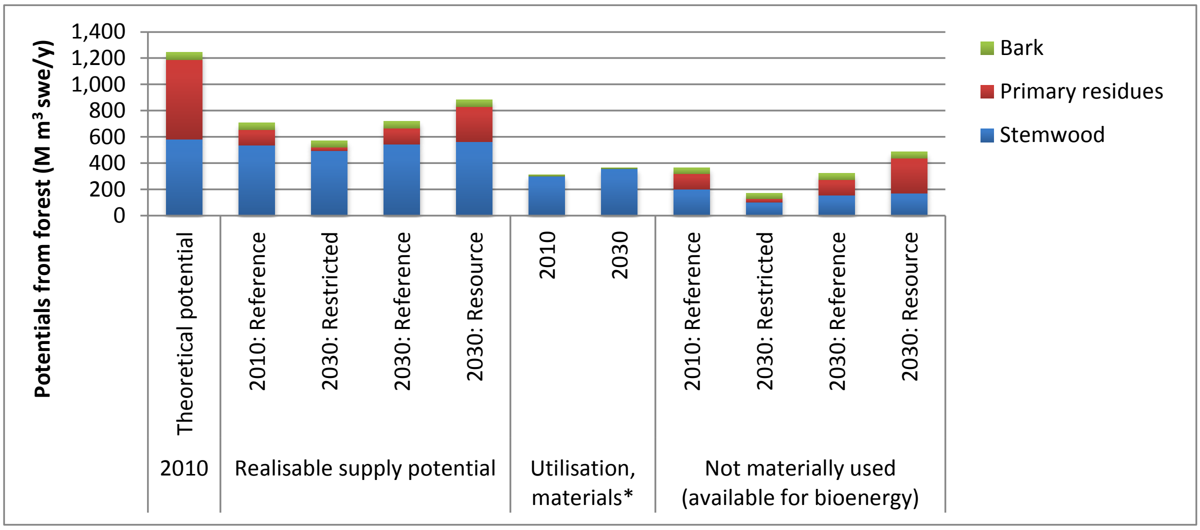
supply of wood sources is not a fixed point but it is represented by a "corridor" of options society may take within given borders. Sustainable utilisation may only occur within the corridor of the realisable supply scenarios. The corridor of supply can be identified based on the following assumptions on:

- **Restricted:** strong environmental restrictions - strict harvesting guidelines (e.g. in terms of forest residues) lead to lower provision of biomass;
- **Reference:** actual management systems - forests are being protected, but with medium impacts on the harvests;
- **Resource:** strong focus on mobilizing wood for energy and other uses; maximum utilization under long-term sustainable conditions.

Current use and potential towards 2030

The **Reference scenario** shows a potential of primary forest biomass for all uses of a bit more than 700 Mm³ (swe), which is equivalent to 57% of the theoretical potential (**Error! Reference source not found.**). The difference between the scenarios is to large extent determined by the chosen utilisation options of forest residues (30 – 265 Mm³ in 2030). The traditional stemwood assortments are not that much affected by the scenario restrictions (493 – 563 Mm³ in 2030). **Error! Reference source not found.** and **Error! Reference source not found.** show the results of different wood assortments in terms of total realisable potential, utilisation for materials and the fraction, which could be available for bioenergy or novel materials.

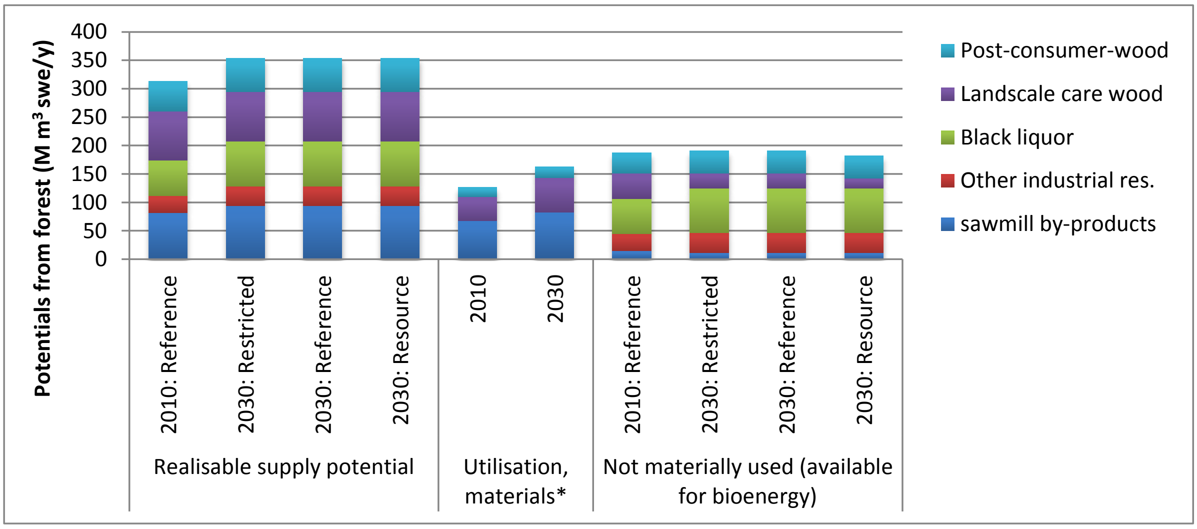
Figure 11-1: Theoretical56 and realisable potentials of biomass from forests (primary forest products and residues), material demand and fraction not used for materials (available for bioenergy and novel materials)



** Excluding material utilisation from imported stemwood in the EU28 in 2010 and 2030.*

[56] The theoretical biomass potentials include the total biomass of stemwood, logging residues (i.e. stem tops, branches and needles), stumps and early thinnings (thinning in very young stands; also referred to as pre-commercial thinnings). It is calculated on the basis of NAI (stemwood) with extraction factors. The realisable biomass is calculated from the theoretical biomass by applying restrictions as laid out in the scenario descriptions.

Figure 11-2: Realisable potentials of biomass from secondary wood sources and wood waste, material demand and fraction not used materially (available for bioenergy and novel materials) in the EU28 in 2010 and 2030.



Total material demand of primary forest products and residues is projected to increase from 310 Mm³ in 2010 to 365 Mm³ in 2030. Coniferous stemwood (softwood) is almost completely used for material uses. Non-coniferous stemwood (hardwood) is technically available (60-110 Mm³), however, the mobilisation of high value assortments for energy use is likely to be problematic, because prices for high-grade hardwood are above the resource price level of biomass plants. Primary forest residues are the largest reserve for woody biomass for energy. Bark is harvested with stems and its potential is, therefore, directly connected with mobilisation of stemwood.

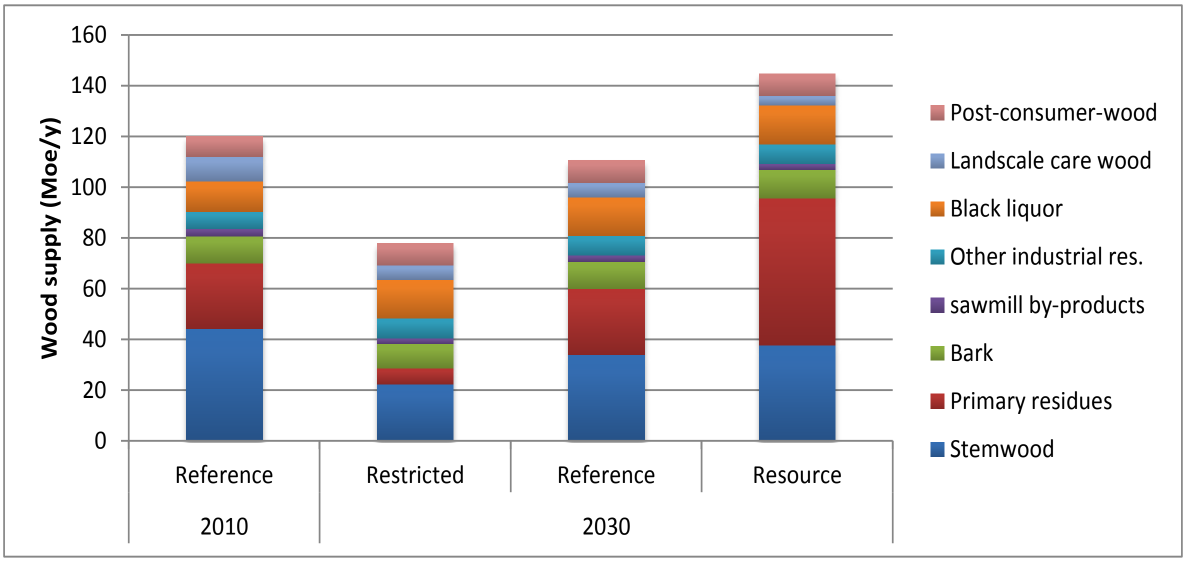
Landscape care wood is an interesting potential especially for communities who are often the owner of such resource. However, a large proportion is garden wood, often used by households as firewood. Post-consumer wood is a significant resource as well. In countries with good collection systems, it is already widely used, while in other countries it is not yet available. Secondary forest residues, including black liquor and sawmill residues, are already used for energy today.

Depending on the scenario, 450 to 550 Mm³ swe are available for energy uses, of which at least 350 Mm³ are already used for bioenergy today (Mantau, 2010). Thus, the additional reserve lies roughly between 100 to 200 Mm³, mostly in the form of forest residues. However, mobilisation of these depends very much on technical solutions, because of the actual technical focus on the stem and high cost of manual collection. Furthermore, there can be quite high environmental restrictions on the use of residues. The environmental effects of residue utilization are discussed controversially in relation the extractions of nutrients and deadwood. This may be solved in accordance to forest stands. However, for instance the German FSC standard does not accept harvesting of forest residues[57].

[57] yearly report Germany FSC 2013, p. 17

Under current management practices (Reference scenario), the total supply potential of wood biomass available for bioenergy in 2030 is projected to decrease by 11% compared to 2010, mainly as a result of increased demand for stemwood from the material sector (Figure 4-16). On the other hand, it could also substantially increase when a strong focus on wood mobilisation for producing energy and materials is pursued, using maximum sustainable biomass (Resource scenario).

Figure 11-3: Total supply of wood sources for bioenergy and novel biomaterials (not materially used wood supply) in the EU28 in 2010 and 2030



11.3 Agricultural biomass

Biomass from agriculture can be segmented into energy crops (agricultural products) and agricultural residues. Agricultural residues include primary or harvest residues (like straw or corn stover) produced in the field and secondary residues from the processing of harvested products (like bagasse, rice husks). The biomass potential from manure is a separate category.

Energy crops

Energy crops are grown for the purpose of bioenergy production. They can be classified in annual crops and perennial crops or food and non-food energy crops. Non-food crops are unsuitable for food and/or feed consumption and are most often perennial. These include perennial grasses (for example, miscanthus, switchgrass) and short rotation coppice (for example poplar, willow). Most food crops used for bioenergy purposes are annual crops, for example wheat, sugar beet or rapeseed. Examples of food type perennial crops include oil palm and sugar cane.

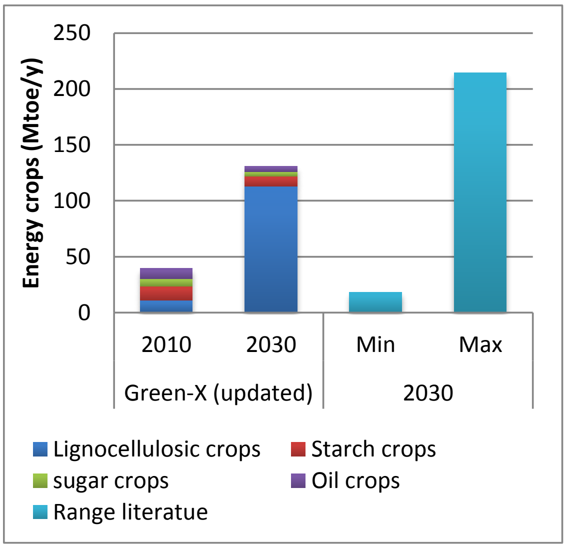
The total Utilised Agricultural Area (UAA) in the EU28 adds up to 180 Mha of which 112 Mha is arable land, 11 Mha is permanent cropland cultivated with perennial crops and 58 Mha is permanent grassland (EUROSTAT). In 2012, total arable land used for biofuel feedstock cultivation in the EU28 was 4.4 Mha (Hamelinck et al. 2014). Furthermore, crops cultivated for co-digestion take up a significant share. In Germany, almost 1 Mha of land was used for cultivation of plants for biogas in 2012 (AEBIOM, 2014). Total supply of lignocellulosic energy crops is still very small. It is estimated that between 60,000 and 70,000 ha of land are used for such crops in the EU28.

To avoid competition, the amount of productive land used for food and feed production is excluded from the potential for the cultivation of dedicated energy crops. To estimate future land supply for bioenergy crop cultivation, the approach used in the Biomass Futures and Biomass Policies projects (Elbersen et al. 2015) is followed. This is based on baseline projections of the agro-economic model CAPRI (CAPRI Reference 2013), which also projects the amount of EU agricultural land to be unused for economic reasons ('surplus land').

Current use and potentials towards 2030

The total land available for bioenergy is projected to be 23 Mha in 2020 and 24 Mha in 2030 (18%-19% of total arable land, 12%-13% of utilized agricultural area). The total supply potential of dedicated energy crops in the EU is estimated to increase from 39 Mtoe in 2010 to 131 Mtoe in in 2030 as shown in **Error! Reference source not found.**.

Figure 11-4: Potential of energy crops in the EU in 2010 and 2030 in Green-X, compared to ranges found in literature published between 2010 and 2014



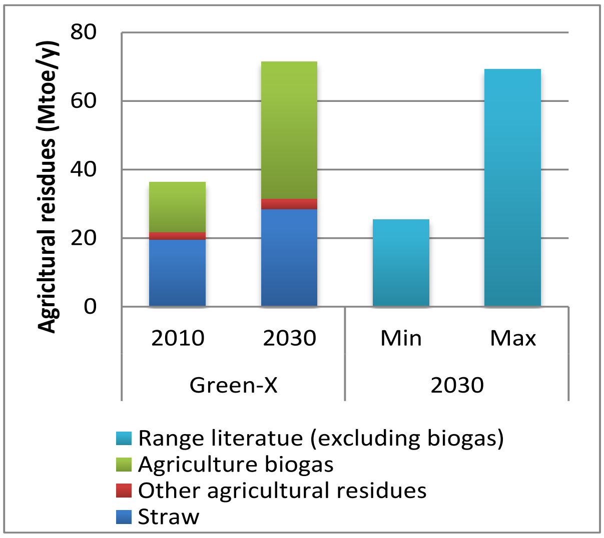
High yield lignocellulosic crops (grassy crops, short rotation coppice) make up the largest potential, increasing to 113 Mtoe in 2030. As a reference, the range in other studies is also shown. A preference for surplus land is desired to ensure food security (Vis et al. 2010), avoid undesirable land use change and a loss of biodiversity. This preference means that a "food first" paradigm should be applied. The amount of land needed for food production highly depends on the level of intensification of crop and livestock production.

Agricultural residues

Agricultural residues can be segmented into primary residues (or harvest residues) that are produced on the field (for example straw, prunings, cuttings), secondary agricultural residues that are produced from processing of harvested products (for example, bagasse or rice husks) and on-farm residues (manure).

Straw currently makes up the largest potential of agricultural residues. Its potential highly depends on the sustainable extraction rate to maintain soil quality and to the competitive uses of the residues (for example for animal bedding); both factors are varying per country. The primary harvest residues potential is estimated to stay fairly constant in time. The largest growth in terms of agricultural residue potentials for energy is, however, projected in agriculture biogas (mainly from co-digestion of manure), increasing from 15 Mtoe in 2010 to 40 Mtoe in 2030. The potential of agriculture biogas is expressed in units of biogas and therefore difficult to compare with literature. Ranges found in the reviewed literature vary between 47 Mtoe to 96 Mtoe (of input expressed in primary energy), but are not shown in **Error! Reference source not found.**.

Figure 11-5: Potentials for agricultural residues in the EU, 2010- 2030. Comparison between Green-X and literature published between 2010 and 2014 (literature does not include biogas).



11.4 Biogenic waste

Next to forestry and agriculture, waste is the third main category of biomass that can potentially be used for energy generation. An important share of waste is of biological origin (paper, wood, food waste, garden waste).

The main waste categories, as reported in Eurostat, consisting partly or entirely of biogenic material are: (1) paper and cardboard wastes, (2) animal and mixed food waste, (3) vegetal wastes, (4) household and similar wastes, (5) common sludges and (6) wood wastes. Wood waste is not included in this assessment as it is already covered in the assessment of forestry biomass. The review includes both household waste and industrial and sectoral waste (NACE). Used cooking oil is considered as a separate category, while in Eurostat these fractions are part of the animal and mixed food waste. Landfill gas is not explicitly mentioned in this potential, as this is energy produced from historically landfilled waste. On the longer term, it is assumed that landfill (and specifically landfill of biodegradable waste and recyclable fractions) will be outphased, as foreseen in the Landfill Directive.

Table 1 shows an overview of the different amounts of the specified waste categories as reported in Eurostat, expressed in energy content of the biogenic share of the waste (with assumptions of moisture content, biogenic fraction and specific lower heating value (LHV) of each of these fractions, based on Arcadis (2009), Waste2Go (2014) and Elbersen et al. (2015)). Current treatment of the waste fractions is also indicated, based on Eurostat data for the year 2012. In order to calculate the potential towards 2030, a similar approach is followed, as in the project Biomass Policies (Elbersen et al. 2015)[58].

[58] Following the principles of the waste hierarchy, waste fractions going to material recovery are

Table 11-1: Overview of biogenic waste fractions, expressed in energy content, and their current treatment

EU28, 2012	Total energy content (LHV) biogenic fraction	Treatment			
		Other recovery	Incineration & energy recovery	Incineration & disposal	Landfill
Paper and cardboard wastes	18.6 Mtoe	98.7%	0.8%	0.1%	0.5%
Animal and mixed food waste	6.6 Mtoe	84.3%	5.7%	2.1%	7.3%
Vegetal wastes	12.3 Mtoe	93.4%	3.4%	0.4%	2.8%
Household and similar wastes	25.4 Mtoe	12.1%	23.0%	15.1%	49.7%
Common sludges	3.2 Mtoe	56.3%	12.7%	12.7%	11.1%

Potential towards 2030

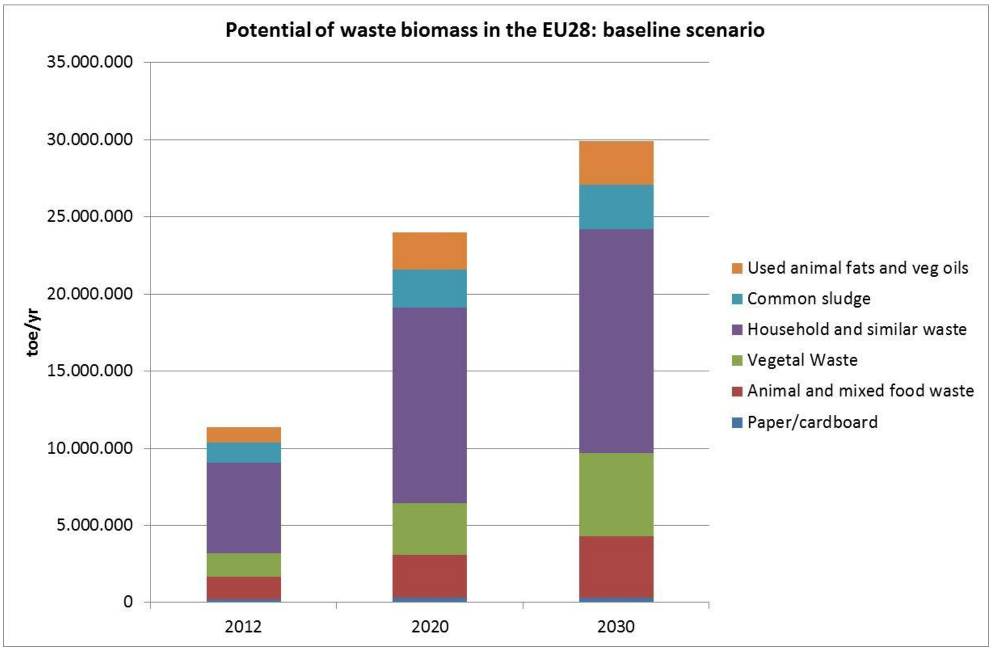
As shown in

, in the baseline scenario total biogenic waste potential reaches 30 Mtoe in 2030. The main potential for waste biomass in the next decades still lies in the incineration (and energy recovery) of mixed household and similar waste in waste-to-energy plants (~14 Mtoe/y). The potential of other (separated) fractions generally varies between 3 and 5 Mtoe each. Used animal fats and vegetable oils can be important as feedstock for ‘advanced’ biodiesel. A substantial share (> 1 Mtoe/y) is already used for this application

excluded from the potential available for energy production. First, the total waste generation per category of waste is considered (based on Eurostat). Then, waste treatment types are identified per type of waste (recovery, incineration with energy recovery, other incineration, disposal on land and land treatment). Waste treatment factors are applied to the total waste generated to identify which part is already going to alternative useful uses (e.g. recycling, compost) and which part of the waste is available for further conversion into energy or other future novel biomaterial uses. So the part already going to energy is also *considered as part of the potential. For future potentials, specific evolutions in terms of demography, waste generation, landfill share and separated collection are assumed. A sensitivity analysis is performed on these evolutions.*

today; mind that used cooking oils are already traded between countries for this purpose.

Figure 11-6: Calculated potential of biogenic waste for energy, in the baseline scenario



Trends in waste management (waste generation, recycling targets, share of landfill) have a substantial impact on total potentials. Different sensitivity runs were performed, applying stronger waste management evolutions compared to the baseline scenario (reduced MSW generation, higher landfill reduction, higher waste separation, decoupling of sector waste from GDP growth). Some of these effects increase the energy potential (e.g. reduced landfill), other reduce the potential (e.g. reduced waste generation, higher waste separation). When combining the different effects, energy potential could reduce by around 5 Mtoe (own calculations).

Overall, a substantial growth of bioenergy from waste is possible, from current levels around 11 Mtoe, up to around 25-30Mtoe in 2030, which is more than double current use.

The potential for paper and cardboard is very low, as most of those fractions will go to recycling. Recovery options for separated waste biomass fractions such as vegetal waste or mixed animal and food waste consist of a balance of material applications (e.g. oleochemicals, but also soil improvers such as compost) and energy applications (EFPRA, 2014). There may be a trend to convert current compost facilities to pre-digestion and post-composting (Arcadis, 2009).

11.5 Demand of biochemicals

A large share of current products of the chemical industry can, in principle, be made from biobased feedstock, such as starch, sugars, vegetable oils, animal fats or lignocellulosic material. CEFIC (2014) estimated that, in 2011, around 10% of organic raw materials in the European chemical industry are biobased (8.6 Mt renewable raw materials). Biobased surfactants and solvents (mostly based on vegetable oils/animal fats, sugar or starch) are currently the most important biobased applications in chemistry.

In this study, the potential role of biobased chemicals by 2030 is indicated in terms of market demand and biomass resource requirements. The study made a review of recent studies in terms of long-term market projections. Some examples are JRC (2005), BREW (2006), PRO-BIP 2009, BIOCHEM (2010), Nova-Institut (2013, 2015), BIO-TIC (2015) and S2Biom (2015, *on-going work*). The focus is on emerging materials, in particular biopolymers that have largest growth projections. The market demand will be translated in potential biomass resource requirements.

Potential demand towards 2030

CEFIC/Ecofys (2013) explored different scenarios for EU chemistry development, and estimated biomass feed requirements for EU chemistry between 5 and 10 Mtoe (expressed in energy content of the feedstocks), moving up to 10-40 Mtoe by 2050.

JRC (2013), based on Busch & Wittmeyer (2012) estimated the following market capacity development for some biobased products in Europe.

Table 11-2: Estimated market capacity development for several bio-based products in Europe

Product category	Market volume 2010	Projected market volume 2020
Biobased plastics	300 kt	3140 kt*
Biolubricants	137 kt	420 kt
Biocomposites	362 kt	920 kt
Biosolvents	630 kt	1100 kt
Biosurfactants	1520 kt	2300 kt

** recently revised down to 1 Mt (see Nova-Institut, 2015)*

Nova-Institut (2015) estimated the global production capacity of biobased polymers at 5.1 Mt in 2013, which is 2% of global structural polymer production. Considering the biobased shares of the different polymers, the total biomass content in the biopolymer production capacity at global level is estimated around 2 Mt in 2013. Nova-Institut (2015) also made projections of global biobased polymer production capacities up to 2020. Total worldwide biobased polymer production capacity would reach 17 Mt per year by 2020, of which around 1 Mt in the EU. Mind that in these figures also partially biobased polymers are included (e.g. bio-PET30), as well as some fossil capacity which could switch to biobased raw materials.

BIO-TIC is a European project that recently presented its final roadmap for the industrial biotechnology sector in Europe. Their market projections are based on extensive stakeholder consultations. BIO-TIC (2015) projected biopolymer demand in the EU by 2030 in the range of 2 to 3 million tonnes.

Mind that the studies mentioned above generally did not transfer these figures into demand for biomass. Current raw materials for biobased plastics in the EU are largely based on 1st generation raw materials like sugar and starch, with exception of cellulose based biopolymers like CA (cellulose acetate). Similar to other applications, there may be a shift to 2nd generation raw materials for bio-plastics in 2030, albeit at a slower rate than for biofuels. Assuming that in 2030 an indicative share of 80% of bioplastics will be derived from sugar/starch and 20% from lignocellulose, this will require around 4 Mt of sugar/starch and 1.5 to 2 Mt (dry mass) of lignocellulose (source: own calculations).

Mind that these resource demand figures are in relation to the European market demand of bioplastics, which may evolve differently from production; with current evolutions it is very likely that a substantial part of the production for the European market will happen outside Europe (e.g. South America, Asia), also using biomass resources from outside Europe (e.g. sugar cane).

Another application of biomass resources in innovative materials would be in biocomposites, which are around 50% biobased. A forecast indicates that more than half of EU composite production (of 2.4 Mt per year) could be biocomposites in 2030, which would require around 0.5 Mt of woody biomass and 0.2 Mt of natural fibres.

11.6 Global biomass available to the EU

Solid biomass

Extra-EU imports of wood pellets increased from 4.4 Mt (1.8 Mtoe) in 2012 to 6.0 Mt (2.5 Mtoe) in 2013 mainly because of growing industrial markets in the UK. The US Southeast has become the largest supplier of wood pellets to the EU (2.8 Mt in 2013), followed by Canada (1.9 Mt in 2013) and NW Russia (1.0 Mt in 2013). Forest residues are still the main feedstock of wood pellet production. However, increasing amounts of pulpgrade stemwood are used. The share of pulpgrade stemwood from wood pellets in the US Southeast increased from zero in 2010 to 61% in 2013 (Abt et al. 2014). Next to EU markets, new markets in Asia are becoming increasingly relevant for international solid biomass trade. In 2013, wood pellet consumption in Asia was estimated to be 600 kt (0.25 Mtoe), mainly from imported sources (560 kt, 0.24 Mtoe in 2013) (AEBIOM 2014). South Korea has set a target of 10 % power generation from renewable sources by 2020 whereas Japan has set a target of 35 % renewable energy and 25 % power generation from renewable sources by 2030 (Goetzl 2015).

To determine the export potential of biomass, generally the geographic scope is limited to relevant supply regions that are already exporting or have the potential to become exporting regions of biomass for energy purposes. Current key export regions of forest biomass include the US Southeast, Canada and northwest Russia. Beyond 2020, dedicated energy crops are expected to contribute to the supply potential of solid biomass. Additional key exporting regions of both residues and energy crops considered are Brazil and Ukraine and (to a smaller extent) countries in Sub-Saharan Africa (mainly Mozambique). The future export potential of these countries is, however, highly uncertain.

Starting point of the supply scenarios of solid biomass are the intermediate results of the IEE project BioTrade2020+, which defines solid biomass trade potentials in six regions in the world. Intermediate results for Brazil, the US Southeast and Ukraine were considered. The Reference scenario and Resource scenario in this study are aligned to the 'Business as Usual'[59] and 'High Trade'[60] scenarios of BioTrade2020+. The Restricted scenario reflects higher competition for solid biomass and lack of investments in infrastructure to mobilize alternative sources. Some key assumptions are briefly explained below.

- **Restricted:** In Ukraine, no investments are made to increase the export potential of solid biomass. Due to growth in domestic demand, export of solid biomass will be phased out beyond 2020. In the US Southeast, the supply potential of forest products (pulpgrade roundwood) is projected to reduce similar to the Business as Usual scenario of BioTrade2020+. Domestic demand reduces the export potential of wood pellets from forest products. A similar trend was assumed for Eastern Canada. Similar volumes of forest residues that are already mobilized today are still available to 2030.
- **Reference:** similar to the Restricted scenario, the potential of pellets from forest products in the US Southeast is reduced. However, in contrast with the Restricted scenario, more forest residues are mobilized and processed into wood pellets for export markets. Furthermore, Sub-Saharan Africa is projected to become a supplier of solid biomass beyond 2020.
- **Resource:** the US Southeast remains export oriented towards the EU, the total production of wood pellets increases to 26 Mt in 2030 compared to 3.9 Mt in 2014. In Brazil, investments in infrastructure and efficient mobilization of sustainable wood residues and agriculture residues

[59] The business-as-usual scenario reflects biomass production and consumption at national levels at current and predicted paces. They are built based on the reports and review of national statistics, FAO reports, scenarios presented in the World Energy Outlook 2012 and 2013 that set the normal development in the studied sectors in the studied countries The BAU scenarios are built on current and expected policies in energy, climate and environmental etc. which are already come into effect in the EU, in the sourcing regions and possible in other world regions. (BioTrade2020plus 2014)

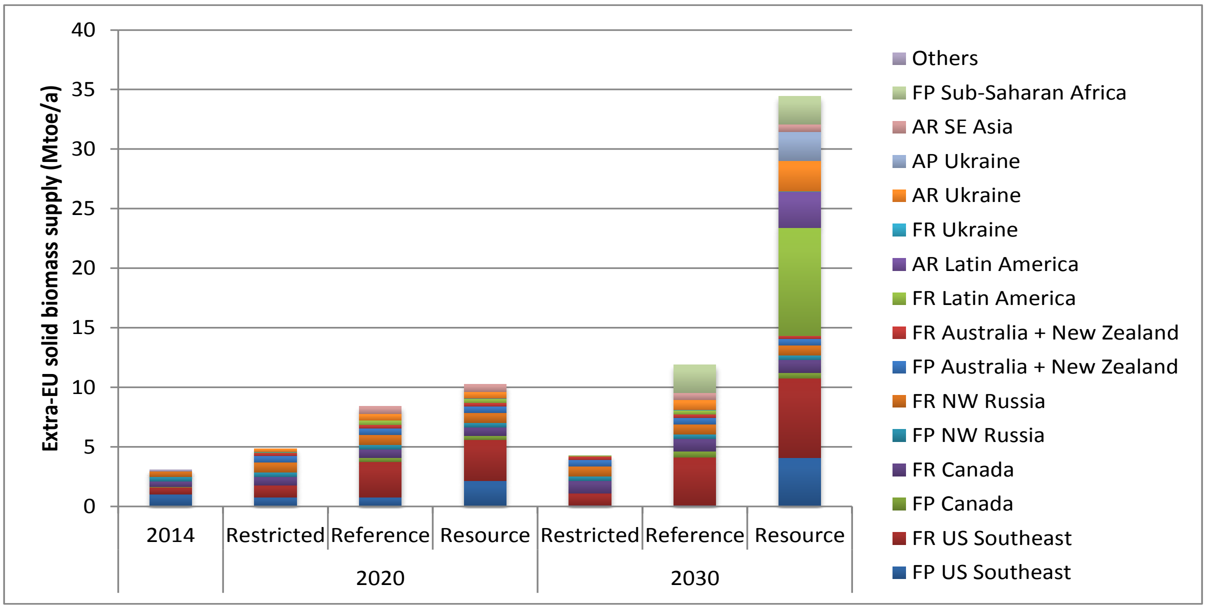
[60] The High scenario explores options under which larger volumes of sustainably produced biomass might become available for export. These may include an assessment of possibilities to increase the yields of both dedicated biomass production for energy, agricultural and forestry yields in general, effective land management and subsequent additional land availability for biomass production; it also envisages more vigorous policy developments in energy, climate and environment sectors. The optimistic scenarios are built amongst other inputs of national statistics, FAO reports, scenarios presented in the World Energy Outlook 2012 and 2013 that sets out an energy pathway consistent with the goal of limiting the global increase in temperature to 2°C by limiting concentration of greenhouse gases in the atmosphere to around 450 parts per million of CO_2. (BioTrade2020plus 2014)

make Brazil the largest supplier of solid biomass to the EU in 2030. In Ukraine, strong growth of export occurs after 2020 with a similar growth rate to the US Southeast between 2009 and 2013 (24%). Perennial crops are grown beyond 2025 to meet the growing demand for lignocellulosic biomass. In 2030, almost half of pellet production is produced from perennial crops.

Potential towards 2030

In 2014, total wood pellet imports to the EU were 7.5 Mt (3.1 Mtoe) of which the US Southeast supplied more than half. In the supply scenarios to 2030, the total potential increases t0 10 Mt (4 Mtoe), 29 Mt (12 Mtoe), and 86 Mt (34 Mtoe) in the Restricted, Reference and Resource scenario in 2030 (**Error! Reference source not found.**). Compared to other studies, the export potential of solid biomass in the BioSustain scenarios of extra-EU supply of solid biomass appears to show a moderate range for 2020. For example, in the Biomass Policies study (Fritsche & Iriarte 2014), the total export potential is estimated to be 29 Mtoe by 2020 increasing to 40 Mtoe by 2030 (95 Mt wood pellet equivalent). The large range between the scenarios reflects the high uncertainty in cultivation of dedicated energy crops and investments in infrastructure to mobilize forest and agricultural residues.

Figure 11-7: Solid biomass supply scenarios to 2030



FP: forest products, FR: forest residues, AP: energy crops (SRC), AR: agriculture residues.

Liquid biofuels

Global trade of biodiesel is almost 100% driven by EU blending targets for biofuels, with important roles for palm oil and soybean oil. One of the recent drivers for increased demand of imported palm oil is the production of drop-in diesel or Hydrotreated Vegetable Oils (HVO) as it uses palm oil next to waste oils as a feedstock (Janssen et al. 2013). The production capacity of HVO in Europe is 1.8 billion litres (1.5 Mtoe). In 2012, total imports added up to 5.1 Mtoe (35% of total biofuel demand in the EU) with soy oil from Argentina and palm oil from Indonesia making up more than half of total import to the EU (**Error! Reference source not found.**) (Hamelinck et al. 2014)[61].

Potential towards 2030

The starting point of the future supply scenario of liquid biofuels from extra-EU countries is the recent E4Tech study 'A harmonised auto-fuel biofuel roadmap for the EU to 2030' (Bauen et al. 2013), containing four scenarios A, B, C and D that address key uncertainties in the future supply of liquid biofuels[62]. E4Tech's scenarios A, B and C are considered representative for the Restricted, Reference and Resource scenarios respectively:

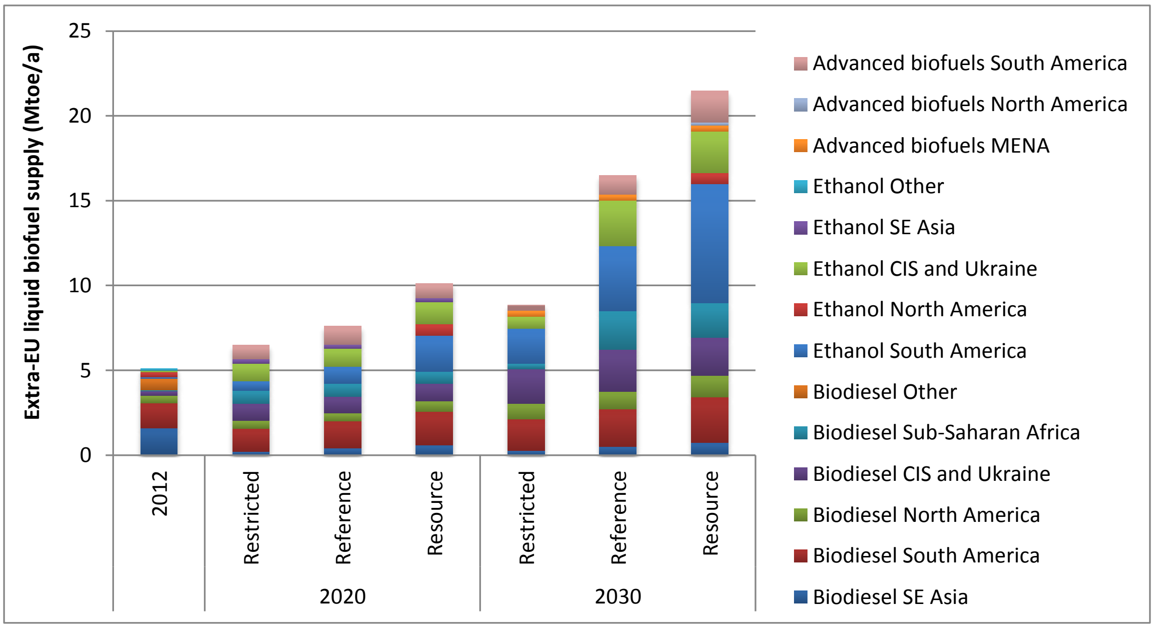
- **Restricted (B):** low export capacity to the EU; medium demand from competing markets other than food/feed. Furthermore, an average yield improvement and high water scarcity are assumed.
- **Reference (C):** medium export capacity to the EU; medium demand from competing markets other than food/feed. Furthermore, an average yield improvement and medium water scarcity are assumed.
- **Resource (A):** high export capacity to the EU, low demand from competing markets other than food/feed. This scenario is however relatively conservative with respect to technology progress and yield improvements.

Scenario D assumes high conservation efforts, but also high yield and efficiencies. In terms of biofuel supply, this scenario is between B and C. Effects of saturation of the EU biofuel market and other constraints, including the share of food-based biofuels, are expected to reduce the demand of liquid biofuel imports to the EU. These effects are not shown in the supply scenarios, but are assessed with the Green-X model.

Figure 11-8: Liquid biofuel feedstock supply in 2012 and supply scenarios to 2030

[61] However, since November 2013, effective anti-dumping measures were taken against extra-EU imports of Indonesian and Argentinean biodiesel (between 120 and 250 €/t) reducing imports substantially. Although this has resulted in some imports from other regions, taking the current saturation of the EU biofuel market and decisions on the iLUC directive into account, it is not expected that EU import of liquid biofuels will recover to the levels of before 2013 (EurObserv'er 2014; Flach et al. 2015).

[62] The E4Tech study was selected for its detailed approach of 200 separate fuel chains (region specific feedstock, conversion combinations) and it addresses key uncertainties in its scenarios as explained below. In all four E4Tech scenarios, the amount of biomass that can be supplied to the EU is constrained by a GHG threshold value of 50% in 2020 and 60% in 2030. Furthermore, an environmental constraint is applied by restricting land used for energy crop cultivation to maximum 10% of agricultural land. Crop yields are assumed to be ~10% lower in regions that are likely to be affected by physical water scarcity.

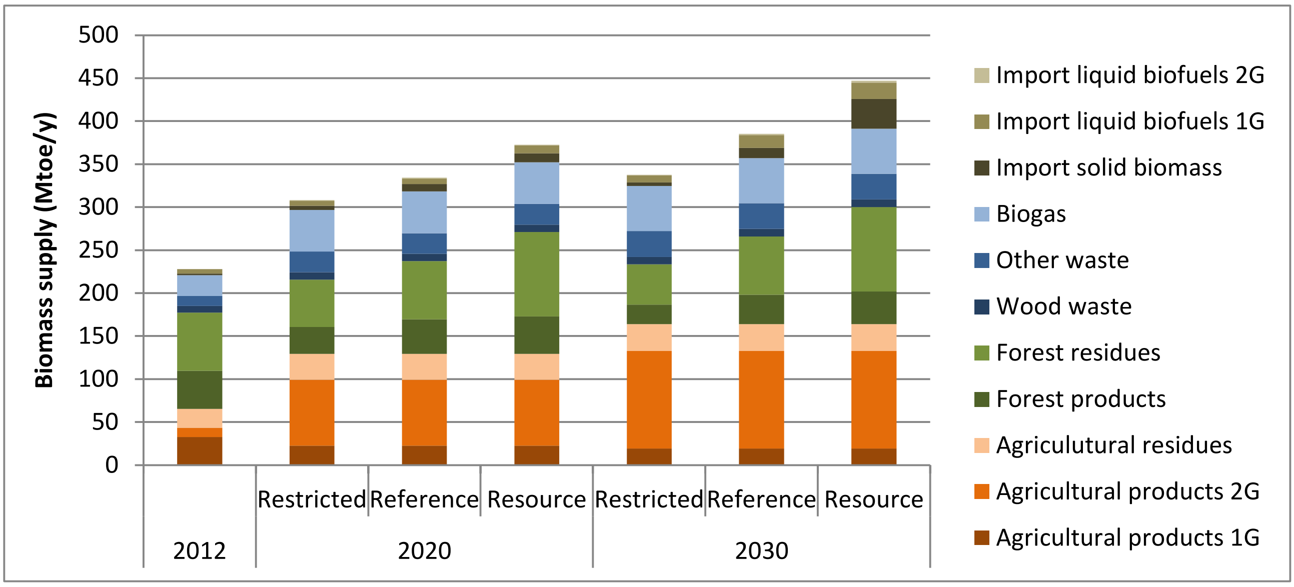


MENA = Middle East and North Africa; CIS = Commonwealth of Independent States (ex-Soviet Union states)

11.7 Total potential supply of biomass for bioenergy use in the EU28 in 2012, 2020 and 2030

Figure 0-1 summarises the total supply potential of biomass for bioenergy from forest, agriculture and waste sectors as well as import from outside the EU. The estimated potential of today is well above today's gross inland consumption of biomass for energy in the EU28 (123 Mtoe in 2012). However, substantial growth in biomass consumption is still expected. Furthermore, part of the supply potential might be difficult to mobilize, especially in case of forest products (stemwood) or depends on forest management constraints (forest residues). The domestic supply in the EU28 in 2030 ranges between 338 Mtoe in the Restricted scenario to 391 Mtoe in the Resource scenario. In 2012, net import of biomass contributed 5% to gross final biomass consumption for energy purposes (AEBIOM, 2014). The future share of solid biomass and liquid biofuels supply from extra-EU sources ranges between 4% (Restricted) to 14% (Resource).

Figure 11-9: Overview of estimated biomass potential for bioenergy in the EU28 in 2010, 2020 and 2030 in terms of primary energy.



Biogas and liquid import of liquid biofuels are shown in final energy units.
1G: food-based energy crops/biofuels
2G: lignocellulosic energy crops/biofuels

12 EU bioenergy demand scenarios up to 2030

12.1 Scenario development

The project will quantitatively model the following bioenergy demand scenarios up to 2030:

- a *reference scenario* in accordance with the EU outlook for energy and transport up to 2050 (i.e. PRIMES reference scenario), assuming for example a gradual phase-out of RES support beyond 2020 and, consequently, non-compliance with 2030 energy and climate targets, and
- a *RES policy scenario* in accordance with the Council agreement on 2030 energy and climate targets, aiming at 40% GHG reduction and (at least) 27% RES and energy efficiency by 2030.

A sensitivity analysis will be carried out on the following parameters:

- *Availability of biomass feedstock for the energy sector:* Aim is to assess the impacts of changing assumptions concerning bioenergy feedstock potentials, reflecting the uncertainty in the availability of forestry biomass feedstock for the energy sector as discussed in section 2.1 (EU potentials) and 11.6 (Extra-EU potentials), respectively. For doing so three different datasets on bioenergy feedstock potentials will be applied, reflecting distinct levels of availability of forestry biomass incl. competition between energy and material use, combined with distinct trends concerning Extra-EU solid biomass potentials available for import to Europe.[63]
- *Energy efficiency / energy demand:* For the RES policy scenario the impact of accompanying energy efficiency measures will be assessed. More precisely, we will analyse how overall RES deployment and specifically bioenergy use is affected by a move towards strong energy efficiency measures (i.e. 30 or 33%).

Interim results will be presented at the workshop, concerning overall RES use in the period up to 2030 and the role of bioenergy, including details by sector, technology (cluster) and country. Complementary to deployment, a first indication of economic and GHG impacts will be undertaken as well.

Further in the course of the project, possible options for EU action will be defined (Task 4) and these will be applied in the Green-X model to identify the impact of those options, in comparison to the baseline scenarios (Task 5). In Box 5 a few examples are provided of sustainability measures that are already implemented in Green-X and how the respective approach works.

[63] The default dataset on feedstock potentials reflects a "reference" case with respect to biomass feedstock that is left over for energy uses (i.e. in accordance with the "reference" scenario concerning biomass feedstock, see sections 2.1 to 2.3) and a reference trend concerning Extra-EU biomass potentials that can be imported to Europe (see section 11.6). Within the sensitivity assessment this dataset will be replaced by a low potential case (i.e. the "restricted" scenario concerning supply potentials) and a high potential case (i.e. the "resource" scenario).

12.2 Modelling framework

The project modelling framework includes the Green-X model, the geospatial ArcGIS Network model and the MULTIREG model.

The Green-X model[64] is a specialized energy system model, geographically bounded to the European Union and its neighbours, that has been used in several impact assessments and research studies related to RES. The core strengths of this tool are its detailed representation of renewable resources and technologies, and its comprehensive incorporation of energy policy instruments, including also sustainability criteria for bioenergy as developed in the BioBench study (Pelkmans et al., 2012). This allows various policy design options to be assessed with respect to resulting costs, expenditures and benefits, as well as environmental impacts.

Identified potentials for bioenergy supply (incl. domestic and imported supply) combined with trends concerning biomass demand for material use as discussed above serve as basis for the modelling works as well as information on related costs. For the incorporation of biomass trade in the Green-X database and the subsequent model-based analysis, a well-established linkage between the Green-X model / database and Utrecht University's geospatial network model is used as outlined in Box 2. The extended database includes for example feedstock specific costs and GHG emissions for cultivation, pre-treatment (for instance, chipping, pelletisation) and country-to-country specific transport chains.

Finally, the techno-economic policy assessment done by use of Green-X is complemented by a brief analysis of socio-economic impacts, indicating how GDP and employment are affected throughout changes in biomass use across scenarios. The outputs of Green-X will consequently serve as input for the MULTIREG model – i.e. a multi-national, multi-sectoral input-output model being capable of assessing the impacts of technical and structural changes in the economic sectors related to biomass use.

Box 2: Specific features of the Green-X model related to bioenergy use and supply

- Within the Green-X model, the *allocation of biomass feedstock* to feasible technologies and sectors is fully internalised into the overall calculation procedure. For each feedstock category, technology options (and their corresponding demands) are ranked based on the feasible revenue streams as available to a possible investor under the conditioned, scenario-specific energy policy framework that may change on a yearly basis.
- A module for *intra-European trade of biomass feedstock* has been added to Green-X that operates on the same principle as outlined above but at a European rather than at a purely national level. Thus, associated transport costs and GHG emissions reflect the outcomes of a detailed logistic model. Consequently, competition on biomass supply and demand arising within a country from the conditioned support incentives for heat, electricity and transport fuels as well as between countries can be reflected. In other words, the supporting framework at Member State level may have a significant impact on the resulting biomass allocation and use as well as associated trade.
- The model allows an *endogenous modelling of sustainability regulations for the energetic use of biomass.* This comprises specifically the application of GHG

[64] More information available at www.green-x.at.

constraints that exclude technology/feedstock combinations not complying with conditioned thresholds. The model allows flexibility in applying such limitations, that is to say, the user can select which technology clusters and feedstock categories are affected by the regulation both at national and EU level, and, additionally, applied parameters may change over time.

Box 3: Modelling biomass transport chains in & to Europe

In order to identify likely trade routes of solid biomass and to quantify the specific costs and GHG emissions of the logistic chains of solid biomass trade, a geospatial network model was developed in the ArcGIS Network Analyst extension by the Copernicus Institute at Utrecht University. The model includes an intermodal network with road, rail, inland waterways and short sea shipping in Europe. The networks are connected via transhipment hubs, where biomass can be transferred to other transport modalities (for instance, from truck to ship).

Recently, the model was extended, incorporating also ocean shipping routes for extra-EU supply chains. The model optimises for least cost or GHG emissions from demand to supply regions. Total cost and GHG emissions depend on the routes taken, transport modes used and number of transfers between different transport modes.

For illustrative purposes, the Figure below (left) depicts an example of a transhipment hub in a region including all transport modalities, such as Rotterdam. Note that in most regions only road and rail networks are available. In addition, in the Figure below (right) an exemplary overview on EU-28 destinations (largest cities per NUTS-1 region and important harbours in the EU-28) is provided.

Figure 12-1: The network model approach (hub-spoke) (left) and EU destinations (largest cities per NUTS-1 region and important harbours) (right)

Box 4: The MULTIREG model and database

The MULTIREG model is a multi-national, multi-sectoral input-output model that covers each of the EU member states and their most important international trade partners in detail and the Rest of World (RoW) as an aggregate. It generally allows analysing economic interdependencies across country borders and has been applied to various research questions involving international trade. MULTIREG is a static Leontief input-output model, where technical and structural change can be introduced exogenously. Transactions within the economy are captured in typical input-output tables. Trade between countries is represented explicitly by commodity and by trade partners. Furthermore, data on sectoral employment, qualification, energy use and GHG emissions are integrated. The sectoral level of disaggregation can be tailored to the research question. With a few exceptions, 59 industries at the NACE 2-digit level can be distinguished for the European countries and 35 industries for the other countries. The current model base year is the year 2008.

The database of the MULTIREG model makes use of the recently published and EU-funded World Input-Output Database (WIOD) as core data. It is extended with data from Eurostat and OECD IO tables as well as national IO tables. Sectoral employment and qualification data are additionally based on the EU KLEMS database. Information on the share of employed persons in SME is based on Eurostat databases. Sectoral energy and emissions data are additionally taken from national NAMEA data and data from the International Energy Agency (IEA). In the EmployRES II project for the European Commission, the MULTIREG model is currently used to calculate past and present as well as future gross economic and employment impacts related to renewable energy use in the EU countries. In this project, the underlying world-input-output-table was extrapolated to the year 2030. This table will be used in the present study.

Box 5: Approaches used in modelling of biomass sustainability measures

Examples of default approaches used for the modelling of sustainability measures are listed below. They shall serve for illustration but details need to be adapted throughout the course of this study:

- For modelling requirements on *minimum supply chain GHG emissions* the following approach will be followed: GHG emissions for assessed biomass pathways are based on calculations by the Joint Research Centre (JRC) and complemented by transport-related emissions derived from the logistic model.
- *Sustainable forest management (SFM)* is assumed to be a proxy of all national regulations introducing biodiversity and ecosystem services criteria for forest biomass. Therefore, compliance costs of these regulations are assumed being equal to compliance with SFM certification schemes, including costs resulting from both compliance with SFM requirements and chain of custody certification.
  For these, data from literature is used to estimate average costs. A premium per MWh primary feedstock will go into modelling.
- *Minimum conversion efficiency standards* have been introduced in various countries as a condition for receiving financial support. Typically, they promote implicitly biomass use in CHP plants rather than electricity-only facilities or they promote biomass use in efficient heating installations. Thus, model implementation is done by limiting financial incentives to efficient biomass supply streams in countries that make use of such standards.
- To model *national regulations introducing air emission limits higher than EU standards*, literature data is used to estimate the additional investment costs for biomass conversion plants to comply with these regulations in the respective countries.
- *Measures to reduce ILUC* will be modelled based on policy scenario assumptions that will restrict the supply of food-based biofuel crops.

13 Assessing sustainability risks and identifying possible EU mitigation actions

13.1 Methodology for assessing risks

The project will review possible risks related to biomass use post-2020, review relevant EU and national mitigation measures (policy landscape), define policy gaps and possible additional options at EU level and assess the impacts of these mitigation options against the baseline.

Risk assessment builds on a literature review of the main risks, as well as risks identified during the review of the potential supply of biomass in Task 1. A first list of key risks includes:

- GHG emissions
    - Supply chain GHG emissions
    - Carbon stock changes
    - Indirect land use change
- Environmental impacts
    - Biodiversity, soil and water
    - Emissions to air
- Resource efficiency impacts
    - Efficiency of the end use conversion
    - Competition with other (higher value) uses

13.2 Relevant measures at EU level

At EU-level, different policies and regulations touch upon the use of biomass for energy. The project will build and further develop the extensive overview of different (more than 60) policy measures prepared within the IEE-project Biomass Policies. Policy measures can have impact on the production or availability of a certain feedstock, or on certain aspects in the biomass value chain.

A preliminary overview is presented in

and **Error! Reference source not found.**. A distinction is made between EU binding measures (directives, regulations) and non-binding measures (incentives, policy documents, recommendations). When aspects are considered in a non-binding way this is expressed as '(x)'.

The relevant EU measures are screened on groups of sustainability issues: greenhouse gas emissions, other environmental issues and resource efficiency. A detailed assessment on the extent to which these risks are effectively covered by EU measures for specific feedstock types will be further elaborated in the project.

Table 13-1: Preliminary overview of relevant binding EU measures, covering certain aspects of identified sustainability risks.

	GHG emissions			Environmental impacts		Resource efficiency	
	supply chain	carbon stock change	iLUC effects	biodiversity, soil, water	air emissions	efficient end-use conversion	competi-tion
CAP Pillar 1: Direct Payments				x			
Nitrates Directive				x			
EU Timber Regulation		x		x			
LULUCF	x	x					
NATURA 2000 / Habitat & Birds Directive				x			
Water Framework Directive				x			
Waste Framework Directive				x			x
Landfill Directive	x			x			
Sewage Sludge Directive				x			
Renewable Energy Directive	x	x		x			(x)
iLUC Directive	x	x	x	x			x
Energy Efficiency Directive						x	
Fuel Quality Directive	x	x		x			
National Emission Ceilings Directive					x		
Industrial Emissions Directive				x	x	x	
Medium					x		

Combustion Plants Directive							
Emission Trading System (ETS)	x					x	
EcoDesign Directive, e.g. solid fuel boilers					x	x	

Table 13-2: Preliminary overview of relevant non-binding EU measures, covering certain aspects of identified sustainability risks.

	GHG emissions			Environmental impacts		Resource efficiency	
	supply chain	carbon stock change	iLUC effects	biodiversity, soil, water	air emissions	efficient end-use conversion	compe-tition
CAP Pillar 2: Rural Development	(x)	(x)		(x)		(x)	
EU Forest Strategy		(x)		(x)			(x)
FLEGT		(x)		(x)			
REDD+	(x)	(x)		(x)			
EU Biodiversity Strategy to 2020				(x)			
Sustainability criteria for biomass for heat and power	(x)	(x)		(x)		(x)	
Green Public Procurement (GPP)	(x)	(x)		(x)	(x)	(x)	

13.3 Relevant national sustainability schemes

In absence of binding EU sustainability criteria for biomass for heat and power, a number of Member States have introduced national sustainability schemes, which are summarised in **Error! Reference source not found.**.

Table 13-3: Preliminary overview of binding and non-binding MS regulations in relation to biomass for heat and power, and their relation with the identified risks

	GHG emissions			Environmental impacts		Resource efficiency	
	supply chain	carbon stock change	iLUC effects	biodiversity, soil, water	air emissions	efficient end-use conversion	compe-tition
UK Renewables Obligation,	x	x		x			

Renewable Heat Incentive, Contracts for Difference							
BE - Flanders: Green Power Certificates	x						x
BE - Wallonia: Green Certificates	x						
NL: Energy Accord, SDE+	x	x		x			
Denmark: Industry agreement	(x)	(x)		(x)			
various MS renewable electricity support schemes, e.g. AT, DK, DE, EE, FI, NL, RO, SI, SE						x	

13.4 Further steps

The EU and national policy landscape will be analysed in comparison to the identified risks and policy objectives, with the view to identify potential gaps and the need for additional action at EU-level. The Green-X modelling will then be used to assess the impacts of such policy options against the baseline.

Modelling framework

Annex C

VITO
Utrecht University
TU Wien
INFRO
Rütter Soceco
PwC

14 Green-X model

The Green-X model is a specialized energy system model, geographically bounded to the European Union and its neighbours, that has been used in several impact assessments and research studies related to RES. The core strengths of this tool are its detailed representation of renewable resources and technologies and its comprehensive incorporation of energy policy instruments, including also sustainability criteria for bioenergy. This allows various policy design options to be assessed with respect to resulting costs, expenditures and benefits, as well as environmental impacts.

Identified potentials for bioenergy supply (including domestic and imported supply) combined with trends concerning biomass demand for material use as discussed above serve as basis for the modelling works as well as information on related costs. For the incorporation of biomass trade in the Green-X database and the subsequent model-based analysis, a well-established linkage between the Green-X model / database and Utrecht University's geospatial network model is used. The extended database includes for example feedstock specific costs and GHG emissions for cultivation, pre-treatment (for instance, chipping, pelletisation) and country-to-country specific transport chains.

I.4. Brief characterisation of the Green-X model

The Green-X model has been developed by the Energy Economics Group (EEG) at TU Wien under the EU research project "Green-X–Deriving optimal promotion strategies for increasing the share of RES-E in a dynamic European electricity market" (Contract No. ENG2-CT-2002-00607). Initially focussed on the electricity sector, this modelling tool, and its database on renewable energy (RES) potentials and costs, has been extended to incorporate renewable energy technologies within all energy sectors. The model is privately owned (by TU Wien) but a public demo version is available to allow for a simplified use and to a better understanding of the functionality.

Green-X covers geographically the EU-28, the Contracting Parties of the Energy Community (West Balkans, Ukraine, Moldova) and selected other EU neighbours (Turkey, North African countries). It allows for detailed assessments of demand and supply of RES as well as of accompanying cost (including capital expenditures, additional generation cost of RES compared to conventional options, consumer expenditures due to applied supporting policies) and benefits (for instance, avoidance of fossil fuels and corresponding carbon emission savings). Results are calculated at both a country- and technology-level on a yearly basis. The time-horizon allows for in-depth assessments up to 2050. The Green-X model develops nationally specific dynamic cost-resource curves for all key RES technologies, including for renewable electricity: biogas, biomass, biowaste, wind on- and offshore, hydropower large- and small-scale, solar thermal electricity, photovoltaic, tidal stream and wave power, geothermal electricity; for renewable heat: biomass, sub-divided into log wood, wood chips, pellets, grid-connected heat, geothermal grid-connected heat, heat pumps and solar thermal heat; and, for renewable transport fuels: first generation biofuels (biodiesel and bioethanol), second generation biofuels (lignocellulosic bioethanol, biomass to liquid), as well as the impact of biofuel imports. Besides the formal description of RES potentials and costs, Green-X provides a detailed representation of dynamic aspects such as technological learning and technology diffusion.

Through its in-depth energy policy representation, the Green-X model allows an assessment of the impact of applying (combinations of) different energy policy instruments (for instance, quota obligations based on tradable green certificates / guarantees of origin, (premium) feed-in tariffs, tax incentives, investment incentives, impact of emission trading on reference energy prices) at both country or European level in a dynamic framework. Sensitivity investigations on key input parameters such as non-economic barriers (influencing the technology diffusion), conventional energy prices, energy demand developments or technological progress (technological learning) typically complement a policy assessment.

Within the Green-X model, the allocation of biomass feedstock to feasible technologies and sectors is fully internalised into the overall calculation procedure. For each feedstock category, technology options (and their corresponding demands) are ranked based on the feasible revenue streams as available to a possible investor under the conditioned, scenario-specific energy policy framework that may change on a yearly basis. Recently, a module for intra-European trade of biomass feedstock has been added to Green-X that operates on the same principle as outlined above but at a European rather than at a purely national level. Thus, associated transport costs and GHG emissions reflect the outcomes of a detailed logistic model. Consequently, competition on biomass supply and demand arising within a country from the conditioned support incentives for heat and electricity as well as between countries can be reflected. In other words, the supporting framework at country level may have a significant impact on the resulting biomass allocation and use as well as associated trade.

Moreover, Green-X was extended throughout 2011 to allow an endogenous modelling of sustainability regulations for the energetic use of biomass. This comprises specifically the application of GHG constraints that exclude technology/feedstock combinations not complying with conditioned thresholds. The model allows flexibility in applying such limitations (for instance: the user can select which technology clusters and feedstock categories are affected by the regulation both at national and EU level and additionally, applied parameters may change over time).

14.1.1 The Green-X database on potentials and cost for RES

The input database of the Green-X model offers a detailed depiction of the achieved and feasible future deployment of the individual RES technologies, initially constraint to the European Union (EU28) but within the course of recent projects extended to the EU’s neighbouring countries / regions (i.e. Western Balkans, North Africa and Turkey). This comprises in particular information on costs and penetration in terms of installed capacities or actual & potential generation. Realisable future potentials (up to 2050) are included by technology and by country. In addition, data describing the technological progress such as learning rates are available. Both serve as crucial input for the modelling of future RES deployment.

An overview on the method of approach used for the assessment of this comprehensive data set is given in **Error! Reference source not found.** (below).

Box 6: About the Green-X potentials and cost for RES

The Green X database on potentials and cost for RES technologies provides detailed information on current cost (i.e. investment -, operation & maintenance -, fuel and generation cost) and potentials for all RES technologies at country level. Geographically the scope of the database has been extended within this project from the EU28 to the assessed neighbouring countries / regions (i.e. Western Balkans, Turkey and North Africa).

The assessment of the economic parameter and accompanying technical specifications for the various RES technologies builds on a long track record of European and global studies in this topical area. From a historical perspective the starting point for the assessment of realisable mid-term potentials was geographically the European Union as of 2001 (EU-15), where corresponding data was derived for all Member States initially in 2001 based on a detailed literature survey and an expert consultation. In the following, within the framework of the study "Analysis of the Renewable Energy Sources' evolution up to 2020 (FORRES 2020)" (see Ragwitz et al., 2005) comprehensive revisions and updates have been undertaken, taking into account recent market developments. Consolidated outcomes of this process were presented in the European Commission's Communication "The share of renewable energy" (European Commission, 2004). Later on throughout the course of the futures-e project (see Resch et al., 2009) an intensive feedback process at the national and regional level was established. A series of six regional workshops was hosted by the futures-e consortium around the EU within 2008. The active involvement of key stakeholders and their direct feedback on data and scenario outcomes helped to reshape, validate and complement the previously assessed information.

Within the Re-Shaping project (see e.g. Ragwitz et al., 2012) and parallel activities such as the RES-Financing study done on behalf of the EC, DG ENER (see De Jager et al., 2011) again a comprehensive update of cost parameter was undertaken, incorporating recent developments – i.e. the past cost increase mainly caused by high oil and raw material prices, and, later on, the significant cost decline as observed for various energy technologies throughout 2008 and 2009. Besides, the process included a survey of related studies (e.g. Krewitt et al. (2009), Wiser (2009) and Ernst & Young (2009) also data gathering with respect to recent RES projects in different countries.
Within the EU project BETTER (see www.better-project.net) and parallel activities, the database has been extended geographically. The extended version comprises in addition to EU member states also all Contracting Parties of the Energy Community (i.e. Western Balkans), Turkey and selected North African countries. Within the case study, work in the BETTER project a literature survey has been conducted, complemented by gathering of statistical information on land use, etc. Finally, a GIS-based assessment of wind and solar potentials was undertaken to derive an up-to-date data set following a harmonised approach for these important renewable energy technologies.

14.1.2 The use and validation of the Green-X model

Since its initial development the Green-X model has been widely used within various studies and research activities both at national and European level. For example Green-X has been successfully applied for the European Commission within several tenders and research projects to assess the feasibility of "20% RES by 2020" and for assessments of RES developments beyond that time horizon (up to 2050). The studies performed comprised generally expert reviews and validation processes of both input data as well as of outcomes derived.

In **Error! Reference source not found.** 14-1 a brief list of selected reference projects is provided.

Table 14-1. Selected recent studies

Project title	Duration	Beneficiaries (private /public)	Description of activity / Partners / Website
EmployRES II: Employment and growth impacts of renewable energies in the EU - Support Activities for RES modelling post 2020	2013-2014	European Commission, EACI, DG Energy (public)	This study has been conducted on behalf of the European Commission, DG Energy by a consortium led by Fraunhofer ISI. Leading research institutions in the respective thematic field teamed up to undertake a detailed model-based analysis and an accompanying qualitative and quantitative impact assessment related to renewable energy use in the EU post 2020. TU Wien/EEG takes in this project the responsibility for the energy sector modelling work, especially referring to RES deployment and accompanying direct cost, expenditures and benefits. Scenarios on future RES deployment up to 2050, both at an EU as well as at a Member State level, are developed and lay the grounds for the follow-up macroeconomic assessment Final report:https://ec.europa.eu/energy/sites/ener/files/documents/EmployRES-II%20final%20report_0.pdf
Beyond2020 Design and impact of a harmonised policy for renewable electricity in Europe	07/2011-12/2013	European Commission, EACI, Intelligent Energy for Europe Contract no. IEE/10/437/SI2.589880 (public)	Aim of this project is to look more closely beyond 2020 by designing and evaluating feasible pathways of a harmonised European policy framework for supporting an enhanced exploitation of renewable electricity in particular, and RES in general. Strategic objectives are to contribute to the forming of a European vision of a joint future RES policy framework in the mid- to long-term and to provide guidance on improving policy design. Partners (selected): TU Wien (coordinator), Fraunhofer ISI, Ecofys, BBH, Oxford University, Comillas, EnBW, EGL Website: www.res-policy-beyond2020.eu
REfinancing Financing renewable energy in the European energy market	01/2010-07/2010	European Commission, DG Energy and Transport (public)	A thorough assessment of the costs of and the support and financing instruments available for renewable energy. Partners (selected): Ecofys (coordinator), TU Wien, Fraunhofer ISI, Ernst & Young, LEI
Re-Shaping Shaping an effective and efficient European renewable energy market	07/2009-12/2011	European Commission, EACI, Intelligent Energy for Europe Contract no. IEE/08/517/SI2.5	Assistance of Member State governments in preparing for the implementation of the RES Directive and guidance of a European policy for RES in the mid- to long term, incl. an evaluation of past and present success of policies for RES and the derivation of recommendations to improve future RES support schemes. Partners (selected): Fraunhofer ISI (coordinator), TU Wien, Ecofys, Utrecht University, EnergoBanking, LEI, KEMA Website: www.reshaping-res-policy.eu

		29243 (public)	
EmployRES Employment and (economic) growth impacts of sustainable energies in the European Union	12/2007-05/2009	European Commission, DG Energy and Transport Contract no. TREN/D1/474/2006 (public)	A complete analysis of employment and economic growth impacts from renewable energy in Europe, observing past, present and future prospects. Partners (selected): Fraunhofer ISI (coordinator), TU Wien, Ecofys, Rütter+Partner, Seureco
FUTURES-e Deriving a Future European Policy for Renewable Electricity	12/2006-11/2008	European Commission, EACI, Intelligent Energy for Europe Contract no. EIE/06/143/SI2.444285 (public)	Analysis of consequences arising from possible policy decisions on the future of RES(-E) support schemes from a national viewpoint, including an in-depth discussion of pros and cons of harmonisation Partners (selected): TU Wien (coordinator), Fraunhofer ISI, Ecofys, EC BREC / CLN, LEI, Ambiente Italia Website: www.futures-e.org
Green-XENVIRONMENT Maximising the environmental benefits of Europe's bioenergy potential	08/2006-08/2008	European Environment Agency (public)	Identification of an environmentally optimised share of biomass deployment in the sectors electricity, heat and transport, incl. an assessment of the avoided GHG emissions and air pollutants (direct and LCA) Partners (selected): TU Wien (coordinator), Fraunhofer ISI, Ökoinstitut

Other reference projects (selected previous studies)

"Deriving a future European Policy for Renewable Electricity (futures-e)"; Project funded by the European Commission (Intelligent Energy for Europe 2006 – DG TREN, Contract No. EIE/06/143/SI2.444285); Project coordinator: EEG; Status: on-going; Duration: December 2006 – November 2008.

"Promotion and growth of renewable energy sources and systems (PROGRESS)"; Project funded by the European Commission, DG TREN (TENDER No. TREN/D1/42-2005/S07.56988); Project participation; Status: on-going; Duration: February 2006 – January 2008.

"Economic Analysis of reaching a 20% share of renewable energy sources in 2020"; Project funded by the European Commission, DG Environment (Service Contract on "Renewables Work Programme 2005", Reference: ENV.C.2/SER/2005/0080r); Project consortium with Fraunhofer ISI and Ecofys; Status: completed; Duration: December 2005 – May 2006.

"Assessment and optimisation of renewable support schemes in the European electricity market (OPTRES); Project funded by the European Commission (Intelligent Energy - Europe 2004 – DG TREN, Proposal No. EIE/04/073/S07. 38567); Project participation; Status: completed; Duration: January 2005 – December 2006.

"Bestimmung der Potenziale und Ausarbeitung von Strategien zur verstärkten Nutzung von erneuerbaren Energien in Luxemburg" (in German); Project funded by Agence de l'Energie (AEL) Luxembourg; Project consortium with Fraunhofer ISI; Status: completed; Duration: January 2006 – March 2007.

"Acceleration of European Grid-integration by ensuring an attractive business environment for key stakeholders realising RES-E projects (RE-XPANSION)"; Project funded by the European Commission (ALTENER 2002 – DG TREN, Proposal No. ALTENER-2002-054); Project coordinator: European Wind Energy Associaton (EWEA); Status: completed; Duration: April 2003 – March 2005.

"Analysis of the Renewable Energy Sources' evolution up to 2020 (FORRES 2020)"; Project funded by the European Commission (TENDER No. TREN/D2/10–2002 – LOT 8); Project participation; Status: completed; Duration: January 2003 – December 2004.

"Study on the Economic Analysis of RE Support Mechanisms", Project funded by Sustainable Energy Ireland, SEI, (reference number RDSV000192), Project coordinator: EEG, Status: completed, Duration: September 2003 – March 2004.

"Deriving optimal promotion strategies for increasing the share of RES-E in a dynamic European electricity market (Green-X)"; Project funded by the European Commission (5th FWP – DG Research, Contract No: ENG2-CT-2002-00607); Project coordinator: EEG; Status: completed; Duration: October 2002 – September 2004.

14.1.3 About the use of Green-X in the BioSustain project

Within BioSustain modelling of future demand and supply of bioenergy and other renewables in the energy sector has been done by using the Green-X model. In this context, Green-X provides a broad set of results concerning environmental (avoidance of fossil fuels and of GHG emissions following a supply chain approach) and economic impacts (CAPEX, OPEX, support expenditures).

14.1.4 Development of baseline scenarios for bioenergy demand

Within the project Green-X is used to quantitatively model the following bioenergy demand scenarios up to 2030:

- a *reference scenario* in accordance with the EU outlook for energy and transport up to 2050 (i.e. PRIMES reference scenario), assuming for example a (gradual) phase-out of RES support beyond 2020 and, consequently, non-compliance with 2030 energy and climate targets
- a *RES policy scenario* in accordance with the Council agreement on 2030 energy and climate targets, aiming at 40% GHG reduction and (at least) 27% RES and energy efficiency by 2030. This case is subsequently named as *Green-X euco27* scenario and is used throughout this study as benchmark for analysing the impacts of policy options to safeguard sustainability of bioenergy supply and use. The underlying policy concept for incentivising RES can be characterised as a

least-cost approach, enhancing an efficient use of bioenergy and other RES for meeting the 2030 RES target in a cost-effective manner.[65] Specifically for biofuels in transport, a continuation of current policy practices is however envisaged post 2020, in accordance with the calculation done by the PRIMES model in related works.

-

A sensitivity analysis is carried out on the following parameters:

- *Availability of biomass feedstock for the energy sector:* Aim is to assess the impacts of changing assumptions concerning bioenergy feedstock potentials, reflecting the uncertainty in the availability of forestry biomass feedstock for the energy sector (EU and Extra-EU potentials), respectively. For doing so three different datasets on bioenergy feedstock potentials are applied, reflecting distinct levels of availability of forestry biomass incl. competition between energy and material use, combined with distinct trends concerning Extra-EU solid biomass potentials available for import to Europe.[66]
- *Energy efficiency / energy demand:* For the RES policy scenario the impact of accompanying energy efficiency measures will be assessed. More precisely, we analyse how overall RES deployment and specifically bioenergy use is affected by a move towards strong energy efficiency measures (i.e. 30 or 33%).

14.1.5 Key input parameters

In order to ensure maximum consistency with existing EU scenarios and projections the key input parameters of the scenarios presented in this report are derived from PRIMES modelling and from the Green-X database with respect to the potentials and cost of RES technologies. **Error! Reference source not found.** shows which parameters are based on PRIMES, on the Green-X database and which have been defined for this study. The PRIMES scenarios used for this assessment are the latest *reference scenario* (European Commission, 2016) and climate mitigation scenarios that build on an enhanced use of energy efficiency and renewables in accordance with the Council agreements taken for 2030 (PRIMES euco27 and euco30 scenario).

[65] The selection of RES technologies in the period post 2020 within the default RES policy scenario as well as within all related scenarios concerning sustainability policy options follows a least-cost approach, meaning that all additionally required future RES technology options (including bioenergy) are ranked in a merit-order, and it is left to the economic viability which options are chosen for meeting the 27% RES target. In other words, a least-cost approach is used from a European perspective to determine investments in bioenergy and other RES post 2020 across the EU. This allows to fully reflect competition across technologies, countries (incorporating well also differences in financing conditions etc.) from a European perspective. Support levels and related expenditures follow then the marginal pricing concept where the marginal technology option determines the support level (like in the ETS or in a quota/certificate trading regime, or similar to the concept of liberalised electricity markets).

[66] The default dataset on feedstock potentials reflects a "reference" case with respect to biomass feedstock that is left over for energy uses (i.e. in accordance with the "reference" scenario concerning biomass feedstock, see section 4.1) and a reference trend concerning Extra-EU biomass potentials that can be imported to Europe (see section 4.1). Within the sensitivity assessment this dataset will be replaced by a low potential case (i.e. the "restricted" scenario concerning supply potentials) and a high potential case (i.e. the "resource" scenario).

Table 14-2: Main input sources for scenario parameters

Based on PRIMES	Based on Green-X database	Defined for this assessment
Primary energy prices	Renewable energy technology cost (investment, fuel, O&M)	Renewable energy policy framework
Conventional supply portfolio and conversion efficiencies	Renewable energy potentials	Reference electricity prices
CO_2 intensity of sectors	Biomass trade specification	
Energy demand by sector	Technology diffusion / Non-economic barriers	
	Learning rates	
	Market values for variable renewables	

14.1.6 Modelling of socio-economic impacts

The introduction of sustainability criteria for the use of biomass mainly has an impact on the technology mix within RES deployment. Since the 27% RES target still applies, the impact on the use of conventional energy technologies is small according to the Green-X results. The policy measures thus mainly affect investment, O&M and fuel expenditures for RES deployment on one hand and energy generation costs as well as policy support expenditures on the other hand. Modelling of socio-economic impacts aims at analysing the impacts of these changes on gross value added as a contribution to GDP, on employment and on employment in SME.

14.1.7 Impact mechanisms

For the economic analysis of the considered policy options, the following impact mechanisms are considered to be relevant. The main economic impulses are changes of RES deployment expenditures on one hand and of policy support expenditures on the other hand.

Changes in *RES deployment expenditures* have the following impacts:

They affect production, value added and employment in the so-called RES industry, that includes operation of RES plants and facilities (e.g. biomass or wind power plants), specialized technology and services suppliers (e.g. manufacturers of wind mills or biogas installations) and fuel supply (e.g. agriculture, forestry or wood pellet manufacturers). This is termed the *direct effect*.
Production in the RES industry initiates production in upstream supply chains, e.g. manufacturing of steel for wind mill towers, iron ore for steel production etc. These complex supply chains usually transcend country borders, so that the international context needs to be taken into account. This is called the *indirect effect*. Together, the direct and the indirect effect can be termed the *deployment effect*.
Changes in production activities have an impact on employment and household income. This in turn affects consumption expenditures for goods and services that need to be produced and thus cause production, value added and employment in the respective supply chains. This impact is called the *income effect*.
The upper mentioned impacts can be positive or negative depending on the changes in deployment levels of biomass and other RES technologies, their costs and cost structures, their supply chains, the location of production (domestic vs. imports), the

capital and labour intensity of production activities or the propensity to consume in different countries.

On the other hand, changes in *policy support expenditures* can affect various economic agents depending on the type of support policy. Investment subsidies e.g. reduce additional generation costs, but typically affect the public budget, whereas feed-in tariffs and the costs of certificate schemes are usually borne by energy consumers. In addition, exceptions may apply, e.g. when energy intensive enterprises are exempted from financing feed-in tariffs. Enterprises that face energy price increases have various options to react, (1) to invest in energy-saving measures and thus to reduce their energy cost burden, (2) to pass on the price increase to their own customers or (3) to accept a reduction of their own margin and thus their value added.

The exact burden of policy support expenditures on the different societal agents is not known for the policy options analysed in this study. For the estimation of socio-economic impacts, we thus assume that in the end policy support expenditures are borne by private households. Implicitly this assumption implies that changes of public subsidies for RES deployment are financed by increasing taxes from households, cost increases of enterprises are passed on to final consumption or are borne by shareholders in the form of reduced capital income. This reduces the purchasing power of private households and thus household consumption after deduction of taxes, social security contributions and savings. This in turn reduces production of consumption goods and services and has indirect impacts in their respective supply chains. This impact is termed the (household) *budget effect*.

14.1.8 Modelling approach

Our modelling of socio-economic impacts aims at tracing these impact mechanisms by *combining techno-economic information with economic modelling*. It aims at capturing the main (in the sense of first-order) economic impacts induced by the analysed policy options. It builds on the output of the Green-X model that allows to analyse how the policy options affect the deployment of biomass technologies for energy use and more generally the deployment of RES technologies. For each policy option, the following *outputs of the Green-X model* are used as an input:

- investment expenditures, O&M expenditures and fuel expenditures for RES deployment and use and
- public support expenditures for electricity, heat and transport fuel generation from RES.

The following *impacts* are calculated for the reference scenario and each policy option,

- the *direct effect* on the RES sector, comprising operation of RES facilities on one hand and dedicated technology, service and biomass suppliers on the other hand,
- the *indirect effect* in the upstream supply chain industries of the RES sector,
- the *income effect* induced by consumption expenditures of persons employed in the RES sector and in supply chain industries
- the *budget effect* induced by reduced consumption expenditures of private households due to policy support expenditures.

The net impact of a policy option is then derived as the difference to the impacts in the reference scenario. The results are reported for the average of the period 2021 - 2030.

In the following the calculation of each impact is briefly explained. More details on the overall approach can be found in the EmployRES II report (Duscha et al. 2014), where a similar approach was used to estimate the gross economic and employment impacts of RES deployment.

14.1.9 Direct effects

The direct effect is calculated in two steps. In a first step, the *direct effect on operation of RES facilities* is estimated for each RES technology. Direct value added of operating RES facilities is estimated as the sum of labour costs and capital depreciation. Capital depreciation is estimated with the linear method by dividing for each RES technology total capital stock by the average economic lifetime. Direct employment for operating RES facilities is estimated from labour costs.

In the second step, the direct effect on *RES technology and service suppliers and suppliers of biomass is calculated*. For this, investment, O&M and fuel expenditures are allocated to cost components and then to supplying industries. The allocation is based on technology specific data on cost structures of RES technologies. The result of this calculation is the demand for goods and services by supplying industry for each RES technology and each EU member state. This data is fed into the MULTIREG model to calculate direct output, gross value added, employment and employment in SME by RES technology, country and supplying industry. This calculation makes use of country- and industry-specific ratios for import shares, value-added-shares, labour productivities and share of employed persons in SME, that are available in the MULTIREG model.

Direct effects on value added and employment are only calculated for market activities, not for activities of private households. Since statistical data on the distribution of RES operation among households and enterprises are not available for the EU countries, we have taken the following assumptions:

- share of commercial operators in small-scale technologies: we assume that 20% of the PV installations, 10% of heat pumps and 10% of small-scale wood heating units belong to commercial enterprises[67] and thus lead to direct value added and employment in operation;
- market share of log wood supply: a significant share of log wood used for heating is not purchased on the market, but collected by forest owners in their own forests. Statistics on the share of non-commercial log wood supply are not available. Mantau (2013, 2016) estimates the share in Germany at 36.5% in 2010 with decreasing tendency and assumes that it will probably be higher in lower-income countries and in more rural countries. For the period 2021 - 2030 we assume an average share of non-commercial log wood supply of 30% in Germany, thus allowing for an increase of market activities. For the other EU member countries we assume shares between 30% and 50%.

14.1.10 Indirect, income and budget effects

The indirect, income and budget effects are roughly estimated with multiplier analysis based on input-output modelling. Starting from direct output by country and industry, *indirect effects* in the upstream supply chain industries are calculated with the MULTIREG

[67] and the rest to private households

model, that allows to trace production in supply chains across country borders. The calculation of *income effects* starts with value added that is generated in the RES sector and in supply chain industries. The MULTIREG model then calculates household income, household consumption expenditures (after deduction of income taxes, social security contributions and savings from income) and the total (i.e. direct and indirect) economic impacts induced by household consumption on value added and employment in all countries and industries.

The Green-X results on policy support expenditures by country are the starting point of the calculation of *budget effects*. As mentioned above, we assume that in the end private households bear the costs of RES policy support and that these additional costs reduce household consumption of other goods and services. The total economic impacts induced by reduced household consumption on value added and employment in all countries and industries is calculated in the MULTIREG model.

14.1.11 The MULTIREG model

The MULTIREG model is a multi-national, multi-sectoral input-output model that covers each of the EU member states and the Rest of the World as an aggregate. In technical terms it is a static Leontief input-output model, where technical and structural change can be introduced exogenously. The model was developed by Rütter Soceco and has since been used for several analyses of energy- and trade-related research questions. It was used in the EU funded projects EmployRES I (Ragwitz et al. 2009) and EmployRES II (Duscha et al. 2016, 2014) to estimate the gross economic and employment impacts of renewable energy deployment in the EU, including a peer review of the methodological approach in the EmployRES I project. In a project for the Swiss State Secretariat for Economic Affairs (SECO) it was used to analyse the economic impact of the integration of Switzerland into global value chains (Nathani et al. 2014).

The main database of MULTIREG is an inter-country input-output table that captures economic transactions within and between countries at the industry level. This includes transactions between industries (intermediate inputs) and final demand (household consumption, government consumption, investment and exports). Trade between countries is represented explicitly by product group and by trade partner. Furthermore, data on sectoral employment and employment in SME are included. The sectoral level of disaggregation allows to distinguish 59 industries at the NACE 2-digit level.

The database of the MULTIREG model makes use of the recently published and EU-funded World Input-Output Database (WIOD)[68] as core data. It is extended with data from Eurostat IO tables for additional sectoral disaggregation. Sectoral employment data are based on the WIOD database and Eurostat national accounts data. Shares of employment in SME are derived from Eurostat's structural business statistics. This set of data refers to the year 2008 (due to data availability in the core WIOD database). The data set was extrapolated to the year 2030 to account for the most important changes in country and sectoral growth patterns and labour productivities. The extrapolation was based on the reference scenario results of the NEMESIS model generated in the EU funded SIMPATIC project (SEURECO et al. 2014). The data set for the year 2030 is used for calculations in the Biosustain project.

[68] http://www.wiod.org

The output of MULTIREG are impacts on gross value added as a contribution to GDP, employment and employment in SME. The results on employment in SME excludes direct effects for operation of RES facilities, since data on their size classes are not available. Economic and employment impacts are estimated for the reference period 2021 - 2030, for each EU member state and the EU as a whole.

14.1.12 Strengths, limitations and uncertainties of the modelling approach

By combining technology specific data with multiplier analysis based on a multi-national, multi-sectoral input-output model, the modelling approach aims at capturing the main (i.e. first order) economic impacts of the analysed policy options. With regard to technology data, the modelling makes use of specific data on cost structures of RES technologies. This allows to adequately take the first-order-effects of RES technology shifts into account. The main data sources are techno-economic studies on the specific cost structures of RES technologies. For wind and PV technologies, that are characterised by rapid cost decreases, studies on future cost structures were evaluated. Most studies refer to generic technologies in Western Europe. Data on cost structures of RES technologies in Eastern European countries are rare and we therefore assume similar cost structures in all countries. Therefore, the results for Eastern European countries may be more uncertain than those for Western European countries.

Furthermore, the levels of market activities in the operation of small-scale RES installations and in the supply of log wood are also uncertain due to missing data. Our assumptions are thus based on expert judgement.

The use of input-output modelling to generate economic impact multipliers is a standard and widely used methodology (see e.g. Miller / Blair 2009). This modelling approach has the advantage of capturing the specific impacts of RES technology shifts on economic structure with a high level of sectoral disaggregation, also across country borders, when using an inter-country IO model. The main limitations of input-output analysis include the following:

- the *input structure of each industry is fixed* (linear limitational production technology) and industries are homogeneous; substitution between inputs is not modelled endogenously, but has to be introduced exogenously, if relevant. In our modelling approach, general structural change until 2030 is captured with the forecast of inter-country IOT to the year 2030. Shifts within the RES sector are explicitly modelled, thus relaxing the limitation for the first-order effect of the analysed policy measures;
- *prices are fixed* in the standard IO model, i.e. price adjustments are not modelled endogenously,
- *absence of supply constraints*: the impact of additional demand is not limited by supply constraints, e.g. with regard to labour or capital. Thus a theoretically possible crowding-out of other economic activities due to supply constraints is not taken into account in our modelling approach. Since the EU economies today are characterised by rather high unemployment, labour supply constraints do not appear to be realistic for the current economic situation in the EU. If in future unemployment would be much lower and labour supply restricted in the EU, this could theoretically limit the estimated socio-economic impacts through crowding out. Given the low level of overall economic and employment impacts of the analysed policy options, we consider this limitation to be acceptable.

Furthermore, the assumption that policy support expenditures are completely borne by private households is a simplification, that captures the main economic impact but simplifies the variety of impact mechanisms that could be induced by different types of support policies.

With regard to quality management, the results of this modelling exercise were validated by analysing the detailed results at the technology and country level, cross-checking with the inputs from the Green-X model, analysing key ratios that characterise the strength of the different impact mechanisms mentioned above and cross-checking between policy options.

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Results public consultation sustainable bioenergy

Annex D

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Results public consultation sustainable bioenergy policy

BioSustain: sustainable and optimal use of biomass for energy in the EU beyond 2020

Contract No ENER/C_1/2013-410/SI_2.685777

Date: July 03, 2016

By: Eric van den Heuvel, Sabine Kreps (VITO NV)

Executive summary

Early 2016, The European commission invited stakeholder to share their views on the sustainable bioenergy policy for the period 2020 to 2030 in which the share of renewable energy is target to grow towards 27% of final energy demand. Stakeholders could provide their input from 10 February 2016 up to and until 10 May 2016. This report is based on those responses, as have been provided by the EC to the authors of this report.

Nearly seven hundred representatives of organisations (civil society organisations, academic/research institutions, private enterprises, public enterprises, professional organisation[69] and public authorities) and nearly three hundred individual responded to the public consultation. A remarkable high share (45%) of the respondents were based in Germany (25%) and Austria (20). Furthermore, the European Commission received via an email campaign about 58 thousand emails from foreign (mainly US-based) activists expressing their concerns on the negative impacts of increased use of biomass resources for energy purposes.

Among the respondents, on the one hand, significant support is expressed for a dominant or important role for bioenergy in the renewable energy mix. But on the other hand half of the respondents want the share of bioenergy to decline in favour of other renewable sources. The latter position is based on the arguments that the most critical sustainability risks, such as change in carbon stock due to deforestation and direct land use change, competition for biomass, indirect land use change) are currently not addressed in an effective way by current sustainability legislations. As a result, stakeholders had different viewpoints on the main characteristics of a post-2020 EU sustainable bioenergy policy.

The types of bioenergy that receive broad and high support for policy intervention could be characterised as: waste-based, high efficiency conversion with strong focus on combined heat and power generation, small-scale bioenergy plants and locally or regionally sourced feedstocks. Food-crop based crops, electricity-only bioenergy and non-EU origin feedstocks encountered limited support among the respondents.

The stakeholders in general were quite united about to which benefits and opportunities bioenergy contributed most: reduction on greenhouse gases, Europe's energy security and resource efficiency and waste management.

The risks that respondents viewed most critical in relation to bioenergy production and use are change of carbon stock (due to deforestation and direct land use change) in non-EU countries, competition for biomass resources, indirect land-use change and varying degrees of biomass conversion efficiency to energy.

[69] Examples of professional organisations are business associations, sector agencies etc. In the public consultation respondents could also indicate whether they were international organisations. It turned out that none of these international organisations were UN type of organisations, but instead were all professional organisations with members in more than one country.

From the responses to the question on the effectiveness of the EU policy in addressing sustainability risks for biofuels and bioliquids it can be concluded that stakeholders have polarized positions: civil society organisations and academic/research institutions value the scheme as counter-productive to issues as indirect land-use change, impacts on biodiversity and on soil, air and water, whereas private and public enterprises, professional organisation and public authorities view these risks as sufficiently addressed. Only a limited number of the respondents were in the opinion that the existing policy was effective in promoting advanced biofuels and in minimising the administrative burden for operators.

Respondents were also asked on their views on the effectiveness of existing EU policies in addressing solid and gaseous biomass sustainability issues. The issues that were most often indicated as effectively addressed were air quality, change in carbon stock in the EU, water and soil quality and biodiversity. Issues for which the EU policies were viewed as counterproductive were indirect land-use change, competition of biomass change in carbon stock in non-EU countries and biodiversity.

With respect to the effectiveness of policies for both biofuels and bioliquids and for solid and gaseous biomass it may be concluded that the issue of greenhouse gas savings is to be read with care: while a large group of respondents view the contribution of bioenergy to greenhouse gas savings as critical or of importance, they see the effectiveness of the current polices towards issues that influence overall greenhouse gas savings as counter-productive.

For a post-2020 bioenergy sustainability policy the stakeholders therefore provide a clear advice to the commission by ranking the following set of objective for that policy as most important:

- Contribute to climate change – this objective receives by far the most support form all stakeholder groups, followed by the following four objectives which received almost equal support
- Promote efficient use of biomass resources
- Avoid environmental impacts
- Ensure long term certainty for operators
- Promote energy security

A majority of the stakeholders, and they were found among all types of stakeholder groups found that additional legislative actions were needed to secure the sustainable contribution of bioenergy. Most of the industrially involved stakeholders valued the current scheme for biofuels and bioliquids as sufficient, while civil society organisations and academic/research instates were best presented among the group that saw the need for additional policy for al types of bioenergy.

A majority of the stakeholders is in the opinion that the EU sustainability scheme currently existing for biofuels and bioliquids should at EU level be expanded to solid and gaseous biomass for the heat and power sector. This will influence in particular biomass resources from the forestry sector. Several stakeholders, among which many from the forestry sector, but also from public authorities indicated that in such case a risk based approach should be followed, in the knowledge that many of the European forests are already controlled under sustainable forest management systems.

15 Introduction

EU Member States have agreed on a new policy framework for climate and energy, including EU-wide targets for the period between 2020 and 2030. The targets include reducing the Union's greenhouse gas emissions by 40% relative to emissions in 2005 and ensuring at least 27% of the EU's energy comes from renewable sources.

In January 2014, in its Communication on A policy framework for climate and energy in the period from 2020 to 2030[70], the Commission indicated that an improved biomass policy would be necessary:

- to maximise the resource efficient use of biomass, and
- to allow a fair competition between the various uses of biomass resources

In 2015 the Commission announced that it would come forward with an updated bioenergy sustainability policy, as part of a renewable energy package for the period after 2020.[71]

Bioenergy is the form of renewable energy currently most used in the EU. It is expected to contribute also a significant part in the overall energy mix in the near future. Several stakeholders have raised concerns about the sustainability impacts and the possible competition for resources as also in a biobased economy more biobased resources are needed for material use and in e.g. the chemical sector. While the Renewable Energy Directive and the Fuel Quality Directive provide at EU-level a sustainability framework that includes harmonised sustainability criteria for bioliquids and biofuels, and takes into account provisions to limit indirect land use change, for solid and gaseous biomass used in electricity, heating and cooling only non-binding sustainability criteria are recommended at EU-level - only a few Member States have developed national sustainability schemes.

The Commission now reviews the sustainability of all bioenergy sources for the period after 2020 and seeks consulted stakeholders on these issues. The Public consultation took place from 10 February up to and until 10 May 2016.[72] This reports presents the outcomes from this consultation, on basis of the information received from DG Energy. Nearly seven hundred representatives of organisations (civil society organisations, academic/research institutions, private enterprises, public enterprises, professional organisation[73] and public authorities) and nearly three hundred individual responded to the public consultation. On top of that the European Commission received via an email campaign about 58 thousand emails from foreign (mainly US-based) activists expressing

[70] COM(2014)15
[71] COM/2015/080 final
[72] https://ec.europa.eu/energy/en/consultations/preparation-sustainable-bioenergy-policy-period-after-2020
[73] Examples of professional organisations are business associations, sector agencies etc. In the public consultation respondents could also indicate whether they were international organisations. It turned out that none of these international organisations were UN type of organisations, but instead were all professional organisations with members in more than one country.

their concerns on the negative impacts of increased use of biomass resources for energy purposes.[74]

15.1 Outline of the report

The public Consultation document[75] was structured in the following sections. This report follows this structure. In the list below is indication in which section the specific topic is discussed.

1. General information about the respondents (section 16.1)
2. Perceptions of bioenergy (section 0 and 16.3)
3. Benefits and opportunities from bioenergy (section 16.4)
4. Risks from bioenergy production and use (section 16.5)
5. Effectiveness of existing EU sustainability scheme for biofuels and bioliquids (section 16.6 to 16.8)
6. Effectiveness of existing EU policies in addressing solid and gaseous biomass sustainability issues (section 16.9)
7. Policy objectives for a post-2020 bioenergy sustainability policy (section 16.10)
8. EU action on sustainability of bioenergy (section 17)

15.2 Methodology

The analysis of the responses to the public consultation is based on information provided by EC DG Energy. The information consisted of statistical processed information and excel-file. This information has been used to develop the graphical representation in this report. Where possible and requested by the EC the information has been analysed on stakeholder group level.

[74] These emails have not been taken into account in this report on the public consultation, as these individuals did not submit a filled out and completed public consultation document.
[75] https://ec.europa.eu/energy/sites/ener/files/documents/BioenergySurvey2016%20final.pdf

16 Results of the stakeholder consultation

16.1 Overall facts and results related to the stakeholder consultation

16.1.1 Number and type of respondents

This public consultation was launched on 04 February 2016 and remained open until 10 May 2016. Until 11 May 2016, the Commission received in total 971 replies.

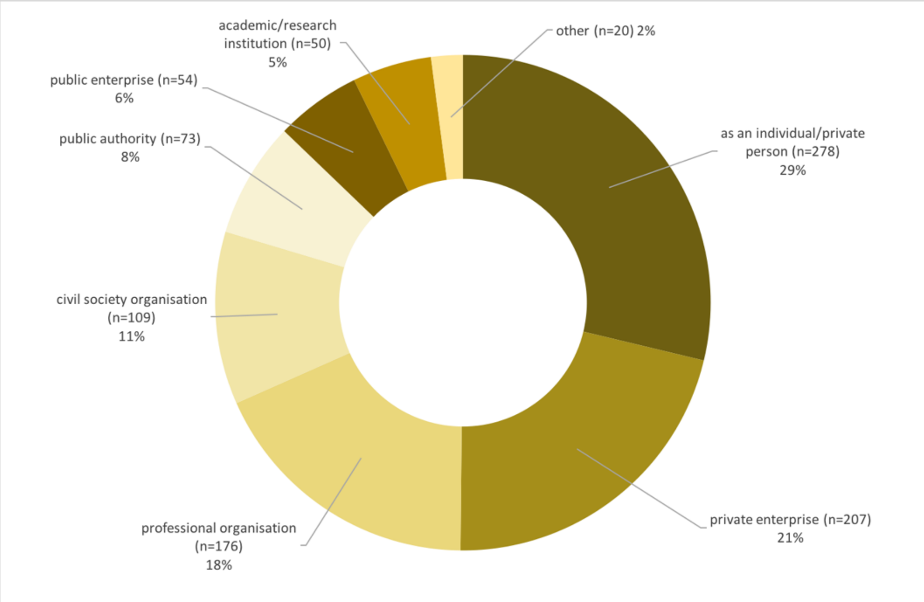
The number of responses from individuals/private persons is high: nearly 30%[76]. This was followed by private enterprises (21%) and professional organisations (16%). An analysis of the respondents who indicated to complete the public consultation as an 'international organisation' turned out to be mostly business associations with international members and not representatives of international bodies like the FAO, World Bank or other UN-type of organisations. In this report the information in tables and graphs is presented on basis of the respondents input. Where possible the information of the professional organization and the international organisations is grouped in one category. In such cases this will explicitly mentioned and the graph with original information is presented in Annex 3. Figure 1 shows the distribution of the various stakeholders (professional organisations and international organisations are grouped together).

Table 16-1: information about the respondents

type	percent	answers
as an individual / private person	28.78 %	278
public authority	7.55 %	72
academic/research institution	5.19 %	50
international organisation	2.17 %	21
civil society organisation	11.27 %	109
professional organisation	16.03 %	155
private enterprise	21.41 %	207
public enterprise	5.58 %	54
other	2.07 %	20

[76] Deeper analysis of this group of respondents showed a high response rate from Germany and, particularly Austria.

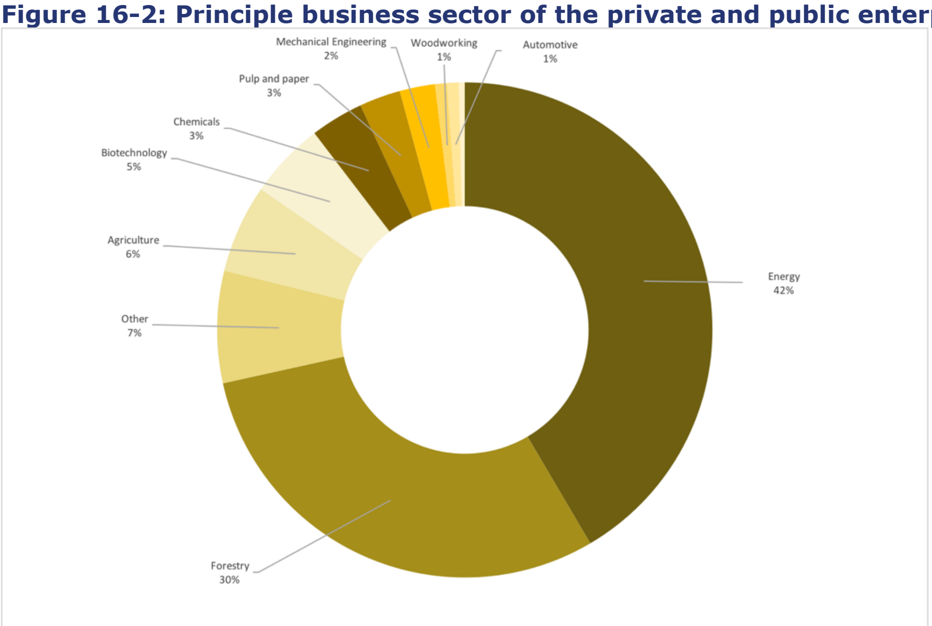
Figure 16-1: Overview of the responses by stakeholder group (international and professional organisations are grouped)



16.1.2 Principal business sector of the private or public enterprises

In total 261 replies (from the 971 in total) of the respondents completed the public consultation in the capacity of a private or public enterprise. The energy sector is the most dominant principal business sector these respondents are active in, followed by Forestry (see Figure 2).

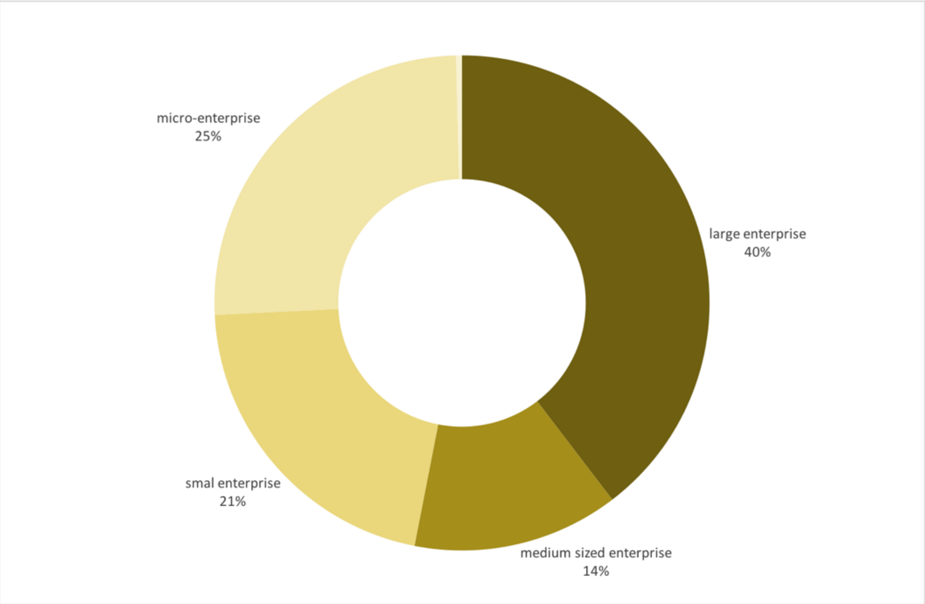
Figure 16-2: Principle business sector of the private and public enterprises



16.1.3 Size of the company, (for private and public enterprises)

40% of the private and public enterprises are large enterprises (more than 250 employees and annual turnover of more than 50 million euro or whose annual balance sheet is more than 43 million euro. 47 % of the private and public enterprises are small or micro-enterprises and employ less than 50 employees and the annual turnover is less than 10 million (see **Error! Reference source not found.**).

Figure 16-3: Distribution of the responding private and public companies on basis f the size of the company



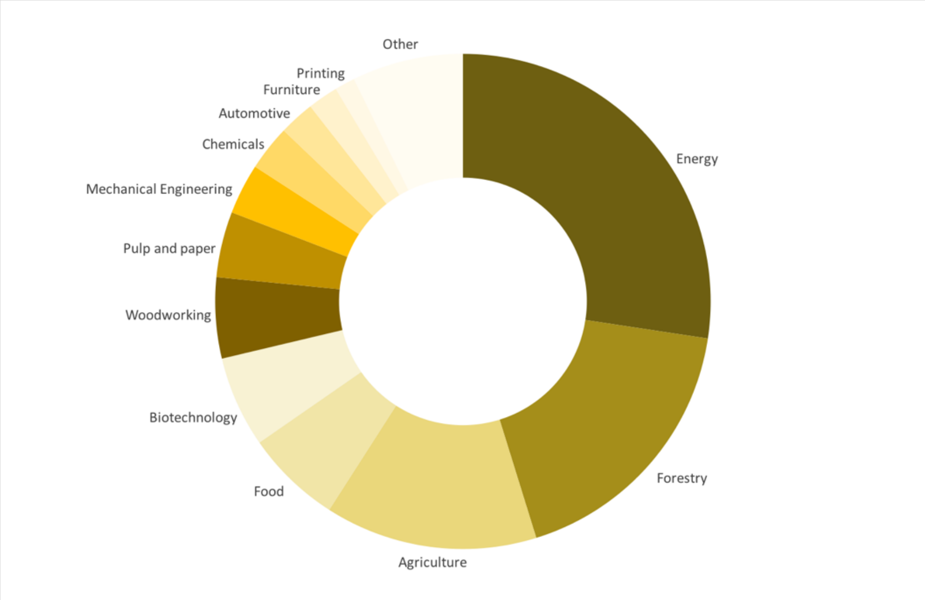
16.1.4 In case of professional organisation, which sectors are represented

155 respondents[77] who completed the consultation document are representing professional organisations (business associations etc.)[78]. They could indicate which sectors their organisation represent. Several indicated more than 1 sector. From Figure 4 it becomes clear that the sectors Energy, Forestry and Agriculture are the main sectors represented by the professional organisations. It can also be concluded that the sector that represents the biomaterial market is also well represented, given a share of about 30% of the respondents (biotechnology, woodworking, pulp and paper, furniture etc.).

[77] More than 90%of these representatives are from EU member states. 8 replies came from North or South America, 1 from Asia and 5 from non-EU European countries.

[78]Additionally, 21 respondents, indicating they were international organisations, are in fact also professional organisations. They however did not provide information on the sectors they represent, as this question was not applicable for 'international organisations'.20 of these respondents originated from a EU member state, the remaining respondent was based in a non-EU European country

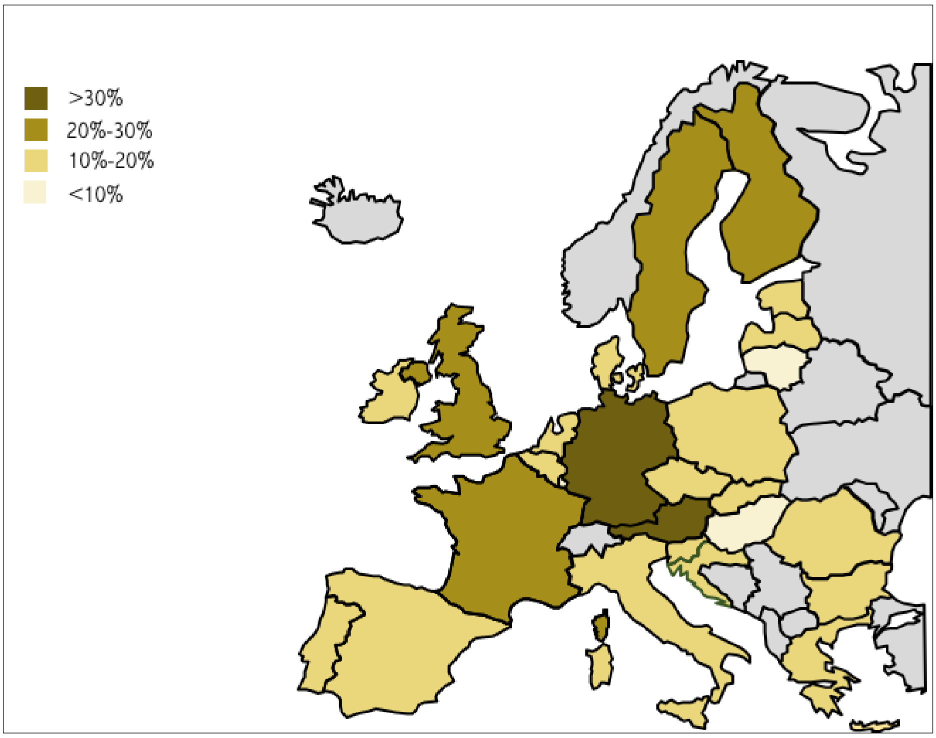
Figure 16-4: Sectors represented by the professional organisations



From the question where the members of the professional organisations are located it can be concluded that members of these 155 the professional organisations are found everywhere in the EU[79]. The members are rather unevenly spread over Europe: 37% of the professional organisations have members in Germany, and 32% of these organisations have members in Austria. Other countries which are well represented by members of various professional organisations are Sweden, Finland, France and the United Kingdom. (see **Error! Reference source not found.**).

[79] Again, the 21 'international organisation'-respondents did not indicate the countries origin of their members

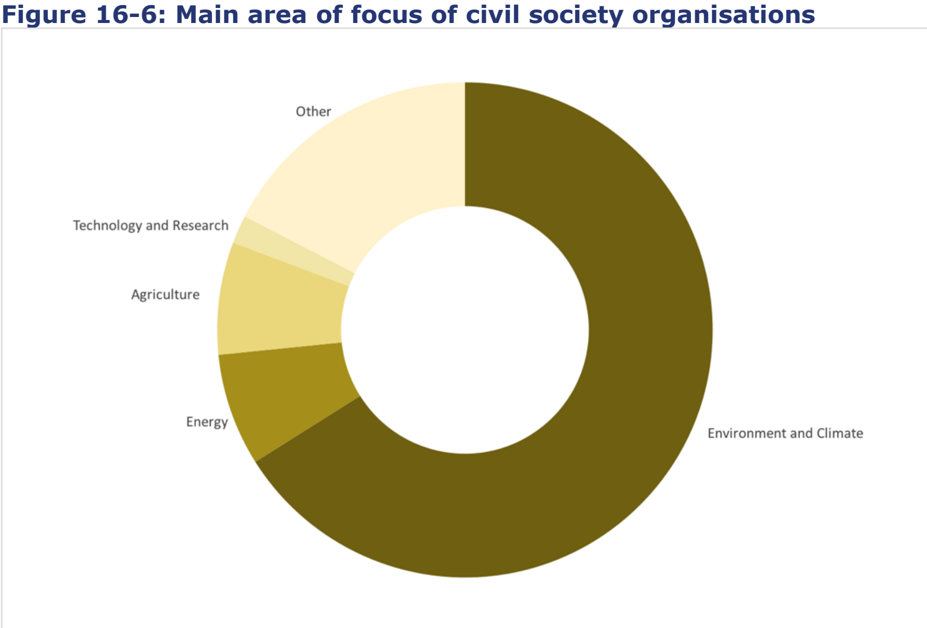
Figure 16-5: Percentage indicate how many of the professional organisations have members in the corresponding countries



16.1.5 In case of civil society organisation, main area of focus

110 replies came from civil society organisations. A large majority of these organisations mainly focuses on environment and climate issues as can bee seen from **Error! Reference source not found.**.

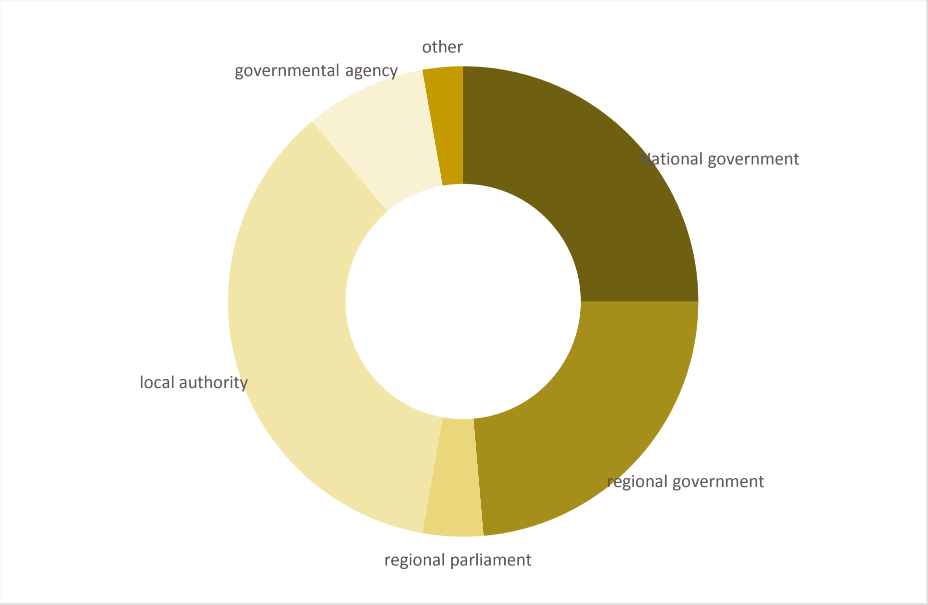
Figure 16-6: Main area of focus of civil society organisations



16.1.6 In case of public authority, main area of competence

73 respondents proved to be public authorities. Most of them (one third) are local governments, followed by national and regional governments (both about 25%).

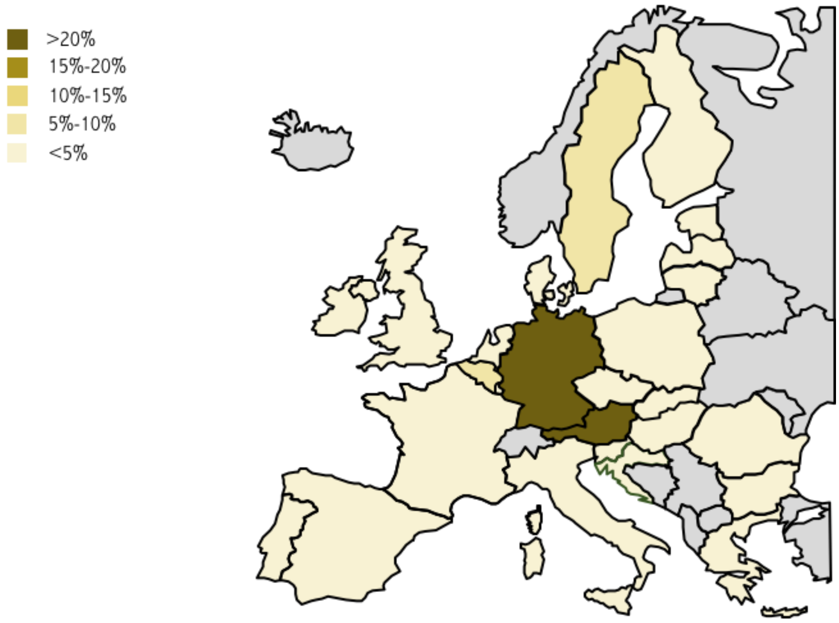
Figure 16-7: Main area of competence of the public authorities



16.1.7 Country of residence/establishment

Of all 971 respondents, 25,7% originate from Germany and 20,3% from Austria. So, 46% of the respondents come from these two countries. In Annex 1 more information is provided on the country of residence/establishment of the respondents, split out per stakeholder group. In e.g. the group 'individual persons' (278 respondents), more than 70% of the respondents were Austrian or German based.

Figure 16-8: Country of residence/establishment of the respondents



76% of the respondents hold residence in only 7 Member States in the EU, as can be seen from the table below. Responses from the other 21 Member States accounted for 18% of the total replies. 3% of the responses originated from America countries. 1% did not disclose its country of origin.

Table 16-2: Information about the country or origin/establishment of respondents from the Member States where most respondents came from

Member State	Share of respondents
Germany	25,7%
Austria	20,3%
Sweden	8,5%
Belgium	8,1%
United Kingdom	5,0%
Finland	5,0%
Netherlands	3,6%

16.2 Role of bioenergy in the achievement of EU 2030 climate and energy objectives

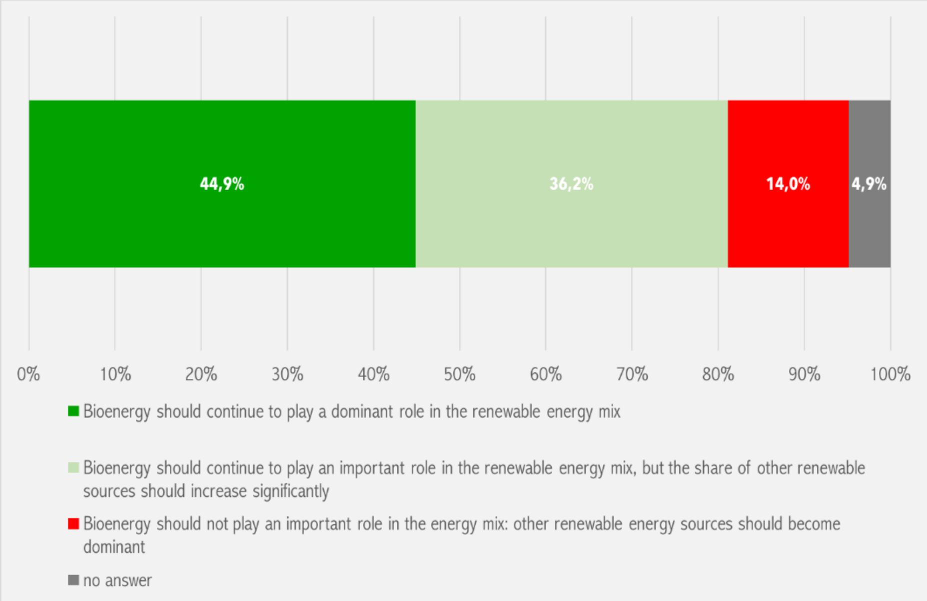
Question 2.1 as stated in the Public Consultation Document was:

"Please indicate which statement best corresponds to your perception of the role of bioenergy in the renewable energy mix, in particular in view of the EU's 2030 climate and energy objectives:

- *Bioenergy should continue to play a dominant role in the renewable energy mix;*

- *Bioenergy should continue to play an important role in the renewable energy mix, but the share of other renewable energy sources (such as solar, wind, hydro and geothermal) should increase significantly;*
- *Bioenergy should not play an important role in the renewable energy mix: other renewable sources should become dominant."*

Figure 16-9: Role of bioenergy in achieving the EU 2030 energy and climate objectives



Nearly half of the respondents are in the opinion that bioenergy should play a dominant role. 36% of the respondents think bioenergy has an important role, but want the share of other renewables to increase significantly. These two groups represent more than 80% of the respondents.

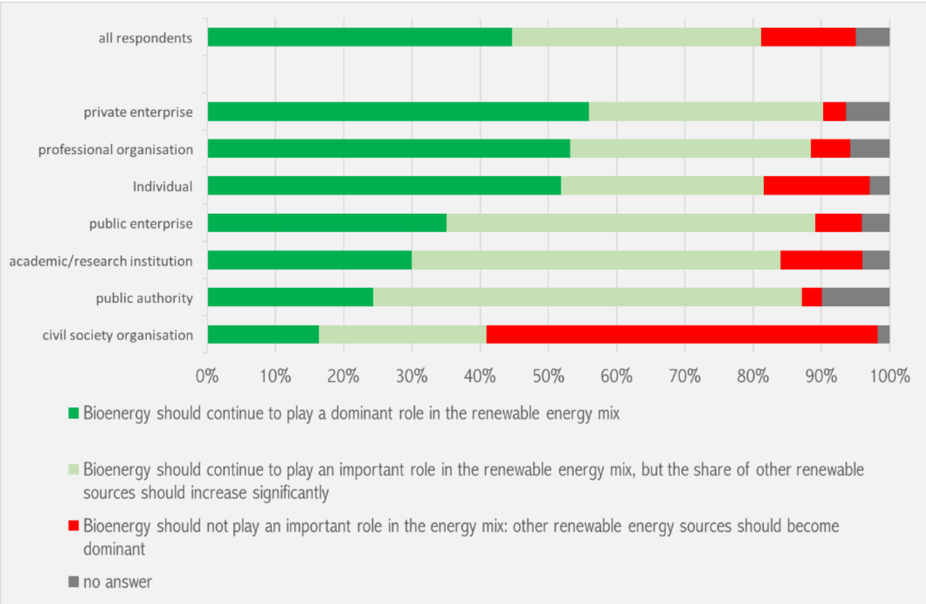
14% of the respondents find that bioenergy should not play an important role in the energy mix and want other renewable source to be come dominant. Together with the respondents that are in the opinion biofuel's role is important but that the share of other renewable sources should increase this represents just more than 50% of the respondents. A conclusion could be drawn that the role of biofuel is seen by the respondents as an important one, but the respondents stress that this should go hand in hand with an increase of the role of other renewable sources.

The various stakeholder groups view the role of bioenergy in the achievement of the EU 2030 climate and energy objectives differently as can be seen from **Error! Reference source not found.**. In three stakeholder groups (private enterprises, professional organisation[80] and individuals) the majority of the respondents are in the opinion that bioenergy should play a dominant role. In these three groups also large majority sees and important role for bioenergy, but want that other renewables (wind and solar energy) should increase more significantly. The stakeholder groups 'public enterprise', public authorities' and academic/research institutions' in majority have scored for an important role of bioenergy coupled to significant growth for other renewable sources.

[80] Including the responses of the 'international organisations'

The civil society organisations are very clear in their responses and don't want bioenergy to play an important role (57,3%).

Figure 16-10: Role of bioenergy in achieving the EU 2030 energy and climate objectives as seen by the various stakeholders



In Annex 2 another representation of this question is provided, to illustrate how respondents from Austria and Germany view the role, given the high share of respondents from these two countries.

16.3 Perception of different types of bioenergy

Question 2.2as stated in the Public Consultation Document was:

"Please indicate for each type of bioenergy described, which statement best corresponds to your perception of the need for public (EU, national, regional) policy intervention."

presents the types of bioenergy, ranked om basis of the scores on 'should be further promoted' and 'should be further promoted, but within limits'. From the graphs it becomes clear that the types of bioenergy can be grouped in three subsets:

- A set of types of bioenergy for which more than 50% of the respondent indicated that this should be further promoted. This set is characterised by waste-base, high efficient conversion (CHP), small scale and based on locally available feedstocks.
- A set for which more than 50% of the respondents indicated that they should be further promoted or that they should be further promote, but within limits.
- A set where less than 50% of the respondents indicated that they should be further promoted or that they should be further promote, but within limits. This set is characterised by types of bioenergy based on large scale, electricity-only, food-crop based bioenergy, using imported, non-European feedstocks. This set of bioenergy options is also the set that received the highest response for discouragement:

The options that received most replies on 'should be discouraged' can also be grouped in three groups (see **Error! Reference source not found.**):

- A set where between 27% and 34% of the respondents indicated that these options should be discouraged. This set consists of bioenergy based on large scale, large-scale electricity-only, food-crop based bioenergy, using imported, non-European feedstocks.
- A set of option with 10% to 19% of the respondents wanting these options to be discouraged. In summary this reflects mainly the origin of the feedstocks: non-residue solid biomass from either agriculture or forestry sector
- A third group of options, where 'discouragement' attracted less than 7% of the respondents. These options are local and regional based biomass, waste and residue based and processed in medium to small scale facilities.

Figure 16-11: Perception of different types of bioenergy, ranked on basis of score on 'should be further promoted' and 'should be further promoted but within limits'

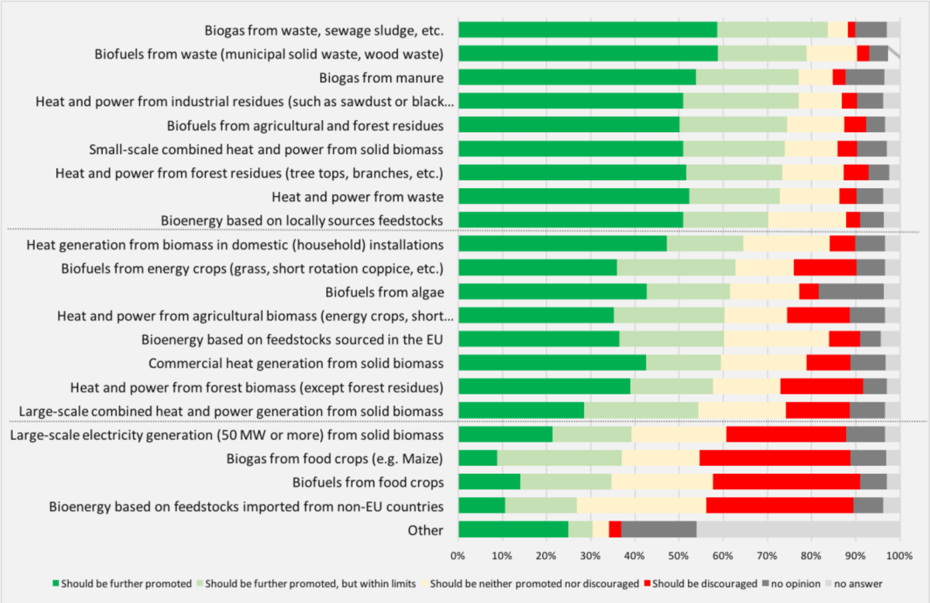
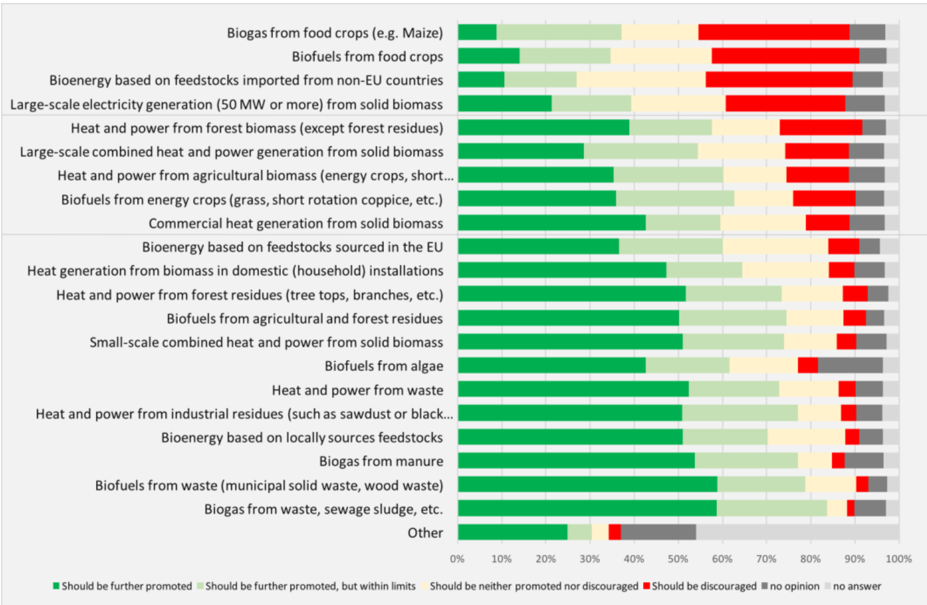


Figure 16-12: Perception of different types of bioenergy, ranked on basis of score on 'should be discouraged'



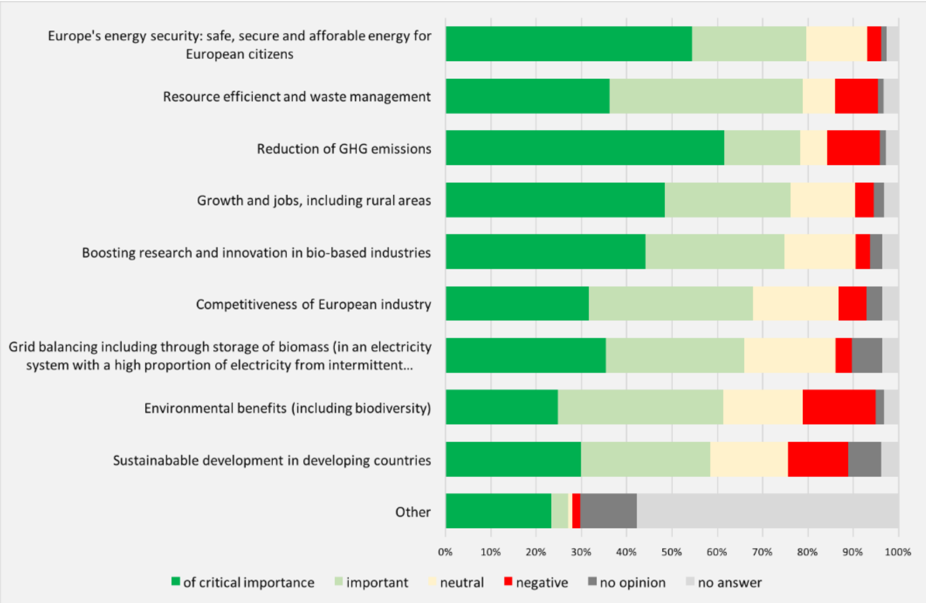
16.4 Benefits and opportunities of bioenergy

Question 3.1 as stated in the Public Consultation Document was:

"Bioenergy (biofuel for transport, biomass and biogas for heat and power) is currently promoted as it is considered to be contributing to the EU's renewable energy and climate objectives, and also having other potential benefits to the EU economy and society. Please rate the contribution of bioenergy as you see it, to the benefits."

- A set where less than 50% of the respondents indicated that they should be further promoted or that they should be further promote, but within limits. This set is characterised by types of bioenergy based on large scale, electricity-only, food-crop based bioenergy, using imported, non-European feedstocks. This set of bioenergy options is also the set that received the highest response for discouragement:

Figure 16-13: Benefits and opportunities of bioenergy



In **Error! Reference source not found.** the benefits of bioenergy are ordered according to the number of answers given for 'of critical importance' and 'important'. All mentioned benefits received relative high responses, with high scores on energy security, resource efficiency and waste management and reduction of HG gasses. The following benefits are viewed as being negatively affected by bioenergy: 'environmental benefits, including biodiversity', 'reduction of GHG emissions' 'resource efficiency and waste management' and 'sustainable development in developing countries'.

16.5 Risks from bioenergy production and use

Question 4.1 as stated in the Public Consultation Document was:

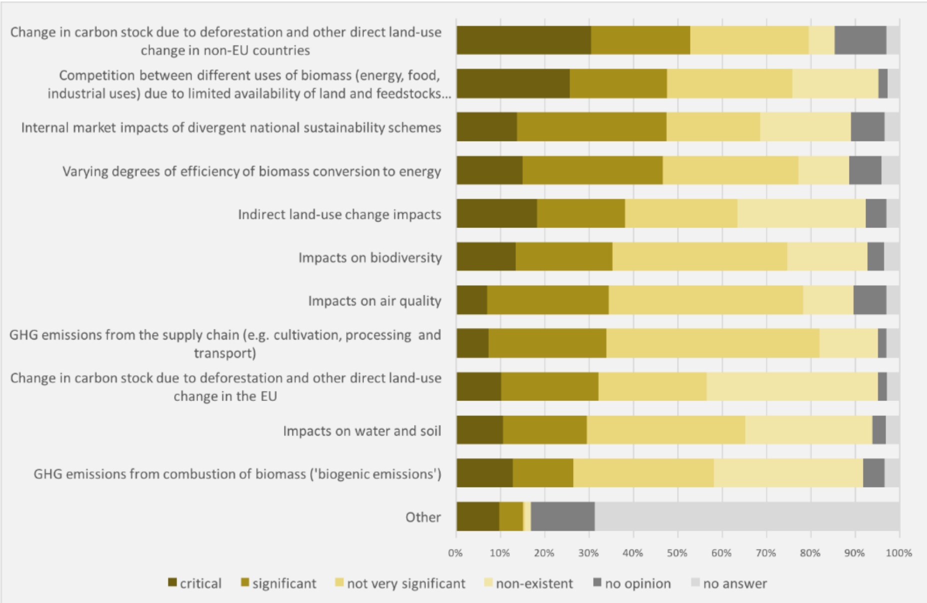
"A number of risks have been identified (e.g. by certain scientists, stakeholders and studies) in relation to bioenergy production and use. These may concern specific biomass resources (agriculture, forest, waste), their origin, (sourced in the EU or imported) or their end-uses (heat, electricity, transport). Please rate the relevance of these risks as you see it."

In

the scores of the respondents[81] are ranked on basis of 'critical' and 'significant'. The options which the highest responses for being viewed as critical risks are:

- Change in carbon stock due to deforestation and other direct land use change in non-EU countries;
- Competition between different uses of biomass (energy food, industrial uses) due to limited availability of land and feedstocks and/or subsidies for specific uses;
- Indirect land-use change impacts.

Figure 16-14: Risks from bioenergy production and use (all respondents)



It is interesting to explore the differences among the scores of the stakeholder groups for these risks viewed as critical (see **Error! Reference source not found.**, **Error! Reference source not found.**, and

).

The results for the other risks can be found in Annex 4.

For all three risks it can be seen that a large majority (approx. 70%) of the civil society organisations value these three risks as critical. Within the academic institutions less respondents value the risks as critical, but when combining the responses to critical and

[81] The results for 'international organisations' are included in the results of 'professional organisations'

significant, these groups score rather identical on carbon stock los due to forestation and other direct land-use change in non-EU countries. The academic institutions also value the competition risk as critical or significant. On the risk of indirect land-use change the civil society organisations are the only stakeholder group who view this as a severe risk (nearly 70% of them answered 'critical', though among the academic institutions viewed this risk as 'critical', but also 25% of the viewed the risk 'significant'. In the case of the carbon stock due to deforestation and other direct land-use risks about 20% of respondents in each of the other groups viewed this as a critical risk.

Figure 16-15: Scores per stakeholder group on the risk for change in carbon stock in non-EU countries

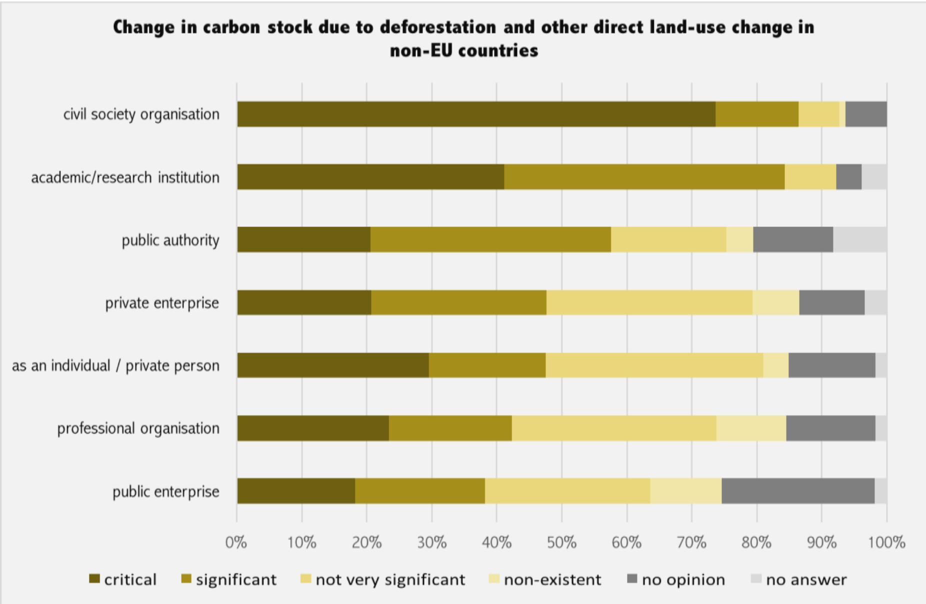


Figure 16-16: Scores per stakeholder group on the risk for competition between different uses of biomass

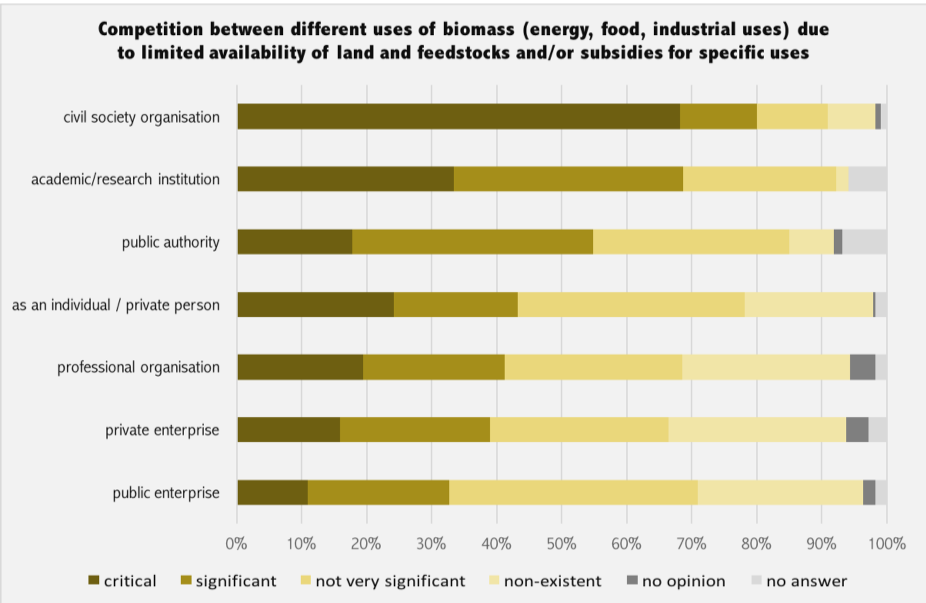
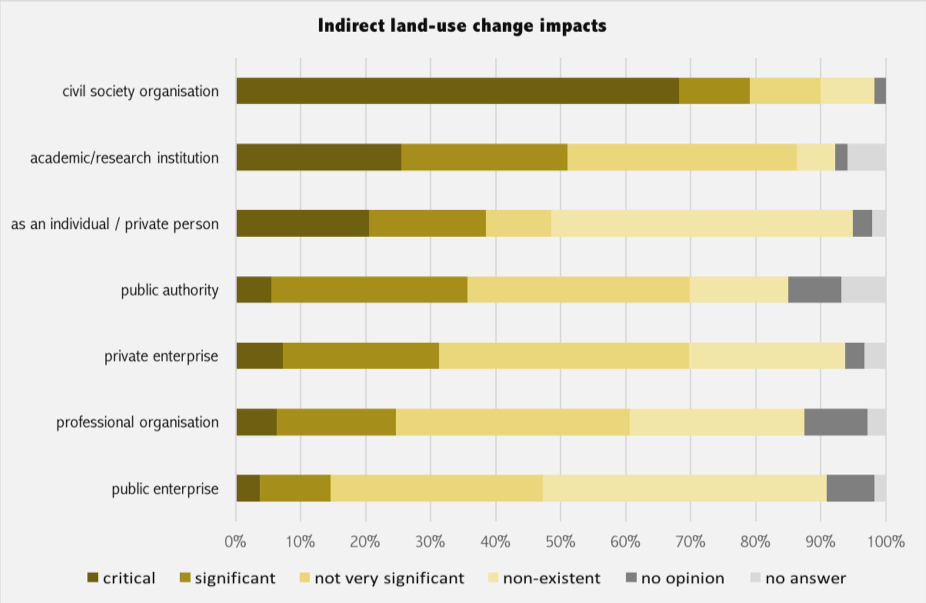


Figure 16-17: Scores per stakeholder group on the risk for indirect land-use change impacts



16.6 Effectiveness of existing EU sustainability scheme for biofuels and bioliquids

Question 5.1 as stated in the Public Consultation Document was:

"In your view how effective has the existing EU sustainability scheme for biofuels and bioliquids been in addressing the risks?"

In **Error! Reference source not found.** it can be seen how the respondents have rated the effectiveness of the EU sustainability scheme for biofuels and bioliquids in addressing the mentioned risks. It becomes clear that those risks that were initially incorporated in the sustainability scheme (GHG emissions from cultivation, processing and transport, and GHG emissions for direct land use change) are viewed as effectively or partly effectively addressed by the sustainability scheme. Those risks that are not, or only with the amendments in 2015 on the RED and FQD, included in the sustainability scheme received higher responses on being regarded as 'counter-productive' to the intentions in the sustainability scheme.

Figure 16-18: Effectiveness in addressing sustainability risks of biofuels and bioliquids

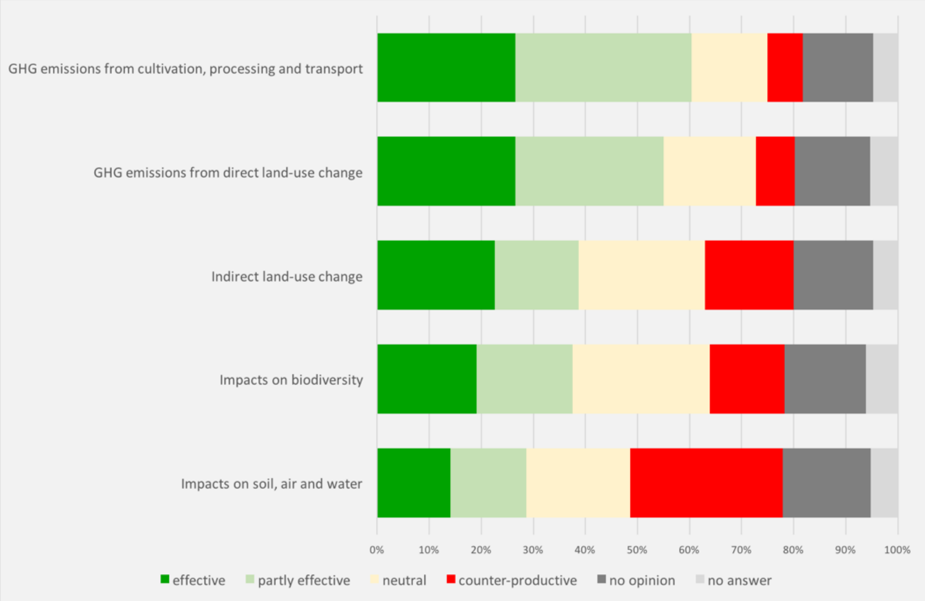


Figure 16-18a-g: Effectiveness in addressing sustainability risks of biofuels and bioliquids, scores per stakeholder group

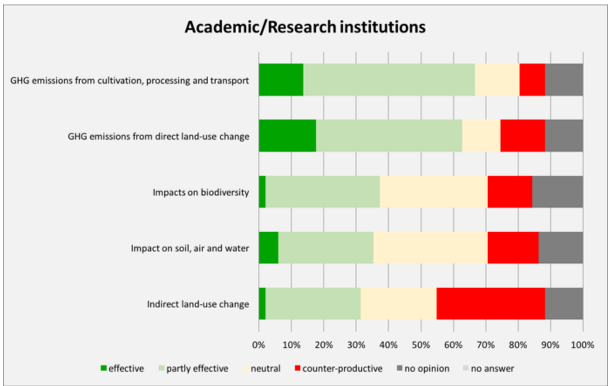


Figure 16-18a (number of respondents: 50)

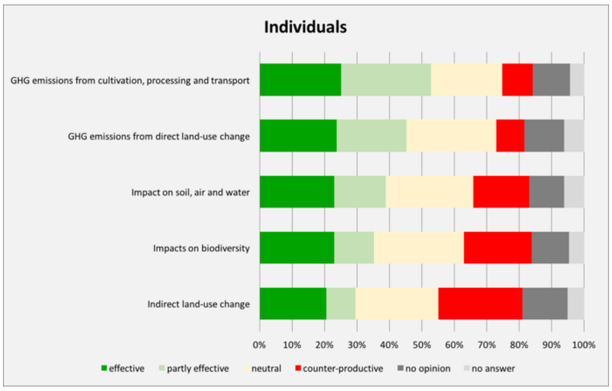


Figure 16-18b (number of respondents: 278)

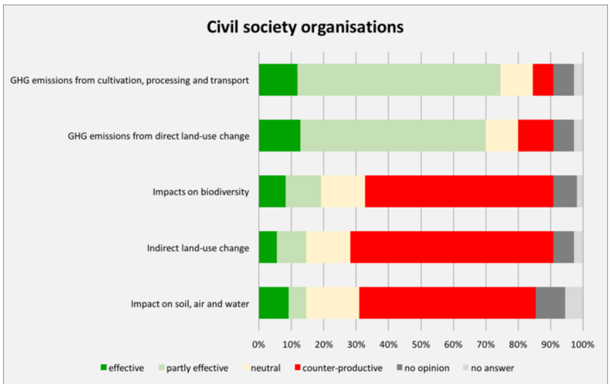


Figure 16-18c (number of respondents: 110)

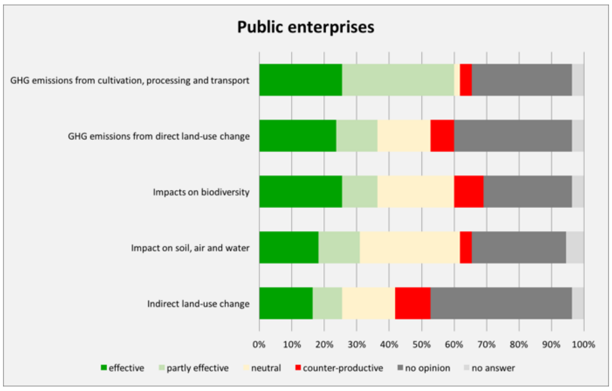


Figure 16-18d (number of respondents: 54)

Figure 16-18e (number of respondents: 207)

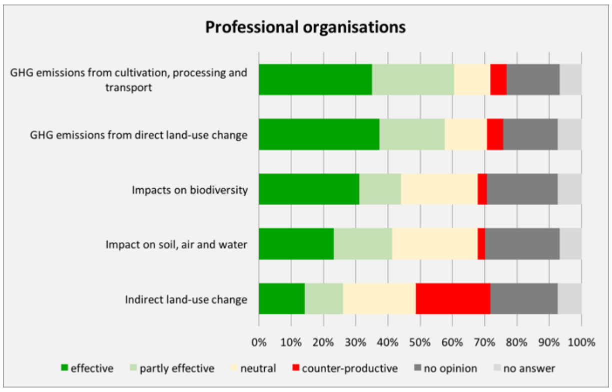


Figure 16-18f (number of respondents: 177, this included the international organisations)

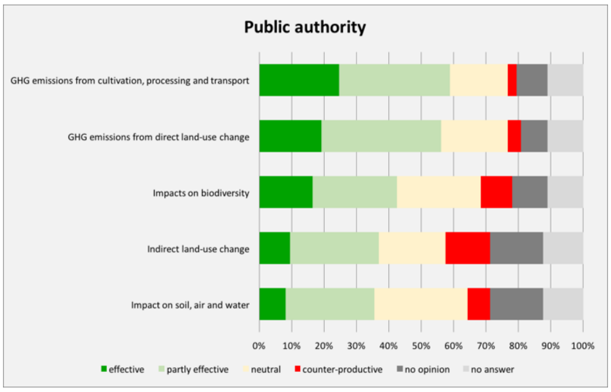


Figure 16-18g (number of respondents: 73)

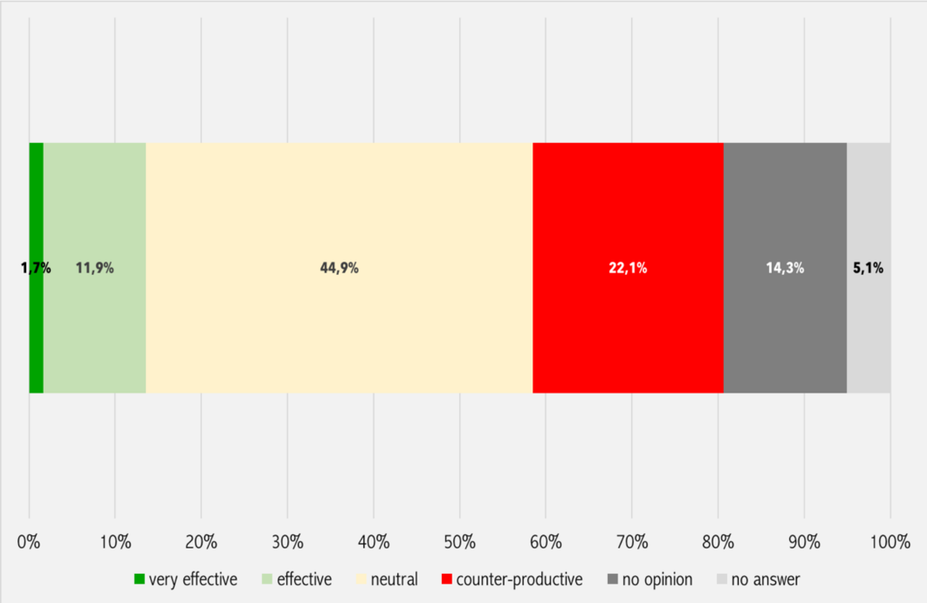
16.7 Effectiveness in promoting advanced biofuels

Question 5.2 as stated in the Public Consultation Document was:

"In your view how effective has the sustainability framework, including its provisions on indirect land use change, been in driving the development of 'advanced' biofuels, in particular biofuels produced from lignocellulosic material (e.g. grass or straw) or from waste material (e.g. waste vegetable oils)?"

From **Error! Reference source not found.** it can be concluded that only a minority of the respondents views the current sustainability framework as effective or very effective. Almost half of the respondents viewed the framework as neutral towards 'advanced' biofuels. This may be caused by the fact that not all respondents are actively involved in the biofuels for transport sector (this is also visible from the high share of 'no opinion' answers. More than 20% of the respondents viewed the framework as counter-productive, double as compared to those who viewed the scheme as (very) effective.

Figure 16-19: Responses on the effectiveness of the sustainability framework in promoting advanced biofuels



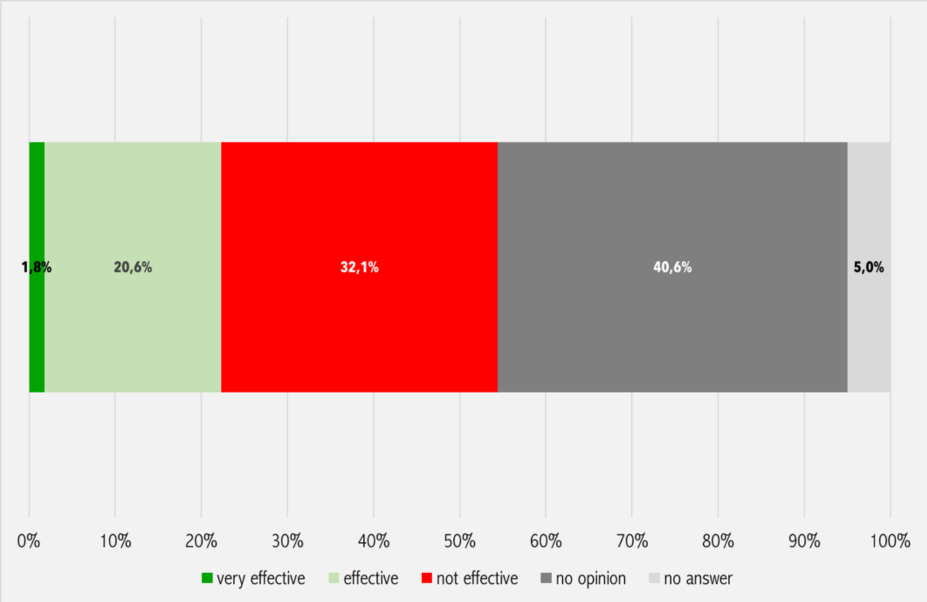
16.8 Effectiveness in minimising the administrative burden on operators

Question 5.3 as stated in the Public Consultation Document was:

"In your view, how effective has the EU biofuel sustainability policy been in reducing the administrative burden on operators placing biofuels on the internal market by harmonising sustainability requirements in the Member States (as compared with a situation where these matter would be regulated by national schemes for biofuel sustainability)?"

Error! Reference source not found. shows that this question has been mainly answered by those respondents that are actively involved in the biofuel sector, given the high 'no-opinion' responses. Furthermore, it is clear that nearly one third of the respondents view the policy as counterproductive.

Figure 16-20: Effectiveness in minimising the administrative burden on operators



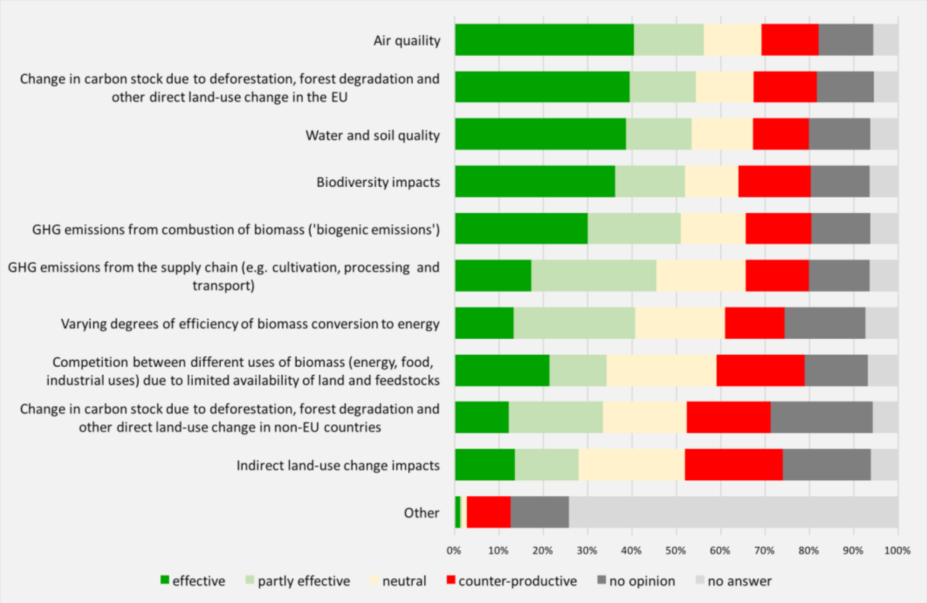
16.9 Effectiveness of existing EU policies in addressing solid and gaseous biomass sustainability issues

Question 6.1 in the public consultation document was:

"In your view, how effective are current EU policies in addressing the following risks of negative environmental impacts associated with solid and gaseous biomass used for heat and power?"

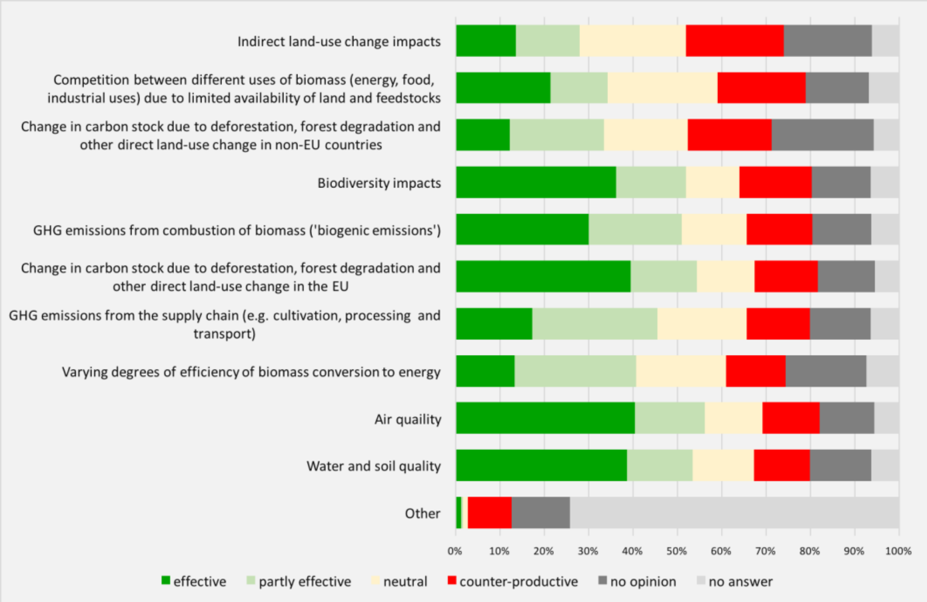
The issues that are viewed as most effectively addressed by the existing EU policies are: Air quality (40.5% of the respondents view this effectively addresses, another 15.7% as partly effective), change in carbon stock in the EU (39,6%/14,9%), water and soil quality (38.7%/14.8%), biodiversity impacts (36.2%/ 15.8%) and GHG emissions from combustion of biomass (30.1%/20.9%.

Figure 16-21: Effectiveness of existing EU policies in addressing solid and gaseous sustainability issues (ranked on (partly) effective)



When focusing on the issues for which the existing EU policies where viewed as counter-productive the following issues received relative high scores (see **Error! Reference source not found.**): indirect land use change (22.1%), Competition between different used of biomass (19.8%), change in carbon stock in non-EU countries (19.0%) and biodiversity impacts (16.2%).

Figure 16-22: Effectiveness of existing EU policies in addressing solid and gaseous sustainability issues (ranked on 'counter-productive' score)



16.10 Policy objectives for a post-2020 bioenergy sustainability policy

Question 7.1 in the Public Consultation document was:

"In your view, what should be the key objectives of an improved EU bioenergy sustainability policy post 2020? Please rank the following objectives in order of importance: most important first, least important 9th/10th."

In **Error! Reference source not found.** the objectives are ranked on basis of the frequency the respondents scored them as most important. The horizontal bar indicates respectively how often the mentioned objected (by all respondents) has been rated as most important (1st), second important (2nd) etc. to 10th important objective. The grey section of the horizontal bar indicated the share of respondents did not provide an answer.

It can be clearly seen from the figure that the objective 'contribute to climate change objective' stands out as compared to the other objectives. From the information presented in Annex 5 it can also be seen that among all stakeholder groups this objective received most often the qualification '1st important objective.

In order to determine whether more clarity can be found about the scoring of the remaining objective, a weighing methodology was carried out. In this method the various shares for scoring 1st or 2nd etc. up to 10th important of each objective was multiplied by a point-score (10 for 1st important, 9 for 2nd important, etc., up to 1 point for 0th important) and added to one final score. In this calculation the 'no answer scores' were not taken into the calculation. As an example: if all respondents (100%) would have ranked an objective as most important the final score would be 1,0 * 10 = 10 points. If 10% of the respondent would score an objective as most important and 90% would see it as least (10th) important, it's final score would be 0,1 * 10 +0,9 * 1 = 1,9 points.

On basis of the method the ordering of the importance of the objectives (see **Error! Reference source not found.**) it can be concluded that besides the objective 'contribute to climate change objectives' four other objectives received relative high 'importance' scores: 'promote efficiency use of the biomass resources, including efficient energy conversion', 'avoid environmental impacts', ensure long term legal certainty for operators' and 'promote energy security'.

Figure 16-23: Responses to the policy objectives for a post-2020 bioenergy sustainability policy (all respondents)

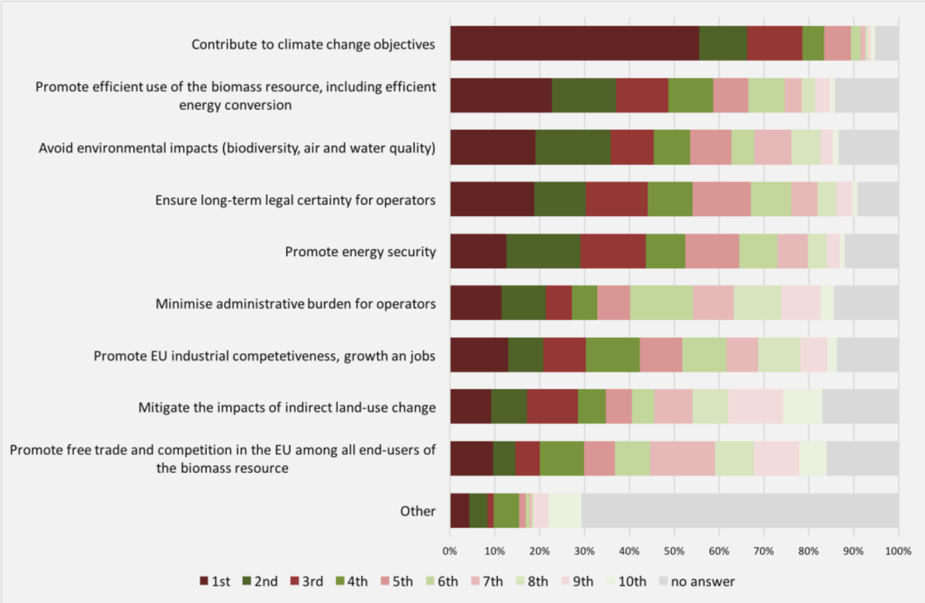
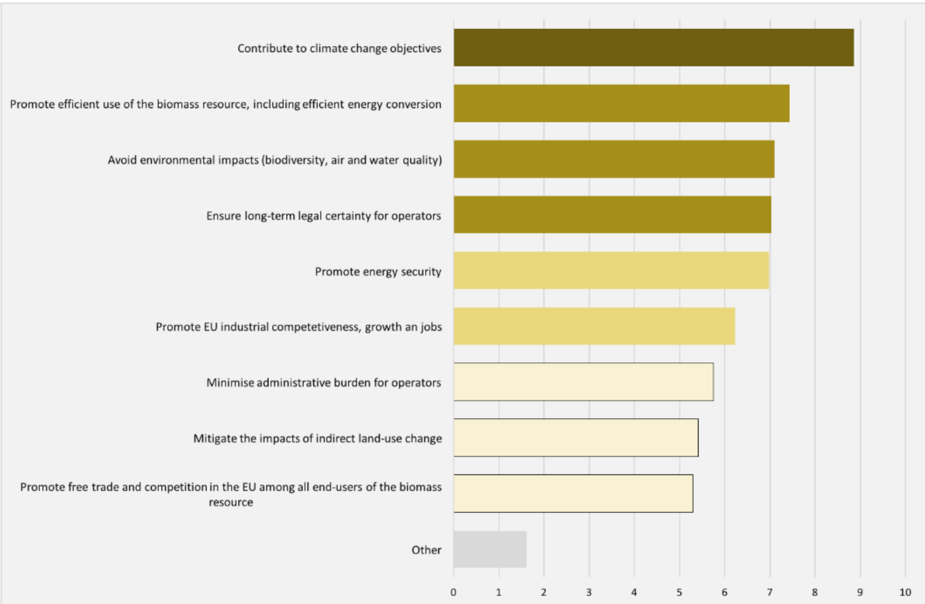


Figure 16-24: Weighted ranking of the scores on the policy objectives for a post-2020 bioenergy sustainability policy (all respondents)



The respondents are clear about the most important four objectives for a post-2020 sustainable bioenergy policy (ranked in order of importance) above and for all:

- It should contribute to the climate change objectives
- It should promote the efficient use of the biomass resource, including efficient end use conversion,
- Avoid environmental impacts (biodiversity, air and water quality)
- It should ensure long term certainly for operators, and
- It should promote energy security.

It must also be concluded that the other mentioned objectives should carefully be taken into account as for all objectives respondents can be found who ranked them as most or second important.

Several respondents provided specific information on which 'other' objective they would like to taken into account. As a summary (the list below is without any ranking order):

- Academic and research institutes mentioned 'promotion of innovation' and 'improving agricultural productivity'
- Civil society organisations stressed 'ensuring a supportive framework for sustainable forest management', ensure policy coherence to sustainable development goals', 'prevent indirect impacts to food security, land and human rights and land grabs'
- Private and public enterprises and professional organisation mentioned 'replace fossil fuels', decentralisation brings more opportunities to rural areas', 'promote fair competition among the various end-user markets

Details on the scoring per stakeholder group can be found in annex 5.

17 Question on EU action on sustainability of bioenergy

17.1 Introduction

In the public consultation document stakeholders are requested to provide their input in 9 different chapters. This report concentrates on Question 8.1 of the document, which aims to get feedback from the respondents on the EU action on sustainability of bioenergy for the period after 2020. The chapter contains 2 questions:

Question 8.1. In your view, is there a need for additional EU policy on bioenergy sustainability?

1. *No: the current policy framework (including the sustainability scheme for biofuels and bioliquids, and other EU and national policies covering solid and gaseous biomass) is sufficient.*
2. *Yes: additional policy is needed for solid and gaseous biomass, but for biofuels and bioliquids the existing scheme is sufficient.*
3. *Yes: additional policy is needed on biofuels and bioliquids, but for solid and gaseous biomass existing EU and National policies are sufficient.*
4. *Yes: a new policy is needed covering all types of bioenergy.*

Question 8.2. In your view, and given your answers to the previous question, what should the EU policy framework on the sustainability of bioenergy include? Please be specific. [a response with maximum 500 characters was possible].

17.2 Overall results

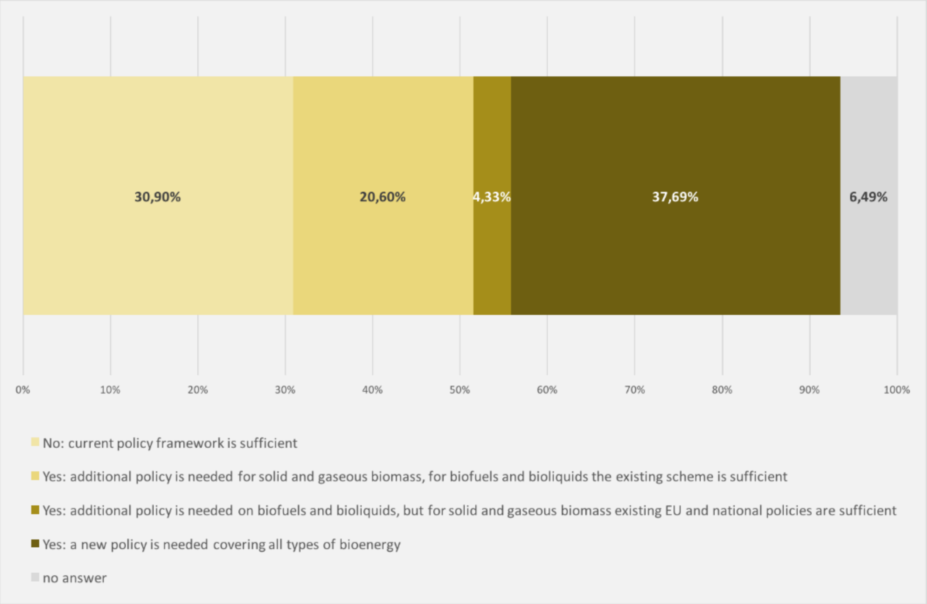
The overall result to Question 8.1 present a rather polarized picture as can be seen in **Error! Reference source not found.**.

30.9% of the respondents replied that the current policy framework is sufficient, whereas 37.7% of the respondents indicated that a new policy is needed to cover all types of bioenergy. One fourth of the respondents were in the opinion that part of the current framework is sufficient, but additional policy is needed. A majority of these respondents said that additional policy is needed for solid and gaseous biomass. 6.5% of the respondents did not provide an answer to this question.

Focusing on biofuels and bioliquids, it can be concluded that 51.5% of the respondents indicated that the policy framework for biofuels and bioliquids is sufficient (combined results of the two first options indicated in section 297). 42.2% of the respondents stated that the framework for biofuels and bioliquids is not sufficient (combines result of option 3 and 4 indicated in section 2).

With respect to solid and gaseous biomass 35.2% of the respondents is in the opinion that existing policy framework is sufficient (combined results of the option 1 and 3 indicated in section 297). 58.3% of the respondents wants an additional policy framework for solid and gaseous biomass (combination of option 2 and 4 in section 2).

Figure 17-1: Overall response to the question on the bioenergy sustainability policy framework (all respondents)



In the following subsections the overall results are analyses per type of stakeholder.

17.3 Results per type of stakeholder

When replying to the public consultation respondent could indicate[82] in what capacity the were competing the questionnaire:

- As academic/research institution,
- As an individual/private person,
- As civil society organisation,
- As international organisation[83],
- As private enterprise,
- As professional organisation,
- As public authority,
- As public enterprise, or
- As other.

Furthermore, civil society organisations and private and public authorities could indicate their main areas of focus, respectively their principal business sector.

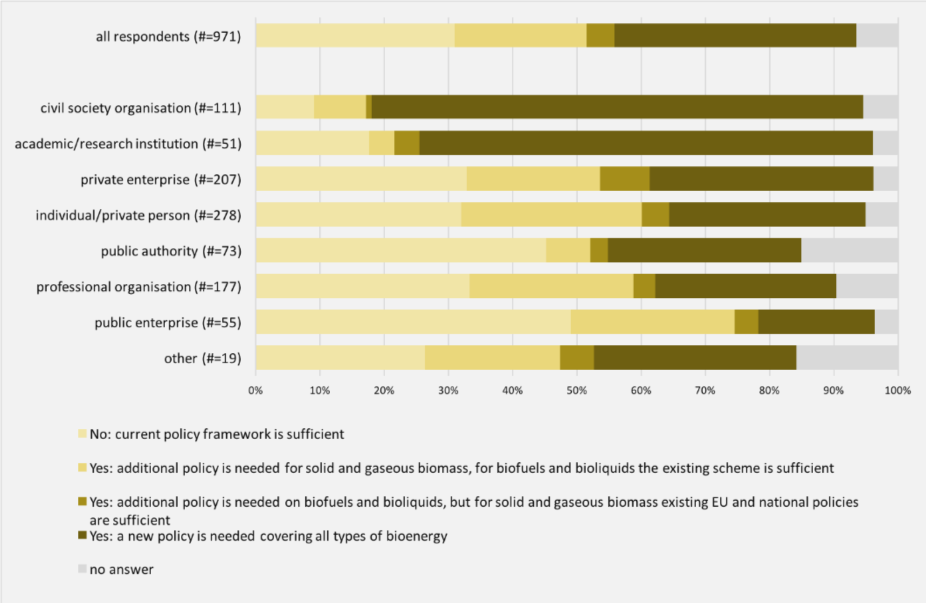
In this section it is analysed how the various stakeholders have responded to question 8.1 and how within the groups of civil society organisation and the private and public organisations the responses differed per area of focus and principal business sector.

[82] No afterward check has been carried out whether this information was correct. The analysis of the public consultation responses has been based on this self-declaration

[83] An analysis of the identity of the respondents that indicated to complete the public consultation showed that all respondents are in fact professional organisations, in the sense of business associations, which represent private and public enterprises from various countries. In the analysis of the public consultation report, the results are presented as provided by the respondents.

In the results per type of stakeholder are presented. For each of the types of respondents it is indicated how many respondents per type of stakeholder have completed the public consultation. Furthermore, except for the 'other' category, the types of respondents are ordered – within their group - on basis of the share on answer that the current policy is sufficient.

Figure 17-2: Response to the question on the bioenergy sustainability policy framework per stakeholder group



From **Error! Reference source not found.** it becomes clear that there is a strong variance in the results: the civil society organisations and the academic/research organisation are strongly in favour for a new policy covering all types of bioenergy. Also among the other stakeholders, except perhaps for the public enterprises, a significant share of approx. 25-30% of the responses indicated the need for a new policy covering all types of bioenergy. The majority of the respondents of public enterprises (74.5%), professional organisations (58.8%), individuals (60.1%), private enterprises (53.6%) and public authorities (52.1%) indicate that the current policy for biofuels and bioliquids is sufficient. Civil society organisations, the academic/research institutions and international organisation have a different viewpoint with respectively 17.1%, 21.6% and 31.8% of the respondents viewing current policy framework for biofuels and bioliquids as sufficient. The current policy framework for solid and gaseous biomass gets less support, among all types of shareholders, and higher shares of the respondents highlight that additional policy is required for solid and gaseous biomass as for biofuels and bioliquids.

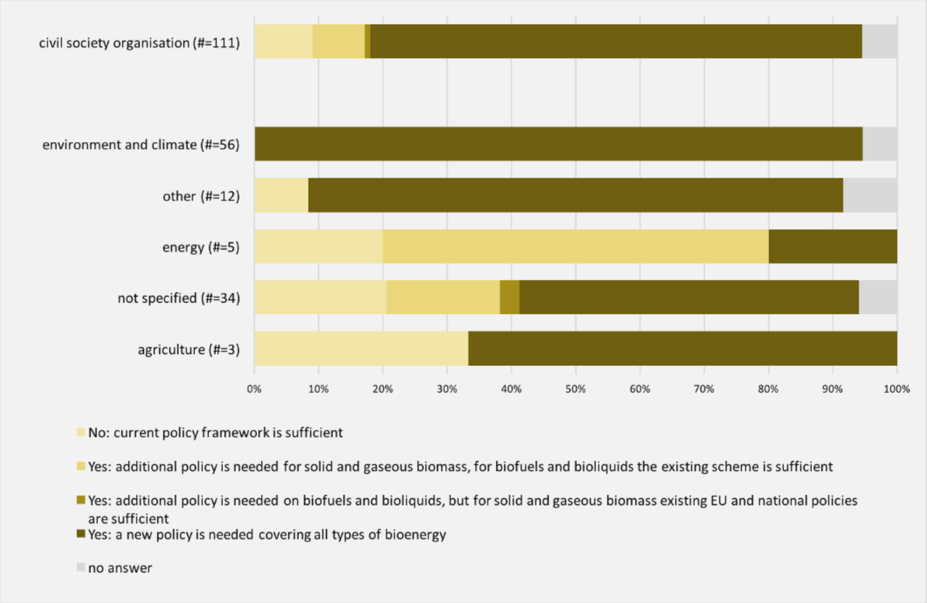
In the following subsections the results within each type of shareholder[84] are given.

[84]Only for civil society organisations and for public/private enterprises this information has been provided. Professional organisations could indicate multiple areas of focus and competence for their activities, which made it not possible to analyse within the context of this analysis.

17.3.1 Civil society organisations

How did civil society organisations with different areas of focus respond to the public consultation? The results are presented in **Error! Reference source not found.**.

Figure 17-3: Response from the civil society organisations



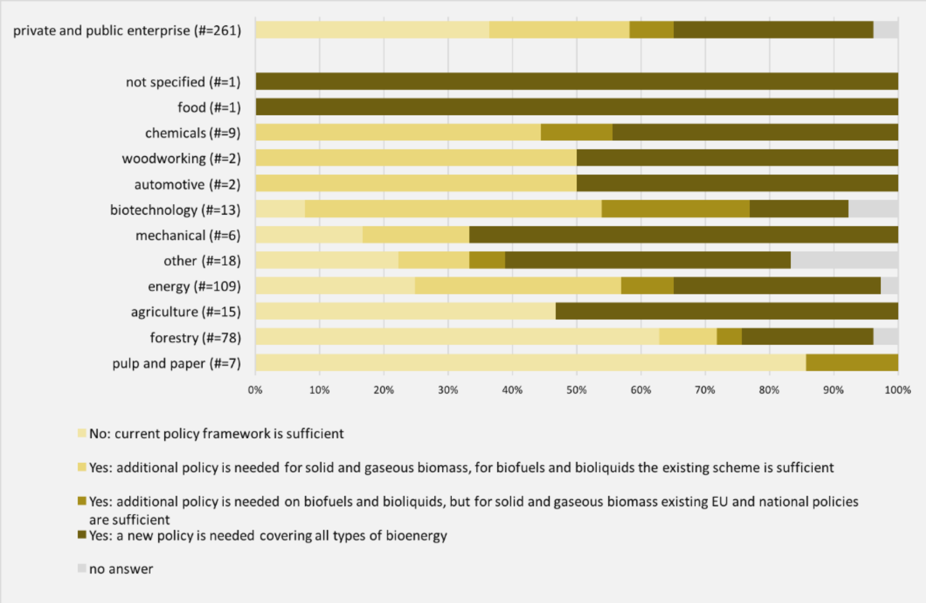
More than half of the civil society organisation focus on environment and climate and they are vey uniform in their response: except for some who did not answer the question, all want a new policy for all types of bioenergy. Except for the five organisations with energy as focus area all others in large majority have responded that a new policy for all types of bioenergy is needed.

17.3.2 Private and public enterprises

The two enterprise groups have been analysis jointly, mainly due to the fact that for certain specific principal business areas there were only a few number of enterprises. The results are presented in **Error! Reference source not found.**. Please be aware that fro several business areas only a limited number of respondents have completed the consultation document.

Almost half of this group is formed by enterprises that indicate that 'energy' is their principal business sector. 24.8% of this group views the current policy framework as sufficient, but also 32% is of the opinion that a new policy for types of bioenergy is needed. The respondents from the forestry sector and the pulp and paper industry are most in favour of the current policy framework (resp. 62.8% and 85.7%), though 20.5% of the forestry sector indicates that a new policy for all bioenergy types is needed.

Figure 17-4: Response from the private and public enterprises

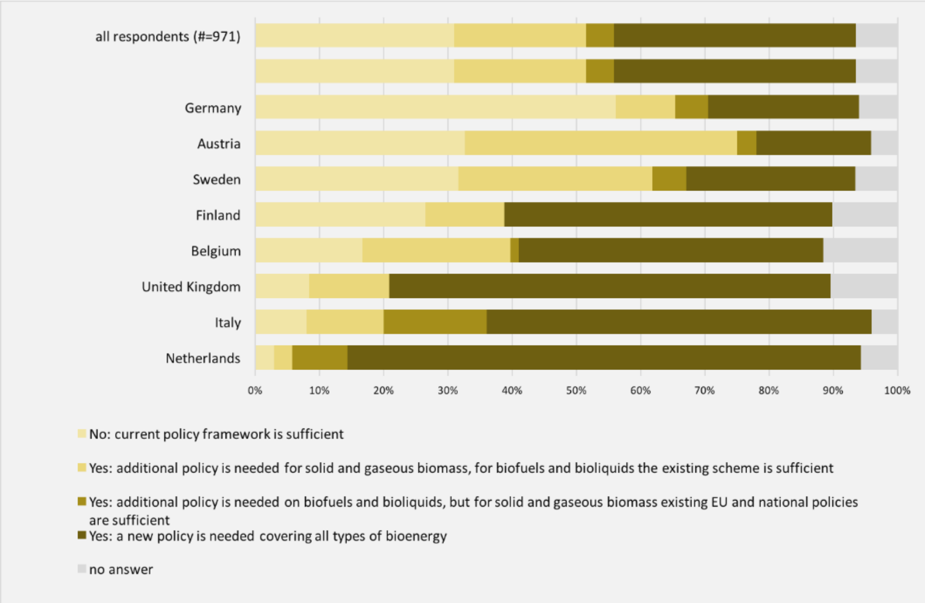


17.4 Responses on the basis of the country of origin of the respondents

Of all 971 respondents, 25.7% originate from Germany and 20.3% from Austria. Other main contributing 'countries' (with 25 or more responses) are Sweden (8.5%), Belgium (8.1%), UK and Finland (both 5,0%), Netherlands (3.6%), Italy (2.6%). These eight countries were responsible for 78.1% of all responses.

How are the responses from these Member States to the question on the future EU action on the sustainable bioenergy policy? **Error! Reference source not found.** present the results. Respondents from Germany, Austria and Sweden indicate in majority (between 61.8% and 75.0%) that current policy framework for biofuels and bioliquids is sufficient. The respondents from other Member States (Finland, Belgium, Italy, Netherlands, United Kingdom) in **Error! Reference source not found.** indicate the need for a new policy for all bioenergy. The first group could be characterised by countries that are biomass resource rich countries, with a strong local biobased industry, whereas the latter group could be characterised by a stronger focus on import and trade of biomass resources, except for Finland.

Figure 17-5: Responses based on the country of origin for a selection of EU Member States



18 Positions of key stakeholders

18.1 Member States and regulatory authorities

18.1.1 Member States

Amongst the Member States, **the Netherlands** supports the strengthening of the current EU bioenergy sustainability framework by introducing mandatory sustainability criteria on biomass and biogas for heat and power. The Netherlands have already introduced national sustainability schemes for biomass and biogas for electricity and heat.

The Netherlands supports improving the existing EU sustainability criteria in order to mitigate the risk of fraud, to improve the transparency of the supply chain, and to better address the risk of ILUC. They are also calling for the introduction of biomass sustainability criteria for all uses, not only energy.

France does not want to modify the existing biofuels criteria but they are in favour of EU criteria for biomass and biogas for heat & power. Provided that they are pragmatic, cost-effective and build on national sustainable forest management policies, i.e. the risk-based approach.

Sweden and **Finland** support the introduction of coherent sustainability criteria for biomass (independently from their final use for biofuels or for heat and power). Concerning forest biomass sustainability, they are open to further investigating the possibility of applying a risk-based approach. This should build on existing national legislation and existing voluntary certification schemes (e.g. FSC and PEFC) and should not lead to additional red tape for EU domestic biomass mobilization. They highlight that emissions from wood (positive or negative) are already addressed by the EU rules on LULUCF (Land use, land use change and forestry) and therefore should not further regulated under the EU bioenergy policy. They also support the extension of the current GHG emission saving requirement for biofuels to biomass for heat and power. Such end use performance criteria should apply to bioenergy plants with a capacity above 20 MW (energy output).

18.1.2 Non-EU countries

The US main message on the public consultation is "the sustainability of biomass and bioenergy may be specific to a region, feedstock or production practice, and other contextual factors such as supply chain characteristics or land management practices." The US suggests that by focusing on "outcomes rather than prescriptive measures to achieve a stated sustainability objective, supply chains can function without disruptions and with greater opportunity for innovation towards sustainability objectives."

18.2 Other Stakeholders

18.2.1 Agriculture/forestry groups

Forest owners are divided regarding the need for additional EU action on forest biomass, while they emphasize that bioenergy from sustainably managed forests is carbon neutral. Generally **small forest owners** oppose additional EU requirements on forest biomass, raising concerns regarding EU competence and subsidiarity. They highlight that forests biomass is already regulated through a number of EU policies, including the Timber Regulation and the LULUCF rules. The EU action should primarily focus on wood imports and ensure that trading partners implement sustainable forest management standards similar to applying to EU biomass. **Large forest owners** acknowledge the need for demonstrating biomass sustainability at EU level. This should be done through a risk-based approach that builds on national regulations existing market-based schemes (such as SFC and PEFC) and that does not add red-tape to biomass mobilization.

18.2.2 Bioenergy generators and other biomass using sectors

Bioenergy generators are in favour of a common EU sustainability framework for all bioenergy uses. The current EU sustainability (land) criteria should be applied to all agriculture biomass, irrespective of final use in transport, heat or power. This should be complemented with a EU requirement an on sustainable harvesting of forest biomass. This criterion should be demonstrated through a risk-based approach, in order to build on existing nation legislation on sustainable forest management. A GHG emission saving target of 60% should apply to biofuels and biomass for heat and power. Such sustainability criteria should be applied to all biofuel plants and to bioenergy plants with a fuel capacity above 20 MW. Austrian bioenergy generators oppose additional EU criteria on bioenergy. A number of bioenergy operators also asked for the EU sustainability criteria to be included in a regulation rather than a directive to ensure full harmonization and avoid conflicting implementation at national level.

Biofuel producers are in favour of simplifying the existing criteria, in order to reduce the administrative burden particularly for small producers. In this regard the use of minimum thresholds excluding small scale producers and reliance on evidence obtained in the framework of cross compliance checks of the common agricultural policy was recommended. Further, many respondents called for more harmonisation in the implementation of the sustainability criteria in the Member States and for measures to reduce the risk of fraud. With regard to the latter the use of an EU wide data base was recommended.

The **pulp and paper** and **wood panel industries** support the extension of the existing criteria to solid biomass and biogas for heat and power. Forest biomass shall be subject to a requirement for sustainable harvesting, through a risk-based approach. All bioenergy uses should be covered by a GHG saving criteria (e.g. 60%). In addition, a conversion efficiency criterion of at least 70% should apply to large biomass heat and power plants. Subsidies for bioelectricity production should be phased-out. The American pulp and paper operators complain about the possible increase in pulp wood prices as a result of increased UK wood pellet demand.

The biofuel industry emphasises the importance of a stable policy framework including support measures such as targets or incorporation mandates for the deployment of advanced biofuels.

18.2.3 NGO’s, citizens and academics

The **environmental NGOs** advocate for 4 four main environmental safeguards: a) capping bioenergy use at EU-level (on the basis of national maximum sustainable potentials for biomass supply); b) applying the cascading principle, including minimum requirements for energy conversion efficiency for bioenergy plants; c) including ILUC and biogenic emissions into the EU common methodology on GHG emission savings; d) introduce robust environmental and social criteria, including land management criteria for avoiding negative impacts on biodiversity, soil and water. The US NGOs have carried out an email campaign targeting the Commission, focusing on the perceived negative impacts (deforestation, increased carbon emissions) of the production and utilisation of wood pellets in the South East US. More than 58 thousand e-mails were addressed to European Union Energy and Climate Commissioner Miguel Arias Cañete.

NGOs mostly argue against volume targets for any kind of biofuel, though some express support to advanced biofuels. According to many stakeholders, the rule of double counting of biofuels based on waste and lignocellulosic feedstocks has incentivised mainly the production of biofuels from waste oils, while it has failed to promote innovative biofuels.

19 Final observations

Nearly half of the respondents completed the public consultation as a private or pubic enterprise or represented these enterprises (professional and international organisations). This needs to be taken into account when reviewing the outcomes of the responses. Based on the results it is logic that those respondents that are active in the bioenergy field on a commercial basis, they are to some extend biased to keep policy 'as is'. Changes in the policy context add risks and uncertainly to their commercial operations.

The group of civil society organisations is also well presented, though at lower numbers than the commercial organisations. The civil society organisations are mostly represented by those with environment and climate as main focus area, which have questioned in the last years the benefits of bioenergy to the environment and climate issues. They clearly argue a shift towards a new sustainability policy for all types of bioenergy and they are supported by the academic and research organisations in their pledge.

For both groups of respondents (commercial organisations on the one hand, and the civil society organisations on the other) it has been noted that they are well organised, given the high number of responses within both groups that are characterised by identical replies and contributions. This was found throughout the questions of the questionnaire: in many cases the respondents of civil society organisations provided identical comments The same appeared in the group of public and private enterprises and the professional organisations. Stakeholders use their organisational power to bring their arguments in an orchestrated way to the table, in order to strengthen their arguments.

Appendix 1: Country of residence/establishment of the respondents per stakeholder group

Figure 0-1: a-h: Country of origin/establishment of the respondents, per stakeholder group

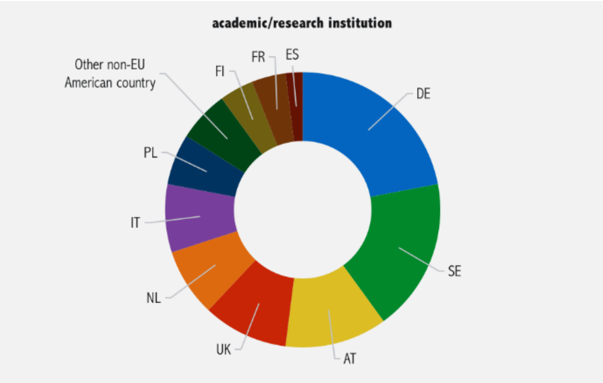


Figure 0-1a

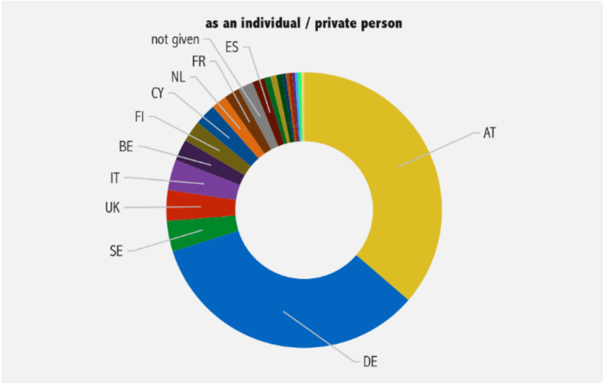


Figure 0-1b

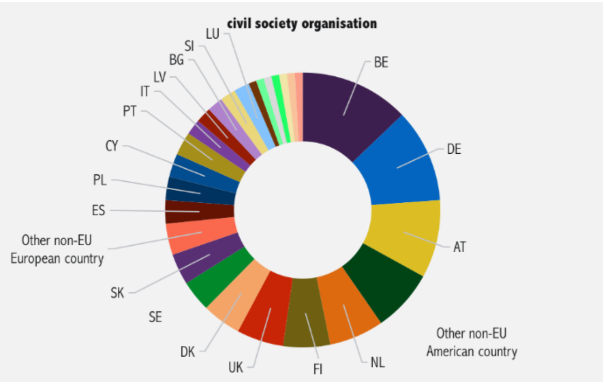


Figure 0-1c

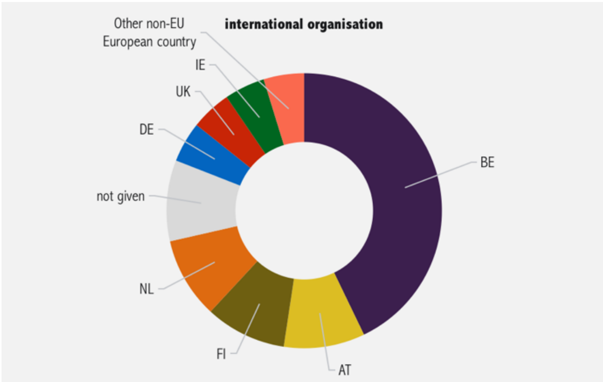


Figure 0-1d

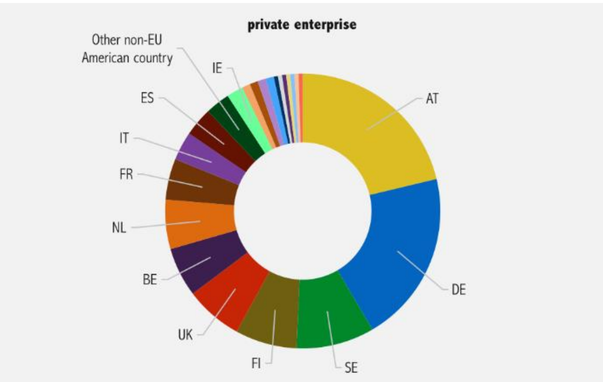


Figure 0-1e

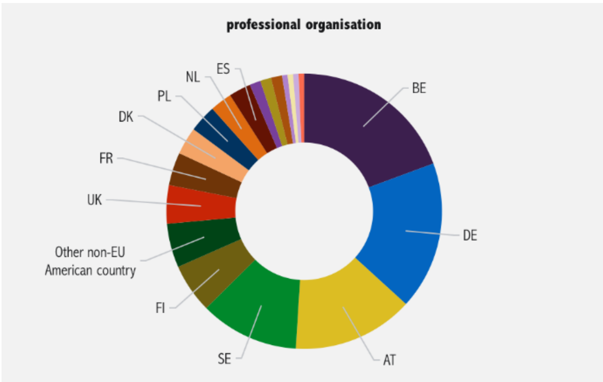


Figure 0-1f

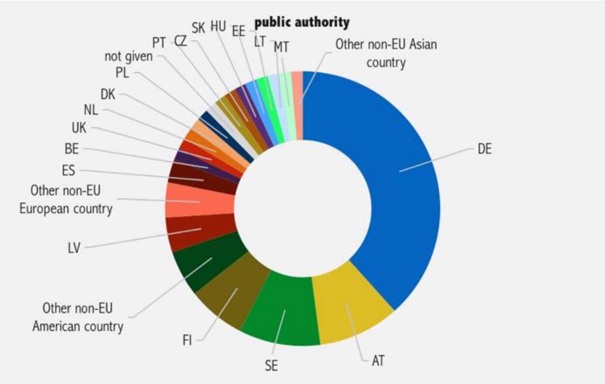


Figure 0-1g

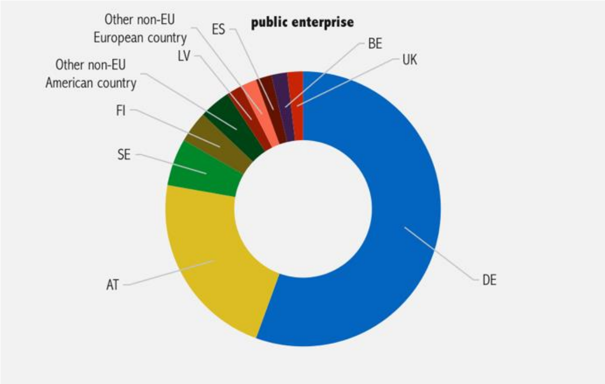
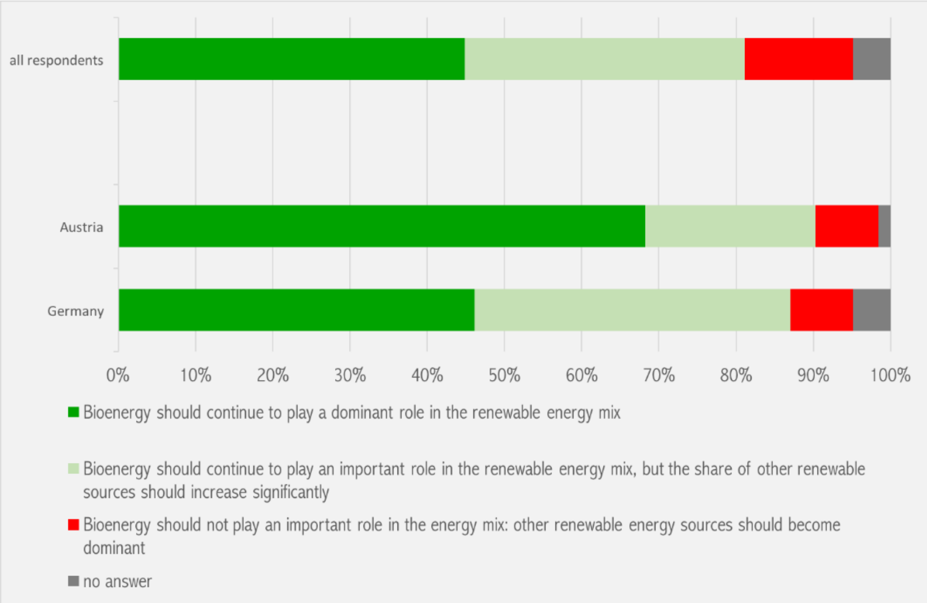


Figure 0-1h

Appendix 2: Austrian and German responses to the role of bioenergy in the achievement of the 2030 climate and energy objectives

Figure 0-1: German and Austrian responses to the role of bioenergy in the achievement of the climate and energy objectives



Appendix 3: Additional graphs on the identification of risks per stakeholder group

Figure 0-1: Scores per stakeholder group on the risk for change of carbon stock in the EU

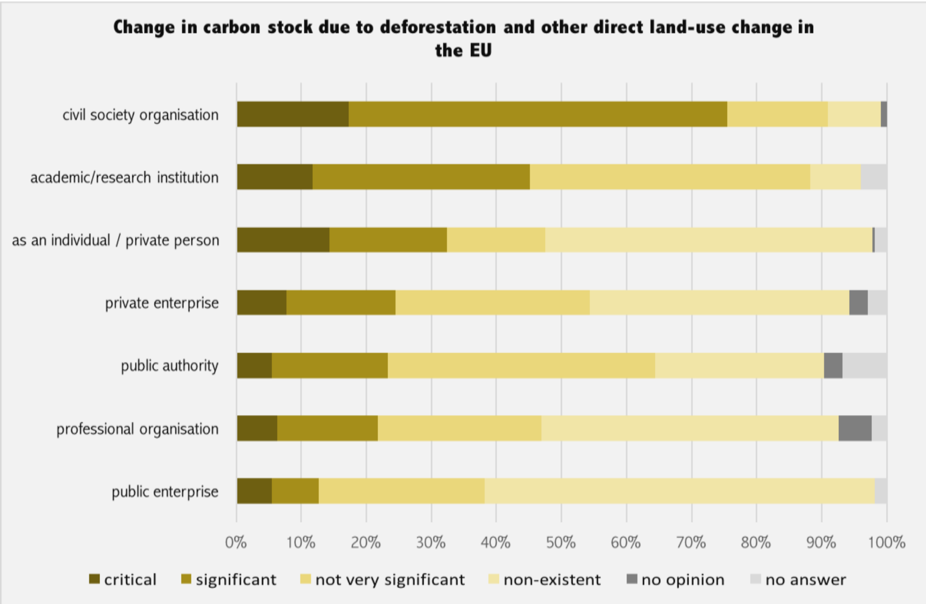


Figure 0-2: Scores per stakeholder group on the risk for GHG emissions in the supply chain

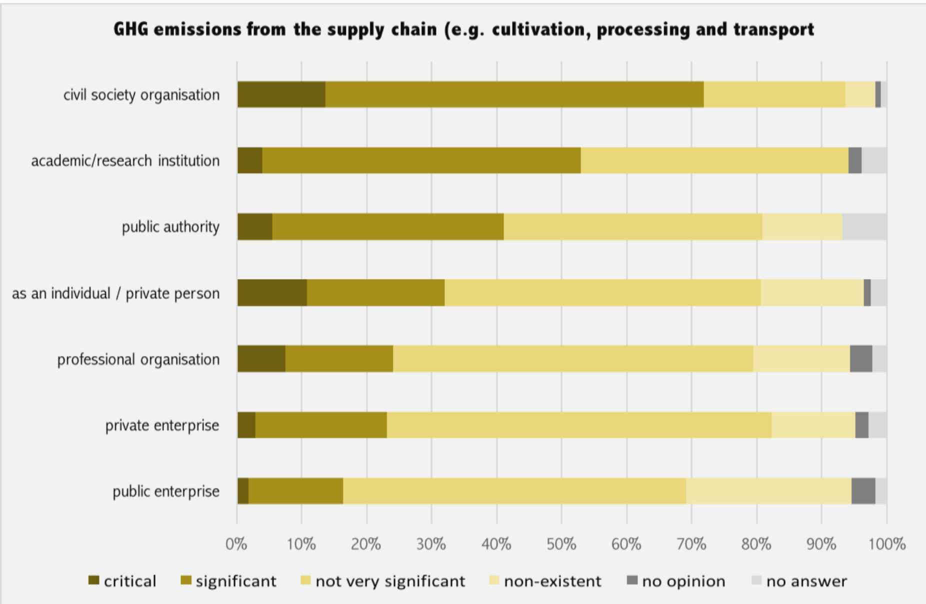


Figure 0-3: Scores per stakeholder group on the risk for GHG emissions from the combustion of biomass

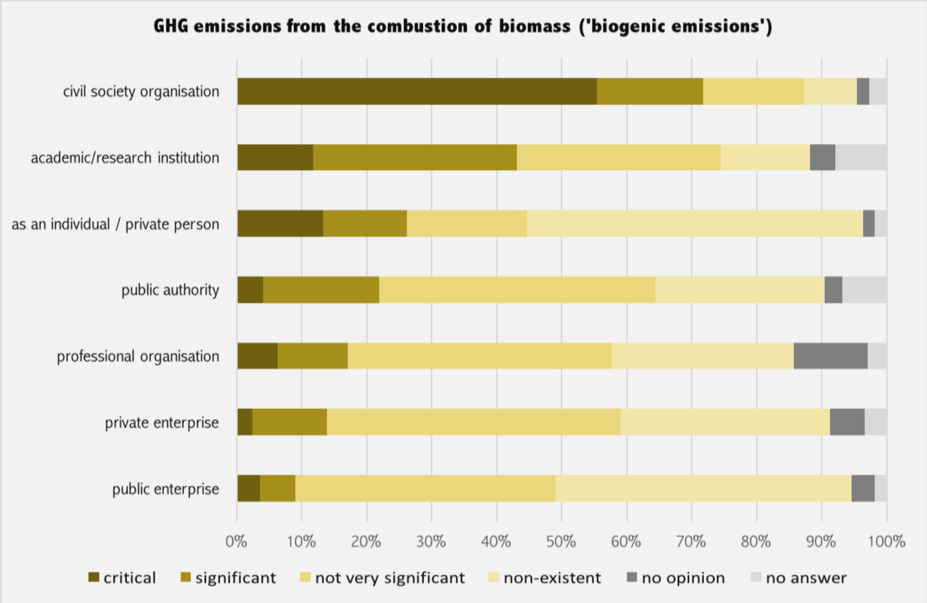


Figure 0-4: Scores per stakeholder group on the risk for impacts on air quality

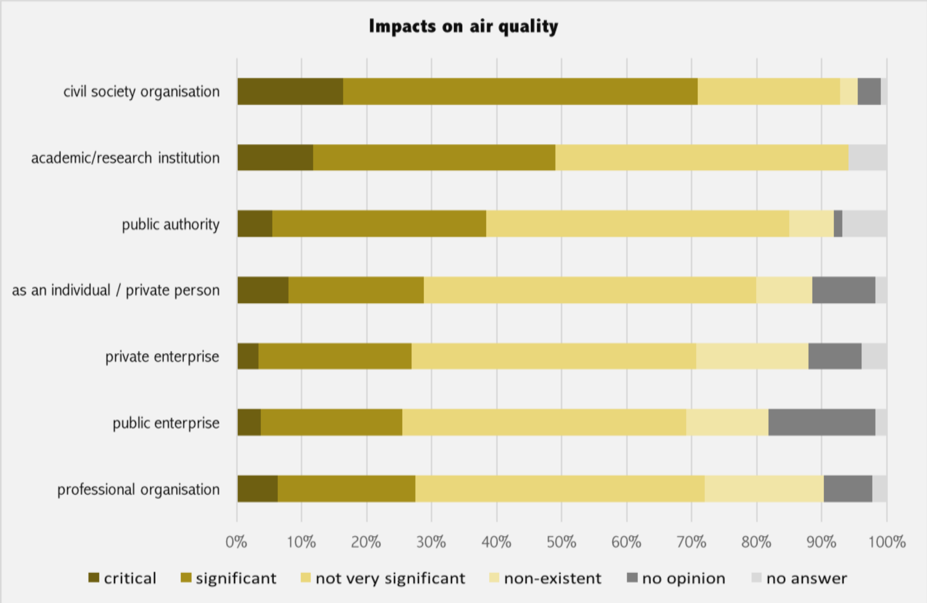


Figure 0-5: Scores per stakeholder group on the risk for impacts on water and soil

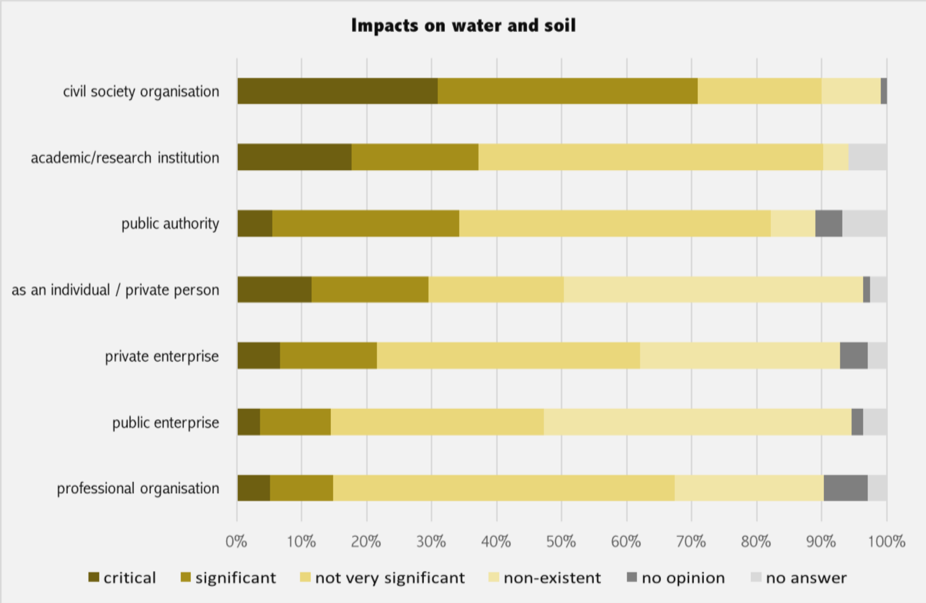


Figure 0-6: Scores per stakeholder group on the risk for impacts on biodiversity

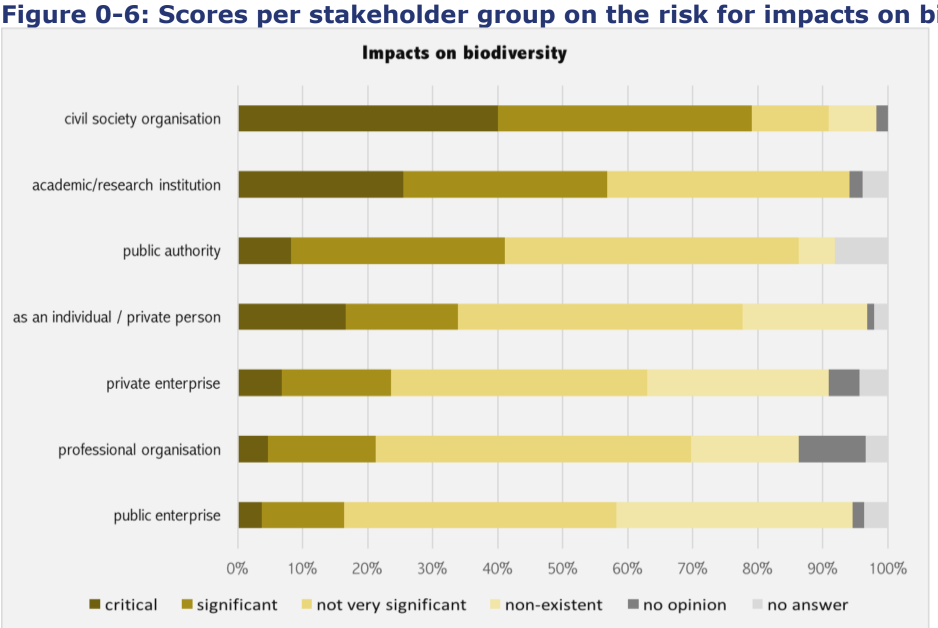


Figure 0-7: Scores per stakeholder group on the risk for varying degrees of biomass conversion to energy

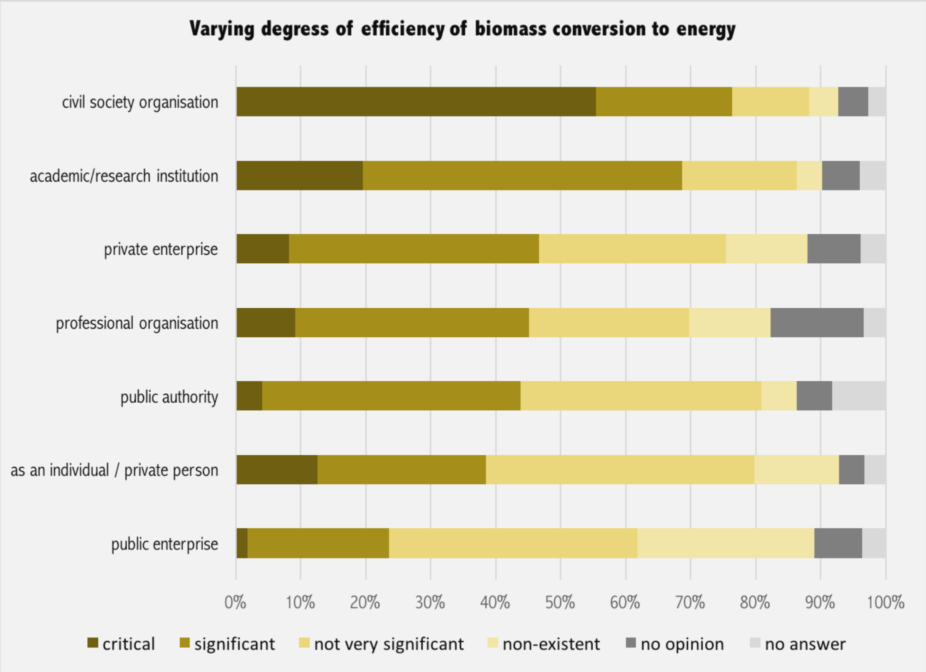
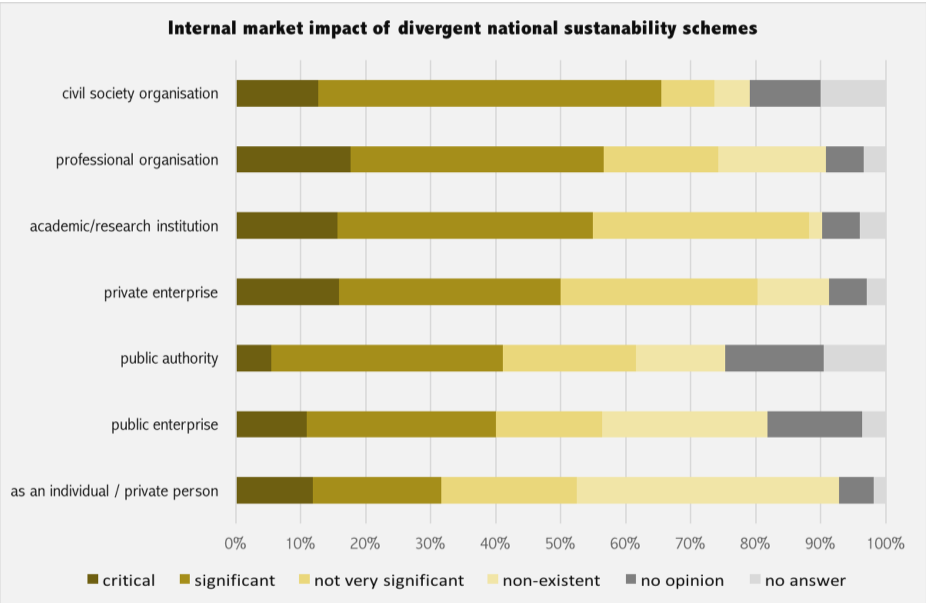


Figure 0-8: Scores per stakeholder group on the risk for internal market impact of divergent national sustainability schemes.



Appendix 4: Graphs with information on professional and industrial organisations

As stated in chapter 1, most of the respondents who filled out the consultation document as ‘international organisations’ are in fact ‘professional organisations.

In the main report some graphs present the information of both groups under the heading ‘professional organisation. In the graphs below the information as submitted to the public consultation is presented.

Figure 0-1: Overview of the responses by stakeholder group (international and professional organisations are grouped)

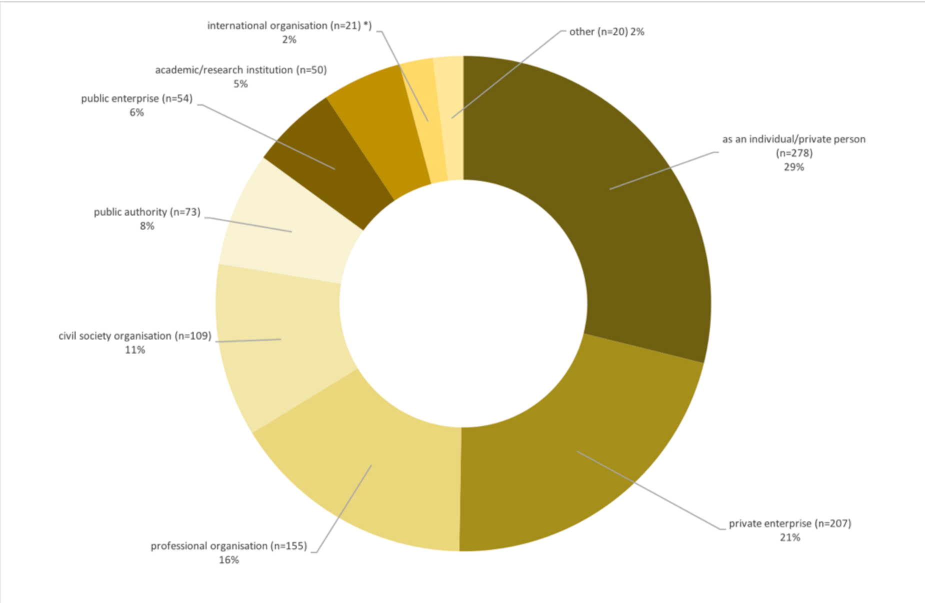
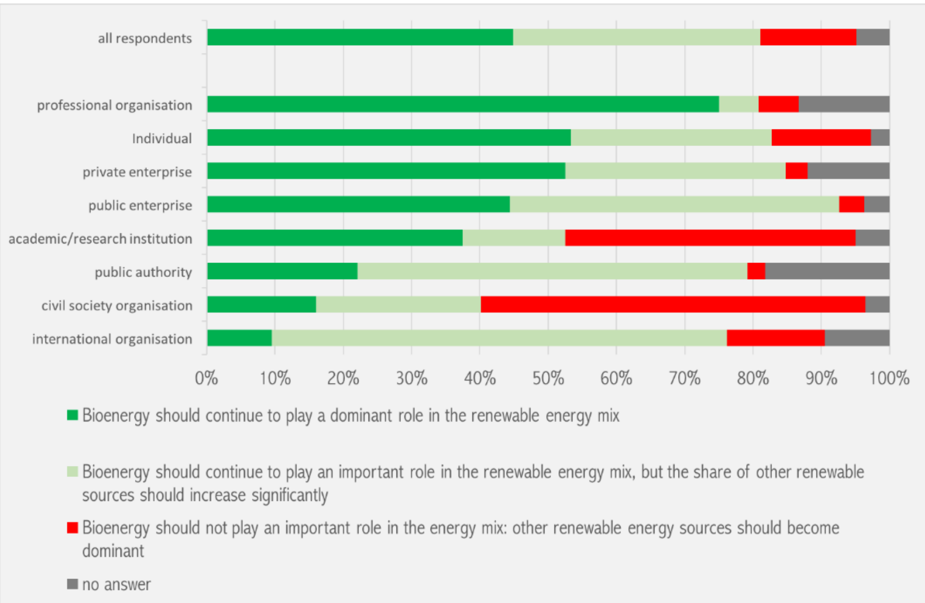


Figure 0-2: Role of bioenergy in achieving the EU 2030 energy and climate objectives as seen by the various stakeholders



Appendix 5: Key objectives for an improved bioenergy sustainability policy post-2020, per stakeholder group

In this annex the results of the scores per stakeholder group[85] are presented.

Figure 0-1: key objectives for a post-2020 policy, as responded by academic/research institutions

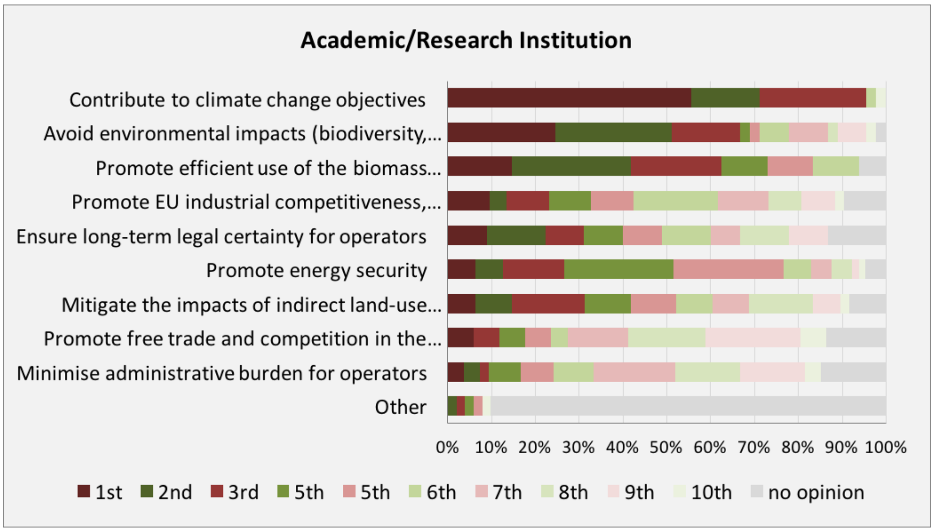
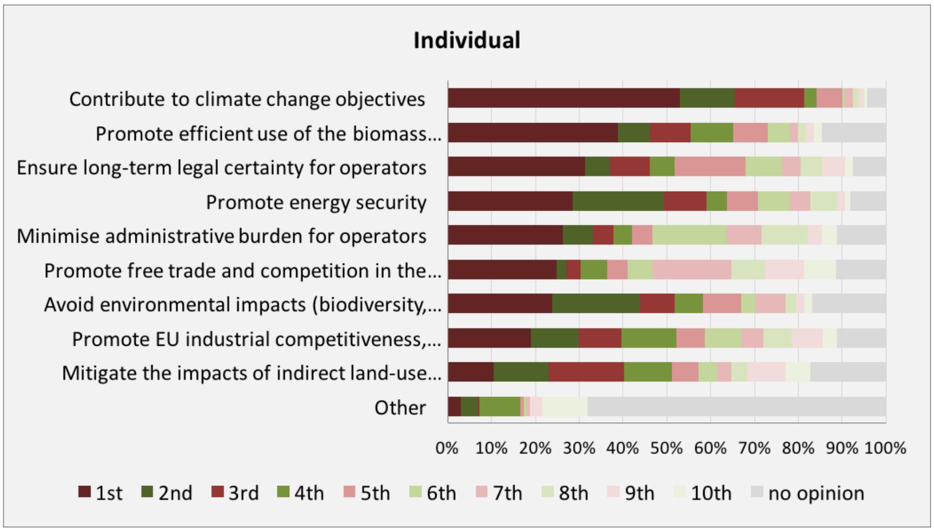


Figure 0-2: key objectives for a post-2020 policy, as responded by individuals



[85] The responses of the 'international organisations' are included in the graph of the 'professional organisations'.

Figure 0-3: key objectives for a post-2020 policy, as responded by civil society organisations

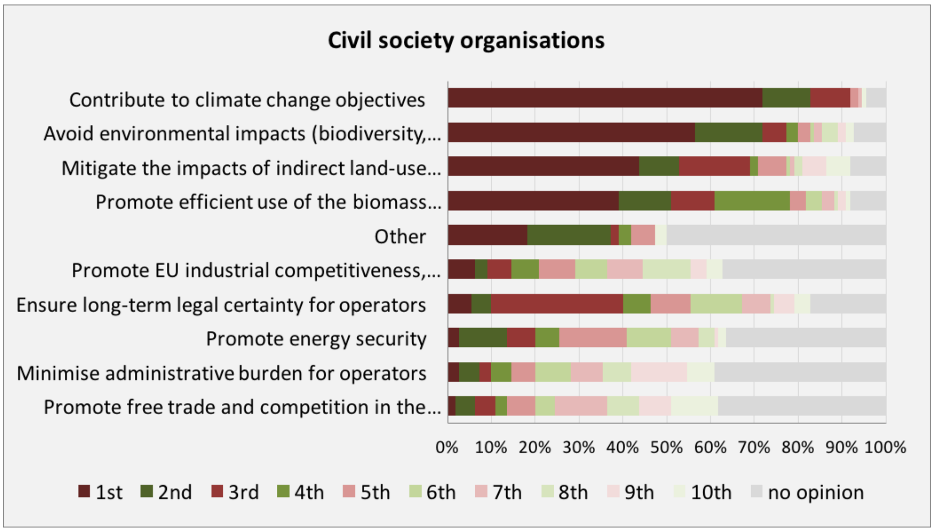


Figure 0-4: key objectives for a post-2020 policy, as responded by private enterprises

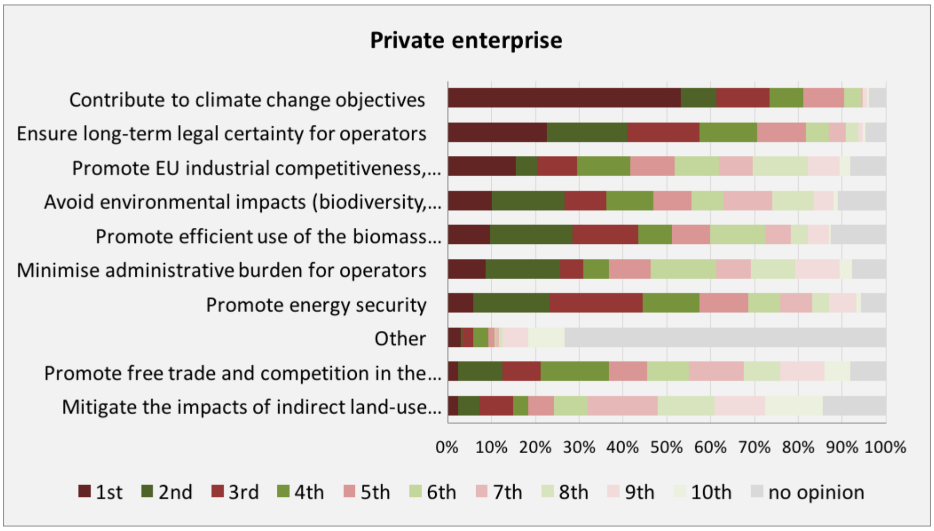


Figure 0-5: key objectives for a post-2020 policy, as responded by public enterprises

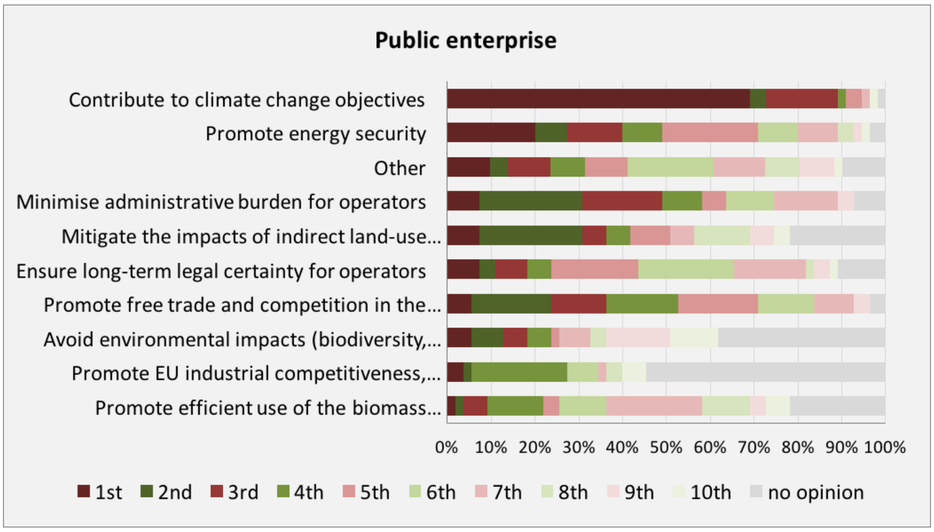


Figure 0-6: key objectives for a post-2020 policy, as responded by professional organisations

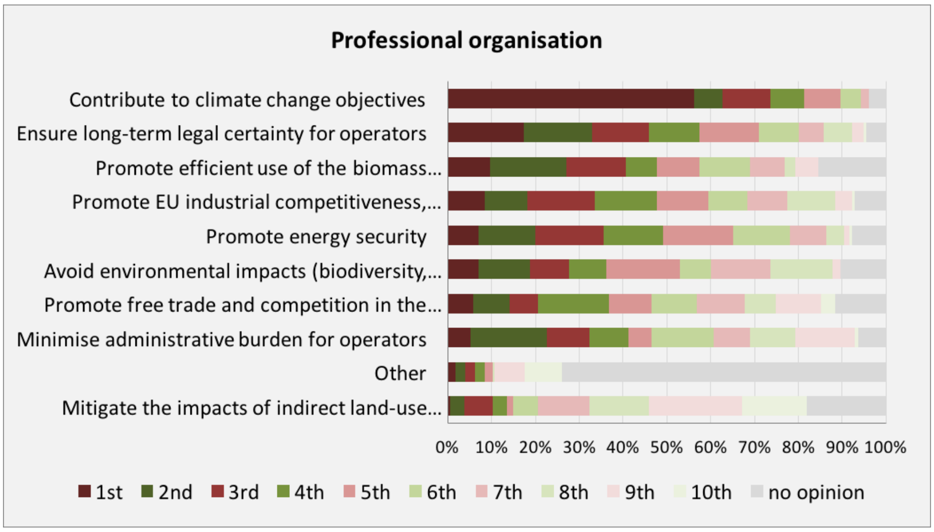
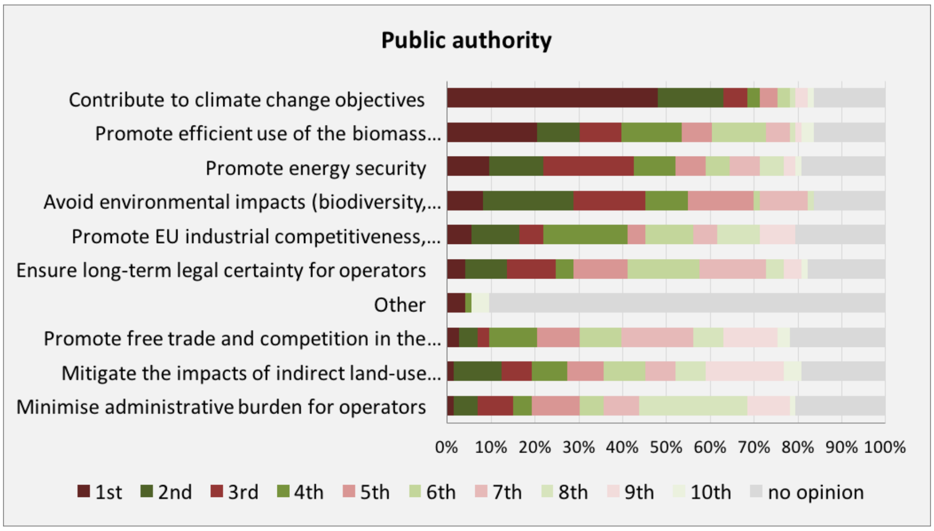


Figure 0-7: key objectives for a post-2020 policy, as responded by public authorities



Policy context and gap analysis

Annex E

VITO
Utrecht University
TU Wien
INFRO
Rütter Soceco
PwC

Policy context and gap analysis

BioSustain: sustainable and optimal use of biomass for energy in the EU beyond 2020

Date: July 03, 2016

By: Eric van den Heuvel, Sabine Kreps (VITO NV)

Executive summary

This report builds on the results of the previous task of the BioSustain project in terms of biomass supply potentials and demand scenarios. In outlook towards to 2030 increased demand for renewable energy in general and for bioenergy may result in particular potential challenges in terms of sustainability and optimal use of biomass.

In order to propose changes to the current policy framework objectives need to be defined on how to address potential sustainability and/or efficiency issues.

This reports review to what level existing EU legislative measures (Directives, Regulations and Decisions) related to a set of identified biomass sustainability issues are addressing possible future risks of biomass use in the EU for the generation of electricity, heating, and cooling and for producing and using transport fuels.

The following set of sustainability risks has been identified:

- upstream – biomass production
  - carbon stock change
  - Indirect land use change
  - Biodiversity, soil and water
- downstream – biomass conversion and end-use in energy
  - GHG emissions in the supply chain
  - Efficient end-use conversion
  - Air emissions
  - Competition with other end-use markets

For each risk it is described which biomass feedstocks are most relevant, from which sector they originate (agricultural sector, forestry, waste sector, whether they originate from within the EU or are imported from a non-EU country) and to what extend the relevant EU legislative measures in place adequately address the concerning risk. On basis of that a possible policy gap is identified. This will form the basis to propose possible policy options for the EU to overcome these gaps.

In summary, the major difference between the upstream and the downstream related risks is characterised by the fact that 'upstream' the sustainability of all biomass production needs to be ***assured*** - whether origination from within or outside the EU, and whether origination from agriculture or from the forest - whereas on the 'downstream' side the use and conversion of the feedstocks into energy needs to be ***optimized*** to ensure resource efficient use of biomass and decrease potential competition pressure for energy and non-energy end use markets.

For the biofuel production it is relevant to develop policy options that secure the sustainability issues of all feedstocks that are meant to be used for energy purposes within the EU. At the moment only biomass feedstocks that are converted into biofuels (for the transport market) and bioliquids (for electricity and/or heat) are governed by sustainability criteria at EU level. It is proposed to design a policy option which explores the extension of the sustainability criteria to solid and gaseous biomass for use in the electricity and heating/cooling market. Ultimately, though this is beyond the scope of this report, extension of the sustainability criteria to the use of biomass resources in the non-energy end-use markets could be considered.

From the gap analysis it has become clear that sustainability issues such as biodiversity, land use change and and soil and water impacts are not well addressed in the existing sustainability criteria for biofuels and bioliquids, and will also not be addressed when the current scheme is extended to solid and gaseous biomass. These issues are most at risk for primary products from non-EU agriculture, but may become also material in the case of increased demand for non-EU forest feedstocks. Because the amended Renewable Energy Directive has set limits to land-based feedstocks for biofuel these risks probably will not further expand. Increased demand for non-EU forest resources could potentially result in more sustainability risks. A way to mitigate those risks would be to request, similar to EU practices in various Member State, the presence of sustainable forest management practices in these non-EU forest regions.

In the 'downstream' case it has been found that existing legislation has not been designed specifically for guaranteeing sustainability or efficiency for biomass use for energy. Current regulation does not explicitly address the risks associated with increased biomass for energy use. For that reason, it is advised to develop additional policy options that address energy efficiency and waste management to enable optimal use of sustainable biomass for both energy and non-energy end-use markets.

20 Introduction

This task (Task 4) builds on the results of the previous tasks of the BioSustain project in terms of supply potentials (Task 1) and demand scenarios (Task 2), which can raise potential challenges in terms of sustainability and optimal use of biomass.

As an outcome of the first two tasks, the baseline/reference situation has been established, which outlines possible problems and issues that may require policy action at EU level. In order to propose changes to the current policy framework objectives need to be defined on how to address potential sustainability or efficiency issues. According to the EC impact Assessment Guidelines (2009) general objectives (impact indicators) need to be translated into specific objectives (result indicators) and where relevant operational objectives (output indicators – deliverables/objects of actions). It is important that these objectives are clearly defined, so that all objectives will be SMART – specific, measurable, achievable, realistic and time-dependent. Only in this way can the objectives inform the development of policy options. For any given problem, more than one objective may be appropriate.

This will reflect how far a problem should be addressed, different ways of addressing it and the timeframe over which the objective should apply. Based on the problems and needs identified and objectives defined, a set of options will be drafted beyond the no-change option. The options will provide an analytical description of the solutions proposed and be defined in a realistic way.

In this regard, the specific objective of this task is to review existing EU measures relating to biomass sustainability issues in order to assess whether and how these measures are addressing possible future risks of biomass use in the EU for the generation of electricity, heating and cooling and transport fuels. In this task an overview will be drawn up of EU measures (i.e. as adopted in Regulations, Directives and Commission Decisions) which are expected to be relevant from the sustainability point of view. Based on the findings from Task 1 and Task 2 on potential supply and demand of biomass for energy purposes towards 2030 a gap analysis will be executed to what extent each of the measures addresses the possible future risks. The results from the gap analysis form the basis to identify possible options for EU actions in order to minimize identified risks.

20.1 Outline of the report

The outline of the following sections in this report will be as follows:

- Chapter 2 provides a brief description of the identified risks and an overview of the most relevant EU legislation
- Chapter 0 contains:
    - For each risk it is described which biomass feedstocks are most relevant and from which sector they originate. This is then followed by a brief description of the relevant legislative measures that might address this particular risk.
    - The description of potential policy gaps that may remain and need to be covered with potential future policy options.

  - In a final section of this chapter the various national sustainability schemes and whether and how they tackle the identified risks is described
- Chapter 0 summarizes the identified potential gaps and aims to structures them to enable the development of possible policy options for the sustainable use of biomass for energy in EU).
- Chapter 24 provides an overview of possible policy options that might mitigate those gaps and risks. These policy options will be evaluated qualitatively and if possible quantitatively in other tasks of the BioSustain Project.
- Chapter **Error! Reference source not found.** draws up relevant conclusions on the outcomes.
- In the Annexes more detailed descriptions of the legislative measures at EU level (Annex 1) and the national schemes (Annex 2) are presented.

21 Methodology

The following approach/methodology is developed to report on:

- the analysis of the risks and how they are addressed in the most relevant existing EU legislation and some national sustainability schemes (related to biomass for heat and power),
- the subsequent gap analysis,
- a description of possible policy options that could mitigate those risks. In Task 5 (Impact Assessment) these options are elaborated in further detail.

21.1 Brief description of the identified risks

In the previous activities of the project the following risks have been determined, based on amongst others the Commission Staff Working Document "State of play on the sustainability of solid and gaseous biomass used for electricity, heating and cooling in the EU"[86].

- Risks associated with greenhouse gas (GHG) emissions:
    - in the supply chain
    - due to carbon stock change
    - emissions related to indirect land use change (iLUC)
- Risks associated with other environmental impacts:
    - Biodiversity, soil and water issues
    - emissions to the air
- Risks associated with resource efficiency:
- based on the efficiency of the end-use conversion of biomass into useful energy
- related to competition for biomass feedstocks in various end-user markets

For the purpose of the analyses about how these issues are addressed in the existing EU legislation we restructure them in two groups:

- issues where the risks may occur in the upstream (production and distribution) section of the supply chain of the biomass resources up to the conversion facilities; and
- issues where the risks may occur at the downstream (conversion and end-use) section of the supply chain, i.e. at the point of conversion or end-use of the biomass for energy.

Re-organising the issues in this manner provides a better insight in where in the supply chain the potential risks may occur and also provides input to the gap-analysis that will be carried out. This helps to develop fit-for-purpose possible policy options, but also provides an understanding where the limits of certain policy options are.

The issues will therefore be analysed as follows:

- upstream – biomass production
    - carbon stock change
    - Indirect land use change
    - Biodiversity, soil and water

[86] EC, 2014, SWD(2014)259 final

- downstream – biomass conversion and end-use in energy
    - GHG emissions in the supply chain
    - Efficient end-use conversion
    - Air emissions
    - Competition with other end-use markets

21.2 Overview of the most relevant EU legislation

As stated in the EC 2014 Commission Staff Working Document on the state of play on the sustainability of solid and gaseous biomass used for electricity, heating and cooling in the EU solid biomass – particularly wood and wood waste – used for electricity, heating and cooling production is the biggest source of renewable energy in the EU and is expected to make a key contribution to the 20% EU renewable energy target by 2020.

Also for the new EU targets for 2030 (at least 27% renewable energy; 40% greenhouse gas emission savings as compared to 1990) biomass for electricity, heating and cooling and biofuels are expected to contribute to a significant level. The sectors from which the required biomass needs to be sourced in a sustainable manner will be the forestry and agricultural sector, as well as the industrial and waste processing sectors (for secondary and tertiary biomass waste and residues). The operations in these sectors are governed by various legislations, both at Member State and European level. As indicated in the Task 1-2 Technical Background report (see Figure 10.1 of that report) about 5-10% of the potentially required biomass in the EU can be expected to be imported from non-EU regions. Utilisation of the feedstocks within the EU will be governed by EU and MS legislation, but the upstream section of these feedstocks will be beyond EU policy governance. Where appropriate this will be addressed in a gap analysis.

In this policy context and gap analysis report only existing EU legislative measures have been taken into account. This means that only adopted and published Directives, Decision and Regulations have been reviewed. The Commission also published communication documents on strategies and roadmaps, but these have not been included in this review for identifying possible policy gaps.

Furthermore, it is important to mention that many of the reviewed legislative measures have been designed to serve a specify policy goal. At the time of the establishment of such legislative tools the sustainability issues that are now under discussion for a sustainable bioenergy policy were not known yet, or did not have yet have the magnitude as the share of bioenergy in the total energy. Other measures, e.g. the EU Timber Regulation or LULUCF, address an issue which is relevant in the context of bioenergy – i.e. deforestation. For most of these measures the potential bioenergy context was not a design parameter but now such measures proof possible relevant to secure the identified sustainability risks. Only the Renewable Energy Directive and the Fuel Quality Directive did explicitly incorporate measures to prevent undesired sustainability risks to happen. In the description of the various measures it is only investigated whether the set of measures provide a sufficient 'security net' for the possible occurrence of sustainability risks. This analysis is not intended to value evaluate the legislative measures and qualify or disqualify them. The only purpose is to see if the framework covers sustainability risks or not and whether policy gaps might exist. For such gaps possible solutions could be identified and further developed, which is beyond the scope of this report.

The following legislative measures are identified on basis of these notions and are grouped according to the policy areas of the European Commission as follows:

Energy

- (amended) Renewable Energy Directive (Directive 2009/28/EC and 2015/1513)
- Energy Efficiency Directive (2012/27/EU)
- EcoDesign Directive.
- Emission Trading Scheme
- (amended) Fuel Quality Directive (Directive 2009/30/EC and 2015/1513)

Climate

- Emission Trading Scheme
- Land Use, Land Use Change and Forestry - LULUCF (Decision 529/2013/EU)
- Fuel Quality Directive (Directive 2009/30/EC and 2015/1513)
- Effort Sharing Decision (Decision 406/2009/EC)

Environment

- the Nitrates Directive (Directive 91/676/EEC)
- the EU Timber Regulation (Regulation 995/2010)
- Natura 2000 / Habitat and Birds Directive (Directive 92/43/EEC and Directive 2009/147/EC
- the Common Agricultural Policy, Pillar 1: Direct Payments (Regulation 1307/2013) and Pillar 2: (support for rural Development) – cross-compliance rules
- Water Framework Directive
- Waste Framework Directive
- Landfill Directive
- Sewage Sludge Directive
- National Emissions Ceiling Directive (Directive 2001/81/EC)
- Industrial Emissions Directive (Directive 2010/75/EU)
- Medium Combustion Plants Directive (Directive 2015/2193/EU)

21.3 Overview of selected EU Member States with national biomass sustainability legislation in place

In absence of binding EU sustainability criteria for biomass for heat and power, some EU Member States have developed sustainability schemes for solid and gaseous biomass to secure the sustainability of the biomass resources used for the generation of electricity and/or heat and cooling. In this report the sustainability schemes of following member states are incorporated in the gap analysis report:

- The UK Renewables Obligation, Renewable Heat Incentive, Contracts for Difference
- Belgium Flanders Green Power Certificates
- Belgium Wallonia Green Certificates
- Netherlands Energy Agreement, SDE+
- Denmark: Industry Agreement

In the following section of this report for each of the legislation measures the background and main characteristics will be described. Following that information will be presented whether and how the discussed EU measures addresses the identified risk at production and/or end use level.

21.4 Gap analysis

The gap analysis consists of a qualitative assessment with respect to the sustainability risks.

For each of the sustainability issues it will be summarized whether and if a policy gap might exist and for which part of the supply and value chain this gap is relevant: for the biomass production or collection side or for the biomass conversion and end-use part of the chain. Furthermore, it will be indicated whether policy gap refers tot the agricultural sector, the forestry sector and/or the waste collection sector (in the case of biomass production and collection) or for the electricity and heating/cooling sector, the transport and/or the non-energy sector.

Furthermore, where appropriate, a distinction will be made between feedstocks' origin (EU vs non-EU) and between the type of feedstock (agricultural crops; agricultural residues; forest products; forest residues; waste) as risks vary per type of feedstock. Some policies also only focus on specific types of feedstocks.

22 Analysis of whether and how the legislative measures address the identified risks relate to biomass use for energy

22.1 Introduction

The previous chapter described that the risks related to biomass for energy use can be distinguished in risks related to the upstream side of the biomass chain, i.e. related to biomass production and to risks related to the downstream side of the biomass chain, i.e. the conversion of the biomass into useful energy. In this chapter these risks are discussed along this distinction.

Firstly, a brief description of the risk is given. This is followed by an overview of the legislative measures that may (or may not) address this particular risk. Additionally, it is clarified whether specific circumstances exist that may lead to a potential policy gap. In the next chapter these gaps are reviewed and structured in order to develop possible policy options to mitigate such gaps in a future policy environment.

22.2 Risks related to the upstream biomass production

In the following sections three risks that are strongly interlinked will be discussed separately: carbon stock change, land use change (both direct and indirect) and impacts on biodiversity, soil and water.

22.2.1 Carbon Stock Change (biogenic emissions)

An increase in the use of biomass resources for bioenergy purposes may result in:

1. using more biomass than can be regenerated on a unit of land, in both agricultural and forestry areas;
2. increasing the level of harvested biomass (even while the total harvested amount stays below the annual increment level)
3. expanding the production of biomass resources to land previously unmanaged or in production for other purposes; and/or
4. using biomass resources previously used for other than energy purposes.

The first two risks relate to carbon stock change and will be discussed in this section. The other two risks will be discussed in the following section as they relate to land use change (both direct and indirect).

The issue of carbon stock change is mainly of importance in the forestry sector, given the carbon stock in above surface biomass and soil biomass in the forest. In the agricultural sector the issue of carbon stock is also important, as the discussion on how much straw can be removed from the field shows. For the latter two risks mentioned before, a review of the activities for biomass for energy production in the agricultural sector becomes more relevant.

According to the EC[87], "forest biomass for energy is currently produced as a complementary co-product of wood material/fibre products. Therefore, it is unlikely that

[87] EC, 2014, SWD(2014)259 final

bioenergy demand is associated to direct deforestation in Europe. As a result of the deforestation programme, natural succession of vegetation and abandonment of farming, EU forest area has increased and, over the last decade, have grown by 2% in area, while the use of bioenergy has been increasing at the same time. It is expected that forest expansion will continue, although the process is slowing down due to agricultural maintenance and urbanization. In addition to growth in area, as only 60-70% of the annual increment is being cut, the growing stock of wood is also rising significantly." The EC document continues that there is 'no evidence of systematic imbalance between forest functions at the European level'. The Technical Background Report of the BioSustain project[88] concluded that on top of the 350 Mm^3 (73 Mtoe) forest products already used "the additional potential for bioenergy use lies roughly between 100 to 200 Mm^3 (21 – 42 Mtoe) in the period 2020-2030, mostly in the form of forest residues. However, mobilisation of these depends very much on technical solutions, because of the actual technical focus on the stem and high costs of manual collection. Furthermore, there can be quite high environmental restrictions on the use of residues. The environmental effects of residue utilization are discussed controversially in relation to the extractions of nutrients and deadwood which may be solved in accordance to forest stands." This may lead to the conclusion that in the EU proper sustainable forest management is in place to secure undesired carbon stock changes. However, in order to meet growing forest biomass demand for energy and other uses, forest production will need to be intensified across the EU.[89] This needs to be done sustainably to prevent negative impacts on biodiversity and ecosystem services, including the carbon pool. Enhancement of sustainable forest management practices throughout the EU are required to preserve the forest health and vitality and its overall biodiversity status.

For forestry biomass originating from non-EU sources the effects on carbon stock change are often not clear. However, according to the BioSustain Technical Background report's assessment, imported biomass resources are limited in relation to EU-based sources. Nevertheless, further research is required to establish whether sustainable forest management practices that are common in the EU are governed by similar regulation in such non-EU regions.

Both the Renewable Energy Directive[90] (RED) and the Fuel Quality Directive[91] (FQD) describe issues related to carbon stock change, though these refer to carbon stock changes as result of land use change (in particular when forestry land is converted to agricultural land for the production of crops for biofuels).Therefore this will be addressed in Chapter 22.2.2.

The following relevant legislative EU measures might address carbon stock change and are briefly described in the Boxes below:

1. the EU Timber Regulation
2. the Decision on Land Use, Land Use Change and Forestry (LULUCF).

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88 BioSustain consortium, 2016, for EC DG Energy, to be published
89 EC, 2014, SWD(2014)259
90 EC, 2009, Renewable Energy Directive 2009/28/EC; EC, 2015 amendments to the RED 2015/1513/EC
91 EC, Fuel Quality Directive, 2009/30/EC; EC, 2015, amendment to the FQD 2015/1513/EC

Detailed descriptions of these regulations (and regulations mentioned in other sections) can be found in Annex 1.

In addition to these two legislative measures the EU also supports the policy target of halting global forest cover loss by 2020 and reduction of gross tropical deforestation by at least 50% by 2020 via other means. Ongoing UNFCCC negotiations on "reducing emissions from deforestation and forest degradation, conservation of forest carbon stocks, sustainable management of forests, and enhancement of forest carbon stocks" (REDD+) could prove an important tool for achieving this goal.[92]. The EU's approach to REDD+ builds on the Forest Law Enforcement, Governance and Trade (FLEGT) Action Plan (see also the description in the box on the EU Timber Regulation) and other on-going initiatives. The European Commission has committed a total of approximately 107 million euros in 2007-2012 to support initiatives that will pilot REDD+ projects in Asia, Africa and Latin America. Almost 64 million will be channelled through FLEGT. [93]

The EU Timber Regulation

The EU Timber Regulation[94] (EUTR) provides obligations for operators who place timber and timber products on the European market with the objective to counter the trade in illegally harvested timber and timber products. – including e.g. fuel wood, wood in chips or particles or wood waste.

The EUTR was published in October 2010 and entered into force in March 3, 2013. The area of influence of the EUTR is limited to operators that bring products to the EU market. A relevant addition to the EUTR are the Voluntary Partnership Agreements (VPA's) - legally binding trade agreements between the EU and a timber-producing country outside the EU – to ensure that the timber and timber products from these countries are from legal sources. However, VPA's do not necessarily guarantee sustainability of resources nor the effects on carbon stock changes. At the moment VPA's have been signed with six countries and nine are under negotiations.

The majority of the imported wood used for bioenergy use though does not stem from these countries. The major non-EU suppliers of wood for energy products to the EU are the US and Canada. For these two countries there is less concern about illegal logging. The US and Canada provide data on forest carbon stock changes.

A recent evaluation of the first two years of application of the EUTR has provided evidence that "the combined effect of the EUTR and the other measures of the EU Forest Law Enforcement, Governance and Trade (FLEGT) Action Plan have the potential to contribute to biodiversity protection, conservation and sustainable management of forests, and climate mitigation and adaptation"[95].

It is important to mention that the EUTR has not been designed to tackle carbon stock change issues but addresses the risk of deforestation.

The Decision on Land Use, Land Use Change, Forestry.

The Decision on Land Use, Land Use Change and Forestry (LULUCF) covers greenhouse gas emissions into the atmosphere resulting from our use of soils, trees, plants, biomass

[92] http://ec.europa.eu/clima/policies/forests/redd/index_en.htm
[93] http://ec.europa.eu/clima/policies/forests/redd/index_en.htm
[94] EU, 2010, Regulation (EU) No. 995/2010
[95] EC, 2016, SWD(2016)34

and timber.[96] In the light of a decision by UNFCCC parties in December 2010 to revise accounting rules for greenhouse gas emissions and removals from soils and forests, the Council and the European Parliament adopted the Decision[97] (529/2013/EU). This Decision sets out accounting rules applicable to emissions and removals of GHGs resulting from 'LULUCF' activities, as a first step towards the including of these activities in the Union's emission reduction commitment, when appropriate. The Decision contains reporting requirements for Member States on their initiatives to decrease emissions from forestry and agricultural related activities as well as increase the carbon sink. It does not provide any accounting or reporting obligations for private parties. Article 3 mentions that for each accounting period, Member States shall prepare and maintain accounts that accurately reflect all emissions and removals resulting from the activities on their territory falling within the following categories:

- Afforestation
- Reforestation
- Deforestation
- Forest Management

From 2021 onwards Member States shall also prepare and maintain annual accounts for the following categories:

- Cropland management
- Grazing land management

Gap analysis for carbon stock change

The EU Timber Regulation (EUTR) requires compliance with the applicable legislation in the country of harvest without describing in detail which elements this legislation should contain. It is therefore not certain whether carbon stock protection is covered by national laws in the particular country. Furthermore, the EUTR does not focus on agricultural or wood products from wood plantations products that are produced on formerly illegally harvested forest regions. These policy gaps might be addressed well by using sustainability requirements similar to those used currently in the RED for biofuels and bioliquids.

The LULUCF Decision sets accounting rules and reporting obligations on EU Member States which mitigate possible risks for carbon stock losses in the forestry sector in EU Member States. And from 2021 onwards the Decision also sets accounting rules for croplands and grazing lands. However, the Decision is limited to the EU region only and does not apply to non-EU countries. Nevertheless, the UNFCCC is committing countries by stating that "under the Kyoto Protocol, Parties shall annually report emissions by sources and removals by sinks of CO2 and other greenhouse gases resulting from LULUCF activities".

Mapping of potential policy gaps

In the following table an overview is presented in which parts of the supply chain and in which sectors potential policy gaps might exist. Utilization of biomass for electricity and/or heating/cooling from forestry land and areas with high conservation values is not

[96] LULUCF in the EU, see: http:/ec.europa.eu/clima/policies/forests/lulucf/index_en.htm
[97] EU, 2013, Decision 529/2013/EU

prevented by sustainability criteria in RED or FQD. Carbon stock changes within the EU forests due to bioenergy utilisation is unlikely due to deforestation programmes and sustainable management practices in Europe. Carbon stock change in the EU agricultural sector might occur when more agricultural residues and wastes are harvested from the agricultural fields. This could cause that the carbon soil balance could deteriorate over the years. Careful monitoring would be needed, which is now not in well covered in any legislative measure. Carbon stock changes might appear for non-EU biomass feedstock, which are meant for use in the electricity and heating/cooling market. Use of biomass for non-energy purposes is not governed by any sustainability system and as a result a policy gap might exist here as well. As biomass that is viewed as non-sustainable for energy could be sold in this sector.

Table 22-1: Where do potential policy gaps appear for carbon stock change (dark coloured cells indicate where gaps may exist)

In biomass production part of the supply chain:	**In the biomass conversion and end use part of the supply chain**
Agricultural sector	Transport
Forestry sector	**Electricity, heating and cooling**
Waste sector	**Non-Energy**

22.2.2 Land use change (direct and indirect)

Land use change can occur in a direct and indirect way. The conversion of primary forest for the purpose of establishing a plantation for a variety of products, including agricultural crops or wood products for bioenergy use is an example of direct land use change. Indirect land use change has been discussed in the last decade in relation to crop-based biofuels. The argument is that the production of feedstocks for biofuels for transport on agricultural land that formerly was producing crops for food or feed 'pushes' the production of those food or feed crops to elsewhere and may lead to expansion into non-agricultural land with indirect land use change and corresponding greenhouse gas emissions as a result.

Both the 2015 amended Renewable Energy Directive and Fuel Quality Directive address in identical way the issue of indirect land use change from crop based feedstocks for biofuels and bioliquids and require Member States to report on the indirect land use change impacts. Below therefore only the RED is discussed. A detailed description of the FQD is found in the Annex. Furthermore, the RED stresses the development of non-food crop based, advanced biofuels. The directives are described in more details in Annex 1.

The amended Renewable Energy Directive

The Renewable Energy Directive (published in 2009 and amended in 2015) established an overall policy for the production and promotion of energy from renewable sources in the EU. It requires the EU to fulfil at least 20% of its final energy use with renewables by

2020. Furthermore, all EU countries must ensure that at least 10% of their road transport energy comes from renewable sources by 2020. Biofuels are instrumental in helping the EU countries to meet these targets.

The RED sets out sustainability criteria for all biofuels and bioliquids consumed in the EU to ensure that they are produced in a sustainable and environmental friendly manner. Companies can show compliance via national systems or voluntary schemes recognized by the EC.

Carbon stock change is addressed in the RED as follows: in recital 70 to 73 it is described how the greenhouse gas impacts of carbon stock loss take place due to land conversion from forestry land or high conservation land to agricultural land for the production of feedstocks for biofuels or bioliquids.

Article 17.3 of RED describes that "biofuels and bioliquids […] shall not be made from raw material obtained from land with high biodiversity value and high carbon stock.

This is however only in force for biofuels and bioliquids and does not relate to solid and gaseous resources that are used for energy generation in the electricity, heat and/or cooling sector. To illustrate: biogas could be produced in a facility where animal manure is co-digested with corn. As no sustainability criteria are applied for such corn when used in the electricity and/or heat sector, the corn could originate from forest to agricultural converted land.

Other legislative measure which address land use change issues are:

- the EU Timber Regulation,
- The Natura 2ooo/Habitats and Birds Directive.

Both the EU Timber Regulation (which is closely linked the the FLEGT, the EU Forest Law Enforcement, Governance and Trade (FLEGT) Action Plan have the potential to contribute to biodiversity protection, conservation and sustainable management of forests, and climate mitigation and adaptation. The legislative measures provide assurance levels to undesired land use change (especially for tropical forests) as a result of increased biomass demand. (see the description of these in section 22.2.1).

The Natura 2000 / Habitats and Birds Directives

At EU level, nature and biodiversity are protected by several laws. The Habitat Directive forms the cornerstone of Europe's nature conservation policy with the Birds Directive and establishes the EU wide Natura 2000 ecological network of protected areas.

The Habitats Directive[98] was adopted in 1992 to help maintain biodiversity. It protects over 1000 animals and plant species and over 200 types of habitat. It also established the EU-wide Natura 2000 network of protected areas.

The Birds Directive[99] was adopted in April 1979, and amended in 2009 and aims to provide comprehensive protection to all wild bird species naturally occurring in the European Union.

[98] EC, 2007, Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora - the consolidated version of 1 January 2007 with the latest updates of the annexes
[99] EU, 2009, Directive 2009/147/EC

The aim of the Natura 2000 network is to ensure the survival of Europe's most valuable and threatened species and habitats, listed under both the Birds Directive and the Habitats Directive. Natura 2000 is therefore a network of core breeding and resting sites for rare and threatened species, and some rare natural habitat types. It stretches across all 28 EU countries, both on land and at sea. Almost 50% of the designated areas is composed of forest (85 forest habitat types are protected under the Habitats Directive)[100]. Farmland makes up around 40% of the total area included in Natura 2000 (EC, 2014[101]).

Gap analysis for land use change

A policy gap exists due to the lack of EU wide sustainability criteria for all biomass used for energy production in the EU. Biomass resources from agricultural production (e.g. short rotation coppice or energy crops) used for electricity and/or heating/cooling generation are currently not covered by such sustainability criteria. This could result in undesired land use changes as result of expanded biomass cultivation for energy generation if the demand for biomass energy increases with the increasing renewable energy targets.

The EU Timber Regulation (EUTR) lays down obligation on operators who place timber and timber products on the European Market with the objective to counter trade in illegally harvested timber and timber products. In this way the EUTR also addresses the risk of land use change resulting from this illegal harvesting. The EUTR does not focus on agricultural or wood products from wood plantations products that are produced on formerly illegally harvested forest regions (indirect land use change). These policy gaps might be addressed well by using sustainability requirements similar to those used currently in the RED for biofuels and bioliquids. The potential gaps therefore main are material in non-EU countries.

The Natura 2000 and Habitats and Bird Directive protect natural areas via designated areas (of which approx. 50% forests and 40% farmland) where threatened species and habitats can survive. This measure can be viewed as a security measure to undesired land use change in the European context.

Mapping of potential policy gaps

In the following table an overview is presented in which parts of the supply chain and in which sectors potential policy gaps might exist. Lack of sustainability criteria for all end-use markets cause that both biofuels for transport and biomass for electricity and/or heating/cooling could still cause land use change in non-EU countries. Solid biomass feedstocks from agricultural land (e.g. energy crops) used for electricity and heating/cooling does not fall under the existing sustainability regimes. This issue occurs for biomass from both EU and non-EU origin. Utilization of biomass for electricity and/or heating/cooling from forestry land and areas with high conservation values is not prevented by sustainability criteria in RED or FQD. Again, also biomass fort he non-energy market is not governed by any sustainability criteria and could lead to land use changes.

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[100] Natura 2000 and Forests, FAQ, see: http://ec.europa.eu/environment/nature/natura2000/management/faq_en.htm#5

[101] EC (2014), Farming for Natura 2000. Guidance on how to support Natura 2000 farming systems to achieve conservation objectives, based on Member States good practice experiences, see: http://ec.europa.eu/environment/nature/natura2000/management/docs/FARMING%20FOR%20NATURA%202000-final%20guidance.pdf

Table 22-2: Where do potential policy gaps appear for land use change (dark coloured cells indicate where gaps may exist)

In biomass production part of the supply chain:	**In the biomass conversion and end use part of the supply chain**
Agricultural sector	**Transport**
Forestry sector	**Electricity, heating and cooling**
Waste sector	**Non-Energy**

22.2.3 Impacts on biodiversity, soil, water

Growth in the production and extraction of biomass resources as a result of growing demand in the energy sector may lead to various undesired impacts. In the previous sections it has been mentioned that carbon stock changes and land use changes may occur in the agricultural and forestry sector. It has been concluded that there are policy gaps due to the fact that current policy does not cover all sectors the feedstocks originate from, or that the regulations only have governance power within the boundaries of the EU, and can not control governance in non-EU countries. It may therefore not come to a surprise that the potential risks on biodiversity, soil and water status also are not fully covered by existing policies. Biodiversity, soil and water issues are strongly related to carbon stock and land use change, especially in the case of changes in forestry. In the agricultural sector the character of the agricultural practice may put biodiversity and quality of soil and water under pressure.

The following legislative measures take biodiversity, water and/or soil issues into consideration:

- The (amended) RED (and identically FQD)
- The Common Agricultural Policy
- The Nitrates Directive
- The EU Timber Regulation
- The Natura 2000 and Habitats and Birds Directive
- The Water Framework Directive
- The Industrial Emissions Directive

These are presented briefly in the next table.

The amended Renewable Energy Directive

The sustainability criteria in the (amended) RED and FQD prohibit the expansion of production of feedstocks for biofuels and bioliquids into forests, areas with high biodiversity and peat land drainage. In this way, direct impacts on biodiversity risks are addressed.

The Common Agricultural Policy

The CAP is a common policy for all the Member States of the European Union. It is managed and funded at European level from the resources of the EU annual budget (EC, 2014). The CAP has three dimensions, which are interconnected (EC, 21014):

- market support,
- income support and
- rural development.

The CAP is structured around two 'Pillars':

- Pillar 1 (Single Payment scheme) and
- Pillar 2 (Rural development Policy).

They each have different amounts of money reserved for them and have different purposes.

The CAP (existing since 1962) has been reformed in 2013 (EC, 2014) and a new system of direct payments was introduced for Pillar I. This new system, aimed at 'Greening' created a link through the in 2003 introduced cross-compliance (CC) system between receipt of CAP support by farmers and respect of a set of basic rules related to the main public expectations on environment, public and animal health, as well as, animal welfare. Member States have a wide range of possibilities of implementation. Under their responsibility standards for good Agricultural and Environmental conditions are defined as one part of the CC.

The CAP applies to all farms in the EU and aims to ensure "good agricultural and environmental conditions" including the protection of climate (carbon stock changes), soil, water and biodiversity.

The Nitrates Directive

The Nitrates Directive came into force in December 1991 for the protection of European waters against pollution caused by nitrates from agricultural sources. The directive acknowledges that the use of nitrogen-containing fertilizers and manure is necessary for agriculture but aims at restricting the excessive use of fertilizers, as that constitutes an environmental risk. The objective of the directive is twofold[102]:

- producing water pollution caused or induced by nitrates from agricultural sources and
- preventing further such pollution

Member States must have established Action Programmes, describing measures to ensure that, for each farm or livestock unit, the amount of livestock manure applied to the land each year shall not exceed the amount of manure containing 170 kg N per hectare.

The Nitrates Directive regulates prevention of water pollution caused by nitrates within the context of agricultural practices within the European Union. Member States may set restrictions or limits for vulnerable zones, as long as it is in line with the objective of the Directive and it is justified on basis of objective criteria.

The EU Timber Regulation

As described in section **Error! Reference source not found.**, The EU Timber Regulation prevents the import of illegal timber and timber products to Europe.

The Water Framework Directive

[102] EC, 1991, Directive 91/676/EEC

Since the mid 70s of the last century there was ongoing focus on setting standards for the quality of water in rivers and lakes that provided drinking water to Europe's citizens. Over time the focus expanded (e.g. to prevent pollution of water from urban waste water and nitrate leakages from agricultural practices. At the turn of the century the water policy was fragmented and a new Water Framework Directive emerged with among others the following key aims:[103] expanding the scope of water protection to all waters, surface waters and groundwater, achieving "good status" for all waters by a set deadline, and, as core of the single system for water management approach: management based on river basins, requiring international collaboration along the course of the river. The Water Framework Directive[104] is complemented by other legislation regulating specific aspects of water use: among others the Groundwater Directive (2006), the Environmental Quality Standards Directive (2008), and two Commission Decisions (2005 and 2008), on ecological status.

The Water Directive aims at getting polluted waters clean again, and ensuring that clean waters are kept clean. As such this Directive effects the potential impact of biomass production (for energy or non-energy purposes) on water.

The Industrial Emissions Directive

To control the pollution (air pollutants, discharge of waste water and generation of waste) from industrial production processes, the EU has developed a general framework based on integrated permitting, laid down in the Industrial Emissions Directive (IED)[105].The IED came into force on 2 January 2011 and had to be transposed by Member States by 7 January 2013. The IED controls emissions to soil and water not at the upstream side of the biomass chain, but at the downstream side, at the location of the facility when biomass is converted to electricity and/or heat.

Gap analysis for biodiversity, soil and water

The RED and FQD do not explicitly set regulations to protect soil and water quality in the production of the feedstocks for biofuels and bioliquids. The RED and FQD also not regulate the use of biomass feedstocks in the electricity and/or the heating and cooling sector.

The Common Agricultural Policy is restricted to ensuring good agricultural and environmental production from biomass produced on agricultural land within the European Union (as also referred to in the Renewable Energy Directive) and therefore does not cover good environmental conditions:

- From biomass produced on agricultural land outside the European Union;
- The guarantee of environmental conditions from biomass from forest land;

The EUTR does not explicitly set conditions for sustainable management systems in legal forests and as a result is also not focusing on biodiversity or soil related issues. Forest resources that comply to EUTR and would be used for energy purposes could still have undesired impacts on biodiversity, soil and/or water quality.

For agricultural biomass feedstocks from non-EU countries water pollution caused by nitrates from agricultural practices could occur as the information on nitrogen levels is only based at indicative levels.

[103] http://ec.europa.eu/environment/water/water-framework/info/intro_en.htm, website visited 24-Feb-2016
[104] 2013, EC, Directive 2000/60/EC, amended latest by Council Directive 2013/64/EU of 17 December 2013
[105] ec.europa.eu/environment/industry/stationary/ied/legislation.htm

Requesting information on the country of origin of imported biomass feedstock from agriculture will enable to determine whether the country of origin has similar water protection legislation in place.

The geographical coverage of the Bird and Habitat Directive and the Natura 2000 sites is the European Union. They do not cover the protection of animal (as birds) and plant species and habitat types from forest and agricultural areas (e.g. produced for biomass to import to Europe) outside Europe.

In terms of biomass availability within Europe: One of the key conservation measures from Natura 2000 sites (and the Habitat Directive) for animal and plant species on agricultural land is adapting low-intensity farming practices. This may be contrary to the ambition to intensify agriculture (and thus counteract for example ILUC with this measure).

Production of biomass feedstocks from waste, agricultural or forestry residues, or the organic components in municipal solid waste within Europe have to take into account the regulations set by the Water Framework Directive. European facilities using imported non-European biomass feedstocks, in their process also have to operate under the regulations of the Water Framework Directive. For those European resources and for the conversion processes that take place on European ground it is not to be expected that the identified risks will emerge at significant level.

For the production of biomass feedstock in non-European countries potential undesired impacts on, in this particular case, water is not covered by the Water Framework Directive. If no similar regulation is in place such impacts could materialise. This is the case for biomass intended for all potential end-markets: electricity, heating and cooling and transport, as water is not one of the sustainability issues as mentioned in the RED, except for a biannual reporting on water legislation in main sourcing areas. In fact, this is also the case for non-European biomass resources intended for non-energy markets in Europe.

The Industrial Emissions Directive (IED) ensures that industrial production processes are governed via permits to prevent pollution related to their emissions of air pollutants, discharges of waste water and the generation of waste. The IED in this way addresses potential risks on air quality and risks of soil and water contamination near the production facilities. For combustion plants these permits apply for plants of 50 MW thermal input or larger. Smaller combustion plants are not governed by the IED, but for those facilities the Medium Combustion Plants Directive apply.

The IED is not designed to control how process feedstocks are produced, transported and pretreated prior to their use in the industrial production facility. As such the IED does not address issues related to biodiversity, soil and water where the feedstocks are produced.

The IED also does not have specific measure or minimum levels determined for conversion efficiency. Indirectly, conversion efficiency is relevant as high conversion efficiency contributes to better achievement of the emission levels.

Mapping of potential policy gaps

In the following table an overview is presented in which parts of the supply chain and in which sectors potential policy gaps might exist. The RED and FQD do not explicitly address biodiversity, soil and water quality issues in the production of feedstocks for biofuels and bioliquids on agricultural land in non-EU countries; in EU this is additionally regulated via the Common Agricultural Policy, the Nitrates Directive and the Water Framework Directive. So for agricultural feedstocks from non-EU countries there is no certainty that biodiversity, soil and water issues are rightfully addressed. The EU Timber Regulation does also not address these issues. The Industrial Emissions Directive controls the pollution from industrial production processes and this will not cause water-related risks in the EU. As a result, it can be concluded that in both the biomass production part of the chain (and in particular in the non-EU countries) as well as in all sectors were biomass is converted for end use (all in EU) potential risks on biodiversity, water and soil issues still exists, for which additional policy measures would be needed.

Table 22-3: Where do potential policy gaps appear for biodiversity, soil and water (dark coloured cells indicate where gaps may exist)

In biomass production part of the supply chain:	In the biomass conversion and end use part of the supply chain
Agricultural sector	Transport
Forestry sector	Electricity, heating and cooling
Waste sector	Non-Energy

22.3 Risks related to the downstream biomass conversion into energy

In the following sections four risks that are relevant in the downstream side of the biomass will be discussed: supply chain greenhouse gas emission reduction performance, air emissions, efficient end use conversion and competition with non-energy end use markets.

22.3.1 Supply chain GHG performance

An important reason to use biomass for energy purposes is the resulting greenhouse gas emission reduction by substituting fossil energy alternatives. Within the Renewable Energy Directive (and similarly in the FQD) for biofuels and bioliquids a minimum threshold for the well-to-wheel, supply chain GHG emission saving is required[106]. Currently this threshold is not in place for biomass resources used for biomass use for electricity and/or heating/cooling, nor for use of biomass as substitute in non-energy markets (like the biochemical sector).

The following other legislative measures address greenhouse gas savings and will be briefly discussed in the next sections:

[106] currently the threshold is 35% GHG savings - as compared to a fossil reference value – is obligatory. Following the amendment of the RED and FQD the greenhouse gas emission saving from the use of biofuels and bioliquids shall be at least 60 % for biofuels and bioliquids produced in installations starting operation after 5 October 2015. In the case of installations that were in operation on or before 5 October 2015 biofuels and bioliquids shall achieve a greenhouse gas emission saving of at least 35 % until 31 December 2017 and at least 50 % from 1 January 2018.

- Emission Trading Scheme, and
- The Effort Sharing Decision

The Emission Trading Scheme

The EU emissions trading system (EU ETS) is a cornerstone of the European Union's policy to combat climate change and its key tool for reducing industrial greenhouse gas emissions cost-effectively. The first - and still by far the biggest - international system for trading greenhouse gas emission allowances, the EU ETS covers more than 11,000 power stations and industrial plants in 31 countries, as well as airlines.[107] The purpose of the EU ETS is to cap greenhouse gas emissions from a number of industrial sectors, notably the energy generation sector and aviation. The transport sector is not part of the EU ETS.

The cap is reduced over time so that total emissions fall. In 2020, emissions from sectors covered by the EU ETS will be 21% lower than in 2005, and by 2030, the commission proposed, they would be 43% lower.

The EU ETS covers about 45% all all greenhouse gas emissions in EU28. Operators exclusively using biomass are not covered by the ETS. Operators who co-fire biomass with fossil fuels do fall within the scope of the ETS, but do not have to surrender allowances against emissions from biomass, which receive a 'zero emission factor'. The Monitoring and Reporting Guidelines[108] that come into force in 2013 provide definitions for biomass, bioliquids and biofuels identical to those provided in the Renewable Energy directive.

The Effort Sharing Decision

The Effort Sharing Decision establishes binding annual greenhouse gas emission targets for Member States for the period 2013–2020. These targets concern emissions from most sectors not included in the EU Emissions Trading System (EU ETS), such as transport (except aviation and international maritime shipping), buildings, agriculture and waste.[109]

For 2020 the EU has set a 10% emission reduction as compare to 2005, and for each Member State different targets have been set.

In the EU Energy and Climate Package for 2030 no sector specific targets are set, but the reduction effort of the non-ETS sectors will be distributed between Member States through the revision of the Effort Sharing Decision. There are two different levels contributing to this reduction effort: the contribution secured by the EU legislation and policies and actions that Member States can take to reduce their own emissions. It can be expected that the transport sector will be an important contributor to the 30% reduction effort in the non-ETS sectors. Apart from new alternative options, like electric mobility and hydrogen based vehicles, biofuels may be a major contributor to these targets.

Gap analysis for supply chain GHG performance

The EU Emission Trading Scheme (EU ETS) relates to the conversion of biomass for heat and power. No greenhouse gas thresholds are applied for biomass.

It is already mentioned that the Renewable Energy Directive sets sustainability criteria for biofuels and bioliquids. Solid and gaseous biomass for heat and power are not governed by these sustainability rules at EU level. A few Member States have developed national sustainability schemes.

[107] http://ec.europa.eu/clima/policies/ets/index_en.htm
[108] Commission Decision 2007/589/EC
[109] http://ec.europa.eu/clima/policies/effort/index_en.htm

The following situations can now occur:

- Solid biomass is used for the generation of power and/or heat. Except for the Member States that have established national sustainability schemes, this biomass does not have to comply to sustainability criteria. Within the EU ETS scheme the energy from solid biomass used for electricity and/or heat is regarded as zero greenhouse gas energy. The GHG emissions that have occurred in the cultivation, harvesting and transport/distribution parts of the biomass supply chain are attributed to those sectors and are not 'associated' to the biomass (which is the case for biofuels in the transport sector).
- Bioliquids are liquid fuels used for power and heat production.
  For bioliquids that do not meet the sustainability criteria laid down in the RED, the GHG emissions resulting from the energy conversion, which are similar to those of fossil fuels[110] are taken into account in EU ETS.
  For bioliquids that do meet the RED sustainability criteria the zero-emission factor will apply.
- Biofuels that are used in the transport sector (except the aviation sector) do not fall under the scope of the EU ETS. They have to meet the RED sustainability criteria. Part of these criteria is that a minimum threshold of supply chain/lifecycle GHG emission reduction needs to be met.

As a result, the supply chain GHG emissions are not taken into account when biomass is used for power and heat generation.

The Effort Sharing Decision may result in more use of biofuels in the transport sector and to more biomass use for heating purposes in buildings. Due to the focus on reduction of greenhouse gas emissions it can result in the utilisation of biofuels with high GHG supply chain performances and in the utilisation of high efficient biomass fuels heat appliances. As such the Effort Sharing Decision is supportive to the Energy and Climate objectives.

For biofuels in the transport sector the sustainability issues are covered by the requirements in the RED and its 2015 amended version. Biomass heat appliances for building are also regulated by various emission control standards.

The sustainability performance of the biomass feedstock for use in heat supply for buildings is however not secured. Increased utilisation of biomass for heat purposes in buildings could therefore lead to increased use of biomass that is not controlled by sustainability criteria.

Mapping of potential policy gaps

In the following table an overview is presented in which parts of the supply chain and in which sectors potential policy gaps might exist. The RED and FQD do not address GHG performance in the electricity and heating/cooling market. Use of biomass for transport (except aviation) is not covered by EU ETS. GHG accounting differs between solid/gaseous biomass for electricity and heating/cooling and liquid biofuels for transport. The Effort Sharing Decision mitigates sustainability risks is it may promote the

[110] burning of biomass releases CO2 into the atmosphere. In the earlier growing/cultivation stage, the tree or plant extracted a similar amount of CO2 from the atmosphere during their growing and cultivation phase. As such the exhausted CO2 does not contribute to increasing of GHG-concentration in the atmosphere when the carbon stock in forests and agricultural areas remains unchanged

use high GHG saving biofuels in the transport sector or the use of biomass for heating purposes in buildings. Biomass in the heating sector is however, contrary to biofuels for transport not governed by sustainability criteria. As a result, sustainability risks could appear in the electricity and and heating/cooling sector.

Table 22-4: Where do potential policy gaps appear for supply chain GHG emissions (dark coloured cells indicate where gaps may exist)

In biomass production part of the supply chain:	In the biomass conversion and end use part of the supply chain
Agricultural sector	Transport
Forestry sector	**Electricity, heating and cooling**
Waste sector	Non-Energy

22.3.2 Air emissions

"Wood burning, especially in case of incomplete combustion, can be an important source of air pollutants, harmful to human health and the environment."[111] At EU level air pollution is addressed by a set of legal measures.

For the purpose of this gap analysis this report focuses on:

- The EcoDesign Directive
- The National Emissions Ceilings Directive
- The Industrial Emissions Directive (see section**Error! Reference source not found.**, and
- The Medium Combustion Plants Directive

The EcoDesign Directive

The EcoDesign Directive (2009/125/EC)[112] provides a coherent framework for improving the environmental performance of products. The Directive sets out minimum mandatory requirements for the energy efficiency of these products. This helps prevent creation of barriers to trade, improve product quality and environmental protection.

[111] EC, 2014, SWD(2014)259
[112] EC, 2009, Directive 2009/125/EC

The EcoDesign Directive was extended in 2009 to all energy-related products (the use of which has an impact on energy consumption) (EC, 2012[113]):

- Energy-using products (EUPs): products which use, generate, transfer or measure energy, including consumer goods such as solid fuel boilers or computers;
- Other energy related products (ERPs): products which do not necessarily use energy, but have an impact on energy consumption and can therefore contribute to saving energy, such as windows.

The Product regulations refer for those products that are covered by the EcoDesign Directive and its Product regulations to[114]:

- Energy efficiency (e.g. for solid fuel boilers: "seasonal space heating energy efficiency for boilers with a rated heat output of 20 kW or less shall not be less than 75 %);
- Air emissions (e.g. for solid fuel boilers: "seasonal space heating emissions of organic gaseous compounds shall not be higher than 20 mg/m3 for automatically stoked boilers";
- Efficient end-use (e.g. for solid fuel boilers, information about the efficiency of the boiler)

The National Emissions Ceiling Directive

The National Emissions Ceiling Directive (NECD, Directive 2001/81/EC) sets upper limits for each Member States for the total emissions in 2010 of the four pollutants[115] responsible for acidification, eutrophication, and ground-level ozone pollution, but leaves it largely to the Member States to decide which measures to take in order to comply. The NECD has been amended in 2006 and 2009, taken into account the accession of new Member States and committee decisions. The implementation of the directive required that Member States develop national programmes in 2002 and, where needed, revised those plans in 2006 that aim at meeting fixed ceilings of national emissions by 2010 and thereafter. Member States have to report their emission inventories to the EEA and the EC in order to monitor progress and verify compliance.

The NECD is currently being reviewed as part of the Clean Air Policy Package (adopted on 18 December 2013). Under this package a proposal for a revised national emissions ceiling directive is brought forward[116] to ensure that the national emission ceilings shall apply until 2020[117] and establishes new national emissions reduction commitments applicable from 2020 and 2030[118].

The Medium Combustion Plants Directive

Directive (EU) 2015/2193 of the European Parliament and the Council of 25 November 2015 on the limitation of emissions of certain pollutants into the air from medium combustion plants regulates pollutant emissions from the combustion of fuels in plants with a rated thermal input equal to or greater than 1 megawatt (MWth) and less than 50 MWth.

Medium combustion plants are used for a wide variety of applications (electricity generation, domestic/residential heating and cooling, providing heat/steam for industrial processes, etc.) and are an important source of emissions of sulphur dioxide (SO_2), nitrogen oxides (NO_x) and dust. The estimated number of MCPs in the EU is around 143 thousand.[119]

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[113] EC (2012), Brochure on the EcoDesign Directive from the European Commission, EcoDesign Your Future How EcoDesign can help the environment by making products smarter
[114] As reference: COMMISSION REGULATION (EU) 2015/1189 of 28 April 2015 implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to EcoDesign requirements for solid fuel boilers
[115] Sulphur dioxide, nitrogen oxides, volatile organic compounds and ammonia.
[116] COM(2013)920, 18 December 2013
[117] For SO2, NOx, NMVOC, NH3
[118] For SO2, NOx, NMVOC, NH3, fine particle matter (PM2,5) and methane (CH4)
[119] http://ec.europa.eu/environment/industry/stationary/mcp.htm

The MCP Directive entered into force on 18 December 2015 and will have to be transposed by Member States by 19 December 2017.

It regulates emissions of SO_2, NO_x and dust into the air with the aim of reducing those emissions and the risks to human health and the environment they may cause. It also lays down rules to monitor emissions of carbon monoxide (CO).

Gap analysis for air emissions

The EcoDesign Directive applies only to those products that are covered in the Product list, and is therefore not inclusive for all products that use or relate to energy consumption and efficiency.

The EcoDesign Directive only applies to product groups or services that are placed on the European market.[120] A number of non-EU countries (USA, Australia, Brazil, China and Japan) have legislation similar to the EU's EcoDesign and Energy Labelling Directives[121];

Regulations to date have mainly addressed the use-phase impacts, most importantly, energy consumption, as this represents, to varying degrees, the most important contribution to the environmental impacts of the regulated products. Some other environmental impacts have already been addressed by both the EcoDesign and Energy Labelling Regulations, including, in EcoDesign, those in other life-cycle phases. Nonetheless, potential for further reduction of environmental impacts have been identified in several studies, e.g. on aspects of reusability, recyclability, and recoverability, recycled content, use of priority materials, or durability.[122]

Potential problems could occur in the case of (older) biomass heating boilers which might generate high air emissions. Regulating minimum energy efficiency performances via the National Emissions Ceiling Directive could realise to push such old systems out of the market to the benefit of more efficient and cleaner versions.

The Industrial Emissions Directive ensures that industrial production processes are governed via permits to prevent pollutive emissions. The IED in this way addresses potential risks on air quality and risks of soil and water contamination near the production facilities. For combustion plants these permits apply for plants of 50 MW thermal input or larger. Smaller combustion plants are not governed by the IED, but for those facilities the Medium Combustion Plants Directive apply.

The implementation of the Medium Combustion Plants Directive fills the regulatory gap at EU level between large combustion plants ($\geq$ 50 MWth), covered under the Industrial Emissions Directive (IED) and smaller appliances (heaters and boilers <1 MWth) covered by the EcoDesign Directive.

As a result, biomass combustion in facilities of various capacities whether used for electricity generation, combined heat and power and for heat are covered by corresponding EU legislation on emissions to air. Air emissions resulting from biofuels in

[120] See article 1: This Directive provides for the setting of requirements which the energy-related products covered by implementing measures must fulfil in order to be placed on the market and/or put into service.
[121] Information about EcoDesign from the European Commission, see also: http://ec.europa.eu/growth/industry/sustainability/ecodesign/index_en.htm
[122] Ecofys (2014), Final technical report Evaluation of the Energy Labelling Directive and specific aspects of the EcoDesign Directive ENER/C3/2012-523, see: http://www.ecofys.com/files/files/final_technical_report-evaluation_eld_ed_june_2014.pdf

transport are covered by the Euro 5 and 6 Regulation 715/2007/EC. This Regulation specifies emission limits for all important toxic pollutants. These include nitrogen oxides (NOx, i.e. the combined emissions of NO and NO2). The currently applicable NOx emission limit for new diesel passenger cars and light vans sold in the EU is 80 mg/km.

Mapping of potential policy gaps

In the following table an overview is presented in which parts of the supply chain and in which sectors potential policy gaps might exist. From the analysis in the previous sub-section it can be concluded that the EcoDesign directive ensures proper operation of listed products, among which household heating solid fuel burners and thus limited impacts on air emissions are expected. The National Emissions Ceiling Directive could push older biomass hearting boilers out of the market due to low efficiency and corresponding high air emissions. This would also impact positively air emissions. The Industrial Emissions Directive regulates emission of industrial scale combustion plants and this would also result in controlled air emissions. The Medium Combustion Plants Directive covers the smaller capacity spectrum. Based on this set of legislative measures no policy gap is noted with respect to air emission issues

Table 22-5: Where do potential policy gaps appear for air emissions (dark coloured cells indicate where gaps may exist)

In biomass production part of the supply chain:	In the biomass conversion and end use part of the supply chain
Agricultural sector	Transport
Forestry sector	Electricity, heating and cooling
Waste sector	Non-Energy

22.3.3 Efficient end use conversion

Given that the supply of biomass feedstock is constraint by the finite availability of land, it is important to ensure that it is used as efficiently as possible. Under the expectation that for the 2030 renewable energy target bioenergy will play an important role, energy efficiency improvements of the biomass conversion facilities will help to reduce the pressure on the amount of feedstock needed. By optimal use of power and heat generation energy efficiency gains are made.

This report reviews the following legislative measures to understand whether further policy gaps may be expected:

- The Energy Efficiency Directive
- The EcoDesign Directive (see section 22.3.2)
- The Emission Trading Scheme (see section 22.3.1)
- The Effort Sharing Decision (see section 22.3.1)

The Energy Efficiency Directive

The Energy Efficiency Directive[123] required Member States to develop national heating and cooling plans and set non-binding energy efficiency targets by mid 2014.

The Directive came into force by the end of 2012 and aims to help the EU reach its 20% energy efficiency target by 2020. The Directive brings forward legally binding measures to step up Member States' efforts to use energy more efficiently at all stages of the energy chain – from the transformation of energy, to its distribution and to its final consumption. These will drive energy efficiency improvements in households, industries and transport sectors. With respect to electricity generation the Directive emphasises to tap the potential of high- efficient cogeneration and district heating and cooling. Special attention is given to small and medium installations to encourage distributed energy generation[124]

Gap analysis on efficient end use conversion

The Energy Efficiency Directive is supportive to the efficient use of biomass for energy purposes. Its emphasis on cogeneration of heat and electricity ensures that the biomass resources are used in an efficient way so that it decreases the amount of feedstock needed for a unit of energy output. As such it helps to mitigate and decrease the impact of undesired risks upstream and elsewhere in the biomass supply chain.

With respect to efficient end use conversion the EcoDesign Directive allows the Commission to regulate the minimum performance of products and thereby push inefficient products out of the market in favour of better performing products. E.g. for solid fuel boilers "the seasonal space heating energy efficiency for boilers with a rated heat output of 20 kw or less shall not be less than 75%".[125]

Within the ETS biomass is viewed as carbon neutral or zero emission. As such the ETS might not promote the energy efficient conversion of biomass to electricity and/or heat. This might result in a gap in policy attention. From the sustainability point of view focus on high energy conversion efficiency is required to limit the amount of biomass resources required.

Furthermore, the EU ETS does not provide any stimulus to the efficient end use conversion in the case of solid biomass and bioliquids for power and heat that meets the sustainability requirements. Only in the case of bioliquids, when used for power and/or heat, that do not meet the sustainability criteria, the efficient energy conversion is of importance as in that case the related GHG-emissions need to be covered under the EU ETS.

The Effort Sharing Decision does not set requirements on the end use efficiency of conversion facilities. Member States have to design national regulations to comply to the 30% reduction target in the non-ETS sectors. Setting efficiency target for combustion appliances could be a supportive tool to the achievement of the Effort Sharing targets. Due to the fact that biomass often is more expensive than its current fossil alternatives will set direction to the purchase by end-users of high efficient biomass heating to achieve overall lower operation costs (less biomass feedstock needed per unit of energy produced.

[123] EC, 2012, Directive 2012/27/EC

[124] See the description of the Think Small First principle in Directive 2012/27/EC

[125] As reference: COMMISSION REGULATION (EU) 2015/1189 of 28 April 2015 implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to EcoDesign requirements for solid fuel boilers

Mapping of potential policy gaps

In the following table an overview is presented in which parts of the supply chain and in which sectors potential policy gaps might exist. From the analysis in the previous subsection it can be concluded that the relevant set of policies (Energy Efficiency Directive, The Renewable Energy Directive, the EcoDesign Directive, EU ETS and Effort Sharing Decision) ensure resource efficient use of the biomass for electricity and heating/cooling, but the sustainable character of the biomass used for this energy efficient conversion is not settled by any of these legislative measures. Also the energy input in the supply chain is not governed by any of these measures, as the supply chain GHG emission calculation methodology is not required for solid and gaseous biomass for the electricity and heating/cooling sector. For that reasons sustainability risks could still occur in parts in the supply chain: in both the agricultural and forestry sector at the biomass production side of the supply chain, as in the electricity, heating and cooling sector at the conversion and use-use part of the supply chain.

Table 22-6: Where do potential policy gaps appear for efficient end use conversion emissions (dark coloured cells indicate where gaps may exist)

In biomass production part of the supply chain:	**In the biomass conversion and end use part of the supply chain**
Agricultural sector	Transport
Forestry sector	**Electricity, heating and cooling**
Waste sector	Non-Energy

22.3.4 Competition with non-energy end use markets

The European Union is in the middle of a transition to a low-carbon and circular economy. This development includes the enhancement of a biobased economy as well. When in the 90s of the last century the use of biomass for energy purposes started to develop, often competition became visible with those sectors that traditionally were common to use wood products and residues, as well as residues from the agricultural sector. Nowadays competition in new sectors emerges as well, as in various sectors fossil resources commonly used are being replaced by alternative, organic sources. Based on the value added principles, the demand for materials and chemicals are given higher priorities as compared to the use of biomass resources for fuel and energy purposes. When further developing the use of biomass for energy use these developments should carefully have crafted to achieve optimization. The BioSustain Technical Background Report[126] reports that “the project biobased raw material demand for chemistry in 2030 is estimated in the range of 5 to 10 Mtoe. This might seem a rather limited demand in comparison to the demand for biofuels or bioenergy. It is however necessary to secure the availability of that amount for the non-energy sector. Competing demand from a growing bioenergy market could drag these volumes from the

[126] BioSustain consortium, 2016, for EC DG Energy, to be published

non-energy market to the energy market, thus preventing or obstructing the development of the biobased economy It is therefore required, as stated before, that policy attention should be given to prevent such undesired competition for biomass resources between the energy and non-energy end use markets. Within the European policy context this issue is mainly addressed from a waste management approach, which sets a clear hierarchy on the preference to waste. For an optimal utilisation of biomass in either the energy or non-energy sector[127], as part of a biobased or circular economy development of legislative measures is still in an early stage and as a result such measures are not yet yet in place. For the purpose of this study therefore the focus has been on waste management measures and the following legislative measures have been reviewed:

- The Waste Framework Directive
- The Landfill Directive
- The Sewage Sludge Directive.
- The amended Renewable Energy Directive

The Waste Framework Directive

The Waste Framework Directive 'lays down measures to protect the environment and human health by preventing or reducing the adverse impacts of the generation and management of waste and by reducing overall impacts of resource use and improving the efficiency of such use'[128]. The directive came into force in 2008.

The Directive was necessary to clarify key concepts such as the definitions of waste, recovery and disposal, to strengthen measures that must be taken in regard to waste prevention, to introduce an approach that takes into account the whole life-cycle of products and materials and not only the waste phase, and to focus on reducing environmental impacts of waste generation and waste management. Furthermore the recovery of waste and the use of recovered materials should be encouraged in order to conserve natural resources.'[129]

The directive clarifies when substances or objects are by-products and not waste and it clarifies when certain waste ceases to be waste, laying down end-of-waste criteria. The waste hierarchy principle lays down a priority order of what constitutes the best overall environmental option in waste legislation and policy:

- Prevention (highest priority),
- preparing for re-use,
- recycling,
- other recovery, e.g. energy recovery, and
- disposal (lowest priority).

The Landfill Directive

[127] several examples of competition could be mentioned as for various biomass feedstocks both energy and non-energy market opportunities exist: cereal straw can be used for production of cellulosic ethanol or for animal husbandry, forest residues can go to pulp industry or biomass boilers, sawmill residues may find market opportunities for wood pellet boilers or be sold to the panel industry

[128] *EC, 2008,* Directive *2008/98/EC.*

[129] *id.*

According to the waste management hierarchy, landfilling is the least preferable option and should be limited to the necessary minimum. Where waste needs to be landfilled, it must be sent to landfills which comply with the requirements of Directive 1999/31/EC on the landfill of waste. The objective of the Directive is to prevent or reduce as far as possible negative effects on the environment, in particular on surface water, groundwater, soil, air, and on human health from the landfilling of waste by introducing stringent technical requirements for waste and landfills.[130]

In December 2015 the Commission adopted a Circular Economy Package, which included revised legislative proposals to amend the Waste Framework Directive and the Landfill Directive.[131] The key elements of the revised waste proposal include:

- A common EU target for recycling 65% of municipal waste by 2030
- A binding landfill target to reduce landfill to maximum of 10% of all waste by 2030
- A ban on landfilling of separately collected waste.

The Sewage Sludge Directive

The Sewage Sludge Directive seeks to encourage the use of sewage sludge in agriculture and to regulate its use in such a way to prevent harmful effects on soil, vegetation, animal and man. To this end, it prohibits the use of untreated sludge on agricultural land unless it is injected or incorporated into the soil. The Directive also lays down limit values for concentrations of heavy metals in the soil, in sludge and for the maximum annual quantities of heavy metals which may be introduced in the soil. In force since 1986.

Gap analysis on the competition with non-energy end use markets

In the amended Renewable Energy Directive[132] it is highlighted that the approach of the waste hierarchy might impact whether and how waste resources can be used. The amended RED refers to biofuels for transport, but in fact the Waste Framework Directive relates to all (energy) use of waste biomass.

"Directive 2008/98/EC of the European Parliament and of the Council (1) helps move the Union closer to becoming a 'recycling society', by seeking to avoid waste generation and to use waste as a resource. The waste hierarchy generally lays down a priority order of what constitutes the best overall environmental option in relation to waste legislation and policy. Member States should support recycling in line with the waste hierarchy and with the aim of becoming a recycling society, and whenever possible not support the landfilling or incineration of such recyclable materials. Some of the feedstocks that pose low indirect land-use change risks can be considered to be wastes. However, they may still be used for other purposes that would represent a higher priority than energy recovery in the waste hierarchy as established in Article 4 of Directive 2008/98/EC. It is therefore appropriate for Member States to have due regard to the waste hierarchy principle in any incentive measures for the promotion of low indirect land-use change risk biofuels or any measures to minimise incentives for fraud in relation to the production of such biofuels, so that incentives to use such biofuel feedstocks do not counter efforts to reduce waste or increase recycling and the efficient and sustainable use of available resources. Member States may include measures they are taking in that respect in their reporting under Directive 2009/28/EC."[133]

[130] *http://ec.europa.eu/environment/waste/landfill_index.htm, site visited 8 March 2016*
[131] *http://ec.europa.eu/environment/circular-economy/index-en.htm*
[132] EC, 2015, Directive (EC) 2015/1513
[133] Id.

From the BioSustain Technical Background Report it has become clear that only a few EU Member States have currently abandoned disposal of waste in landfills and optimised the waste hierarchy with energy recovery from waste as a major part of the waste management. In the majority of the Member States, including countries like UK and France, landfilling of municipal household waste (MSW) still occurs at large scale. This landfill waste contains valuable resources for material recycling ánd organic fractions that could be used for energy recovery. The Technical Background report concluded that currently about 7% of the biomass energy produced originates from energy recovery of the organic fraction in MSW. Based on Eurostat data on waste management in 2013 this share could potentially double if all Member States would develop waste management profiles compared to those EU Member States that have abandoned disposal of waste in landfills (like Germany, Netherlands, Belgium and Denmark). Focus on 'mining' this potential could bring several benefit, among others freeing up valuable resources for use in both energy and non-energy markets and reducing the pressure on virgin biomass (resource) feedstocks from forestry and agricultural areas, whether from within or outside the EU28.

The Landfill Directive and the current proposed amendments may result both in risks and opportunities for the use of biomass for energy. An important issue relates to the possible competition for non-energy utilization of biomass. The proposals for amendments of the Landfill Directive focus on a more ambitious recycling performance of municipal solid waste. This may result in improved management and separation of waste streams causing that also biogenic fractions will be reused rather than becoming available for energy generation. This will decrease the possible competition. It should be noted that anaerobic digestion is considered as a 'recovery' option. It may lead to the situation that less energy from MSW is generated, for which other biomass resources need to be deployed.

Given the current status of MSW processing, with still a (too) high share of MSW being landfilled it can be expected that the focus to reduce landfilling tot 10% of all waste by 2030 will lead to higher volumes of MSW to be processed for either material and energy recovery. This will enable the possibility to develop a balanced approach by which the volumes of recycling and reutilisation will grow and problems of competition foe use in energy or non-energy market may be avoided

Use of sewage sludge for the generation of biogas is commercial practice (though often under the regimes with subsidy support) in many EU Member States. After the anaerobic digestion the digestate is re-used in the agricultural sector.

Mapping of potential policy gaps

The Waste Framework directive targets via the waste hierarchy the avoidance and reutilisation of waste. The Directive sets specific rules for the use of waste for energy purposes. For the near future this would enable better processing and management of waste and making more resources available for both the energy and non-energy market. Together with the Landfill Directive this would improve the availability of organic resources for energy purposes. This again could relieve pressure for competition for other biomass feedstocks (from agriculture or forestry), as these resources could be set off in the non-energy markets. As such the set of measures regulating waste management actually contribute positively to preventing competition in other biomass markets where energy and non-energy users are competing. A possible issue is that the non-energy sector is not governed by sustainability criteria like is the case for biofuels and liquids and growing use of on-sustainable biomass in the non-energy sector would be imaginable. A sustainability risk of competition with the non-energy market is a strong expansion of the biomass demand for both the energy and non-energy sector, resulting in biomass supply from both EU and non-EU (including internationally traded waste), putting pressure on the biomass production sectors. As a result, it is judged that though the policy framework on waste management does help to balance bringing the waste streams to the right end-use markets, the fact that the development to a biobased economy will put pressure on the resource base as a whole, and the lack of sustainability schemes for all end-use markets (except for the transport market) will cause that sustainability risks are not well addressed.

Table 22-7: Where do potential policy gaps appear for competition with non-energy use market (dark coloured cells indicate where gaps may exist)

In biomass production part of the supply chain:	**In the biomass conversion and end use part of the supply chain**
Agricultural sector	Transport
Forestry sector	**Electricity, heating and cooling**
Waste sector	**Non-Energy**

22.4 Discussion of the national sustainability schemes

The following Member States have national sustainability schemes in place for the use of solid biomass for electricity and/or heat generation:

- The Netherlands
- United Kingdom
- Belgium

In Denmark, the Danish District Heating Association and the Danish Energy Association have established an industry-initiated voluntary framework, without regulation from the government.

In the next table these schemes are briefly presented:

The Netherlands Energy Agreement

In the Netherlands, an agreement has been made between government, energy utilities and NGO to apply sustainability criteria for the co-firing of biomass.[134] Under this agreement, energy companies will only receive a subsidy for co-firing of biomass when these sustainability criteria are met.

The sustainability criteria are defined for different biomass categories, including woody biomass (distinguished to large and small Forest Units), residues, and waste streams. The sustainability

[134] 2015, Convenant Duurzaamheid Biomassa.

criteria include requirements on:

- GHG emission reduction (for the end-user in the value chain);
- Carbon and land use change;
  - Carbon debt and maintenance carbon stocks
  - ILUC
- Sustainable (forest) management;
  - Legal Compliance;
  - Ecological aspects (including no conversion);
  - Regulation functions (water, soil, IPM, use of chemicals, forest fires, waste, diseases);
  - Economic aspects (productivity, contribution to the local economy);
  - Management;
  - Group certification
  - Chain of Custody

There are also a number of above-legal criteria, laid down in a covenant of March 2015 between energy companies and NGOs. The set of above-legal criteria mostly relate to social criteria.

The sustainability requirements apply for those energy utilities in the Netherlands that co-fire biomass and that want to receive support – the legal criteria are therefore directly linked to subsidies. In addition, some of the (social) criteria are laid down in a covenant and have no legal or policy basis.

The criteria only apply to energy utilities that use biomass for co-firing in the Netherlands, and not for the ones located in other EU member States.

The United Kingdom Sustainability Scheme

The Renewables Obligation (RO) is designed to incentivize large- scale renewable electricity generation in the UK, to help the UK meet its 15% target to come from renewable sources by 2020. The scheme puts an obligation on licensed electricity suppliers in England and Wales, Scotland and Northern Ireland to acquire an increasing proportion of electricity from renewable sources.

In 2015, the Renewables Obligation Order was consolidated and the requirement for solid biomass and biogas stations to meet the sustainability criteria in order to receive support under the scheme was introduced. The legislation requires operators of generating stations using bioliquids, and operators of generating stations with a total installed capacity ≥1MW using solid biomass and biogas, to report against, and meet, the sustainability criteria to get support under the scheme. For generating stations with a declared net capacity >50KW and total installed capacity of <1MW using solid biomass or biogas, operators must report against the sustainability criteria, however this does not link to support under the scheme.

The sustainability requirements are described into four categories: Fuel classification, mass balance, GHG reduction and land criteria. The land criteria make a distinction between land criteria for bioliquids (based on the Renewable Energy Directive), for woody biomass and for other fuels. The GHG account to the life cycle of the biomass.

The land criteria for woody biomass are:

A consignment of woody biomass meets the land criteria if at least 70% of the woody biomass was obtained from a sustainable source (…).

1) Woody biomass is obtained from a sustainable source if it:
   - Was grown within an area of forest or other land which is managed in a way that is consistent with the Forest Europe SFM Criteria, or a set of international principles for the SFM of land (see below)
   - Was residue (or…other exemptions)

2) The requirements on the SFM principles are that:
    - the principles have been adopted following a process ("the principle setting process") (e.g. balanced representation), and
    - can be changed by a process ("the change process") (e.g. no single interest group)
3) Specifies that stakeholder consultation comes from economic, environmental and social interest groups;
4) In relation to SFM:
    - harm to ecosystems is minimized, in particular by:
        - Assessing the impacts of the extraction of wood and minimizing impacts;
        - Protecting soil, water and biodiversity;
        - Controlling the use of chemicals;
        - Using Integrated Pest Management;
        - Disposing waste such to minimize impacts
    - The productivity of the area is maintained by (….)
    - Compliance is monitored, reviewed and planned accordingly;
    - The health and vitality of ecosystems is maintained by (….);
    - Biodiversity is maintained, in particular by (….);
    - Compliance with local and national laws relating to health and safety and welfare of workers;
    - Regard to (…) rights of tenure and land use, mechanisms for resolving grievances, safeguarding to health and safety and rights of workers.

There are two possibilities for proof of evidence of the sustainable forest management criteria:

- Evidence A: forest certification schemes (FSC/PEFC) are used as proof of evidence;
- Evidence B: document based evidence is provided.

Green Power Certificate Systems in Belgium

Stationary energy (including bioliquids, but also solid and gaseous biomass) falls under responsibility of the regions (Flanders, Walloon Region, Brussel Capital District) in Belgium. The three regions introduced sustainability criteria directly into their supporting scheme. All calculations must be proven by an audit of an independent body.

In the Flemish region certain biomass streams (e.g. wood (waste) streams that are still suitable for recycling in board or pulp and paper industry) are not entitled to receive green power certificates as a resource for the production of renewable electricity. Also the energy used for transporting and pre-treatment of the biomass, is deducted from the green power certificates.

In the Brussels and the Walloon region a greenhouse gas balance and reduction compared to a best available natural gas system is calculated to determine the amount of green certificates.

From economic perspective this is a driver to install efficient conversion facilities to ensure that the amount of biomass needed per green certificate is as low as possible. The system does however not set minimum threshold levels for the efficient operation of biomass power facilities.

In the Flemish Region the risk of competition with other, non-energy end-user markets is taken care of by the regulation that biomass streams that are still suitable for recycling in board or pulp and paper. In the Walloon and Brussels Region this competition prevention measure does not exist. Increased demand for renewable electricity and/or heating/cooling from biomass could result in increased flows of biomass to plants in these regions, resulting in lower biomass availability or availability at higher costs for the non-energy market.

Danish Industry Agreement

The Danish District Heating Association and the Danish Energy Association have established an industry-initiated voluntary framework (without regulation from the Danish government) for the sustainable use of solid biomass in CHP plants (wood pellets and wood chips) in Denmark[135, 136]. The Agreement is based on existing regulation and guidelines in place in the EU, and consists of eight criteria[65]:

- Legality: Legality of forest management and utilization is safeguarded
- Ecosystems: Protection of forest ecosystems
- Carbon cycle: Forests productivity and ability to contribute to the global carbon circle must be maintained
- Condition of the forest: The forests must be healthy and well-functioning
- Biodiversity: Protection of biodiversity, sensitive areas and areas worthy of preservation
- Rights: Social and work-related rights must be respected
- CO_2 Limits: CO_2 emissions from the biomass value chain: a reduction compared to fossil fuels (70% reduction in 2016, 72% in 2020, 75% in 2025)
- Additional requirements targeted at carbon cycle, maintenance of forest carbon stock, indirect land use change (ILUC) and indirect wood use change (IWUC)

The requirements for sustainable biomass include and apply (only) for[66]:

- All plants that generate heat and electricity using biomass. Only plants whose rated thermal input exceeds 20 MW, will be subject to documentation requirements.
- Biomass categories: wood chips (comminuted wood) and wood pellets (compressed wood shavings and sawdust)

Companies must demonstrate compliance with the biomass sustainability criteria through annual reporting (to be made publicly available) on compliance with the requirements. This is to be verified by a 3rd party.

The documentation requirements enter into force from August,1st 2016, thus impacting purchases for the heating season 2016-2017. The CHP stations affected have to commit to demonstrating on an annual basis that a proportion (by weight) of wood pellets and wood chips is in compliance with the requirements (2016: 40 %, 2017: 60 %, 2018: 75 % and 2019: Fully phased-in). An evaluation in 2018 will include a discussion on possible adoption of sustainability requirements and on the 20MW requirement (phased out of reduced)[66].

22.4.1 Gap analysis related to the national sustainability frameworks

In 2016, University of Utrecht[137] assessed the most relevant differences in the operation of these schemes. The next table provides an overview of how sustainability criteria are included in the national support schemes.

Table 22-8: Summary of Sustainability Criteria included in the National Support Schemes[138]

	RO[1], RHI[2], CfDs[3]	GCs[4]	IA[5]	SDE+[6]

[135] The Danish Industry Agreement for Sustainable Biomass, Danish Energy Association, http://www.ens.dk/sites/ens.dk/files/undergrund-forsyning/vedvarende-energi/bioenergi/analyse-bioenergi-danmark/temadag-biomasse-og-baeredygtighed/the_danish_industry_agreement.pdf

[136] Industry agreement to ensure sustainable biomass (wood pellets and wood chips), 9 September 2015, Dansk Energi

[137] 2016, Utrecht University, Mai-Moulin, Th., Junginger, M., Towards a harmonisation of national sustainability requirements for solid biomass

[138] Source: 2016, Utrecht University

	UK	BE	DK	NL
Strictness of legislation	Legally binding – to receive support	Legally binding – to receive support	Voluntary	Legally binding (when implemented) to receive support
Timeline of implementation	End of 2015	Already implemented	2016	To be identified
Sustainability Requirements Coverage				
A **Greenhouse Gas Emission**	✓	✓	✓	✓
B **Land Use:**				
B1 Sustainable Forest management:				
Legal sustainable sourcing and certification	✓	±	✓	✓
Forest productivity and well-functioning forests	✓	✗	✓	✓
Biodiversity protection	✓	✗	✓	✓
Ecosystems conservation	✓	✗	✓	✓
B2 Land criteria	✓	✗	✗	✓
B3 iLUC	✗	✗	➔	✓
C **Other sustainability requirements**				
C1 Fuel classification	✓	±	➔	✓
C2 Carbon debt	✗	➔	➔	✓
C3 Compliance with laws & local rights	✓	±	✓	✓
C4 Chain of Custody	✓	±	✓	✓
C5 Mass Balance	✓	✓	➔	➔
C6 Cascading use of biomass	✗	➔	➔	➔
C7 Prevention pf feedstock competition	✗	±	±	✓
Recognition of international voluntary certification schemes	✓	±	✓	➔
Legend	✓	Covered in the legislation		
	±	Partly covered in the legislation		
	➔	Plans to be covered in the future		
	✗	Not covered in legislation		

1	RO: Renewable Obligation
2	RHI: UK Renewable Heat Incentive
3	CfD: Contracts for Difference
4	GC: Green Certificates
5	IA: Industry Agreement
6	SDE+: Energy Agreement on Sustainable Growth

One of the conclusions from the analysis of Utrecht University is that the legislation and support schemes in these countries "have, to certain degree, different goals and targets whilst there are also differences among various sustainability criteria and reporting requirements. This situation may cause trade barriers for solid biomass, and therefore, it is important to explore in how far harmonisation of sustainability requirements is possible." Furthermore, it is concluded that there are only a number of sustainability criteria for solid biomass that may be harmonised in the four countries (biodiversity protection, ecosystems conservation, forest productivity and well-functioning forests). Other sustainability requirements differ in these countries. E.g. the GHG emission thresholds are not (yet) aligned in the four countries investigated, though by 2020 they will be similar. Criteria to limit carbon stock and indirect land use change are introduced and tested only in the Netherlands. In the next tables this is summarized[139]:

Table 22-9: Harmonisation possibilities in National Schemes for GHG emissions

	Harmonisation possibility	**Level of harmonisation**	**Remarks**
Data collection	Possibly in the future	Medium	Harmonisation possible between the four countries (UK, BE, DK, NL)
Calculation methods	Harmonisation might be reached	Medium	Harmonisation possible between the four countries
Threshold (compared to 1990 baseline level	Possibly in the future	Medium	Harmonisation possible between the four countries
Time of implementations	Possibly in the future	High	Harmonisation possible between the four countries

Table 22-10: Harmonisation possibilities in National Schemes for Land use

	Harmonisation possibility	**Level of harmonisation**	**Remarks**
Sustainable forest management:			
• Legal, sustainable sourcing and	Possibly in the future	Low	Harmonisation possible between the four countries.

[139] Source: 2016, Utrecht University

certification			Detailed requirements for large/small forest sized in Dutch SDE+ are not included in other schemes
• Forest productivity and well-functioning	Harmonisation possible	High	Harmonisation possible between the four countries
• Biodiversity protection/Ecosystem conservation	Harmonisation possible	High	Harmonisation possible between the four countries
Land use	Possibly in the future	Low	Harmonisation rarely possible between the four countries: UK has land categories for woody/not woody biomass following the RED guidance, Denmark mainly forest biomass, NL forest land/agricultural wastes and residues, BE no requirements

Table 22-11: Harmonisation possibilities in National Schemes for Other sustainability requirements

	Harmonisation possibility	Level of harmonisation	Remarks
Fuel classification	Harmonisation not possible		NL SDE+ scheme requires carbon debt/iLUC to be applied for woody biomass from large forest units but these are not included in the UK
Compliance with local rights	Harmonisation might be reached	Low	Harmonisation unlikely possible between the four countries: different levels and details of requirements in DK, NL, UK
Chain of custody	Harmonisation might be reached	Low	Harmonisation unlikely possible between the four countries: NL SDE+ scheme requires CoC from the forest unit of origin to the bioenergy producer but this is not defined in other schemes
Mass balance	Harmonisation might be possible	High	Harmonisation unlikely possible by between LN and UK: NL SDE+ scheme includes mixed wood/composite products/mixed raw materials not sources from forestry whilst there are not provided in UK legislation.

Table 22-12: Harmonisation possibilities in National Schemes for Reporting requirements

	Harmonisation possibility	Level of harmonisation	Remarks
Station capacity	Harmonisation not possible		Belgium has a different approach whilst station capacity differs between DK and UK
Reporting requirements linked with fuel classification/sust. criteria	Harmonisation not possible		Sustainability criteria applied in the NL are still being debated in other countries
Reporting procedure	Harmonisation possibly in the future	Low	Harmonisation possible, depend on agreement of verification level / audit requirements

From this research by the University of Utrecht it can be concluded that full harmonisation of these national schemes is unlikely to happen in the near future. As a result of different approaches there are market limitations in the sense that supply chains have to be developed for each particular end-market. The lack of harmonisation prevents the operation of the market as a commodity market, which results in higher administrative costs and probable higher operational costs. The countries reviewed here are the major countries importing biomass from non-EU regions. From a sustainability risk point of view these sustainability schemes all mostly mitigate the sustainability risks discussed earlier in this report.

Other EU Member States mostly use EU-based biomass feedstocks. In most of these countries the feedstocks are governed by national systems for sustainable forest management. This will be briefly discussed in the next section.

22.5 National systems for Sustainable Forest Management

In the previous sections often the forestry sector has mentioned several times as a sector which may be associated with sustainability risks when biomass demand would rely more and more on biomass feedstock collected and harvested from this sector. From section 22.4 it could be seen that only a few EU Member States have implemented sustainability schemes for solid and gaseous biomass for electricity and heating/cooling. These Member States largely rely on imported biomass and do not have large indigenous forest areas for which they could source their biomass from. Other Member States do often have national schemes in place which govern the sustainable forest management practices that secure sustainability risks associated with the biomass feedstock production side of the supply chain. The Standing Forestry Committee ad hoc Working

Group on Sustainable Forest Management Criteria and Indicators proved a good overview of such national schemes and is summarised below.[140]

The Working Group has analysed different systems that Member States have in place to ensure sustainable forest management. The report found that these systems include "legislation, a variety of additional requirements set forward in legislation, forest programmes, strategic plans both on national and regional and local level, and soft mechanisms, such as guidelines, best practice examples and voluntary mechanisms, such as forest certification." To ensure sustainable forest management at national level, Member States have different legal frameworks in place, which vary per Member State, depending on the existing system of governance in each Member State. The report illustrates that legislation sometimes sets more general obligations, while subnational and or regions ones set stricter, local specific regulation, however still compatible with national legislation. The objectives for sustainable forest management differ, depending on the specific circumstances in Member States. Countries where forest surface is low will focus on increasing the forest area, other opt for increasing the role of forests in bringing economic benefits, while other Member States see securing biodiversity as the main goal. The report concluded that, despite these differences, 'the background to national legislation for forests is based on a 'basket' of legislation, including specific forest legislation plus a range of other legislation affecting forests, including provisions on environment, energy, information, educational efforts, guidance and support' and access to forest data bases'.

With the increase of demand for energy purposes, biomass from forests has become subject to specific regulation requiring evidence of sustainability, as is presented in the previous section. In other Member States forest biomass for energy is treated similar as wood for non-energy purposes, governed by their national forest legislation. Based on sustainable forest management practices, the argument is, that risks as discussed in section 22.2 are mitigated sufficiently by this legislation.

The report highlights that several Member States are exploring the approach of a risk-based approach. Such an approach is based on the existence of a structured framework or set of legislations and the presence of measures and processes which would minimise the risk of unsustainable forest management occurring in the supply chain of wood and wood-based products used in the EU, enabling users of biomass to manage the risk to a negligible risk for the purpose of providing sustainability assurance.

In the context of this policy context and gap analysis report it is concluded that this approach might result in mitigating the sustainability risks relation to the biomass collection and harvesting in the forestry sector, but not straight away. As has been indicated in section 3.2 for several sustainability risks policy gaps may exist for the forestry sector, though more related to non-EU origin biomass than for EU origin. Nevertheless, an assessment per country or region would be needed to carry out in order to determine which level of risk would be associated with the assessed country or region. Only in the case of a low-risk region the necessity to address a policy gap for a specific sustainability risk would be no longer necessary.

Given the large varieties in national legislation and the requirement to determine the risk-levels of the various EU Member States for at least the near future it would be advised to repair any identified policy gap.

[140] http://ec.europa.eu/agriculture/forest/publications/pdf/sfcci-report_en.pdf

23 Policy gap analysis

23.1 Introduction

In the previous chapter the relevant legislative measures have been reviewed to determine whether and how they address identified risks. The objective is to determine how the further development of the sustainability regime under which the use of biomass for energy purposes can be designed in such a way that undesired impacts on these potential risks are mitigated.

The potential risks were structured as follows (see Chapter 21):

- upstream – biomass production
    - Carbon stock change
    - (In)direct land use change
    - Biodiversity, soil and water
- downstream – biomass conversion and end-use in energy
    - GHG emissions in the supply chain
    - Efficient end-use conversion
    - Air emissions
    - Competition with other end-use markets

From the discussion on the various possible sustainability risks in Chapter 0 it can be concluded that in both the upstream/biomass feedstock production and the downstream/biomass conversion part of the supply chain the set of policy frameworks that currently are in place are not sufficiently addressing the possible sustainability risks that in the various sectors where biomass feedstock sourced from (agriculture, forestry and waste sector) or are converted into end use energy or products ((transport, electricity and/or heating/cooling, non-energy). This is illustrated by the table below which summarizes how often for that sector a possible policy gap was identified. It is clear that in the biomass production side of the supply chain both in the agricultural sector and the forestry sector sustainability risks could materialize, although this is most often related to biomass from non-EU origin, as the EU legislation cannot govern local agricultural or forestry management and practices. At the conversion and end-use side sustainability risks can occur in all end use sectors, though in the electricity and heating/cooling sector and the non-energy sector the set of legislative measures seem not sufficient to prevent the occurrence of sustainability risks in the absence of sustainability criteria at EU level.

Table 23-1: Summary of in which part of the supply chain and sectors current policy framework might not sufficiently address sustainability risks (dark coloured cells indicate where gaps may exist)

In biomass production part of the supply chain:	In the biomass conversion and end use part of the supply chain
Agriculture	**Transport**
Forestry sector	**Electricity, heating and cooling**
Waste sector	**Non-Energy**

The following overview provides in more detail how each of the identified sustainability risks are addressed by a certain set of legislative measure and where in the supply chain of bioenergy policy gaps could well appear. In the next section these gaps are briefly discussed.

Identified risks	Legislative measures	Potential policy gaps appear in:	
		Biomass production part of the supply chain	**Biomass conversion and end-use part of the supply chain**
Carbon stock change	(amended) Renewable Energy and Fuel Quality Directive; EU Timber Regulation; Decision on Land Use, Land Use Change, Forestry	Agricultural Sector Forestry Sector	Electricity and heating/cooling sector Non-energy sector
Land use change	(amended) Renewable Energy and Fuel Quality Directive; EU Timber Regulation;, Natura 2000/Habitat and Birds Directive	Agricultural Sector Forestry Sector	Transport sector Electricity and heating/cooling sector Non-energy sector

Identified risks	Legislative measures	Potential policy gaps appear in:	
		Biomass production part of the supply chain	**Biomass conversion and end-use part of the supply chain**
Biodiversity, soil and water	(amended) Renewable Energy and Fuel Quality Directive; Common Agricultural Policy; Nitrates Directive; EU timber Regulation; Natura 2000/Habitat and Bird Directive; Water Framework Directive; Industrial Emissions Directive	Agricultural Sector Forestry Sector	Transport sector Electricity and heating and cooling sector Non-energy sector
Supply chain GHG performance	(amended) Renewable Energy and Fuel Quality Directive; EU Emission Trading Scheme; Effort Sharing Decision		Electricity and heating/cooling sector
Air emissions	EcoDesign Directive; National Emissions Ceiling Directive; Industrial Emissions Directive; Medium Combustion Plants Directive		
Efficient end use conversion	Energy Efficiency Directive; EcoDesign Directive; EU Emission Trading Scheme; Effort Sharing Directive; Industrial Emissions Directive	Agricultural Sector Forestry Sector	Electricity and heating/cooling sector
Competition with non-energy end use markets	Waste Framework Directive; Landfill Directive, Sewage Sludge Directive	Agricultural Sector Forestry Sector Waste sector	Electricity and heating/cooling sector Non-Energy sector

23.2 Upstream related policy gaps

23.2.1 EU-dimension versus non-EU dimension

Biomass feedstocks originate from within or from outside the EU. The Technical Background report has shown that the biomass supply potentials to cover the 2030-demand for biomass resources for energy utilization are largely European-based – only 5 to 10% of all biomass needed will have to be imported. It is mainly in the non-EU dimension where the identified sustainability risks (carbon stock change, indirect land use change and risks related to biodiversity, soil and water) might appear and for which it should be considered how to prevent such risks by adequate policy measures. Obviously, managing these risks directly extends beyond the EU governance's capacities. However, the sustainability criteria for biofuels and bioliquids try to manage these risks, also for feedstocks from outside the EU. This could also be designed for solid biomass for the electricity sector of for the non-use markets.

23.2.2 Agriculture versus forestry

Another issue that needs to be addressed is the sector from which the biomass feedstock may be harvested or collected: from agriculture or from the forestry sector.

Most of the non-EU agricultural resources that are used for energy purposes are meant for the production of biofuels and bioliquids and most of the mentioned upstream risks are governed by the sustainability criteria of the (amended) RED and FQD, though this does not yet fully address sustainability issues like carbon stock change, land use change and biodiversity.

Currently, all non-EU forestry resources for energy generation are used for electricity and/or heat generation. These resources are currently not governed by sustainability criteria, except for those EU Member States that have established national sustainability schemes. It should be explored how in other EU Member states, with national level sustainable forest management regulation in place, the risks for unsustainable use of biomass are valued.

With respect to EU-based feedstocks from both the agricultural and the forestry sector in general the sustainability risks are sufficiently addressed. Most of the agricultural products and residues are used for the production of biofuels and bioliquids and partly for the production of biogas for electricity and heating, whereas most forest biomass resources are meant for heating (mainly) and electricity (and CHP) generation. Based on the analysis on supply potentials and demand expectations it may be expected that demand for EU agricultural resources could grow before it would meet supply potential limits, without interfering with other non-energy uses. This might however result in increased indirect land use change impact if not accompanied by the well designed measures.

23.2.3 Feedstock to different end-user market

A third policy gap exists in different requirements on feedstocks for the different end-user markets: transport sector versus the electricity and heating/cooling market and the non-energy end-use market. Biomass resources for the transport sector are governed by mandatory sustainability criteria, resources for the electricity and heating/cooling are not governed by sustainability criteria, except in Member States with national schemes, and for biomass resources that are used in non-energy end-use markets no governance measures have yet been designed, developed or proposed.

23.3 Downstream related policy gaps

The downstream related risks (GHG emission performance in the supply chain, efficient end-use conversion, air emission and competition with other end-use markets) only have a European dimension: the conversion of biomass resources to energy takes place in facilities that are situated within the EU. The end-use within the transport sector is governed by the sustainability criteria (and the other conditions) laid down in the Amended RED and FQD). The conversion for electricity and heating/cooling is not governed by similar or equal sustainability criteria. The major concerns relate to other types of risks: securing health issues (air quality), securing optimized use of limited resources (efficiency and competitive use in various end-use markets). From the analysis of the legislative measures it becomes clear that a wide range of adjacent regulations and directives exist. These are supportive to establish the sustainable use of biomass resources, but they are not articulated for efficient use of biomass. Adjacent regulations were designed to serve other purposes.

23.3.1 GHG performance in the supply chain

Currently only biofuels in transport and bioliquids have to comply to GHG thresholds. For biomass resources used in the generation of electricity and/or heating cooling such requirement do not exist (except for those biomass resources governed by national sustainability schemes). The logic behind being that for agricultural based feedstocks, often used for biofuels, the energy input and non-CO2 emissions (CH4, N2O) in the cultivation phase can be significant, as compared to forestry products and residues. Nevertheless, when focusing on efficient conversion processes to limit the amount of resources needed, it can be helpful to also optimize the energy input in the supply chain and favour those resources that have a better energy input/output ratio.

23.3.2 Efficient end use conversion

Efficient end use conversion measures assure that the amount of biomass used to produce a unit of useful energy in the electricity and heating/cooling market is reduced. Resource efficiency is the result, causing that pressure on competition with other used is partially prevents. The measures however do not regulate how efficiently the biomass feedstock is grown, cultivated, collected or harvested (and which energy input was needed and GHG emissions resulted from these steps), nor does it settle under which (if at all) sustainability regime or sustainable forest management practice the biomass was sourced.

23.3.3 Competition with non energy end use marrkets

Current legislative measures in place are mainly based on waste management and waste prevention and settle the hierarchy for how waste and residues are preferably processed. The Landfill Directive will give an impulse to the current situation in the EU, characterized by (still) high levels of landfilling in the majority of the EU member States, to have improved material recovery and energy utilisation from waste streams. This will increase the availability of biomass residue resources for energy (mainly electricity and heat) and reduce the need for virgin biomass feedstocks which could become available for non-energy use as well. Nevertheless, the current frameworks do not sufficiently address how a balanced use of agricultural and forestry products and residues in energy and non-energy markets should be organised while in both sectors demand is expected to increase.

23.4 Conclusion

In summary, the major difference between the upstream and the downstream related risks is characterised by the fact that ‘upstream’ the sustainability of all biomass production needs to be ***assured*** - whether origination from within or outside the EU, and whether origination from agriculture or from the forest - whereas on the 'downstream' side the use and conversion of the feedstocks into energy needs to be ***optimized*** to ensure resource efficient use of biomass and decrease potential competition pressure for energy and non-energy end use markets.

For the biofuel production it is relevant to develop policy options that secure the sustainability issues of all feedstocks that are meant to be used for energy purposes within the EU. At the moment only biomass feedstocks that are converted into biofuels (for the transport market) and bioliquids (for electricity and/or heat) are governed by sustainability criteria at EU level. It is proposed to design a policy option which explores the extension of the sustainability criteria to solid and gaseous biomass for use in the electricity and heating/cooling market. Ultimately, though this is beyond the scope of this report, extension of the sustainability criteria to the use of biomass resources in the non-energy end-use markets could be considered.

From the gap analysis it has become clear that sustainability issues such as biodiversity, land use change and and soil and water impacts are not well addressed in the existing sustainability criteria for biofuels and bioliquids, and will also not be addressed when the current scheme is extended to solid and gaseous biomass. These issues are most at risk for primary products from non-EU agriculture, but may become also material in the case of increased demand for non-EU forest feedstocks. Because the amended Renewable Energy Directive has set limits to land-based feedstocks for biofuel these risks probably will not further expand. Increased demand for non-EU forest resources could potentially result in more sustainability risks. A way to mitigate those risks would be to request, similar to EU practices in various Member State, the presence of sustainable forest management practices in these non-EU forest regions.

In the 'downstream' case it has been found that existing legislation has not been designed specifically for guaranteeing sustainability or efficiency for biomass use for energy. Current regulation does not explicitly address the risks associated with increased biomass for energy use. For that reason, it is advised to develop additional policy options that address energy efficiency and waste management to enable optimal use of sustainable biomass for both energy and non-energy end-use markets.

24 Policy options

Following the policy gap analysis, it is proposed to assess the impacts of the following policy options, as compared to the baseline situation for 230, which is based on the following 2030 targets:

- Renewable energy has at least a 27% share in final energy use in EU28
- Energy Efficiency improvement at least 27% (as compared to 1990)

Proposed policy options:

- **Option 1: Baseline** (No additional EU actions on bioenergy sustainability)
  - Continuation of current EU sustainability criteria for biofuels and bioliquids
  - Cap on food based crops at 7% in period 2020 to 2030
  - For feedstocks land criteria apply only for agricultural biomass
  - GHG saving thresholds only for biofuels and bioliquids
- **Option 2: Extension of the sustainability criteria for biofuels to biomass for heat and power**
  - Continuation of current EU sustainability criteria for biofuels and bioliquids
  - Cap on food based crops at 7% in the period 2020 to 2030
  - RED land criteria for agricultural and forestry biomass
  - GHG saving thresholds for biofuels and for biomass for heat and power
- **Option 3: option 2, except that the land criteria for forest biomass are replaced by criteria for Sustainable Forest Management for forest biomass**
  - Continuation of current EU sustainability criteria for biofuels and bioliquids
  - Cap on food based crops at 7% in period 2020 to 2030
  - land criteria apply only for agricultural biomass
  - Sustainable forest management criteria for forest biomass
  - GHG saving thresholds for biofuels and for biomass for heat and power
- **Option 4: Option 2 plus energy end use conversion criteria**
  - Continuation of current EU sustainability criteria for biofuels and bioliquids
  - Cap on food based crops at 7% in the period 2020 to 2030
  - RED land criteria for agricultural and forestry biomass
  - GHG saving thresholds for biofuels and for biomass for heat and power
  - End use efficiency criteria

Appendix 1: Detailed description of the relevant legislative measures at EU level

(Amended) Renewable Energy Directive (Directive 2009/28/EC and 2015/1513/EC)

The Renewable Energy Directive[141] was published in 2009 and established an overall policy for the production and promotion of energy from renewable sources in the EU. It requires the EU to fulfil at least 20% of its total energy needs with renewables by 2020. All EU countries must also ensure that at least 10% of their transport energy come from renewable sources by 2020. Biofuels are instrumental in helping EU countries to meet this 10% target. Biomass is expected to be a major contributor to the 2020 Renewable energy targets. The EC estimated in its report on sustainability requirements for the use of solid and gaseous biomass sources in electricity, heating and cooling[142] that biomass could "contribute around half of the total effort for reaching the 20% renewable energy target in 2020".

The RED sets out sustainability criteria for all biofuels consumed in the EU to ensure that they are produced in a sustainable manner. Companies can show they comply with the sustainability criteria through national systems or so-called voluntary schemes recognized by the European Commission.

In 2010 the European Commission analysed the requirements for extending the sustainability scheme in place for transport biofuels and bioliquids for solid and gaseous biomass for electricity and heat production. The Commission concluded that at that stage it would not propose binding criteria at EU level. The wide variety of biomass feedstocks make it difficult to put forward a harmonised scheme, as they present different challenges on sustainable production, greenhouse gas performance or efficient energy conversion. It was also considered that the sustainability risks of domestic biomass production from wastes and agricultural and forestry residues were considered low.[143]

The RED has the following sustainability criteria for all biofuels/bioliquids consumed in the EU (see Table 1).

Table 0-1: Sustainability criteria all biofuels consumed in the EU

Requirement	Scope
GHG emission reduction savings	Irrespective whether the raw materials are cultivated inside or outside the EU
Biofuels and bioliquids shall not be made from raw material obtained from land: • **With a high biodiversity value;** • **With high carbon stock that was converted to another status after January 2008;** • **That was peat land in January 2008;**	Irrespective whether the raw materials are cultivated inside or outside the EU

[141] EC, 2009, Directive EU 2009/28
[142] *EC, 2010, COM(2010)11.*
[143] Id.

Agricultural raw materials used for the production of biofuels and bioliquids shall be obtained in accordance with the the minimum requirements for good agricultural and environmental conditions (see also the CAP);	Agricultural raw materials cultivated *in the Community* and used for the production of biofuels and bioliquids

The RED requires the Commission, in addition, to report on specific topics (See Table 2).

Table 0-2: Reporting requirements

Reporting requirement on:	Scope
National measures taken to respect the sustainability criteria (see above) and for soil, water and air protection.	Both third countries and Member States that are a significant source of biofuels or of raw material for biofuels consumed within the Community
The impact on social sustainability of increased demand for biofuel, the impact of Community biofuel policy on the availability of foodstuffs at affordable prices, in particular for people living in developing countries, and wider development issues. Land-use rights.	In the Community and in third countries
whether the country has ratified and implemented each of the following Conventions of the International Labour Organization (ILO)	Both for third countries and Member States that are a significant source of raw material for biofuel consumed within the Community

In 2015 new rules were published which amend the RED and the FQD to reduce the risk of indirect land use change and to prepare the transition towards advanced biofuels. They were laid down in the 'Directive to reduce indirect land use change for biofuels and bioliquids'[144] and include the following amendments that relate to sustainability criteria:

- A limit of the share of biofuels from crops grown on agricultural land that can be counted towards the 2020 renewable energy targets to 7%;
- An indicative 0.5% target for advanced biofuels as a reference for national targets which will be set by EU countries in 2017;
- Biofuels produced in new installations shall emit at least 60% fewer GHGs than fossil fuels;
- Includes a number of additional reporting obligations for the fuel providers, EU countries and the EC, as for example:
    - Commission reporting on the effectiveness of the measures introduced by this Directive in limiting ILUC-GHG emissions associated with the production of biofuels and bioliquids;
    - Provisional mean values of estimated ILUC emissions should be included in the reporting by fuel suppliers.

[144] EC, 2015, Directive (EU) 2015/1513.

The EU Timber Regulation (Regulation 995/2010)

The European Timber Regulation[145] (EUTR) lays down obligations on operators who place timber and timber products on the European market with the objective to counter the trade in illegally harvested timber and timber products – including for example fuel wood, wood in chips or particles, sawdust or wood waste.

The EUTR has three key obligations, being:

- Illegally harvested timber and products derived from such timber are prohibited on the EU market;
- EU traders who place timber products on the EU market for the first time are required to exercise 'due diligence';
- Once on the market, the timber and timber products may be sold on and/or transformed before they reach the final consumer under the condition that economic operators in this part of the supply chain keep records of their suppliers and customers to facilitate the traceability of timber products.

Illegally harvested is defined under the EUTR as "harvested in contravention of the applicable legislation in the country of harvest". Applicable legislation means the legislation in force in the country of harvest covering the following matters:

- Rights to harvest timber within legally gazetted boundaries;
- Payments for harvest rights and timber including duties related to timber harvesting,
- Timber harvesting, including environmental and forest legislation including forest management and biodiversity conservation, where directly related to timber harvesting,
- Third parties' legal rights concerning use and tenure that are affected by timber harvesting, and
- Trade and customs, in so far as the forest sector is concerned.

The EUTR was published in October 2010 and entered into force in March, 3rd 2013.

The EUTR was developed for an EU importers focus from the EU Forest Law Enforcement, Governance and Trade (FLEGT) Action Plan. Established in 2003 the FLEGT Action Plan aimed to eliminate illegal timber in international trade and acknowledging the shared responsibility of exporters and importers. Voluntary Partnership Agreements (VPA's) - legally binding trade agreement between the European Union and a timber-producing country outside the EU - are a central part of this Action Plan to ensure that timber and timber products exported to the EU come from legal sources. The agreements also help timber-exporting countries stop illegal logging by improving regulation and governance of the forest sector. The EU has signed VPA's with six non-EU timber producing countries.[146] Nine more countries are in negotiations with the EU.[147]

February 2016 the European Commission published an evaluation report on the first two years of the application of the Regulation, in line with Article 20(3) of the EUTR. The

[145] EU, 2010, Regulation (EU) No 995/2010
[146] Cameroon, Central African Republic, Ghana, Indonesia, Liberia and Republic of Congo (Source: EC, 2016, SWD(2016)33.
[147] Côte d'Ivoire, Democratic Republic of the Congo, Gabon, Guyana, Honduras, Laos, Malaysia, Thailand, Vietnam (Source: http://www.euflegt.efi.int/vpa, site visited 23-Feb-2016)

purpose of the evaluation was to review the functioning and the effectiveness of the Regulation. The major conclusions, according to the Executive Summary of the Evaluation[148] are that:

- the implementation of the EUTR has been slow in most Member States, overall implementation remains insufficient and there are still four not fully compliant Member States;
- insufficient resources allocated to Competent Authorities limit the effective enforcement of the EUTR. Types and level of sanctions for infringements vary among Member States. Though EU operators increasingly apply due diligence requirement, implementation and compliance by the private sector has been uneven."[149]
- Being in force so recently, no significant shifts in trade flows where yet possible to determine.
- The EUTR encourages other consumer countries to adopt similar legislative acts.

The EUTR is coherent with other policy instruments like the Voluntary Partnership Agreements and the FLEGT licencing scheme.

The (Amended) Fuel Quality Directive

The Fuel Quality Directive applies to all petrol, diesel and biofuels used in road transport, as well as to gasoil used in non-road-mobile machinery[150]. In April 2009, Directive 2009/30/EC was adopted which revises the Fuel Quality Directive [Directive 98/70/EC]. It amends a number of elements of the petrol and diesel specifications as well as:

- introducing in Article 7a a requirement on fuel suppliers to reduce the GHG intensity of energy supplied for road transport (6% by 2020)[151]. The GHG intensity of fuels is calculated on a life-cycle basis: emissions from the extraction, processing and distribution of fuels are included (EU Climate, 2016).
- The Directive establishes sustainability criteria that must be met by biofuels if they are to count towards the GHG intensity reduction obligation Fuel Quality Monitoring (EU Environment, 2016). This is aligned with the Renewable Energy Directive.

The Fuel Quality Directive is amended in 2015 by Directive 2015/1513 to address sustainability issues of biofuels, in particular with respect to indirect land use change based emissions. The amended FQD includes the requirement for fuel suppliers to include in their reporting the provisional mean values of estimated indirect land-use change emissions due to the biofuels and bioliquids they have supplied.[152]

The sustainability criteria in the FQD only apply to biofuels used in the transport sector in the European Union. Bioliquids, e.g. vegetable oils that are used in combined heat and

[148] EC, 2016, SWD(2016)33.
[149] Id.
[150] (EU Climate, 2016) Information from EC DG Climate on Fuel Quality, see also: http://ec.europa.eu/clima/policies/transport/fuel/index_en.htm
[151] (EU Environment, 2016), Information from EC DG Environment on Fuel Quality monitoring, see also: http://ec.europa.eu/environment/air/transport/fuel.htm
[152] EC, 2015, Directive EU/2015/1513

power plants, however also have to comply to the sustainability criteria in the FQD. These criteria are equal to the sustainability criteria in the Renewable Energy Directive.

The FQD has a limited scope to road transport, and does not refer to the use of petrol, diesel and biofuels in (for example) sea transport or air transport. Sea Transport and air transport are part of ETS, but ETS does not address sustainability issues.

The geographical scope of the FQD is the European Union.

Decision on Land Use, Land Use Change and Forestry (Decision 529/2013/EU)

Land use, Land Use Change and Forestry (LULUCF) covers greenhouse gas emissions into the atmosphere and removal of carbon from the atmosphere resulting from our use of soils, trees, plants, biomass and timber[153].

In the light of a decision by UNFCCC parties in December 2011 to revise accounting rules for GHG emissions and removals from soils and forests, the Council and the European Parliament adopted the Decision[154] (529/2013/EU). This Decision sets out accounting rules applicable to emissions and removals of GHGs resulting from 'LULUCF' activities, as a first step towards the inclusion of those activities in the Union's emission reduction commitment[155], when appropriate. The Decision contains reporting requirements for Member States on their initiatives to decrease emissions from forestry and agriculture-related activities as well as increase the carbon sink. It does not lay down any accounting or reporting obligations for private parties.

The accounting rules for GHG emissions and removals from forests and soils meet international standards by maintaining the voluntary nature of accounting for draining and rewetting of wetlands, but goes beyond the UNFCCC decision by making accounting for cropland and grassland management mandatory for Member States[156].

Article 3 mentions that for each accounting period, Member States shall prepare and maintain accounts that accurately reflect all emissions and removals resulting from the activities on their territory falling within the following categories:

- Afforestation[157];
- Reforestation;
- Deforestation;
- Forest management.

[153] LUCLUF in the EU, see: http://ec.europa.eu/clima/policies/forests/lulucf/index_en.htm
[154] EU, 2013, Decision 529/2013/EU
[155] See Decision: Emissions and removals of GHGs resulting from the LULUCF sector are not counted towards the Union's 20 % greenhouse gas emission reduction targets for 2020 pursuant to Decision No 406/2009/EC of the European Parliament […],though they count in part towards the Union's quantified emission limitation and reduction commitments pursuant to Article 3(3) of the Kyoto Protocol to the United Nations Framework Convention on Climate Change ('UNFCCC'), approved by Council Decision 2002/358/EC (5).
[156] See LSE (2013), http://www.lse.ac.uk/GranthamInstitute/law/land-use-land-use-change-and-forestry-lulucf-decision-no-5292013eu-on-accounting-rules-on-ghg-emissions-and-removals-resulting-from-activities-relating-to-lulucf-and-on-information-concerning/
[157] In accounts relating to afforestation and reforestation, Member States shall reflect emissions and removals resulting only from such activities taking place on those lands that were not forest on 31 December 1989.

Beginning on January 1, 2021, and thereafter, Member States shall also prepare and maintain annual accounts for the following categories:

- Cropland management;
- Grazing land management.

Article 8 further specifies the accounting rules for cropland management, grazing land management, re-vegetation, and wetland drainage and rewetting.

Member States shall include in their accounts any change in the carbon stock of the following carbon pools (see Art 4): (a) above-ground biomass; (b) below-ground biomass; (c) litter; (d) dead wood; (e) soil organic carbon and (f) harvested wood products. The accounts should cover emissions and removals of the following greenhouse gases: Carbon dioxide, methane and nitrous oxide.

Member States shall account for emissions and removals resulting from forest management activities, calculated as emissions and removals in each accounting period. The accounts and calculation methods for forest management activities cover the following aspects: (a) carbon pools and greenhouse gases; (b) area under forest management; (c) harvested wood products and (d) natural disturbances (Art. 7). The category 'Harvested wood products' considers the emissions and removals resulting from changes in the pool of harvested wood products (specified in paper, wood panels and sawn wood), including emissions from harvested wood products removed from its forests prior to 1 January 2013.

The new rules are also intended to better recognize the efforts of farmers and forest owners to maintain carbon stored in soils and forests and to facilitate a more climate-friendly architecture (funds are available through the CAP Rural Development pillar). Annex IV provides some indicative measures that may be included in the information on LULUCF actions submitted:

- Measures related to cropland management: improving agronomic practices by selecting better crop varieties;
- Measures related to grazing land management and pasture improvement such as increasing productivity;
- Restoration of degraded lands
- Measures related to forestry activities such as: afforestation and reforestation, conservation of carbon in existing forests, enhancing production in existing forests, enhancing forest management, including through optimized species composition, and soil conservation.
- Preventing deforestation.
- Measures to substitute GHG-intensive energy feedstocks and materials with harvested wood products.

The EU decision does not set a target for emission reductions in the LULUCF sector. Instead, progress will be made on improving the accounting systems by Member States. The Commission will consider whether to propose GHG targets for agriculture and forestry sectors once the accounting systems have proven that they are robust and effective[158].

[158] LUCLUF in the EU, see: http://ec.europa.eu/clima/policies/forests/lulucf/index_en.htm

- This Decision sets accounting rules and reporting obligations on Member State level but does NOT set any target on emission reductions for the agricultural and forestry sector. It should therefore be seen as a first step to harmonize information;
- When further elaborated, this Decision could strongly contribute to mitigating the impact on (I)LUC and biogenic emissions from the agricultural and forestry sector, and has herewith also a strong link with the ambitions set in the Renewable Energy Directive;
- The Decision applies to EU Member States. However, it has a strong international link through the UNFCCC and the Decision made on December 2011 on accounting rules related to LULUCF. As mentioned under the UNFCCC, "under the Kyoto Protocol, Parties shall annually report emissions by sources and removals by sinks of CO2 and other greenhouse gases resulting from LULUCF activities"[159].

The Common Agricultural Policy

The CAP is a common policy for all the Member States of the European Union. It is managed and funded at European level from the resources of the EU annual budget (EC, 2014). The CAP has three dimensions, which are interconnected (EC, 21014):

- market support,
- income support and
- rural development.

The CAP is structured around two 'Pillars':

- Pillar 1 (Single Payment scheme) and
- Pillar 2 (Rural development Policy).

They each have different amounts of money reserved for them and have different purposes.

The CAP (existing since 1962) has been reformed in 2013 (EC, 2014) and a new system of direct payments was introduced for Pillar I. This new system ensures the provision of environmental public goods. As from 2015, active EU farmers will have access to compulsory schemes applicable in all MS, and to voluntary schemes (depending on the choice of the MS) (EC, 2015)[160] (see Table 3).

Cross-compliance is compulsory for all farmers in order to receive direct payments and some other forms of support. This means that farmers are required to respect certain rules concerning statutory management requirements and good agricultural and environmental conditions. Rules relate to food safety, animal health, plant health, the climate, the environment, the protection of water resources, animal welfare and the

[159] Under the Kyoto Protocol, Parties shall annually report emissions by sources and removals by sinks of CO2 and other greenhouse gases resulting from: LULUCF activities under Article 3.3, namely afforestation, reforestation and deforestation that occurred since 1990. Any elected human-induced activities under Article 3.4, which can be: forest management (mandatory in the second commitment period), revegetation, cropland management and grazing land management. See: http://unfccc.int/land_use_and_climate_change/lulucf/items/4129.php

[160] *EC (2015), Brochure from the European Commission on Direct Aids Schemes, January 2015, see: http://ec.europa.eu/agriculture/direct-support/direct-payments/docs/direct-payments-schemes_en.pdf*

condition on which farmland is maintained. If a farmer is found not to respect these rules, his or her direct payments may be reduced (EC, 2015).

Table 0-3: System of CAP Pillar 1 Direct Payments

Compulsory Schemes (all MSs)	Voluntary schemes (MS Choice)
Basic payment (or Single Area Payment)	Redistributive payment
Green Payment	Support in areas with natural constraints
Young farmers scheme	Couples support
All farmers are subject to cross compliance and have access to the Farm Advisory System. **Alternatively, a simplified scheme is established for small farmers (voluntary of MS)**	

In addition to the Basic Payment, each holding will receive a Green payment per hectare for respecting certain agricultural practices beneficial for the climate and the environment. This is compulsory and failure to respect the Greening requirements will result in penalties (EC, 2015). In practice this means that they must maintain permanent grassland areas; they must grow a minimum number of crops and must farm 5 % of their arable area in a manner that promotes biodiversity (known as an ecological focus area). Farmers may also receive additional support if they adopt stricter agri-environmental farming practices.[161]

Whilst Member States compose their programmes from the same list of measures, they have the flexibility to address the issues of most concern within their respective territory reflecting their specific economic, natural and structural conditions (EC, 2014).

The CAP applies to all farms in the EU and aims to ensure "good agricultural and environmental conditions" including the protection of climate (carbon stock changes), soil, water and biodiversity.

The CAP is restricted to ensuring good agricultural and environmental production from biomass produced on agricultural land within the European Union (as also referred to in the Renewable Energy Directive) and therefore does not cover good environmental conditions:

- From biomass produced on agricultural land outside the European Union;
- The guarantee of environmental conditions from biomass from Forest land;

The insurance of good environmental conditions goes 'until the farm gate' under the CAP so sustainability of processing of agricultural products are not covered by the CAP.

The Nitrates Directive (Directive 91/676/EEC)

The Nitrates Directive came into force in December 1991 for the protection of European waters against pollution caused by nitrates from agricultural sources. The directive acknowledges that the use of nitrogen-containing fertilizers and manure is necessary for

[161] *EC (2014) Brochure on "The EU's common agricultural policy (CAP): for our food, for our countryside, for our environment", see also: http://ec.europa.eu/agriculture/cap-overview/2014_en.pdf*

agriculture but aims at restricting the excessive use of fertilizers, as that constitutes an environmental risk. The objective of the directive is twofold[162]:

- producing water pollution caused or induced by nitrates from agricultural sources and
- preventing further such pollution

Member States must have established Action Programmes, which includes measures that are laid down in Annex III of the Nitrates Directive, including rules relating to, among others, the periods in which land application of certain types of fertilizers are prohibited, the capacity of storage vessels for livestock manure, limitations of the land application of fertilizers, consistent with good agricultural practices and taking into account the characteristics of the vulnerable zone concerned. These measures will ensure that, for each farm or livestock unit, the amount of livestock manure applied to the land each year shall not exceed the amount of manure containing 170 kg N per hectare. Member States may fix different amounts, as long as in line with the objective of the Directive and must be justified on the basis of objective criteria, e.g. long growing seasons, crops with high nitrogen uptake, high net precipitation in the vulnerable zone, soils with high denitrification capacity.

The Nitrates Directive regulates prevention of water pollution caused by nitrates within the context of agricultural practices within the European Union. For biomass feedstocks from agriculture from non-EU countries information on limits on fertilizer and manure application there are indicators or the average dosing of nitrates in countries. Especially within the EU the risk of application of too high nitrogen levels exists.

Water pollution caused by nitrates from agricultural practices could occur.

Requesting information on the country of origin of imported biomass feedstock from agriculture will enable to determine whether the country of origin has similar water protection legislation in place.

The Natura 2000 / Habitat and Birds Directive (Directive 92/43/EEC and Directive 2009/147/EC

At EU level, nature and biodiversity are protected by several laws. The Habitat Directive forms the cornerstone of Europe's nature conservation policy with the Birds Directive and establishes the EU wide Natura 2000 ecological network of protected areas.

The Birds Directive

The Birds Directive[163] was adopted in April 1979, and amended in 2009 and aims to provide comprehensive protection to all wild bird species naturally occurring in the European Union. The Bird Directive protects wild bird species in various ways[164]:

- The Directive places emphasis on the protection of habitats for endangered and migratory species. It establishes a network of Special Protection Areas (SPAs) including all the most suitable territories for these species. Since 1994, all SPAs

[162] EC, 1991, Directive 91/676/EEC
[163] EU, 2009, Directive 2009/147/EC
[164] Information about the Birds Directive from the European Commission, see: http://ec.europa.eu/environment/nature/legislation/birdsdirective/index_en.htm

are included in the Natura 2000 ecological network, set up under the Habitats Directive 92/43/EEC.

- Around 82 bird species can be hunted. However, the hunting periods are limited and hunting is forbidden when birds are at their most vulnerable. Overall, activities that directly threaten birds, such as their deliberate killing, capture or trade, or the destruction of their nests, are banned. The directive provides for the sustainable management of hunting but Member States must outlaw all forms of non-selective and large scale killing of birds.
- The directive promotes research to underpin the protection, management and use of all species of birds covered by the Directive.

All Member States have to submit reporting on the status and trend in bird populations (see article 12) as well as on derogations they may apply to the directive's obligations.

The Habitats Directive

The Habitats Directive[165] was adopted in 1992 to help maintain biodiversity. It protects over 1000 animals and plant species and over 200 types of habitat. It also established the EU-wide Natura 2000 network of protected areas. The species and habitat types are protected in various ways[166]:

- Annex II species (about 900): core areas of their habitat are designated as sites of Community importance (SCIs) and included in the Natura 2000 network. These sites must be managed in accordance with the ecological needs of the species.
- Annex IV species (over 400): a strict protection regime must be applied across their entire natural range within the EU, both within and outside Natura 2000 sites.
- Annex V species (over 90): Member States must ensure that their exploitation and taking in the wild is compatible with maintaining them in a favourable conservation status.

The EC has published guidance on species protection to help Member States implement correctly the Directive's provisions. EU Species Action Plans are developed to restore the populations of certain species across their range within the EU. The EC also promotes the conservation of Europe's 5 species of large carnivores and supports the European Red Lists of Threatened Species, developed by the IUCN to provide an overview of the conservation status of around 6,000 European species, so that appropriate action can be taken to protect those threatened with extinction.

Certain articles of the Habitats Directive (Art. 6, 12, 16 and 17) require Member States to report on the conservation status of habitats and species, on compensation measures taken for projects having a negative impact on Natura 2000 sites or on derogations they may have applied to the strict protection measures.

Natura 2000

The aim of the Natura 2000 network is to ensure the survival of Europe's most valuable and threatened species and habitats, listed under both the Birds Directive and the

[165] EC, 2007, Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora - the consolidated version of 1 January 2007 with the latest updates of the annexes

[166] Information about the Habitats Directive from the European Commission, see: http://ec.europa.eu/environment/nature/legislation/habitatsdirective/index_en.htm

Habitats Directive. Natura 2000 is therefore a network of core breeding and resting sites for rare and threatened species, and some rare natural habitat types. It stretches across all 28 EU countries, both on land and at sea. Almost 50% of the designated areas is composed of forest (85 forest habitat types are protected under the Habitats Directive)[167]. Farmland makes up around 40% of the total area included in Natura 2000 (EC, 2014[168]).

Article 6 is one of the most important articles in the Habitats Directive as it defines how Natura 2000 sites are managed and protected[169]:

- Take appropriate conservation measures to maintain and restore the habitats and species for which the site has been designated to a favourable conservation status (6.1 and 6.2);
- Avoid damaging activities that could significantly disturb these species or deteriorate the habitats of the protected species or habitat types (6.1 and 6.2);
- Paragraphs 6(3) and 6(4) lay down the procedure to be followed when planning new developments that might affect a Natura 2000 site.

Natura 2000 is thus not a system of strict nature reserves from which all human activities are excluded.

Most of the farmland in Natura 2000 is located in the more marginal, low-intensity farming areas, that have usually developed over time, with farm structures and farming practices being closely adapted to local conditions (EC, 2014). An example is low intensity arable systems (for example on poor soils or in remote locations), often in rotation with semi-natural fallow vegetation. Low intensity agricultural management is necessary for the continued existence and conservation of key habitats and species linked to agricultural practices in Natura 2000 sites (EC, 2014).

The Bird and Habitat Directive and the Natura 2000 sites specifically aim to protect biodiversity including animal (as birds) and plant species and over 200 types of habitats in the European Union, both on land and on sea.

The geographical coverage of the Bird and Habitat Directive and the Natura 2000 sites is the European Union. They do not cover the protection of animal (as birds) and plant species and habitat types from forest and agricultural areas (e.g. produced for biomass to import to Europe) outside Europe;

In terms of biomass availability within Europe: One of the key conservation measures from Natura 2000 sites (and the Habitat Directive) for animal and plant species on agricultural land is adapting low-intensity farming practices. This may be contrary to the ambition to intensify agriculture (and thus counteract for example ILUC with this measure).

[167] Natura 2000 and Forests, FAQ, see: http://ec.europa.eu/environment/nature/natura2000/management/faq_en.htm#5

[168] EC (2014), Farming for Natura 2000. Guidance on how to support Natura 2000 farming systems to achieve conservation objectives, based on Member States good practice experiences, see: http://ec.europa.eu/environment/nature/natura2000/management/docs/FARMING%20FOR%20NATURA%202000-final%20guidance.pdf

[169] Management of Natura 2000 sites, http://ec.europa.eu/environment/nature/natura2000/management/guidance_en.htm

The Water Framework Directive

Since the mid 70s of the last century initial focus has been given to set standards for the rivers and lakes providing drinking water to Europe's citizens. This was followed by setting binding quality targets for the drinking water, as well as quality objective legislation on fish waters, shellfish waters, bathing waters and ground waters. In the nineties the focus widened to, among others, prevent pollution of water from urban waste water and nitrate leakages from agricultural practices. By the end of the nineties it was concluded that the water policy at that time was fragmented, in terms both of objectives and of means. A new Water Framework Directive emerged with among others the following key aims:[170] expanding the scope of water protection to all waters, surface waters and groundwater, achieving "good status" for all waters by a set deadline, and, as core of the single system for water management approach: management based on river basins, requiring international collaboration along the course of the river. The Water Framework Directive[171] is complemented by other legislation regulating specific aspects of water use: among others the Groundwater Directive (2006), the Environmental Quality Standards Directive (2008), and two Commission Decisions (2005 and 2008), on ecological status.

The Water Directive aims at getting polluted waters clean again, and ensuring that clean waters are kept clean. As such this Directive addresses the potential impact of biomass production (for energy or non-energy purposes) on water.

Production of biomass feedstocks from waste, agricultural or forestry residues, or the organic components in municipal solid waste within Europe have to take into account the regulations set by the Water Framework Directive. European facilities using imported non-European biomass feedstocks, in their process also have to operate under the regulations of the Water Framework Directive. For those European resources and for the conversion processes that take place on European ground it is not to be expected that the identified risks will emerge at significant level.

For the production of biomass feedstock in non-European countries potential undesired impacts on, in this particular case, water is not covered by the Water Framework Directive. If no similar regulation is in place such impacts could materialise. This is the case for biomass intended for all potential end-markets: electricity, heating and cooling and transport, as water is not one of the sustainability issues as mentioned in the RED, except for a biannual reporting on water legislation in main sourcing areas. In fact, this is also the case for non-European biomass resources intended for non-energy markets in Europe.

The Industrial Emissions Directive (Directive 2010/75/EU)

To control the pollution (air pollutants, discharge of waste water and generation of waste) from industrial production processes, the EU has developed a general framework based on integrated permitting, laid down in the Industrial Emissions Directive (IED)[172].

[170] http://ec.europa.eu/environment/water/water-framework/info/intro_en.htm, website visited 24-Feb-2016

[171] 2013, EC, Directive 2000/60/EC, amended latest by Council Directive 2013/64/EU of 17 December 2013

[172] ec.europa.eu/environment/industry/stationary/ied/legislation.htm

The IED came into force on 2 January 2011 and had to be transposed by Member States by 7 January 2013.

The IED aims to achieve a high level of protection of human health and the environment taken as a whole by reducing harmful industrial emissions across the EU, among others by taken an integrated approach, application of Best Available Techniques (BAT), flexibility for authorities to adapt the permits and grant derogations, environmental inspections and public participation via involvement in the permitting process. About 50 thousand installations undertaking industrial activities that are listed in the directive are required to operate accordance to a permit.

For certain activities (among others large combustion plants, waste incineration and co-incineration) the IED sets EU wide emission limit values for selected pollutants. This relates to combustion plants with a total rated thermal input of 50 MW or more, independent of the fuel used. This is ruled by Chapter III and Annex V of the IED. In the context of this report this may apply for biomass burned in stand-alone facilities, for co-firing of biomass in coal-fired power stations and for waste that contains organic matter.

The IED has among others set stricter emission levels for plants that have come into operation after 7 January 2013.

The IED ensures that industrial production processes are governed via permits to prevent pollutive emissions. The IED in this way addresses potential risks on air quality and risks of soil and water contamination near the production facilities. For combustion plants these permits apply for plants of 50 MW thermal input or larger. Smaller combustion plants are not governed by the IEA, but those facilities the Medium Combustion Plants Directive apply.

The IED is not designed to control how process feedstocks are produced, transported and pretreated prior to their use in the industrial production facility. As such the IED does not address issues related to biodiversity, soil and water where the feedstocks are produced.

The IED also does not have specific measure or minimum levels determined for conversion efficiency. Indirectly, conversion efficiency is relevant as high conversion efficiency contributes to better achievement of the emission levels.

The Emission Trading Scheme

The EU emissions trading system (EU ETS) is a cornerstone of the European Union's policy to combat climate change and its key tool for reducing industrial greenhouse gas emissions cost-effectively. The first - and still by far the biggest - international system for trading greenhouse gas emission allowances, the EU ETS covers more than 11,000 power stations and industrial plants in 31 countries, as well as airlines.[173] The purpose of the EU ETS is to cap greenhouse gas emissions from a number of industrial sectors, notably the energy generation sector and aviation. The transport sector is not part of the EU ETS.

The cap is reduced over time so that total emissions fall. In 2020, emissions from sectors covered by the EU ETS will be 21% lower than in 2005. By 2030, the

[173] http://ec.europa.eu/clima/policies/ets/index_en.htm

Commission proposes, they would be 43% lower. The cap translates into a number of European Emission Allowances (EUA's), representing a tonne of carbon dioxide equivalent. Covered operators are required to surrender each year a number of EUA's matching their emissions in the previous year, or pay fines. EUA's may be traded and companies can sell and buy emission allowances as needed. This cap-and-trade approach gives companies the flexibility to cut their emissions in the most cost-effective way.

Launched in 2005[174], the EU ETS is now in its third phase, running from 2013 to 2020. A major revision approved in 2009 in order to strengthen the system means the phase 3 is significantly different from phases 1 and 2 and is based on rules which are far more harmonised than before. The main changes are:

- A single, EU-wide cap on emissions applies in place of the previous system of national caps;
- Auctioning, not free allocation, is now the default method for allocating allowances. In 2013 more than 40% of allowances are auctioned, and this share will rise progressively each year;
- For those allowances still given away for free, harmonised allocation rules apply which are based on ambitious EU-wide benchmarks of emissions performance;
- Some more sectors and gases are included.

The EU ETS covers about 45% all all greenhouse gas emissions in EU28. Operators exclusively using biomass are not covered by the ETS. Operators who co-fire biomass with fossil fuels do fall within the scope of the ETS, but do not have to surrender allowances against emission from biomass, which receive a 'zero emission factor'. The Monitoring and Reporting Guidelines[175] that come into force in 2013 lays down definitions for biomass, bioliquids and biofuels identical to those provided in the Renewable Energy directive.

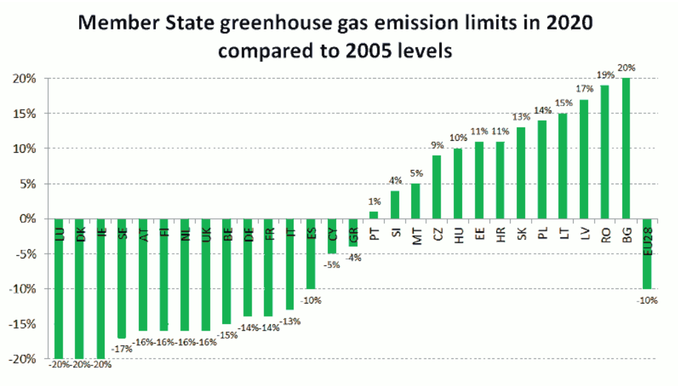
The Effort Sharing Decision (Decision 406/2009/EC)

The Effort Sharing Decision establishes binding annual greenhouse gas emission targets for Member States for the period 2013–2020. These targets concern emissions from most sectors not included in the EU Emissions Trading System (EU ETS), such as transport (except aviation and international maritime shipping), buildings, agriculture and waste.[176]

For 2020 the EU has set a 10% emission reduction as compare to 2005, and for each Member State different targets have been set. See Figure 1.

[174] Directive 2003/87/EC
[175] Commission Decision 2007/589/EC
[176] http://ec.europa.eu/clima/policies/effort/index_en.htm

Figure 0-1: MS GHG reduction targets under Effort Sharing Decision for 2020 (Source, website EC DG Clima177)



The 2030 emission reduction target is 30%.

In the Energy and Climate Package for 2030 no sector specific targets are set, but the reduction effort of the non-ETS sectors will be distributed between Member States through the revision of the Effort Sharing Decision. There are two different levels contributing to this reduction effort: the contribution secured by the EU legislation and policies and actions that Member States can take to reduce their own emissions. It can be expected that the transport sector will be an important contributor to the 30% reduction effort in the non-ETS sectors. Apart from new alternative options, like electric mobility and hydrogen based vehicles, biofuels may be a major contributor to these targets.

The Effort Sharing Decision may result in more use of biofuels in the transport sector and to more biomass use for heating purposes in buildings. Due to the focus on reduction of greenhouse gas emissions it can result in the utilisation of biofuels with high GHG supply chain performances and in the utilisation of high efficient biomass fuels heat appliances. As such the Effort Sharing Decision is supportive to the Energy and Climate objectives. For biofuels in the transport sector the sustainability issues are covered by the requirements in the RED and its 2015 amended version. Biomass heat appliances for building are also regulated by various emission control standards. The sustainability performance of the biomass feedstock for use in heat supply for buildings is however not secured. Increased utilisation of biomass for heat purposes in buildings could therefore lead to increased use of biomass that is not controlled by sustainability criteria.

The Effort Sharing Decision does not set requirements on the end use efficiency of conversion facilities. Member States have to design national regulations to comply to the 30% reduction target in the non-ETS sectors. Setting efficiency target for combustion appliances could be a supportive tool to the achievement of the Effort Sharing targets. Due to the fact that biomass often is more expensive than its current fossil alternatives will set direction to the purchase by end-users of high efficient biomass heating to achieve overall lower operation costs (less biomass feedstock needed per unit of energy produced.

[177] http://ec.europa.eu/clima/policies/effort/images/2020_limits_en.png

The EcoDesign Directive (2009/125/EC)

The EcoDesign Directive (2009/125/EC)[178] provides a coherent framework for improving the environmental performance of products. The Directive sets out minimum mandatory requirements for the energy efficiency of these products. This helps prevent creation of barriers to trade, improve product quality and environmental protection.

The EcoDesign Directive was extended in 2009 to all energy-related products (the use of which has an impact on energy consumption) (EC, 2012[179]):

- Energy-using products (EUPs): products which use, generate, transfer or measure energy, including consumer goods such as solid fuel boilers or computers;
- Other energy related products (ERPs): products which do not necessarily use energy, but have an impact on energy consumption and can therefore contribute to saving energy, such as windows.

The EcoDesign Directive allows the Commission to regulate the minimum performance of products. As a consequence, it "pushes" the market away from the worst performing products. The EcoDesign Directive foresees two types of mandatory product requirements (EC, 2012):

- Specific requirements, which set limit values, such as minimum energy efficiency, maximum emission levels or minimum quantities of recycled material;
- Generic requirements, which do (i) not set limit values but may require, for example, that (ii) a product is "energy efficient" or "recyclable" or (iii) may entail information requirements or (iv) may require that the manufacturer perform a life- cycle analysis of the product.

The EcoDesign Directive does not create binding requirements on products by itself: product requirements are set in Commission Regulations[180], directly applicable in all EU countries[181] (EC, 2012). National market surveillance authorities verify whether products sold in the EU follow the requirements laid out in EcoDesign and Energy Labelling Regulations[182].

Under the Ecodesign Directive, if a voluntary agreement by industry fulfils certain conditions, it is considered as a priority alternative to mandatory requirements. The voluntary agreement must, however, achieve the same objectives as binding legislation in a more rapid and cost-effective manner. The voluntary agreement must thus deliver added value compared to the 'business as usual' scenario. It must also foresee credible monitoring and reporting and represent a large majority of the industrial sector under consideration (EC, 2012).

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[178] EC, 2009, Directive 2009/125/EC
[179] EC (2012), Brochure on the EcoDesign Directive from the European Commission, EcoDesign Your Future How EcoDesign can help the environment by making products smarter
[180] See list of implementing Regulations on:
https://ec.europa.eu/energy/sites/ener/files/documents/list_of_ecodesign_measures.pdf
[181] For instance, the EcoDesign Regulation on standby requires that many domestic electrical and electronic products such as washing machines do not consume more than 0.5W in Off-mode as of 2013.
[182] Information about EcoDesign from the European Commission, see also:
http://ec.europa.eu/growth/industry/sustainability/ecodesign/index_en.htm

The EcoDesign Directive is meant to be used together with other policy tools, in particular the Energy Labelling Directive. The Energy Label classifies products remaining on the market according to their efficiency, with an A to G scale (A being the most efficient). It thus "pulls" the market towards more efficient products by better informing consumers (EC, 2012).

The Product regulations refer for those products that are covered by the EcoDesign Directive and its Product regulations to[183]:

- Energy efficiency (e.g. for solid fuel boilers: "seasonal space heating energy efficiency for boilers with a rated heat output of 20 kW or less shall not be less than 75 %);
- Air emissions (e.g. for solid fuel boilers: "seasonal space heating emissions of organic gaseous compounds shall not be higher than 20 mg/m3 for automatically stoked boilers";
- Efficient end-use (e.g. for solid fuel boilers, information about the efficiency of the boiler)

The EcoDesign Directive applies only to those products that are covered in the Product list, and is therefore not inclusive for all products that use or relate to energy consumption and efficiency;

The EcoDesign Directive only applies to product groups or services that are placed on the European market.[184] a number of non-EU countries (USA, Australia, Brazil, China and Japan) have legislation similar to the EU's EcoDesign and Energy Labelling Directives[185];

Regulations to date have mainly addressed the use-phase impacts, most importantly, energy consumption, as this represents, to varying degrees, the most important contribution to the environmental impacts of the regulated products. Some other environmental impacts have already been addressed by both the EcoDesign and Energy Labelling Regulations, including, in EcoDesign, those in other life-cycle phases. Nonetheless, potential for further reduction of environmental impacts have been identified in several studies, e.g. on aspects of reusability, recyclability, and recoverability, recycled content, use of priority materials, or durability.[186]

The Medium Combustion Plants Directive (2015/2193/EU)

Directive (EU) 2015/2193 of the European Parliament and the Council of 25 November 2015 on the limitation of emissions of certain pollutants into the air from medium combustion plants regulates pollutant emissions from the combustion of fuels in plants with a rated thermal input equal to or greater than 1 megawatt (MWth) and less than 50 MWth.

[183] As reference: COMMISSION REGULATION (EU) 2015/1189 of 28 April 2015 implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to EcoDesign requirements for solid fuel boilers

[184] See article 1: This Directive provides for the setting of requirements which the energy-related products covered by implementing measures must fulfil in order to be placed on the market and/or put into service.

[185] Information about EcoDesign from the European Commission, see also: http://ec.europa.eu/growth/industry/sustainability/ecodesign/index_en.htm

[186] Ecofys (2014), Final technical report Evaluation of the Energy Labelling Directive and specific aspects of the EcoDesign Directive ENER/C3/2012-523, see: http://www.ecofys.com/files/files/final_technical_report-evaluation_eld_ed_june_2014.pdf

Medium combustion plants are used for a wide variety of applications (electricity generation, domestic/residential heating and cooling, providing heat/steam for industrial processes, etc.) and are an important source of emissions of sulphur dioxide (SO_2), nitrogen oxides (NO_x) and dust. The estimated number of MCPs in the EU is around 143 thousand.[187]

The MCP Directive entered into force on 18 December 2015 and will have to be transposed by Member States by 19 December 2017.

It regulates emissions of SO_2, NO_x and dust into the air with the aim of reducing those emissions and the risks to human health and the environment they may cause. It also lays down rules to monitor emissions of carbon monoxide (CO).

The emission limit values set in the MCP Directive will have to be applied from 20 December 2018 for new plants and by 2025 or 2030 for existing plants, depending on their size. The flexibility provisions for district heating plants and biomass firing will ensure that climate and air quality policies are consistent and their synergies are maximised.

The MCP Directive addresses the potential need for Member States to apply stricter emission limit values in areas where this can improve local air quality in a cost-effective way. The Commission will help Member States dealing with such hotspots by providing information on the lowest emissions achievable with the most advanced techniques.

The Commission will regularly report on the implementation of the MCP Directive, and will address further issues, such as energy efficiency and carbon monoxide emissions, as foreseen under its review clauses.

The MCP Directive is a good example of Better Regulation. It has been designed to be affordable for SMEs, and provides long-term certainty for all economic operators concerned whilst minimising the administrative burden for both industry and Member States. In addition, beyond being environmentally efficient, the MCP Directive will encourage continued innovation and help EU industry gaining shares of the rapidly growing global market of pollution control technology.[188]

The Medium Combustion Plants Directive addresses the issue of air quality and air emissions

The implementation of the Medium Combustion Plants Directive fills the regulatory gap at EU level between large combustion plants ($\geq$ 50 MWth), covered under the Industrial Emissions Directive (IED) and smaller appliances (heaters and boilers <1 MWth) covered by the EcoDesign Directive.

As a result, biomass combustion in facilities of various capacities whether used for electricity generation, combined heat and power and for heat are covered by corresponding EU legislation on emissions to air. Air emissions resulting from biofuels in transport are covered by the Euro 5 and 6 Regulation 715/2007/EC. This Regulation specifies emission limits for all important toxic pollutants. These include nitrogen oxides (NOx, i.e. the combined emissions of NO and NO2). The currently applicable NOx emission limit for new diesel passenger cars and light vans sold in the EU is 80 mg/km.

[187] http://ec.europa.eu/environment/industry/stationary/mcp.htm
[188] Id.

The Energy Efficiency Directive

The Energy Efficiency Directive[189] establishes a common framework of measures for the promotion of energy efficiency within the European Union. The Directive came into force by the end of 2012 and aims to to help the EU reach its 20% energy efficiency target by 2020. Member States have transposed the Directive's provisions into their national law by June 2014. The Directive brings forward legally binding measures to step up Member States' efforts to use energy more efficiently at all stages of the energy chain – from the transformation if energy to its distribution to its final consumption. Measures include the legal obligation to establish energy efficiency obligation schemes or policy measures in all Member States. These will drive energy efficiency improvements in households, industries and transport sectors. Other measures include an exemplary role to be played by the public sector and a right for consumers to know how much energy they consume. With respect to electricity generation the Directive emphasises to tap the potential of high- efficient cogeneration and district heating and cooling; new electricity generation installations and existing installations which are refurbished should be equipped, when a cost benefit analysis proves positive, with high-efficiency cogeneration units to recover waste heat stemming from the production of electricity. Special attention is given to small and medium installations to encourage distributed energy generation[190]

The Energy Efficiency Directive is supportive to the efficient use of biomass for energy purposes. It's emphasis on cogeneration of heat and electricity ensures that the biomass resources are used in an optimal way and prevent inefficient use so that it decreases the amount of feedstock needed for a unit of energy output. As such it helps to mitigate and decrease the impact of undesired risks.

The Waste Framework Directive (2008/98/EC)

The Waste Framework directive 'lays down measures to protect the environment and human health by preventing or reducing the adverse impacts of the generation and management of waste and by reducing overall impacts of resource use and improving the efficiency of such use'[191] the directive came into force in 2008 and replaced Directive 2006/12/EC that established the legislative framework for the handling of waste in the Community. The 2008 Directive was necessary to clarify key concepts such as the definitions of waste, recovery and disposal, to strengthen measures that must be taken in regard to waste prevention, to introduce an approach that takes into account the whole life-cycle of products and materials and not only the waste phase, and to focus on reducing environmental impacts of waste generation and waste management […]. Furthermore the recovery of waste and the use of recovered materials should be encouraged in order to conserve natural resources.'[192] An example of waste management principle is the extended producer responsibility to ensure that any natural or legal person who professionally develops, manufactures processes, treats, sells or imports products (producer of the product) has to take measures to e.g. accept returned

[189] *EC, 2012, Directive 2012/27/EC*
[190] *See the description of the Think Small First principle in Directive 2012/27/EC*
[191] *EC, 2008,* Directive *2008/98/EC.*
[192] id.

products or the waste that remains after those products have been used. The directive clarifies when substances or objects are by-products and not waste and it clarifies when certain waste ceases to be waste, laying down end-of-waste criteria. 'This directive should help move the EU closer to a 'recycling society', seeking to avoid waste generation and to use waste as a resource.'[193] The waste hierarchy principle lays down a priority order of what constitutes the best overall environmental option in waste legislation and policy: a) prevention, b) preparing for re-use, c) recycling, d) other recovery , e.g. energy recovery, and e) disposal.

The Waste Framework Directive has clearly described the waste hierarchy in which prevention is given the highest priority, followed by preparation for re-use, recycling, other recovery (e.g. energy recovery, as a least prioritized step), disposal. The directive also defines under which conditions waste should be regarded as 'by-products'[194] or under which circumstances waste reached a 'end-of-waste' status[195], due to the undergoing of one of the higher priority stages of the waste hierarchy.

In the amended Renewable Energy Directive[196] it is highlighted that the approach of the waste hierarchy might impact whether and how waste resources can be used. The amended RED refers to biofuels for transport, but in fact the Waste Framework Directive relates to all (energy) use of waste biomass.

"Directive 2008/98/EC of the European Parliament and of the Council (1) helps move the Union closer to becoming a 'recycling society', by seeking to avoid waste generation and to use waste as a resource. The waste hierarchy generally lays down a priority order of what constitutes the best overall environmental option in relation to waste legislation and policy. Member States should support the use of recyclates in line with the waste hierarchy and with the aim of becoming a recycling society, and whenever possible not support the landfilling or incineration of such recyclates. Some of the feedstocks that pose low indirect land-use change risks can be considered to be wastes. However, they may still be used for other purposes that would represent a higher priority than energy recovery in the waste hierarchy as established in Article 4 of Directive 2008/98/EC. It is therefore appropriate for Member States to have due regard to the waste hierarchy principle in any incentive measures for the promotion of low indirect land-use change risk biofuels or any measures to minimise incentives for fraud in relation to the production of such biofuels, so that incentives to use such biofuel feedstocks do not counter efforts to reduce waste or increase recycling and the efficient and sustainable use of available resources. Member States may include measures they are taking in that respect in their reporting under Directive 2009/28/EC."[197]

The Landfill Directive

According to the waste management hierarchy, landfilling is the least preferable option and should be limited to the necessary minimum. Where waste needs to be landfilled, it must be sent to landfills which comply with the requirements of Directive 1999/31/EC on the landfill of waste. The objective of the Directive is to prevent or reduce as far as

[193] id.
[194] See Article 5 of the Waste Framework Directive.
[195] See Article 6 of the Waste Framework Directive.
[196] EC, 2015, Directive (EC) 2015/1513
[197] Id.

possible negative effects on the environment, in particular on surface water, groundwater, soil, air, and on human health from the landfilling of waste by introducing stringent technical requirements for waste and landfills.[198]

The Landfill Directive defines the different categories of waste (municipal waste, hazardous waste, non-hazardous waste and inert waste) and applies to all landfills, defined as waste disposal sites for the deposit of waste onto or into land. Landfills are divided into three classes:

- landfills for hazardous waste;
- landfills for non-hazardous waste;
- landfills for inert waste.

As was stated in section 6.2 of BioSustain Technical Background report[199] the actual situation with respect to landfill of waste is still very different in the various EU Member States. On average in the EU about 31% of the Municipal Solid Waste (MSW) is landfilled. Only 6 EU Member States landfill less than 5% of their MSW and focus mainly on incineration of waste with energy recovery (electricity and heat). 14 Member States still dispose 50% or more (some up to more than 90%) of their MSW in landfills. MSW contains significant portions of biogenic fractions and that share is fractions for those countries where landfilling is still dominant. Based on Eurostat information the report indicated that the gross inland energy production from the biogenic fraction of MSW in 2012 was 8744 ktoe, about 7% of total biomass use for energy.[200] If all EU Member States would copy the MSW processing profile of the 5 member states with the lowest level of landfilling, and would develop to a balanced processing of composting/digestion, material recovery and incineration with energy recovery the gross inland energy production from the biogenic fraction of MSW could nearly double. This could impact the need for import of biomass.

The Landfill Directive, which came into force in 1999 introduced targets to reduce the amounts of biodegradable MSW going to landfill. By 2016 the level should go down to 35% of the 1995 level. From the argument in the previous section it could be emphasis to accelerate a policy approach towards a balanced energy and material recovery strategy.

In December 2015 the Commission adopted a Circular Economy Package, which included revised legislative proposals to amend the Waste Framework Directive and the Landfill Directive.[201] The key elements of the revised waste proposal include:

- A common EU target for recycling 65% of municipal waste by 2030
- A binding landfill target to reduce landfill to maximum of 10% of all waste by 2030
- A ban on landfilling of separately collected waste.

The Landfill Directive and the current proposed amendments may result both in risks and opportunities for the use of biomass for energy.

[198] http://ec.europa.eu/environment/waste/landfill_index.htm, site visited 8 March 2016
[199] Hoefnagels, R., Resch, G., Mantau, U, Pelkmans, L., 2016, Biomass supply potentials for the EU and biomass demand from the material sector by 2030, Technical Background report of the BioSustain study for EC DG Energy.
[200] Id.
[201] http://ec.europa.eu/environment/circular-economy/index-en.htm

An important issues relates to the possible competition for non-energy utilization of biomass.

The proposals for amendments of the Landfill Directive focus on a more ambitious recycling performance of municipal solid waste. This may result in improved management and separation of waste streams causing that also biogenic fractions will be reused rather than becoming available for energy generation. This will decrease the possible competition. It may lead to the situation that less energy from MSW is generated, for which other biomass resources need to be deployed.

Given the current status of MSW processing, with still a (too) high share of MSW being landfilled it can be expected that the focus to reduce landfilling tot 10% of all waste by 2030 will lead to higher volumes of MSW to be processed for either material and energy recovery. This will enable the possibility to develop a balanced approach by which the volumes of recycling and reutilisation will grow and problems of competition foe use in energy or non-energy market may be avoided.

Administrative cost analysis

Annex F

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25 Estimation of certification costs

25.1 Methodology

For this assessment, a qualitative and quantitative analysis is undertaken for each policy option to identify the main administrative costs carried by each kind of player involved (public administration & private operators). For the analysis, the Standard Cost Model methodology has been used, as described in the tool #53 of the Better Regulation "Toolbox".

In order to present a high level of detail of the assessment, the analysis follows the "step-by-step" method for the application of the Standard Cost Model. Some steps are generic and affect all policy options in the same manner, other steps will be adapted to the context of each policy option. For clarity, the main differences of each policy option analysis are highlighted.

An estimation of the number of actors involved in each policy option was carried out, building on data from relevant studies, official statistics and the results of the Green-X model. In order to allow for a suitable assessment of overall impacts of sustainability regulations, default outcomes on administrative cost for bioenergy producers are, in turn, incorporated in Green-X modelling.

25.2 Estimation of certification costs: Baseline Scenario

This part presents the results obtained in the estimation of the administrative costs supported by private operators. Option 1 is the baseline scenario, which includes provisions in the EU Renewable Energy Directive. The RED Directive introduced sustainability criteria for biofuels and bioliquids as a condition for their inclusion in national targets and for eligibility to financial support. Voluntary schemes of certification can be used to prove that RED regulation is met.

The main economic operators affected by current criteria are biomass producers of agricultural biomass, traders and biofuel producers. The most obvious cost incurred by agricultural biomass producers are certification costs to prove that RED criteria are met. The estimation considered only direct costs incurred by economic operators. Direct costs of certification include costs related to external verification, payable to the auditing company; and costs related to participation in the certification scheme (membership fee, fee based on volume of biomass or entity size, a fee per certificate).

The present estimation does not cover indirect costs. Indirect costs are the extra costs to meet sustainability criteria for the production and transport of biomass (costs related to preparation for certification and/or investments to comply with sustainability criteria).

Direct and indirect costs related to solid biomass certification can vary significantly depending on many variables: yield of the product, the certification scheme chosen, the handled volumes and the total production costs and prices. Certification costs can be reduced when larger product volumes are involved[202].

[202] Selecting a biomass certification system – a benchmark on level of assurance, costs and benefits (2012). NL Agency.

There are three different kinds of direct costs:

- **One-off costs:** annual fees (generally certification membership fees);
- **Recurring costs:** quantity dependent fees and other periodic costs (generally a fee per metric ton of biomass or biofuel certified);
- **Auditing costs:** fees for an external audit to become certified (preparation, field audit and reporting costs).

Methodology applied

For the estimation certification schemes were selected within the scope of the baseline scenario. The eight certification schemes for the certification of feedstock for biofuels and bioliquids are listed in **Error! Reference source not found.**.

Table 25-1: Scope of certification schemes

Certification Schemes Option 2	Types of biomass covered
Bonsucro	Sugar for bioethanol and food market; for the moment the emphasis is on sugar for the food
RSB	All feedstock for liquid biofuels
2BSvs	All feedstock for biofuels and bioliquids under the scope of RED
Rountable on Sustainable Palm Oil (RSPO)	Palm oil for food and biofuel market
RTRS	Soy for food, feed and biofuel market
REDcert	The certification system can be applied to all of the steps involved in the process, starting with production and collection of input materials through to processing in oil mills and the production of biofuels and liquid biofuels
NTA8080	All biomass feedstock for all types of biomass end-uses (electricity, heat & cold and transportation fuels)
International Sustainability & Carbon Certification (ISCC)	Solid, liquid and gaseous biomass from all types of origin, including wastes & residues

Each kind of cost was estimated separately: one-off costs, recurring costs and auditing costs. To estimate one-off costs the average was calculated of annual membership fees of all schemes considered. The same method was applied for the quantity dependent fees. For the auditing cost calculation a low and a high cost scenario was assumed. Finally an overall cost in €/ton was estimated considering all costs.

Two main assumptions were set up to make the estimation:

- Two kinds of entity-size were considered depending on the tons produced: A large-size entity produces 250,000 tons of biomass product and a medium-size 100,000 tons;
- Auditing costs: Two scenarios were considered, a low auditing cost scenario which involves 2 days of audit whereas a high auditing cost scenario involves 5 days.

Estimation and results

Overall results are presented in Table 0-2. Depending of the size of the entity and auditing costs, overall certification costs are between 0.27-0.36€/ton in average. Thus, for instance, the certification cost in average for a large entity with low auditing costs is 0.27€/ton of feedstock for biofuels.

Some differences have been found in the on-off costs (membership costs) among the schemes, the membership costs of Bonsucro is the higher among the schemes, 9,446 € for large entities, on the opposite side, membership costs of REDcert certification is quite slow compared with the rest of the schemes (250€ for large entities and 150€ for small entities). Besides, there are some differences in the quantity dependent fees. The quantity dependent fee is particularly low for NTA8080, 0.03€/ton, whereas the cost of RSPO is significantly higher, 0.74€/ton.

Table 25-2: Estimation considering all direct costs: yearly costs + quantity dependent fees + auditing costs (€/ton)

Entity size and auditing scenarios	Certification costs Policy Option 2
Large-scale & low auditing costs	€ 0.27
Large-scale & high auditing costs	€ 0.29
Medium-scale & low auditing costs	€ 0.30
Medium-scale & high auditing costs	€ 0.36

Table 25-3: Cost breakdown of direct costs of certification

<table>
<tr><th>Size of the entity</th><th>Yearly costs (average)*</th><th>Quantity dependent fees (average)*</th><th colspan="2">Auditing costs</th></tr>
<tr><td>Large-scale entities</td><td>€ 4,203</td><td rowspan="2">€ 0,23</td><td>Low</td><td>€ 4,000</td></tr>
<tr><td>Medium-scale entities</td><td>€ 2,297</td><td>High</td><td>€ 10,000</td></tr>
<tr><td colspan="2">* Yearly costs refer to certification membership costs
* Quantity dependent fee per metric ton</td><td colspan="3"></td></tr>
</table>

25.3 Estimation of certification costs: Policy Option 2

In this case, more economic operators need to comply with land criteria. The assumptions considered and the methodology applied are the same than the estimation of certification costs for option 1.

The main difference between the estimation for this option 2 and the estimation for the baseline scenario remains in the scope of the schemes selected. In this estimation, three schemes were selected by their wider coverage of biomass and an additional one specific for woody biomass was included in the selection. Two of the three schemes selected not only include agriculture biomass in their criteria; they also cover solid biomass (in plantations, agriculture and forests).

Methodology applied

For the estimation, the certification schemes selected are within the scope of Policy Option 2. All of them are schemes that covers the biomass used for energy production: NTA 8080, International Sustainability & Carbon Certification (ISCC) and Sustainable Biomass Partnership (SBP). NTA 8080 and ISCC are generic bio-energy schemes[203]. Generic bio-energy schemes include sustainability criteria for the production of biomass, in plantations/agriculture as well as in forests[204]. On the other hand, the SBP scheme is designed for woody biomass, mostly in the form of wood pellets and wood chips, used in industrial and large-scale energy production.

Table 25-4: Scope of certification schemes

Certification Schemes Option 2	Types of biomass covered
Sustainable Biomass Partnership (SBP)	Woody biomass, used in industrial and large scale energy production
NTA 8080	All biomass feedstock for all types of biomass end-uses (electricity, heat & cold and transportation fuels)
International Sustainability & Carbon Certification (ISCC)	Solid, liquid and gaseous biomass from all types of origin, including wastes & residues

As in Option 1, each kind of cost was estimated separately: one-off costs, recurring costs and auditing costs. To estimate one-off costs the average was calculated of annual membership fees of all schemes considered. The same method was applied for the quantity dependent fees. Finally an overall cost in €/ton was estimated considering all costs.
The same assumption of tons produced by entity size and auditing costs scenarios were used for this estimation.
Estimation and results

Overall results are presented in **Error! Reference source not found.** Depending on the size of the entity and auditing costs, overall certification costs are between 0.11-0.20€/ton on average. Thus, for instance, the certification cost in average for a large entity with low auditing costs is 0.11€/ton of biomass feedstock.

Although large differences have not been found in the one-off costs (membership costs) among the schemes, there are some differences in the quantity dependent fees. The quantity dependent fee is particularly low for NTA8080, 0.03€/ton, whereas the cost of SBP is significantly higher, 0.12€/ton.

[203] The scope of biomass is broad and includes solid, liquid and gaseous biomass. These schemes focus on biomass for all types of bio-energy applications, including transport biofuels, electricity and heating.
[204] Handbook on Sustainability Certification on Solid Biomass for Energy Production. NL Agency – *Ministry of Economic Affairs*

Other studies reached similar results. In Ryckmans, Y. and Andre, N. (2008) the Laborelec certification system from Belgium[205] was analysed. It was estimated that certification procedures costs less than 0.1% of the biomass fuel cost[206]. Comparing that result with the ranges estimated in the present analysis, certification costs are between 0.09-0.16% of one ton of wood pellet (assuming that one ton of wood pellet cost 125€)[207].

Table 25-5: Estimation considering all direct costs: yearly costs + quantity dependent fees + auditing costs (€/ton)

Entity size and auditing scenarios	Certification costs Policy Option 2
Large-scale & low auditing costs	€ 0.11
Large-scale & high auditing costs	€ 0.13
Medium-scale & low auditing costs	€ 0.14
Medium-scale & high auditing costs	€ 0.20

Table 25-6: Cost breakdown

<table>
<tr><th>Size of the entity</th><th>Yearly costs (average)*</th><th>Quantity dependent fees (average)*</th><th colspan="2">Auditing costs</th></tr>
<tr><td>Large-scale entities</td><td>€ 3,667</td><td rowspan="2">€ 0.08</td><td>Low</td><td>€ 4,000</td></tr>
<tr><td>Medium-scale entities</td><td>€ 2,333</td><td>High</td><td>€ 10,000</td></tr>
<tr><td colspan="2">* Yearly costs refer to certification membership costs
* Quantity dependent fee per metric ton</td><td colspan="3"></td></tr>
</table>

25.4 Estimation of certification costs: Policy Option 3

The main economic actors affected by new criteria are forest landowners or forest managers. Under this policy option, they have to follow SFM criteria and need to be certified through specific schemes on SFM.

It is worth mentioning the main differences between land criteria established by RED Directive and Sustainable Forest Management criteria. Despite there is no clear consensus on the definition of Sustainable Forest Management, criteria focus on forest

[205] A certification system for biomass for energy production in Belgium.

[206] Ryckmans, Y., Andre, N., Novel certification procedure for the sustainable import of wood pellets to power plants in Belgium, 2008, 4 p.

[207] Other results from different studies are similar to the figures presented in this analysis. Here below the main findings:

- In *Criteria for sustainable biomass production* was estimated that costs amount to between 0.1 - 1% of the overall costs of the main product;
- In Van Dam et al., *Overview of recent developments in sustainable biomass certification* was estimated that costs for the certification process itself and chain-of custody are (in case of large-scale operations) much lower, a range of 0.1 - 1.2% was found.

vitality, nutrients, soil erosion and water conservation. The main forestry certification schemes used (FSC and PEFC) do not cover GHG emission savings and biodiversity principles are only partially covered compared to RED criteria (RED considers important biodiverse grasslands protection).

Main Sustainable Forest Management schemes (FSC and PEFC) offer the possibility of group certification, therefore a group of several individual forest owners can be certified through issuing one certification. Thus, certification costs are shared by a number of forest owners and may lead to lower costs per member.
Main cost incurred by forest managers are those related to become certified to show compliance with Sustainability requirements of Forest Management.

There are direct and indirect costs related to forest biomass certification. Indirect costs are those costs related to preparations and activities to meet sustainability criteria (new production practices and changes in management planning). Direct cost are linked to the certification process itself.

In this section, an estimation of the Forest Stewardship Council (FSC) certification costs was made for two typology of forest size: forest less than 30,000 hectares has lower costs and forests larger than 30,000 hectares results to have higher costs (costs related with internal and external auditing activities). The estimation uses as a reference the schedule of fees applied for the FSC forest management scheme used by the German certification body DIN CERTCO[208].

FSC certification is one of the main SFM systems used to certify forest biomass at worldwide level. Its criteria considers biodiversity, soil, water, carbon stocks and forest management. This certification offers a 5 year certification cycle.

There are two kind of costs identified in main Sustainable Forest Management schemes:

- Initial certification costs: processing of application, consultancy for the preparation of external audit (invoiced by consultant), certification audit costs (on-site audit, audit report, certification of audit conformity), issuing of certificate and internal auditing costs incurred by the company interested in the certification;
- Surveillance costs: costs related to the annual audit required to maintain the certification (document review, on-site audit, audit report, certification of audit conformity and internal auditing costs incurred by the company interested in the certification).

Table 25-7: Cost structure of certification costs for FSC forest management certification

Initial certification costs (first year)	Surveillance annual costs (subsequent years 2, 3, 4 and 5)
Processing of application	Document review

[208] Schedule of fees available at http://www.dincertco.de/en/dincertco/produkte_leistungen/zertifizierung_produkte/umwelt_1/fsc__forest_management/FSCForestManagement.html

Initial certification costs (first year)	Surveillance annual costs (subsequent years 2, 3, 4 and 5)
Consultancy for the preparation the external audit (hiring costs of an external consultant)	On-site audit
Certification audit (on-site audit, audit report, certification audit conformity assessment)	Audit report generation
Issuing the certificate	Certification audit conformity assessment
Internal auditing costs undertaken by the forest biomass producer for its own preparations	Internal auditing costs undertaken by the forest biomass producer for its own preparations

Depending on the size of the forest, three assumptions were set up to make the estimation[209]:

- In the first year, the forest owner needs to hire an external consultant to receive advice and prepare the external audit costs:
  - The cost for a forest of less than 30,000 hectares is 5,000€
  - The cost for a forest of more than 30,000 hectares is 15,000€
- In the first year, the forest owner undertakes internal auditing actions related to its own preparations:
  - The cost for a forest of less than 30,000 hectares is 2,000€
  - The cost for a forest of more than 30,000 hectares is 6,000€
- Annually the forest owner undertakes internal auditing costs for the preparation of the subsequent audits:
  - The cost for a forest of less than 30,000 hectares is 1,500€
  - The cost for a forest of more than 30,000 hectares is 5,000€
- For an on-site audit of a certification body, 1 day is needed for a forest land-size of less than 30,000 hectares and 2 days are needed if the forest land-size is larger than 30,000 hectares

Estimation and results

Overall results in hectares per year are presented in **Error! Reference source not found.**. Depending of the size of the forest, yearly certification costs of FSC scheme are € 6,761 for a forest area of less than 30,000 ha, and € 13,395 for forests of more than 30,000 ha.

[209] Similar ranges were used in the report entitled *Sustainability Criteria & Certification Systems for Biomass Production* prepared by Biomass Technology Group for DG TREN

Table 25-8: Estimation of certification costs of FSC

Forest size	1st year	2nd year	3rd year	4th year	5th year	TOTAL	Yearly cost
< 30,000 ha	€ 11,514	€ 5,573	€ 5,573	€ 5,573	€ 5,573	€ 33,806	€ 6,761
> 30,000 ha	€ 26,788	€ 10,047	€ 10,047	€ 10,047	€ 10,047	€ 66,976	€ 13,395

Similar results were reached in the study carried out by Biomass Technology Group for DG TREN, *Sustainability Criteria & Certification Systems for Biomass Production*[210]. In that report, assuming 5 years certification cycle as well, it was estimated that biomass certification direct costs of a forest of 100 ha size are 76 €/ha/year, for 10,000 ha 1.22 €/ha/year and for 60,000 ha 0.34 €/ha/year.

Note about the reference used to estimate external costs related with the SFM certification process for forest owners and operators in Options 3a and 3b

External costs for forest owners are those costs linked with the SMF certification process. In order to achieve a realistic estimation using the Standard Cost Model (see point 5.1.2 of this report), external costs are aligned with the range of direct certification costs of SFM estimated by the same study mentioned in this Annex (see previous point).

In that study, direct SFM certification costs varies between 76 €/ha/year (for a forest size of 100 ha) to 0.34 €/ha/year (for a forest size of 60,000 ha). Using those results, a linear correlation (between the two variables: hectares of the forest and direct costs) has been used to assess the costs for a forest of 150,000 hectares (considered to be the average size of a SFM certified forest)211 which results to be 0.27 €/ha/year. This figure was considered in the Standard Cost Model to estimate administrative costs related with SFM certification procss for forest owners.

[210] Available at http://iet.jrc.ec.europa.eu/remea/sites/remea/files/sustainability_criteria_certification_systems.pdf

Price increases for Scenario Option 5

Annex G

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Executive summary

The following data sources were used as a proxy for price increases:

- Price peak 2007-2008

Between 2005 and 2007/08, pine pulp prices increased between 69% (Finland) and 101% (Estonia) as shown in Table 9. The average increase of 85% was used as a proxy for possible price fluctuations, as shown in **Error! Reference source not found.**.

Table 0-1: Annual pine pulp prices in Finland and Estonia US$/m3, 2005 – 2014 [1]

Year	Finland		Estonia		Average	
2005	$	30.4	$	31.0	$	30.7
2006	$	31.1	$	26.2		
2007	$	41.7	**$**	**62.5**		
2008	**$**	**51.3**	$	53.6		
2009	$	36.4	$	25.0		
2010	$	37.5	$	32.4		
2011	$	42.3	$	45.8		
2012	$	37.6	$	34.8		
2013	$	39.5	$	37.8		
2014	$	39.0	$	40.1		
Maximum price 2005 - 2014	**$**	**51.3**	**$**	**62.5**	**$**	**56.9**
Price increase EU forest products (stemwood)	69%		101%		85%	
Price increase extra-EU (FOB wood pellets)					24%	

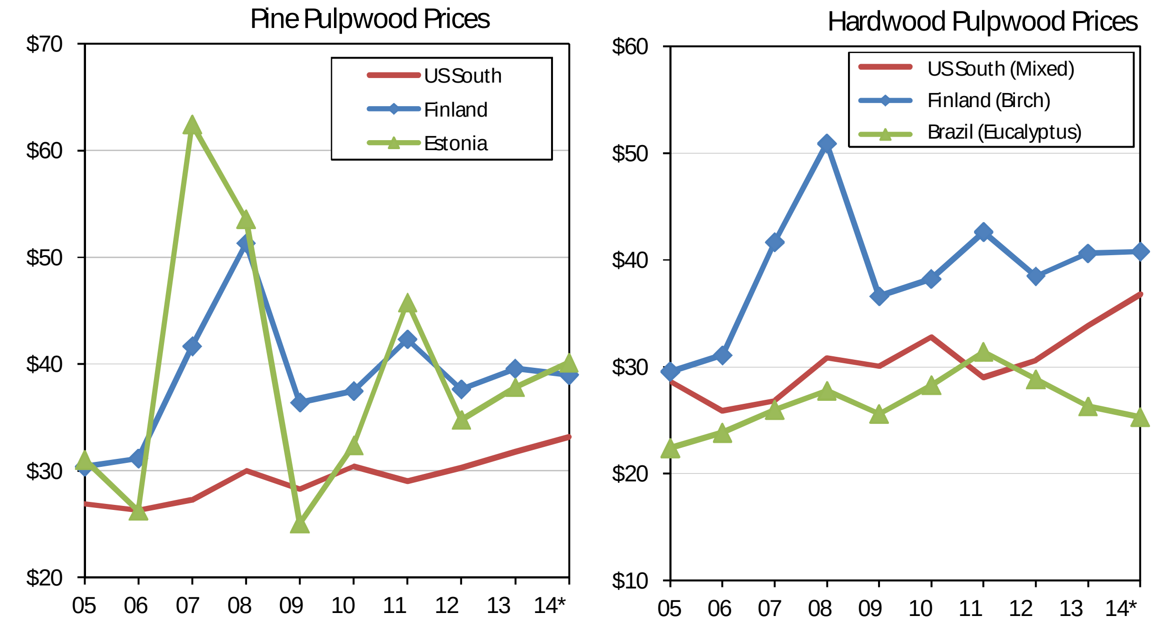
Extra-EU biomass prices are based on the increased cost of raw material compared to the FOB prices of wood pellets in export terminals. Raw biomass feedstock is calculated to contribute between 27% and 31% to FOB prices of wood pellets (105 – 117 €/t). Raw material cost was derived from Ehrig et al. [2] (28.06 – 33.5 €/t pellets).

Price peak 2007-2008

In the period 2007 – 2009, the sawn timber market experienced a strong peak caused by, amongst others a construction bubble, a strong Euro and import tariffs on timber. Due to the crisis, demand for timber collapsed in 2008-2009 with sawlog prices reaching an inherent floor.

For non-sawntimber markets, including pulpwood, such a strong peak in demand, followed by a collapse, did not occur. Pulpwood demand remained relatively flat and declined slightly in 2014, despite the increasing demand for energy markets. According to RISI (2015), the upward trend in pulpwood prices are mainly caused by weather conditions. High precipitation rates made it difficult to reach forest stands.

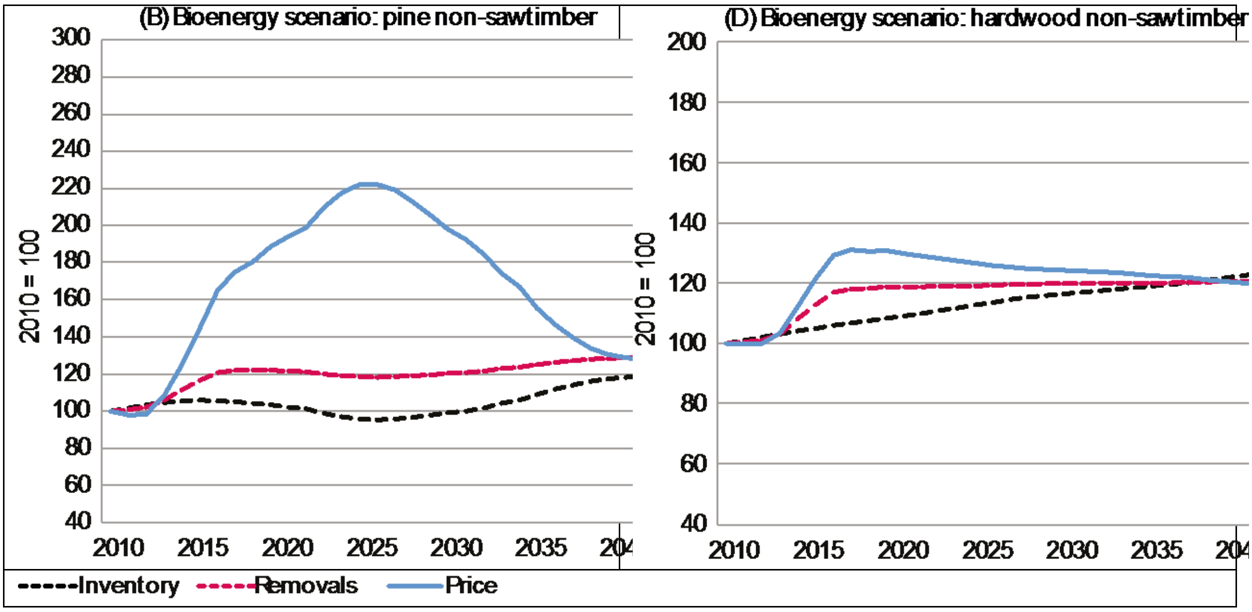
Figure 0-2: Annual pine and hardwood pulp prices in US$/m3, 2005 – 2014 [1]



* Based on the average of the dat a available.

The two key sectors that do compete for raw material are pulp and paper and oriented strand board (OSB). According to Pöyry, pellet plants are at the lower end of the wood paying capability (WPC) in the Southeast of the US and are therefore not a real competitive threat to traditional industries. Increased demand for wood pellets might however tighten supply – demand resulting in regionally occurring price increases. The two key sectors that do compete for raw material are pulp and paper and oriented strand board (OSB). According to Pöyry, pellet plants are at the lower end of the wood paying capability (WPC) in the Southeast of the US and are therefore not a real competitive threat to traditional industries. Increased demand for wood pellets might however tighten supply – demand resulting in regionally occurring price increases.

Figure 0-3: U.S. Coastal South projection of inventory, removals, and price indices for non-sawtimber projections in the bioenergy scenario for 2010–2040 [3]



Maxima derived from the graphs:

- non-sawntimber pine: 222 (2025)
- non-sawntimber hardwood: 130 (2015)

Note that Abt et al assume relatively high exports form the US Southeast in 2020 and no growth beyond 2020.

References

[1] RISI, "World Timber Price Quarterly - February 2015," 2015.

[2] R. Ehrig, F. Behrendt, M. Wörgetter, and C. Strasser, *Economics and Price Risks in International Pellet Supply Chains*. Springer Cham Heidelberg New York Dordrecht London, 2015.

[3] K. L. Abt, R. C. Abt, C. S. Galik, and K. E. Skog, "Effect of Policies on Pellet Production and Forests in the U.S. South A Technical Document Supporting the Forest Service Update of the 2010 RPA Assessment," Asheville, NC, 2014.