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REPORT

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EXECUTIVE SUMMARY

The project "harmonisation and monitoring platform for certification schemes and labels to advance the sustainability of bio-based systems" (HARMONITOR) has the aim to improve the effectiveness of certification schemes and labels (CSLs) in different sectors of the EU Bioeconomy. Within the HARMONITOR project, data and figures have been collected on trade volumes and the level of sustainability certification of a broad selection of biological resources, bio-based chemicals, wooden products and textiles. The full publicly available reports can be found here:

- D3.1: Selection of bio-based value chains
- D3.3: Trade flows of biological resources, bio-based materials and products
- D3.4: Level of certification and labelling of biological resources, bio-based materials and products.

The trade flows have been visualised in an online trade flow tool and a pivot table.

This report synthesises the main results. It provides a state-of-the-art overview and summary of the trade flows and levels of sustainability certification of selected biological resources and bio-based materials and products. It gives an overview of data gaps and possible solutions to overcome them. Moreover, it provides practical instructions on how to use the online trade flow tool and pivot table.

Trade flows

The EU is a major player in the global trade of bio-based products, with the total trade volume of the selected bio-based value chains reaching 183.4 million tonnes in 2021. Table 1 shows that biological resources and wooden products form the largest share of total trade. However, the most dominant biological resources, e.g. sugar, starch and oil crops, are mainly used for food and feed production. Wooden products dominate the trade of bio-based products and materials, followed by bio-based textiles and fibre crops. The selected bio-based chemicals[1] account for only 0.3% of total trade. Among these bio-based chemicals, the largest production capacities were found for bio-based epichlorohydrin, acetic acid, ethylene and polylactic acid.

Table 1: Total EU trade of selected bio-based value chains, in million tonnes, 2021

Trade of bio-based value chains	Intra-EU trade	Extra-EU imports	Extra-EU exports	Total EU trade (2021)
Biological resources	54.4	35.6	10.3	**100.4**
Drop-in bio-based chemicals	0.11	0.04	0.02	**0.18**
Dedicated bio-based chemicals	0.21	0.14	0.09	**0.44**
Bio-based textiles & fibre crops	2.1	1.4	1.4	**4.9**
Wooden products	51.2	12	14.3	**77.5**
Grand Total	**108.1**	**49.2**	**26.1**	**183.4**

Level of sustainability certification

It is difficult to determine the level of sustainability certification of specific wooden products but given that about 56% of the area of European forests has a sustainability certificate, the level of sustainability certification of wooden products is expected to be substantial. Figure 1 indicates that the level of sustainability certification of the selected bio-based chemicals is rather high. Among the identified producers of the selected biobased chemicals, 78% of producers within the EU (31 out of 40 producers) applied sustainability certification. Outside

[1] Please note that some bio-based chemicals are partly bio-based. In this report the total volumes of these chemicals have been accounted for.

the EU this number came down to 55% (24 out of 44 producers), and overall 65% of the identified producers (55 out of 84 producers) applied sustainability certification.

Regarding textiles, it is found that 27% of cotton production is certified under a wide range of schemes, but other fibres and textiles like flax, jute and bio-based insulation materials show a low level of sustainability certification, possibly because they are generally accepted as sustainable, also without certificate. Similarly, sustainability certification is generally applied to palm oil, especially if imported to the EU, but products like sugar, starch and other oil crops are only certified if these biological resources are used for biofuels production, as sustainability certification is required to count towards the EU sustainable transport targets.

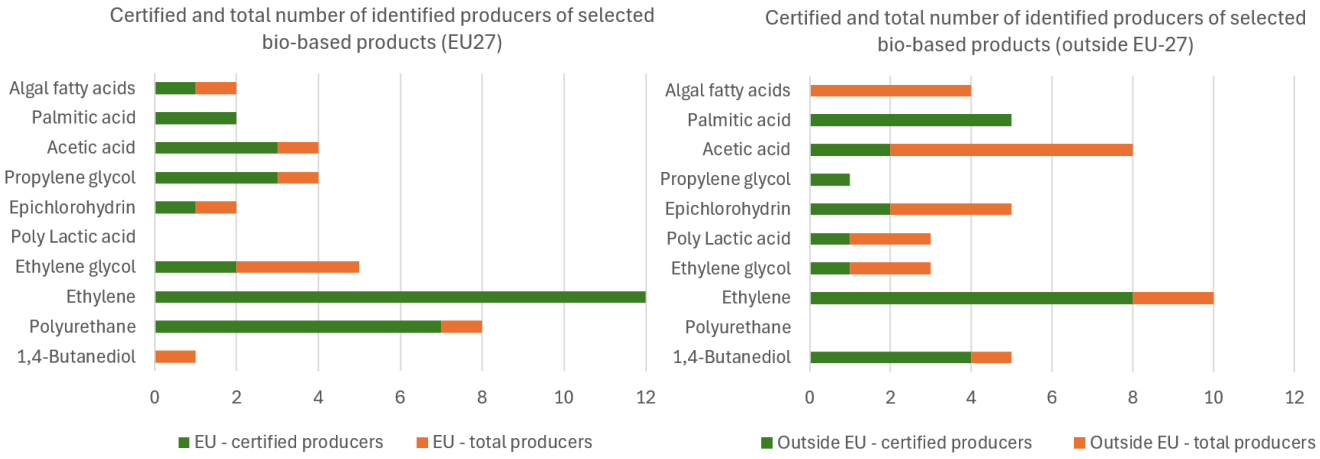

Figure 1: Certified and total number of identified producers of selected bio-based products within and outside the EU-27. Source: own elaboration.

Data gaps and solutions

Several data gaps have been identified in the collection on bio-based trade flows, their level of sustainability certification and a number of possible solutions have been identified.

Regarding the assessment of trade flows the following gaps and solutions were identified:

- Given the lack of reliability of trade data as revealed by the uncertainty indicator, the responsible authorities are recommended to continue their work to improve the quality of international trade data.
- Joint Research Centre (JRC) and the involved research community, supported by the European Commission, are recommended to perform further research on relevant uncertainty indicators of EU and international trade data.
- Comext and UN Comtrade are particularly difficult to navigate for non-experts. We recommend the European Commission and United Nations to make efforts to make (bio-based) trade data better accessible for a non-expert public.
- Given that biomass residues and waste streams are highly relevant for of the bioeconomy and circular economy, we recommend the EU to better monitor and publish trade data on biological waste streams.
- It is recommended to the European Commission or JRC to tender or carry out at least biannually an expert study on the EU market of bio-based chemicals and their level of sustainability certification, resulting in a free and publicly accessible report.

Regarding assessment of the level of certification the following gaps and solutions were identified:

- The level of detail of publicly accessible information on amounts of certified biological resources and bio-based products and materials varies strongly. It would be helpful if certification scheme owners

would gather and publish more information on the volumes and origin of certified bio-based products. The Textile Exchange platform can serve as a good example.

- Data was acquired on production capacities and checking availability of sustainability certificates at company level. A way to improve the quality of data collection could be to organise a survey and ask producers how much certified product, and how much they produce in total.
- A possible solution to increase the availability of data of certified bio-based products, is to apply the approach of the Union Database (UDB) for biofuels, or even to include bio-based products in the UDB.
- In the coming years, further work such as performed in the HARMONITOR project will be needed, checking the level of sustainability, based on available literature and company data, building on the approaches for data collection as established in this report.

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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) has the aim to improve the effectiveness of certification schemes and labels (CSLs) in different sectors of the European Union (EU) Bioeconomy. In the frame of WP3 of the HARMONITOR project, data and figures have been collected on volumes of biological resources, bio-based materials and products in European and global trade flows. Furthermore, insight has been obtained in the degree to which sustainability certification and labelling is applied to these biological resources and materials/products. Full reporting on these insights can be found in the following publicly available deliverables:

- D3.1: Selection of bio-based value chains
- D3.3: Trade flows of biological resources, bio-based materials and products
- D3.4: Level of certification and labelling of biological resources, bio-based materials and products.

Moreover, the trade flows for which statistical data is available, have been visualised in an online trade flow tool and a pivot table. This report provides instructions on how to use these tools.

1.2 Goal and scope

The overall goal of this report is to synthesize, visualise and make accessible all collected data on trade in certified/uncertified biological resources and bio-based products and materials. Moreover, the main findings, including information on data gaps and practical solutions have been summarised. The trade flows have been visualised in an online trade flow tool and a pivot table.

1.3 This report

Chapter 2 report gives insight into the trade flows and level of sustainability certification of selected bio-biobased products and their biological resources. See also Table 2. Chapter 3 shows how the trade flows have been visualised in an online trade flow tool and a pivot table. In chapter 4 the data gaps and potential solutions are discussed.

Table 2: Overview of selected biological resources, bio-based products and materials

Resource/product	Selected biological resources, bio-based products and materials	Trade flows (section)	Level of certification (section)
Biological resources	• Sugar crops: beet, cane • Starch crops: corn, potatoes • Oil crops: rapeseed, palm oil, sunflower • Straw and algae	2.1.1	2.1.2
Biobased chemicals	• Dedicated: lactic acid, polylactic acid, palmitic acid, and algal fatty acids • Drop in: 1,4-butanediol, ethylene, ethylene glycol, propylene glycol, polyurethane, epichlorohydrin, and polypropylene	2.2.1 dedicated 2.2.2 drop-in	2.2.3
Fibre-based crops and textiles	• Cotton, flax, jute, hemp and leather	2.3.1	2.3.2
Wood and wood-based products	• Sawnwood, fibreboard, particle board, OSB and similar board, wooden packaging products, wood wool, lignin-based products, graphic paper, paper board, sanitary and household paper, and tall oil.	2.4.1	2.4.2

2 Trade flows and level of certification of bio-based products

The EU is a major player in the global trade of bio-based products, with the total trade volume of the selected bio-based value chains reaching 183.4 million tonnes in 2021. Table 3 shows that biological resources and wooden products account for the largest share of total trade. Biological resources are mainly used for feed and food, and only partly used to produce bio-based products and materials The selected bio-based chemicals account for only 0.3% of total trade. Details can be found in the next sections and in the Pivot table and Flow Map tool.

Table 3, Total EU trade of selected bio-based value chains, in million tonnes, 2021

Trade of bio-based value chains	Intra-EU trade	Extra-EU imports	Extra-EU exports	Total EU trade (2021)
Biological resources	54.4	35.6	10.3	**100.4**
Drop-in bio-based chemicals	0.11	0.04	0.02	**0.18**
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2.1 Biological Resources

This section describes the trade flows and level of sustainability certification and labelling of biological resources used in the selected value chains, namely wood, sugar crops, starch crops, oil crops, straw and algae. These biological resources are mainly used for food and feed production and partly used to produce various bio-based chemicals and other bio-based products.

2.1.1 Trade flows of biological resources

The trade data of selected biological resources as of 2021 is summarized in Figure 2 and Table 4. It shows the trade within the EU, and trade to and from countries outside of the EU, based on statistical trade data collected using Eurostat (Comext) and UN (Comtrade) databases. Intra-EU trade in starch and starch crops from the largest category, followed by the oil seeds and oil. These crops are mainly used for food and feed production but are important biological resources to produce bio-based products as well. Relatively small countries such as the Netherlands and Belgium appear as large importers and exporters due to their large international harbours.

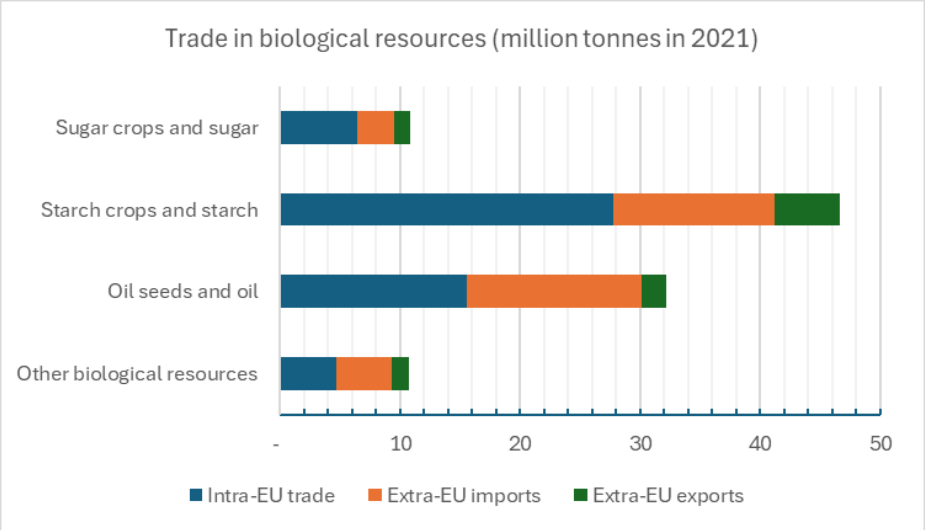


Figure 2: Summary of intra- and extra-EU trade in biological resources (thousand tonnes, 2021)

Table 4: Summary trade data of biological resources (in thousand tonnes, 2021)

Trade of biological resources (thousand tonnes)	***Intra-EU trade***	***Extra-EU imports***	***Extra-EU exports***	***Total EU trade***	***Largest importers***	***Largest exporters***
Sugar (all)	5,360	1,884	938	**8,182**	IT, ES, BE	DE, FR, PL
Cane sugar	328	1,174	83	**1,585**	IT, ES, BE	FR, DE, PL
Sugar beets	596	0	318	**914**	CZ, CH, HR	DE, SK, LV
Beet sugar	132	2	38	**172**	IL, ES, IT	AT, FR, DE
Sugar cane	0	1	0	**1**	BE, NL	DE, EG, VN
Corn	18,587	12,897	3,939	**35,423**	ES, IT, NL	UA, RO, FR
Potatoes	8,017	428	671	**9,116**	BE, NL, ES	FR, DE, NL
Potato starch	519	7	679	**1,206**	NL, US, KR	DE, NL, DK
Corn starch	667	67	168	**902**	FR, DE, IT	ES, FR, DE
Rapeseed & colza	7,783	5,589	481	**13,853**	DE, FR, BE	AU, UA, NL
Palm oil	1,714	6,073	224	**8,012**	NL, IT, ES	ID, MY, NL
Sunflower seeds	2,950	454	555	**3,959**	BG, NL, ES	RO, BG, FR
Sunflower & Safflower oil	1,290	1,574	407	**3,270**	NL, ES, IT	UA, BG, HU
Rapeseed & colza oil	1,754	333	392	**2,480**	NL, BE, CN	DE, FR, NL
Palm kernel oil	54	501	8	**563**	DE, NL, ES	MY, ID, PG
Palm nuts and kernels	2	0	5	**7**	UK, IE, IT	IE, FR, EL
Natural rubber	771	2,602	23	**3,396**	DE, ES, NL	ID, TR, TH
Animal and vegetable fertilizers	2,130	99	358	**2,588**	FR, BE, NL	NL, BE, IT
Municipal waste	352	1,945	162	**2,458**	SE, NL, CH	UK, NO, IE
Cereal straw	1,429	5	830	**2,264**	NL, CH, SA	ES, FR, DE
Algae (human consumption)	6	2	0	**8**	DE, ES, AT	CN, NL, DE
Sugar crops and sugar	6,416	3,061	1,377	**10,854**	IT, ES, PT	DE, FR, BR
Starch crops and starch	27,790	13,399	5,457	**46,647**	ES, NL, IT	FR, UA, RO
Oil seeds and oil	15,547	14,524	2,072	**32,144**	NL, DE, BE	NL, DE, UA
Other biological resources	4,688	4,653	1,373	**10,714**	SE, NL, FR	UK, NL, BE
Total	**54,441**	**35,637**	**10,279**	**100,359**	NL, ES, DE	FR, NL, DE

[1)] A list of country codes can be found here: https://www.iban.com/country-codes

2.1.2 Level of certification of biological resources

The level of certification of biological resources varies considerably between products and regions, as shown in Table 5. Sugar beets reached a relatively low level of 4.3%. Sugar beets used for bioethanol production and sugar beet wastes used for biogas production are certified under pressure of the renewable energy directive, but the level of voluntary certified sugar beets for other purposes such as food and feed is very low. On global level, a similar picture is found. Brazil, as important bioethanol producer reaches a 20.2% certified sugar cane, while at global level only 5.5% of the sugar is Bonsucro certified.

Table 5: Summary of the level of certification of biological resources.

Biological resource	Level of certification (%)
Wood	Global: 10.7% of the forest area under an independently verified forest management system EU27: 49.0% of the European forest area is certified by a an independently verified forest management system
Sugar Beet	EU: 4.3% certified under schemes for RED II (Renewable Energy Directive).
Sugar Cane	Brazil 20.2%, Asia 0.7%, Global 5.5% certified Bonsucro.
Palm oil	Exported to Europe: 65-93% certified RSPO.

Palm oil is used in various products, as well as for biodiesel production. Under pressure of concerns that palm oil production takes place at the cost of rainforests, the level of certification is very high, especially if the palm oil is directed to European markets. In Europe 49% of the forest area is under an independently verified forest management system, while at global level only 10.7% of the forest area is certified. Please note that the share of forest area certified does not necessarily correspond with the share of certified wood that is harvested, as both production forests and non-productive forests are being certified.

2.2 Bio-based chemicals

This chapter describes the trade flows of a selection of dedicated and drop in bio-based chemicals.

- **Dedicated bio-based chemicals** do not have a chemically identical equivalent, and as such, there is trade flow information available for many of them. Additionally, information on bio-based production sites was included in some cases. The dedicated bio-based chemicals included in this chapter are lactic acid, polylactic acid, palmitic acid, and algal fatty acids.
- **Drop-in bio-based chemicals** have a chemically identical equivalent, and as such, for many of them, there is no trade data available for the bio-based chemical specifically. As such, information on bio-based production was included and from this, trade flows can be concluded. The bio-based chemicals assessed are 1,4-butanediol, ethylene, ethylene glycol, propylene glycol, polyurethane, epichlorohydrin, and polypropylene.

2.2.1 Trade flows of bio-based dedicated chemicals

The trade data on bio-based dedicated chemicals is summarized in Table 6. The table shows the total trade of the chemical, the trade within the EU, and trade to and from countries outside of the EU. Additionally, the largest importers and exporters (to/from the EU) are also shown.

Table 6: Summary trade data bio-based dedicated chemicals (thousand tonnes in 2021)

Trade of bio-based chemicals (thousand tonnes)	*Intra-EU trade*	*Extra-EU imports*	*Extra-EU exports*	*Total EU trade*	*Largest importers*	*Largest exporters*
Lactic acid	228	25	79	**228**	NL, DE, BE	NL, BE, FR
Polylactic acid (PLA)	136	71	7	**136**	NL, DE, IT	NL, US, TH
Palmitic acid	77	42	5	**77**	NL, ES, DE	DE, US, ES
Total	441	212	138	**91**	NL, DE, IT	NL, US, BE

For poly lactic acid (PLA) and algal fatty acids, data on production capacities could be found, which is presented in Table 7.

Table 7: Identified production capacities of bio-based chemicals (# of plants and capacity in ktonnes/year)

	EU		Asia		North America		Latin America		Total	
Bio-based chemical	#	cap.	#	cap.	#	cap.	#	cap.	#	cap.
Polylactic acid	0	0	2	175	1	150	0	0	3	325
Algal fatty acids	2	70	2	4	1	14	1	110-330	6	202-418
Total										

2.2.2 Trade flows of bio-based drop-in chemicals

Trade statistics do usually not distinguish between drop-in biobased chemicals and fossil-derived chemicals. The exception is 1,4-Butanediol (BDO) for which specific trade statistics on the bio-based variant is available. To understand the role of bio-based drop-in chemicals, first, the countries and production capacities[2] of the selected drop-in bio-based chemicals have been collected. The results are summarised in Table 8. Detailed information on the identified companies, their capacities and county can be found in Deliverable D3.4, including an indication whether a sustainability certificate was found. The table below shows that we identified the most production facilities of drop-in bio-based products in the EU, but most of the production takes place in Asia. In Africa and the Middle East no production facilities were identified. It is well possible that the actual production capacity and number of facilities are higher than as presented, as information on production facilities is hard to find, and easily overlooked. Also, it is not possible to verify if all the identified production capacity is actually in operation.

Table 8: Identified production capacities of bio-based chemicals (# plants, capacity in ktonnes/yr)

	EU		Asia		North America		Latin America		Total		Biobased market share
Bio-based chemical	#	cap.	#	cap.	#	cap.	#	cap.	#	cap.	%
1,4-Butanediol (BDO)	1	30	2	20-50	3	n.d.	0	0	6	50-80	1.5-2.4%
Polyurethane	7	n.d.	0	0	0	0	0	0	7	>2.5	>0.01%
Ethylene	12	> 66	4	n.d.	5	n.d.	1	260	22	> 326	0.3%
Ethylene glycol	5	> 10	3	>177	0	0	0	0	8	>187	0.7%
Epichlorohydrin	2	80	5	480	0	0	0	0	7	560	25.9%
Propylene glycol	4	> 115	0	0	1	100	0	0	5	>215	8.5%
Acetic acid	4	72-88	7	242	1	0	0	0	12	314-330	~2.0%
Total	35	373-389	21	919-949	10	100	1	260	67	1655-1701	~0.9%

[2] Information on the actual production of bio-based products is very difficult to obtain at company level and, therefore, data on production capacities have been collected.

For each drop-in biobased chemical, their share in total fossil and bio-based production has been estimated. As can be seen in the last column of Table 8, in most cases this bio-based market share is rather low. This means that it in most cases it does not make sense to use the trade statistics that cover both fossil and bio-based trade, to make statement on the trade flows of the drop-in bio-based chemicals.

2.2.3 Level of certification of bio-based chemicals

Figure 3 indicates that the level of sustainability certification of the selected bio-based chemicals is rather high. Of the identified producers of the selected bio-based chemicals, within the EU 78% (31 out of 40 producers), and outside the EU 55% (24 out of 44 producers), applied sustainability certification. In total 65% of the identified producers (55 out of 84 producers) applied sustainability certification.

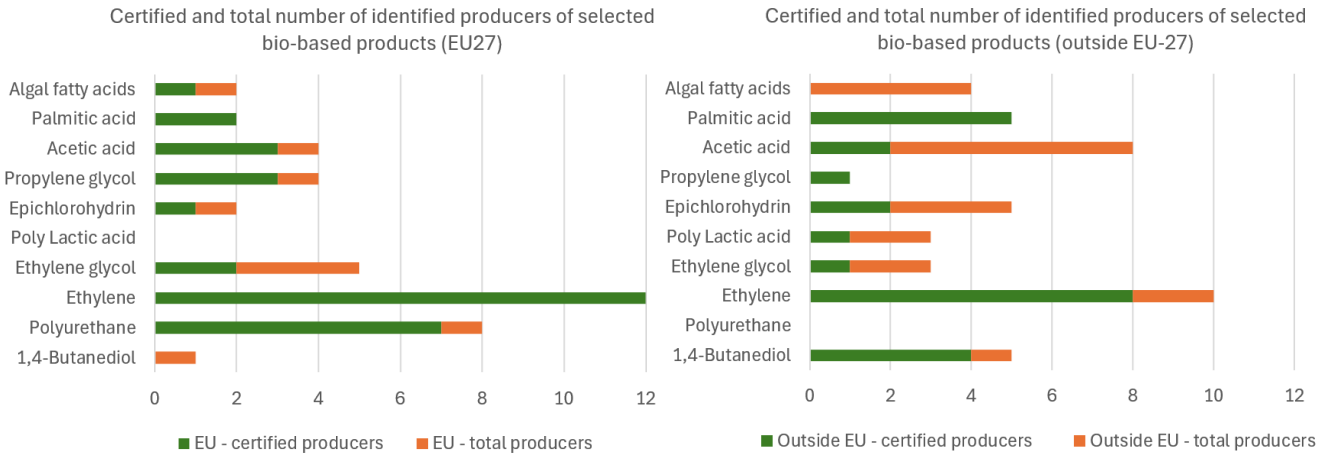


Figure 3: Certified and total number of identified producers of selected bio-based products within and outside the EU-27. Source: own elaboration.

In specific cases the production capacities are identified, but also then it is still unknown if producers certify all or just part of their bio-based production. Therefore, we cannot make a solid statement on the volumes of certified bio-based production. Nevertheless, the found result is an important indication that sustainability certification is widely applied for bio-based chemicals. This can be explained by the fact that in case of drop-in bio-based chemicals, sustainability certification, or at least bio-based content certification is needed to prove that the product is bio-based, or "linked to bio materials"[3] in case of a mass balance approach. Secondly, these products are generally substantially more expensive than the fossil-based chemicals, and the sustainability certificate shows that this is a genuinely green product.

[3] See https://www.iscc-system.org/wp-content/uploads/2022/11/ISCC-208-Logos-and-Claims-1.3.pdf

2.3 Fibre-based crops and textiles

This section gives an overview of the trade flows and level of certification of the main fibre crops used for textiles, namely, cotton, flax, jute, hemp and leather.

2.3.1 Trade flows of fibre-based crops and textiles

The trade data of fibre-based crops and textiles are summarized in Table 9. The table shows the total trade of the fibre value chains, the trade within the EU, and trade to and from countries outside of the EU. Additionally, the largest importers and exporters (to/from the EU) are also shown. Additionally, Table 9 shows the EU trade of fibre crops as well as the estimations on the trade of textile articles of bio-based fibres. It shows that especially for cotton and jute, the total amount of textile articles traded is much higher than in the other steps of the value chain. This makes sense as cotton and jute fibres are both primarily produced in Asian countries, which are also major players in textile processing. As such, the entire fibre-to-textile process appears to be happening in these countries, with little trade of the fibres or yarn, but a much larger trade of the finished textile article.

Table 9: Summary trade data fibre crops and textiles

Fibre & textile value chains (thousand tonnes)	**Intra-EU**	**EU imports**	**EU exports**	**Total EU trade**	**Largest importers (from EU countries)**	**Largest exporters (to EU countries)**
Flax fibres	289	21	215	**525**	CN, BE, NL	FR, BE, CA
Flax yarn	12	14	1	**27**	IT, PT, NL	CN, IT, PL
Woven flax fabrics	10	15	6	**31**	IT, ES, LT	CN, IT, BE
Cotton fibres	39	133	386	**558**	TR, EG	EL, ES, TR
Cotton yarn	86	297	14	**397**	PT, IT, DE	TR, IN, PK
Woven cotton fabrics	125	167	47	**338**	IT, BE, DE	PK, TR, DE
Industrial hemp fibres	31	0	5	**36**	ES, NL, DE	FR, NL, DE
Hemp yarn	0	0	0	**1**	US, PT, IT	CN, RO, DE
Jute fibres	9	5	1	**14**	DE, ES, FR	BE, BD, DE
Jute yarn	1	18	0	**19**	BE, ES, PL	BD, IN, BE
Woven fabrics of jute	4	17	1	**22**	NL, DE, IT	IN, BD, DE
Total bio-based fibre crops & intermediate products	**606**	**687**	**676**	**1968**		
Raw hides and leather	871	533	531	1935	IT, CN, DE	IT, DE, FR
Leather articles	446	81	18	546	DE, BE, FR	DE, NL, IT
(all) finished textile articles	*6149*	*7438*	*3049*	*16636*	DE, FR, NL	CN, DE, NL

Trade in finished textile products

Using information from Textile Exchange[4] on the market share of the plant-based fibres, we can make the following estimations (presented in Table 10):

- Cotton fibres accounted for 22% of the global fibre market in 2021. Using this share, the EU trade of cotton textile articles is estimated at around 3.7 million tonnes.
- Rayon is the most used man-made cellulosic fibre (MMCF), with a market share of about 5% of the global fibre market. As such, it is estimated that the EU traded about 0.8 million tonnes of rayon textile articles in 2021.
- Jute is the second most used plant fibre with an estimated share of 3% of the global fibre market in 2021. Using this share, the total EU trade of jute is estimated to be around half a million tonnes.
- Flax has a market share of about 1% of the global fibre market, making the estimated EU trade of flax textile articles around 166 thousand tonnes.

[4] https://textileexchange.org/app/uploads/2022/10/Textile-Exchange_PFMR_2022.pdf

- Hemp has a relatively small market share of 0.22%. As such, the EU trade of hemp textile articles is estimated at around 37 thousand tonnes.

It should be kept in mind that these estimates of trade flows have high uncertainty. Especially for those with a low share of the textile market, the trade in finished textile articles could differ greatly from the actual trade flows.

Table 10, EU trade of finished textile articles and estimations of trade plant-based textiles

Trade of textile articles (thousand tonnes)	**Total EU trade**	**Intra-EU**	**EU imports**	**EU exports**	**Largest producers**
Finished textile articles	**16,701**	6,149	7,442	3,110	Largest exporters: China, Germany, Netherlands
Share cotton: **22%**	**3,674**	1,353	1,637	684	*China, India, United States*
Share rayon: **5%**	**835**	307	387	155	*China, Indonesia, India*
Share jute: **3%**	**501**	184	223	93	*India, Bangladesh, China*
Share flax: **1%**	**167**	61	74	31	*France, Belgium, Netherlands*
Share hemp: **0.22%**	**37**	14	16	7	*France, Poland, Netherlands*

2.3.2 Level of certification of fibres and fibre-based products

Fibre based products, especially consumer textiles, often encompass a complex value chain with many production steps in different countries. This is also reflected in the availability of data: For the raw materials, comprehensive data is available for cotton and for the Europe-grown flax. On the end-product side, data is much harder to find with few statistics on consumer textiles and inconclusive entries in certification databases (due to unknown volumes and the variety of labels). There is no demand for sustainability certification in the straw insulation market. This could be explained by the assumption that the use of local residues is considered sustainable.

Table 11: Level of certification of selected fibre-based products

Fibre-based product	**Level of certification (%)**
Cotton based textiles	Global: ~27% of cotton production certified under a wide range of schemes Good statistics for virgin cotton, but little statistics for European consumer market shares
Flax based textiles	Main production in Europe under "European Flax" label. Value chain of certified material volumes however not traceable to degree of certification for textile products in EU
Jute based textiles	No information on level of certification
Bio-based insulation materials	No sustainable certification scheme available (Feedstock = straw)
Straw	Cultivation area | EU27 share organic = 4.6% (cereals)

Table 11 summarises the main findings on the level of certification of different fibre-based products. Cotton fibres are the largest biological resource for textile production. The most important certification schemes were the better cotton initiative (BCI), Cotton made in Africa (CmiA), Organic production and Fairtrade. In 2018, 21% of the produced cotton are reported as sustainable[5] and in 2021, BCI alone states that more than 20% of the global production is certified by their standard.[6] In the global fiber market report from 2022 of Textile Exchange, already ~27% of cotton is reported as certified under a range of schemes.[7]

[5] Sustainable cotton ranking, https://sustainablecottonranking.org/market-update, accessed 25th of August 2023.
[6] Better Cotton Initiative Annual Report 2021, https://bettercotton.org/wp-content/uploads/2022/06/Better-Cotton-2021-Annual-Report.pdf, accessed 25th of August 2023.

Table 12: Level of certification for virgin cotton.[7]

Virgin cotton 2021/22	Total Certified	Better Cotton	Organic	Fairtrade	REEL[a)]
Turkey	~18%	~8%	~10%	-	-
India	~21%	~16%	~3%	~0.2%	~2%
Pakistan	~68%	~65%	~0.2%	undisclosed	~3%
China	~3%	~2%	~1%	-	~1%

[a)] The REEL Cotton Programme is a three-year agricultural programme providing farmers with training on sustainable cotton farming practice

Cotton yarn imported to Europe comes mainly from Turkey, India, and Pakistan. The shares of certified yarn are not available, but – as shown in Table 12, there is data on the level of certification of virgin cotton production from these countries, which can serve as a first indicator for the local degree of certification.[7]

2.4 Wood and wood-based products

This chapter gives an overview of trade flows and level of certification of the selected wood-based products, namely sawnwood, fibreboard, particle board, OSB and similar board, wooden packaging products, wood wool, lignin-based products, graphic paper, paper board, sanitary and household paper, and tall oil.

2.4.1 Trade flows of wood and wood-based products

The trade data of wood-based products have been summarized in Table 13 and Figure 4, that show the total trade of the different categories of wood-based products and their value chain, the trade within the EU, and trade to and from countries outside of the EU. Additionally, the largest importers and exporters (to/from the EU) has been also shown.

Table 13 wood-based products EU-trade 2021(million tonnes)

Trade of wood-based products	Total EU trade	Intra-EU trade	Extra-EU imports	Extra-EU exports	Largest EU exporters	Largest EU importers	Largest non-EU exporters	Largest non-EU importers
Sawnwood	29.6	16.6	6.4	6.5	DE, SE	DE, NL	RU, BY	CN, JP
Fibreboard	9.3	7.0	1.0	1.4	DE, PL	NL, BE	BY, RU	BO, CA
Particle board, OSB, and similar board	11.3	8.9	1.2	1.2	DE, AT	PL, DE	BY, UA	CN, JP
Wooden packaging products	0.41	0.34	0.03	0.03	PL, DE	DE, FR	UK BY	KR, MD
Wooden pallets	6.0	5.0	0.8	0.2	PL, DE	DE, NL	UA, BY	NO, CA
Wood wool, wood flour	0.10	0.07	0.01	0.02	DE, NL	NL, DE	UK, UA	HK, KR
Lignin based products	0.62	0.31	0.19	0.13	SE, DE	DE, SE	NO, RU	UK, IN
Graphic paper	9.1	5.9	0.8	2.4	SE, DE	DE, FR	NO, BR	US, TR
Paper board	9.5	6.2	1.0	2.3	SE, AT	IT, DE	US, RU	TT, CN
Sanitary and household paper	1.27	0.74	0.39	0.15	IT, DE	DE, EL	TR, ID	UK, US
Tall oil	0.27	0.10	0.17	0.01	SE, PL	FI, FR	US, RU	RU, IN
Total	***77.47***	***51.16***	***11.99***	***14.34***				

[7] Textile Exchange Materials Market Report 2023, https://textileexchange.org/app/uploads/2023/11/Materials-Market-Report-2023.pdf, accessed 17th of October 2024.

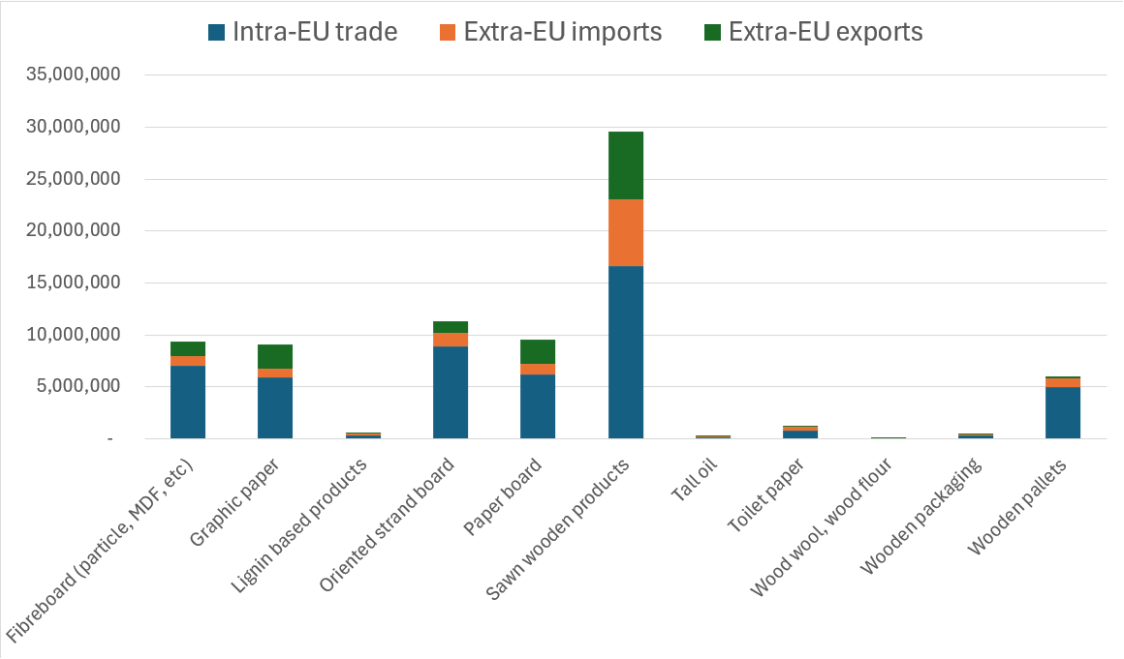


Figure 4: wood-based products EU-trade 2021

2.4.2 Level of certification of wood and wooden products

Table 14 shows the level of FSC, PEFC certification and the share of double certified areas, using the latest available public information. Overall, PEFC is the most applied scheme with 47% of the EU's forest coverage, while FSC has a coverage of 25% in the EU. As part of the area is double certified, in total 56% of the forest area in Europe is certified.

Table 14: Level of FSC (Nov. 2024), PEFC (June 2024) certification and double certified areas as (mid 2023) in the EU countries, Canada and USA.

	FSC[a)]	PEFC[b)]	of which double certified[c)]	Total certified[d)]	Total forest area[e)]	FSC	PEFC	Double	Total[g)]
	1000 ha	1000 ha	1000 ha	1000 ha	1000 ha	%	%	%	%
Austria	1	3,380	1	3,380	3,899	0%	87%	0%	87%
Belgium	43	262	10	294	689	6%	38%	2%	43%
Bulgaria	2,056	244	-	2,300	3,893	53%	6%	0%	59%
Croatia	2,033	-	-	2,033	1,939	105%[f)]	0%	0%	105%[f)]
Czechia	130	1,782	114	1,799	2,677	5%	67%	4%	67%
Denmark	233	350	228	355	628	37%	56%	36%	56%
Estonia	1,269	1,692	1,257	1,704	2,438	52%	69%	52%	70%
Finland	2,462	19,491	2,224	19,729	22,409	11%	87%	10%	88%
France	121	5,732	74	5,779	17,253	1%	33%	0%	33%
Germany	1,262	8,942	1,397	8,807	11,419	11%	78%	12%	77%
Greece	-	-	-	-	3,902	0%	0%	0%	0%

Hungary	495	-	-	495	2,053	24%	0%	0%	24%
Italy	115	1,014	63	1,066	9,566	1%	11%	1%	11%
Ireland	452	467	451	468	782	58%	60%	58%	60%
Latvia	411	1,765	1,224	952	3,411	12%	52%	36%	28%
Lithuania	1,278	-	-	1,278	2,201	58%	0%	0%	58%
Luxembourg	27	41	20	48	89	31%	46%	23%	54%
Netherlands	165	3	2	166	370	45%	1%	0%	45%
Poland	2,980	7,267	4,560	5,687	9,483	31%	77%	48%	60%
Portugal	616	332	294	653	3,312	19%	10%	9%	20%
Romania	2,741	654	12	3,383	6,929	40%	9%	0%	49%
Slovakia	585	1,131	381	1,335	1,926	30%	59%	20%	69%
Slovenia	272	295	261	306	1,238	22%	24%	21%	25%
Spain	762	2,834	387	3,210	18,572	4%	15%	2%	17%
Sweden	19,824	16,405	12,640	23,590	27,980	71%	59%	45%	84%
EU - total	40,332	74,084	25,599	88,818	159,058	25%	47%	16%	56%
USA	14,203	33,164	7,751	39,617	309,795	5%	11%	3%	13%
Canada	45,686	133,307	16,858	162,135	346,928	13%	38%	5%	47%

[a)] Source: https://connect.fsc.org/impact/facts-figures [b)] Source: PEFC Global statistics, Data: June 2024 [c)] PEFC Factsheet – mid 2023, PEFC and FSC double certification (2016-2023); [d)] Total certified, calculated as FSC area plus PEFC area minus double certified area. [e)] Eurostat, Area of wooded land (FAO, FE), for_area, FAOStat https://doi.org/10.2908/FOR_AREA; Canada, USA: FAO (2020) Global Forest Resources Assessment 2020, Main report https://openknowledge.fao.org/items/d6f0df61-cb5d-4030-8814-0e466176d9a1; [f)] There seems to be a mismatch in area certified in Croatia and total forest area. [g)] The colour scale can be used to identify countries with a large (green), medium (yellow & orange) or limited (red) share of certified forest. This table has also been published as part of 3-CO Deliverable *1.5 "Cost and relevance of labels and certification schemes for the bioeconomy"*.

Whilst information on the certified areas can readily be obtained from the forest certification schemes and FAOstat, collection of information on the level of certification expressed in tonnes of wooden products is difficult to find. As an alternative approach, in HARMONITOR, the share of FSC and PEFC Chain of Custody certificates found within and outside the EU have been analysed and compared to the EU share of global production of the wooden products.

Table 15 shows that for all wooden products analysed, the share of FSC and PEFC CoC certificates is higher than the share of EU production, indicating that FSC and PEFC sustainability certification is relatively more often used within the EU than in the rest of the world. Secondly, the table shows that for each product the EU share of PEFC certificates is higher than the share of FSC certificates. This is because within the EU, PEFC is more often used than FSC certification, which is confirmed by Table 14 on the level of forest certification at area level.

There is no data on the extent to which certified products have been produced outside Europe for the European market and could therefore increase the European market share. Therefore, the comparison only reflects the production side. No statement can be concluded about the European market share of certified products.

Table 15: The share CoC certificates found in the EU27 compared with the total number of certificates found in the FSC and PEFC schemes.

Wood-based product	% of global FSC-certificates found in EU27	% of global PEFC-certificates found in EU27	% of global production in EU27
Sawn wood	54.8%	79.3%	21.8%
MDF board	47.0%	81.9%	14.0%
Wood based packing	49.3%	93.4%	n.d.
Pulp	44.5%	43.7%	15.8%
Graphic paper	36.3%	59.7%	25.2%
Paperboard	39.5%	68.6%	19.6%
Toilet paper	37.1%	79.3%	17.7%
Rubber products - tires	Global: 2.6% of forest FSC/PEFC certified. Pioneer projects for tires		
Rayon	4 out of 4 EU rayon producers use certified wood (100%)		

3 Visualisation of trade flows

3.1 Introduction

The assessment focuses on EU trade flows data of biological resources, bio-based materials and products, both intra-EU and extra-EU. The trade data assessed includes imports and exports of the different products from selected value chains, from, to and within the EU, for three years: 2015, 2018 and 2021.

The data was collected using Eurostat (Comext) and UN (Comtrade) databases and was summarized into an excel sheet, which was used to make interactive pivot tables (link). See section 3.2 and this video for further information and instruction. In the case of bio-based products for which no statistical data is available[8] - this is the case for most drop-in bio-based products -, the total trade flows (that include both the fossil and bio-based part) are provided.

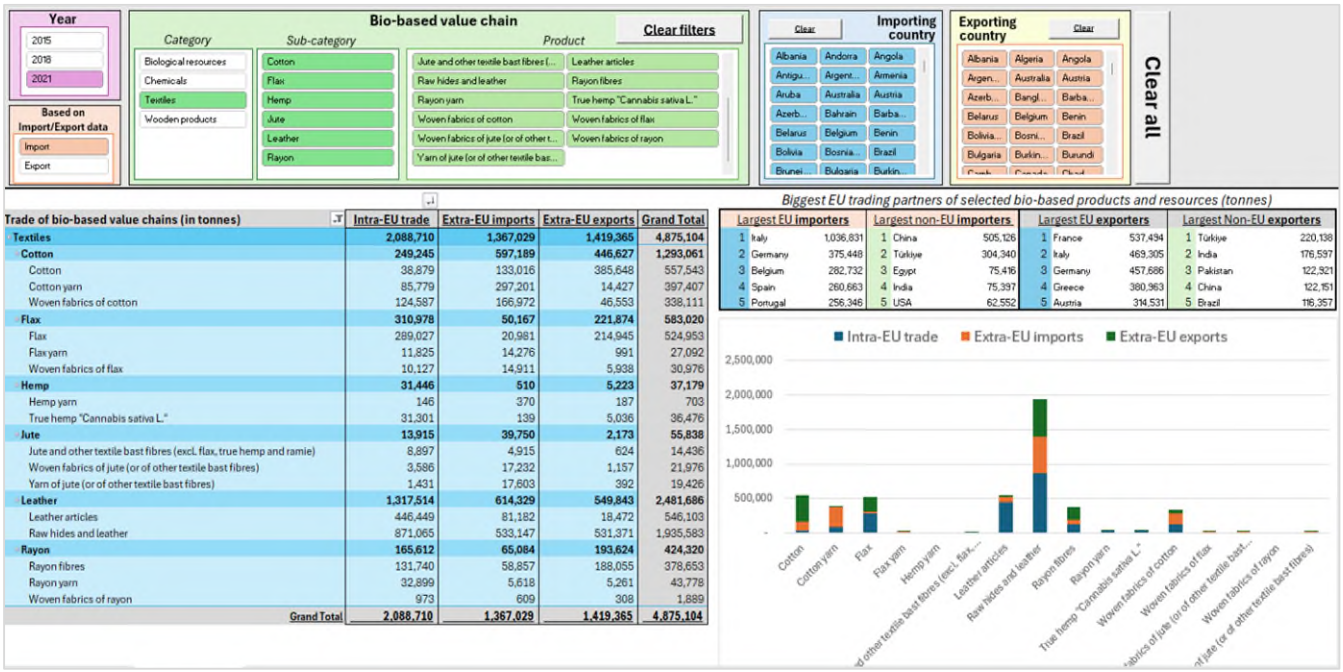
To make the data more accessible and interactive, an **online trade flow tool** was used to visualize trade flows. The flow map tool is also embedded into the HARMONITOR website, where it shows the different bio-based products and biological resources, trade quantities and specific trade flows (see section 3.3).

[8] Please note that in case no statistical data on the bio-based part is available, as best alternative, the main producers were identified, as well as their production locations and capacities, using various literature resources, as far as available. This information can be found in Deliverable D3.4.

3.2 Pivot table

Using the combined data from Comext and the UN Comtrade databases, a comprehensive dataset was created for EU trade data of the selected bio-based value chains. This dataset is presented in a pivot table format, offering enhanced filtering options for products, import and export data, and intra- and extra-EU trade. The connected Excel file (link) contains three tabs:

Tab 1. EU trade totals: This tab allows filtering by years (2015, 2018, 2021), import/export data, categories, sub-categories, specific products within the bio-based value chain, import and export countries, and trade direction (intra-EU trade, extra-EU imports, extra-EU exports). The data is presented in a graph that shows both the totals and the share of intra-EU and extra-EU trade. Based on these filters, the largest importers and exporters within and outside of the EU are also shown, as well as their trade volumes.



Trade of bio-based value chains (in tonnes)	Intra-EU trade	Extra-EU imports	Extra-EU exports	Grand Total
Textiles	**2,088,710**	**1,367,029**	**1,419,365**	**4,875,104**
Cotton	**249,245**	**597,189**	**446,627**	**1,293,061**
Cotton	38,879	133,016	385,648	557,543
Cotton yarn	85,779	297,201	14,427	397,407
Woven fabrics of cotton	124,587	166,972	46,553	338,111
Flax	**310,978**	**50,167**	**221,874**	**583,020**
Flax	289,027	20,981	214,945	524,953
Flax yarn	11,825	14,276	991	27,092
Woven fabrics of flax	10,127	14,911	5,938	30,976
Hemp	**31,446**	**510**	**5,223**	**37,179**
Hemp yarn	146	370	187	703
True hemp "Cannabis sativa L."	31,301	139	5,036	36,476
Jute	**13,915**	**39,750**	**2,173**	**55,838**
Jute and other textile bast fibres (excl. flax, true hemp and ramie)	8,897	4,915	624	14,436
Woven fabrics of jute (or of other textile bast fibres)	3,586	17,232	1,157	21,976
Yarn of jute (or of other textile bast fibres)	1,431	17,603	392	19,426
Leather	**1,317,514**	**614,329**	**549,843**	**2,481,686**
Leather articles	446,449	81,182	18,472	546,103
Raw hides and leather	871,065	533,147	531,371	1,935,583
Rayon	**165,612**	**65,084**	**193,624**	**424,320**
Rayon fibres	131,740	58,857	188,055	378,653
Rayon yarn	32,899	5,618	5,261	43,778
Woven fabrics of rayon	973	609	308	1,889
Grand Total	2,088,710	1,367,029	1,419,365	4,875,104

Largest EU importers		Largest non-EU importers		Largest EU exporters		Largest Non-EU exporters	
1 Italy	1,036,831	1 China	505,126	1 France	537,494	1 Türkiye	220,138
2 Germany	375,448	2 Türkiye	304,340	2 Italy	469,305	2 India	176,597
3 Belgium	282,732	3 Egypt	75,416	3 Germany	457,686	3 Pakistan	122,921
4 Spain	260,663	4 India	75,397	4 Greece	380,963	4 China	122,151
5 Portugal	256,346	5 USA	62,552	5 Austria	314,531	5 Brazil	116,357

Figure 5: PIVOT Tab 1: EU trade totals (example of textile value chains)

Tab 2. Trade Development Over Time: Like the first tab, this tab displays trade totals over the years 2015, 2018, and 2021, allowing users to observe trade developments over this period.

Total trade of bio-based value chains per year (in tonnes)	2015 Intra-EU trade	2015 Extra-EU imports	2015 Extra-EU exports	2015 Total	2018 Intra-EU trade	2018 Extra-EU imports	2018 Extra-EU exports	2018 Total	2021 Intra-EU trade	2021 Extra-EU imports	2021 Extra-EU exports	2021 Total
Chemicals	136,229	111,323	71,924	319,476	165,360	112,537	87,370	365,327	211,279	138,369	91,400	441,048
Dedicated chemicals	136,229	111,323	71,924	319,476	165,360	112,537	87,370	365,327	211,279	138,369	91,400	441,048
Lactic acid, its salts and esters	91,974	43,458	63,108	198,540	103,865	37,630	74,741	216,236	123,977	25,229	78,878	228,085
Palmitic acid and its salts and esters	24,184	41,427	5,695	71,306	21,609	30,755	6,768	59,133	29,411	41,853	5,237	76,501
Poly"lactic acid"	20,071	26,438	3,120	49,629	39,886	44,212	5,861	89,959	57,891	71,287	7,285	136,463
Grand Total	136,229	111,323	71,924	319,476	165,360	112,537	87,370	365,327	211,279	138,369	91,400	441,048

Figure 6: PIVOT Tab 2: Trade developments over the years (example of dedicated bio-based chemicals)

Tab 3. EU trade between countries: This tab provides a detailed view of trade between specific importing and exporting countries. Users can filter by year, import/export data, bio-based value chain, trade direction, and specific importing or exporting countries to see the trade volume between pairs of countries.

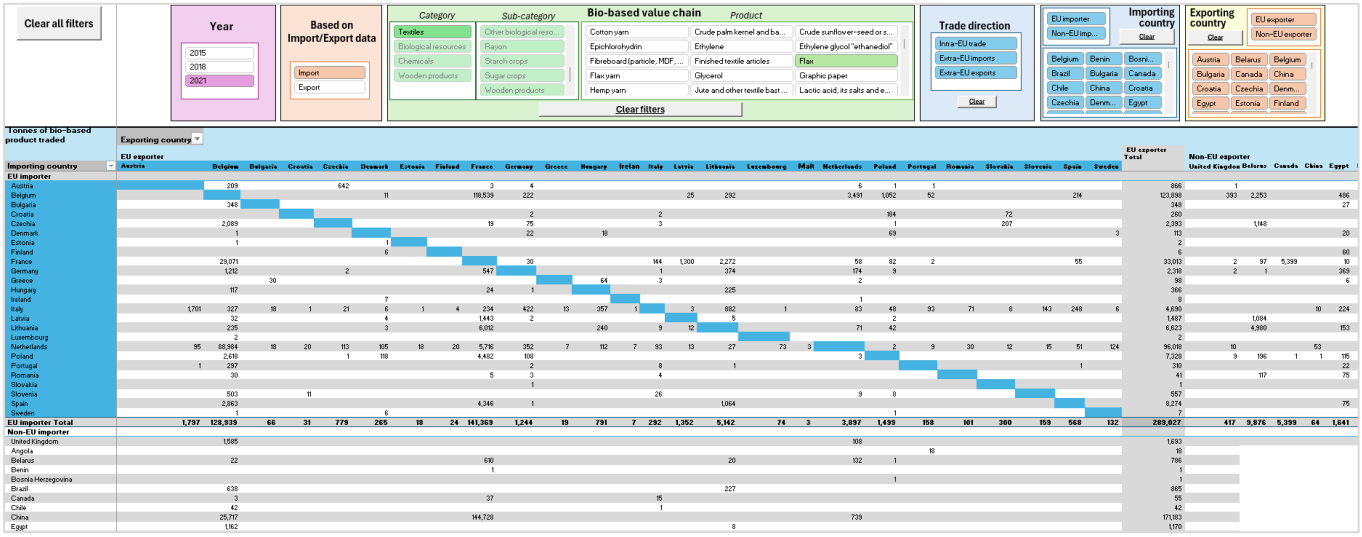


Figure 7: PIVOT Tab 3: EU trade between countries (example flax)

More information on how to use the Pivot tables can be found in this video.

3.3 Online trade flow tool

To visualize the trade flows, the data was entered into the 'FlowmapBlue' tool, which gives the following online interactive map: https://flowmap.blue/1VWZpdRU-Gk8kWX2NQEtnaq3UvDH3tqZjWErpI2AfEzg/d34f5c2. This tool gives the possibility to filter between the different value chains (Figure 8), to see the individual trade flows between countries; and the total imports and exports of a specific country (Figure 9).

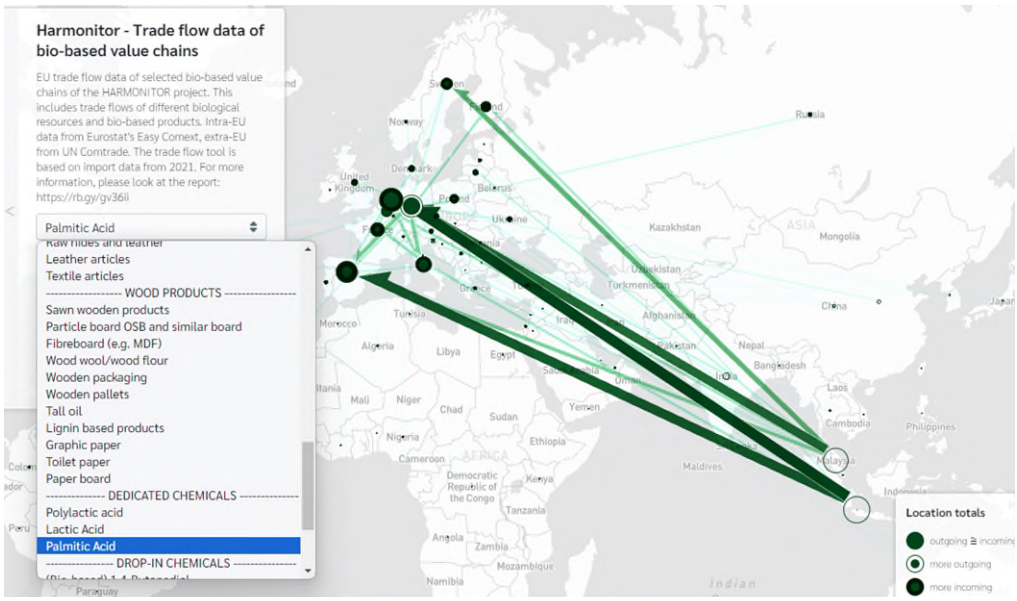


Figure 8: Interactive map of trade flows, showing the option of different value chains and visible individual trade flows.

Figure 9: Interactive flow map, showing a specific country's imports and exports of a product

The flow map tool is also embedded into the HARMONITOR website, where it shows the different bio-based products and biological resources, trade quantities and specific trade flows. More information on how to use the online trade flow map can be found in this video.

4 Data gaps and possible solutions

With the help of statistical data supplemented with literature research, we were able to provide insight into the trade of a broad spectrum of bio-value chains, from biological resources to intermediate chemicals or products. The performed work revealed several data gaps and uncertainties, as well as possible solutions, which are discussed below.

Distinguishing drop-in bio-based products in trade statistics
Trade data for drop-in bio-based products is often not separately recorded, as it is combined with data for their fossil-based counterparts. This lack of differentiation underscores the need for additional CN codes to accurately distinguish between bio-based and fossil-based trade. Although specific CN-codes for drop in bio-based chemicals are necessary to collect statistical trade data, given the modest trade flows found of investigated drop-in bio-based products, and the high uncertainty associated with statistical trade data, especially when it concerns smaller trade flows, it may, however, be still too early to introduce them. This solution makes sense in case a sufficient market volume of the drop-in biobased products has been reached.

Improved trade statistics for waste and residues
There is a lack of statistical trade data on waste streams. The absence of trade data for many types of residues and products thereof, such as compost, complicates efforts to fully understand the trade of bio-based products and resources. To address these gaps, there is a clear need for the introduction of more specific CN-codes.

Discrepancies in trade data statistics
The trade data does not always appear to be complete. If we take for example the trade of sugar, which is primarily produced from sugar beets and sugar cane. The total trade of sugar is much higher than the trade of beet sugar and cane sugar combined. Also, the extra-EU imports of cane sugar are higher than the EU imports of all sugar. This is most likely due to the way these products are reported by the receiving country.

To evaluate the trade data quality of the different bio-based products included, the bilateral asymmetric rate of export and import data was calculated. It measures the degree of bilateral asymmetry on a scale from 0 to 1. The closer to 1, the higher the asymmetric degree. Intra-EU and Extra-EU trade flows were evaluated separately because they are based on different data sources (EU Comext and UN Comtrade respectively).

For *intra-EU trade flows* (see Figure 10, left graph), 38 out of 60 (63%) evaluated commodities have an uncertainty level of 1 ($\alpha < 0.1$) which means that both importing and exporting countries report the same trade flows with less than 22% difference. *Extra-EU trade flows*, based on UN Comtrade data, are more uncertain compared to the intra-EU trade flows based on EU Comext (See right graph in Figure 10). Almost half (29 out of 60) of the extra-EU bio-based trade flows included have an uncertainty level of 1 ($\alpha < 0.1$) and 14 commodities are at high or very high uncertainty ($\alpha > 0.3$).

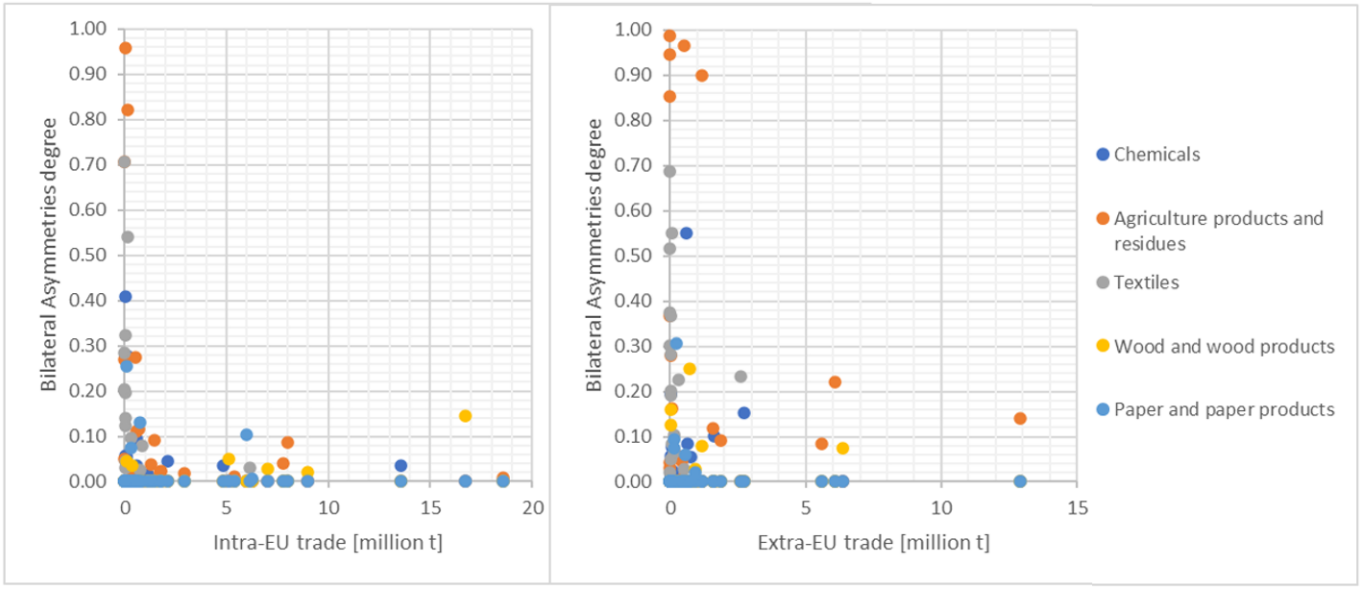


Figure 10: Bilateral Asymmetries degree of intra-EU and extra trade flows of selected bio-based commodities in 2021.

Indirect trade[9] is a main cause of errors in trade data and is specifically relevant to bio-based products. The emerging market of multi-output biorefineries that operate in an international market could create additional challenges to reporting trade data and increases its relevance for further research. The responsible authorities are recommended to continue their work to improve the quality of international trade data.

Furthermore, a classification of uncertainty caused by the asymmetry of published trade data could help inform users of its limitations for further analysis. JRC and the involved research community are recommended to perform further research on relevant uncertainty indicators of EU and international trade data, and to make these indicators easy to apply for (expert) users. The European Commission is recommended to allocate funding to this type of research.

Improved access to trade data

Comext and UN Comtrade are particularly difficult to navigate for non-experts. We recommend the European Commission and United Nations to make efforts to make (bio-based) trade data better accessible for a non-export public. The HARMONITOR Consortium is recommended to make efforts to keep the trade flow tool online, and update it say every two years, when new trade data is available, provided that they are able to find funding to perform these updates.

Lack of availability of market data

Market data on (drop-in) bio-based chemicals, for which no statistical data is available - tend to be available only behind a paywall provided by commercial market research organisations. The publicly available study "*Insights into the European market for bio-based chemicals*" of Joint Research Centre (Spekreijse et al 2019)[10] is already six years old, and the current report provides additional and updated insights. Given that trade data on drop-in

[9] Indirect trade either means that products are transported through a third reporter (Chen et al. 2022) or when the product is traded and used for multiple markets, such as round wood used for material and its by-products used for energy (Junginger et al. 2019).

[10] Spekreijse, J., Lammens, T., Parisi, C., Ronzon, T. and Vis, M., Insights into the European market for bio-based chemicals, EUR 29581 EN, Publications Office of the European Union, Luxembourg, 2019, ISBN 978-92-76-01500-0, doi:10.2760/739561, JRC112989. https://publications.jrc.ec.europa.eu/repository/handle/JRC112989

bio-based products are difficult to obtain, and statistical data availability may remain limited in the coming decade, it is recommended to the EC and the JRC to carry out, or tender, at least biannually an expert study on the EU market of bio-based chemicals, resulting in a publicly accessible report.

Challenges to determine the level of certification of biological resources (large number of producers)
Scheme owners, supported by universities or consultancies do provide information on the level of certification of certain biological resources like wood, palm oil and sugar. The level of detail varies strongly between the products. It would be helpful if certification scheme owners would gather and publish more information on the volumes and origin of certified bio-based products. The Textile Exchange platform can serve as a good example. Certification scheme owners would require support and, moreover, this would require the support of certificate holders. Possibly a future joint effort could be made in the frame of a follow up project in cooperation with the joint platform of BiobasedCert.

Challenges and solutions to obtain level of certification of bio-based chemicals (limited number of producers)
For obtaining an indication on the level of certification of bio-based chemicals, data was acquired on production capacities and checking availability of sustainability certificates at company level. This is doable as long as the number of production companies is limited to, say, at most 20 players, which is the case for selected bio-based chemicals. Identification of the producers, their location and production capacities is time consuming, though. In some cases, no production capacities could be found. A weak point of this approach is that it is not known whether the full production capacity is met each year, and only part of the production may be certified. The website of the scheme owner only states that the company has a certificate, but not the volumes certified product. A way to improve the quality of data collection could be to organise a survey and ask producers how much certified product, and how much they produce in total. Especially in situations where only a small number of producers are in the market, it is highly uncertain whether producers will disclose amounts of produced volumes on a voluntary basis, as this is commercially sensitive information.

Database of certified bio-based products
A possible solution to increase the availability of data of certified bio-based products, is to apply the approach of the Union Database (UDB) for biofuels, or even to include bio-based products in the UDB. This database is operational since 21 November 2024 for biofuels that count towards the EU renewable transport targets. Renewable and low-carbon fuels that have a GHG reduction claim (70% compared to fossil reference) will eventually also be included in the Union Database[11]. Please note that, contrary to biofuels, currently no binding targets are set for bio-based products or chemicals, which could result in a low rate of (voluntary) participation. Reporting could become attractive if the production or use of the bio-based product would be associated with an incentive or would be used as a coregulation tool. If such incentives or coregulation tool would be introduced, the experiences with the current startup and operation of the UDB form relevant input for the design of a possible similar future system for bio-based products and chemicals.

Need for further research
In the coming years, further work such as performed in the HARMONITOR project will be needed, checking the level of sustainability, based on available literature and company data, building on the approaches for data collection as established in this report. It provides additional insight in the level of sustainability certification of bio-based chemicals, wood based-products and fibre-based products and summarising the state of play of

[11] See Directive (EU) 2024/1788 of the European Parliament and of the Council of 13 June 2024 on common rules for the internal markets for renewable gas, natural gas and hydrogen, Article 9 point 11.

biological resources. Moreover, such study could be broadened to cover a larger selection of bio-based products, and especially bio-based chemicals.

Given that trade data on drop-in bio-based products are difficult to obtain, and statistical data availability may remain limited in the coming decade, it is recommended to the European Commission or JRC to tender or carry out at least biannually an expert study on the EU market of bio-based chemicals, resulting in a free and publicly accessible report.