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REPORT

Lead Beneficiary	BTG Biomass Technology Group B.V.
Authors (Organisation)	Martijn Vis (BTG) Jurjen Spekreijse (BTG) Stefan Mayer (DBFZ) Michele Mutchek (UU) Sergio Ugarte (SQ)
Responsible Author	Martijn Vis, vis@btgworld.com
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CONTENTS

EXECUTIVE SUMMARY	4
1 Introduction	6
1.1 Background.....	6
1.2 Goal.....	6
1.3 Scope	6
1.4 Approach	6
2 Selection of bio-based materials and products	8
2.1 Step 1: Extensive list of bio-based materials and products	8
2.2 Step 2: Pre-selection of dedicated bio-based materials and products	9
2.3 Step 3: Pre-selection of drop-in bio-based materials and products	9
2.4 Step 4: Identification of main biological resources	10
2.5 Step 5: Additional considerations	11
3 Description of selected bio-based materials and products	13
3.1 Bio-based chemicals	13
3.2 Wood sector	14
3.3 Paper products	15
3.4 Textiles.....	15
3.5 Other additions.....	15
3.6 Final selection.....	16
4 CONCLUSIONS.....	20

EXECUTIVE SUMMARY

The HARMONITOR project aims to improve the effectiveness of certification schemes and labels (CSLs) in different sectors of the EU Bioeconomy and therewith strengthen their use as a co-regulation instrument. As part of this project, production and trade data will be collected on bio-based value chains and their levels of sustainability certification. As a first step, 35 value chains from biomass to bio-based products or materials needed to be selected for further assessment. Furthermore, this selection will be used for work to be performed in other tasks within the HARMONITOR project, i.e., the selection and assessment of certification schemes and labels (in short CSLs), and the assessment of costs, benefits, and economic feasibility of CSLs.

The selection of 35 value chains has been performed in 5 steps:

Step 1: Starting point was an extensive list of 350 bio-based materials and products (NACE^a 20, 21 and 22) supplemented with 188 wood products and other bio-based products (NACE 13, 16, 17), resulting in a long list of 538 bio-based products. It was indicated whether these are drop-in (identical to their fossil alternative) or dedicated (chemically unique) bio-based materials or products.

Step 2: All dedicated bio-based materials and products (...) were pre-selected.

Step 3: The 40 drop-in bio-based materials and products with the highest bio-based production volumes were pre-selected for further assessment.

Step 4: For all bio-based materials and products selected in step 1 – 3, the main biological resources used for their production were identified by a quick assessment of their value chains.

Step 5: Final selection taking into account several criteria and considerations.

After a pre-screening on the representativeness of the PRODCOM^b and CN^c codes, 226 dedicated bio-based materials and products were pre-selected as well as a list of 101 drop-in bio-based products. Their biological sources were identified and, based on the production (PRODCOM) and, if needed, trade (CN) volumes, an initial selection was made. As a result of several project meetings, including a three-hour workshop on the 2nd of November in Berlin, and exchanges with sister projects, the final selection of bio-based value chains was made considering:

- Market size of value chains & coverage by existing statistics (focus of steps 1-4)
- Representative distribution between bio-based sectors
- Inclusion of both innovative and traditional bio-based products
- Inclusion of value chains using residues and wastes
- Inclusion of both EU and imported feedstocks and products
- Value chains with environmental and social challenges (where CSL play an important role)
- Coverage by sustainability certification schemes and labels
- Relevance for EU bioeconomy policies such as the CAP reform, Taxonomy Regulation, Farm to Fork strategy, EU Forest Strategy, Circular Economy Action Plan, European Regulation on Sustainable products, recast of RED, and the EU Strategy for Sustainable and Circular Textiles.

The final selection aims to be a representative mix of bio-based products, using various feedstocks (including residues and wastes), covering a broad range of sectors, relevant for EU policy making, currently traded, and relevant for further analysis of sustainability certification schemes. The 35 selected bio-based value chains are presented in Table 1.

^a NACE is the statistical classification of economic activities in the European Community

^b PRODCOM is an acronym for "COMMunity PRODUCTION, European production statistics

^c CN is an acronym for Combined Nomenclature, European trade statistics

Table 1: Overview of selected bio-based value chains

#	Intermediary chemical	Sector	biomass type in	Products out	Intermediary included in statistics?	Feedstock: EU, import, or both?	Existing bio-based market?	Innovative bio-based product?	Feedstock: waste/residue?
1	Acetic acid	Chemicals	Sugar/starch	PTA, VAM, acetic anhydride, acetate esters	n	both	y	y	n
2	Ethylene glycol	Chemicals	Sugar/starch	PET	n	import	y	y	n
3	Ethylene	Chemicals	Sugar/starch	Polyethylene (PE), HDPE	n	import	y	y	n
4	Butanediol (1,4)	Chemicals	Sugar/starch	Solvent, production of polyurethanes	n	both	y	y	n
5	Lactic acid	Chemicals	Sugar/starch (cane sugar)	PLA	y	import	y	y	n
6	Lactic acid	Chemicals	Sugar/starch (cane sugar)	Salts and esters	y	both	y	n	n
7	Starch polymers	Chemicals	Starch (potatoes), corn	Plastic utensils	y	both	y	n	n
8	Palmitic acid with its salts and esters	Chemicals	Palm oil	Cosmetics, surfactants	y	import	y	n	n
9	Propylene glycol	Chemicals	Oil crop (glycerol)	Propylene glycol	n	both	y	y	both
10	Poly(urethane) PUR	Chemicals	Vegetable oil - soybeans	PUR	n	import	y	y	n
11	Epichlorohydrin	Chemicals	Vegetable oil, glycerol	Solvent in resin, paints	n	both	y	y	both
12	Rayon	Chemicals	Wood	Tarn	y	EU	y	y	n
13	PHA	Chemicals	wastewater	Plastics	n	EU	n	y	y
14	(Poly)propylene	Chemicals	UCO	Plastics	n	both	n	y	y
15	Algal fatty acids	Chemicals	Algae	Cosmetic ingredient	n	both	n	y	n
16	Sawn wooden products	Wood	Wood	Several	y	both	y	n	n
17	Fibreboard (particle, MDF, etc)	Wood	Wood, waste wood	MDF, Particle board	y	both	y	n	y
18	Oriented strand board	Wood	Wood	OSB	y	both	y	n	n
19	Wooden packaging	Wood	Wood	Cases, boxes, drums	y	both	y	n	n
20	Wooden pallets	Wood	Wood	Pallets	y	both	y	n	n
21	Wood wool, wood flour	Wood	Wood	Panels, fibre cement, insulation, filler	y	both	y	n	n
22	Lignin based products	Wood	Wood	Binders and aromatic chemicals, asphalt/bitumen	n	both	n	y	y
23	Tall oil	Wood	Wood	Chemicals	n	both	y	y	y
24	Pulp	Paper	Wood, wastepaper	Graphic paper	y	both	y	n	y
25	Pulp	Paper	Wood, wastepaper	Paper board	y	both	y	n	y
26	Pulp	Paper	Wood, wastepaper	Toilet paper	y	both	y	n	y
27	Cotton fabrics	Textile	Cotton	Woven fabrics, table and bed linen, sacks and bags	y	import	y	n	n
28	Wool fabrics	Textile	Wool	Textile	y	both	y	n	n
29	Jute	Textile	Jute	Textile	y	import	y	n	n
30	Flax	Textile	Flax	Textile, table linen	y	EU	y	n	n
31	Hemp	Textile	Hemp	Textile, insulation materials	n	EU	y	n	n
32	Straw	Building	Straw	building materials	n	EU	y	y	y
33	Biowaste	Waste	Biowaste	Compost	y	EU	y	n	y
34	Leather	Textile	Animal skin	Clothing, textiles	y	import	y	n	n
35	Natural rubber	Chemicals	Natural rubber	Tyres, various products	y	import	y	n	n

1 Introduction

1.1 Background

The project “*harmonisation and monitoring platform for certification schemes and labels to advance the sustainability of bio-based systems*” (HARMONITOR) will improve the effectiveness of certification schemes and labels (CSLs) in different sectors of the EU Bioeconomy and therewith strengthen their use as a co-regulation instrument. As part of this project, production and trade data on bio-based value chains and their levels of sustainability certification will be collected. As a first step, about 35 value chains from biomass to bio-based product or materials needed to be selected for further assessment within the HARMONITOR project.

1.2 Goal

The objective of this task was to select 35 relevant value chains from biomass to a specific (group of) bio-based products or materials that will be subject to the assessment of global and EU trade flows and their level of certification. Furthermore, this selection will be used for work to be performed in other tasks within the HARMONITOR project, i.e., the selection and assessment of certification schemes and labels (in short CSLs) in Work Package 4 (WP4), and the assessment of their costs, benefits, and economic feasibility (WP6).

1.3 Scope

According to CEN EN 16575, “*Bio-based*” simply means “*derived from biomass*”. In the frame of the HARMONITOR project, the focus is on industrial bio-based systems excluding food/feed, biofuels, bioenergy and cultural/recreational sectors. This allows for a better focus on the existing and emerging bio-based sectors within the larger bioeconomy. Given the relevance for the bio-based economy and the prominent role of sustainability certification in forestry, trade flows of certified and non-certified wood and forestry-based products are within the scope of the project. Primary biomass resources, bio-waste and residues intended for bio-based industrial value-chains, bio-based materials and products are included in the scope of the project. In case of resources with multiple applications, e.g., food, feed, materials and energy, for example palm oil, they will be regarded as within the scope of the assessment.

1.4 Approach

The selection of 35 value chains was performed in 5 steps:

- Step 1: Starting point is an extensive list of 350 bio-based materials and products (...) supplemented with wood products and other bio-based products (NACE 13, 16, 17)
- Step 2: All dedicated bio-based materials and products (...) will be pre-selected
- Step 3: The 40 drop-in bio-based materials and products with the highest bio-based production volumes will be pre-selected for further assessment
- Step 4: For all bio-based materials and products selected in step 1 – 3, the main biological resources used for their production will be identified by a quick assessment of their value chains



- Step 5: Final selection taking into account several criteria and considerations.

In chapter 2 each step of this approach has been described in further detail. Chapter 3 shows which bio-based products have been selected as a result of this step wise approach.

2 Selection of bio-based materials and products

2.1 Step 1: Extensive list of bio-based materials and products

Approach

Starting point was an extensive list of 350 bio-based materials and products - mostly chemicals, pharmaceuticals and plastics, NACE 20, 21, 22, as presented in Spekrijse et al. (2019) - supplemented with wood products and other bio-based products (NACE 13, 16, 17).

This list was used to provide an overview of:

- (i) bio-based materials and products for which statistical trade information is available, and
- (ii) bio-based materials and products for which statistical trade information is not readily available.

Next, it was indicated whether these are drop-in (identical to their fossil alternative) or dedicated (chemically unique) bio-based materials or products.

Drop-in bio-based chemicals appear in the same statistical category as their chemically identical fossil-based counterparts, making it impossible to determine the volumes of the bio-based chemical using only statistics. Although considerable effort is performed to improve statistics of bio-based materials (e.g., the BioMonitor project), additional sources are needed to determine trade flows of drop-in bio-based products. Therefore, drop-in bio-based materials were assessed in a separate step.

Result

A long list of 538 product was established including the following NACE categories:

- NACE 13: Manufacture of textiles
- NACE 16: Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials
- NACE 17: Manufacture of paper and paper products
- NACE 20: Manufacture of chemicals and chemical products
- NACE 21: Manufacture of basic pharmaceutical products and pharmaceutical preparations
- NACE 22: Manufacture of rubber and plastic products.

	A	B	C	D	G	H	U	V	X	Y	Z
	Product	NACE	CPA	Prodcom	characteristic	type	PRODCOM text	Specific PRODCOM code?	CN Code	CN text	Specific CN code?
1	Product	NACE	CPA	Prodcom	characteristic	type	PRODCOM text	Specific PRODCOM code?	CN Code	CN text	Specific CN code?
2	Carboxymethyl cellulose and salts	20.16	201659	20165950	polysaccharide	dedicated	Cellulose and its chemi	no	3912 31 00	carboxymethylcellulose a	y
3	Cellulose esters	20.16	201659	20165950	polyether	dedicated	Cellulose and its chemi	no	3912 90 10	cellulose esters	y
4	Cellulose ethers	20.16	201659	20165950	polyether	dedicated	Cellulose and its chemi	no	3912 39	other cellulose ethers	y
5	Alginate with salts and esters	20.16	201659	20165950	polyether	dedicated	Cellulose and its chemi	no	3913 10 00	alginic acid polymer	y
6	Pure glycerol	20.41	204110	20411000	polyol	dedicated	Glycerol (glycerine), crude	no	2905 45 00	Glycerol	y
7	Fructose	Other	106213	10621320	polyol	dedicated	Chemically pure fructose	no	1702 50 00	pure fructose	y
8	Ethanol	20.14	201474	20147400	alcohol	dedicated	Undenatured ethyl alcohol	no	2207 20 00	denatured ethanol	y
9	Mannitol	20.14	201423	20142337	polyol	dedicated	Diols and polyhydric alco	no	2905 43 00	mannitol	y
10	Coenzyme Q10 (ubiquinone)	20.14	201462	20146260	alkene	dedicated	Quinones	no	2914 62 00	coenzyme Q10	y
11	Palmitic acid with salts and esters (aka hexadecanoic acid)	20.14	201432	20143235	organic acid	dedicated	Palmitic acid, stearic acid	no	2915 70 40	palmitic acid with salts a	y
12	Stearic acid with salts and esters (aka octadecanoic acid)	20.14	201432	20143235	organic acid	dedicated	Palmitic acid, stearic acid	no	2915 70 50	stearic acid with salts an	y
13	Lauric acid with salts and esters (aka dodecanoic acid)	20.14	201432	20143280	organic acid	dedicated	Lauric acid and others; st	no	2915 90 30	lauric acid with salts and	y
14	Azelaic acid (aka nonanedioic acid) with salts and esters	20.14	201433	20143381	organic acid	dedicated	Oxalic, azelaic, malonic, i	no	2917 13 90	azelaic acid with salts ar	y
15	Sebacic acid (aka decanedioic acid)	20.14	201433	20143381	organic acid	dedicated	Oxalic, azelaic, malonic, i	no	2917 13 10	sebacic acid	y
16	Tartaric acid	20.14	201433	20143381	organic acid	dedicated	Oxalic, azelaic, malonic, i	no	2918 12 00	tartaric acid	y
17	Lactic acid with salts and esters	20.14	201434	20143475	organic acid	dedicated	Carboxylic acid with alcohol	no	2918 11 00	lactic acid with salts and	y
18	Citric acid	20.14	201434	20143473	organic acid	dedicated	Citric acid and its salts a	combined	2918 14 00	citric acid	y
19	Lecithin and phospholipids	2110	211020	21102040	phosphate	dedicated	Quaternary ammonium si	no	2923 20 00	lecithins and other phospho	y
20	Methionine	20.14	201451	20145133	amino acid	dedicated	Thiocarbamates and dith	no	2930 40 10	Methionine	y

Figure 1: Excerpt from the longlist of 538 bio-based materials and products.

The longlist contains the product description, NACE, CPA, PRODCOM and CN code, as well as the PRODCOM and CN text. It is indicated whether the products have a specific PRODCOM and CN code. If this is not the case, the product is part of a group of products. Moreover, for all products it was determined whether it is a “dedicated” or “drop-in”. product. In case of chemicals, the type of chemical was characterized. See Figure 1.

2.2 Step 2: Pre-selection of dedicated bio-based materials and products

Approach

All dedicated bio-based materials and products for which statistical trade information is readily available (usually requiring to be identifiable at 6-digit CN code level), including wood-based products, were pre-selected.

Result

All dedicated products were taken from the longlist for further assessment. In some cases, sub-categories were combined to get a group for which statistical data is available. For example, no data is available for “lactic acid”, but data is available for “lactic acid, its salts and esters”. Not all products are well described by single PRODCOM and/or CN code. For example, “furan” falls in the category “20145225; Heterocyclic compounds with oxygen only hetero-atom(s)” containing a range of compounds including furan. In this case the bio-based product was not preselected. Given that usually compounds with smaller production or trade volumes are grouped, this approach can be justified. This first screening resulted in **226 dedicated bio-based materials and products** that have at least a unique PRODCOM or CN code (226).

The level of detail of CN, which is used by the customs to obtain import/export tax, is generally higher than PRODCOM. Therefore, if the PRODCOM code is known, this usually means that production data (PRODCOM) and trade data (CN) is available in statistics. However, in many other cases no PRODCOM code is known, but the CN code is known, meaning that only trade data is available in statistics.

In order to get a first impression of the size of the production and trade flows, for each dedicated product of which a unique PRODCOM is available, the highest production volume of the last three years has been obtained from Eurostat, via COMEXT. For all the other products the import to and export from the EU, as well as the import and export within the EU was obtained, via the CN codes. The list was ordered from highest to lowest production and or trade volumes.

2.3 Step 3: Pre-selection of drop-in bio-based materials and products

Approach

The 40 drop-in bio-based materials and products with the highest bio-based production volumes were selected for further assessment. Production volumes are not readily accessible from trade statistics but can be obtained from bio-based market studies and reports.

Result

Like in the case of the dedicated products, some aggregation of categories was performed, and drop-in bio-based products without unique PRODCOM or CN code removed, resulting in a list of 101 drop-in bio-based products.

Based on earlier work, especially Spekrijse et al (2019)^d and Spekrijse et al (2021)^e, and an initial assessment of bio-based products that are currently allowed for certification under ISCC PLUS, a shortlist of about **40 drop-in bio-based products** was drawn. It was decided not to further reduce the shortlist, but to make the final selection in step 5 for the dedicated and drop-in bio-based materials and products together.

Table 2: overview of pre-selected drop-in bio-based materials and products

Pre-selection of 40 bio-based drop-in materials and products			
Acetaldehyde	Formic acid	Poly (methyl methacrylate) - PMMA	Cyclohexanone
Acetic acid	Isoprene	Poly (vinyl acetate) - PVA	Ethane
Acetone	Poly (ethylene terephthalate) - PET*	Acrylic acid with salts	Ethylene dichloride
Adipic acid	Poly(ethylene) - PE*	Methanol	Ethylene Propylene Diene Monomer (EPDM) rubber
Butadiene	Poly(urethane) - PUR	Styrene	Methane
Butanediol (1,4-)	Propylene oxide	Acetylene	Phenol (and its salts)
Butanol (n-)	Caprolactam	Acrylamide	Poly (vinyl chloride) - PVC
Epichlorohydrin	Cyclohexane	Acrylonitrile	Propane
Ethylene*	Methyl methacrylate (MMA)	Benzene	Propylene
Ethylene oxide*	Poly (butylene terephthalate) - PBT	Cyclohexanol	Toluene

* Several drop-in bio-based products can be present in the same value chain. This is for example the case with ethylene, ethylene oxide and poly(ethylene).

2.4 Step 4: Identification of main biological resources

For all bio-based materials and products selected in step 1 – 3, the main biological resources used for their production were identified by a quick assessment of their value chains. Typical resources include wood, sugar/starch, and oil crops. Residues and biowaste streams were also selected, even if they are currently not used, in case they form suitable resources for the selected bio-based materials and products.

^d Spekrijse, J, T. Lammens, C. Parisi, T. Ronzon, M. Vis (2019) Insights into the European market for bio-based chemicals, analysis based on 10 key product categories, JRC science for policy report, EUR 29851 EN, Publications office of the European Union, Luxembourg, 2019, ISBN 978-92-79-985419-8, doi:10.2760/673071, JRC112989.

^e Spekrijse, J., K. Vikla, M. Vis, K. Boysen-Urban, G. Philippidis, R. M'barek (2021) Bio-based value chains for chemicals, plastics and pharmaceuticals, a comparison of bio-based and fossil-based value chains, EUR 30653 EN, Publications office of the European Union, Luxembourg, 2021m ISBN 978-92-76-32459-1, doi: 10.2760/712499, JRC124141.

2.5 Step 5: Additional considerations

The final selection of value chains for further analysis should be a representative mix of bio-based products, using various feedstocks (including residues and wastes), covering a broad range of sectors, relevant for EU policy making, currently traded, and relevant for further analysis of sustainability certification schemes.

EU Policies and bio-based value chains

A Broad range of relevant EU legislation and policy expresses directly or indirectly sustainability requirements for bio-based value chains. Examples include the CAP reform, Taxonomy Regulation, Farm to Fork strategy, EU Forest Strategy, Circular Economy Action Plan, European Regulation on Sustainable products, recast of RED, and the EU Strategy for Sustainable and Circular Textiles. In the assessment of CSL and the setup of the monitoring system for assessing the sustainability of bio-based value chain within HARMONITOR, these policies will be assessed in detail. For the selection of bio-based value chains, we would like to highlight that the selected bio-based value chains should contribute to the main objectives of the European Bioeconomy Strategy:

- Ensure food and nutrition security
- Manage natural resources sustainably
- Reduce dependence on non-renewable, unsustainable resources
- Limit and adapt to climate change
- Strengthen European competitiveness and create jobs.

We have taken these objectives as follows in the selection of value chains. If bio-based value chains should ensure food and nutrition security, it makes sense to select value chains that are based on residues and wastes, which do not require additional land. *Managing natural resources sustainably*, can mean that value chains with high sustainability risks should be selected (for example cotton products), as CSLs can make the difference between sustainable and unsustainable practices. On the other hand, sustainable value chains could be selected, as CSLs gives them a platform to present their sustainability benefits (for example hemp). *Reduce dependence on non-renewable, unsustainable resources* and *limit and adapt to climate change* means that value chains with considerable production and trade volumes should be selected, as these value chains have generally more impact on use of unsustainable sources and climate change. The objective to *strengthen European competitiveness and create jobs* means that innovative bio-based value chains should be selected that create economic activity such as research, scale up and new commercial activities within the EU.

Relevance of bio-value chains for assessment of CSLs

The *Study of the environmental sustainability requirements of bio-based value chains and supply chains for bio-based industry in future EU funded R&I demonstration and flagship projects* (not published yet), identified five overarching environmental principles for bio-based value chains, i.e., mitigate global warming, conserve and protect biodiversity, conserve and protect water resources, protect soil quality and productivity, and promote good air quality. It has been assessed whether environmental or social concerns exist regarding the selected bio-based value chains, which is the case for the vast majority of selected value chains, and whether CSLs covering these concerns exist (see Table 7 on page 18).

Final selection approach

BTG has made a draft final selection of bio-based value chains considering:

- Market size of value chains & coverage by existing statistics (focus of steps 1-4)
- Representative distribution between bio-based sectors

- Inclusion of both innovative and traditional bio-based products
- Inclusion of value chains using residues and wastes
- Inclusion of both EU and imported feedstocks and products
- Value chains with environmental and social challenges (where CSL play an important role)
- Coverage by sustainability certification schemes and labels
- Compatibility with environmental requirements from EU bioeconomy policies (CBE, EU Bioeconomy Strategy).

Several meetings were organised to discuss the approach and the selection of value chains:

- On the 14th of October 2022, BTG presented the value chain selection approach in an online meeting with the two sister projects STAR4BBS and SUSTCERT4BIO-BASED.
- On the 24th of October 2022, the results of step 1 – 3 of the value chain selection procedure was presented and discussed with the HARMONITOR consortium in an online meeting.
- On the 28th of October 2022, the HARMONITOR value chain selection approach and results of step 1 – 3 were discussed with the sister projects. The sister projects will select the value chains at a later stage. Therefore, it was not possible to discuss or divide certain value chains with the sister projects. On the one hand, some overlap between the selection could support the presentation of differences in approach between the sister projects. On the other hand, it would be worthwhile that the three projects together cover a broad range of different value chains.
- On the 2nd of November, as part of the hybrid HARMONITOR progress meeting in Berlin, the first draft of the final selection of value chains (step 1 – 5) were discussed in detail, during a three-hour workshop fully dedicated to the selection of value chains. Several suggestions for inclusion of additional value chains were made based on the final selection criteria presented above.
- On the 9th of November, based on the outputs of the workshop, BTG has sent the draft of the final selection of value chains to the consortium partners, for their final comments or approval.
- On the 14th of November, the draft final selection was presented during an online meeting with the sister projects and the EU project offers of the three projects. During this meeting, some remarks were made, for example whether value chains with import of the bio-based product were included in the selection, which is indeed the case.
- On the 18th of November, the final selection was made after having processed some final remarks from HARMONITOR consortium partners.

In the next chapter the resulting selection of bio-based value chain is further described and discussed.

3 Description of selected bio-based materials and products

3.1 Bio-based chemicals

From the list of drop-in chemicals (step 3), six significant ones were selected. All these chemicals show significant bio-based production in Europe and a large potential market (Table 3).

Table 3: Bio-based chemicals

	EU Bio-based production (kt/y)	EU Fossil-based production (kt/y)
1,4-butanediol	30 ^f	n.a.
Acetic acid	24.5 ^g	968 ^d
Epichlorohydrin	36 ^d	265 ^d
Ethylene glycol	220 ^h	1180 ^d
Propylene glycol	20 ^d	633 ^d
PUR	39 ^d	3500 ^d

The selection was further expanded by the largest volume of dedicated bio-based chemicals (step 2). The largest PRODCOM categories are those involving starch (maize starch, modified starch, wheat starch, and potato starch, each with over 1400 kt/y produced). These categories were taken into the selection as 'starch polymers'. The next largest produced dedicated bio-based chemical is glycerol (20411000, Glycerol (glycerine), crude; glycerol waters and glycerol lyes) with an EU production of 730 kt/y. However, glycerol is not a final product and can be seen as a feedstock. This feedstock is already included in the value chain for propylene glycol. The next chemical in the list is citric acid (20143473, Citric acid and its salts and esters). However, citric acid was excluded since it finds its main application in food. The next entry, Tall Oil (20147130, Tall oil; whether or not refined, 480 kt/y) was included. This results in the addition of starch polymers and tall oil to the final selection.

From the chemicals from which only the CN data can be used, ethanol scores the highest trade statistics with 1252.4 kt/yⁱ traded within and across the EU borders. However, it is expected that the bulk of the bio-based ethanol will be used as fuel and is excluded from the selection. The next three groups (CN 29232000, lecithins and other phosphoaminolipids; CN 391239, other cellulose ethers; and 29181100, lactic acid with salts and esters) all show trade values between 250 and 500 kt/y. Due to its interest for CSLs, the lactic acid into PLA value chain was selected from these.

^f Spekreijse, J., K. Vikla, M. Vis, K. Boysen-Urban, G. Philippidis, R. M'barek (2021) Bio-based value chains for chemicals, plastics and pharmaceuticals, a comparison of bio-based and fossil-based value chains, EUR 30653 EN, Publications office of the European Union, Luxembourg, 2021m ISBN 978-92-76-32459-1, doi: 10.2760/712499, JRC124141.

^g Spekreijse, J, T. Lammens, C. Parisi, T. Ronzon, M. Vis (2019) Insights into the European market for bio-based chemicals, analysis based on 10 key product categories, JRC science for policy report, EUR 29851 EN, Publications office of the European Union, Luxembourg, 2019, ISBN 978-92-79-985419-8, doi:10.2760/673071, JRC112989.

^h Green Chemicals Blog, <https://greenchemicalsblog.com/2022/08/25/upm-gears-up-for-bio-meg-commercialization/>

ⁱ The highest trade volumes: extra EU import, extra EU export, plus intra EU trade of the period 2019-2021 was taken using COMEXT.

Finally, two additional chemicals were selected to ensure a variety in biomass feedstocks within the selection (step 4). These chemicals are rayon (from wood) and palmitic acid (from palm oil). The final list of included chemicals is presented in Table 4.

Table 4: Selected bio-based value chain in the chemical sector

Intermediary chemical	Biomass type in	Products out
Acetic acid (see tab 1)	Sugar/starch	PTA, VAM, acetic anhydride, acetate esters
Ethylene glycol (see tab 2)	Sugar/starch	PET, PE
Butanediol (1,4)	Sugar/starch	Solvent, production of polyurethanes
Lactic acid	Sugar/starch (cane sugar)	PLA (USA, Thailand)
Lactic acid	Sugar/starch (cane sugar)	Salts and esters
Starch polymers	Starch (potatoes), corn	Plastic utensils
Palmitic acid with its salts and esters	Palm oil	Cosmetics, surfactants
Propylene glycol	Oil crop (glycerol)	Propylene glycol
Poly(urethane)	Vegetable oil - soybeans	PUR
Epichlorohydrin	Vegetable oil, glycerol	Solvent in resins, paints
Rayon	Wood	Tarn
Tall oil	Wood	Chemicals

3.2 Wood sector

For the wood sector (NACE 16), a similar approach was taken as for the dedicated chemicals. Since in this sector nearly all products are bio-based, and all those products are dedicated, only a list with dedicated bio-based products exists. The nine PRODCOM categories with the highest production numbers within the EU27 are presented in Table 5.

Table 5: overview of the nine PRODCOM categories from the wood sector with the highest production volumes within the EU27

PRODCOM	PRODCOM text	Production (kt/y) ^{a)}	Included as
16102503	Coniferous wood in chips or particles	36,000	<i>Excluded (fuel)</i>
16291500	Pellets and briquettes of pressed and agglomerated wood and of wood waste and scrap	17,926	<i>Excluded (fuel)</i>
16231900	Builders joinery and carpentry of wood (excluding windows, French windows and doors, their frames and thresholds, parquet panels, shuttering for concrete constructional work, shingles and shakes)	6,300	Sawn wooden products
16102505	Non-coniferous wood in chips or particles	5,639	<i>Excluded (fuel)</i>
16102110	Coniferous wood continuously shaped (including strips and friezes for parquet flooring, not assembled)	3,063	Sawn wooden products
16241320	Cases, boxes, crates, drums and similar packings of wood (excluding cable drums)	2,687	Wooden packaging

16102400	Wood wool; wood flour	2,080	Wood wool, wood flour
16211543	Fibreboard (excluding medium density fibreboard [MDF]), of wood or other ligneous materials, whether or not bonded with resins or other organic substances, of a density exceeding 0.8 g/cm ³	900	Fibreboard (particle, MDF, etc.)
16241133	Flat pallets and pallet collars of wood	824	Wooden pallets

^{a)} For each PRODCOM category the highest production volume of the period 2019, 2020 and 2021 was taken from COMEXT.

Three of the nine PRODCOM categories with highest production numbers (16102503, 16291500, and 16102505) were excluded due to their high use in fuel applications, which is out of the scope of the HARMONITOR project. The remaining products were all taken up in the selection, although with some modifications. For clarity, some categories were taken wider than the PRODCOM classification. For example, in the category fibreboard, also MDF of different sizes (16211529, 16211523 and 16211526 and particle board of wood (16211200), is included, whereas our final selection simply included all fibreboard as one product entry.

Finally, the selection of wooden products was completed with the inclusion of Oriented Strand Board (OSB) (16211316), as to provide a rather complete picture of the wooden panel sector.

3.3 Paper products

The PRODCOM classification of paper products has several PRODCOM product entries that have a high production value due to their generic description. For example, fluting (17123400) and corrugated paper (17211100) have high production volumes of 11,051 kt/y and 10,821 kt/y^j, respectively. In this selection, we gave priority to well defined products. The well-defined products with the highest production values are graphic paper, paperboard (17121439 and 17121425) with a total EU production of 9,015 kt/y and toilet paper (17221120), at a production of 4,651 kt/y. These groups were included in the HARMONITOR selection as three separate entries: graphic paper, paperboard, and toilet paper.

3.4 Textiles

The PRODCOM classification for textiles is fragmented into several categories that focus on functionality rather than material. For example, next to 'woven fabrics of cotton' (132020), cotton products can be found in, amongst others, 'Bed linen of cotton' (13921253), 'sacks and bags, of cotton' (13922130), and 'table linen of cotton' (13921353). To prevent the selection of several cotton products and to maximise the diversity in feedstocks, six textiles from different feedstocks were selected. These are cotton, wool, jute, flax, hemp, and leather.

3.5 Other additions

To adhere to all the additional considerations (step 5), several other products were added to the selection. Moreover, a selection purely based on currently large production numbers would omit important and innovative

^j The highest production volume of the period 2019, 2020 and 2021 was taken from COMEXT

value chains that are expected to become relevant in the next decade. These selections are each highlighted here.

In order to include both EU and imported feedstocks & products, two value chains for lactic acid were selected. On one hand the production of PLA from lactic acid, which mostly takes place in the USA and Thailand. On the other hand, the production of lactic acetate salts and esters, which also takes place within the EU. Moreover, ethylene, which is mainly produced outside of the EU, was included with the value chain towards bio-based polyethylene.

The use of straw as a building material was included as innovative bio-based value chain in the construction sector. Compost from kitchen and garden waste, the production of PHA from wastewater and the production of polypropylene from used cooking oil were selected in order to increase the number of value chains that rely on rest streams. Natural rubber and leather were selected, since they were not identified in the initial list of 350 chemicals and polymers even though it is an important bio-based product, and finally, algal fatty acids were added to represent the upcoming blue economy.

3.6 Final selection

Table 6 on page 17 presents the selected 35 value chains, starting with the main intermediary chemical, sector, typical biomass resource used and outgoing products. Furthermore, it is indicated if the intermediary chemical is readily available in EU statistics. This is not the case for drop-in bio-based chemicals, and some more innovative and waste-based value chains. The next column shows whether the feedstock for the bio-based product as sold in the EU is mainly grown in the EU, imported or both. During trade flow analysis, more information will be collected on this aspect. The next columns show whether an existing bio-based market has been established, and if the product can be regarded as new/innovative bio-based product. The next column shows whether the product is a waste or residue.

Table 7 and Table 8 show whether possible major environmental and social concerns exist for the selected value chains. This does not mean that these value chains are unsustainable, but it does indicate a certain need for CSLs. Next, it is indicated whether the value chains are covered by existing CSLs. Further research is needed to investigate if and to what degree CSLs are applied in these value chains. Moreover, a number of relevant CSLs are mentioned. This list may not be complete, during the project a more detailed assessment of CSLs will be performed.

Table 6: Overview of selected bio-based value chains

#	Intermediary chemical	Sector	biomass type in	Products out	Intermediary included in statistics?	Feedstock: EU, import, or both?	Existing bio-based market?	Innovative bio-based product?	Feedstock: waste/residue?
1	Acetic acid	Chemicals	Sugar/starch	PTA, VAM, acetic anhydride, acetate esters	n	both	y	y	n
2	Ethylene glycol	Chemicals	Sugar/starch	PET	n	import	y	y	n
3	Ethylene	Chemicals	Sugar/starch	Polyethylene (PE), HDPE	n	import	y	y	n
4	Butanediol (1,4)	Chemicals	Sugar/starch	Solvent, production of polyurethanes	n	both	y	y	n
5	Lactic acid	Chemicals	Sugar/starch (cane sugar)	PLA	y	import	y	y	n
6	Lactic acid	Chemicals	Sugar/starch (cane sugar)	Salts and esters	y	both	y	n	n
7	Starch polymers	Chemicals	Starch (potatoes), corn	Plastic utensils	y	both	y	n	n
8	Palmitic acid with its salts and esters	Chemicals	Palm oil	Cosmetics, surfactants	y	import	y	n	n
9	Propylene glycol	Chemicals	Oil crop (glycerol)	Propylene glycol	n	both	y	y	both
10	Poly(urethane) PUR	Chemicals	Vegetable oil - soybeans	PUR	n	import	y	y	n
11	Epichlorohydrin	Chemicals	Vegetable oil, glycerol	Solvent in resin, paints	n	both	y	y	both
12	Rayon	Chemicals	Wood	Tarn	y	EU	y	y	n
13	PHA	Chemicals	wastewater	Plastics	n	EU	n	y	y
14	(Poly)propylene	Chemicals	UCO	Plastics	n	both	n	y	y
15	Algal fatty acids	Chemicals	Algae	Cosmetic ingredient	n	both	n	y	n
16	Sawn wooden products	Wood	Wood	Several	y	both	y	n	n
17	Fibreboard (particle, MDF, etc)	Wood	Wood, waste wood	MDF, Particle board	y	both	y	n	y
18	Oriented strand board	Wood	Wood	OSB	y	both	y	n	n
19	Wooden packaging	Wood	Wood	Cases, boxes, drums	y	both	y	n	n
20	Wooden pallets	Wood	Wood	Pallets	y	both	y	n	n
21	Wood wool, wood flour	Wood	Wood	Panels, fibre cement, insulation, filler	y	both	y	n	n
22	Lignin based products	Wood	Wood	Binders and aromatic chemicals, asphalt/bitumen	n	both	n	y	y
23	Tall oil	Wood	Wood	Chemicals	n	both	y	y	y
24	Pulp	Paper	Wood, wastepaper	Graphic paper	y	both	y	n	y
25	Pulp	Paper	Wood, wastepaper	Paper board	y	both	y	n	y
26	Pulp	Paper	Wood, wastepaper	Toilet paper	y	both	y	n	y
27	Cotton fabrics	Textile	Cotton	Woven fabrics, table and bed linen, sacks and bags	y	import	y	n	n
28	Wool fabrics	Textile	Wool	Textile	y	both	y	n	n
29	Jute	Textile	Jute	Textile	y	import	y	n	n
30	Flax	Textile	Flax	Textile, table linen	y	EU	y	n	n
31	Hemp	Textile	Hemp	Textile, insulation materials	n	EU	y	n	n
32	Straw	Building	Straw	building materials	n	EU	y	y	y
33	Biowaste	Waste	Biowaste	Compost	y	EU	y	n	y
34	Leather	Textile	Animal skin	Clothing, textiles	y	import	y	n	n
35	Natural rubber	Chemicals	Natural rubber	Tyres, various products	y	import	y	n	n

Table 7: Selected value chains – initial assessment of applicable CSLs

#	Intermediary chemical	biomass type in	Products out	Possible major environmental concerns	Possible major social concerns	ISCC PLUS	Better Biomass	RSB	REDCert	Bonsucro	SAI	Alliance Water	Fairtrade Int.	VCS	Nature Care Products	Recognised	SGE 21	OK biobased	TFS	ZNU	FSC	PEFC	SBP	ARSO	EU Ecolabel - textiles	Textile exchange	FAIR Rubber	GPSNR	Total # CSLs
1	Acetic acid	Sugar/starch	PTA, VAM, acetic anhydride,	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y									15
2	Ethylene glycol	Sugar/starch	PET	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y									15
3	Ethylene	Sugar/starch	Polyethylene (PE), HDPE	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y									15
4	Butanediol (1,4)	Sugar/starch	Solvent, polyurethanes	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y									15
5	Lactic acid	Sugar/starch (cane sugar)	PLA	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y									15
6	Lactic acid	Sugar/starch (cane sugar)	Salts and esters	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y									15
7	Starch polymers	Starch (potatoes), corn	Plastic utensils	y	y	y	y	y			y	y	y		y	y	y	y	y	y									13
8	Palmitic acid & salts and esters	Palm oil	Cosmetics, surfactants	y	y	y	y		y			y	y	y	y	y	y	y	y	y									13
9	Propylene glycol	Oil crop (glycerol)	Propylene glycol	y	y	y	y		y			y	y	y	y	y	y	y	y	y									13
10	Poly(urethane) PUR	Veg oil, soybeans	PUR	y	y	y	y		y			y	y	y		y	y	y	y	y									12
11	Epichlorohydrin	Vegetable oil, glycerol	Solvent in resins, paints	y	n	y	y		y			y	y	y	y	y	y	y	y	y									13
12	Rayon	Wood	Tarn	y	n	y	y	y												y	y	y	y	y					8
13	PHA	wastewater	Plastics	n	n	y	y	y	y											y	y								6
14	(Poly)propylene	UCO	Plastics	n	n	y	y	y	y											y	y								6
15	Algal fatty acids	Algae	Cosmetic ingredient	y	n	y		y				y	y	y							y								6
16	Sawn wooden products	Wood	Several	y	y	y	y	y				y		y						y	y	y	y	y					10
17	Fibreboard (particle, MDF)	Wood, waste wood	MDF, Particle board	y	n	y	y	y				y		y						y	y	y	y	y					10
18	Oriented strand board	Wood	OSB	y	n	y	y	y				y		y						y	y	y	y	y					10

Table 8: Selected value chains – initial assessment of applicable CSLs (continued)

#	Intermediary chemical	biomass type in	Products out	Possible major environmental concerns	Possible major social concerns	ISCC PLUS	Better Biomass	RSB	REDCert	Bonsucro	SAI	Alliance Water Stewardship	Fairtrade Int.	VCS	Nature Care Products	Recognised	SGE 21	OK biobased	TFS	ZNU	FSC	PEFC	SBP	ARSO	EU Ecolabel - textiles	Textile exchange	FAIR Rubber	GPSNR	Total # CSLs
19	Wooden packaging	Wood	Cases, boxes, drums	y	n	y	y	y				y	y						y	y	y	y	y						10
20	Wooden pallets	Wood	Pallets	y	n	y	y	y				y	y						y	y	y	y	y						10
21	Wood wool, wood flour	Wood	Panels, fibre cement, insulation, filler	y	n	y	y	y				y	y						y	y	y	y	y						10
22	Lignin based products	Wood	Binders and aromatic chemicals, asphalt/bitumen	y	n	y	y	y				y	y						y	y	y	y	y						10
23	Tall oil	Wood	Chemicals	y	n	y	y	y				y	y						y	y	y	y	y						10
24	Pulp	Wood, wastepaper	Graphic paper	y	n	y	y	y				y	y						y	y	y	y	y						10
25	Pulp	Wood, wastepaper	Paper board	y	n	y	y	y				y	y						y	y	y	y	y						10
26	Pulp	Wood, wastepaper	Toilet paper	y	n	y	y	y				y	y						y	y	y	y	y						10
27	Cotton fabrics	Cotton	Woven fabrics, table and bed linen, sacks and bags	y	y	y	y	y				y	y							y				y	y	y			9
28	Wool fabrics	Wool	Textile	y	y	y	y	y				y	y							y				y	y	y			9
29	Jute	Jute	Textile	y	n	y	y	y				y	y							y				y	y	y			9
30	Flax	Flax	Textile, table linnen	y	n	y	y	y				y	y							y				y	y	y			9
31	Hemp	Hemp	Textile, insulation materials	y	n	y	y	y				y	y							y				y	y	y			9
32	Straw	Straw	building materials	y	n	y		y	y																				3
33	Biowaste	Biowaste	Compost	n	n	y					y																		2
34	Leather	Animal skin	Clothing, textiles	y	y	y						y	y							y				y	y	y			7
35	Natural rubber	Natural rubber	Tyres, various products	y	y	y															y	y					y	y	5

4 CONCLUSIONS

35 bio-based of value chains were selected for further assessment within the HARMONITOR project. A systematic five step approach was applied, starting with a longlist of 538 products from NACE 13, 16, 17, 20, 21 and 22. After a pre-screening on the representativeness of the PRODCOM and CN codes of the bio-based product, 226 dedicated bio-based materials and products were pre-selected as well as a list of 101 drop-in biobased products. Their biological sources were identified and based on the production (PRODCOM) and, if/needed, trade (CN) volumes, an initial selection was made. During several online meetings and a workshop in Berlin, a further screening was applied taking into account considerations such as representative distribution between bio-based sectors, inclusion of both innovative and traditional bio-based products, inclusion of value chains using residues and wastes, inclusion of both EU and imported feedstocks and products, coverage by sustainability certification schemes and labels, relevance for EU bioeconomy policies such as the CAP reform, Taxonomy Regulation, Farm to Fork strategy, EU Forest Strategy, Circular Economy Action Plan, European Regulation on Sustainable products, recast of RED, and the EU Strategy for Sustainable and Circular Textiles.

The final selection aimed to be a representative mix of bio-based products, using various feedstocks (including residues and wastes), covering a broad range of sectors, relevant for EU policy making, currently traded, and relevant for further analysis of sustainability certification schemes.