Delivery of sustainable supply of non-food biomass to support a
"resource-efficient" Bioeconomy in Europe

S2Biom Project Grant Agreement n°608622

D8.1
Overview report on the current status of biomass for bioenergy, biofuels and biomaterials in Europe

November 2016

About S2Biom project

The S2Biom project - Delivery of sustainable supply of non-food biomass to support a "resource-efficient" Bioeconomy in Europe - supports the sustainable delivery of non-food biomass feedstock at local, regional and pan European level through developing strategies, and roadmaps that will be informed by a "computerized and easy to use" toolset (and respective databases) with updated harmonized datasets at local, regional, national and pan European level for EU28, western Balkans, Turkey and Ukraine. Further information about the project and the partners involved are available under www.s2biom.eu.

Project coordinator

FNR Fachagentur Nachwachsende Rohstoffe e.V.

Scientific coordinator

Imperial College London

Project partners

About this document

This report corresponds to 'D8.1 Overview of the current status of biomass for bioenergy, biofuels and biomaterials in Europe' of S2Biom. It has been prepared by:

Imperial College London
14 Prince's Gardens, South Kensington, London, SW7 1NA
Dr Calliope Panoutsou
E-mail: c.panoutsou@imperial.ac.uk
Phone: + 44 755 734 1846

with contributions from: Marco Pantaleo (Imperial College London), Matthias Dees (University Freiburg), Berien Elbersen (Alterra/ DLO), Leire Iriarte (IINAS), Uwe Fritsche (IINAS), Branko Glavonjic (University of Belgrade; Forestry), Dejan Stojadinovic, Tetiana Zhelyezna (REA) and Dirk Carrez (CleverConsult)

This project is co-funded by the European Union within the 7th Framework Programme. Grant Agreement n°608622. The sole responsibility of this publication lies with the author. The European Union is not responsible for any use that may be made of the information contained therein.

Table of contents

Summary

This report provides an overview for the use of biomass for biomaterials, biofuels and bioenergy in the European Union, western Balkans, Turkey and Ukraine.

The current market share for bio-based products in EU28 is already significant and it is growing fast. Consumer awareness and product availability is increasing in European markets. Industry has expressed expectations for substantially higher market share from 2020 and beyond.

The respective market in the Energy Community Contracting Parties is highly focused on bioenergy (mainly heat and a few CHP/ DH plants) while the development of biobased markets is still quite slow.

Analysis of several recent published studies of biomass assessments in the period 2020-2030 shows that there is significant potential to expand the use of biomass for energy and materials in a sustainable way and without conflict with food and feed security. This is contrary to some of the common perceptions that have arisen from the "food versus fuel" debate.

These studies identify four sources that could provide additional biomass and support growth of bio-based industries, namely:

- field agricultural residues
- forest biomass
- wastes
- non-food crops.

All studies reviewed found significant under-utilisation of agricultural residues. Estimates for their potential are in the range 186 - 242 million tonnes per year by 2030, with availability depending on factors such as the strength of environmental regulations, for example protection of soil fertility.

It is estimated that EU forests could sustainably supply 615- 728 million tonnes per year of additional woody biomass by 2030.

A further source of biomass is waste from households and businesses. Estimates are in the range of 110 - 150 tonnes per year by 2030.

The fourth major source of biomass is dedicated production of industrial crops on agricultural land released from food production, for example the area of grassland required for dairy production is expected to reduce. Estimates are in the range 138 - 242 million tonnes annually.

In summary, the total potential for all four categories are in the range of 1,049 - 1,372 million tonnes of biomass which can be technically available within Europe by

2030 under sustainable practices.

To put this into perspective, compared to current use:

- the current consumption of wood from European forests is estimated to be 530 million tonnes (out of which 485 million tonnes in EU28 and the rest in W. Balkans, Moldova and Ukraine) per year.
- The annual consumption of agriculture based lignocellulosic biomass is estimated at 5-10 million tonnes (dry) but information relies on individual studies without recent harmonisation across EU.
- Estimates of annual wastes consumption reach up to 73 million tonnes.

Based on the above figures, a high level estimate of additional biomass for 2030 is in the range of 436- 760 million tonnes.

There are various ways in which such additional resource could be used by industry sectors, for example:

An additional 60 million tonnes of biomass used in the chemicals industry would approximately triple the current use and achieve an industry vision for 30 % of all chemicals to be bio-based by 2030.

Transport fuel consumption in 2030 is projected to reach 400 Mtoe in EU28. Biomass availability should enable 100 Mtoe or a 25 % contribution of advanced biofuels to the transport fuel mix. This translates to an average use of **** million tonnes lignocellulosic biomass.

Additional biomass would remain available for other biomaterial and energy uses i.e. production of electricity and heat. With the range found by the studies (described above), this could be expanded to in the region 300-400 Mtoe by 2030.

These additional biomass resources would represent transformation of the respective sectors. There is evidence that the resource quantities exist. There are significant challenges in terms of costs of raw materials, technical suitability and quality of resources and the investment required to exploit and deliver these resources in an economically and environmentally sustainable way. At the other end of the value chain, large investment is also required in human and physical capital to utilize these resources, mobilising support within sectors that have for used fossil-fuel resource for decades. This report provides further observations and data on these challenges.

Introduction

The aim of the report is to understand the current state of biomass use for bioenergy, biofuels and bio-based materials and appreciate the factors influencing the security and future prospects of their supply. Further to this, the final section provides an outline of the project's scientific contribution to advancing knowledge for lignocellulosic biomass value chains that will supply the European bioeconomy. Despite the fact that the S2Biom project focuses on lignocellulosic biomass, this overview covers a broader spectrum of biomass resources currently used in the biobased economy sectors to give evidence-based information and allow a comprehensive understanding of the overall situation in the different markets across Europe.

The European biobased economy in figures

This section presents an overview of current biobased products deployment in terms of markets; value chains, perspectives for sustainable growth of biomass supply as well as biomass costs for agricultural residues and woody biomass.

Markets of the European (EU28, Western Balkans, Moldova and Ukraine) biobased economy

The market share for biobased products in EU28 is currently limited but growth is fast. High expectations have been expressed by the industrial sectors for the share by 2020 with consumer awareness and product availability increasing in European markets.

A recent overall estimation of the **bioeconomy** markets in the EU has been provided in the staff working paper[1] accompanying the Commission communication on the bio-economy. In 2009 the bioeconomy in broad terms (including agriculture, forestry, food, pulp & paper, chemicals, etc.) accounts for more than 2000 billion € annual turnover and more than 22 million jobs.

The same study values the segment of **bio-based industries** at approximately 57 billion € in annual turnover with some 300,000 jobs involved. Bio-based industries in

[1] SWD(2012) 11 final 13.02.2012

this assessment include the following main categories: biochemicals and plastics (50 billion €); enzymes[2] (0.8 billion €) and biofuels (6 billion €).

Europe has a few small companies specialised in bio-based products and several major chemical companies developing bio-based applications[3].

In 2013, almost 10% (8 out of 79 million tonnes)[4] of the raw materials base for the **European chemical industries** was based on renewables, with sugar and starch having the higher share (1.56 million tonnes), followed by plant oils (1.26 million tonnes), bioethanol ETBE (1 million tonnes), natural rubber (1.06 million tonnes), pure bioethanol (0.46 million tonnes), animal fats (0.43 million tonnes), glycerine (0.41 million tonnes) and several other smaller categories.

	Current state	2020	2030
Bioplastics	• European Bioplastics: 280 kT (2013) • BioTic: around 1 B€	• European Bioplastics: 512 kT (2018) • BioTic: around 2 B€	• - • BioTic: around 5,2 B€
Biolubricants	• ERRMA: 137 kT (2008) • BioChem: 150 kT (2008)	• ERRMA: 420 kT (2020) • BioChem: 230 kT (2020)	• -
Biocomposites	• ERRMA: 362 kT (2010) • Nova institute: 315 kT (2010)	• ERRMA: 920 kT (2020) • Nova institute: 830 kT (2020)	• - • -
Biochemicals	• Chemical industry is estimated to use 8-10% renewable raw materials • BioTic: around 1 B€ (Chemical building blocs - 2013)	• The share of biobased chemicals is expected to be 20% • BioTic: around 1,5 B€ (Chemical building.g blocks)	• The share of biobased chemicals is expected to be 30% (BIC Vision) • BioTic: around 3 B€ (Chemical building blocks)
Bioenergy & biofuels	• BioTic: bioethanol around 4 B€ • Nova institute: biofuels (all) around 6 B€ (2011) • DG Agri: bioethanol 3,3 Mtoe (2013)	• BioTic: bioethanol around 11 B€ and 0,5 B€ aviation fuels • DG Agri: bioethanol 6,1 Mtoe (2023)	• BioTic: bioethanol around 14,2 B€ and 1 B€ aviation fuels

Figure 1 Current state and expected market shares by 2020 and 2030 for biobased markets in Europe

[2] Often applied as "intermediate products" in the bio-based industries, enzymes are proteins that are used to "catalyse" certain chemical reaction steps that are essential in the production process of biochemical or biofuels.
[3] EC Enterprise and Industry (2009): Taking Bio-based from Promise to Market – Measures to promote the market introduction of innovative bio-based products
[4] Sources: Cefic, VDI

Western Balkans

According to the FAO statistics[5], the value of agricultural production in the region of Western Balkans reached 11.8 billion USD in 2012, and production of roundwood - the most important forestry product in the region - increased to 21 million m^3.

Overall volume of the bio-based economy markets in the region of Western Balkans is not easy to estimate, mostly due to the absence of national bioeconomy strategies, comprehensive studies or sufficient statistical data.

Activities related to advanced bio-plastics, bio-lubricants, bio-composites, and bio-chemicals are rare, occurring mainly in the area of EU financed research and scientific programmes. Traditional biobased materials - wood products - play an important role in the use of biomass resources. Annual consumption of biomass for wood products was 0.99 million m3 in 2013.

Bioenergy is important in the region which covered 7.7% in Croatia, 12.2% in Serbia and 24.1% in Montenegro of total final energy consumption in 2013, using biomass[6]. Expressed in figures, total consumption of woody biomass on the Western Balkans was 32.1 million m^3 in 2013, out of which 23.2 million m^3 or 72.4% was used for energy purposes and 8.8 million m^3 was used for industrial purposes.

The main characteristic of woody biomass consumption in the form of firewood in all the countries in the region is the high inefficiency of firewood utilization which is manifested in large amounts of wood consumed for heating purposes compared to the size of the heated area.

Value chains

Biomass is already today an important resource with forest based raw materials having notably higher shares in biobased products and bioenergy than agricultural resources which in turn are dominant in food, feed and first generation biofuels.

Total amount of forest based lignocellulosic biomass used in the EU for energy and material uses in 2013 is estimated to amount to 485 million tonnes (530 million including WB, UKR, MD).

An estimated 261 million tonnes (with 245 in EU28) of wood used as a "classical" bio-based material primarily used in the woodworking and pulp and paper industry.

[5] FAO Stat 2014 - data for Montenegro and Kosovo* not included/available

[6] Based on Montenegro Energy Balance - MONSTAT, Energy balance of the Republic of Croatia, Energy balance of the Republic of Serbia

269 million tonnes (with 240 in EU28) of wood are used for production of energy (mainly heat and power).

Total amount of agriculture based lignocellulosic biomass ranges from 5-10 million dry tonnes per year but information relies on individual studies without recent harmonisation across EU.

In 2013, almost 10% (8 out of 79 million tonnes)[7] of the raw materials base for the chemical industries in the EU was based on renewables, with sugar and starch having the higher share (1.56 million tonnes), followed by plant oils (1.26 million tonnes), bioethanol ETBE (1 million tonnes), natural rubber (1.06 million tonnes), pure bioethanol (0.46 million tonnes), animal fats (0.43 million tonnes), glycerine (0.41 million tonnes) and several other smaller categories.

Biofuels are currently mainly produced from agricultural biomass, today mostly food crops. The estimated 2013 use of biomass in the EU for liquid biofuel production amounted to approximately 9 million tonnes of oil (of which 5.5 million tonnes were rapeseed oil) and approximately 18 million tonnes of starch/sugar crops (sugarbeet, wheat, corn & other cereals[8]).

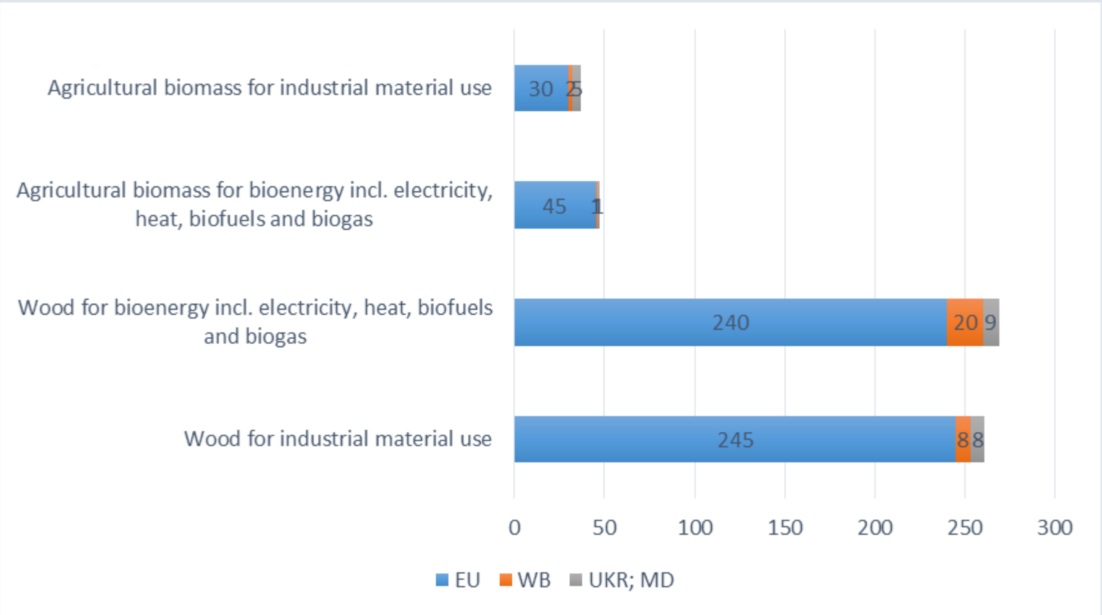

Figure 2 Agriculture (including lignocellulosic, sugar, starch and oil) and wood biomass used in biobased value chains in EU

[7] Sources: Cefic, VDI
[8] http://www.energies-renouvelables.org/observ-er/stat_baro/observ/biofuels_2011.pdf

Despite the fact that liquid biofuels are a subject of more active debate, on a weight basis, the use of **wood** for energy production (mainly heat and power) is estimated to exceed by a factor of more than four the use of **agricultural** biomass for energy production.

Table 1 presents the current and projected market volumes by 2020 for several bio-based products in Europe.

Table 1: Current volumes and future market prospects for several bio-based products in Europe[9]

Bio-product category	Bio-products	Market volume "Bio" 2010 (tonnes)	Projected market volume "Bio" 2020 (tonnes)
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**
Bio-lubricants (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	**372,000**	**920,000**
Bio-solvents[10]	(2012)	630,000	**630,000** [11]
Bio-surfactants [12]	(2012)	**1,520,000**	[13]
Biofuels total	(2011)	12,414,000	12,500,000[12]
Total		**14,738,000**	**≤ 20,000,000**

In the textile sector, the share of bio-based activities is estimated to be around 50 % (based on natural fibres).

[9] Source: Busch & Wittmeyer, Current market situation 2010 and market forecast 2020.
[10] Figures by Industries & Agro-Ressources IAR
[11] To be estimated by respective CEFIC sector groups
[12] http://www.sustainablebiofuelsforum.eu/images/ESBF_Biofuels_Production_in_the_EU_MetricTonnes.pdf

In the chemical industry, experts estimate that the current share by volume of bio-based inputs is approximately 10 %, with a higher fraction for specialty and fine chemicals and a lower fraction for polymers and other bulk chemicals.

Residual fractions and waste streams are still of limited relevance in the overall picture of biomass-based energy and materials production.

Table 2: The requirements and performance of each industry in relation to projections for 2030

Industry	Current state of market	2030 target	Investment required	Estimated turnover	Jobs
Chemicals: EU sector represents 21% of the world's chemicals, employs 1.2 million workers and contributes €491 billion to the EU economy.	in 2010 the European chemical industry is estimated to use 8-10% renewable raw materials to produce various chemical substances [13] Based on a McKinsey report biotechnology account for €30 billion in value in the EU in 2010	30% of overall chemical production is biobased.	-	If the 2010 figures are almost tripled, then the biotechnology could account for more that €82.4 billion in value in the EU in 2030	The McKinsey report estimated that the share of biotechnology in the employment of the chemicals sector was 190.000 jobs in 2011 (with an average 10% of biobased share), so the 2030 figures could reach up to 600.000 jobs.
Transport	In the biofuels sector, EurObserv'Er[14] estimates an aggregated cumulated employment level for the EU-27 close to 151.200 and a turnover of around €13.3 billion for 2010. This is the result of a 4.7% of transport fuel in the respective year.	25% of Europe's transport energy needs are supplied by biofuels, with advanced fuels	To meet 25% of the EU-27 transport energy needs with second generation biofuels, an average of 80 million litres of fuel is required. Using an indicator of €1.22 per litre of annual capacity[15] the total investment required reaches up to € 98 million.	Based on the 2010 figures, a five-fold increase in turnover could reach up to €67 billion for 2010.	Based on the 2010 figures, a five-fold increase in jobs can be projected reaching up to 750.000 jobs for 2030

[13] The Commission report "A lead market initiative for Europe - Explanatory Paper on the European Lead MarketApproach: Methodology and Rationale", pages 63-64. An estimate from Fachagentur Nachwachsende Rohstoffe is 8% in2003. A McKinsey report estimated the share to 10% in 2010.
[14] http://www.eurobserv-er.org/pdf/barobilan11.pdf
[15] Bloomberg New Energy Finance, " Moving towards a next generation ethanol economy", 2012

Industry	Current state of market	2030 target	Investment required	Estimated turnover	Jobs
Paper and pulp	€ 75 billion turnover in 2012 and 185.000 jobs (60% of direct & indirect jobs in rural areas") €15 billion value added to EU GDP (2012)	Traditional fibre products such as paper remain 100% biobased	Approx. 100 billion €[16]. That equates to 6 billion €/ year, compared to recent investment levels of 5.5 billion €/year.	-	-
Heat & Electricity	The turnover of the EU energy sector (covering electricity,gas, steam and hot water supply) was €940 billion in 2007. There were more than 26,800 companies in the sector, employing some 12.2 million people, and the industry contributed €200 billion of value added.	30% of Europe's heat and power generation is from biomass. Based on the WEO 2009 reference scenario, the total heat & electricity capacity will increase 1.2% annually, growing from 804 GW in 2007 to 1,067 GW in 2030.	Using an indicator of € 3 million/ MW, the total investment required 356 GW (30%) amounts to almost € 1 trillion	356 GW installed capacity can generate approximately 2,9 million GWh. With an average selling price of € 80/MWh[17], the estimated annual turnover can be over € 200 billion/year.	Using an indicator of 2 direct jobs per MW[18] the total direct jobs for 2030 can reach up to more than 700.000. If the indirect jobs from the supply chain are added to this figure then the number can reach up to 1 million jobs by 2030

[16] http://www.unfoldthefuture.eu/uploads/CEPI-2050-Roadmap-to-a-low-carbon-bio-economy.pdf
[17] http://2011annualreport.edprenovaveis.pt/creating-value/financial-performance/europe/
[18] Domac J, Richards K. Final results from IEA bioenergy task 29: socio-economic aspects of bioenergy systems. In: Proceedings from 12th European conference on biomass for energy and climate protection, Amsterdam: The Netherlands; 2002. p. 1200–04.

Perspectives for sustainable growth of biomass supply

A potential increase in the share of energy and materials derived from biomass in the 2020 to 2030 timeframe, can be achieved by:

- making better use of biomass resources as they already exist today (e.g. forest resources, agricultural residues and biowaste streams)
- producing greater quantities of biomass as well as more types of biomass by, for example, increasing agricultural productivity, using under-utilized land, expanding production of specific non-food biomass crops.

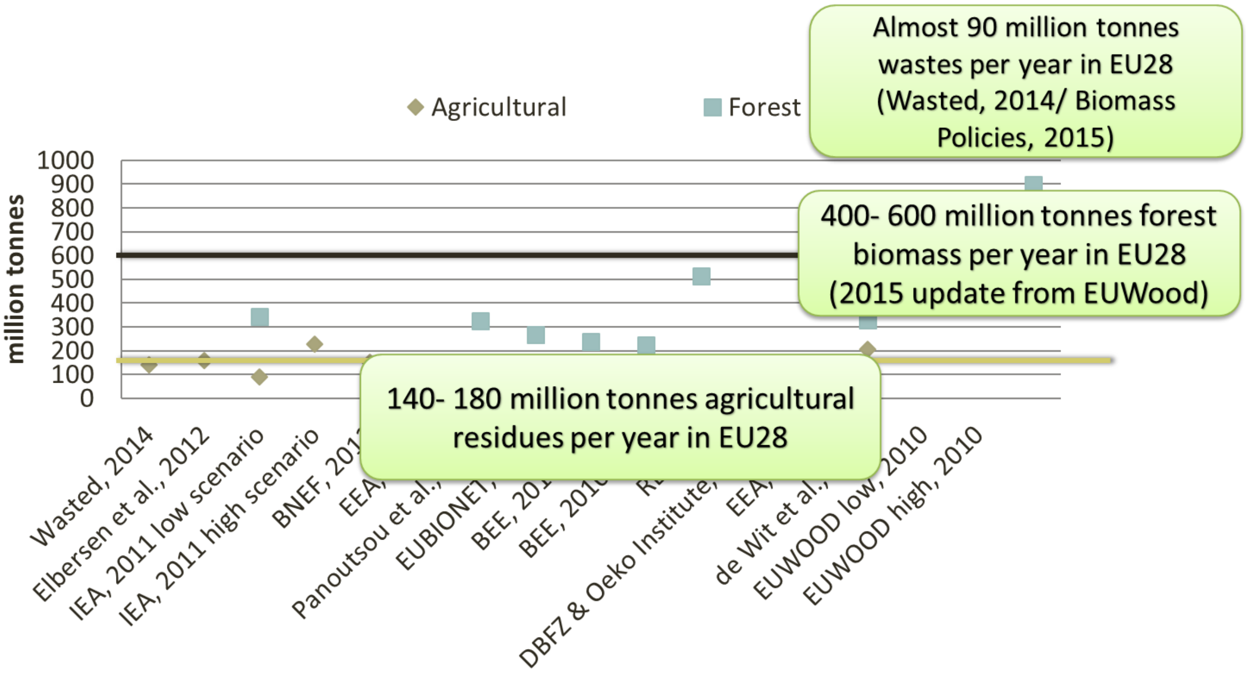

Figure 3 The resource efficient base (in dry tonnes of potential including currently used) to supply the European bioeconomy to 2030: Forest, agriculture and wastes

Progress will also depend on advances in biomass conversion technologies (e.g. making new types of biomass accessible to efficient conversion) and on possibilities to use biomass in a smarter way (e.g. producing multiple products from a single source material).

The "food versus fuel" debate sometimes creates a perception that there is limited scope for greater or better use of biomass for energy and/or materials production.

An outlook of several in-depth studies on biomass potential is presented in Figure 3, in a high level attempt to estimate the future availability of lignocellulosic biomass in EU.

All the reviewed studies conclude that there is significant potential to expand the share of energy and/or materials production from biomass in a 2020 to 2030 timeframe in a sustainable way and without entering into conflict with food and feed security.

A range of estimates for EU and Energy Community (Western Balkans, Ukraine, Moldova) is available for **four major sources of biomass** that could support further growth of the bio-based industries as compared to the current status i.e. field agricultural residues, forest biomass, wastes and land available for non-food crops.

A first source of biomass relates to different **types of agricultural residues** that are currently underutilized. Estimates range from 186 Million tonnes to 252 Million tonnes in the 2030 timeframe.

The lower estimates put strong restrictions on collection of agricultural residues, e.g. for reasons related to protection of soil fertility.

A second source of biomass relates to **additional biomass from sustainable forestry**. Estimates range from 615 Million tonnes to 728 Million tonnes in the 2030 timeframe. Compared to an estimated current use of 530 Mio tonnes, it is estimated that EU forests could sustainably supply between 85 and 198 Mio tonnes of additional woody biomass by 2030.

A third source of biomass relates to **wastes,** mainly deriving from households and businesses which also produce a considerable amount of cellulosic material in the form of unused food and garden waste, such as lawn and tree cuttings, with previous estimates in the range of 110-150 million tonnes per year in EU for 2030.

A fourth major source of biomass relates to **dedicated production of industrial crops on released agricultural land**, e.g. as a result of a reduction in the need for grassland for dairy production. Estimates for the EU in 2030 are in the range of 84 to 180 million tonnes of biomass while the respective figures for Western Balkans, Moldova and Ukraine add another 54- 62 Million tonnes. So, in total the estimates for the production of industrial crops in EU28 & Energy Community are totalling a range of 138- 242 million tonnes.

The overall figures for all four categories are in the range of 1,049 – 1,372 million tonnes of biomass which can be technically available within Europe by 2030 under sustainable practices. A consolidated picture then emerges, indicating that in addition to current uses of biomass there are two potential ranges:

- Low range: some 176 Million tonnes of agricultural residues + 85 Million tonnes of forest material + 37 Million tonnes of wastes+ 144 Million tonnes of biomass from industrial crops could serve as sustainable feedstock for new bio-based industries. **This represents a total "additional biomass potential" of 436 Million tonnes.**

- High range: some 242 Million tonnes of agricultural residues + 198 Million tonnes of forest material + 77 Million tonnes of wastes+ 242 Million tonnes of biomass from industrial crops could serve as sustainable feedstock for new bio-based industries. **This represents a total "additional biomass potential" of 759 Million tonnes.**

Table 3: Estimates for dedicated production of industrial crops on released agricultural land

Study	Cropped Biomass Potential (million dry tonnes)	Comments
Commission's 2030 impact assessment for BBI JU (2014)	84- 180	The impact assessment estimates **7-12 million ha** being available for biomass crops. We assumed that the low value will result in 84 million tonnes by using an average crop yield of 12t/ha while the high mobilization will result in 180 million tonnes by using an average crop yield of 15t/ha
World Bank, 2015. ''Sector Study on Biomass-based Heating in the Western Balkans'':	26	Part 1 - Regional assessment of technically available and sustainable biomass resource potential for heating in the Western Balkans According to Allen et al.**Error! Bookmark not defined.**, expected yields for energy crops that are grown on land that is marginal for agriculture at commercial scale, may range from 4.7 to 11.5 dry tons/ha. In this study an annual yield of 4.7 dry tons/ha was conservatively adopted. Data for Moldova and Ukraine were estimated.
Biomass Policies (2015)	230	**20 million ha** in 2030, reference scenario - Biomass Policies project
EEA, 2012	217	**16.7 million ha** available in 2020 in Storyline 1 (economy & market first)
Biomass Futures, 2012	234	**18.8 million ha** in 2030, reference scenario - Biomass Futures project
REFUEL, 2010	575	Agricultural land potentially available for growing biofuel feedstocks in 2030: EU27 & Ukraine/ LU-Env scenario: **44.2 million ha**

To meet the industry vision for 30 % of all chemicals to be biobased by 2030 – increasing from current share of approximately 10 % - would mean that biomass use for production of chemicals will need to be multiplied by a factor of approximately three (3). Today's production of chemicals is primarily derived from food crops, with an estimated use of less than 30 Million tonnes (this figure includes textiles). Extrapolating from the current status (and assuming the use of food crops is maintained at the current level) we can thus estimate that allocating around 60 Million tonnes or only 10 % of the "additional biomass potential" to industrial materials uses should go a long way in supporting the projected transformation of the chemical industry to much greater use of bio-based resources.

This overall estimate makes abstraction of specific types of biomass available and is obviously based on the assumption that suitable conversion processes will be developed for the types of biomass that is actually available.

If 'industrial materials' targets can be reached with 60 Million tonnes, 400 - 650 Million tonnes of biomass is left for energy related uses over and above current energy uses. This represents an energy equivalent of 273 - 440 Mtoe. With projected transport fuel consumption in 2030 at 400 Mtoe, biomass availability per se is not an obstacle to reach 100 Mtoe or a 25 % contribution of advanced biofuels to the transport fuel mix, thereby liberating the 30 Million tonnes of agricultural materials currently dedicated to first generation biofuels.

In fact, an additional 170-340 Mtoe would remain available to expand other types of energy and non-energy uses.

Cost assessment

In Europe, recent analysis of four biomass feedstock types and supply chains identified feedstock costs of between 67.2 and 107.2 €/ tonne for European sourced woodchips[19]. Local agricultural residues were estimated to cost 58.5 to 73.5 €/tonne. Imported pellets from North America are competitive with European wood chips if they must be transported from Scandinavia to continental Europe[20]. These are only average representative examples, and one should bear in mind that there will be significant variation in actual feedstock costs, depending on the actual feedstock origin and project details[21]. Some more analytical costs are presented in the following sections per EU Member State for the agricultural residues and forest

[19] European Climate Foundation et al., 2010
[20] According to the report, at present forest residues and agricultural residues are only utilised to a significant extent in Scandinavia and Denmark respectively and there are only two pellet mills in the world with a production capacity of 500 000 tons per year or more.
[21] For pellets the heat value considered was 16 900 kJ/kg and moisture content of 10%.

biomass categories.

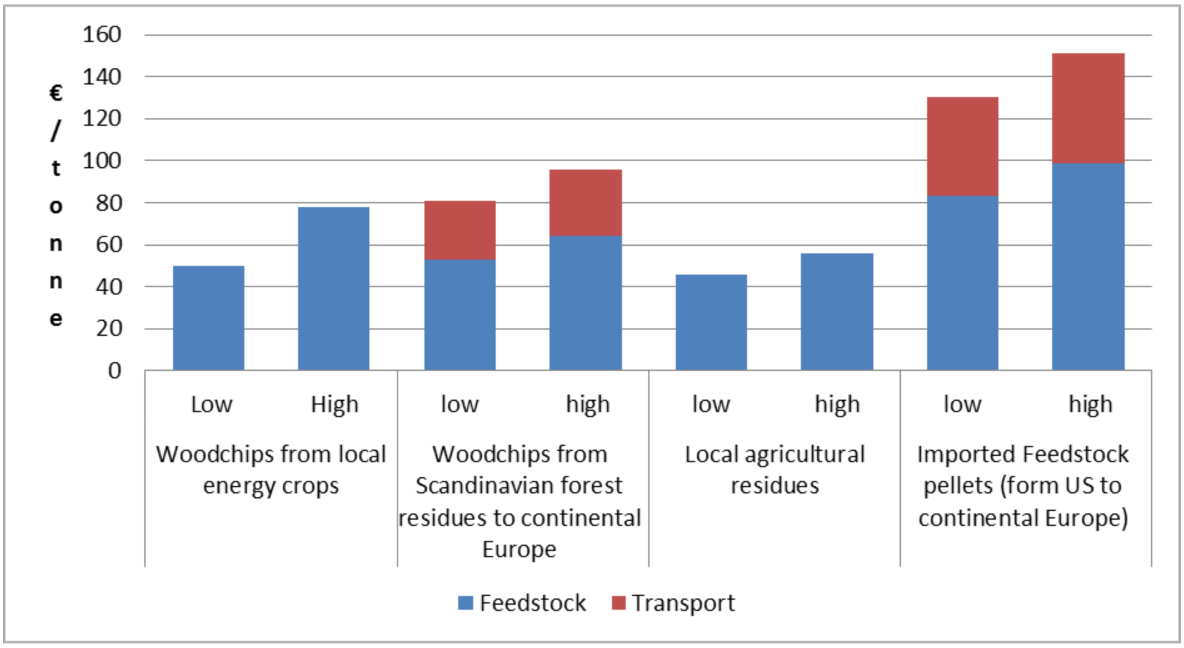

Figure 4 Biomass feedstock costs including transport for use in Europe (€/ tonne)

Costs and potential revenue from agricultural residues

Bloomberg New Energy Finance (BNEF) report[22] states that industry consensus suggests agricultural residue delivered gate prices will be between 50- 100 €/ tonne.

If we assume that an average EU gross margin for cereals[23] farmers is around 400 €/ ha[24] and that the average productivity of cereals is 4t/ha with an equivalent of 2 t/ ha straw (main product to residue factor at 0.5) then with the above price range the farmer can increase his gross income by 100 – 200 €/ ha. These figures correspond to an increase of 25- 50%.

The figures are averaged for EU Member states and therefore distinct variations can be expected across Europe depending on country, climate, etc. Figure 4 presents the cost ranges per EU Member State for solid agricultural residues (mainly straw) based on two of the reviewed studies, Siemons [25] (2004) and REFUEL (2008).

[22] Bloomberg New Energy Finance, "Bioproducts: diversifying farmers' income. 2011
[23] Only small grain cereals, incl. wheat, barley, rye, not maize as the respective gross margins for this crop exceed 800 €/ tonne.
[24] http://ec.europa.eu/agriculture/rica/pdf/cereals_report_2010.pdf
[25] Siemons, R., Vis, M., v.d. Berg, D., Chesney, I. M., Whiteley, M., Nikolaou, N., 2004. Bioenergy's role in the EU energy market- A view of developments until 2020.

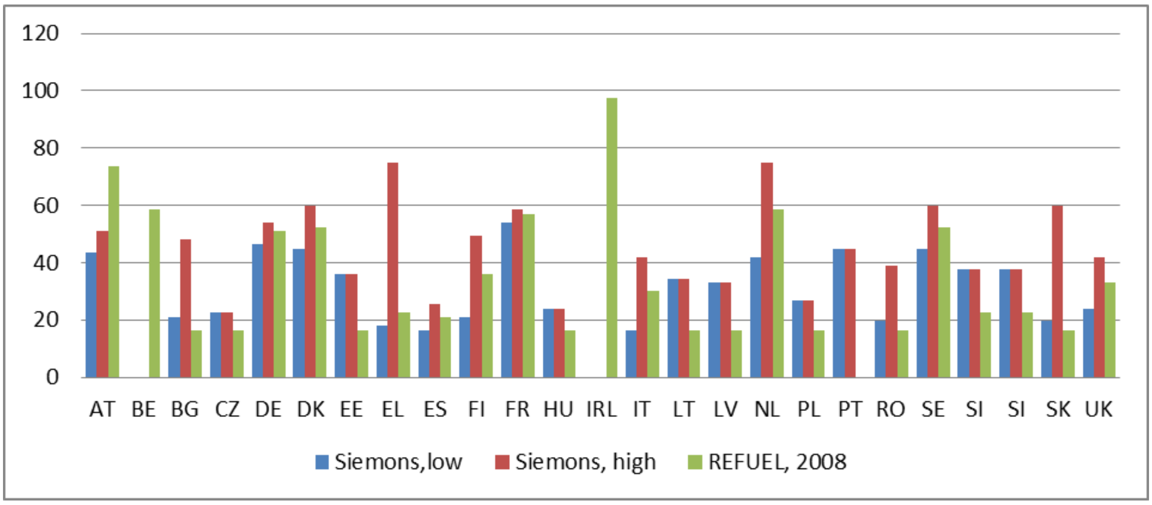

Figure 5 Costs for solid agricultural residues (mainly straw) in EU Member States (€/ tonne)

Concerning the region of Western Balkans, the main characteristic of the agricultural residues market is that it is still undeveloped. There are sporadic examples of the utilization of certain types of agricultural biomass, most often residues of cereal crops. The price of agricultural residues is negotiated bilaterally, between the seller and purchaser. According to Brkić 2013[26], average prices of straw in small bales in Serbia range from 44.5-49.6 EUR/ton, the prices of round bales are 43.0-47.1 EUR/ton, and the prices for large bales are 41.3-45.5 EUR/ton. These prices include purchase of straw, pressing, transportation, loading, unloading and storing. In other countries in the region (except Croatia), the majority of straw is still burnt in the field.

Woody biomass costs

Figure 6 below presents the cost ranges per EU Member State for refined wood fuels and wood industrial residues based on Siemons et al (2004). The most common range of costs is between 25- 65 €/ tonne, with a few higher and lower outlier costs. This cost is higher than agricultural residues, mainly reflecting the increased difficulty in harvesting and handling woody type resources as compared to agricultural residues.

[26] Brkic M., 2013.'' Resources and technical and technological problems of usage biomass'', Conference: Actual state and development of utilization of biomass for energy purposes in the Republic of Serbia, Chamber of Commerce of Serbia, Belgrade.

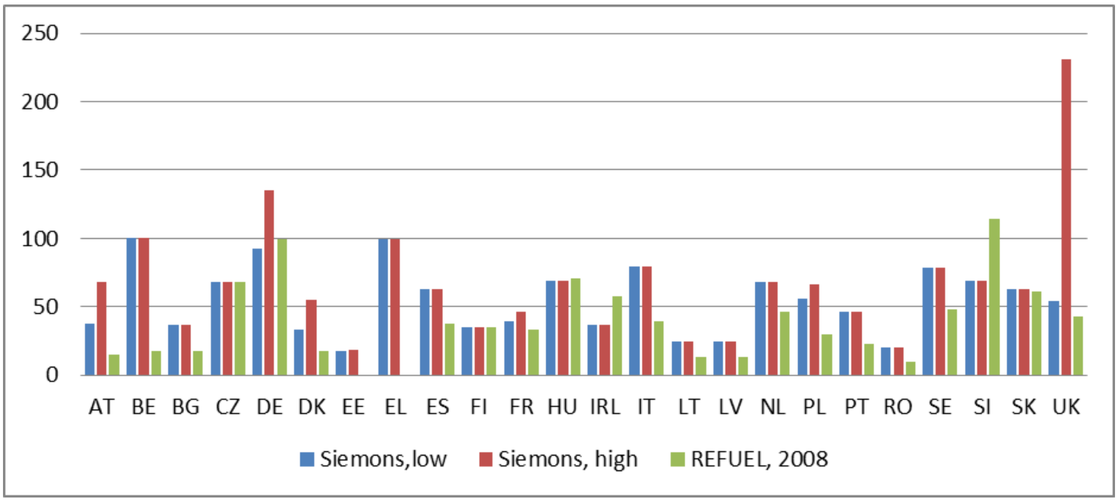

Figure 6 Costs for woody biomass types in EU Member States (€/ tonne)

Concerning the prices of woody biomass and wood biofuels, they have constantly increased in the last five years in all the countries in Western Balkans. Overview of average prices for firewood (1m) as the most common wood fuels in the period 2011-III quarter of 2015 by countries is given in **Error! Reference source not found.**7.

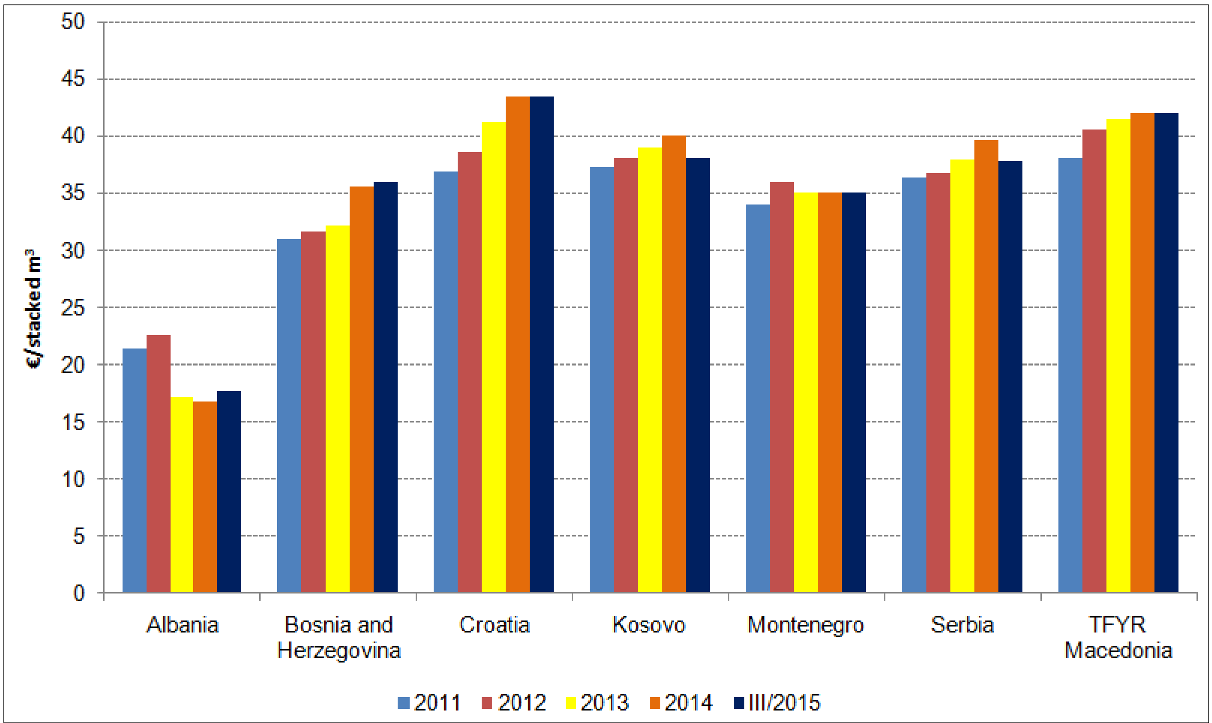

Figure 7 Costs for firewood (1 m) in Western Balkans countries (€/ stacked m^3)

The most common range of costs is between 35- 45 €/ stacked m^3 except Albania where the price of firewood is below 20 EUR/stacked m^3. Compared to the prices of 1m long firewood in Austria which was 93.5 EUR/stacked m^3, VAT included, in the

2nd quarter of 2014 (Metschina 2015), firewood prices in the region were 2.1 times lower in Croatia and up to 5.3 times lower in Albania in the same period.

General overview regarding wood fuel prices in the region of Western Balkans are the following:

- They are significantly lower than the prices in the developed EU countries;
- They largely depend on the prices of wood fuels imported into Europe from other parts of the world (especially wood pellets);
- They are influenced by the increase of prices for wood raw material and increase of other costs of production (primarily electricity);
- They are under a very strong negative impact of unarranged market and the related unfair competition operating in grey zone.

Concerning woody biomass residues in the form of sawdust and slabs, their prices are increasing year after year. Prices of sawdust in sawmills in the middle of 2015 loaded into container ranged from 12 EUR/ton in Albania to 25 EUR/ton in Serbia (2015). Dynamic price increase of woody biomass residues is best confirmed by the example that sawdust prices in Serbia in 2006 were 3 EUR/ton to reach 25 EUR/ton in the middle of 2015, which is the increase of more than 8 times. The situation is also similar with the prices of other types of wood residues.

Biorefinery options for Europe

This section provides an overview of biorefinery options in Europe in relation to resource types, conversion process and biobased products, logistics of supply, locations within Europe where they can be situated, capital expenditure requirements, potential for job creation and a short description of selected plants.

According to the project Biorefinery Euroview, "Biorefineries could be described as integrated biobased industries using a variety of technologies to make products such as chemicals, biofuels, food and feed ingredients, biomaterials, fibres and heat and power, aiming at maximising the added value along the three pillars of sustainability (Environment, Economy and Society)."

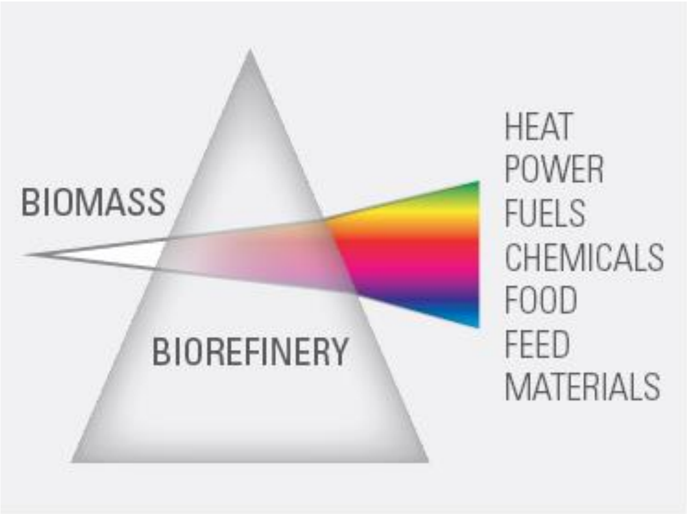

Figure 8 Schematic representation of the biorefinery concept[27]

Significant activities have been taking place in Europe in the field of biorefineries and most of the related industries have already implemented pilot projects. Recently, a set of targets[28] has been set which aims to cover a significant proportion of the overall European demand for chemicals, energy, materials and fibres in 2030 by using biomass as a feedstock for biorefining technologies. In detail:

- 30% of overall chemical production is biobased. For high added-value chemicals and polymers (specialties and fine chemicals) the proportion is more than 50%, whilst less than 10% of bulk commodity chemicals are derived from renewable feedstocks.
- 25% of Europe's transport energy needs are supplied by biofuels, with advanced fuels – especially biobased jet fuels – taking an increasing share.

[27] IEA Bioenergy Task 42 Biorefinery, 2009

[28] http://www.star-colibri.eu/files/files/vision-web.pdf; http://www.biobasedeconomy.nl/wp-content/uploads/2012/07/Bio-Based-Industries-PPP-Vision-doc.pdf

- The European market for biobased fibre and polymers such as viscose, carbon fibres, nano-cellulose derivatives and bioplastics will continue to grow rapidly. Traditional fibre products such as paper remain 100% biobased.
- A new generation of biobased materials and composites produced in biorefineries allow the production of lightweight, better-performing components for industries including automotive and construction.
- 30% of Europe's heat and power generation is from biomass.

This section presents a macro level overview of the potential biorefinery options for Europe to meet the targets in 2030 in terms of size, turnover, investment, jobs, geographic distribution and required logistics.

Starch/ Sugar biorefinery

The starch and sugar biorefinery processes starch crops, such as cereals (e.g. wheat or maize) and potatoes, or sugar crops, such as sugar beet or sugar cane. In Europe, the main application of this biorefinery is currently the production of starch derivatives, ethanol and organic acids, with the protein stream being used for food and feed and other co-products mainly going to animal feed.

Starting from a process stream based on starch and sugar crops, the plants will progressively use lignocellulosic feedstocks and integrate the fractionation processes by 2030. The first step will be the integration of cereal straw into the supply chain, followed by the use of dedicated lignocellulosic crops (mainly arable).

There will be a diversification of products from sugar and starch-derived C6-sugars (hexoses) towards other alcohols, chemicals and organic acids, as new biological and chemical processes to produce platform chemicals become available and competitive.

Agro-industries have long been involved in sugar extraction, starch fractionation, fermentation and distillation. With this level of expertise, they can easily integrate biotech processes for first and second generation bioethanol and, at a later stage, other fermentation products. The feedstock quantities used at each biorefinery location are in the range of 200,000 to 400,000 tonnes/year of dry biomass. These requirements should be met from locally produced feedstock, which makes for easier management of sustainability parameters in the overall production chain (carbon sequestration, nitrogen and other mineral nutrient cycles).

This model will lead to the development of small/medium scale rural biorefineries close to agricultural areas producing the required biomass. These rural starch and sugar biorefineries will be established in the most efficient production and supply areas. "Mid Europe" (from West to East Europe) is ideal for this.

Small-scale biorefineries that produce ethanol, biogas and protein for animal feed or human food are being developed at a scale of 10,000-50,000 tonnes of primary dry weight inputs[29]. Starch and sugar biorefineries may also be located at major centres for grain and sugar import. These are likely to focus on product diversification rather than the integration of lignocellulosic streams.

[29] Sanders, J.P.M.; Meesters, K.P.H., 2008. Method and installation for producing electricity and conversion products, such as ethanol

Table 4: Biorefinery in the European Industry; current state and bottlenecks to further development[30]

Biorefinery types	Current state	Bottlenecks
Sugar Industry	Most production is made into crystallised or liquid sugar for food applications. The residue of sugar beet pulp is used for animal feed, while molasses from the refining process goes into feed or is fermented to produce bioethanol. Sugar is also processed into alcohol for the drinks industry and used by the chemical sector in fermentation processes. Currently only 2% of total sugar production is used in non-food applications.	• Capitalise on synergies between the starch and sugar industries for fermentation applications • Use the cellulose-based pulp residue for the development of second generation fermentation products
Oil industry	Vegetable oil (or animal fat) is increasingly being used to make biodiesel (fatty acid methyl ester or FA ME), via the trans-esterification process, which produces glycerol as a by-product. Chemical and enzymatic modification of vegetable oil produces oleochemicals, such as fatty acids, alcohols, fatty esters, ketones, dimer acids and glycerol. Oleochemicals are primarily used in personal care products or as raw materials and additives in industrial applications[31] such as textiles, lubricants, household cleaners and detergents, plastic and rubber.	• Key bottlenecks are the oilseed feedstock cost and land availability for increased production. • Oil crushers and biodiesel producers' focus will be on process cost reduction and value creation through integration with downstream transformation.
Forest Industry	Some pulp mills have already transformed their businesses to derive value from compounds extracted from wood, creating higher value from what were previously "energy side-streams". These mills are, highly innovative and diversified biorefineries. Integrated pulp and paper mills are currently the best examples of wood-based biorefineries. Currently, wood-based chemicals are mainly isolated from pulping spent liquors and only a few processes are used to prepare or isolate any chemicals directly from wood or wood residues. Examples include the extraction of bioactive substances or other soluble compounds (such as tannins) from wood or bark. In addition, small volumes of essential oils are isolated from different tree species. Thermal processes are used to prepare tar and certain tar-derived fractions.	• Developing innovative products to fit with changing markets and meet customer needs • Developing intelligent, efficient and lower energy • manufacturing processes • Enhancing availability and use of forest biomass for products and energy • Meeting the multifunctional demands on forest resources and their sustainable management
Bioenergy & Biofuels	Much of the existing biorefinery network has a strong link to biofuel production, particularly: • Co-production of feed (DDGS) from ethanol and pressed cake from biodiesel • Co-production of glycerol from biodiesel, used in the cosmetic and chemical industries • Co-production of CO 2 from ethanol manufacture, used for horticulture or soft drinks	• Enlarging the feedstock base • Developing processing technologies for a wider range of feedstocks and increasing the efficiency of conversion to valuable biofuels

[30] Star Colibri, www.star-colibri.eu/files/files/vision-web.pdf
[31] Frost & Sullivan, 2007. The impact of green trends in the European oleochemicals market, Jul-2007. http://www.frost.com/prod/servlet/market-insighttop.pag?docid=102601717.

Biorefinery types	Current state	Bottlenecks
		and other products • Minimising overall energy consumption and improving environmental footprint of biofuels
Chemical industry	Today, biorefining operations in the chemical industry are based largely on either sugar or starch and vegetable oil. Integration of primary and secondary processing of the raw material remains limited. The chemical industry uses sugar or starch for fermentation or chemical processing as a “green” alternative to oil-based feedstocks to make products with the same functionality and performance[32]. Raw materials for oleochemical production come from the well-established world market for vegetable oil and there is no integration with the companies doing the primary processing of the oil. Most biobased chemicals and oleochemicals are high value-added, speciality chemicals. Some integration of biomass primary processing with chemicals manufacture is emerging, with the diversification of product streams from some agro-industries (e.g. starch producers) towards chemical intermediates (lactic acid, succinic acid, etc.) and speciality chemicals (e.g. polyols)[33]. Choice of the right starting molecules to minimise energy inputs and capital costs – as is the practice in the petrochemical industry – can help to build efficient processes and extract greater value from some biomass-derived chemicals. One example is the use of glycerol to produce epichlorhydrin: Solvay has built two factories since 2007. This process produces the bulk chemical without the need for chlorine, which reduces energy needs considerably. Another example of the use of appropriate molecular structures present in plants is the manufacture of amino acids from biomass residues[34].	• Resource efficiency and the development of renewable alternatives • New routes for cost-competitive plug-in building • blocks from biomass Improving competitiveness and increasing availability of biomass feedstock, for example by breeding better adapted, dedicated crop varieties, pre-processing/ compaction of biomass for more efficient transport, and more efficient processing of lignocellulosic biomass • Reducing the costs of biological processing through increased efficiency and the integration of processes to minimise energy, water, and raw material use Integrating chemical and biological processing steps • Exploiting specific molecular structures from plant components • Developing biotech crops which express useful intermediate chemicals.

[32] World Economic Forum report The Future of Industrial Biorefineries. http://www3.weforum.org/docs/WEF_FutureIndustrialBiorefineries_Report_2010.pdf
[33] Scott, E.L.; Peter, F.; Sanders, J.P.M., 2007. Biomass in the manufacture of industrial products - the use of proteins and amino acids, Applied Microbiology and Biotechnology 75 (4). - p. 751 - 762.
[34] Haveren, J. van; Scott, E.L.; Sanders, J.P.M., 2007. Bulk chemicals from biomass. Biofuels Bioproducts and Biorefining 2 (1). - p. 41 - 57.

Oilseed biorefinery

The oilseed agro-industry will change significantly over the next twenty years. In 2011, the major focus is on first generation biodiesel and the development of oilseed biorefineries with multiple product streams. With glycerol as the major by-product, a clear target is to develop an integrated process stream to make value-added products from this raw material. However, the development of oilseed biorefineries by 2030 will feature the introduction of new oleochemical process streams, based on long chain fatty acids from European oilseeds (mainly rapeseed and sunflower) and the progressive integration of these processes into the biodiesel production chain. This trend will be reinforced by the continuing evolution of European biofuel production, in particular the decreasing relative importance of first generation biodiesel due to its inefficient use of farmland.

With decreasing financial support for biofuels, and higher environmental constraints, it is likely that small-scale production of biodiesel from oilseeds will be reduced and will be mainly used for local energy requirements (e.g. for farms or rural communities). At the same time, medium/large scale production will increasingly focus on higher added-value applications such as jet fuels and oleochemicals.

Green biorefinery

A green biorefinery processes wet biomass, such as grass, clover, alfalfa, etc. This is pressed to obtain two separate product streams: fibre-rich press juice and nutrient rich pressed cake. The pressed cake fibres can be used as green feed pellets or as a raw material for chemical production. The pressed juice contains valuable compounds such as proteins, free amino acids, organic acids, minerals, hormones and enzymes. Lactic acid and its derivatives, ethanol, proteins and amino acids are the most profitable end-products which can be made from this stream[35]. The pressed juice residues are mainly used to produce biogas, itself then used to generate heat and electricity.

In 2030 many of these smaller scale green biorefineries can be set up, as new industrial value chains are established in regions that traditionally produce high quantities of wet biomass, such as grassland areas.

Lignocellulosic biorefinery

There are two primary process routes: thermochemical and biochemical. The thermochemical approach uses heat to convert lignocellulosic feedstocks to syngas,

[35] Kamm, B., Gruber, P.R. & Kamm, M. (ed.), 2006. Biorefineries – Industrial Processes and Products. Status Quo and Future Directions. Vol. 1 and 2. WIL EY-VCH Verlag GmbH & Co. KGaA, Weinheim. p 441 + p 497.

which is then used to produce transport fuels and chemicals. Many different biomass types can be used as feedstock for this type of biorefinery: dry agricultural residues (e.g. straw, peelings, and husks), wood, woody biomass, and organic waste (e.g. waste paper, residues from waste paper pulping and lignin). These are relatively dry biomass feedstocks and well-suited for new thermochemical conversion processes such as gasification.

Vegetable oils are also suitable feedstocks. Depending on the heating conditions, so-called pyrolysis liquids or pyrolysis oil can also be formed. These are easy to handle (with good storage, atomisation and pressurisation properties) and transport and can be used as liquid fuels.

Another option is the biochemical approach which uses a primary biological refining step to fractionate lignocellulosic raw material into three separate raw material streams: cellulose, hemicellulose and lignin. These fractions then go into three separate process streams and are converted into value- added products. Cellulose can be hydrolysed to produce sugars which are then used as a fermentation substrate to make alcohols (e.g. ethanol), organic acids and solvents. The hemicellulose fraction can be converted to xylose, gelling agents, barrier agents, furfural and, further downstream, to nylon. Finally, lignin can be used to make binders and adhesives (glyoxalised lignin, for example, is being studied as a potential alternative to formaldehyde-containing resins for applications such as fibreboard panels). Alternative uses are the production of fuels or carbon fibres and as a feedstock for syngas production, itself a valuable feedstock for a range of uses.

The forestry-based pulp and paper industry has long experience of the logistics of production and use of woody and lignocellulosic biomass. It is therefore a good candidate for the introduction of thermochemical (gasification) processes, to convert woody biomass (forest biomass and residues or dry organic waste) to second generation biofuel and/ or chemicals from syngas. The industry also has access to a large amount of lignin, which is currently mainly used as an energy source. Greater value will be obtained by integrating processes for the chemical conversion of lignin. An in-depth study of lignin structure is needed to make the most of this raw material.

Agriculture is another source of lignocellulosic biomass. A range of agricultural residues and dedicated crops will be processed in lignocellulosic biorefineries, either as part of newly-developed industrial value chains, or to provide additional raw material streams for sugar/starch biorefineries. Agricultural lignocellulosic crops and residues are more likely to be processed via the biochemical route. It is assumed that the technical and economic barriers to lignocellulosic biomass fractionation will be solved over the current decade, and that both approaches will lead to commercially viable lignocellulosic biorefineries by 2030.

Logistics of supply

A key parameter for the cost efficient implementation of biorefineries is easiness of access to transport, for the year round supply of raw material. The cost of transportation to customers depends on distance and cost/quality of transport infrastructure. Recent findings from the Dalberg study report that Benelux, northern France, Germany and southern England have the best access to transport infrastructure. Also the potential customers in the chemical, rubber and plastic industries are mostly concentrated in Germany, France and the UK. This makes central Europe, one if the best options for biorefineries in the short term.

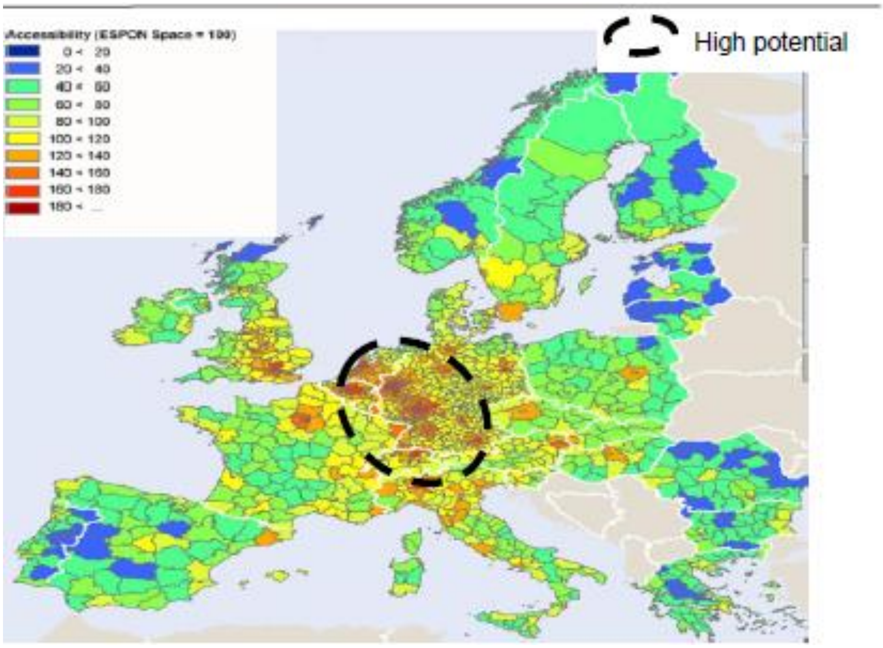

Figure 9 Accessibility to transport (as defined by ESPON)

Figure 9 combines level of economic activity in a certain region with the effort, time, distance and cost needed to reach that area.

Table 5 below presents the required logistics for a 10 tons/ day and a 100/ day biorefinery facility. The storage figures are based on the assumption that the plant will have a two-month storage capacity to allow for security in winter periods, etc. The estimated storage is based assuming an average pile height ~ 4m.

Table 5 Logistics for a 10 tons/ day and a 100/ day biorefinery facility

Plant capacity	10 tons/day	100 tons/day
Trucks[36]/ day	1	5
Quantity for 60 days security of supply	600	6000

[36] Estimation for trucks with capacity of 20 ton/ journey

Storage requirements (ha)	0.1	1

Locations that could support second-generation biorefineries

The location of the biorefinery should seek to optimize the plant's economics and operations, in order to provide the best simulation for larger-scale plants[37]. The importance of the location variables depends on the scale of the plant, the time horizon considered, local feedstock cost, transportation costs, synergies from co-location, and funding availability. There are numerous locations across Europe that would be attractive for bio-refineries, with different regions especially suitable for certain types of reactors (e.g. wood-based in Scandinavia). Figure 10 below presents the findings of a recent study[38] on the number of biorefineries that different European regions can support (based on the raw material supply potentials), the jobs created and their annual revenues.

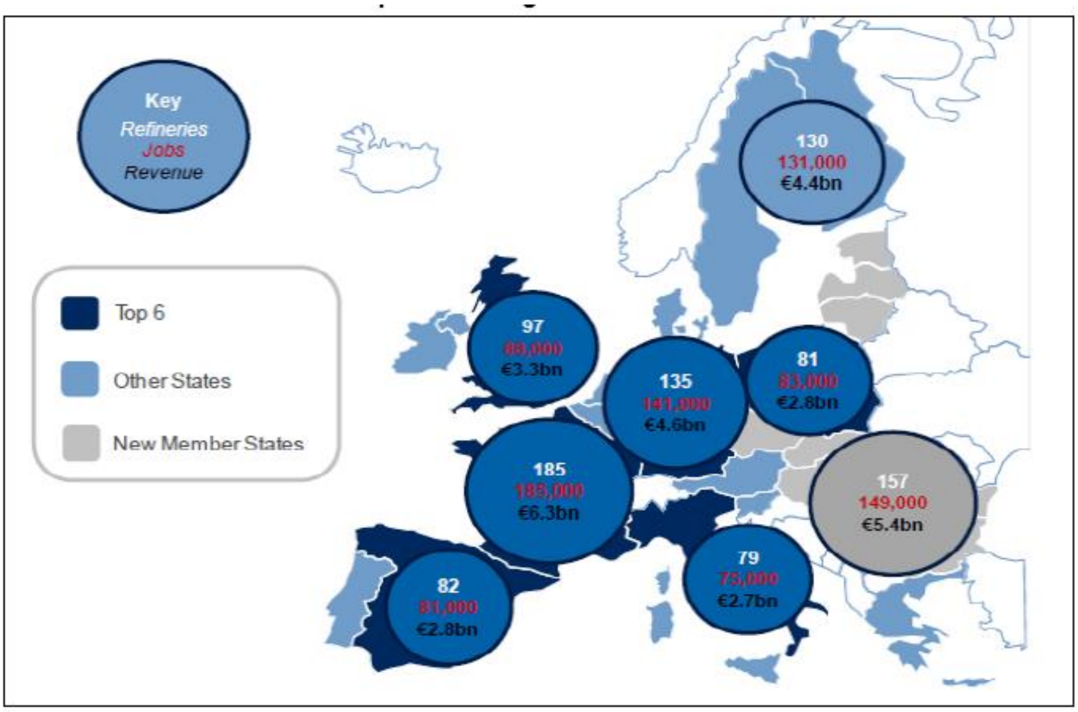

Figure 10 Locations of potential biorefineries in Europe, annual revenues and jobs

In the short-term, some EU countries (e.g. France, Germany, Belgium, the Netherlands, Denmark, UK, Sweden and Finland) are more attractive locations for a biorefinery (agriculture-based in central Europe and UK, wood-based in Scandinavia).

37 Dalberg Study on Biorefineries. 2011.

38 Bloomberg. 2012. The numbers of biorefineries are determined by the ability of each region or member state within the EU27 to supply bioproducts. Jobs in the chart represent the total man-years of employment between 2010 and 2020, not the number of jobs in 2020 alone. Included jobs are in management, operation and construction of the biorefineries. Revenues are per year

In the medium to long-term, different EU regions might improve their cluster landscape, funding schemes, and feedstock availability or transportation network. This would increase the number of potential good hosting regions for the biorefinery.

In the long-term – and as full commercial scale biorefineries emerge - other regions could become attractive locations for a biorefinery provided improvement in key location variables (e.g. Eastern Europe).

Capital requirements

Demonstration and pilot facilities are sensitive to the availability of local co-funding. At early stage facilities capex is the main cost to minimize while commercial scale plants are much more sensitive to operating costs. External financial support and co-location synergies have a high impact on funding needed and are key issues for demonstration scale facilities.

Feedstock costs are especially important for commercial scale facilities. It is worthwhile to mention at this point that countries with strong biorefinery activity offer advantages beyond financial support (upstream, midstream and downstream synergies).

Based on the findings from the Dalberg study[39], the estimated capital requirements for second generation biorefinery demo facilities are:

- For a 10 dry biomass tonnes/day facility of biological enzymatic conversion of agricultural residue, hard wood and energy crops into C5 and C6 sugars and ultimately chemicals, materials and energy: the investment would be approximately € 25-50 million per bio-refinery.
- For a 100 dry biomass tonnes/day facility of thermo-chemical conversion of wood and black liquor into chemicals, materials, fibres and energy. The investment would be approx. € 150-200 million per bio-refinery.

BNEF[40] recent study reports that the investment requirements for total facility costs for a next-generation ethanol refinery will be approximately €1.22 per litre[41] of annual capacity.

There is also a strong economies of scale: a facility twice the size will only be ca. 1.6 times the cost (scaling factor of about * 0.7). The first ever facilities built will be considerably more expensive than later facilities. Similarly, building on existing facilities will allow building on accumulated knowledge and skills. In addition, there are hardly any investment synergies to co-locating a full bio-chemical and thermo-

[39] Dalberg Study on Biorefineries. 2011.
[40] Bloomberg New Energy Finance, “ Moving towards a next generation ethanol economy”, 2012
[41] conversion of $1.50 per litre based on exchange rate 1 USD = 0.814231 EUR, 2nd August 2012

chemical biorefinery. However, expanding / adjusting existing facilities can significantly lower the investment required.

Job creation

The net job creation effect from the development of biorefineries depends highly on the economic situation of the given country where a biorefinery is located.

It should be emphasized that biorefineries' operations have the potential to generate significant long-run increases in employment but at the same time can generate some (mostly short-term) displacement effects in the labour market - by shifting employment from other sections of the mother company towards the new activity of biorefinery.

Another observation is that the term 'biorefinery' does not necessary mean a new plant (industrial object) but a biorefinery can also be when the well-established factory applies a new manufacturing process based on renewable raw materials. Therefore the biorefinery does not have to be a completely new facility (new building etc.) but it can be a part of the existing facility. In such case socio-economic impacts are less visible than in case of the setup of a new industrial facility. For example less construction work is needed to establish such a biorefinery and therefore the impact on employment as regards construction workers in the preparation phase is almost negligible.

From the figures in Table 2, the total number of jobs that the bio based industry could have by 2030 can easily reach 2.5 million.

Selected biorefinery cases in Europe

Biorefinery deployment has taken place in Europe since 2008, with a variety of plants being established in EU Member States. Below is a description of selected cases.

- **Sunliquid (Germany)**: since 2010 a cellulosic ethanol demonstration plant with straw as feedstock is built at the center for renewable resources in Straubing. One of the target products are cellulosic ethanol and lignin. Partners are among others Süd-Chemie AG, TU Munich and several other academic and industrial partners. The project is funded by the German Federal Ministry of Education and Research (BMBF), the Bavarian state government and the German agency for renewable resources (FNR).
- **BioHub (France)** is a cereal-based biorefinery in Lestrem (France). It targets on platform-chemicals like succinate and isosorbide. Partners are among others Roquette, DSM and the University of Georgia. The project is funded by the

French Industrial Innovation Agency. The isosorbide demonstration plant has been launched in 07/2009.

- **Bio Base Europe (Belgium)** is a joint initiative by Europe, Belgium and the Netherlands to build an open innovation Pilot Plant and a Training Centre for biobased products and processes with a budget of 21 million euros. The Bio Base Europe Pilot Plant is a flexible and diversified pilot plant, capable of scaling up and optimising a broad variety of biobased processes up to the 10 m^3 scale. This European research and training infrastructure is an important building block for the development of the biobased economy in Europe.
- **Neste Oil (Finland)** has developed a process of hydrogenation to produce Hydrotreated Vegetable Oils (HVO) with the product name NExBTL. In 2009, a second plant came on stream, capable of producing another 190,000 tons of NExBTL per year. Raw materials used are palm oil, waste fat from food processing industry and rapeseed oil. In 2011, Neste Oil opened up a renewable diesel plant in Singapore with an annual capacity of 900,000 tons and a similar plant in Rotterdam. The hydrogenation process to produce HVO is reportedly the most cost effective process currently available to produce advanced biofuels.
- In 2010, **Neste Oil and Stora Enso (Finland)** opened a demonstration plant in Varkaus for biomass to liquids production utilizing forestry residues. A 50/50 joint venture NSE Biofuels OY, has been established first to develop technology and later to produce on commercial-scale biodiesel. The demonstration facility at Stora Enso's Varakus mill includes a 12 MW gasifier. The demonstration process units will cover all stages, including drying of biomass, gasification, gas cleaning and testing of Fischer- Tropsch catalysts. NSE Biofuels OY is now looking for sites for a unit capable of producing approximately 200,000 MT of renewable diesel per year from wood biomass.
- **Chemrec (Sweden)** produces synthesis gas from black liquor at its pilot gasification plant. Since the summer of 2010, the syngas is further transformed into DME (Dimethyl Ether) through the process of oxygenate synthesis. The capacity of the pilot plant is 4 MT of DME per day. The Chemrec gasification technology will be implemented in a new industrial-scale demonstration plant at Domsjö Fabriker biorefinery for production of about 100,000 MT of DME and 140,000 MT of methanol per year. In February 2011, the EC approved a Euro 55 million R&D grant awarded by the Swedish Energy Agency for the construction of this industrial scale demonstration plant.
- **BioMCN (The Netherlands)** started advanced biofuel production in June 2010. The plant has a capacity of 250 million litres and produces biomethanol from glycerine. The glycerine is a by-product of biodiesel production. The glycerine is converted into syngas, which is used to synthesize the bio-methanol. Bio-methanol can be blended with gasoline or used for the production of bio-MTBE, bio-DME, or synthetic biofuels.

- **Neste Oil (The Netherlands)** has an operational advanced biofuels plant since December 2011. The production capacity of the plant is 900,000 million liters of Hydrotreated Vegetable Oils (HVO). Two plants applying the same technology are operational in Finland (see above) and one in Singapore. Neste Oil will reportedly use mainly palm oil, but can use a variety of feedstocks.
- **The Choren Industries Company (Germany)** in cooperation with the automobile makers Volkswagen and Daimler, has developed a process for gasification of biomass as feedstock for the production of BtL. Choren has erected a pilot plant in Germany with a production capacity of 15,000 MT of BtL in Freiberg. Production would reportedly have started at the end of 2011 with fast growing wood will be used as feedstock. However, the company became insolvent in July 2011. In February, the Carbo-V technology was sold to Linde engeneering Dresden, while an investor for the pilot plant in Freiberg still has to be found. An alternative project for the research and production of BtL fuels is run by the Karlsruhe Institute for Technology (KIT). It is known as the Bioliq® project. KIT works on processes to convert crop residues and wood residues into diesel and gasoline fuels. The bioliq process allows the physical separation of the pyrolysis from the rest of the process. This means that feedstock can be converted into pyrolysis oil in decentralized plants which is then shipped to a central plant for final conversion. This helps to reduce volume and costs for feedstock transport.
- **Inbicon's (Denmark)** demonstration plant in Kalundborg is using wheat straw to produce bioethanol. The volume of feedstock used is about 30,000 MT per year for the production of 5.4 million liters ethanol. Novozymes and Danisco are supplying enzymes for the plant. The plant is reportedly the largest cellulosic ethanol demonstration plant in Europe. Inbicon's parent company is Dong Energy, one of the leading energy groups in Northern Europe. In addition to ethanol, the plant is expected to produce 13,000 MT of lignin pellets, which will be supplied to the Dong Energy power plant to replace coal and 11,000 MT of C5 molasses for animal feed.
- **Chemtex (Italy)** is developing a commercial-scale cellulosic ethanol plant, which is operational since 2013. The nominal capacity is 20 million gallons, and supply is based on local energy crops and residues.
- **UPM (Finland)** announced plans[42] to invest in a biorefinery producing biofuels from crude tall oil in Lappeenranta, Finland. The industrial scale investment is the first of its kind globally. The biorefinery will produce annually approximately 100,000 tonnes of advanced second generation biodiesel for transport. Construction of the biorefinery will begin in the summer of 2012 at UPM's Kaukas mill site and the total investment will amount to approximately EUR 150 million.

[42] http://www.upm.com/EN/INVESTORS/Investor-News/Pages/UPM-to-build-the-world%E2%80%99s-first-biorefinery-producing-wood-based-biodiesel-001-Wed-01-Feb-2012-10-10.aspx

Standardization on bio-based products: Current state

Current limited availability of statistical data on new bio-based products and processes[43] and differences in bio-based product definitions and statistical classification references[44] make it still difficult to comprehensively estimate their corresponding markets.

Consequently, a more suitable methodological approach would be to focus on the most promising (both economically and environmentally) supply chains where bio-based products can substitute the traditional ones.

The European Commission, in the framework of the Lead Market Initiative[45], appointed an Ad-hoc Advisory Group for Bio-based Products. It has elaborated new European product performance standards, and issued, since 2008, the following mandates in the field of bio-based products:

- M/429 on the elaboration of a standardization programme for bio-based products
- M/430 on bio-polymers and bio-lubricants
- M/491 on bio-solvents and bio-surfactants
- M/492 for the development of horizontal standards for bio-based products

Several criteria and thresholds have been or are to be established for bio-lubricants bio-plastics/bio-polymers, bio-surfactants, bio-solvents, chemical building blocks and enzymes (i.e. technical, food and animal feed enzymes).

A specialized CEN working group, CEN/TC 411/WG 4, has been established for sustainability criteria and life-cycle analysis[46]. The group is developing standards for bio-based products covering also horizontal aspects:

- consistent terminology
- certification tools
- bio-based content
- application of and correlation towards life cycle analysis
- sustainability criteria for biomass used & final products

The focus of the work is on bio-based products, other than food & feed and bio-mass for energy[47].

[43] Zika, E., Papatryfon, I., Wolf, O., Gómez-Barbero, M., Stein, A.J and Bock, A.K. (2007), Consequences, Opportunities and Challenges of Modern Biotechnology for Europe, JRC-IPTS, April 2007. http://ec.europa.eu/dgs/jrc/downloads/jrc_reference_report_200704_biotech.pdf
[44] Use of NACE and PRODCOM codes proves to be inappropriate as they cover much more products that the bio-based ones (for a detailed discussion, CSES (2011).
[45] European Commission, DG Enterprise and Industry, Lead Market Initiative – Bio-based Products, http://ec.europa.eu/enterprise/policies/innovation/policy/lead-market-initiative/biobased- products/index_en.htm
[46] European Committee for Standardization, Technical Committee 411, Bio-based products - http://www.cen.eu/cen/Sectors/TechnicalCommitteesWorkshops/CENTechnicalCommittees/Pages/TCStruc.aspx?param=874780&title=Bio-based%20products
[47] www.biobasedeconomy.eu; www.cen.eu/cen/Sectors/Sectors/Biobased

Further research is being conducted on issues such as harmonization of sustainability certification systems for biomass production, conversion systems and trade[48], sustainability assessment of technologies, including bio-refineries[49], and environmental performance of products[50].

Table 6 CEN publications for bio-based products

Title	Mandate	TC	Publication Date
CEN/TR 16208:2011 Biobased products- Overview of standards	M/429	___	2011-05-04
CEN/TR 15932: 2010 Plastics - Recommendation for terminology and characterisation of biopolymers and bioplastics	___	CEN/TC 249	2010-03-24
CEN/TS 16137:2011 Plastics - Determination of bio-based carbon content	M/430	CEN/TC 249	2011-04-27
CEN/TS 16398 Plastics - Template for reporting and communication of bio-based carbon content and recovery options of biopolymers and bioplastics- Data sheet	M/430	CEN/TC 249	2012-10-31
CEN/TR 16227 Liquid petroleum products – Bio-lubricants – Recommendation for terminology and characterisation of bio-lubricants and bio-based lubricants	M/430	CEN/TC 19	2011-08-10

In order to monitor the technological and commercial market developments related to the most innovative and competitive bio-products (e.g. bio-based plastics, bio-lubricants, bio-base solvents, bio-based surfactants, bio-composites and bio-based platform and fine chemicals), new technical standards (e.g. carbon content derived from renewable raw materials) and separate statistical codes should be assigned to them, in addition to the existing ones[51] in official goods classification (i.e. the CN and PRODCOM) and trade statistics. DG Enterprise has already proposed CN codes for several products (i.e. bio-based lubricants, succinic acid and 1.4-butandiol), together with the technical verification methods for bio-based renewable content.

[48] Global-Bio-Pact research project, http://www.globalbiopact.eu/
[49] PROSUITE research project, www.prosuite.org
[50] "LCA to go" research project, http://www.lca2go.eu/
[51] The already existing CN and PRODCOM codes are: bio-based glycerol; enzymes; ethanol; polylactic acid; natural polymers and modified natural polymers in primary form; ethanol; other butanols; butan-1-ol; polyacetals including other polyethers and epoxy resins, in primary forms, polycarbonates, alkyl resins, polyallyl esters and other polyesters, in primary forms-others, others; other plates, sheets, film, foil and strip, of plastics, non-cellular and not reinforced, laminated, supported or similarly combined with other materials, -of cellulose or its chemical derivatives, -of regenerated cellulose; other – acyclic polycarboxcylic acid, their anhydrides, halides, peroxides, peroxyacids and their halogenated, sulphonated, nitrated or nitrosated derivatives; wholesale of solid, liquid and gaseous fuels and related products - wholesale of fuels, greases, lubricants, oils.

Policy overview

Biomass policy framework

During the last fifteen years, R&D and policy formation for biomass has seen very active development in the bioenergy and biofuels fields, starting from the basic targets of the RED and paths towards their achievement from the Member States in their National Renewable Energy Action Plans and the subsequent reporting periods, and following with several other initiatives for sustainability and market support at Member State level.

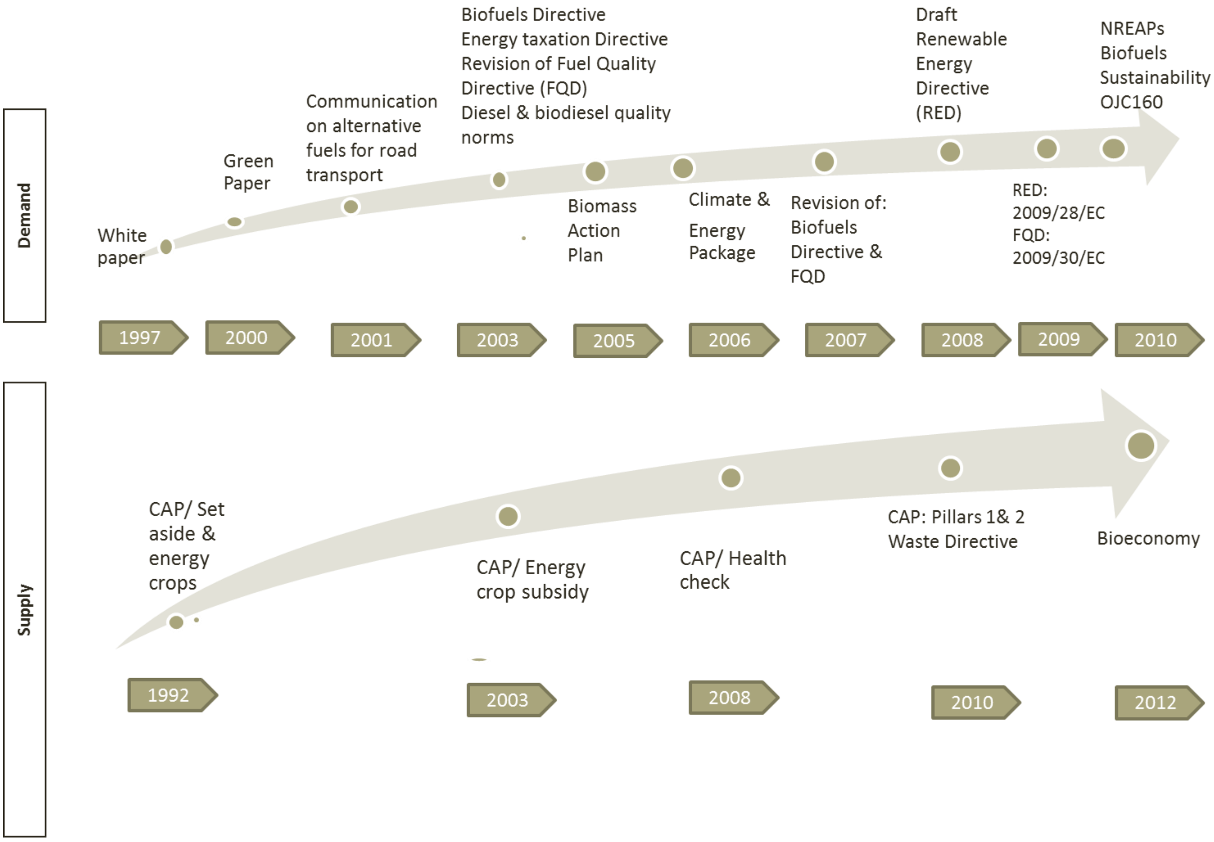

Figure 11 EU main policy mechanisms and their time of implementation[52]

However, most of the National Renewable Energy Action Plans (NREAPs[53]) were prepared without fully recognizing market dynamics including: the ETS; delayed deployment of 2nd generation biofuels; implications of sustainability criteria on supply (particularly the indirect Land Use Change- ILUC[54]); competition with other biomass using sectors; cooperation mechanisms included in the RED Directive; and the appreciation of longer-term resource efficiency and environmental policies.

Furthermore, opportunities of the bioeconomy such as cascading use of biomass, and the integration of electricity, heat, transport fuel and bio-based markets seems to

[52] Panoutsou et al., 2013. Policy regimes and funding schemes to support investment for next generation biofuels. In Biofuels, Bioprod. Bioref. 7:000–000 (2013); DOI: 10.1002/bbb
[53] http://en.wikipedia.org/wiki/National_Renewable_Energy_Action_Plan
[54] http://en.wikipedia.org/wiki/Indirect_land_use_change_impacts_of_biofuels

not have been sufficiently reflected in the NREAPs and the broader EU policy at a coordinated and consistent level.

Several initiatives are ongoing at EU and national level to facilitate future planning and policy formation for sustainable biomass. The key issues that shape the working assumptions for some of these are briefly described below:

a. How can EU Member States themselves accurately define and characterise their indigenous feedstock options in terms of cost-supply and logistical aspects of their deployment as well as sustainability risks?
b. Is there a mismatch between supply and demand and how to best address this in the future monitoring process of NREAPs along with prioritising efficient and sustainable value chains?
c. How to develop policies at national level which can be tailored to prioritise indigenous capacities both in terms of supply and demand sectors, whilst allowing for sustainable imports as well?

Technical and policy gaps

This section describes the most important knowledge gaps in feedstock, technology, policy, financing and sustainability.

Feedstock and technology knowledge gaps

The main technical gaps in bio-based value chains are related to the needs to enlarge the feedstock base by additional sustainable and competitive resources and to further develop processing technologies able to deal with a wider feedstock base, enhance feedstock conversion efficiency into valuable energy and co-products, enlarge the range of potential outputs from biomaterials processing and minimise the overall energy consumption and meet EU sustainability criteria.

To enable supply of additional and sufficient biomass for a bio-based economy, it is critical to increase the productivity and output of biomass from European forest and agricultural land in a sustainable way and to unlock the potential of the residues and side-streams and waste. Most of the research programs focus on optimising utilisation of existing feedstock (forest and agricultural biomass) and the development of new feedstock supply chains (e.g. forest residues, agricultural lignocellulosic residues or dedicated crops), as well as industrial side streams and organic municipal waste. Albeit essential for the future of the bio-based economy, the advanced feedstock supplies are still underdeveloped and require significant infrastructure for mobilisation and logistics and technologies for optimal biomass upgrading and integration into existing energy infrastructures and facilities.

The main resource-related challenges for future biorefineries can be summarized as follows:

(i) biomass supply constraints, in particular most operators in forest-abundant countries mentioned a diminishing trend in domestic forestry production, reducing growth in residues for the energy sector;
(ii) efficiency gains in the agricultural sector, both in biomass production and processing/upgrading to fed energy conversion plants;
(iii) increased availability of wood biomass/fostering forest biomass supply chains. Among the economic and market related challenges, particular relevance has the rising land prices driving up feedstock prices and hence biofuel costs. On the other side, providing new markets for biomass producers strengthens rural economies, and allows further development and investment in the production system.

Concerning the Western Balkan countries, problems regarding the irrational use of wood raw material, especially in the form of roundwood, should be added to all above mentioned. Namely, owing to a large number of producers and capacities for wood fuels production, needs for raw material are 2-3 times higher than the available potentials. This is the reason why more than 80% of the total production of wood pellets in the region is produced from roundwood including sawmill logs of class C, not from wood residue as in the EU countries. Beside the aforementioned, extremely low ratio between the amount of energy obtained from burning the produced wood fuel and the amount of energy consumed in the processes of logging, transportation and storing of wood raw material and in technological process of producing a certain wood fuel is a significant problem. For some producers, this ratio does not exceed 2. Inefficient technology is one of the reasons for such a high consumption of energy in the processes of wood fuels production. Namely, the technology in most companies producing wood fuels is secondhand, imported from west European countries with low efficiency degree.

More advanced technologies, such as the technologies for cogenerating power and heat, do not exist yet in the countries in the region, with the only exception of Croatia where 3 woody biomass CHP plants existed in the middle of 2015. So far, there are no initiatives regarding the technologies and production of the second generation biofuels. Since the existing situation is unfavourable, it will be so in the next 5-10 years as well.

Policy, financing and sustainability gaps

The main policy gaps in the bio-based economy rely on the reliability of policy frameworks and support measures related to energy, agricultural-forestry and environmental sectors, that highly affect the bioeconomy investors choices and entrepreneurs confidence. However, continued financial support for bio-based energy and materials could be a challenge in times of tight public budgets. This in particular is confirmed by the situation in Western Balkan countries where the support to the development of bioenergy market is limited because of the public budgetary problems.

At supply side level, the mobilization of the agricultural sector to deliver to biobased markets is a key factor. This is particularly important in relation to non-food crops, since farmers are often reluctant to commit to growing, such as in the case of short rotation coppice for a policy-driven bioenergy market; in this case, high and rising prices in traditional agricultural markets could hinder the long term land conversion to focus on energy or non-food markets. In this segment, there is no legislation yet in the Western Balkan countries allowing and setting the conditions under which agricultural land could be converted into the land for energy plantations.

Moreover, processing technologies should not be developed at industrial scale on a stand-alone basis, but as part of commercial “value chains”, i.e. integrated process schemes, from feedstock to end products and markets. Because of the magnitude of the investment needed, they are unlikely to be met in a context of uncertainty on the availability of required feedstock as well as on the economic and political frameworks.

Developing biorefinery facilities will take time as the industry moves up the learning curve. Likewise, the economic viability of next generation biofuel facilities will improve overtime. Simple, fair, efficient and reliable support mechanisms are needed to commercialise the technologies.

The energy balance of biomass supply and various sustainability concerns are also perceived as a major challenge by the majority of operators. The implementation of sustainability schemes represents a challenge, in particular the verification and application of voluntary schemes and related costs. Small producers in particular are expected to face economic challenges arising from additional costs associated with certification. The perceived need for imports to reach targets in the EU-27 also raises concerns about the sustainability of imported biomass. This statement refers in particular to the Western Balkan countries from which large amounts of green energy are exported in the form of wood fuels. With such a trend, it is a big question whether the countries in this region will reach the set objectives 2020.

In light of the high complexity of bio-based value chains, a coordinated vision and action across the different industries and sectors involved is required, in particular to facilitate the development of a common language and synergies among the different sectors involved into the bioeconomy business. The need to accompany technical development with appropriate technical standards to facilitate market development and trade represents another crucial issue for legislation.

Last but not least, weak public acceptance (mainly driven by sustainability concerns, 'food versus fuel' debate but also 'NIMBY', ie 'not-in-my-backyard' attitudes and prejudices about the competitiveness of bioenergy versus fossil energy sources) represents a major drawback of bio-based chains. Regarding this, prejudice is quite expressed in the Western Balkan countries. Additionally, with the exception of Croatia and Serbia, in other countries there are no expressed initiatives and projects with the purpose to educate end users about the advantages and benefits of biofuels.

The policy gaps can be grouped into four broad categories as reported in table 7 below.

Table 7: Policy gaps in bio-based chains[55]

Domestic sustainable biomass supply	There is a gap of knowledge about EU domestic supply potential (ie estimates derived based on coherent datasets and methodologies across the EU); further biomass categories, geographical detail, sustainability constraints should be integrated into available datasets, including diverse feedstock types (prunings, wastes, landscape care wood, manure, rotational crops, forestry residues, etc.); Biomass cost-supply curves for EU and Member States should be developed
Global context	The dynamics between the EU bioenergy demand and world markets and related footprint should be deepened; the evolution of biofuel markets within and outside of the EU under different sustainability constraints (including a global no deforestation scenario) is uncertain, such as their impacts on agricultural production, trade and prices; the resulting emission pathways should take into account savings from displaced fossil fuel use and land use change emissions

[55] European Biofuel technology Platform, European Biofuels Technology Platform, Strategic Research Agenda 2010 Update - innovation driving sustainable biofuels – www.biofuelstp.eu accessed sept 2014

Meeting demand from RE-H, RE-E and RE-T and non-energy related sectors	Accurate analysis of the competition for least-cost biomass between energy sectors (electricity, heating, transport) and non-energy ones, including imports and intra-EU trade is required; no accurate information on most promising refined segments within three energy markets for future uptake is available
Reconcile renewable energy development and sustainability concerns	There is a clear need to form agreement between different parts of society on what sustainable bioenergy means and how to get there; this is crucial for all bioenergy policy, and also water, soil, social issues for all bioenergy should be addressed, including Indirect effects through ILUC factors (domestic and imports) and related perspectives on the broader bioeconomy

In conclusion, an EU framework more supportive of bio-based value chains and in particular next generation biofuels, and which effectively provides increased financial support to its commercialization, will be a pre-requisite for the growth of the sector and to attract private sector funding. The framework should be consistent, account for next generation biofuels as a part of the future bio-based economy, and ensure coherent sustainability rules. However, funding of innovative technologies (including the next-generation biofuel ones) has become increasingly tight in Europe in recent years, due to the current financial crisis, that strongly reduced both venture capital and private equity funding, while funding from large industry players has also tightened, making it difficult to finance pilot commercial plants and to obtain debt funding. This is also true for the funds required to invest into building full-scale commercial plants and the respective infrastructure for bio-based chains.

S2Biom contribution to research beyond current state

The S2Biom project supports the sustainable delivery of non-food biomass feedstock at local, regional and pan European level through developing strategies, and roadmaps that will be informed by a "computerised and easy to use" toolset (and respective databases) with updated harmonised datasets at local, regional, national and pan European level for EU28, Western Balkans, Ukraine, Moldova and Turkey.

It aims to build on a set of selected initiatives and further improve knowledge through the biomass value chains in the following research areas.

This section provides an outline of the project's scientific contribution to advancing knowledge for lignocellulosic biomass value chains that will supply the European bioeconomy.

Lignocellulosic biomass supply: Atlas & database on sustainable biomass

Up to now, most of the recent research work on biomass availability and supply data has been driven by the high demand in the bioenergy and biofuels sectors. As the biobased economy evolves to cover a wider range of markets and end products it is important that future research and development work should carefully examine the synergies/ conflicts and interdependencies amongst the different feedstocks and develop coherent indicators for careful evaluation of their quantity and quality attributes and costs associated with their production/ collection.

Approach for biomass potentials atlas: The most recent attempt to harmonise assumptions and provide a coherent methodology for biomass assessments in Europe has been in the framework of the Biomass Energy Europe (BEE) project[56], which resulted (2010) in a set of harmonised methodologies for biomass resource assessments for energy purposes in Europe and its neighbouring countries in order to improve consistency, accuracy and reliability as well as serve the future planning towards a transition to renewable energy in the European Union itself.

Atlas on biomass feedstocks: The Biomass Futures project[57] resulted in 2012 in a coherent Atlas of sustainable biomass cost supply in EU27 with disaggregated data at NUTS2 level, for a variety of feedstocks including all lignocellulosic biomass types (from agriculture, forestry and waste sectors- including residual and cropped options). For the Atlas in combination with EEA (ETC-SIA) an assessment was also made of the sustainable potential and production cost for perennial biomass crops for EU-27. It estimated the potential on released land (assessed with the CAPRI model) in different scenarios taking account of sustainability criteria regarding no-go areas and minimal mitigation thresholds. This assessment was however only done using a

[56] www.eu-bee.com/

[57] http://www.biomassfutures.eu/

limited suit of perennial crops (3 grassy crops and SRC willow) based on a limited number of EU wide field observations of attainable yields and costs. This will be significantly improved, in S2Biom with the approach to make an assessment of the most environmentally and economically sustainable cost-supply of lignocellulosic crops.

Cost estimates: Estimates of biomass cost-supply for current and for different scenario situations in EU27 have been done in several projects of which an extensive inventory was made as part of BEE. In Biomass Futures a further quantification of both cost and supply for current, 2020 and 2030 situation was also made from primary, secondary and tertiary resources from waste, forest and agriculture sector was made taking account of environmental constraints. As to the forest potential the Biomass Futures project built on the results from the EU-Wood project[58], but for the other sectors new quantified assessments were made. Also in the currently on-going Bioboost[59] project costs of lignocellulosic biomass sources in EU-27 will be determined. These data will be taken into account within the research work foreseen in this project.

Regional coverage: The most recent datasets for lignocellulosic biomass feedstocks include only detailed analysis for the EU27 and the respective Member States. For the other countries covered in the scope of this call (Western Balkans, Moldova, Ukraine and Turkey) only fragmented efforts and studies exist that do not of course use the most recent methodological concepts and tools.

Baseline from which S2Biom starts: S2Biom will build on biomass assessments that have been performed in Biomass Futures project which produced a coherent Atlas of sustainable biomass cost supply in EU27 with disaggregated data at NUTS2. It will also take the BEE harmonised methodology for biomass resource assessments for energy purposes in Europe as a starting point.

S2Biom progress beyond the state of the art: The Biomass Futures Atlas will be refined as follows: a) it will take full account of the BEE harmonised methodology and b) it will have higher resolution level (NUTS3[60]) for all lignocellulosic feedstocks under study. Therefore this project will focus on non-food lignocellulosic biomass feedstocks and **provide improved and higher spatial resolution estimates for EU28[61] and expand the regional coverage to include Western Balkans, Ukraine, Moldova and Turkey taking into account the appropriate sustainability criteria.** The latter are expected to become more relevant from the perspective of resource efficient use of biomass and from the perspective of novel conversion and pre-treatment technologies.

---

[58] Mantau et al., 2010: http://ec.europa.eu/energy/renewables/studies/doc/bioenergy/euwood_final_report.pdf

[59] www.BioBoost.eu

[60] http://en.wikipedia.org/wiki/Nomenclature_of_Territorial_Units_for_Statistics

[61] Croatia joined EU in July 2013; all the Biomass Futures work has been performed only for EU27 as it was delivered in 2012, prior to Croatia becoming formally a Member State.

Furthermore, the work planned will also develop new approaches to making more accurate and spatially detailed estimates of biomass resources especially from forests, agricultural residues, perennial biomass crops and secondary and tertiary lignocellulosic waste resources. Attention is also paid to fill the gaps on biomass resources for which accurate estimates have not been produced until now. One of these is for example the potential from dedicated perennial crops to be grown on abandoned and/or marginal lands. The involvement of integrated spatial assessment techniques and crop growth and environmental impact models and LCAs combining statistical, bio-physical and environmental information. This innovative approach will facilitate the development of optimal land allocation maps for lignocellulosic crops.

Industrial conversion pathways

Biomass conversion technologies (including bio-refineries) form the essential link between the different available lignocellulosic biomass sources with their wide range of properties and the different identified end uses and markets. The European biorefinery sector will evolve from established biorefinery operations for products like food, biofuels, paper and board, to a broader, more mature sector. In 2030 biorefineries will use a wider range of feedstocks and will produce a greater variety of end-products than today.

Each conversion technology has specific biomass input requirements (i.e. cellulose, hemicellulose, lignin content, moisture content, minerals like chlorine, particle size etc.), while the quality of biomass differs largely between the different biomass types, harvest and drying techniques, and pre-treatment technologies. Also regionalised differences have to be taken into account (for instance increased chlorine content in coastal areas). Obviously some biomass types can be used in many different technology options, while others are hard to process or will need extensive pre-treatment.

The project will describe the state of art of a wide range of existing and future (up to 2030) conversion technologies and build among others on EU projects like EMPYRO, Supra-Bio, SuperMethanol, BioCoup, Bioliquids-CHP, BioSynergy, Optima, Sector, BioBoost, etc.

<u>S2Biom progress beyond state of the art:</u> In this project a database and method will be developed to match the available non-food lignocellulosic biomass feedstocks with the most suitable conversion technologies, taking into account the pyramid of end use applications (materials, chemicals, fuels, energy). The method will build on the available information on the specifications from the various conversion technologies and on the biomass characteristics. An analytic tool will be developed for viewing the characteristics of conversion technologies and guiding the user to find the optimal match between biomass sources of a certain quality with pre-treatment and conversion technologies.

By implementing the use of a “value chain” concept, a key gap which will be covered **<u>is the systems integration of different technologies with different functions across the value chain such as densification, pre-processing, intermediates production and production and use of final energy vectors</u>.** Without such a representation, technologies are considered in isolation and it is very hard to identify the most promising technologies without understanding their role in the overall bio-based system.

S2Biom addresses these issues, aiming at the provision of tools allowing an optimized exploitation of existing feedstock sources across borders and frontiers as well as by providing local communities with roadmaps towards sustainable feedstock production.

Optimal Logistics

The efficiency at which biomass feedstock can be used for producing bio-based (energy & non energy) products is very important. In this respect biomass feedstock poses a real logistical challenge as the quality and handling characteristics, and often also moisture content of biomass often restricts options for efficient logistics and of efficient conversion into bio-energy. There are three factors that affect biomass feedstock quality for thermal and biochemical conversion. These factors require careful optimisation through tailored design of sustainable biomass feedstock supply chains. Following is a summary of these factors.

<u>Ash content and –composition:</u> Many biomass feedstocks contain larger amounts of inorganic components (generally referred to as ash) compared to the clean wood fuels that are currently being mobilised and used for (co-)firing. In addition, the composition of the ashes is such that the biomass fuels exhibit a poor quality for thermal combustion or gasification, in particular as they lead to a relatively low ash melting point. This in turn leads to ash slagging and agglomeration problems in large thermal conversion installations. Furthermore, if chlorine is present in annual biomass, enhanced boiler tube corrosion may occur. Even in smaller scale combustion systems, the low ash melting point leads to difficulties. These ash-related problems are one of the main reasons that annual biomass feedstocks are often not used for energy conversion. In a decentralised conversion facility e.g. at biomass hubs, the biomass could first pass through a biochemical conversion process, where many of the potentially problematic ash components such as potassium and chlorine, are transferred to the liquid fraction given that they are soluble nature. As a result, the produced solid lignin fraction has a much better quality from a thermal conversion point of view, since troublesome inorganic components are no longer in the solid biomass fraction. Therefore, it is anticipated that a larger number of biomass feedstocks will become suitable for energy conversion, if they first pass through a decentralised pre-treatment process.

<u>Heterogeneity of feedstocks:</u> Many available biomass feedstocks are currently not used for energy conversion, as they are very heterogeneous in nature, which makes

the large scale conversion in energy conversion systems expensive. For instance, in many large boiler systems it is not possible to accept biomass fuels with a wide variety in shape and size of particles, as it makes blending with coal fuels and/or firing in fluidized bed systems problematic. As a result, heterogeneous feedstocks are either not used for conversion, or they need to undergo costly pre-treatment, such as size reduction (milling), screening, and/or pelletisation. This makes the conversion of low cost biomass feedstocks often economically unfeasible. A decentralised facility can accept a wide variety of biomass fuels in terms of particle shape, size and density. It is anticipated therefore that a large number of heterogeneous, low-cost biomass feedstocks can in principle be used for energy conversion, without costly mechanical pre-treatment steps such as milling and densification. Finally, feedstocks that exhibit a large season-to-season variation in quality, may also be used.

Fragmented supply chains: In combination with the two previous quality aspects (ash quality, heterogeneity), the fragmented availability of many biomass feedstocks often leads to biomass feedstocks not being used for energy conversion, in particular combustion for electricity generation. The fragmented supply results in high costs for collection and transportation, whereas it is often not feasible to develop optimized supply chain systems for every biomass feedstock. Although fragmented supply is an intrinsic quality of biomass, it is envisioned that decentralised pre-treatment facilities that can accept a much wider group of biomass feedstock will also incur lower feedstock cost, in particular for these fragmented feedstocks. For instance, biomass feedstocks of different qualities may be combined or blended at the point of collection or somewhere along the feedstock supply chain, which may lead to better optimization opportunities in feedstock collection and lower feedstock costs.

S2Biom progress beyond state of the art: *Logistics in an integrated value chain framework:* The integration of new logistics concepts (e.g. hubs and spokes) together with emerging near-farm pre-processing and densification technologies (e.g. torrefaction, pyrolysis, pelletisation) in an optimisation framework will facilitate the identification of new logistics systems which reduce the issues around trading off economies of scale in conversion with the logistics costs of feedstock supply, which have hampered the emergence of the bioenergy system to date.

Computerised Toolsets and decision support systems

The integration of the major research developments of the project into a tool that can be used by stakeholders across the bio-based value chain will represent a major step forward. The ability to perform a variety of economic and environmental analyses for a variety of biomass delivery chains at different geographical scales and to understand the sensitivities of these to uncertain parameters will be an important new functionality.

The development of integrated (web-based) tools that facilitate integrated spatially explicit economic and environmental assessments is not new. In the past there have already been several EU and national projects that developed integrated toolsets in the field of integrated assessments for agricultural markets and/or environmental impact assessments (e.g. SEAMLESS[62], CCAT[63], NITROEUROPE[64]) or for Rural development and land use changes (SENSOR[65]) or in the field of biomass demand land use change impacts such as the ToSIA tool[66] now developed in the Volante project[67].

Also in the field of employment of biomass for bioenergy there are several examples of integrated tools that have been developed in more recent years. . There are several tools that facilitate obtaining a better overview of where and how much biomass there is. The BIORAICE and BioSat tools[68] do this and also include economic information on the costs of the biomass. Both tools are rather sophisticated as they enable the calculation of different types of biomass availability and related costs from pre-selected points on interactive maps in the tools. The Biomass Wiki[69] operates at a global scale and provides a platform to add and use data on biomass availability all over the world. The BIORAICE and BioSat tools are part of a user interface providing the user access to several other informative sources of information that go beyond biomass potential availability and which are presented in report and text format. Another type of tool is the Waste to Biogas tool[70] and the Interactive Map of Biomass Conversion installations both developed in and for the USA territory. Both tools are aimed to support economic operators (potential investors) in finding the right locations for their installations away from competitors or to create synergies with other operators (e.g. production or use of bio waste for biogas or use of (rest) heat).

The 'Biobased Economy Route Kaart[71]' is designed to provide a better understanding of the different types of industries and technological aspects of biomass delivery chains that make up the biobased economy and that go beyond energy production but particularly are aimed at production of bio-products and chemicals. The information contained in the tool is informative and the user can decide himself which chains to view and which details to read. There is no option to assess the feasibility of such a chain in relation to biomass availability in a particular geographical location. It is purely a viewing-only tool.

The Biograce tool is unique in that it offers specific support to economic operators that are somehow involved in the biofuels production chain delivering biofuels to the EU market. These have to comply with the minimal mitigation targets as specified in

---

62 http://www.seamless-ip.org/
63 http://www.wageningenur.nl/en/Expertise-Services/Research-Institutes/alterra/Facilities-Products/Software-and-models/CCAT.htm
64 http://www.nitroeurope.eu/
65 https://www.wageningenur.nl/en/Publication-details.htm?publicationId=publication-way-333834333635
66 http://tosia.efi.int/
67 http://www.volante-project.eu/
68 http://biosat.net/
69 http://biomass.geo-wiki.org/login.php?ReturnUrl=/index.php
70 http://epamap21.epa.gov/biogas/index.html
71 http://www.biobasedeconomy.nl/routekaart/

the EU Renewable Energy Directive[72] (2009/28/EC) in order to make their product sound to the Renewable energy targets. This tool enables the user to both further design and specify a chain and to make a calculation of the full life cycle emission of GHG in their biofuel chain.

Baseline from which S2Biom starts: From the extensive but not exhaustive overview we can conclude that most tools developed provide understanding and support in setting up biomass delivery chains by addressing and facilitating one of the many aspects that need to be addressed when setting up a biomass delivery chain. The facilitation on both the design of a biomass delivery chain and the assessment of the biomass delivery chain impacts in terms of spatial, environmental and economic implications has also already been integrated in the BeWhere[73] and the ME4 tools[74]. These provide a very complete support to end-users, but are now still only applicable to a limited number of biomass delivery chains. Both tools work on a different scale as ME4 only does regional level designs and assessments and was developed for the Netherlands only and BeWhere works at national and EU wide scale.

S2Biom progress beyond state of the art: In S2Biom both BeWhere and the ME4 will be used as a basis for further work to ensure local, regional and national level coverage options. The current tools can be applied at the moment to a limited number of conversion technologies but in the framework of the project they will be further developed for covering:

- a broader territory at local, regional and national level and
- a wider number of conversion technologies- expanding to bio-based products
- including pre-treatment and logistical concepts such a hubs and yards taking account of the 4) up-dated and improved biomass cost-supply,
- sustainability constraints and resource efficient optimisation
- demand from markets and influenced by policies, and
- end-user requirements for such an integrated tool.

Beside the further elaboration of the BeWhere and ME4 tool into full chain design and assessment tools for the biobased economy at regional and wider national and pan-European level as described above, **S2Biom will also provide, viewing, download and further spatial assessment facilities for several types of new data and knowledge collected and further generated**. These will include:

i. Display and download of all parameters contained in the databases and generated in the different work modules within the project related to the delivery of sustainable non-food biomass feedstocks in Europe.

[72] Directive 2009/28/EC of the European Parliament and of the Council of 5 June 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC. The RED requires the EU to generate 20 per cent of energy from renewable sources by 2020, and each Member State to achieve a 10 per cent share of renewable energy sources in the transport sector.
[73] http://www.iiasa.ac.at/web/home/research/modelsData/Bewhere/BEWHERE1.en.html
[74] http://edepot.wur.nl/262549

ii. Provision of selection and conversion functionality to choose and switch units/currencies, select desired biomass feedstocks, zoom in desired areas and perform simple user-weighted analyses of the sustainability of the quantities shown in a variety of units exceeding energy and related to the biobased products as well (e.g., tonnes dry mass, tonnes/ha, kJ, in €/tonne dry matter, €/GJ).
iii. Quantified and objectively scaled sustainability performance of the biomass supply in relation to key sustainability criteria.
iv. Allow for regional searches, i.e. determine the area needed to supply a certain amount of feedstock or determine the amount of feedstock within a defined region.
v. The tool will be readily adaptable to future developments, by allowing additional and new data to be added to the system.
vi. Functionalities will provided to allow for manipulation of basic calculations, enabling these users to address the assumptions underlying the presented data and adapt them to their own specifications.

In addition this project will also generate a general user interface (GUI) that provides easy use and access through the internet to all the strategies, roadmaps and tools developed within this project. It will also enable linking the output generated by one tool as the input for the assessment of another tool.

Sustainability

The sustainability of bioenergy has been a key issue in the formulation of the legally binding criteria of the RED and the Fuel Quality Directive[75] (FQD) since 2005, but the current EU legislation only addresses biofuels and liquid bioenergy carriers. Since 2008, several communications from the Commission and EU-funded projects and studies, as well as national (e.g. by Austria, Germany, Sweden, The Netherlands, UK) and international bodies (IEA, IEA Bioenergy, FAO, GBEP, UNEP, among others) broadened the view to cover the sustainability of all bioenergy. Further work in the EU and beyond began addressing the sustainability of the *overall biomass* use for non-food purposes, i.e. including biomaterials, and biorefineries. As a part of that, significant improvement of knowledge on the sustainability issues of forest bioenergy has been achieved in various fora both within the EU, and internationally, but also questions such as the carbon neutrality of forest bioenergy and biodiversity impacts of intensified extraction of agricultural and forestry residues are still controversial.

Thus, there is no consensus or harmonised approach yet on how to “frame” the sustainability of the bioeconomy, neither in its environmental nor its economic dimension, and adequate considerations of social aspects such as access to land and water, and food security are lacking, especially regarding feedstock provision impacts in developing countries.

[75] Directive 98/70/EC relating to the quality of petrol and diesel fuels; and Directive 2009/30/EC amending Directive 98/70/EC as regards the specification of petrol, diesel and gas-oil and introducing a mechanism to monitor and reduce greenhouse gas emissions; see http://eurex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:140:0088:0113:EN:PDF

S2Biom progress beyond state of the art: S2Biom will build on the existing knowledge available on the Member State and EU levels, integrate the JRC capabilities on the sustainability domain as well as the international domain (through IEA Bioenergy, and GBEP), will collect and compile respective approaches especially regarding the broader biobased economy, and will develop integrated sustainability criteria for bioeconomy value chains based on lignocellulosic biomass. Furthermore, guidelines for harmonized methodologies to measure and assess respective impacts will be suggested and included in the toolset. In that, emphasis will be given to the environmental and social dimensions, while economic issues will be addressed more broadly (beyond costs[76]). The development of the sustainability criteria for the bioeconomy based on lignocellulosic biomass will give due respect to views of stakeholders.

Economic and regulatory framework for the biobased economy in Europe

To develop a bioeconomy for energy, fuels and biobased products, a number of challenges need to be addressed, e.g. the competing uses of biomass, and securing a reliable and sustainable supply of biomass feedstock. Over the last decade, various policies and economic frameworks have been put in place to tackle some of these challenges. But we also have to consider that various policies on EU, national and regional level exist (e.g. in relation to agriculture, forestry, waste, environment, energy, trade) and are playing a role in the bioeconomy. Some may be contradictory and cause confusion and market barriers, thereby prohibiting the efficient development of the bioeconomy.

The sustainability of bioenergy has been legally addressed in the RED and FQD by establishing mandatory criteria, especially for GHG emissions, biodiversity, and carbon stocks, but these regulations are restricted to biofuels and liquid bioenergy carriers[77]. Important other sustainability issues such as access to land and water, food security etc. are subject only to reporting requirements by economic operators, and the Commission.

Regarding to the non EU countries under study in this project, it is worth mentioning that in October 2012, Energy Community contracting parties[78] adopted the obligation to implement RED Directive. However, Contracting Parties did not develop specific policies or targets for biomass yet, and there are no specific policies on sustainability of production and use of biomass as well.

S2Biom progress beyond state of the art: Within the EU27 Member States there is a clear need to give a structured overview of which regulatory and economic frameworks exist at different levels, to benchmark the effectiveness of different

[76] The costs of bioeconomy value chains based on lignocellulosic biomass are analysed in WP 2, 3 and 4.

[77] See footnote **Error! Bookmark not defined.**.

[78] Albania, Bosnia & Herzegovina, Croatia, FYROM, Moldova, Montenegro, Serbia, UNMIK, Ukraine/ Turkey is an observer.

approaches and develop coherent policy guidelines to support the sustainable development of the biobased economy.

At the same time, for Western Balkans, Ukraine, Moldova and Turkey it is very important to develop a biomass and biofuels policy that is aiming at fulfilling the EU requirements and more importantly, to provide the emerging bioenergy sector with regulations required for their sustainable growth and performance.

Policy development in EU

The biobased economy is considered as one of the key elements to achieve a smart and green Europe (EU 2020 Strategy; Bioeconomy Strategy to 2030, etc.). To develop a bioeconomy for energy, fuels and biobased products a number of challenges need to be addressed, e.g. the competing uses of biomass, and securing a reliable and sustainable supply of biomass feedstock. Over the last decade, various policies and economic frameworks have been put in place to tackle some of these challenges. But we also have to consider that various policies on EU, national and regional level exist (e.g. in relation to agriculture, forestry, waste, environment, energy, trade) and are playing a role in the bioeconomy. Some may be contradictory and cause confusion and market barriers, thereby prohibiting the efficient development of the bioeconomy.

The sustainability of bioenergy has been legally addressed in the EU Renewable Energy Directive 2009/28/EC (RED) and Fuel Quality Directive (FQD) by establishing mandatory criteria, especially for GHG emissions and carbon stocks, but these regulations are restricted to biofuels and liquid bioenergy carriers[79].

Regarding to the non EU countries under study in this project, it is worth mentioning that in October 2012, Energy Community contracting parties[80] adopted the obligation to implement RED Directive. However, Contracting Parties did not develop specific policies or targets for biomass yet, and there are no specific policies on sustainability of production and use of biomass as well.

<u>S2Biom contribution to policy for the bioeconomy:</u> Within the EU28 Member States there is a clear need to give a structured overview of which regulatory and economic frameworks exist at different levels, to benchmark the effectiveness of different approaches and develop coherent policy guidelines to support the sustainable development of the biobased economy.

At the same time, for Western Balkans, Ukraine, Moldova and Turkey it is very important to develop a biomass and biofuels policy that is aiming at fulfilling the EU requirements and more importantly, to provide the emerging bioenergy sector with regulations required for their sustainable growth and performance.

[79] See footnote **Error! Bookmark not defined.**.

[80] Albania, Bosnia & Herzegovina, Croatia, FYROM, Moldova, Montenegro, Serbia, UNMIK, Ukraine/ Turkey is an observer.

The project:

- provided a structured overview of all elements of economic and regulatory frameworks that relate to the sustainable delivery of non-food biomass at different levels of governance across Europe (i.e. local, regional and pan-European), and
- developed coherent policy guidelines (with a set of indicators) that will allow policy makers from the respective levels of policy determination to quickly appreciate the support frameworks that exist and the most efficient ways to apply them for the future use of biomass in a sustainable manner.