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

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A selection method to match biomass types with the best conversion technologies.

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1. Introduction

1.1. Background

In the S2Biom project the most relevant lignocellulosic biomass types for conversion into energy or products have been identified (in WP1). The classification of these biomass types is mainly based on species. The technologies for conversion of these different types of biomass have been identified (WP2).

1.2. Task description

This report provides a selection method to match biomass types with the best conversion technologies (task 2.3). This method will be further worked out into a tool for matching biomass types and conversion technologies (task 4.2). Task 2.2 covers the definition of quality characteristics of identified biomass resources from WP1 and required quality for the biomass conversion technologies identified in task 2.1 Each of the existing and future conversion technologies (both conventional biomass plants and biorefineries) as described in task 2.1 has specific biomass input requirements (i.e. cellulose, hemicellulose, lignin content, moisture content, minerals like chlorine etc.), while the quality of biomass differs largely between the different biomass types. It is remarked here that the possibility to alter the characteristics by pre-treatment of the biomass (like drying, sizing, densification, etc.) will be considered in WP3.

1.3. Problem description

The suitability of a biomass type for a specific conversion technology is determined by different parameters that cannot be directly deduced from the current lignocellulosic biomass classification used in WP1. In other words, based on this current classification we cannot determine if a specific biomass type is suitable for a specific conversion system and to what extend it is suitable and therefore what the value of that biomass type is for a specific conversion system.

Therefore we need a system that can classify biomass based on relevant characteristics for determining its suitability for conversion technologies. Such a classification system should help to determine what type of conversion systems are needed to effectively utilise the available biomass types in Europe under competitive conditions. Less suitable biomass will also have to find an energy application.

The current international classification system for solid biofuels (ISO 17225 series) should also be taken into account, because this is used in trade.

1.4. Approach

We need to classify the biomass types according to their suitability for conversion systems. The main purpose is to match the biomass types distinguished in WP1 with the conversion technologies.

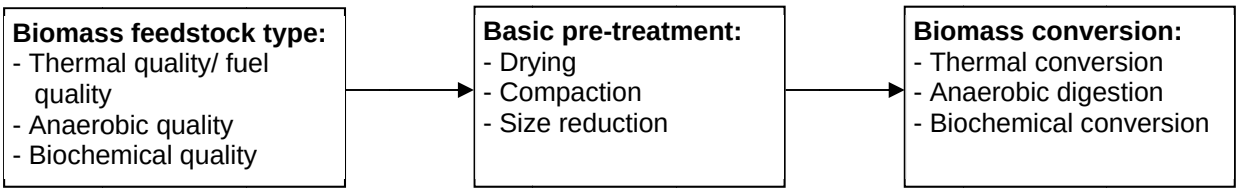

Figure 1. Simplified classification concept to match biomass types based of fundamental chemical characteristics to the main conversion options.

We distinguish three main conversion categories:

A. Thermal conversion technologies
B. Anaerobic digestion
C. Biochemical conversion

To match biomass types with conversion technologies we must identify the fundamental biomass characteristics which determine the value of biomass for a conversion system. Examples are chlorine content as indicator for corrosion risk, ash melting point, ash content, nitrogen in the biomass. Characteristics that can be adjusted with basic pre-treatment methods such as drying, compacting (i.e. pelletizing), or size reduction (i.e. chipping) will not be considered, but treated later as a cost factor. Based on expert judgement the most relevant characteristics per conversion category are identified.

2. Thermal conversion technologies

Here four main issues determine the quality:

- corrosion;
- ash melting (which leads to fouling and sintering);
- total ash content;
- NOx emission.

These issues will be described in the next sections.

2.1. Corrosion

Corrosion is mainly determined by chlorine (Cl) content and the ration of chlorine to sulphur (S) of the biomass. Sulphur in the biomass can counteract the corrosive effect of Cl. In general biomass will not contain a lot of sulphur.

Table 1. Chlorine to Sulphur ratio indicator for corrosion risk during thermal conversion in four stages.

Sulphur/Chlorine index, molar, Cl%	Corrosion risk	Suitability	Classification
> 6	Very low	Most desirable	1
> 4	Low	Desirable	2
2 - 4	High	Undesirable	3
< 2	Very high	Very undesirable	4

*S/Cl is important especially for fluidized bed combustion.

Explanation:

The risk of corrosion is directly related to the chloride content of biomass in thermal conversion. This can be reduced by the presence of sulphur (S). If the Cl/S ratio is lower than 4 the risk of corrosion is very high.

2.2. Ash agglomeration

Ash agglomeration leads to fouling of the thermal conversion (reactor/boiler/gasifier). The main indicator is the ash melting temperature. When this is not available an ash agglomeration indicator can provide an indication of the risk for fouling and agglomeration. These indicators give a measure of the alkali metal (K, Na) content of the ash or the alkali to other ash compounds ratio.

Here we use 2 of most used indicators that give an indication for risk of slagging:

2.2.1. Alkali Index

An often used indicator for slagging and fouling risk is the Alkali Index proposed by Miles at al. (1996).

Alkali Index: (Na_2O + K_2O)/Gross calorific value (HHV)

Table 2. Alkali index as indicator of risk of slagging and fouling in 3 stages.

Alkali index	Risks	Suitability	Classification
<0.17	slagging/fouling unlikely	Desirable	1
0.17 – 0.34	probably fouling	Undesirable	3
>0.34	fouling certain	Very undesirable	4

2.2.2. Fouling index

Another indicator for fouling risk is the Fouling index developed by Teixeira et al. (2012). This index is based on the Base to Acid ratio of the ash using the formula:

Fouling Index: ((Fe_2O_3+CaO+MgO+K_2O+Na_2O) / (Al_2O_3+SiO_2+TiO_2)) * (K_2O+Na_2O)

Table 3. Fouling index as indicator of ash fouling in 4 stages.

Fouling index	Fouling risks	Suitability	Classification
<0.6	Low	Desirable	1
0.6 – 1.6	Medium	Less desirable	2
1.6 – 40	High	Undesirable	3
>40	Extremely high	Very undesirable	4

2.2.3. Ash melting temperature: (initial deformation temperature, IDT)

Table 4. Ash melting temperature in 4 stages.

Initial deformation temperature, DT °C	Risk of ash melting	Suitability	Classification
< 800	Very high	Very undesirable	4
800 – 1,000	High	Undesirable	3
1,000 – 1,200	Low	Desirable	2
> 1,200	Very low	Most desirable	1

2.3. Ash content:

Ash is undesirable in thermal conversion because i) it does not contribute to energy production, ii) it may increase wear of the machinery and iii) it will generally cost money to discard ash (in The Netherlands € 100,- per tonne is a good cost indication) iiii stoves are

generally designed to a limited ash amount. We have chosen the following ash content stages:

Table 5. Ash content in 4 stages.

Ash content (550°C), w-% on dry basis	Qualification	Suitability	Classification
< 1	Very low	Ideal	1
1 – 3	Low less	Desirable	2
3 – 10	High	Undesirable	3
> 10	Very high	Very undesirable	4

2.4. NOx emission

NOx emissions from biomass thermal conversion is undesirable as it leads to air pollution and eutrophication. The nitrogen content of the biomass and the conversion methods will determine the NOx emissions. The NOx emission standards differ between countries in the EU.

Nitrogen content should not be so relevant for operation of the thermal conversion technology itself. However, emission reduction measures make the conversion technology more expensive, and less economical to apply on a small scale (= below 1 MWth). Therefore the nitrogen content is indeed relevant (especially for smaller conversion systems). Nitrogen content can be high for waste wood (used wood), grasses and many other biomass types. The allowed ranges depend on (local) emission legislation e.g. industrial emission directive and national legislation e.g. for small-scale combustion (example Austria and the Netherlands). Typical Nitrogen contents in biomass for thermal conversion will range from below 0.3% for clean wood to more than 2.5% for green leaves of grasses of green field crops.

Table 6. Nitrogen content (% dry matter basis) as indicator of NOx emission.

Nitrogen % on dry basis	Qualification	Suitability	Classification	Classification
< 0.3 %	Very low	Ideal	no emission reduction measures needed	1
0.3 – 1	Low	Desirable	process design measures like stage combustion needed	2
1 – 2.5	High	Undesirable	SCR**, SNCR* probably needed	3
>2.5	Very high	Very undesirable	SCR, SNCR definitely needed	4

*SNCR: Selective non-catalytic reduction. Reduces NOx emissions by 40%-75%.
**SNR; Selective Catalytic Reduction. Reduces NOx emissions by 60%-90%.

3. Anaerobic digestion

In aerobic digestion a large part of the cost is determined by the size of the reactor. It is important that the yield per reactor m^3 per year is high enough. Therefore the methane yield per ton (or m^3) of substrate is very relevant. Of course the cost of the disposal of the digestate will also be relevant.

Table 7. Biogas yield classification indication of suitability as substrates.

Biogas yield per tonne (as is basis)*	Qualification	Suitability	Classification
< 50 m^3	Very low	Not desirable	4
50 – 150 m^3	Low	Less desirable	3
150 – 300 m^3	High	Desirable	2
>300 m^3	Very high	Very desirable	1

* Biogas yield is expressed as in m^3 biogas per m^3 of fresh substrate. Assuming the biogas has a methane content of 55%.

For many substrates the biogas yield is known. The expected biogas yield can be estimated based on the biomass composition (BLfL, 2015). A digester will produce large amounts of residues, called digestate. Generally this digestate will be used as a soil amendment (fertilizer). If application as a soil amendment/fertilizer is not allowed the cost of disposal is generally very high. Local legislation will determine if a certain type of digestate can be used as soil amendment. The option to apply digestate as a fertilizer depends on local legislation and on the type of substrate(s) used. For example in The Netherlands any digestate that is made from a waste product will also be classified as a waste and therefore cannot be applied as a fertilizer. For applicability of the substrate as a soil amendment we have chosen only two simple stages.

Table 8. Applicability of digestate as a soil amendment as indicator of suitability for anaerobic digestion.

Application of digestate possible	Suitability	Classification
Yes	Desirable	1
No	Undesirable	4

Other aspects may also be relevant for the suitability of biomass for an anaerobic digester but they should be covered by the general criterion “biogas yield”. For instance, high lignin content is not good for biogas yield. However, all (high lignin) woody biomass can be already excluded from anaerobic digestion technology.

4. Biochemical conversion

Biochemical conversion is defined here as the pre-treatment of lignocellulosic biomass into sugars, followed by fermentation into fuels or chemicals. We use cellulosic ethanol production as a reference here.

Fundamental biomass characteristics that influence the potential success of biochemical conversion of lignocellulose biomass into fuels and chemicals (apart from productivity per ha and production cost), are:

- **Lignin content**: lignin can hardly be degraded by enzymes and micro-organisms. Secondly, it acts as a shield that prohibits the bio-conversion of cellulose and hemicellulose. The higher the lignin content, the more difficult it is to use lignocellulose as feedstock in biochemical conversion processes
- **High carbohydrate content (specifically cellulose and hemicellulose)**": the main components of interest in biochemical conversion of (lignocellulosic) biomass are cellulose and hemicellulose, which are carbohydrate polymers, as most conversion processes are based on sugars. The higher the cellulose and hemicellulose content, the more suitable the biomass type is for biochemical conversion.
- **Low ash content**: as with other two conversion methods, ash or inorganic material cannot be converted within biochemical processes and generally adds to the costs of conversion.
- **Low antiquality compounds**: For certain processes, the biomass should have a limited concentration of polyphenols, and toxic (Examples?) components that might hinder fermentation processes.
- **Protein:** for biorefinery purposes, protein could be extracted and valorised so a higher content could be desirable.

Other important factors are seasonality which influences the availability timeframe of biomass, differences in composition throughout the season, and morphological factors (like particle size etc.).

For our suitability approach we only use the three most basic indicators:

- Lignin content;
- Cellulose+ hemicellulose content;
- Ash content.

Protein is not being considered here. Still, protein content can be relevant as is has no real function for biochemical conversion but may have a value by itself. In general a high protein content should be less desirable.

4.1. Lignin content

Table 9. Ash-free lignin concentration as an indicator of biomass suitability for biochemical conversion.

Ash-free lignin concentration % on dry weight basis	Suitability	Classification
< 10 %	Desirable	1
10 – 20 %	Standard	2
20 – 30 %	Less desirable	3
> 30 %	Undesirable	4

4.2. Cellulose + hemicellulose content

Table 10. Total Carbohydrate (cellulose and hemi-cellulose) concentration as suitability indicator for biochemical conversion.

Total carbohydrate - cellulose and hemicellulose % - on dry weight basis	Suitability	Classification
> 65 %	highly desirable	1
50 – 60 %	Desirable	2
30 – 50 %	Less desirable	3
< 30 %	Undesirable	4

4.3. Ash content (same as for thermal conversion):

In a similar way as for thermal conversion, ash is undesirable for biochemical conversion. Some ash components may also interfere with chemical pre-treatment processes or recovery of chemicals used for pre-treatment.

Table 11. Ash content as indicator of biomass suitability for biochemical conversion.

Ash content (550°C), % on dry weight basis	Suitability	Classification
< 1	Ideal	1
1 – 3	Desirable	2
3 – 10	Undesirable	3
> 10	Very undesirable	4

5. Database set-up

In the previous chapters the main quality indicators have been identified that determine the value of biomass for different technologies. We now need to determine the quality scores for the different lignocellulosic biomass types that have been defined in the S2Biom project. See Annex 1 for the list of biomass types. Keep in mind that some of the biomass classifications in Annex 1 will a large range of biomass quality characteristics making it necessary to divided the class in sub-classes. In Table 13 an outline of the data base is given to attach the quality indicators to the different biomass types.

Table 12. Database set-up to classify biomass types according to suitability indicators for the main lignocellulose conversion options

	Conversion technology quality factor	Indicator	Biomass 1	Biomass 2
	Thermal conversion			
1	Corrosion	% S/Cl		
2	Ash agglomeration/fouling	Alkali index		
3		Fouling index		
4		Ash melting temperature		
5	Ash	% ash		
6	NOx emission	% nitrogen		
	Anaerobic digestion			
7	Biogas yield	m^3 biogas		
8	Applicability of digestate to soil	Yes or no		
	Biochemical conversion			
9	Lignin	% lignin		
10	Carbohydrate - cellulose + hemicellulose	% carbohydrate		
11	Ash	% ash		

For each of the technologies that have been defined in the S2Biom project we need to define the quality requirements as defined above. In Table 14 the database outline is given defining the quality requirements per conversion technology type.

Table 13. Quality demand per conversion technology for different conversion technologies.

	Conversion technology quality factor	Indicator	Technology 1	Technology 2
	Thermal conversion			
1	Corrosion	% chlorine	1,2,3,4	1,2
2	Ash agglomeration/fouling	Alkali index*		
3		Fouling index*		
4		Ash melting temperature		
5	Ash	% ash	1,2,3,4,	1, 2, 3
6	NOx emission	% nitrogen **		
	Anaerobic digestion			
7	Biogas yield	m^3 biogas	4,5	1,2,3,4
8	Applicability of digestate to soil	Yes or no	1, 2	1
	Biochemical conversion			

9	Lignin				% lignin		
10	Carbohydrate hemicellulose	-	cellulose	+	% carbohydrate		
11	Ash				% ash	1,2,3,4,	1, 2, 3

*Alkali Index, Fouling index and % Nitrogen have not yet been included in the S2Biom technology database (March 2015).

** % Nitrogen is important for local NOx emission limits.

References

Miles et al, Alkali Deposits found in Biomass power plants, a preliminary investigation of their extent and nature, NREL/TP-433-8142, US DOE, February 1996

Teixeira P, Lopes H, Gulyurtlu I, Lapa N, Abelha P (2012) Evaluation of 529 slagging and fouling tendency during biomass co-firing with coal in a fluidized 530 bed. Biomass Bioenergy 39: 192-203.

Appendix 1. Lignocellulosic biomass categories covered by the data base

Table 14 Lignocellulosic biomass categories covered by the data base

Origin	Category – Level 1	Category – Level 2	Category – Level 3	Consideration by S2BIOM	IDs of the Solid Biofuels Classification System of ISO/FDIS / DIN EN ISO 16559 (see Appendix)
1. Forestry	1.1 Primary production	1.1.1 Stemwood from thinnings and final fellings	1.1.1.1 Stemwood from final fellings originating from broadleaf trees	YES	1.1.3 Stemwood; 1.1.3.1 Broad-leaf with bark; 1.1.3.3 Broad-leaf without bark This category also includes harvests from full tree harvesting reduced to the stemwood fraction.
			1.1.1.2 Stemwood from final fellings originating from conifer trees	YES	1.1.3 Stemwood; 1.1.3.1 Coniferous with bark; 1.1.3.3 Coniferous without bark This category also includes harvests from full tree harvesting reduced to the stemwood fraction. Includes possibly 1.1.6 Bark (from forestry operations) where wood is debarked at the forest road side
			1.1.1.3 Stemwood from thinnings originating from broadleaf trees	YES	1.1.3 Stemwood; 1.1.3.1 Broad-leaf with bark; 1.1.3.3 Broad-leaf without bark This category also includes harvests from full tree harvesting reduced to the stemwood fraction.
			1.1.1.3 Stemwood from thinnings originating from conifer trees	YES	1.1.3 Stemwood; 1.1.3.1 Coniferous with bark; 1.1.3.3 Coniferous without bark This category also includes as well harvests from full tree harvesting reduced to the stemwood fraction Includes possibly 1.1.6 Bark (from forestry operations) where wood is debarked at the forest road side.
		1.1.2 Stem and crown biomass from early thinnings	1.1.2.1 Stem and crown biomass from early thinnings originating from broadleaf trees	YES	1.1.1 Whole trees without roots; 1.1.3.1 Broad-leaf with bark; 1.1.3.3 Broad-leaf without bark Without leaves if harvested in winter time Includes possibly 1.1.6 Bark (from forestry operations) where wood is debarked at the forest road side.
			1.1.2.2 Stem and crown biomass from early thinnings originating from conifer trees	YES	1.1.1 Whole trees without roots; 1.1.3.1 Coniferous with bark; 1.1.3.3 Coniferous without bark
	1.2 Primary residues	1.2.1 Logging residues from thinnings and final fellings	1-2-1 Logging residues from final fellings originating from broadleaf trees	YES	1.1.4 Logging residues; 1.1.4.1 Fresh/Green, Broad-leaf (including leaves); 1.1.4.3 Stored, Broad-leaf Without leaves if harvested in winter time.
			1-2-1 Logging residues from final fellings originating from conifer trees	YES	1.1.4 Logging residues; 1.1.4.2 Fresh/Green, Coniferous (including needles); 1.1.4.4 Stored, Coniferous
			1-2-1 Logging residues from thinnings originating from broadleaf trees	YES	1.1.4 Logging residues; 1.1.4.1 Fresh/Green, Broad-leaf (including leaves); 1.1.4.3 Stored, Broad-leaf Without leaves if harvested in winter time.
			1.2.1 Logging residues from thinnings originating from conifer trees	YES	1.1.4 Logging residues; 1.1.4.2 Fresh/Green, Coniferous (including needles); 1.1.4.4 Stored, Coniferous
		1.2.2 Stumps from thinnings and final fellings	1.2.2.1 Stumps from thinnings and final fellings originating from broadleaf trees	YES	1.1.5 Stumps/roots; 1.1.5.1 Broad-leaf
			1.2.2.2 Stumps from thinnings and final fellings originating from conifer trees	YES	1.1.5 Stumps/roots; 1.1.5.2 Coniferous

Origin	Category – Level 1	Category – Level 2	Category – Level 3	Consideration by S2BIOM	IDs of the Solid Biofuels Classification System of ISO/FDIS / DIN EN ISO 16559 (see Appendix)	
	1.3 Harvests from traditional coppice forests that does not focus on stemwood production			Not separately considered, quantities are included in section 1.2 and 1.3. This management form plays a negligible role in current forest management in all countries under consideration.	Not considered by ISO/FDIS / DIN EN ISO 16559	
2. Agriculture on arable land & grass land N. B. This includes marginal lands, abandoned lands, lands currently released from agriculture: i.e. land formerly used for agriculture but currently not used and ready to be utilised again	2.1 Primary production of lignocellulosic biomass	2.1.1. Energy grasses, annual & perennial crops (non wood)	2.1.1.1 Sweet and biomass sorghum (Annual grasses)	YES	2.1.2 Grasses	2.1.2.1 Whole plant without roots
			2.1.1.2 Miscanthus (Perennial grass)	YES	2.1.2 Grasses	2.1.2.1 Whole plant without roots
			2.1.1.3 Switchgrass (Perennial grass)	YES	2.1.2 Grasses	2.1.2.1 Whole plant without roots
			2.1.1.4 Giant reed (Perennial grass)	YES	2.1.2 Grasses	2.1.2.1 Whole plant without roots
			2.1.1.5 Cardoon (Perennial crop)	YES	2.1.3 Oil seed crops	2.1.3.2 Stalks and leaves 2.1.3.3 Seeds
			2.1.1.6 Reed Canary Grass (Perennial crop)	YES	2.1.2 Grasses	2.1.2.1 Whole plant without roots
			2.1.1.7 Other	Not considered since the role of further species is regarded negligible in a short term.		
		2.2.2 Short rotation coppice on agricultural land	2.2.2.1 Willow	YES	1.1.1 Whole trees without roots 1.1.2 Whole trees with roots 1.1.5 Stumps/roots	1.1.1.3 Short rotation coppice 1.1.2.3 Short rotation coppice 1.1.5.3 Short rotation coppice
			2.2.2.2 Poplar	YES	1.1.1 Whole trees without roots 1.1.2 Whole trees with roots 1.1.5 Stumps/roots	1.1.1.3 Short rotation coppice 1.1.2.3 Short rotation coppice 1.1.5.3 Short rotation coppice
			2.2.2.3 Other (incl. Eucalyptus)	YES	1.1.1 Whole trees without roots 1.1.2 Whole trees with roots 1.1.5 Stumps/roots	1.1.1.3 Short rotation coppice 1.1.2.3 Short rotation coppice 1.1.5.3 Short rotation coppice

Origin	Category – Level 1	Category – Level 2	Category – Level 3	Consideration by S2BIOM	IDs of the Solid Biofuels Classification System of ISO/FDIS / DIN EN ISO 16559 (see Appendix)
2. Agriculture on arable land & grass lands N. B. This includes marginal lands, abandoned lands, lands currently released from agriculture: i.e. land formerly used for agriculture but currently not used and ready to be utilised again.	2.2 Primary residues from - production for food, feed and other utilisations	2.2.1 Straw/ stubbles	2.2.1.1 Cereals and rice straw	YES	2.1.1 Cereal crops; 2.1.1.2 Straw parts
			2.2.1.2 Sunflower straw	YES	2.1.3 Oil seed crops; 2.1.3.2 Stalks and leaves
			2.2.1.3 Oil seed rape straw	YES	2.1.3 Oil seed crops; 2.1.3.2 Stalks and leaves
			2.2.1.4 Maize stover	YES	2.1.1 Cereal crops; 2.1.1.2 Straw parts
		2.2.2 Primary residues - woody pruning, & orchards residues	2.2.2.1 Residues from vineyards	YES	2.1.7 Segregated herbaceous biomass from gardens, parks, roadside maintenance, vineyards and fruit orchards
			2.2.2.2 Residues from fruit tree plantations	YES	2.1.7 Segregated herbaceous biomass from gardens, parks, roadside maintenance, vineyards and fruit orchards
			2.2.2.3 Residues from olive tree plantations	YES	2.1.7 Segregated herbaceous biomass from gardens, parks, roadside maintenance, vineyards and fruit orchards
			2.2.2.4 Residues from citrus tree plantations	YES	2.1.7 Segregated herbaceous biomass from gardens, parks, roadside maintenance, vineyards and fruit orchards
			2.2.2.5 Residues from nuts plantations	YES	2.1.7 Segregated herbaceous biomass from gardens, parks, roadside maintenance, vineyards and fruit orchards
			2.2.2.6 Grass biomass from various types of plantations	Only considered since as far as not reserved for feed and if it will be possible to identify data that allows for reliable estimates.	2.1.2 Grasses; 2.1.2.6 Blends and mixtures
	2.3 Grass land	2.3.1 Gras used for feed		Not considered since reserved for feed.	
		2.3.2 Currently unused grass land (Gras land not used for feed)	2.3.1 Grass from currently unused grass land	Only considered since as far as not reserved for feed and if it will be possible to identify data that allow reliable estimates.	2.1.2 Grasses; 2.1.2.6 Blends and mixtures
3. Other land use	3.1 Biomass from trees/hedges and other biomass from areas outside forests and outside of agriculture	3.1.1 Biomass from road side verges		YES	2.1.7 Segregated herbaceous biomass from gardens, parks, roadside maintenance, vineyards and fruit orchards
		3.1.2 Biomass from other areas under landscape maintenance		YES	2.1.7 Segregated herbaceous biomass from gardens, parks, roadside maintenance, vineyards and fruit orchards

Origin	Category – Level 1	Category – Level 2	Category – Level 3	Consideration by S2BIOM	IDs of the Solid Biofuels Classification System of ISO/FDIS / DIN EN ISO 16559 (see Appendix)	
4. Production based on lignocellulosic biomass	4.1 Secondary residues from wood industries	4.1.1 Secondary residues from wood-products industries by products (Saw mills and equivalent)	4.1.1.1 Saw dust, chips, veneer cores etc. (residues of stemwood)	YES	1.2.1 Chemically untreated wood by-products and residues	1.2.1.1 Broad-leaf with bark
						1.2.1.2 Coniferous with bark
						1.2.1.3 Broad-leaf without bark
						1.2.1.4 Coniferous without bark
			4.1.1.1 Other saw mill by products (bark etc,)	YES	1.2.1 Chemically untreated wood by-products and residues	1.2.1.5 Bark (from industry operations)
		4.1.2 Residues from industries using semi-finished wood & manufactured wood	4.1.2.1 Residues from semi-finished wood & from manufactured wood products	YES	1.2.1 Chemically untreated wood by-products and residues	1.2.1.1 Broad-leaf with bark
						1.2.1.2 Coniferous with bark
						1.2.1.3 Broad-leaf without bark
						1.2.1.4 Coniferous without bark
						1.2.1.5 Bark (from industry operations)
					1.2.2 Chemically treated wood by-products, residues, fibres and wood constituents	1.2.2.1 Without bark
						1.2.2.2 With bark
						1.2.2.3 Bark (from industry operations)
						1.2.2.4 Fibres and wood constituents
					1.2.3 Blends and mixtures	
		4.1.3 Secondary residues from pulp and paper industries by products	4.1.3.1 Black liquor	Not considered by S2BIOM since this is not solid biomass.		
	4.2 Secondary residues of industry utilising agricultural products	4.2.1 By-products and residues from food and fruit processing industry	4.2.1.1 Olive stones	YES	3.2.1 Chemically untreated fruit residues	3.2.1.2 Stone/kernel fruits/fruit fibre
			4.2.1.2 Other by-products and residues from food and fruit processing industry	Only considered since as far as it will be possible to identify data that allow reliable estimates.	3.2.1 Chemically untreated fruit residues	3.2.1.1 Berries
						3.2.1.2 Stone/kernel fruits/fruit fibre
						3.2.1.3 Nuts and acorns
						3.2.1.4 Crude olive cake
						3.2.1.5 Blends and mixtures
					3.2.2 Chemically treated fruit residues	3.2.2.1 Berries
						3.2.2.2 Stone/kernel fruits
						3.2.2.3 Nuts and acorns
						3.2.2.4 Exhausted olive cake
						3.2.2.5 Blends and mixtures
					3.2.3 Blends and mixtures	
		4.2.2 Cotton industry by-products	4.2.2. Cotton acorns	YES	3.2.1 Chemically untreated fruit residues	3.2.1.3 Nuts and acorns
	4.3 Secondary residues of industries utilising biomass			Not considered since not yet of practical relevance.		

Origin	Category – Level 1	Category – Level 2	Category – Level 3	Consideration by S2BIOM	IDs of the Solid Biofuels Classification System of ISO/FDIS / DIN EN ISO 16559 (see Appendix)
5. Post consumer biomass (tertiary residues)	5.1 Biodegradable municipal waste (BMW)	5.1.1 Biodegradable biomass fraction from municipal solid waste	5.1.1.1 Biowaste (Separately collected biodegradable municipal waste, excluding textile and paper)	YES	5. Blends and mixtures | 5.2 Mixtures
			5.1.1.2 Biowaste in mixed waste (Not separately collected biodegradable municipal waste, excluding textile and paper)	YES	5. Blends and mixtures | 5.2 Mixtures
			5.1.1.3 Separately collected paper and textile	Not considered by S2BIOM, since priority is reuse. Still: part of it might still be used for energy generation in practice	
			5.1.1.2 Paper and textile in mixed waste (Not separately collected biodegradable municipal waste, excluding textile and paper)	Not considered by S2BIOM since priority is reuse. Still: part of it will be used for energy in practice (incineration).	
		5.1.2 Biodegradable biomass fraction from municipal liquid waste		Liquid waste is not considered by S2BIOM (i.e. sewage sludge and refood)	
	5.2 Post consumer wood	5.2.1 Construction and demolition wood	5.2.1.1 Non hazardous post consumer wood	YES	1.3.1 chemically untreated used wood | 1.3.1.1 without bark
			5.2.1.2 Hazardous post consumer wood	YES	1.3.3 Blends and mixtures
6. Aquatic biomass	6.1 Aquatic biomass from inland water			Not considered, since not yet of significant relevance.	
	6.2 Aquatic biomass from costal zones			Not considered, since not yet of significant relevance.	

Appendix 2. ISO Categories of ISO/FDIS / DIN EN ISO 16559

1. Woody biomass	1.1 Forest, plantation and other virgin wood	1.1.1 Whole trees without roots	1.1.1.1 Broad-leaf
			1.1.1.2 Coniferous
			1.1.1.3 Short rotation coppice
			1.1.1.4 Bushes
			1.1.1.5 Blends and mixtures
		1.1.2 Whole trees with roots	1.1.2.1 Broad-leaf
			1.1.2.2 Coniferous
			1.1.2.3 Short rotation coppice
			1.1.2.4 Bushes
			1.1.2.5 Blends and mixtures
		1.1.3 Stemwood	1.1.3.1 Broad-leaf with bark
			1.1.3.2 Coniferous with bark
			1.1.3.3 Broad-leaf without bark
			1.1.3.4 Coniferous without bark
			1.1.3.5 Blends and mixtures
		1.1.4 Logging residues	1.1.4.1 Fresh/Green, Broad-leaf (including leaves)
			1.1.4.2 Fresh/Green, Coniferous (including needles)
			1.1.4.3 Stored, Broad-leaf
			1.1.4.4 Stored, Coniferous
			1.1.4.5 Blends and mixtures
		1.1.5 Stumps/roots	1.1.5.1 Broad-leaf
			1.1.5.2 Coniferous
			1.1.5.3 Short rotation coppice
			1.1.5.4 Bushes
			1.1.5.5 Blends and mixtures
		1.1.6 Bark (from forestry operations)	
		1.1.7 Segregated wood from gardens, parks, roadside maintenance, vineyards, fruit orchards and driftwood from freshwater	
		1.1.8 Blends and mixtures	
	1.2 By-products and residues from wood processing industry	1.2.1 Chemically untreated wood by-products and residues	1.2.1.1 Broad-leaf with bark
			1.2.1.2 Coniferous with bark
			1.2.1.3 Broad-leaf without bark
			1.2.1.4 Coniferous without bark
			1.2.1.5 Bark (from industry operations)
		1.2.2 Chemically treated wood by-products, residues, fibres and wood constituents	1.2.2.1 Without bark
			1.2.2.2 With bark
			1.2.2.3 Bark (from industry operations)
			1.2.2.4 Fibres and wood constituents
		1.2.3 Blends and mixtures	
	1.3 Used wood	1.3.1 Chemically untreated used wood	1.3.1.1 Without bark
			1.3.1.2 With bark
			1.3.1.3 Bark
		1.3.2 Chemically treated used wood	1.3.2.1 Without bark
			1.3.2.2 With bark
			1.3.2.3 Bark
		1.3.3 Blends and mixtures	
	1.4 Blends and mixtures		
2. Herbaceous biomass	2.1 Herbaceous biomass from agriculture and horticulture	2.1.1 Cereal crops	2.1.1.1 Whole plant
			2.1.1.2 Straw parts
			2.1.1.3 Grains or seeds
			2.1.1.4 Husks or shells
			2.1.1.5 Blends and mixtures
		2.1.2 Grasses	2.1.2.1 Whole plant
			2.1.2.2 Straw parts
			2.1.2.3 Seeds
			2.1.2.4 Shells
			2.1.2.5 Bamboo

			2.1.2.6 Blends and mixtures
		2.1.3 Oil seed crops	2.1.3.1 Whole plant
			2.1.3.2 Stalks and leaves
			2.1.3.3 Seeds
			2.1.3.4 Husks or shells
			2.1.3.5 Blends and mixtures
		2.1.4 Root crops	2.1.4.1 Whole plant
			2.1.4.2 Stalks and leaves
			2.1.4.3 Root
			2.1.4.4 Blends and mixtures
		2.1.5 Legume crops	2.1.5.1 Whole plant
			2.1.5.2 Stalks and leaves
			2.1.5.3 Fruit
			2.1.5.4 Pods
			2.1.5.5 Blends and mixtures
		2.1.6 Flowers	2.1.6.1 Whole plant
			2.1.6.2 Stalks and leaves
			2.1.6.3 Seeds
			2.1.6.4 Blends and mixtures
		2.1.7 Segregated herbaceous biomass from gardens, parks, roadside maintenance, vineyards and fruit orchards	
		2.1.8 Blends and mixtures	
	2.2 By-products and residues from food and herbaceous processing industry	2.2.1 Chemically untreated herbaceous residues	2.2.1.1 Cereal crops and grasses
3. Fruit biomass	3.1 Orchard and horticulture fruit	3.1.1 Berries	3.1.1.1 Whole berries
			3.1.1.2 Flesh
			3.1.1.3 Seeds
			3.1.1.4 Blends and mixtures
		3.1.2 Stone/kernel fruits	3.1.2.1 Whole fruit
			3.1.2.2 Flesh
			3.1.2.3 Stone/kernel/fruit fibre
			3.1.2.4 Blends and mixtures
		3.1.3 Nuts and acorns	3.1.3.1 Whole nuts
			3.1.3.2 Shells/husks
			3.1.3.3 Kernels
			3.1.3.4 Blends and mixtures
		3.1.4 Blends and mixtures	
	3.2 By-products and residues from food and fruit processing industry	3.2.1 Chemically untreated fruit residues	3.2.1.1 Berries
			3.2.1.2 Stone/kernel fruits/fruit fibre
			3.2.1.3 Nuts and acorns
			3.2.1.4 Crude olive cake
			3.2.1.5 Blends and mixtures
		3.2.2 Chemically treated fruit residues	3.2.2.1 Berries
			3.2.2.2 Stone/kernel fruits
			3.2.2.3 Nuts and acorns
			3.2.2.4 Exhausted olive cake
			3.2.2.5 Blends and mixtures
		3.2.3 Blends and mixtures	
		3.3 Blends and mixtures	
4. Aquatic biomass	4.1 Algae	4.1.1 Micro algae (latin name to be stated)	
		4.1.2 Macro algae (latin name to be stated)	
		4.1.3 Blends and mixtures	
	4.2 Water hyacinth		
	4.3 Lake and sea weed	4.3.1 Lake weed (latin name to be stated)	
		4.3.2 Sea weed	4.3.2.1 Blue sea weed (latin name to be stated)
			4.3.2.2 Green sea weed (latin name to be stated)
			4.3.2.3 Blue-green sea weed (latin name to be stated)
			4.3.2.4 Brown sea weed (latin name to be stated)
			4.3.2.5 Red sea weed (latin name to be stated)
			4.3.3 Blends and mixtures

	4.4 Reeds	4.4.1 Common reed
		4.4.2 Other reed
		4.4.3 Blends and mixtures
	4.5 Blends and mixtures	
5 Blends and mixtures	5.1 Blends	
	5.2 Mixtures	

Appendix 2. WP 1 lignocellulose biomass data base categories

Origin	Category – Level 1	Category – Level 2	Category – Level 3	Consideration by S2BIOM	IDs of the Solid Biofuels Classification System of ISO/FDIS / DIN EN ISO 16559 (see Appendix)
1. Forestry	1.1 Primary production	1.1.1 Stemwood from thinnings and final fellings	1.1.1.1 Stemwood from final fellings originating from broadleaf trees	YES	1.1.3 Stemwood / 1.1.3.1 Broad-leaf with bark; 1.1.3.3 Broad-leaf without bark. This category also includes harvests from full tree harvesting reduced to the stemwood fraction.
			1.1.1.2 Stemwood from final fellings originating from conifer trees	YES	1.1.3 Stemwood / 1.1.3.1 Coniferous with bark; 1.1.3.3 Coniferous without bark. This category also includes harvests from full tree harvesting reduced to the stemwood fraction. Includes possibly 1.1.6 Bark (from forestry operations) where wood is debarked at the forest road side
			1.1.1.3 Stemwood from thinnings originating from broadleaf trees	YES	1.1.3 Stemwood / 1.1.3.1 Broad-leaf with bark; 1.1.3.3 Broad-leaf without bark. This category also includes harvests from full tree harvesting reduced to the stemwood fraction.
			1.1.1.3 Stemwood from thinnings originating from conifer trees	YES	1.1.3 Stemwood / 1.1.3.1 Coniferous with bark; 1.1.3.3 Coniferous without bark. This category also includes as well harvests from full tree harvesting reduced to the stemwood fraction Includes possibly 1.1.6 Bark (from forestry operations) where wood is debarked at the forest road side.
		1.1.2 Stem and crown biomass from early thinnings	1.1.2.1 Stem and crown biomass from early thinnings originating from broadleaf trees	YES	1.1.1 Whole trees without roots / 1.1.3.1 Broad-leaf with bark; 1.1.3.3 Broad-leaf without bark. Without leaves if harvested in winter time Includes possibly 1.1.6 Bark (from forestry operations) where wood is debarked at the forest road side.
			1.1.2.2 Stem and crown biomass from early thinnings originating from conifer trees	YES	1.1.1 Whole trees without roots / 1.1.3.1 Coniferous with bark; 1.1.3.3 Coniferous without bark
	1.2 Primary residues	1.2.1 Logging residues from thinnings and final fellings	1-2-1 Logging residues from final fellings originating from broadleaf trees	YES	1.1.4 Logging residues / 1.1.4.1 Fresh/Green, Broad-leaf (including leaves); 1.1.4.3 Stored, Broad-leaf. Without leaves if harvested in winter time.
			1-2-1 Logging residues from final fellings originating from conifer trees	YES	1.1.4 Logging residues / 1.1.4.2 Fresh/Green, Coniferous (including needles); 1.1.4.4 Stored, Coniferous
			1-2-1 Logging residues from thinnings originating from broadleaf trees	YES	1.1.4 Logging residues / 1.1.4.1 Fresh/Green, Broad-leaf (including leaves); 1.1.4.3 Stored, Broad-leaf. Without leaves if harvested in winter time.
			1.2.1 Logging residues from thinnings originating from conifer trees	YES	1.1.4 Logging residues / 1.1.4.2 Fresh/Green, Coniferous (including needles); 1.1.4.4 Stored, Coniferous
		1.2.2 Stumps from thinnings and final fellings	1.2.2.1 Stumps from thinnings and final fellings originating from broadleaf trees	YES	1.1.5 Stumps/roots / 1.1.5.1 Broad-leaf
			1.2.2.2 Stumps from thinnings and final fellings originating from conifer trees	YES	1.1.5 Stumps/roots / 1.1.5.2 Coniferous

Origin	Category – Level 1	Category – Level 2	Category – Level 3	Consideration by S2BIOM	IDs of the Solid Biofuels Classification System of ISO/FDIS / DIN EN ISO 16559 (see Appendix)	
	1.3 Harvests from traditional coppice forests that does not focus on stemwood production			Not separately considered, quantities are included in section 1.2 and 1.3. This management form plays a negligible role in current forest management in all countries under consideration.	Not considered by ISO/FDIS / DIN EN ISO 16559	
2. Agriculture on arable land & grass land N. B. This includes marginal lands, abandoned lands, lands currently released from agriculture: i.e. land formerly used for agriculture but currently not used and ready to be utilised again	2.1 Primary production of lignocellulosic biomass	2.1.1. Energy grasses, annual & perennial crops (non wood)	2.1.1.1 Sweet and biomass sorghum (Annual grasses)	YES	2.1.2 Grasses	2.1.2.1 Whole plant without roots
			2.1.1.2 Miscanthus (Perennial grass)	YES	2.1.2 Grasses	2.1.2.1 Whole plant without roots
			2.1.1.3 Switchgrass (Perennial grass)	YES	2.1.2 Grasses	2.1.2.1 Whole plant without roots
			2.1.1.4 Giant reed (Perennial grass)	YES	2.1.2 Grasses	2.1.2.1 Whole plant without roots
			2.1.1.5 Cardoon (Perennial crop)	YES	2.1.3 Oil seed crops	2.1.3.2 Stalks and leaves 2.1.3.3 Seeds
			2.1.1.6 Reed Canary Grass (Perennial crop)	YES	2.1.2 Grasses	2.1.2.1 Whole plant without roots
			2.1.1.7 Other	Not considered since the role of further species is regarded negligible in a short term.		
		2.2.2 Short rotation coppice on agricultural land	2.2.2.1 Willow	YES	1.1.1 Whole trees without roots 1.1.2 Whole trees with roots 1.1.5 Stumps/roots	1.1.1.3 Short rotation coppice 1.1.2.3 Short rotation coppice 1.1.5.3 Short rotation coppice
			2.2.2.2 Poplar	YES	1.1.1 Whole trees without roots 1.1.2 Whole trees with roots 1.1.5 Stumps/roots	1.1.1.3 Short rotation coppice 1.1.2.3 Short rotation coppice 1.1.5.3 Short rotation coppice
			2.2.2.3 Other (incl. Eucalyptus)	YES	1.1.1 Whole trees without roots 1.1.2 Whole trees with roots 1.1.5 Stumps/roots	1.1.1.3 Short rotation coppice 1.1.2.3 Short rotation coppice 1.1.5.3 Short rotation coppice

Origin	Category – Level 1	Category – Level 2	Category – Level 3	Consideration by S2BIOM	IDs of the Solid Biofuels Classification System of ISO/FDIS / DIN EN ISO 16559 (see Appendix)
2. Agriculture on arable land & grass lands N. B. This includes marginal lands, abandoned lands, lands currently released from agriculture: i.e. land formerly used for agriculture but currently not used and ready to be utilised again.	2.2 Primary residues from - production for food, feed and other utilisations	2.2.1 Straw/ stubbles	2.2.1.1 Cereals and rice straw	YES	2.1.1 Cereal crops; 2.1.1.2 Straw parts
			2.2.1.2 Sunflower straw	YES	2.1.3 Oil seed crops; 2.1.3.2 Stalks and leaves
			2.2.1.3 Oil seed rape straw	YES	2.1.3 Oil seed crops; 2.1.3.2 Stalks and leaves
			2.2.1.4 Maize stover	YES	2.1.1 Cereal crops; 2.1.1.2 Straw parts
		2.2.2 Primary residues - woody pruning, & orchards residues	2.2.2.1 Residues from vineyards	YES	2.1.7 Segregated herbaceous biomass from gardens, parks, roadside maintenance, vineyards and fruit orchards
			2.2.2.2 Residues from fruit tree plantations	YES	2.1.7 Segregated herbaceous biomass from gardens, parks, roadside maintenance, vineyards and fruit orchards
			2.2.2.3 Residues from olive tree plantations	YES	2.1.7 Segregated herbaceous biomass from gardens, parks, roadside maintenance, vineyards and fruit orchards
			2.2.2.4 Residues from citrus tree plantations	YES	2.1.7 Segregated herbaceous biomass from gardens, parks, roadside maintenance, vineyards and fruit orchards
			2.2.2.5 Residues from nuts plantations	YES	2.1.7 Segregated herbaceous biomass from gardens, parks, roadside maintenance, vineyards and fruit orchards
			2.2.2.6 Grass biomass from various types of plantations	Only considered since as far as not reserved for feed and if it will be possible to identify data that allows for reliable estimates.	2.1.2 Grasses; 2.1.2.6 Blends and mixtures
	2.3 Grass land	2.3.1 Gras used for feed		Not considered since reserved for feed.	
		2.3.2 Currently unused grass land (Gras land not used for feed)	2.3.1 Grass from currently unused grass land	Only considered since as far as not reserved for feed and if it will be possible to identify data that allow reliable estimates.	2.1.2 Grasses; 2.1.2.6 Blends and mixtures
3. Other land use	3.1 Biomass from trees/hedges and other biomass from areas outside forests and outside of agriculture	3.1.1 Biomass from road side verges		YES	2.1.7 Segregated herbaceous biomass from gardens, parks, roadside maintenance, vineyards and fruit orchards
		3.1.2 Biomass from other areas under landscape maintenance		YES	2.1.7 Segregated herbaceous biomass from gardens, parks, roadside maintenance, vineyards and fruit orchards

Origin	Category – Level 1	Category – Level 2	Category – Level 3	Consideration by S2BIOM	IDs of the Solid Biofuels Classification System of ISO/FDIS / DIN EN ISO 16559 (see Appendix)	
4. Production based on lignocellulosic biomass	4.1 Secondary residues from wood industries	4.1.1 Secondary residues from wood-products industries by products (Saw mills and equivalent)	4.1.1.1 Saw dust, chips, veneer cores etc. (residues of stemwood)	YES	1.2.1 Chemically untreated wood by-products and residues	1.2.1.1 Broad-leaf with bark
						1.2.1.2 Coniferous with bark
						1.2.1.3 Broad-leaf without bark
						1.2.1.4 Coniferous without bark
			4.1.1.1 Other saw mill by products (bark etc,)	YES	1.2.1 Chemically untreated wood by-products and residues	1.2.1.5 Bark (from industry operations)
		4.1.2 Residues from industries using semi-finished wood & manufactured wood	4.1.2.1 Residues from semi-finished wood & from manufactured wood products	YES	1.2.1 Chemically untreated wood by-products and residues	1.2.1.1 Broad-leaf with bark
						1.2.1.2 Coniferous with bark
						1.2.1.3 Broad-leaf without bark
						1.2.1.4 Coniferous without bark
						1.2.1.5 Bark (from industry operations)
					1.2.2 Chemically treated wood by-products, residues, fibres and wood constituents	1.2.2.1 Without bark
						1.2.2.2 With bark
						1.2.2.3 Bark (from industry operations)
						1.2.2.4 Fibres and wood constituents
					1.2.3 Blends and mixtures	
		4.1.3 Secondary residues from pulp and paper industries by products	4.1.3.1 Black liquor	Not considered by S2BIOM since this is not solid biomass.		
	4.2 Secondary residues of industry utilising agricultural products	4.2.1 By-products and residues from food and fruit processing industry	4.2.1.1 Olive stones	YES	3.2.1 Chemically untreated fruit residues	3.2.1.2 Stone/kernel fruits/fruit fibre
			4.2.1.2 Other by-products and residues from food and fruit processing industry	Only considered since as far as it will be possible to identify data that allow reliable estimates.	3.2.1 Chemically untreated fruit residues	3.2.1.1 Berries
						3.2.1.2 Stone/kernel fruits/fruit fibre
						3.2.1.3 Nuts and acorns
						3.2.1.4 Crude olive cake
						3.2.1.5 Blends and mixtures
					3.2.2 Chemically treated fruit residues	3.2.2.1 Berries
						3.2.2.2 Stone/kernel fruits
						3.2.2.3 Nuts and acorns
						3.2.2.4 Exhausted olive cake
						3.2.2.5 Blends and mixtures
					3.2.3 Blends and mixtures	
		4.2.2 Cotton industry by-products	4.2.2. Cotton acorns	YES	3.2.1 Chemically untreated fruit residues	3.2.1.3 Nuts and acorns
	4.3 Secondary residues of industries utilising biomass			Not considered since not yet of practical relevance.		

Origin	Category – Level 1	Category – Level 2	Category – Level 3	Consideration by S2BIOM	IDs of the Solid Biofuels Classification System of ISO/FDIS / DIN EN ISO 16559 (see Appendix)
5. Post consumer biomass (tertiary residues)	5.1 Biodegradable municipal waste (BMW)	5.1.1 Biodegradable biomass fraction from municipal solid waste	5.1.1.1 Biowaste (Separately collected biodegradable municipal waste, excluding textile and paper)	YES	5. Blends and mixtures | 5.2 Mixtures
			5.1.1.2 Biowaste in mixed waste (Not separately collected biodegradable municipal waste, excluding textile and paper)	YES	5. Blends and mixtures | 5.2 Mixtures
			5.1.1.3 Separately collected paper and textile	Not considered by S2BIOM, since priority is reuse. Still: part of it might still be used for energy generation in practice	
			5.1.1.2 Paper and textile in mixed waste (Not separately collected biodegradable municipal waste, excluding textile and paper)	Not considered by S2BIOM since priority is reuse. Still: part of it will be used for energy in practice (incineration).	
		5.1.2 Biodegradable biomass fraction from municipal liquid waste		Liquid waste is not considered by S2BIOM (i.e. sewage sludge and refood)	
	5.2 Post consumer wood	5.2.1 Construction and demolition wood	5.2.1.1 Non hazardous post consumer wood	YES	1.3.1 chemically untreated used wood | 1.3.1.1 without bark
			5.2.1.2 Hazardous post consumer wood	YES	1.3.3 Blends and mixtures
6. Aquatic biomass	6.1 Aquatic biomass from inland water			Not considered, since not yet of significant relevance.	
	6.2 Aquatic biomass from costal zones			Not considered, since not yet of significant relevance.	