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

S2Biom Project Grant Agreement n°608622

Deliverable 7.2
Market analysis for lignocellulosic biomass as feedstock for bioenergy, biobased chemicals & materials in Europe

A quantitative estimate of biomass demand in 2020 and 2030

November 2015




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 EU-28, Western Balkans, Moldova, Turkey and Ukraine. Further information about the project and the partners involved are available under www.s2biom.eu.

Project coordinator

Scientific coordinator

Project partners

About this document

This report corresponds to D7.2 ‘Markets for bio-based industry, including biochemical and bioplastics’ of S2Biom. It has been prepared by:

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Executive summary

The main aim of the S2Biom project is to support 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, Moldova, Turkey and Ukraine. The research work foreseen will cover the whole biomass delivery chain from primary biomass to end-use of non-food products and from logistics, pre-treatment to conversion technologies.

As a part of this, the S2Biom project explores perspectives for producing energy and materials from lignocellulosic biomass. The crucial general question to be addressed in WP7 is under which conditions there will be sufficient biomass to meet the EU renewable energy objectives (and the role biomass has to play in that) and provide a good feedstock basis for novel biobased chemicals and materials. Task 7.2 in WP7 is an analysis of the current and future markets for biobased industries. This task builds further on techno-economic data collected in WP2 and provides additional relevant information for the integrated assessment of tasks 7.3-7.5.

For the market analysis, 10 PMCs (product-market combinations) were identified as possibly significant consumers of biomass resources in the Pan-European area. The focus was to quantify the demand for biomass feedstock for these PMCs in 2020 and 2030. The considered PMCs are:

1. Heat
2. Electricity
3. (Advanced) biofuels
4. C6 chemistry (the wide variety of products to be produced from C6 sugars)
5. C5 chemistry (the wide variety of products to be produced from C5 sugars)
6. Biomethane
7. Aromatics (BTX)
8. Methanol
9. Hydrogen
10. Ethylene.

Table 1 presents an indicative consumption of domestic lignocellulosic biomass for the PMCs 1-3 in EU28+; while Figure 1 presents the projected total lignocellulosic biomass demand for PMCs 4-10 excluding the biomethane PMC in 2020 and 2030. Although methane is also used as feedstock for some processes within the (petro)chemical industry, It is assumed that biomethane would mainly be used in the bioenergy sector either as a biofuel, or for the generation of heat and/or electricity (PMCs 1-3). The lignocellulosic biomass demand for biomethane PMC in Europe is estimated up to 80 PJ in 2020 and 280 PJ in 2030.

Table 1: Indicative primary biomass consumption (PJ) for PMCs 1-3 in EU28+

PMCs 1-3	2020	2030
Indicative consumption of domestic lignocellulosic biomass in EU28+	5,173	7,238

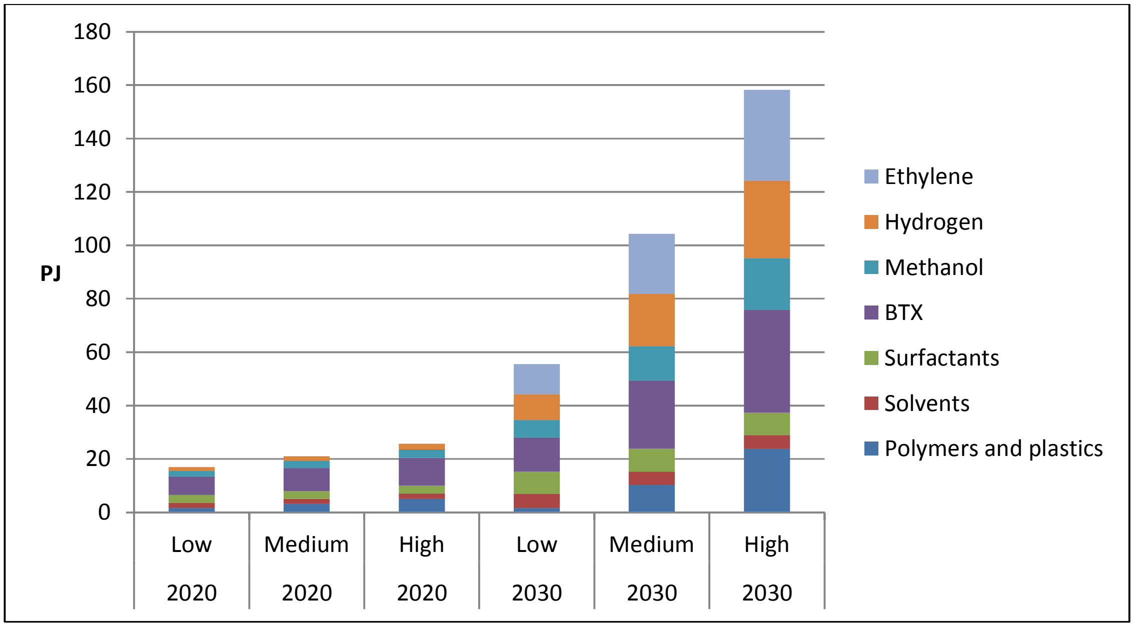

Figure 1: Projected total lignocellulosic biomass demand for PMCs 4-10 excluding biomethane

The results of the review indicate that:

- Demand for lignocellulosic biomass for chemicals and materials at pan European level in 2020 would be around one million tonne, increasing to less than 10 million tonnes in 2030.
- Based on the energy content, the demand would be around 0.4% of the corresponding demand for bioenergy and biofuels (PMCs 1-3) in 2020, increasing to 1.4% in 2030.

Key factors affecting this picture are:

- The rate of technology development (both for advanced chemicals/material and for biofuels and bioenergy)
- The exact shaping of the supporting policy framework, and
- The future of the (petro)chemical industry in Europe
- Besides, the oil price is a strong factor affecting the prospects for biobased chemicals and materials.

As the performed market review is indicative in many respects, both the review results and the outcomes of the integrated assessment for which they will be used (Tasks 7.3-7.5) will be subject to stakeholder consultation in WP10 of the project.

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1. Introduction

The S2Biom project (EU-FP7) provides support to the delivery of sustainable non-food biomass for energy, fuels and chemicals/materials. One of the activities in S2Biom Work Package 7 is a market review: “How much biomass demand can be foreseen up to 2030 when production of biobased chemicals and materials develops further?” The focus is on biomass demand for European production facilities (EU28, Western Balkans, Moldova, Turkey and Ukraine) and on lignocellulosic biomass feedstocks and their applications.

The market review is important in two respects:

- So far, only few projections for future demand for biobased chemicals and materials are available, and none of them contains a translation back to a corresponding demand for lignocellulosic biomass.
- The key question in S2Biom WP7 is to what extent the additional demand for biomass from chemicals and materials could be sufficiently significant to influence lignocellulosic biomass prices and induce scarcity and competition issues with energy applications.

For this review, the focus is directed towards sectors that can create significant biomass demand, i.e. relatively bulky chemicals markets. Specialties and fine chemicals can have high added value and can therefore be most relevant for a biorefinery business case, but their production will by definition not induce bulky amounts of biomass demand.

For the market analysis 10 product-market combinations (PMCs) were identified as possible significant consumers of biomass resources in the Pan-European area (Table 2)[1]. The focus was to quantify the demand for biomass feedstock for these PMCs in 2020 and 2030.

The market analysis for the first three bioenergy-related PMCs is presented in Chapter 2. Analysis regarding the market for a wide variety of products to be produced biochemically from C6-C5 sugars (PMCs 4&5) is presented in Chapter 3. The remaining PMCs (6 to 10), mainly based on thermochemical conversion of biomass to different products, are handled in Chapter 4. Chapter 5 summarizes the outcomes of the market analysis, followed by conclusions and recommendations presented in Chapter 6.

[1] Originally, three more PMCs were identified: lignin, bioethanol and mixed alcohols. Current bioplastic routes only use the cellulose and hemicellulose parts of the lignocellulosic feedstock. Lignin is a more complex resource for which less biochemical pathways are available today. It is expected, that lignin up to 2030 would mainly be used as a source of bioenergy. Bioethanol was first identified as a separate PMC, but has later been considered as a biofuel within the third PMC, and as a biochemical in the dehydration reaction for the production of bio-ethylene (PMC 10). The process of mixed alcohol production is still at the early stage of development. No data is found for the conversion efficiency of this process. The process is mostly developed in the USA (NREL), where the major focus lies on renewable alternatives for fossil-based gasoline. An alternative to this process in Europe is ethanol production via biochemical conversion of lignocellulosic biomass.

Table 2: Product-market combinations considered within this market analysis

	Product	Market
1	Heat	District heating
2	Electricity	Power market
3	Advanced Biofuels	Transport fuel
4	C6 sugars	C6 chemistry: polymers & plastics, others
5	C5 sugars	C5 chemistry: polymers & plastics, others
6	Bio-methane	Grid, transport
7	BTX	Petrochemical industry
8	Methanol	Transport, chemical industry
9	Hydrogen	Transport, (petro)chemical industry
10	Ethylene	(petro)chemical industry

2. Market analysis of heat, electricity and (advanced) biofuels

A detailed description of the market analysis of heat, electricity and (advanced) biofuels is given in the S2Biom Deliverable 7.2a [1]. For all countries historical data as used in the National Renewable Energy Action Plans (NREAPs) was used for the year 2005 [2], [3]. For the year 2010, for all countries included in this research, data was sourced from a variety of sources, such as national statistics, Eurostat [4], the EU Energy, Transport and GHG Emissions Trends to 2050 – reference scenario 2013 [5], or the NREAPs when no other data was available.

The future projections[2] on bioenergy consumption in these three PMCs are based on data from the Green-X model as used in the FP7 project BETTER (Bringing Europe and Third countries Together through renewable EneRgies) [6]. For this, use was made of the scenario with a 27% RES target in the EU and Energy Committee countries, assuming Turkey would not become an EU member nor Energy Community (EnC) affiliate (thus having a weaker RES target), and with cooperation within the EU possible, but no cooperation between the EU28 and non-EU28 countries (specific name of the scenario: Default-TRLowAmbition(weak)).

For Moldova and Ukraine, who were not part of the Green-X modelling, use was made of data from their respective National Renewable Energy Action Plans (NREAPs). This was further extrapolated to 2030 using the average growth of bioenergy in EU13 countries (Bulgaria, Cyprus, Czech Republic, Estonia, Croatia, Hungary, Lithuania, Latvia, Malta, Poland, Romania, Slovenia, and Slovakia).

For the year 2015 a combination was made between the data available from the same sources as 2010 data and the Green-X modelling data. Most often either of the two data options was chosen in order to create a growth as smooth as possible between the historical data and the future projections. In rare cases taking the average of the two data points resulted in a much smoother growth line and was thus chosen. Only in PMC3: (Advanced) Biofuels Green-X data is also used for 2010 for some countries when this helps smooth the growth trend.

Table 3 presents the total historical, as well as the expected final consumptions of bio-heat, bio-electricity and biofuels in the EU28+ in PJ; while Table 4 presents primary biomass consumption (PJ) for electricity, heat and biofuels according to a RESolve run in the EU28+.

[2] 2015 and beyond

Table 3: Final consumption of bioheat, bio-electricity and biofuels: historical as well as expected total final consumption of these options in the EU28+ (in PJ)

	2005	2010	2015	2020	2025	2030	2040
Heat from biomass	2178	2350	2715	3242	3899	4740	6003
Electricity from biomass	216	391	566	743	984	1040	1275
Biofuels consumption	188	668	962	1216	1033	1258	3379
Total	2582	3409	4243	5201	5916	7038	10657

Table 4: Primary biomass consumption (PJ) for electricity, heat and biofuels according to a RESolve run, consistent with the final consumption in the EU28+, as presented in Table 3

Biomass type	2015	2020	2025	2030
Lignocellulosic biomass (PJ)				
Domestic	4,208	5,173	6,106	7,238
Import	79	294	279	522
Total lignocellulosic biomass	4,287	5467	6,385	7,760
Non-lignocellulosic biomass (PJ)				
Domestic	1,169	1,002	1,016	971
Import	374	321	531	623
Total non-lignocellulosic biomass	1,543	1,322	1,548	1,594
Total biomass (PJ)	5,830	6,789	7,932	9,354

According to this scenario, heat remains the dominant energy application of biomass, although the relative shares of transport biofuels and electricity increase in the coming decades. In terms of primary biomass, use of lignocellulosic biomass grows by almost a factor 2 between 2015 and 2030, while non-lignocellulosic consumption remains relatively stable. EU-domestic biomass remains dominant, particularly for lignocellulosic biomass, but the role of imports increases.

3. Market analysis of sugar-lignin platforms

One of the market review products is Deliverable 7.2b: *A Market analysis of sugar-lignin platforms* [7]. This document contains extensive information on possible production routes, with some in-depth reviews of key biobased chemicals. In an additional memo: *Quantitative estimate of future market volumes of biobased chemicals: Annex to S2Biom Deliverable 7.2b* [8][3], information from [7] and other sources are used to come to a quantitative estimate.

The memo goes into four questions:

- What could be the total production capacity of biobased chemicals in Europe by 2020?
- How much of this would use lignocellulosic biomass (or its components) as a feedstock?
- What could be the corresponding demand for lignocellulosic biomass in Europe by 2020?
- What could be an indication for the European production capacity and lignocellulosic biomass demand for 2030?

Based on many assumptions specified in the Annex, the demand for biobased chemicals in 2020 and 2030 is summarized in Table 5.

Table 5: Projected EU production capacity of various biobased chemicals (in million tonnes)

2020	**Plastics**	**Lubricants**	**Solvents**	**Surfactants**
High	0.6	0.2	1.1	2.3
Medium	0.5			
Low	0.4			
2030	Plastics	Lubricants	Solvents	Surfactants
High	4.0	0.3	1.8	3.2
Medium	2.6			
Low	1.0			

Based on the assumptions made for the feedstocks and conversion efficiencies (see Table 6), the corresponding demand for biomass feedstocks in both years has been calculated and presented in Table 7[4].

[3] This memo is included in this report (see Annex I).

[4] See Annex I for the assumptions regarding the no-ligno feedstocks.

Table 6: Assumptions feedstocks and conversion efficiencies

Subject	Assumption
Biomass	Lignocellulosic (dry matter content: 90%), 17 MJ/kg
Lignocellulosic biomass	• 70% (hemi)cellulose (currently used as feedstock) • 30% lignin (more complex resource/less biochemical pathways available today)
(hemi)cellulose hydrolysis	90% conversion efficiency to corresponding sugars
Sugars to product monomers	One overall conversion efficiency of 80%
Monomers to polymers	One overall conversion efficiency of 90%

Table 7: Projected corresponding demand for biomass feedstocks for biobased chemicals production (in million tonnes)

2020	**Lignocellulosic biomass**	**Wheat (50%) / Sugar beet root (50%)**	**Wheat (20%) / Sugar beet root (80%)**	**(Vegetable) oil crops**
High	0.6	7.8	10.7	6.9
Medium	0.5	7.5	10.3	
Low	0.4	7.1	9.8	
2030	**Lignocellulosic biomass**	**Wheat (50%) / Sugar beet root (50%)**	**Wheat (20%) / Sugar beet root (80%)**	**(Vegetable) oil crops**
High	2.2	18.5	25.4	9.7
Medium	1.4	13.7	18.8	
Low	0.9	9.2	12.6	

The resulting estimates for feedstocks indicate that lignocellulosic biomass demand for biobased chemicals even in 2030 is still significantly lower than the total demand for other biomass feedstocks.

Figure 2 presents the projected EU lignocellulosic biomass demand for PMCs 4 & 5.

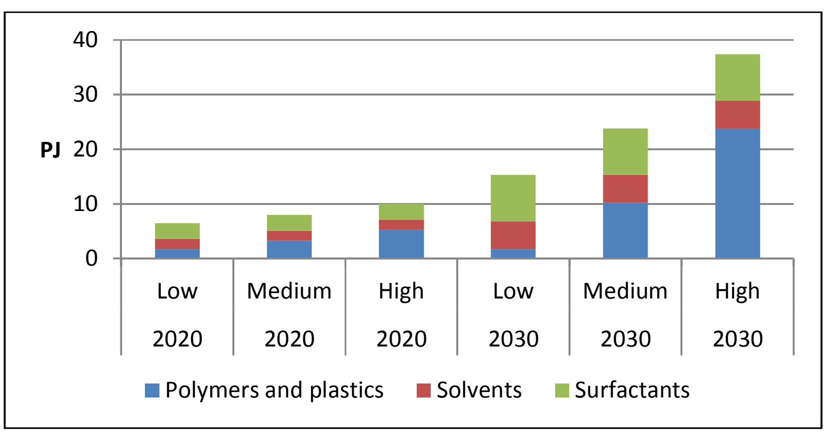

Figure 2: Projected lignocellulosic biomass demand for PMCs 4 and 5 in Europe

4. Market analysis of biomethane, BTX, methanol, hydrogen, ethylene, and mixed alcohols

A detailed description of the market analysis of biomethane, BTX, methanol, hydrogen, ethylene, and mixed alcohols is given in the S2Biom Deliverable 7.2c [9].

Table 8 presents the intermediate resp. final products and markets for each considered product-market combination.

Table 8: Considered product-market combinations

Interm. product	Interm. market	Final product	Final Market
		Biomethane	Grid, transport fuel
BTX	Petrochemical industry	Polystyrene, PET, fuel additives (Toluene)	Chemical industry, transport sector
Methanol	Chemical industry	Methanol, MTBE, DME, FAME, formaldehyde, acetic acid	Transport sector, chemical industry
Hydrogen	(Petro)chemical industry	Hydrogen, hydrogenates, ammonia, hydrochloric acid	Transport sector, Chemical industry
Ethylene	(Petro)chemical industry	Polyethylene, ethylbenzene, ethylene oxide, ethylene dichloride	Chemical industry

In deliverable 7.2c [9] current market for the above-mentioned PMCs is reviewed, followed by the introduction of the reference (fossil) production routes and the alternative biobased production routes. Table 9 presents the selected biobased production routes for the considered PMCs.

Table 9: Selected production routes for the considered PMCs

PMC	Production route
Biomethane	Indirect gasification of solid biomass to a methane-rich producer gas, followed by methanation of the remaining carbon monoxide and gas upgrading to bio-SNG
BTX	The same route as for the production of biomethane, however, with optimisation towards BTX production
Methanol	Gasification of biomass in a pressurized CFB gasifier, followed by steam reforming, and methanol synthesis from produced syngas
Hydrogen	Syngas production from biomass gasification, followed by water-gas shift reaction and hydrogen separation
Ethylene	Bioethanol production via biochemical conversion route of lignocellulosic biomass, followed by dehydration of bioethanol to bio-ethylene

Figure 3 presents current and expected fossil-based production levels in EU for BTX, methanol, hydrogen and ethylene. Also the expected biobased production levels in EU for the medium scenario are presented. The expected biomass demand for each PMC can then be determined by taking the (assumed) conversion efficiencies of the selected biobased production routes into account. Table 10 presents the demand in

2020 and 2030 in PJ for different PMCs. Note that BTX and biomethane PMCs are related to each other, as BTX is a co-product of biomethane production based on biomass gasification (see also section 2.5 in [9]). Figure 4 presents the projected lignocellulosic biomass demand (in PJ) for PMCs 6-10 in Europe.

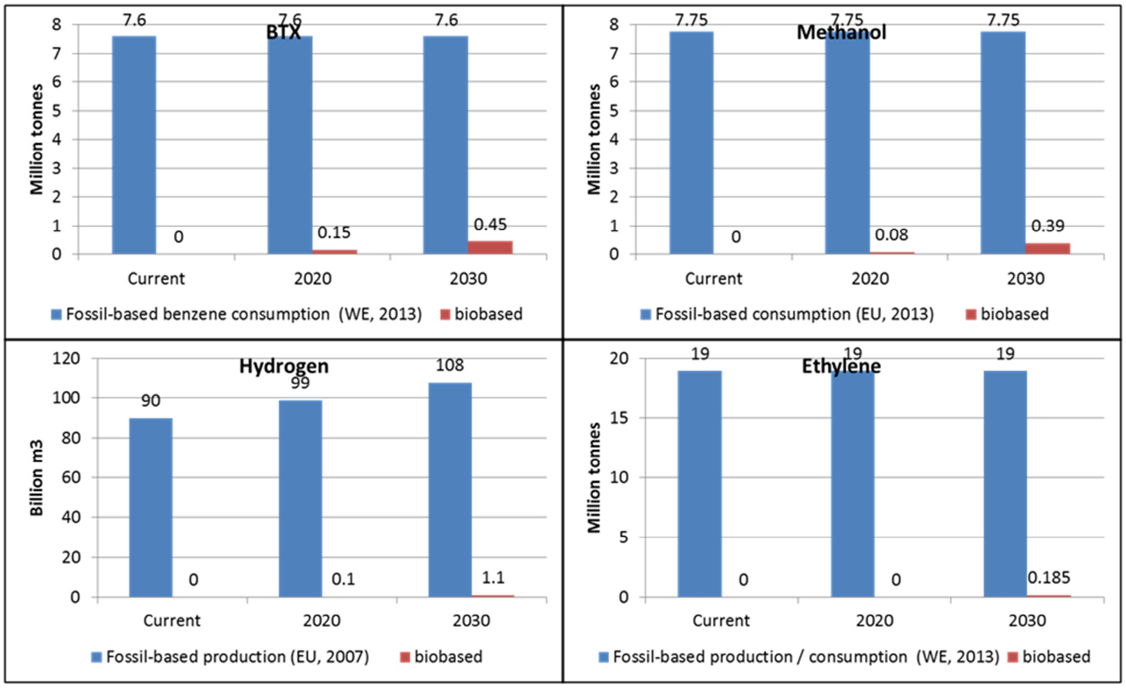

Figure 3: Current and expected fossil-based resp. biobased production levels in EU

Table 10: Total expected biomass demand (in PJ) in 2020 and 2030 for considered PMCs (Low/Middle/High scenarios)

PMC	**2020 (PJ)**	**2030 (PJ)**
Biomethane	51 / **64** / 77	94 / **188** / 282
BTX	58 – 51 / **73 – 64** / 87 – 77 7 / **9** / 10	107 – 94 / **214 - 188** / 321 – 282 13 / **26** / 39
Methanol	2 / **3** / 3	6 / **13** / 19
Hydrogen	1 / **2** / 2	10 / **19** / 29
Ethylene	0 / **0** / 0	11 / **23** / 34

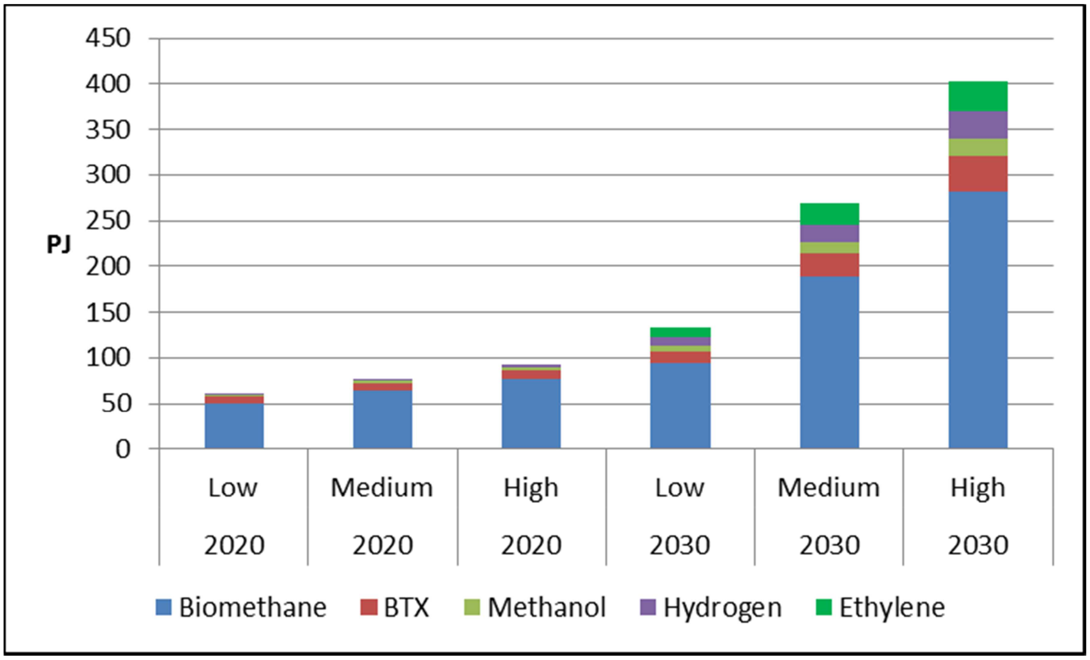

Figure 4: Projected lignocellulosic biomass demand for PMCs 6-10 in Europe

5. Summary of the outcomes

The projected total lignocellulosic biomass demand (PJ) for the PMCs 4-10 excluding biomethane PMC in 2020 and 2030 are summarized in Figure 5. Although methane is also used as feedstock for some processes within the (petro)chemical industry, It is assumed that biomethane would mainly be used in the bioenergy sector either as a biofuel, or for the generation of heat and/or electricity (PMCs 1-3). The lignocellulosic biomass demand for biomethane PMC in Europe is estimated up to 80 PJ in 2020 and 280 PJ in 2030.

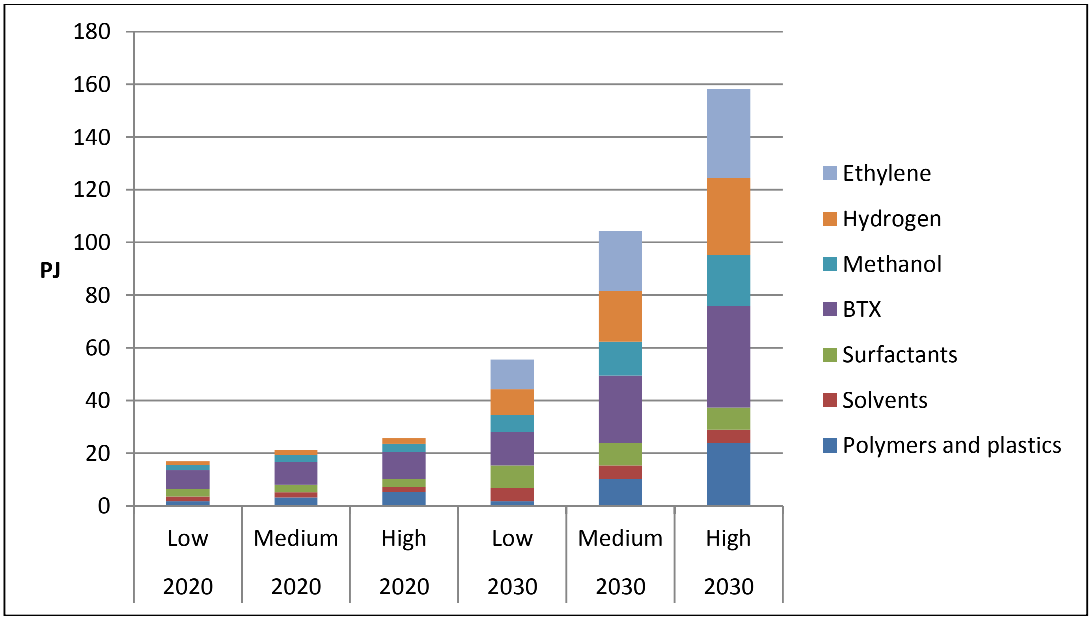

Figure 5: Projected total lignocellulosic biomass demand for PMCs 4-10 excluding biomethane PMC

Table 11 gives impressions of the significance of the projected amounts[5] of the lignocellulosic-based chemicals and materials in Europe. For example, the projected lingo-based biopolymers & plastics in 2030 correspond to about 60% of the EU biobased polymers & plastics production in 2012. In order to produce the projected amount of bio-methanol in 2030, about 5 wood gasification plants with a thermal input of 100 MW would be required. Finally, the expected production of bio-hydrogen in 2020 would be sufficient to fuel more than 75,000 hydrogen vehicles, with average annual mileages of 11,000 km and an average hydrogen consumption of 1 kg/100 km.

In Table 12 an indicative consumption of domestic lignocellulosic biomass for the PMCs 1-3 in EU28+ is compared to the expected consumption of domestic lignocellulosic biomass for the PMCs 4-10 excluding biomethane PMC.

[5] Medium Scenario

Table 11: Projected lignocellulosic-based chemicals & materials in Europe

	Unit	2020	Impression	2030	Impression
Biopolymers & bioplastics	kt	77	≈20% of EU biobased polymers & plastics production in 2012	233	≈60% of EU biobased polymers & plastics production in 2012
Solvents	kt	44	7% of EU biobased solvent production in 2008	141	22% of EU biobased solvent production in 2008
Surfactants	kt	69	5% of EU biobased surfactant production in 2008	195	13% of EU biobased surfactant production in 2008
BTX	kt	150	Requires 10 wood gasification plants of 150 MW_{th} (input)	450	Requires 28 wood gasification plants of 150 MW_{th} (input)
Methanol	kt	77	Requires ≈ 1 wood gasification plant of 100 MW_{th} (input)	387	Requires ≈ 5 wood gasification plants of 100 MW_{th} (input)
Hydrogen	Bm3	0.1	Enough to fuel > 75,000 hydrogen vehicles	1.1	Enough to fuel ≈ 1,000,000 hydrogen vehicles
Ethylene	kt	0	-	185	44% of current global bio-ethylene production

Table 12: Comparison demand (PJ) lignocellulosic biomass EU28+

	2020	2030
PMCs 1-3 Consumption of domestic lignocellulosic biomass in EU28+	5,173	7,238
Consumption of domestic lignocellulosic biomass for PMCs 4-10 excluding biomethane PMC	21.1	104.3
Biomass demand for PMCs 4-10 excluding biomethane PMC, compared to biomass demand for PMCs 1-3	0.41%	1.44%

6. Conclusions and recommendations

The results of this exploratory study indicate that:

- Demand for lignocellulosic biomass for chemicals and materials at pan European level in 2020 would be around one million tonne, increasing to less than 10 million tonnes in 2030.
- Based on the energy content, the demand would be around 0.4% of the corresponding demand for bioenergy and biofuels (PMCs 1-3), increasing to 1.4% in 2030.

Key factors affecting this picture are:

- The rate of technology development (both for advanced chemicals/material and for biofuels and bioenergy)
- The exact shaping of the supporting policy framework, and
- The future of the (petro)chemical industry in Europe
- Besides, the oil price is a strong factor affecting the prospects for biobased chemicals and materials.

As the performed market review is indicative in many respects, both the review results and the outcomes of the integrated assessment for which they will be used (Tasks 7.3-7.5) will be subject to stakeholder consultation in WP10 of the project.

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Annex I: Quantitative estimate of future market volumes of biobased chemicals: Annex to S2Biom Deliverable 7.2b [8]

Author: H.M. Londo

Date: 15 November 2015

1. Introduction

The S2Biom project (EU-FP7) provides support to the delivery of sustainable non-food biomass for energy, fuels and chemicals/materials. One of the activities in S2Biom Work Package 7 is a market review: how much biomass demand can be foreseen up to 2030 when production of biobased chemicals and materials develops further? The focus is on biomass demand for European production facilities (EU28, Western Balkans, Moldova, Turkey and Ukraine) and on lignocellulosic biomass feedstocks and their applications.

One of the market review products is Deliverable 7.2b: *A Market analysis of sugar-lignin platforms* [7]. This document contains extensive information on possible production routes, with some in-depth reviews of key biobased chemicals. This memo uses information from [7] and other sources to come to a quantitative estimate.

The memo goes into four questions:

- What could be the total production capacity of biobased chemicals in Europe by 2020?
- How much of this would use lignocellulosic biomass (or its components) as a feedstock?
- What could be the corresponding demand for lignocellulosic biomass in Europe by 2020?
- What could be an indication for the European production capacity and lignocellulosic biomass demand for 2030?

Section 2 to 5 go into the assumptions and data sources we used for the calcuations. Section 6 summarises the outcomes.

All sources stress the indicative nature of their projections. This because biobased chemicals are a mostly new group of products, beyond business as usual, they require significant investments in a risky environment, also because the environmental benefits of biobased chemicals are not clearly valued yet in relevant policy frameworks. Besides, the economic situation is uncertain, in Europe in general and in the chemistry sector in particular, and the prices of oil, the competing feedstock, have been extremely volatile during the past years. Therefore, we propose ranges for the projected values.

2. Projected European production capacity of biobased chemicals

There are several outlooks presenting estimates of global biobased chemicals. For this review, we are searching for sectors that can create significant biomass demand. Therefore, we concentrate on the relatively bulky chemicals markets. Specialties and fine chemicals can have high added value and can therefore be most relevant for a biorefinery business case, but their production will by definition not induce bulky amounts of biomass demand. Therefore we have left them out of consideration here.

For the S2Biom project, the main interest lies with lignocellulose-based chemicals. However, for the broader picture on the matter, we also summarise outlooks for biobased chemicals that are based on food crop inputs, such as starch and vegetable oils.

2.1 Biobased plastics

As an illustration of uncertainties, global production capacity estimates for biobased plastics in 2020 vary widely:

- The BIOCHEM study [11] reviews several literature sources which range between 1.5 and 4.5 million tonnes
- Aeschelmann and Carus [10] project a production capacity of more than 6.7 million tonnes by 2018, with a dominance of biobased PET, and smaller contributions of a wide variety of other plastics, including PLA, polyesters, starch blends and PE.

Specifically on European biobased plastic production capacities, the prospects found are:

- BIOCHEM [11] refers to a Pöyry study that projects 0.9 million tonnes of biobased plastics production.
- Aeschelmann and Carus [10] of the Nova Institute give the same number with a subspecification of various plastic types.
- On the basis of the same extensive source material Dammer et al. [12] of Nova come to an indication of 1.2 million tonnes (see Figure 6). The key difference of this study with Aeschelmann and Carus [10] seems to be the inclusion of PET, with a foreseen capacity of 0.2 million tonnes.

On this basis, we propose to start with a European production capacity for biobased plastics of 1 million tonnes by 2020. This corresponds to 15% of global production capacity by that year as given by Aeschelman et al [10].

Many of these biobased plastics are not for 100% produced from biomass. Co-polymers such as PET, for example, are produced from two different monomers: currently a biobased and a fossil one. On the basis of detailed breakdowns in Dammer et al. [12], a weighted average share of biomass-based components of 50% seems defendable for 2020.

Given the general uncertainties it seems reasonable to create a range around the 0.5 million tonnes estimate of biomass-based components in biobased plastics. We propose to use:

- As an upper range a situation in which the share of EU capacity in global biobased capacity goes to 18%;
- As a lower range in which this share is 12% of global biobased production.

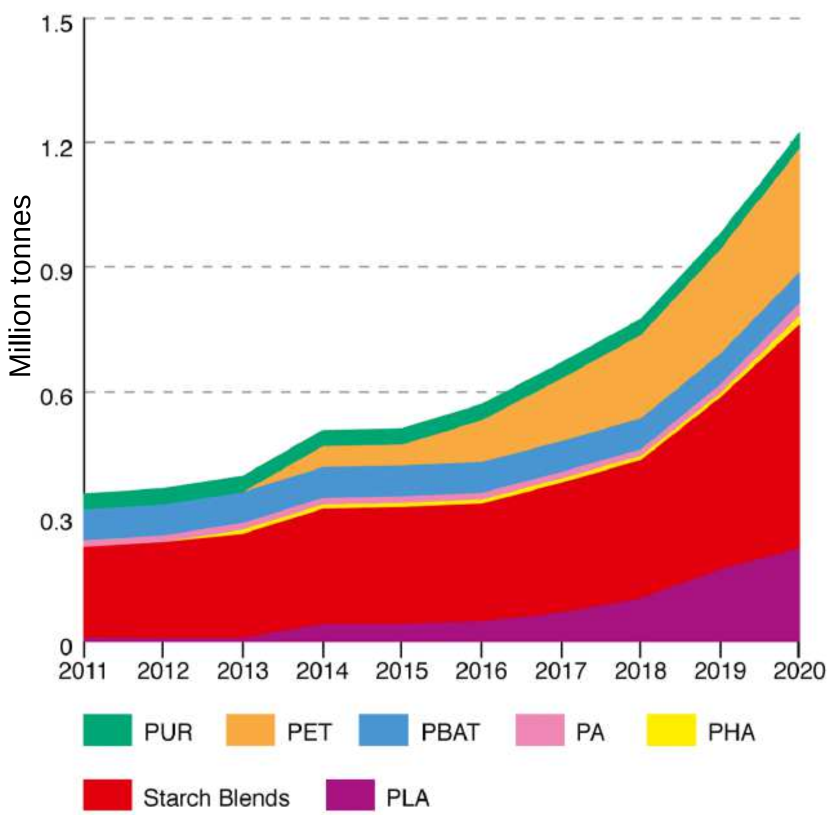

Figure 6: Biobased polymers projection for Europe, excluding cellulose acetate and thermosets. Source: Dammer et al. [12]

2.2 Biobased surfactants, lubricants and solvents

Biobased surfactants, lubricants and solvents all have higher biobased consumption levels in Europe than biobased plastics [11]. The estimated growth rates of these biobased substances are significantly lower than that of biobased plastics and polymers, and current production routes are mostly based on vegetable oils and starch, for which lignocellulosic biomass is an improbable feedstock. The key estimates of the BIOCHEM study [11] on these substances is summarized in Table 13.

Table 13: Estimated EU production volumes of biobased lubricants, solvents and surfactants. Source: [11] and [7]

Substance	EU total consumption 2008 (Mtonne)	EU biobased consumption 2008 (Mtonne)	Biobased potential in 2020 (Mtonne)	Growth potential (%/a)	Biomass feedstocks (products)
Lubricants	5.2	0.15	0.23	3.6%	Vegetable oils (derivatives)
Solvents	5.0	0.63	1.1	4.8%	Vegetable oils (esters), Sugars (lactate esters) Citrus oils (D-limonene)
Surfactants	2.7	1.52	2.3	3.5%	Vegetable oils and sugars (derivatives)

These markets are already well-established in comparison with the biobased plastics markets. Therefore uncertainty ranges around these numbers were not created.

3. Indicative shares of feedstock

3.1 Biobased plastics

The breakdown of European production capacity of biobased plastics (Figure 6) gives a basis for this when corrected for the biomass-based share of it. For 2020 it is assumed that 85% of polymers & plastics are based on starch and sugar crops and 15% are lignocellulosic-based. For the high and low estimates, we assume that 80% respectively 90% of polymers & plastics are based on starch and sugar crops and 20% respectively 10% are lignocellulosic-based.

3.2 Biobased lubricants, solvents and surfactants

For these categories, we propose the folllowing shares regarding feedstocks in 2020:

- Biobased lubricants are assumed to be 100% based on vegetable oils.
- Solvents are assumed to be 50% based on vegetable oils, 40% based on sugars, and 10% based on other specific biomass feedstocks such as citrus

oils. Of these sugars, we assume in 2020 90% still to be derived from sugar or starch crops, and 10% from lignocellulosic feedstocks.

- Biobased surfactants are assumed to be 70% based on vegetable oils and 30% based on sugars. Of these sugars, we assume in 2020 90% still to be derived from sugar or starch crops, and 10% from lignocellulosic feedstocks.

4. Corresponding lignocellulosic biomass demand in Europe by 2020

For this translation, we made the following assumptions[6]:

- A biomass dry matter content of 90% was assumed for lignocellulosic biomass.
- Current bioplastic routes for e.g. PLA and PE only use the cellulose and hemicellulose parts of the feedstock; lignocellulosic biomass consist for ca 70% of (hemi)cellulose. Lignin is a more complex resource for which less biochemical pathways are available today.
- A conversion efficiency for the hydrolysis of (hemi)cellulose to their corresponding sugars of 90%.
- Conversion efficiencies from sugars to product monomers vary widely. For example:
  - On energy basis, cellulosic ethanol production has a typical conversion efficiency of 60% [14], or almost 70% when taking into account a 90% cellulose-to-sugars efficiency.
  - For succinic acid production, a lab-scale conversion efficiency of 92% (mass/mass) has been reported [13].
  - For lactic acid, a comparable efficiency of 93% (mass/mass) was reported by Yang et al. [15].

  Given the scope of the assessment, we've taken one overall conversion efficiency of 80% as a basis for the calculations.
- Conversion efficiencies from product monomers to polymers: for this step, we take an overall efficiency of 90%.

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[6] And the following assumptions were made concerning the non-ligno biomass:

- For starch-based plastics, a standard starch-to-plastic conversion efficiency of 80% (mass-based);
- For lubricants, solvents and surfactants based on vegetable oils and sugars, a conversion efficiency of 80% (mass-based);
- Non-ligno sugars are all produced from sugar beet root (with 80wt.% moisture, 15wt.% sugar and 5wt.% pulp);
- Starch is produced from wheat (with about 65wt.% carbohydrates);
- Vegetable oil is assumed to be produced from rapeseed (45wt.% of the rapeseed; source: http://www.bioref-integ.eu/fileadmin/bioref-integ/user/documents/Final_Report.pdf, page 38, figure 3-1).

5. Projections for 2030

For this year, we made the following assumptions:

For plastics:

- In the high variant, a growth percentage of 15% is assumed for biobased plastics in 2020-2030. In that year, the share of actual biomass-based components in the plastics is assumed to have increased from 50% to 70%. Of this, 80% is based on starch and sugar crops, and 20% is lignocellulose-based.
- In the medium variant, a growth percentage of 10% is assumed for biobased plastics in 2020-2030. In that year, the share of actual biomass-based components in the plastics is assumed to have increased from 50% to 60%. Of this, 85% is based on starch and sugar crops, and 15% is lignocellulose-based.
- In the low variant, a growth percentage of 10% is assumed for biobased plastics over the entire period of 2012-2030. The share of actual biomass-based components in the plastics is kept constant at 50%. Of this, 90% is based on starch and sugar crops, and 10% is lignocellulose-based.

For lubricants, solvents and surfactants:

- The growth rates for 2012-2020 [11] were extended until 2030.
- We propose the folllowing shares regarding feedstocks in 2030 :
  - Biobased lubricants are assumed to be 100% based on vegetable oils.
  - Solvents are assumed to be 50% based on vegetable oils, 40% based on sugars, and 10% based on other specific biomass feedstocks such as citrus oils. Of these sugars, we assume 80% still to be derived from sugar or starch crops, and 20% from lignocellulosic feedstocks.
  - Biobased surfactants are assumed to be 70% based on vegetable oils and 30% based on sugars. Of these sugars, we assume 80% still to be derived from sugar or starch crops, and 20% from lignocellulosic feedstocks.

6. Summary of the outcomes

The resulting demand for biobased chemicals in 2020 and 2030 are summarized in Table 14.

Table 14: Projected EU production capacity of various biobased chemicals (in million tonnes)

2020	Plastics	Lubricants	Solvents	Surfactants
High	0.6	0.2	1.1	2.3
Medium	0.5			
Low	0.4			
2030	**Plastics**	**Lubricants**	**Solvents**	**Surfactants**
High	4.0	0.3	1.8	3.2
Medium	2.6			
Low	1.0			

Table 15 summarises the correponding demand for biomass feedstocks in both years.

Table 15: Projected corresponding demand for biomass feedstocks for biobased chemicals production (in million tonnes)

2020	Lignocellulosic biomass	Wheat (50%) / Sugar beet root (50%)	Wheat (20%) / Sugar beet root (80%)	(Vegetable) oil crops
High	0.6	7.8	10.7	6.9
Medium	0.5	7.5	10.3	
Low	0.4	7.1	9.8	
2030	**Lignocellulosic biomass**	**Wheat (50%) / Sugar beet root (50%)**	**Wheat (20%) / Sugar beet root (80%)**	**(Vegetable) oil crops**
High	2.2	18.5	25.4	9.7
Medium	1.4	13.7	18.8	
Low	0.9	9.2	12.6	

The resulting estimates for feedstocks indicate that lignocellulosic biomass demand for biobased chemicals even in 2030 is still significantly lower than the total demand for other biomass feedstocks.

As this review is indicative in many respects, both the review results and the outcomes of the integrated assessment for which they will be used (Tasks 7.3-5) should be subject to stakeholder consultation in WP10 of the project.