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REPORT

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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.

This deliverable describes the trade flows of the 35 bio-based value chains selected in Deliverable 3.1 'the Selection of Bio-Based Value Chains', with a specific focus on the further selection as performed in Deliverable 2.1 'Inventory and Characterisation of Identified CSLs and Selection of Bio-based Value Chains'. This includes an overview and description of the selected value chains, as well as production data of the associated biological resources and the trade flows at different steps in the value chain. Trade flows are given for the biological resources, both the dedicated and drop-in bio-based chemicals, as well as different fibre crops and textile products. For the wood-based value chains, value chain descriptions are given, and trade flow information will be given in the next deliverable. In the case of bio-based products for which no statistical data is available - this is the case for most drop-in bio-based products -, the total trade flows (fossil and bio-based) are given, as well as an assessment of bio-based production, in which the main producers were identified, as well as their production locations and capacities, if available. Using this bio-based production information, estimations on the bio-based production share were made, which were translated to estimations on the bio-based trade of drop-in products.

The trade flow information is shown at different steps of the value chain, giving a geographical indication of where different steps of the value chain occur and at what quantities. For example, for textiles, it can be seen that a lot of the textile processing occurs in countries outside of the EU. Even when fibre crops such as flax are primarily produced in Europe, the fibres are mostly exported to Asia and later return to Europe as a yarn, fabric, or finished textile article. We can deduce that a large share of the fibre-to-textile process occurs outside of Europe and using the trade flow data, the specific countries and, in some cases, the companies can be identified. This information can later be used for the assessment of sustainability certification.

However, the value chains of many bio-based products can be quite complicated. Various bio-based chemicals can be produced in several ways, using different biological resources. As such, the trade of the main categories of feedstocks of bio-based chemicals was studied, namely wood, sugar crops, starch crops and oil crops. Additionally, natural rubber, algae and straw were also included. The origin, destination, and trade quantities of these biological resources can give a better overview of the value chain of these bio-based chemicals.

The assessment focuses on the EU27, collecting both intra-EU and extra-EU trade data. The trade data includes both imports and exports of the different products from selected value chains, from, to and within the EU. The data was collected using Eurostat (Comext) and UN (Comtrade) databases and was summarized into a pivot table. In order to make the data more interactive, an online mapping tool was used that visualizes trade flows. As shown in Figure 1, 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.

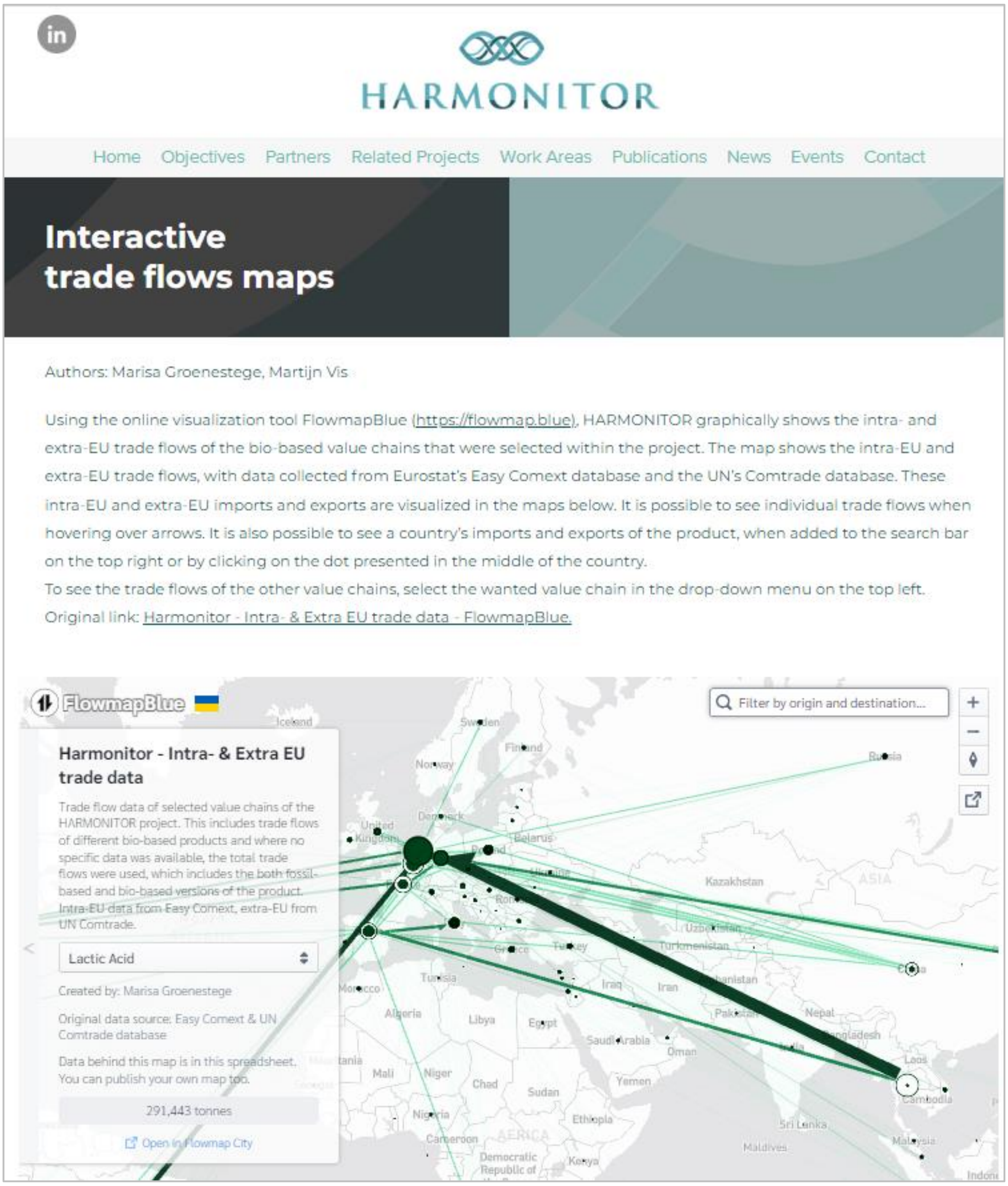

Figure 1, Flowmap tool on HARMONITOR website

A further assessment of the value chains and their final products will be included in the next deliverable (D3.3 'Trade flows of biological resources, bio-based materials and products'). For example, while we now have information on the production and trade of straw, the uses of straw, specifically as an insulation material will be studied, primarily using qualitative information. Information on trade flows of the selected wood-based value chains will be included as well.

Trade data on compost and biowaste was not included in D3.2 but will be included in D3.3. Since biowaste and compost were not selected in D2.1 as feedstock for further assessment of CSLs, the delayed assessment of biowaste and compost has no further consequences for the progress of the project.

In Deliverable 3.4 'Level of certification and labelling of biological resources, bio-based products and materials', the trade flow data will be used to help distinguish between certified and non-certified production. The initial assessment of level of certification and labelling of the selected value chains (Milestone 4) can be found in the Annex.

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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) 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. The project will collect data and figures on volumes of biological resources, bio-based materials and products in global trade flows and imports into (export from) the EU and their geographic distribution, distinguishing between certified and uncertified resources and materials/products. Earlier in the project, value chains from biomass to bio-based products or materials have been selected for further assessment.

1.2 Goal

The overall goal of Task 3.2 'Assessing trade flows of biological resources, bio-based materials and products' is to perform a mapping of the trade flows of the selected bio-based resources, materials, and products, providing insight into the current market size and trade flows of a broad spectrum of bio-based value chains. The production and trade data also form the basis for further assessment of the level of certification of different bio-based value chains as foreseen in Task 3.3 'Assessing level of certification and labelling of biological resources, bio-based materials and products'.

1.3 Scope

The scope of this deliverable is the statistical data of the selected value chains. This deliverable shows a mapping of the trade flows of both the dedicated and drop-in bio-based chemicals, their biological resources, as well as different fibre crops and textile products. For the chemically unique bio-based (drop-in) products, the total trade flows (fossil and bio-based) are given, as well as a further assessment of bio-based production and bio-based share. The assessment focuses on the EU27, collecting both intra-EU and extra-EU trade flows.

While this deliverable gives the production and trade data of the value chains, qualitative data explaining certain flows and giving information on final products is still minimal. In Deliverable 3.3 'Trade flows of biological resources, bio-based materials and products', this information will be given, as well as the statistical data for the wood-based value chains. Additionally, compost and biowaste will also be included in Deliverable 3.3. As biowaste and compost were not selected in D2.1 as a feedstock for further assessment of CSLs, the delayed assessment of biowaste and compost has no further consequences for the progress of the project.

1.4 Approach

A mapping of the trade flows of the selected dedicated bio-based products was performed and is presented in this report, primarily using existing and consolidated market databases (e.g., Eurostat, Comext, UN Comtrade).

For drop-in bio-based materials, the total trade volumes (fossil and bio-based) were taken from existing market databases.

Exact trade volumes of drop-in bio-based cannot be determined from statistics alone but were obtained from analysis of information on main production locations and markets of the bio-based materials and products (e.g., Spekreijse et al. 2019[1], Platt et al. (2021), databases (e.g. Knowledge for Policy Dashboard Bio-based Industry and market studies).

Next to this, the bio-based materials and products were also linked with biological resources through value chain descriptions. A mapping of the trade flows of biogenic feedstock was performed based on existing databases (e.g., Eurostat/Easy Comext, UN Comtrade). Where no statistical information was available, other sources will be used, primarily from sources that are regularly updated, from e.g., sector organisations.

On a regular basis, we have exchanged our ideas, approaches, and intermediary results with the two sister projects STAR4BBS and SUSTCERT4BIOBASED, especially with the colleagues from nova and Wageningen University, the partners doing the trade flow assessments within these projects. So far, four sister project meetings have taken place in which the selection of value chains and trade flows played a role (16 June 2022, 28 Oct 2022, 12 Nov 2022 and 18 July 2023). Moreover, BTG has provided input to a joint presentation on trade flows during a dedicated workshop with the three sister projects as part of the EUBCE conference in Bologna, in June 2023.

A more detailed methodology on the work performed for this report can be found in Chapter 2.

[1] https://publications.jrc.ec.europa.eu/repository/handle/JRC112989

2 Methodology

Within the HARMONITOR project, 35 value chains from biomass to bio-based products or materials have been selected for further assessment. See Deliverable 3.1 'the Selection of Bio-Based Value Chains'. This list has been further specified in Deliverable 2.1 'Inventory and Characterisation of Identified CSLs and Selection of Bio-based Value Chains', which describes common starting points for the analysis of value chains and CSLs. This report shows the preliminary assessment of the trade flows and imports of the selected value chains. This assessment includes the statistical data collection. Several choices were made towards the selection of statistical data. These are as follows:

- Statistical data is collected separately for the biogenic feedstock, the different intermediary chemicals/products and the outgoing chemicals/products.
- Data is collected and presented at least for one base year, namely 2021. Eurostat trade data on 2022 is at the time of writing (Autumn 2023) not expected to be complete yet.
- Data collection is focused on trade volumes (in tonnes) (using Combined Nomenclature to identify the products), and production volumes if available in Prodcom.
- The trade flows between the EU and non-EU countries/regions are shown.
- If available, the following data is collected.
  - Import to EU countries from EU countries;
  - Import to EU countries from non-EU countries;
  - Export from EU countries to EU countries (is often slightly and in some cases very different, even if volumes are used)
  - Export from EU countries to non-EU countries.
- The focus lies on obtaining a big-picture overview of the selected value chains. Therefore, no substantial effort will be put into explaining outliers, data gaps and omissions of trade between EU countries.
- Where no statistical information was available, other sources were used, primarily sources that are regularly updated, from e.g., sector organisations.
- In the future update of this deliverable (D3.3), the quality of information sources will be ranked with an uncertainty indicator. This methodology has been developed and used in two JRC studies executed by BTG (Spekreijse et al 2019, 2021).
- The resulting trade flows will show the production, market, import and export of the major global regions.
- Where available, a more detailed mapping of trade with and between EU Member States will be presented. The statistical information was checked on obvious errors; where possible data gaps in trade between EU and non-EU countries were identified and filled with data from FIGARO or commercially free available trade databases (e.g., Abrams Wiki).
- The data is presented in a comprehensive manner using tables, graphs, and highlighting the highest importing/exporting countries to obtain insights from the collected data.

2.1 Statistical data collection

The two main databases used for the statistical data collection are Comext, also known as Easy Comext and the UN Comtrade database. Comext is Eurostat's statistical database on the trade of goods and uses data from the EU Member States' national statistical administration. The United Nations Comtrade database uses trade data collected from approximately 200 countries[2]. The Comext database appears to be more complete when it comes to declarations of EU countries. As such, in order to get the most desirable data, Eurostat's Easy Comext database was used for intra-EU data, while the UN Comtrade database was used for extra-EU data.

As certain products are not included in the UN Comtrade database but are available in the Comext database, mirror data was used for certain value chains. This mirror data is derived from the declarations of the partner country. For example, for certain value chains, extra-EU imports were taken from EU Member States' declarations of extra-EU exports and vice versa.

Differences between import and export data between the declaring countries were observed. In general, imports are usually recorded with more accuracy as these generate tariff revenues, while exports do not. The quality of the data collection can also vary among countries[3]. Data from 2021 was used, as this is the most recent year with the full data available for all value chains.

In general, the import data appears to be more complete and as mentioned above, it is often more accurate due to the relevance of import data for countries to collect import tax revenues. As such, import data was used for the mapping of EU trade. For the mapping, the tool 'FlowmapBlue' was used, an online flow map visualization tool, which shows the quantity of trade of the selected value chains between countries. FlowmapBlue is free to be used in non-commercial projects.

Table 1 shows the CN code and official name of the chosen value chains, as well as the category, indicating in which sub-chapter it will be included. As mentioned before, for some value chains, the CN code was not included in the UN Comtrade database. Mirrored data from Comext was then used for extra-EU data.

[2] https://unstats.un.org/wiki/display/comtrade/EU+in+UN+Comtrade
[3] https://wits.worldbank.org/wits/wits/witshelp/content/data_retrieval/T/Intro/B2.Imports_Exports_and_Mirror.htm

Table 1, Full names, CN codes and categories of products analysed

Name	*Full name (with CN code)*	*CN Code*	*Category*
Sugar beet	**Sugar beet**	1212 91	Sugar crops
Sugar cane	**Sugar cane**	1212 93	Sugar crops
Beet sugar	**Beet sugar**	1701 12	Sugar crops
Cane sugar	**Cane sugar**, other cane sugar	1701 13 1701 14	Sugar crops
Cane or beet sugar	**Cane or beet sugar** and chemically pure sucrose, in solid form	1701	Sugar crops
Potatoes	**Potatoes** (excluding seed)	0701 90	Starch crops
Corn	**Corn**	1005	Starch crops
Potato starch	**Potato starch**	1108 13	Starch crops
Corn starch	Maize (**corn**) **starch**	1108 12	Starch crops
Palm nuts and kernels	Palm nuts and kernels	120710	Oil crops
Palm kernel oil	Crude **palm kernel** (& babassu) **oil**	151321	Oil crops
Palm oil	**Palm oil** and its fractions, whether or not refined, but not chemically modified	1511	Oil crops
Rape or colza seeds	**Rape or colza seeds**, whether or not broken	1205	Oil crops
Rape or colza oil	Low-erucic-acid **rape or colza oil** and its fractions	1514 11 1514 91 1514 99	Oil crops
Sunflower seeds	**Sunflower seeds**, whether or not broken	1206	Oil crops
Sunflower seed or safflower oil	**Sunflower-seed or safflower oil** and fractions thereof, crude oil	1512 11	Oil crops
Glycerol	**Glycerol**, crude; glycerol waters and glycerol lyes	1520	Oil crops
Biodiesel	**Biodiesel** and mixtures thereof, not containing or containing less than 70% by weight of petroleum oils or oils obtained from bituminous minerals	3826	Oil crops
Seaweed & Algae	Seaweeds and other algae fit for human consumption	1212 21	Other
Straw	**Cereal Straw**	1213	Other
Lactic acid	**Lactic acid**, its salts and esters	291811	Dedicated bio-based chemicals
Polylactic acid (PLA)	**Poly(lactic acid)**	390770	Dedicated bio-based chemicals
Palmitic acid	**Palmitic acid** and its salts and esters	29157040 (Mirror Comext)	Dedicated bio-based chemicals
Natural rubber	**Natural rubber** latex, Natural rubber in other forms	40010, 400121 400122 401129	Dedicated bio-based chemicals
1,4-butanediol	Butane-1,4-diol or tetramethylene glycol (**1,4-butanediol**) having a bio-based carbon content of 100% by mass	2905 3926 (Mirror Comext)	Drop-in chemicals
Ethylene	**Ethylene**	2901 21	Drop-in chemicals
Ethylene glycol	**Ethylene glycol** (ethanediol)	2905 31	Drop-in chemicals

Propylene glycol	**Propylene glycol** (propane-1,2-diol)	2905 32	Drop-in chemicals
Polyurethanes	**Polyurethanes**	3909 50	Drop-in chemicals
Epichlorohydrin	1-Chloro-2,3-epoxypropane (**epichlorohydrin**)	2910 30	Drop-in chemicals
Polypropylene	**Polypropylene**	3902 10	Drop-in chemicals
Flax	**Flax**, raw or processed but not spun, flax tow and waste (including yarn waste and garnetted stock)	5301	Fibre crops
Flax yarn	**Flax yarn**	5306	Fibre crops
Woven fabrics of flax	**Woven fabrics of flax**	5309	Fibre crops
Jute	**Jute** and other textile bast fibres (excluding flax, true hemp and ramie), raw or processed but not spun, tow and waste of these fibres (including yarn waste and garnetted stock)	5303	Fibre crops
Yarn of jute	**Yarn of jute** or other textile bast fibres	5307	Fibre crops
Woven fabrics of jute	**Woven fabrics of jute** or other textile bast fibres	5310	Fibre crops
Hemp	**True hemp** (Cannabis sativa L.), raw or processed but not spun; tow and waste of true hemp (including yarn waste and garnetted stock)	5302	Fibre crops
Hemp yarn	**True hemp yarn**	530820	Fibre crops
Cotton	**Cotton**, not carded or combed; Cotton, carded or combed	5201 5203	Fibre crops
Cotton yarn	**Cotton yarn** (other than sewing thread), containing 85% or more by weight of cotton, not put up for retail sale; Cotton yarn (other than sewing thread), not containing 85% or more by weight of cotton, not put up for retail sale;	5205 5206	Fibre crops
Woven fabrics of cotton	**Woven fabrics of cotton**, containing 85% or more by weight of cotton, weighing not more than 200g/m2; Woven fabrics of cotton, containing less than 85% by weight of cotton, weighing not more than 200g/m2; Woven fabrics of cotton, containing less than 85% by weight of cotton, weighing more than 200g/m2;	5208 5210 5211	Fibre crops
Finished textile articles	Carpets and other textile floor coverings; special woven fabrics, tufted textile fabrics, lace, tapestries, trimmings, embroidery; impregnated, coated, covered or laminated textile fabrics, textile articles of a kind suitable for industrial use; knitted or crocheted fabrics; articles of apparel and clothing accessories, knitted or crocheted; articles of apparel and clothing accessories, not knitted or crocheted; other made-up **textile articles**, sets, worn clothing and worn textile articles, rags.	57 58 59 60 61 62 63	Fibre crops

2.2 Statistical data collection of wood

Similar to the other selected value chains, statistical data for wood on intra-EU trade is to be collected from Comext and extra-EU trade from the UN Comtrade database for the year 2021. Trade data in both databases are subject to variations in data quality and discrepancies. Some of these are prominent in wood product trade including inconsistencies or errors in conversion in quantities and differences in methods in assessing trade data between reporting countries. The wood trade flows were compared with the overall wood balances of EU member states based on JRC wood resource balances and conversion factors (Cazzaniga et al 2021)[4]. The wood resource balances were updated to 2021 based on UNECE's Joint Forest Sector Questionnaire (JFSQ) data for 2021[5].

The compilation of data was based on commodity codes of the Harmonized System Nomenclature (HS) without the additional digits of the CN system (8-digit code). Table 2 shows the HS codes of the chosen value chains for wood products. More information on the statistical information will be given in the final report.

Table 2, HS code, type and data source of chosen value chains for wood.

Value chain and HS codes	*Type and products out*
4407 - Wood sawn or chipped lengthwise, sliced or peeled, whether or not planed, sanded or end-jointed, of a thickness exceeding 6 mm	Sawn wooden products (Several)
4411 - Fibreboard of wood or other ligneous materials, whether or not bonded with resins or other organic substances	Fibreboard (particle, MDF, etc) (MDF, Particleboard)
4410 - Particle board, oriented strand board (OSB) and similar board (for example, waferboard) of wood or other ligneous materials, whether or not agglomerated with resins or other organic binding substances.	Oriented strand board (OSB)
441510 - Cases, boxes, crates, drums and similar packings; cable-drums	Wooden packaging (Cases, boxes, drums)
441520 - Pallets, box pallets and other load boards; pallet collars	Wooden pallets (Pallets)
440500 - Wood wool; wood flour.	Wood wool, wood flour (Panels, fibre cement, insulation, filler)
380400 - Residual lyes from the manufacture of wood pulp, whether or not concentrated, desugared or chemically treated, including lignin sulphonates, but excluding tall oil of heading 38.03.	Lignin-based products (Binders and aromatic chemicals, asphalt/bitumen)
380300 - Tall oil, whether or not refined	Tall oil (Chemicals)
4802 - Uncoated paper and paperboard, of a kind used for writing, printing or other graphic purposes, and non-perforated punchcards and punch tape paper, in rolls or rectangular (including square) sheets, of any size, other than paper of heading 48.01 or 48.03; hand-made paper and paperboard.	Pulp (Graphic paper)
4804 - Uncoated kraft paper and paperboard, in rolls or sheets, other than that of heading No 4802 or 4803	Pulp (Paper board)
4818 - Toilet paper and similar paper, cellulose wadding or webs of cellulose fibres, of a kind used for household or sanitary purposes, in rolls of a width not exceeding 36 cm, or cut to size or shape; handkerchiefs, cleansing tissues, towels, tablecloths, serviettes, bed sheets and similar household, sanitary or hospital articles, articles of apparel and clothing accessories, of paper pulp, paper, cellulose wadding or webs of cellulose fibres	Pulp (Toilet paper)

[4] Cazzaniga N.E., Jasinevičius G., Jonsson R., Mubareka S. (2021). Wood Resource Balances of European Union and Member States - Release 2021. European Commission Joint Research Centre, Publications Office of the European Union, Luxembourg, JRC126552

[5] Available at: https://unece.org/forests/jfsq

2.3 Statistical analysis of trade flows

Using the combined data from Comext and the UN Comtrade databases, a dataset was created from the data of each country within the EU27. This data was then presented in the form of a pivot table, as shown in Figure 1. The pivot table gives the option to filter between products, import and export data, intra- and extra-EU trade, the Comext and Comtrade database and the CN codes.

Product	Sugar beet
Flow	Import
Intra-/Extra-EU trade	(All)
Source	(All)
Code	(All)

Quantity (tonnes) in 2021	Partner																									
Declarant	Austria	Belgium	Bulgaria	Croatia	Czechia	Denmark	France	Germany	Hungary	Ireland	Italy	Latvia	Lithuania	Luxembourg	Netherlands	Poland	Portugal	Romania	Slovakia	Slovenia	Spain	Sweden	Russian Federation	United Kingdom	Costa Rica	China	Grand Total
Austria								2	12,065						8				15,868								27,943
Belgium							8,991	751							4,134									1			13,877
Bulgaria								2																			2
Croatia									65,870											10,264							76,134
Czechia							9	120,069								60,287			124,705								305,071
Denmark								24					2,516		23,400	11											25,951
Estonia						1						400	153														553
France	637							89						1							434						1,161
Germany	402	48,068			1,053										181								1		1	4	49,709
Greece			6												7												13
Hungary	6,055																										6,055
Ireland																								47			47
Italy	269						163	4				14				62		13			56						580
Latvia													2,504														2,504
Lithuania												69,067															69,067
Netherlands	611	6,307					110	6,611	1			1												5			13,646
Poland								22																			22
Portugal															7						23						29
Romania								2																			2
Slovakia	218				788				670																		1,676
Slovenia	115			1,779	196				123																		2,213
Spain		11					84	49			7				6		18										174
Iceland																					1						1
Jamaica															200												200
Norway																						1					1
Saudi Arabia																					15						15
Senegal							2																				2
South Africa								21																			21
Switzerland							63	299,488																			299,551
United Kingdom						11		182		570		10,895			6,279	7					83						18,026
Grand Total	8,307	54,385	6	1,779	2,037	12	9,422	427,317	78,729	570	7	80,377	5,173	1	34,221	60,367	18	13	140,573	10,264	610	1	1	53	1	4	914,245

Figure 2, Pivot table with EU import data of sugar beets

In order to visualize the trade flows, the data was then entered into the 'FlowmapBlue' tool, which gives the following online interactive flow map: https://flowmap.blue/1VWZpdRU-Gk8kWX2NQEtnaq3UvDH3tqZjWErpI2AfEzg/d34f5c2.

This tool gives the possibility to filter between the different value chains (Figure 3), to see the individual trade flows between countries; and the total imports and exports of a specific country (Figure 4).

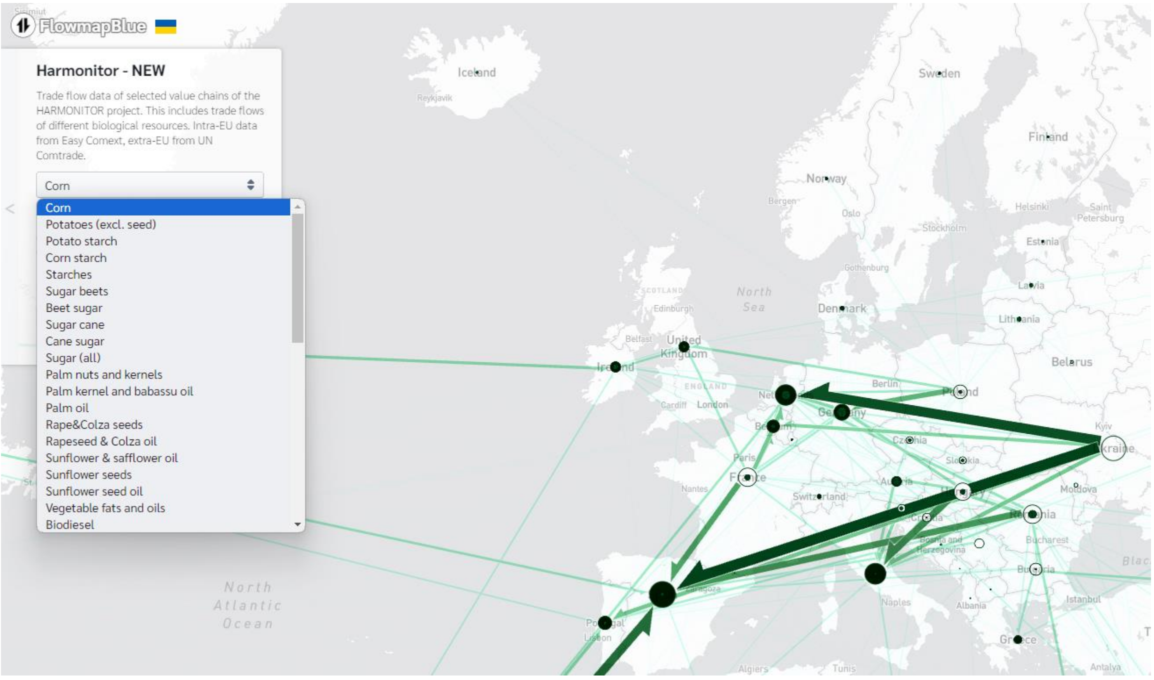

Figure 3, Interactive map of trade flows, showing the option of different value chains and visible individual trade flows.

Figure 4, 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.

3 Biological Resources

This chapter describes the biological resources used in the selected value chains. By giving information on the trade flows of the biological resources, at different steps in the chain, it is possible to see where processes occur and at what quantities the products are traded at different steps in the value chain. This chapter describes the main biological resources of the selected value chain, namely wood, sugar crops, starch crops, oil crops, straw and algae. These biological resources can be used to produce various bio-based chemicals and other bio-based products, which will be explained further in the next chapters. Additionally, the value chains and trade flows of textile products and their fibre crops were also analysed, which is included in Chapter 6.

3.1 Wood

Wood products are traded in multiple forms and steps in the value chain. It is traded as primary industrial roundwood, intermediate products (for example, sawn wood, pulp, wood chips and particles), and final products (for example paper, wood-based panels and sawn wood products). But to make these products, industrial roundwood passes through different forest industry subsectors, each playing a unique role in the overall production, and utilization of forest resources (Cazzaniga et al. 2021). And in each step of the value chain, forest products are traded. As an example, wood chips and particles are produced in sawmills as a by-product from sawnwood production from domestic and imported industrial roundwood. These wood chips and particles are used domestically or traded, amongst others for pulping and panel production (fibreboard, particle board). Furthermore, recycled products, such as recycled paper and recovered wood, are used to produce paper products and wood-based panels respectively. Tracing the origins of wood and quantification of indirect trade flows is complex[6], but it is important to consider that the trade of final products only represents a part of the forest product trade.

The trade flows of wood products in the present report are focused on direct trade flows of traded processed products derived from wood without considering the trade of roundwood or intermediate upstream in the value chain. Wood Resource Balance sheets of EU countries, developed by JRC, were updated to 2021 (see Section 2.2) and were used to provide insight into the different sources and uses of wood products in EU countries throughout the wood product value chains. A detailed analysis will be provided in the final report.

[6] See for example indirect trade of wood for bioenergy: Scarlat, N., Dallemand, J., Taylor, N. and Banja, M., Brief on biomass for energy in the European Union, Sanchez Lopez, J. and Avraamides, M. editor(s), Publications Office of the European Union, Luxembourg, 2019, ISBN 978-92-79-77235-1, doi:10.2760/546943, JRC109354.

3.2 Sugar

Sugar crops are one of the main feedstocks used in the production of bio-based chemicals. For the trade of biological resources, the two main sugar crops will be studied, namely sugar beets and sugar cane. Figure 5 shows the value chain of sugar crops studied in this sub-chapter.

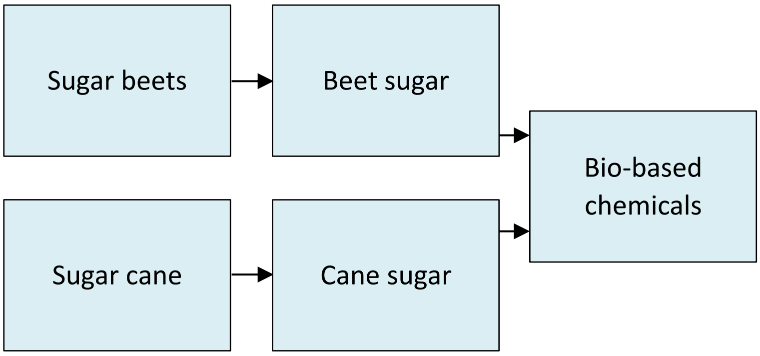

Figure 5, Sugar crops as a feedstock

The EU is the world's biggest producer of beet sugar, accounting for about half of global production. However, sugar from beets only accounts for 20% of global sugar production, as the majority of sugar is produced from sugar cane. Due to Europe's climate, sugar cane cannot be produced. However, the EU does import and refine raw cane sugar. The climate in Europe is more suitable for the production of sugar beets, which are primarily grown in the northern half of Europe[7].

[7] https://agriculture.ec.europa.eu/farming/crop-productions-and-plant-based-products/sugar_en

3.2.1 Sugar beets

The EU is a major producer of sugar beets. Over 1.4 million hectares in the EU are dedicated to the production of sugar beets. In the 2020/2021 campaign, the EU produced 14.2 million tonnes of beet sugar. As shown in Figure 6, the two largest producers are France and Germany, together producing about half of the EU's total amount of beet sugar.

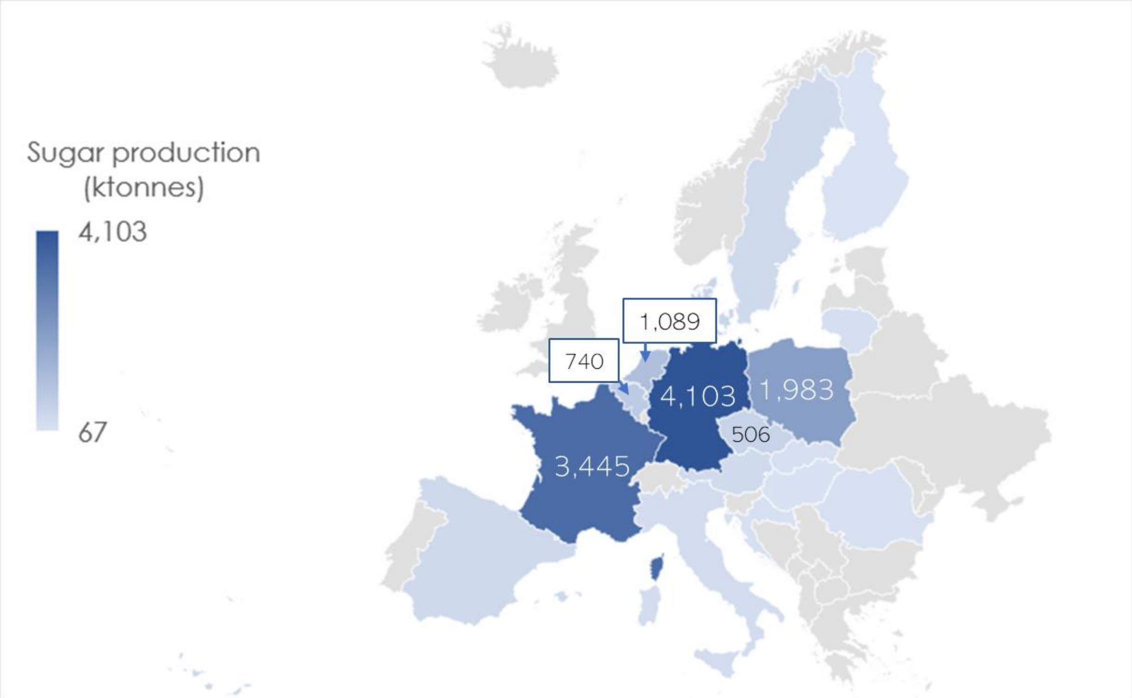

Figure 6, EU sugar production (in thousand tonnes) in the 2020/2021 season, data from the European Association of Sugar Manufacturers (2022)[8].

At the same time, there were 91 beet sugar factories operational across the EU. The largest number of factories are located in France (21), Germany (18), Poland (17) and the Czech Republic (7)[9]. As France and Germany are both large producers of sugar beets, and have a high number of factories, it can be assumed that the majority of beets are processed into sugar in the country of production.

[8] https://cefs.org/wp-content/uploads/2022/04/CEFS-Statistics-2020-2021.pdf
[9] https://cefs.org/wp-content/uploads/2022/04/CEFS-Statistics-2020-2021.pdf

Figure 7 shows the trade flows of sugar beets in the EU. In total, the EU traded a little under a million tonnes of sugar beets in 2021. Of this, the majority (596 kt) was traded within the EU and the other 318 thousand tonnes was exported to countries outside of the EU. The EU's biggest exporters of sugar beets are Germany (427 kt), Slovakia (141 kt), and Hungary (79 kt). The EU's biggest importers are the Czech Republic (305 kt), Croatia (76 kt), and Lithuania (69 kt); and outside of the EU Switzerland (300 kt).

A point of interest is the trade with the Czech Republic, which imports about 300 thousand tonnes from Germany, Slovakia and Poland. These imports could be explained by the fact that the Czech Republic has a relatively low production of sugar beets but has 7 sugar beet factories.

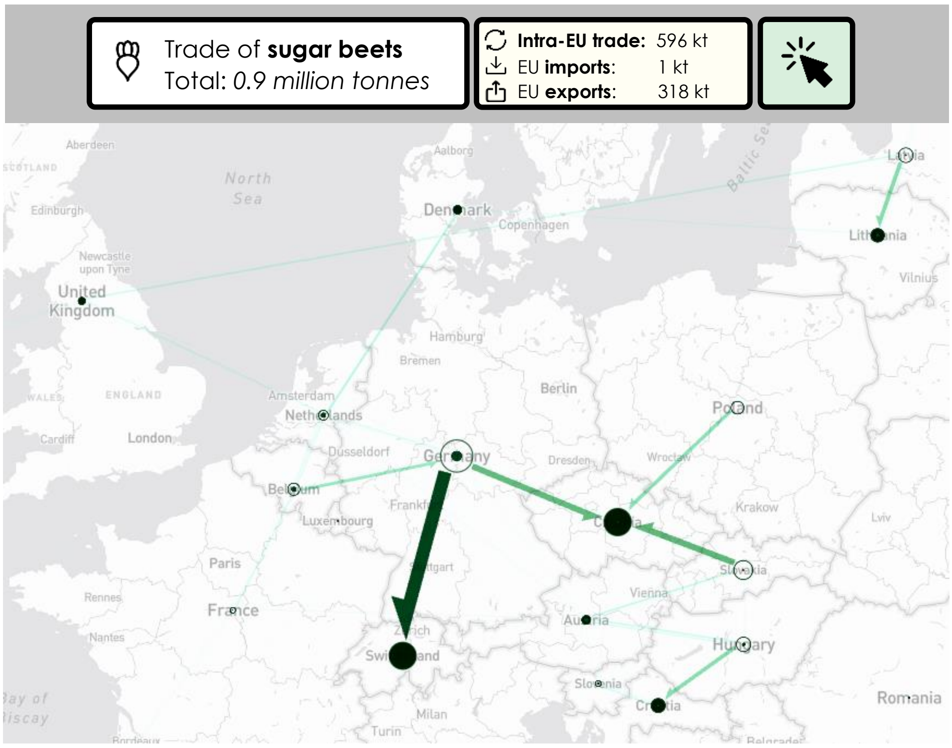

Figure 7, Trade of sugar beets

Figure 8 shows the EU trade of beet sugar. The total amount of beet sugar traded within and by the EU is relatively low, at 173 thousand tonnes in 2021. This could be due to the fact that most EU countries have their own production of sugar beets, albeit smaller than the production of France and Germany.

The EU's largest importers of beet sugar are Spain (24 kt), Italy (17 kt), and the Netherlands (14 kt). The EU's largest exporters are Austria (49 kt), France (33 kt), and Germany (22 kt). As we can see in Figure 6, production is lower in southern Europe, which could explain the export of beet sugar of France to Spain and Germany to Italy. Outside of the EU, the largest importer of EU beet sugar is Israel, which imported over 30 thousand tonnes of beet sugar from Austria. Israel is one of the world's largest importers of beet sugar[10].

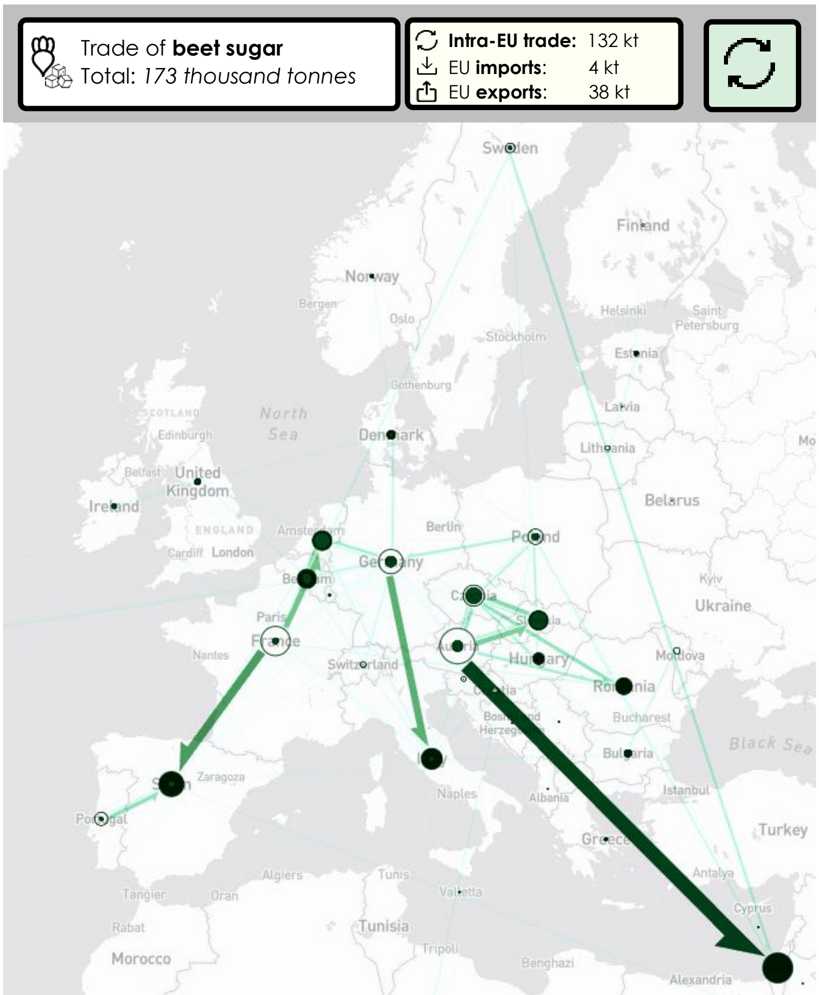

Figure 8, EU trade of beet sugar

[10] https://en.abrams.wiki/tools/marketintelligence?hscode=170112&tradeflow=import&from=2018-01&to=2018-12&overview=101100010

3.2.2 Sugar cane

Figure 9 shows the global production of sugar cane. The majority of sugar cane is produced in South America and Asia, with by far the biggest producer being Brazil, with an annual production of over 700 million tonnes, followed by India (405 Mt) and China (107 Mt)[11].

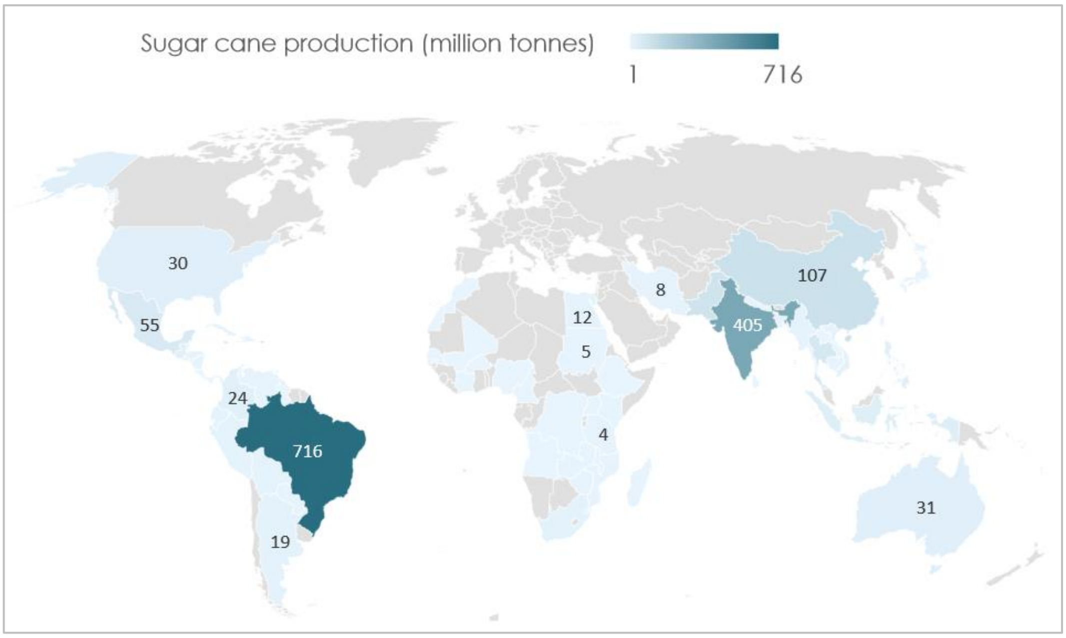

Figure 9, Global production of sugar cane in 2021, data from FAOSTAT[12].

As can be seen in Figure 10, the EU trade of sugar cane is relatively low (1391 tonnes). As the EU has to import sugar cane from quite far away (mostly Asia and South America), it makes sense that cane sugar is traded instead of sugar cane, as this would not be efficient logistically. The EU's largest importers of sugar cane are Belgium (244 t), the Netherlands (237 t), and Germany (164 t). The EU's largest exporters are Germany (281 t), Belgium (163 t), and Romania (50 t). The largest exporters to the EU are Egypt (183 t) and Vietnam (181 t).

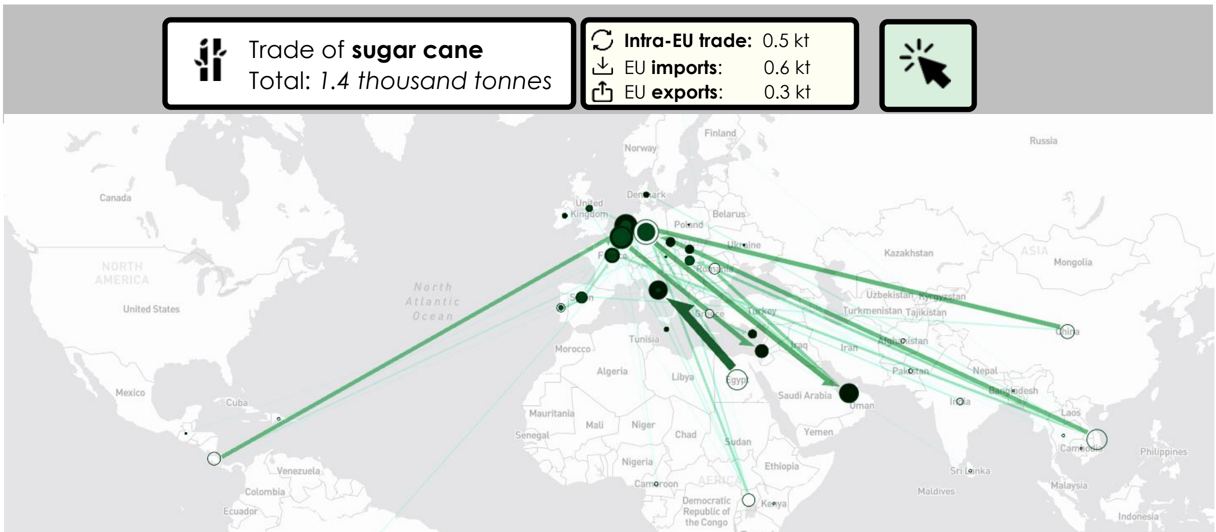

Figure 10, EU trade of sugar cane

[11] https://www.fao.org/faostat/en/#data/QCL
[12] https://www.fao.org/faostat/en/#data/QCL

Unsurprisingly, as can be seen in Figure 12, much larger amounts of cane sugar are traded to the EU. In 2021, the EU traded 2.4 million tonnes of cane sugar, of which 2 million tonnes were imported, primarily from Central and South America and Africa. The EU's main importers of cane sugar are Spain (741 kt), Italy (507 kt), and Portugal (375 kt). The EU's largest exporters of cane sugar are France (216 kt), Italy (69 kt) and Germany (30 kt). The world's largest producer of sugar cane, Brazil, is also the main exporter of cane sugar to the EU, with 576 thousand tonnes of cane sugar being exported to the EU. Other large exporters of cane sugar include South Africa (291 kt), Eswatini (215 kt), and Belize (223 kt).

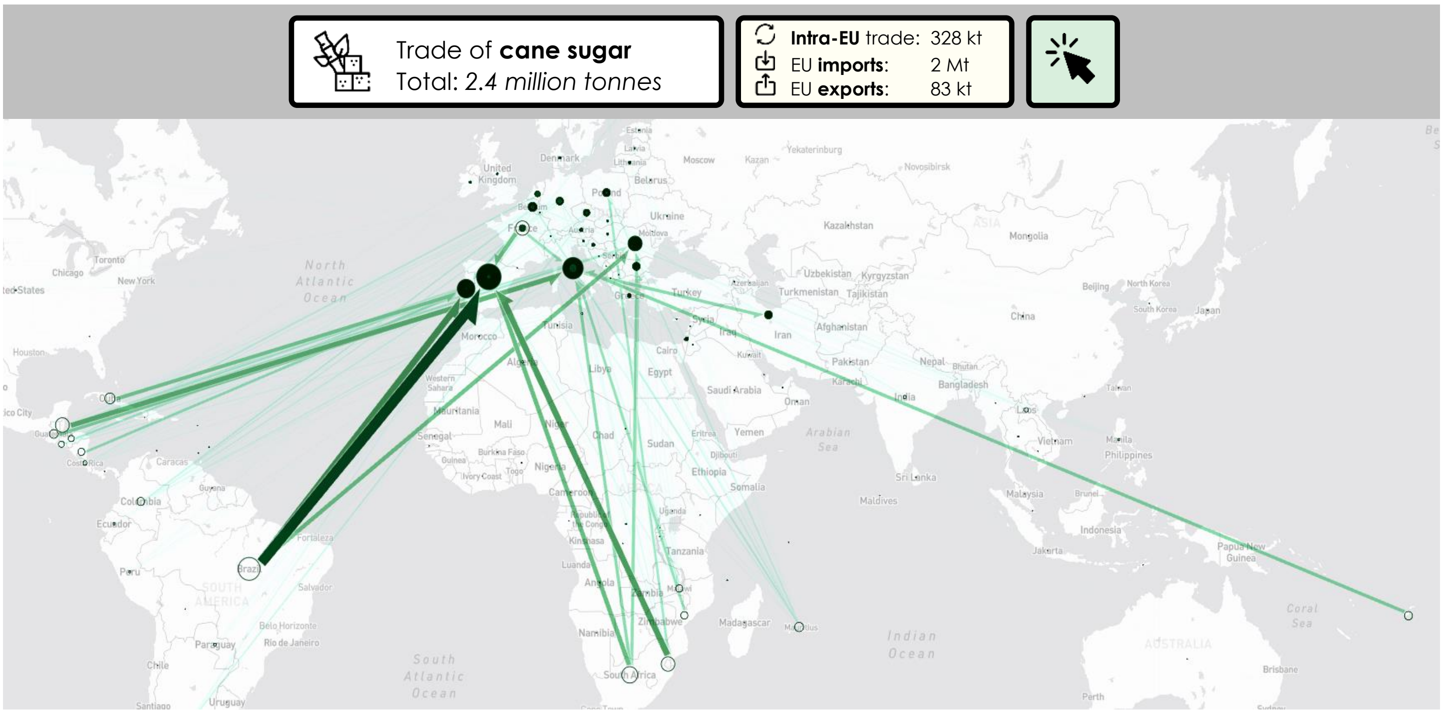

Figure 11, EU trade of cane sugar

Figure 13 shows the trade of all sugar, including beet sugar, cane sugar and chemically pure sugar. The EU traded over 8 million tonnes of sugar in 2021. Of this, 5.4 million tonnes were traded within the EU, almost 2 million were imported and almost a million were exported to countries outside of the EU. The EU's biggest importers of sugar are Italy (1.6 Mt), Spain (1.2 Mt) and Belgium (571 kt). The biggest EU exporters are France (1.7 Mt), Germany (1.7 Mt), and Poland (505 kt). The EU's main trading partners are Brazil, which exports 480 thousand tonnes of sugar to the EU, and Mauritius with 174 thousand tonnes of sugar exported to the EU. Not all trade of cane sugar appears to be included in this data set, as Brazil's exports of sugar to the EU are lower (480 kt) than in the dataset for solely cane sugar (576 kt).

Figure 13, EU trade of sugar (including beet sugar, cane sugar and chemically pure sucrose)

3.3 Starch crops

Starch crops are one of the main feedstocks used in the production of bio-based chemicals. For the trade of biological resources, the two main starch crops in the EU will be studied, namely potatoes and corn. The value chain of these starch crops, when used for bio-based chemicals is shown in Figure 14.

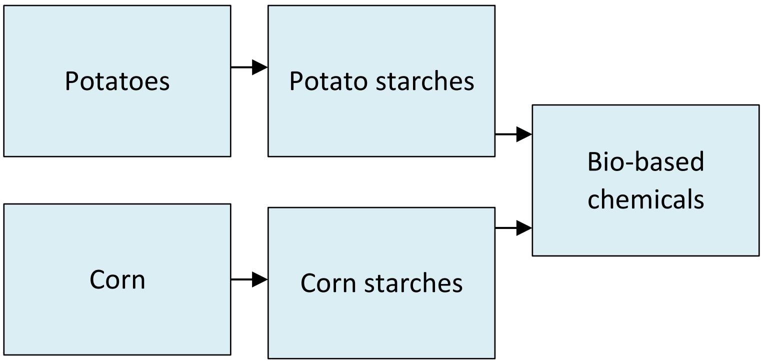

Figure 14, Starch crops as a feedstock

3.3.1 Potatoes

In 2021, the EU produced over 47 million tonnes of potatoes. As can be seen in Figure 15, the EU's largest producers of potatoes are Germany (11 Mt), France (8 MT), the Netherlands (7 Mt) and Poland (6 Mt).

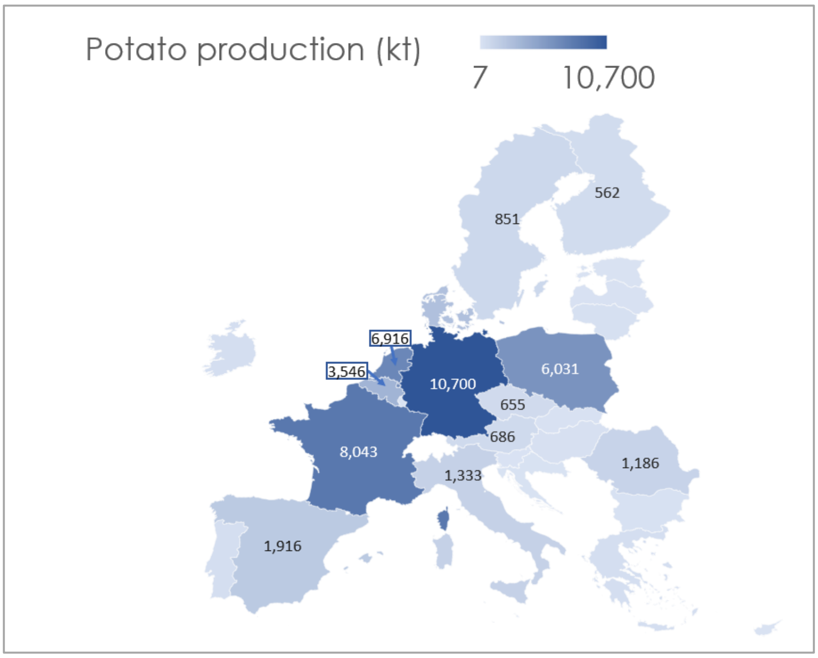

Figure 15, Production of potatoes (thousand tonnes harvested) per EU Member State. Data from Eurostat[13].

[13] https://ec.europa.eu/eurostat/databrowser/view/APRO_CPSH1__custom_7582897/default/table?lang=en

As can be seen in Figure 16, the main trade of potatoes (excluding seed potatoes), occurs between the Netherlands, Germany, Belgium, France and Spain. The biggest EU importer of potatoes is Belgium (2.9 Mt), followed by the Netherlands (1.8 Mt), while France is the biggest exporter (3 Mt), closely followed by Germany (2.7 Mt). The EU imported about 474 thousand tonnes of potatoes from countries outside of the EU, primarily from the United Kingdom, Israel and Egypt. The EU exported about 600 thousand tonnes to countries outside of the EU, with the largest extra-EU importer of potatoes being Ukraine.

Figure 16, EU trade of potatoes (excluding seed potatoes), data from Comext and UN Comtrade.

The EU also trades in the starch of potatoes, primarily exporting to North America and Asia. Of the 1.2 million tonnes of potato starch traded by the EU in 2021, about half a million was traded within Europe, while over 700 thousand tonnes of potato starch were exported to countries outside of the EU. The biggest exporters of potato starch are Germany (282 ktonnes), the Netherlands (276 ktonnes) and Denmark (259 ktonnes). Within Europe, the biggest importers are the Netherlands (151 ktonnes), Germany (90 ktonnes) and Belgium (88 ktonnes). Outside of Europe, the United States is the biggest importer (133 ktonnes), followed by South Korea (96 ktonnes), and China (78 ktonnes).

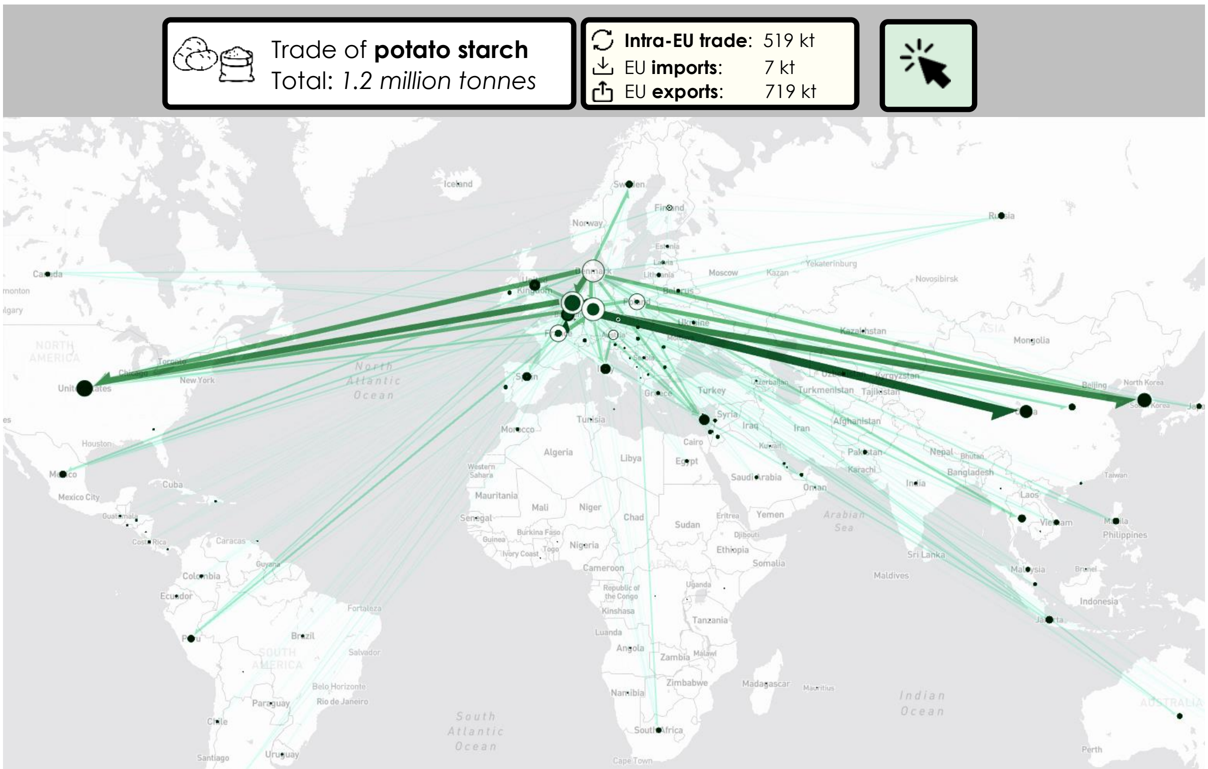

Figure 17, EU trade of potato starch

3.3.2 Corn

Another main starch crop is corn. About 73 million tonnes of corn were produced in the EU in 2021. The largest producers of corn in the EU are France (15.4 Mt) and Romania (14.8 Mt).

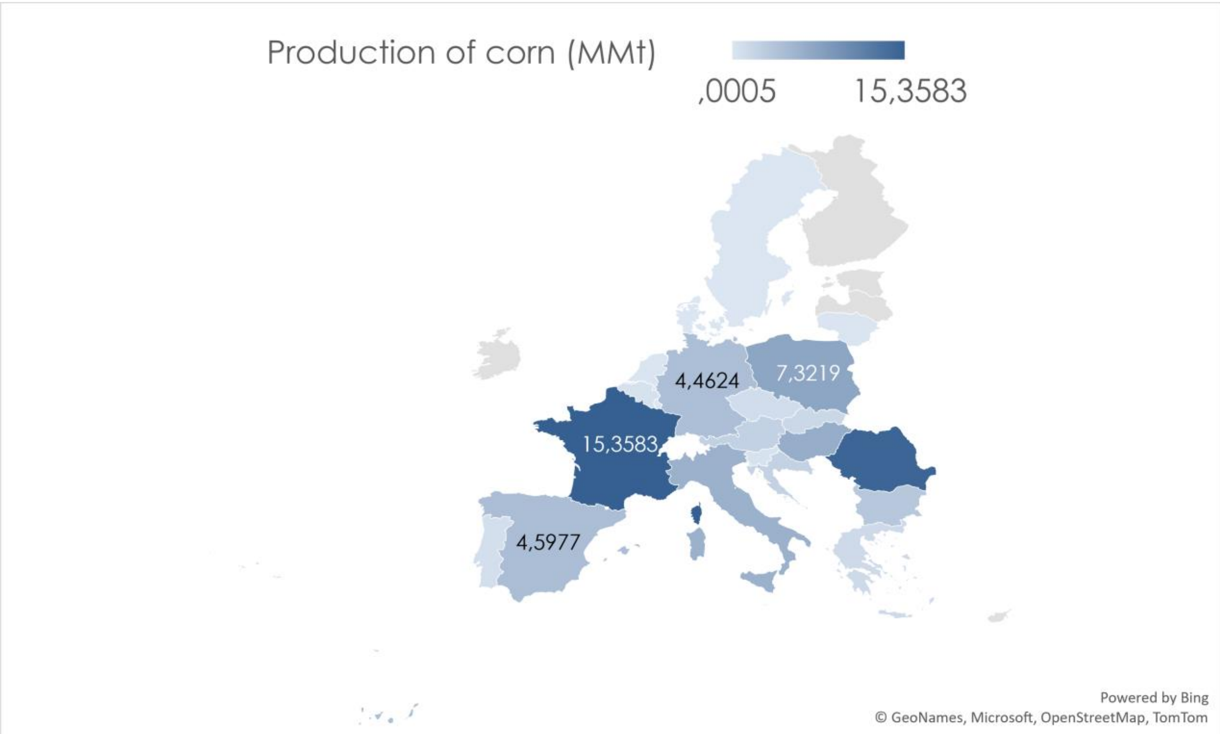

Figure 18, EU production of corn, data from Eurostat

The EU traded about 35.4 million tonnes of corn in 2021. Of this, 3.5 million tonnes are EU exports to non-EU countries, 13.7 million are EU imports from non-EU countries, and the remaining 18.6 million tonnes is corn that was traded within the EU. As can be seen in Figure 19, the EU's main trading partners are Ukraine, which exported over 7.4 million tonnes of corn to the EU, Brazil (3 Mt), and Canada (1 Mt).

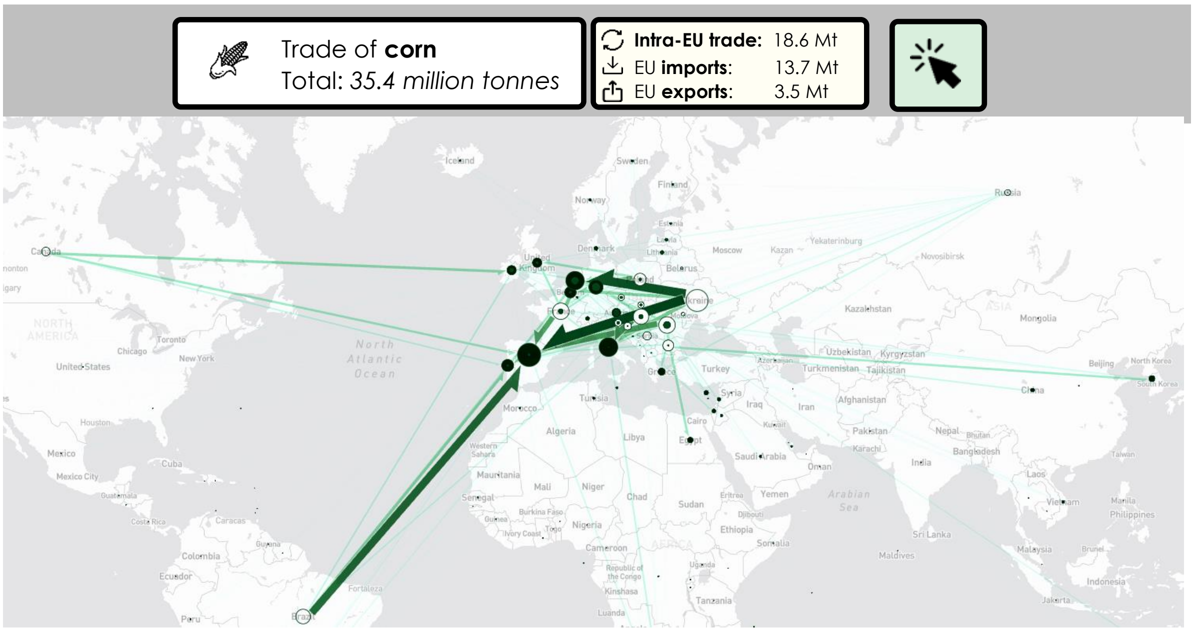

Figure 19, EU trade of corn

Figure 20 shows a zoomed-in version of the map of Figure 19. It shows that the main EU exporters of corn are Romania (4.1 Mt), France (4 Mt), Hungary (3.6 Mt) and Poland (2.2 Mt). The main EU importers are Spain (8.3 Mt), Italy (5.3 Mt), the Netherlands (5.1 Mt) and Germany (3 Mt). This corresponds with the production numbers of corn, as France and Germany are the largest EU producers of corn, as well as the largest exporters.

Figure 20, EU trade of corn, zoomed in on Europe

The EU has a total trade of corn starch of about 900 thousand tonnes, which is primarily traded within the EU. The biggest EU exporters of corn starch are Spain (147 kt), France (133 kt) and Germany (103 kt). The biggest EU importers are France (188 kt), Germany (161 kt) and Italy (62 kt). The biggest extra-EU trading partner of corn starch is the United Kingdom, which imported almost 80 thousand tonnes of corn starch from the EU in 2021.

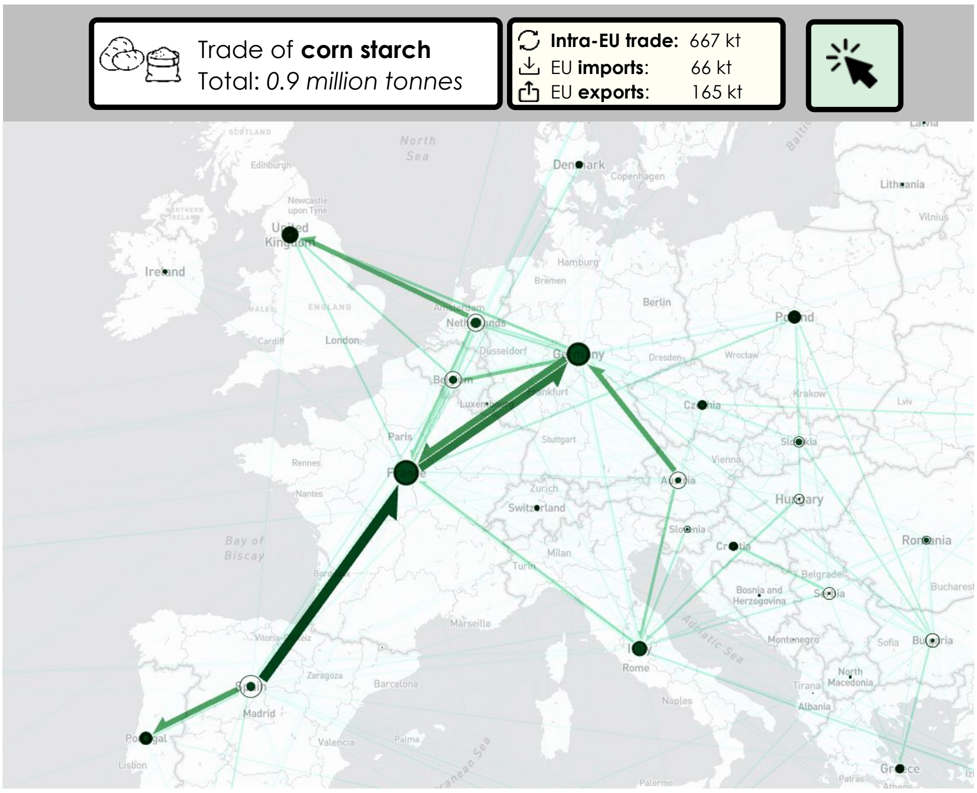

Figure 21, EU trade of corn starch

3.4 Oil crops

Oil crops are one of the main feedstocks used in the production of bio-based chemicals. For the trade of biological resources, three main oil crops used in the production of biodiesel will be studied, namely sunflower oil, rapeseed and colza oil, and palm oil. The value chain of these oil crops, when used for bio-based chemicals is shown in Figure 22.

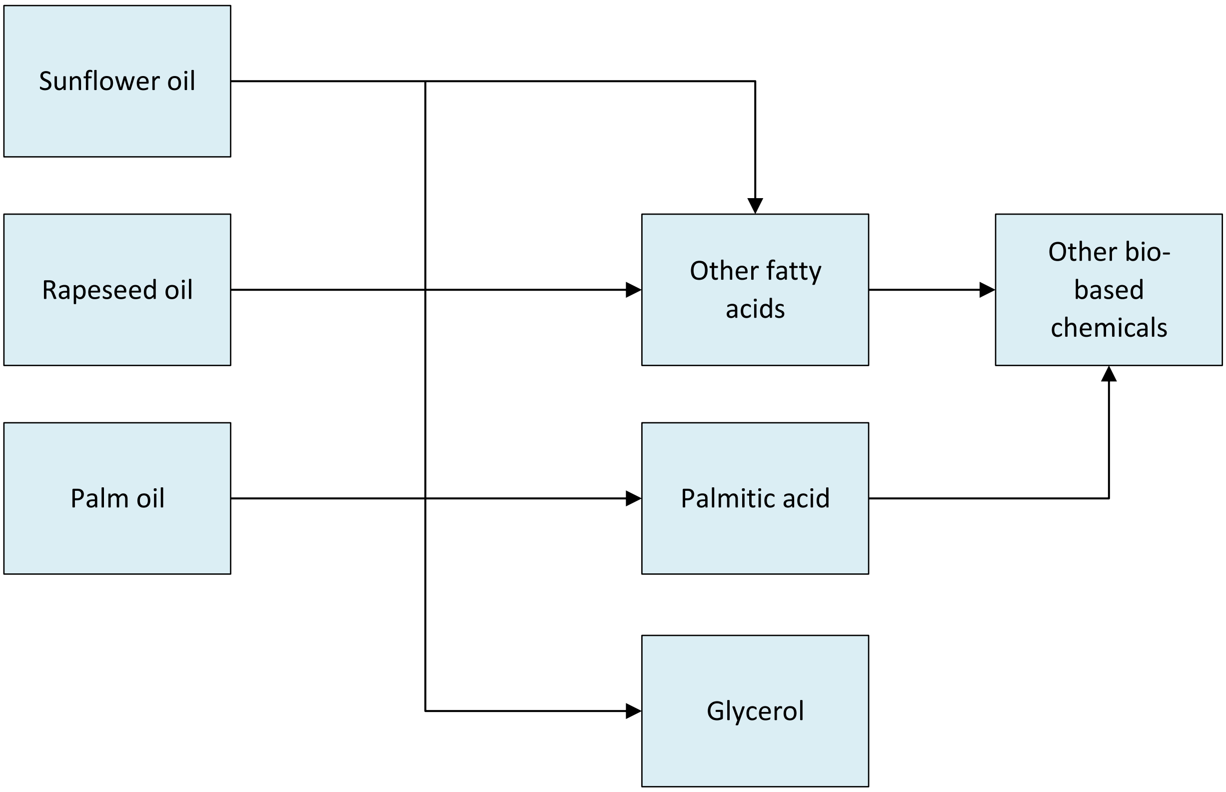

Figure 22, Value chain oil crops for chemicals

As shown in Figure 23, the EU's biggest producers of oilseeds are France (5.7 Mt), Romania (4.6 Mt) and Germany (3.7 Mt). These countries primarily produce rapeseed and sunflower seed, and in smaller quantities also soy.

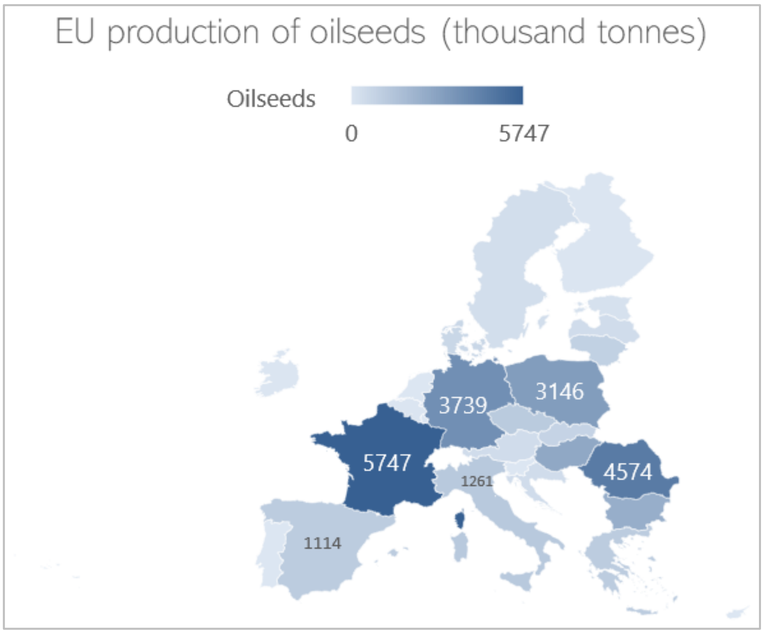

Figure 23, EU production of oilseeds, data from Eurostat[14]

3.4.1 Sunflower

Sunflower oil is produced from the seeds of the sunflower. The EU produced over 10 million tonnes of sunflower seeds in 2021. The EU's largest producers of sunflower seeds are Romania (2.8 Mt), Bulgaria (2 Mt), France (1.9 Mt) and Hungary (1.8 Mt). Outside the EU, major producers of sunflower seeds are Russia and Ukraine, which both produced more than 10 million tonnes of sunflower seeds in the same year[15].

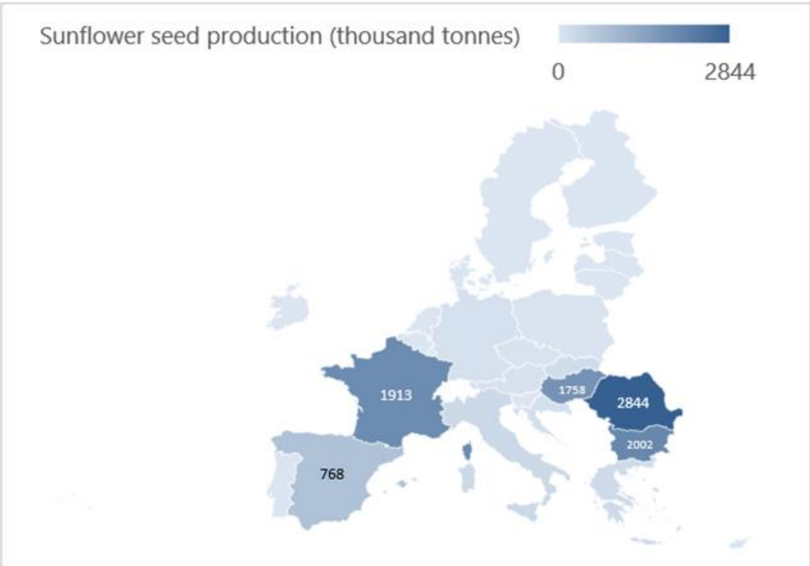

Figure 24, EU production of sunflower seeds (thousand tonnes), data from Eurostat[16]

[14] https://ec.europa.eu/eurostat/databrowser/view/APRO_CPSH1__custom_8535292/default/table?lang=en
[15] https://ourworldindata.org/grapher/sunflower-seed-production
[16] https://ec.europa.eu/eurostat/databrowser/view/APRO_CPSH1__custom_7582897/default/table?lang=en

An overview of the EU trade in sunflower seeds can be seen in Figure 25. In total, the EU traded about 4 million tonnes of sunflower seeds in 2021, which is mostly traded within the EU (3 Mt). The EU's largest exporters of sunflower seeds are Romania (1.4 Mt), Bulgaria (760 kt) and France (445 kt), while the largest importers are also Bulgaria (585 kt), as well as the Netherlands (484 kt) and Spain (356 kt). A major trading partner of sunflower seeds outside of the EU is Turkey, which imported about 350 thousand tonnes of sunflower seeds from the EU, mostly from Romania and Bulgaria.

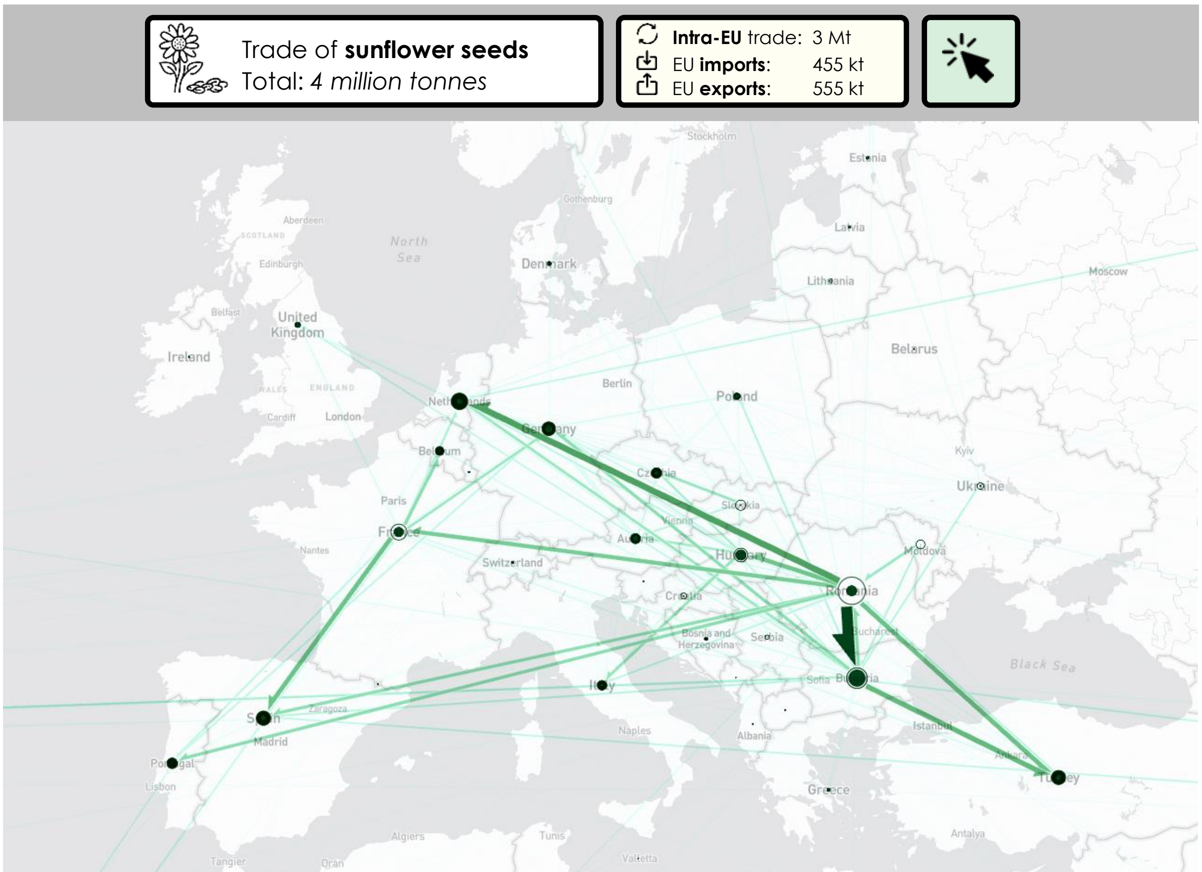

Figure 25, EU trade of sunflower seeds

Sunflower oil can be extracted from the sunflower seeds. Figure 26 shows the EU trade of sunflower and safflower oil. In 2021, the EU traded about 3.1 million tonnes of sunflower and safflower oil. Of this, 1.3 million tonnes were traded within the EU, 1.6 million tonnes were imported (primarily from Ukraine) and 281 thousand tonnes were exported to extra-EU countries.

The EU's largest trading partner for sunflower oil is Ukraine. In 2021, Ukraine produced over 4 million tonnes of sunflower oil, which is about a third of global production[17]. Ukraine exported about 1.4 million tonnes of sunflower and safflower oil to the EU in 2021, primarily to the Netherlands (491 kt), Spain (368 kt) and Italy (253 kt). Other major exporters are Bulgaria (353 kt) and Hungary (311 kt). The largest importers of sunflower and safflower oil in the EU overall are the Netherlands (596 kt), Spain (538 kt) and Italy (503 kt).

[17] https://www.fas.usda.gov/sites/default/files/2022-07/Ukraine-Factsheet-July2022.pdf

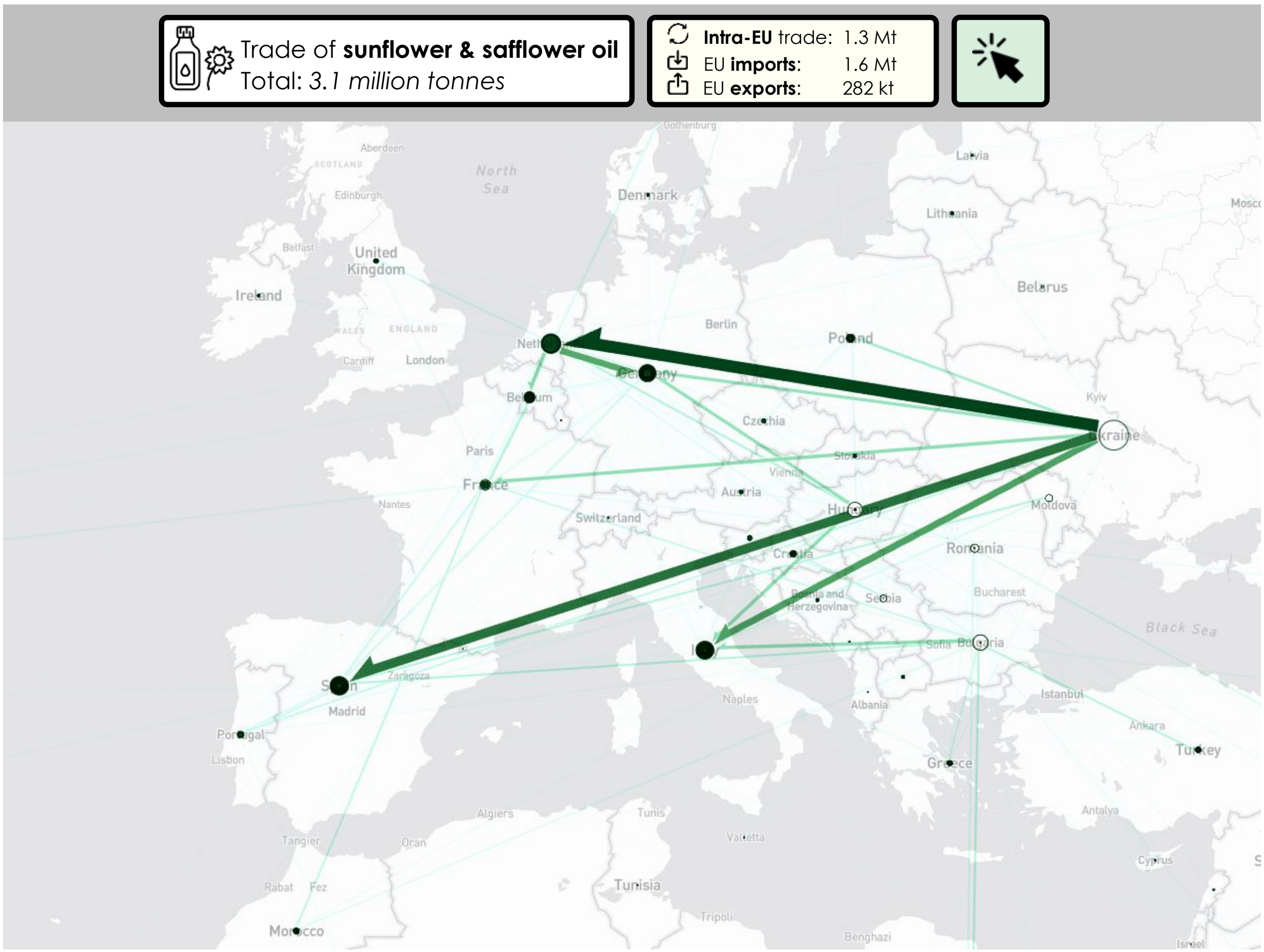

Figure 26, EU trade of sunflower and safflower oil

3.4.2 Rape and colza seeds

Rape and colza seeds originate from plants in the same family (Brassicaceae). However, colza (also known as canola) is the genetically modified version of the rapeseed plant[18]. The two terms are often used interchangeably as the differences between plants and oils are minor and are also often combined in trade data. In 2021, the EU produced almost 17 million tonnes of rape and colza seeds. The EU's biggest producers are Germany (3.5 Mt), France (3.3 Mt), and Poland (3.1 Mt).

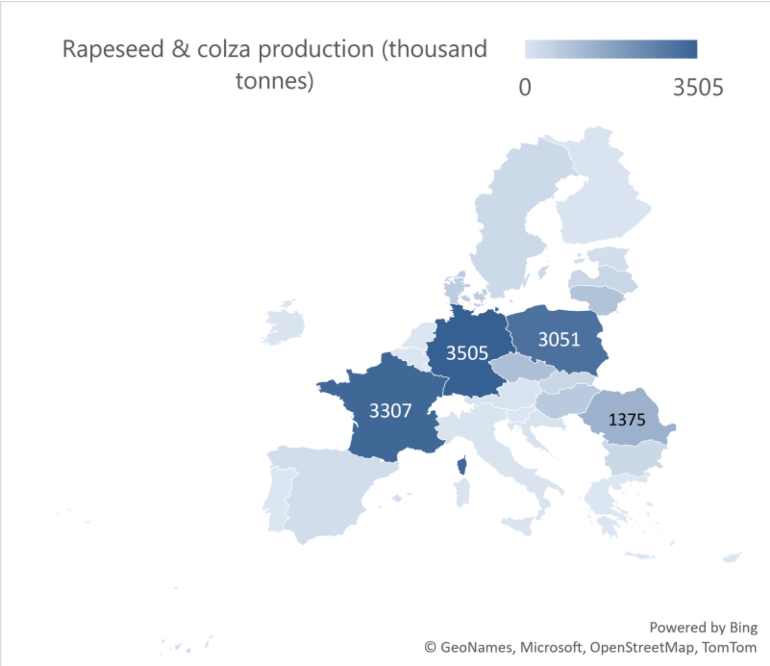

Figure 27, EU production of rape and colza seeds, data from Eurostat[19]

As can be seen in Figure 28, in 2021, the EU traded almost 14 million tonnes of rape and colza seeds. Of this, 7.8 million tonnes were traded within the EU, 5.6 million tonnes were imported from countries outside of the EU and almost half a million were exported to countries outside the EU. The EU's biggest importer is by far Germany (6.3 Mt), followed by France (1.7 Mt), Belgium (1.6 Mt) and the Netherlands (1.5 Mt). The EU mostly imports its rape and colza seeds from Australia (2.1 Mt), Ukraine (2 Mt), and Canada (1.1 Mt). Within the EU, the biggest exporters of rape and colza seeds are the Netherlands (1.9 Mt), France (1.3 Mt), and Belgium (0.7 Mt).

[18] https://www.thekitchn.com/whats-the-difference-between-canola-and-rapeseed-206047
[19] https://ec.europa.eu/eurostat/databrowser/view/APRO_CPSH1__custom_7582897/default/table?lang=en

Figure 27, EU trade of rape and colza seeds

In 2021, the EU traded about 2.5 million tonnes of rapeseed and colza oil, of which the majority (1.8 Mt) was traded within the EU. The EU imports 330 thousand tonnes and exports 379 thousand tonnes of rapeseed and colza oil. The largest EU importer is the Netherlands (634 kt), followed by Belgium (452 kt) and Germany (171 kt). The largest EU exporters are Germany (656 kt), France (521 kt) and the Netherlands (200 kt). The largest trading partner outside of the EU is China, which imports about 287 thousand tonnes of rapeseed and colza oil from the EU.

Figure 29, EU trade of rapeseed and colza oil

3.4.3 Palm

Figure 30 shows the value chain of palm products. Fresh Fruit Bunches of palm trees can be processed into crude palm oil or palm kernel oil. Crude palm oil is extracted from the fruit pulp of the oil palm, while palm kernel oil is extracted from the kernels. However, the market for palm oil is much larger than for palm kernel oil. Palm oil can be used to produce biodiesel and thereby glycerol, as well as palmitic acid and other bio-based chemicals.

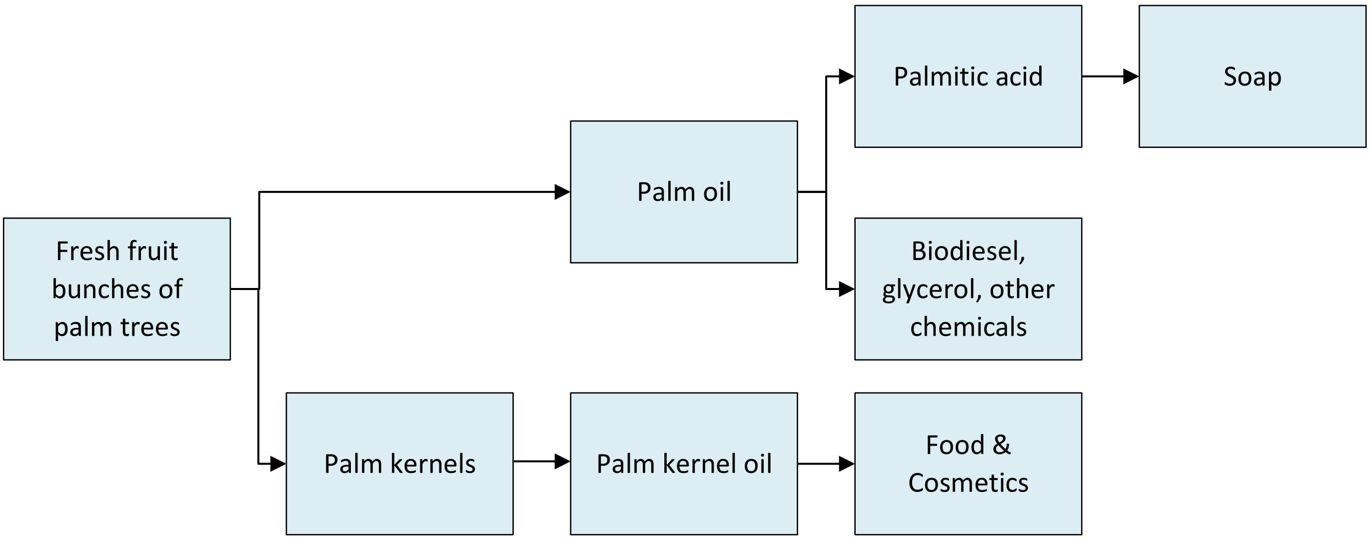

Figure 30, Value chain of palm products

Palm trees are native to tropical and subtropical climates. As such, the majority of palm trees can be found in Central and South America as well as Southern Asia. If we look at the production of palm oil (Figure 31), we can see that the largest producer of palm oil is Indonesia, with almost 45 million tonnes of palm oil being produced in 2020, followed by Malaysia, which had a production of over 19 million tonnes of palm oil in the same year. Other large producers are Thailand (3 Mt), Colombia (1.6 Mt), and Nigeria (1.3 Mt) [20].

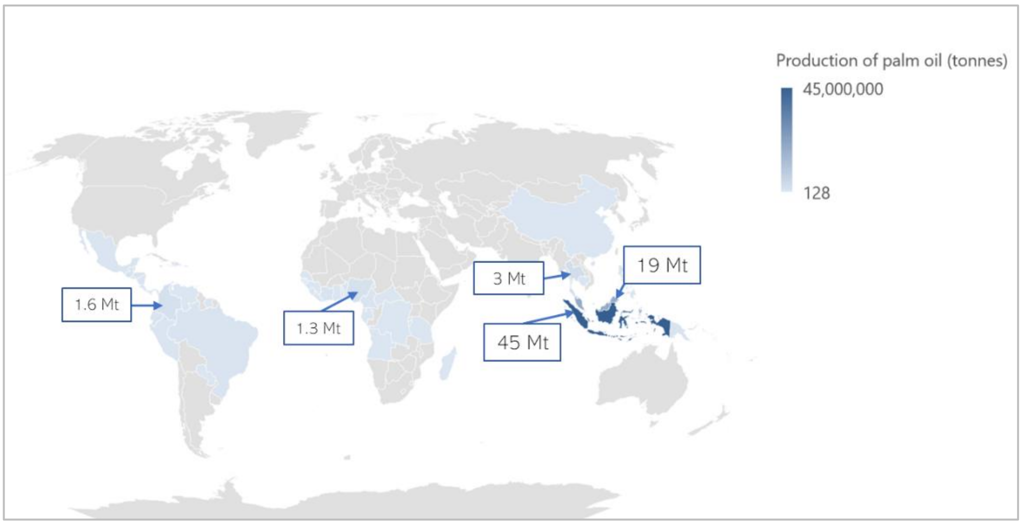

Figure 31, Global production of palm oil (tonnes) in 2020, data from Our World in Data[21].

[20] https://ourworldindata.org/palm-oil
[21] https://ourworldindata.org/palm-oil

There is relatively little trade of palm nuts and kernels. In total, the EU traded 7 thousand tonnes of palm nuts and kernels in 2021. Of this, 2 thousand tonnes were traded within the EU, primarily between France and Ireland as well as a few hundred tonnes between Greece and Italy. Another 5 thousand tonnes were exported outside of the EU, namely from Ireland to the UK.

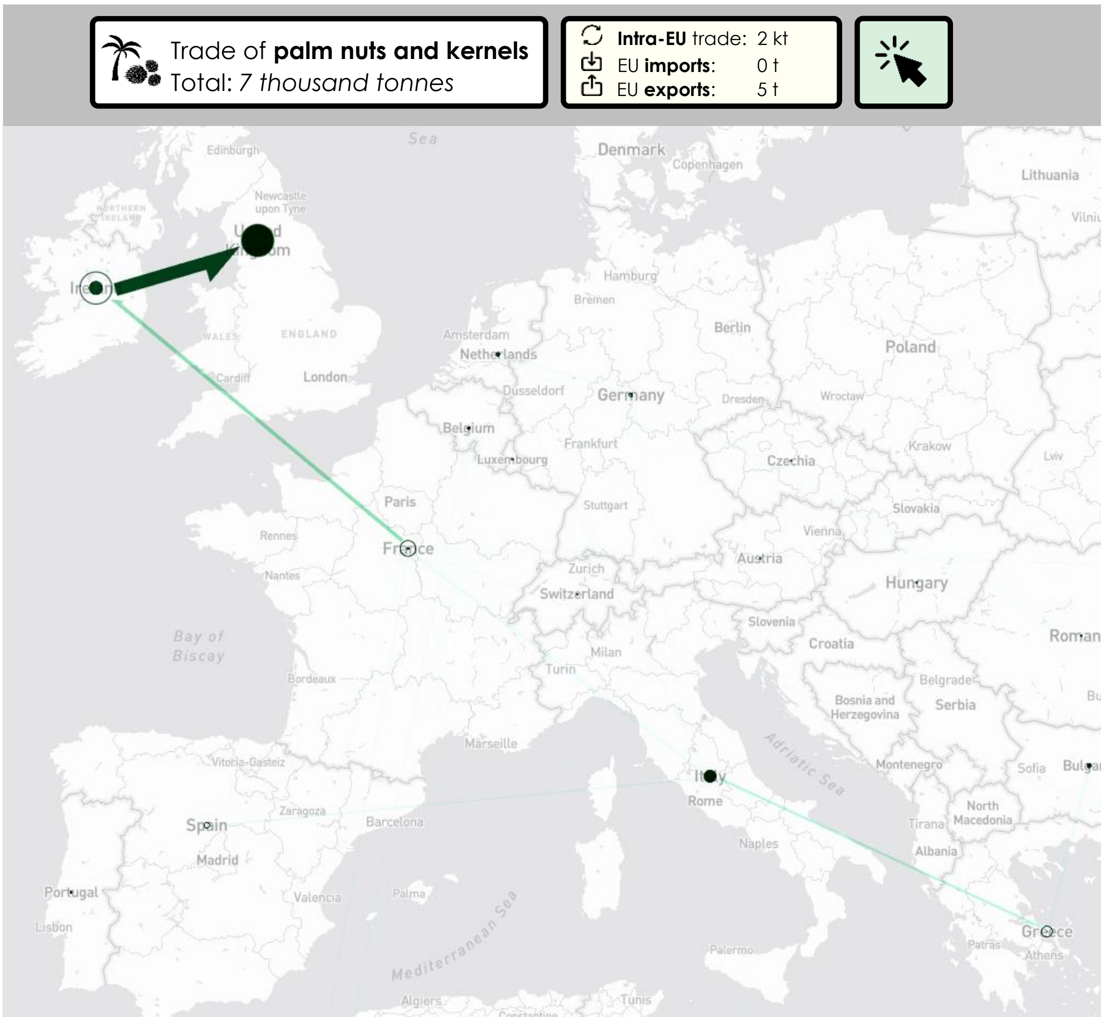

Figure 32, EU trade of palm kernels

Oil from palm kernels is traded in larger volumes. Figure 33 shows the EU trade of palm kernel oil, including bassasu oil, which is extracted from the bassasu palm tree. The EU traded about 700 thousand tonnes of palm kernel oil in 2021. Of this, the majority (over half a million tonnes) is imported, mostly from South East Asia and Central America. The largest exporter of palm kernel oil to the EU is Malaysia (300 kt), followed by Indonesia (56 kt) and Papua New Guinea (55 kt). The largest EU importers of palm kernel oil are Germany (251 kt), the Netherlands (207 kt) and Spain (47 kt). The EU's largest exporters are the Netherlands (48 kt), Germany (19 kt), and Italy (16 kt).

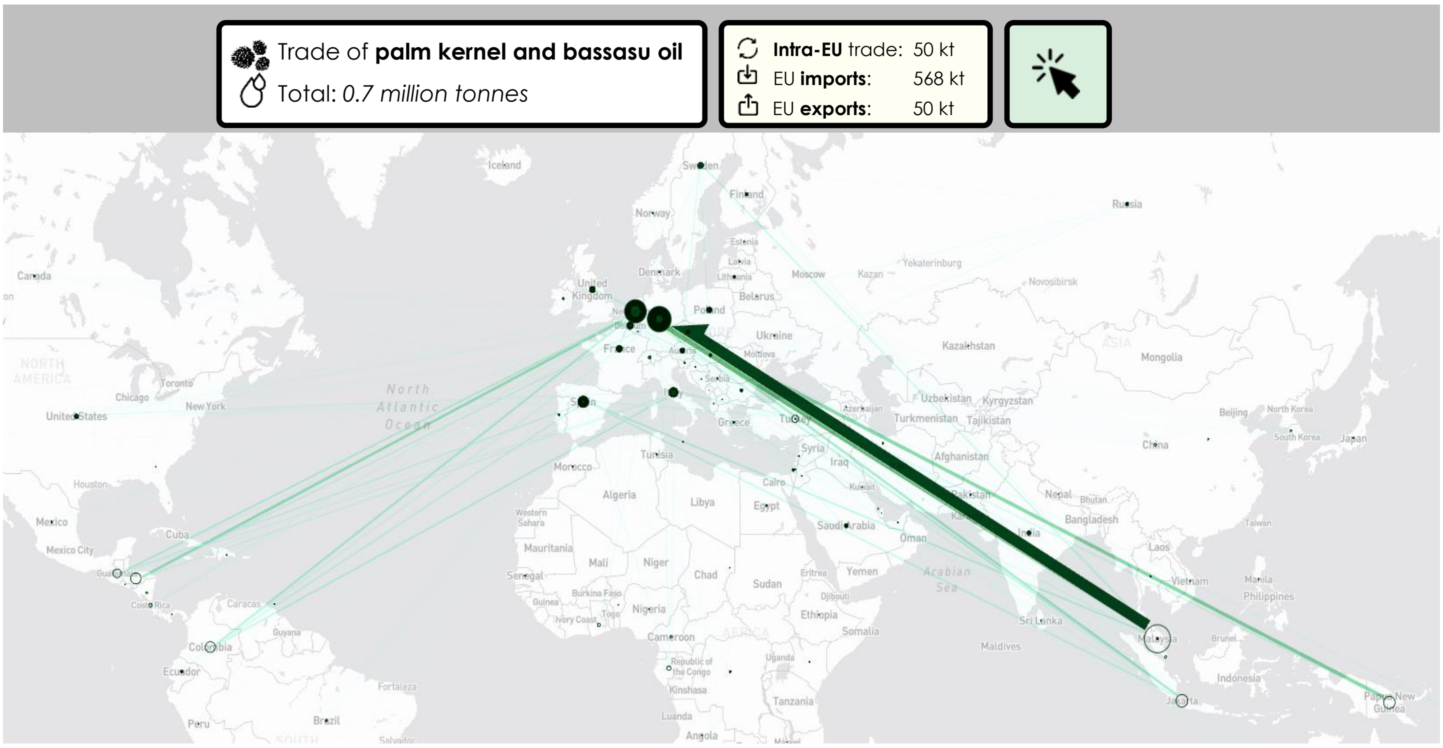

Figure 33, EU trade of palm kernel oil

In 2021, the EU imported about 6.1 million tonnes of palm oil. As can be seen in Figure 34, the EU primarily imports its palm oil from South-East Asia and Central America. The two largest exporters of palm oil to the EU are Indonesia, with over 2.7 million tonnes of palm oil exported to the EU in 2021, and Malaysia, with 1.6 million tonnes of palm oil exported to the EU. The biggest EU importers of palm oil are the Netherlands (2 Mt), Italy (1.5 Mt) and Spain (1.4 Mt). The majority of this palm oil remains in Italy and Spain, while the Netherlands re-exports almost 60% of this palm oil, mostly to other European countries.

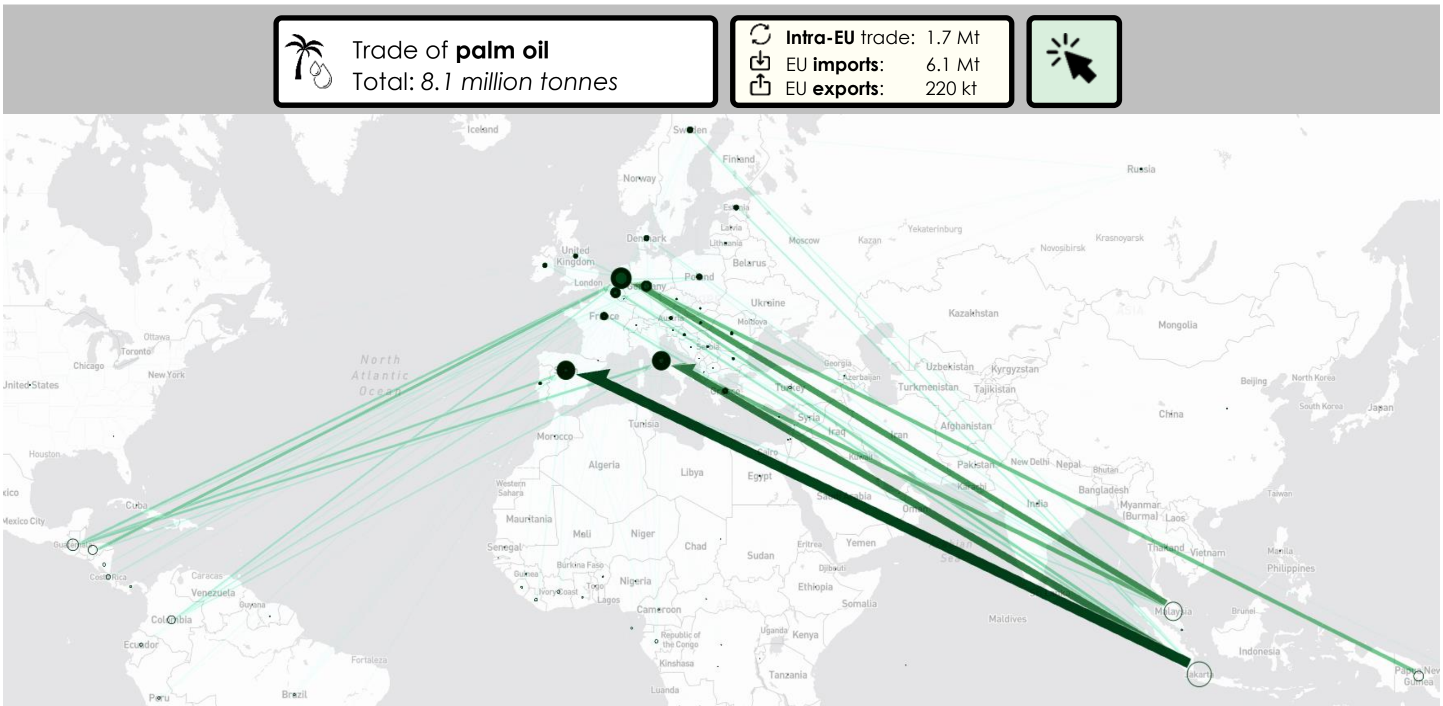

Figure 34, EU trade of palm oil

3.5 Natural rubber

Rubber can be produced from natural or synthetic rubber, 75% of the global production is synthetic.[22] In the following, the value chain of natural rubber, produced from liquid tree sap of the rubber tree (Hevea brasiliensis) is considered.

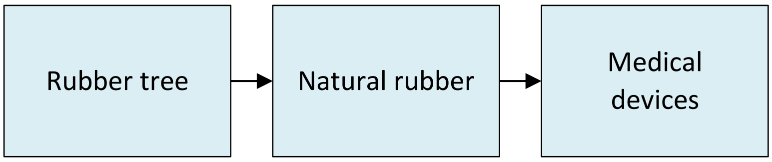

Figure 35, Natural rubber value chain

About 90% of the world's natural rubber production is occurring in Asia, primarily in Thailand, Indonesia, Vietnam and Malaysia[23]. This is also shown in Figure 36, which shows the amount of natural rubber produced per country in 2021. Globally, about 14 million tonnes of natural rubber is produced, of which over 12 million tonnes are produced in Asia. The two main producers are Thailand and Indonesia, which produce 4.64 million tonnes and 3.12 million tonnes respectively[24].

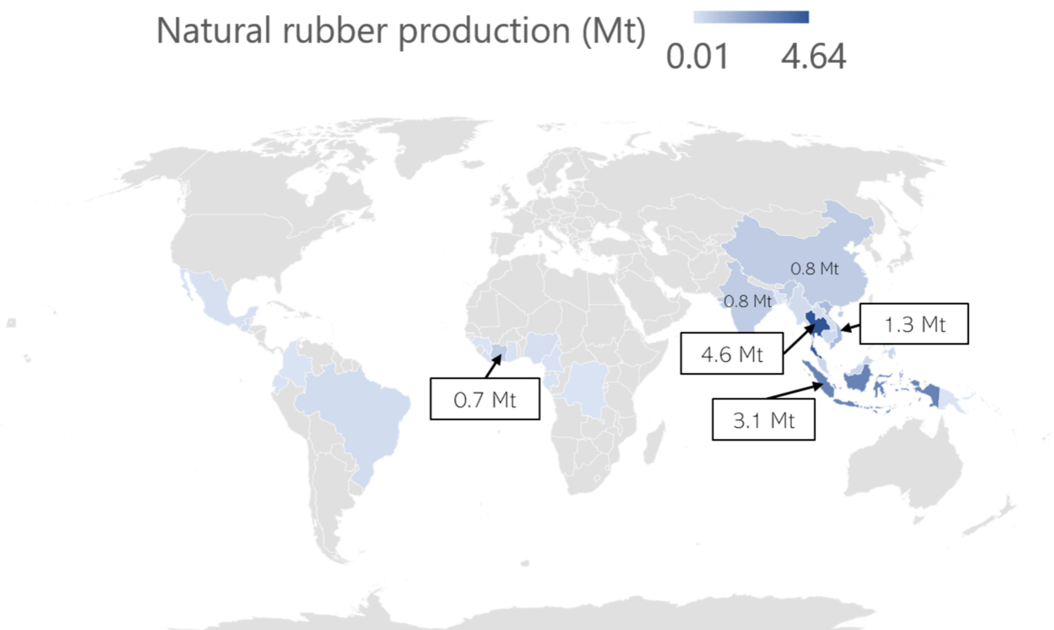

Figure 36, Production of natural rubber per country in 2021, data from World Population Review[24]

[22] Erca European rubber chemicals association, https://erca.cefic.org/how-is-rubber-made/, accessed 25th of August 2023.
[23] https://www.statista.com/statistics/275397/caoutchouc-production-in-leading-countries/
[24] https://worldpopulationreview.com/country-rankings/rubber-production-by-country

The EU traded 1.8 million tonnes of natural rubber in 2021, of which 424 thousand tonnes were traded within the EU. As was mentioned before, natural rubber is mostly grown in South-East Asia, which can also be seen in Figure 37. The EU imported 1.4 million tonnes of natural rubber in the same year, primarily from Asia and Turkey. The EU's largest trading partners for exports of natural rubber from Indonesia (346 kt), Turkey (344 kt), which does not grow natural rubber, but is also a major importer and re-exporter, and Thailand (292 kt). The EU's largest importers are Germany (354 kt), Spain (206 kt), and Luxembourg (156 kt). The EU's largest exporters are Belgium (170 kt), the Netherlands (64 kt) and Germany (57 kt).

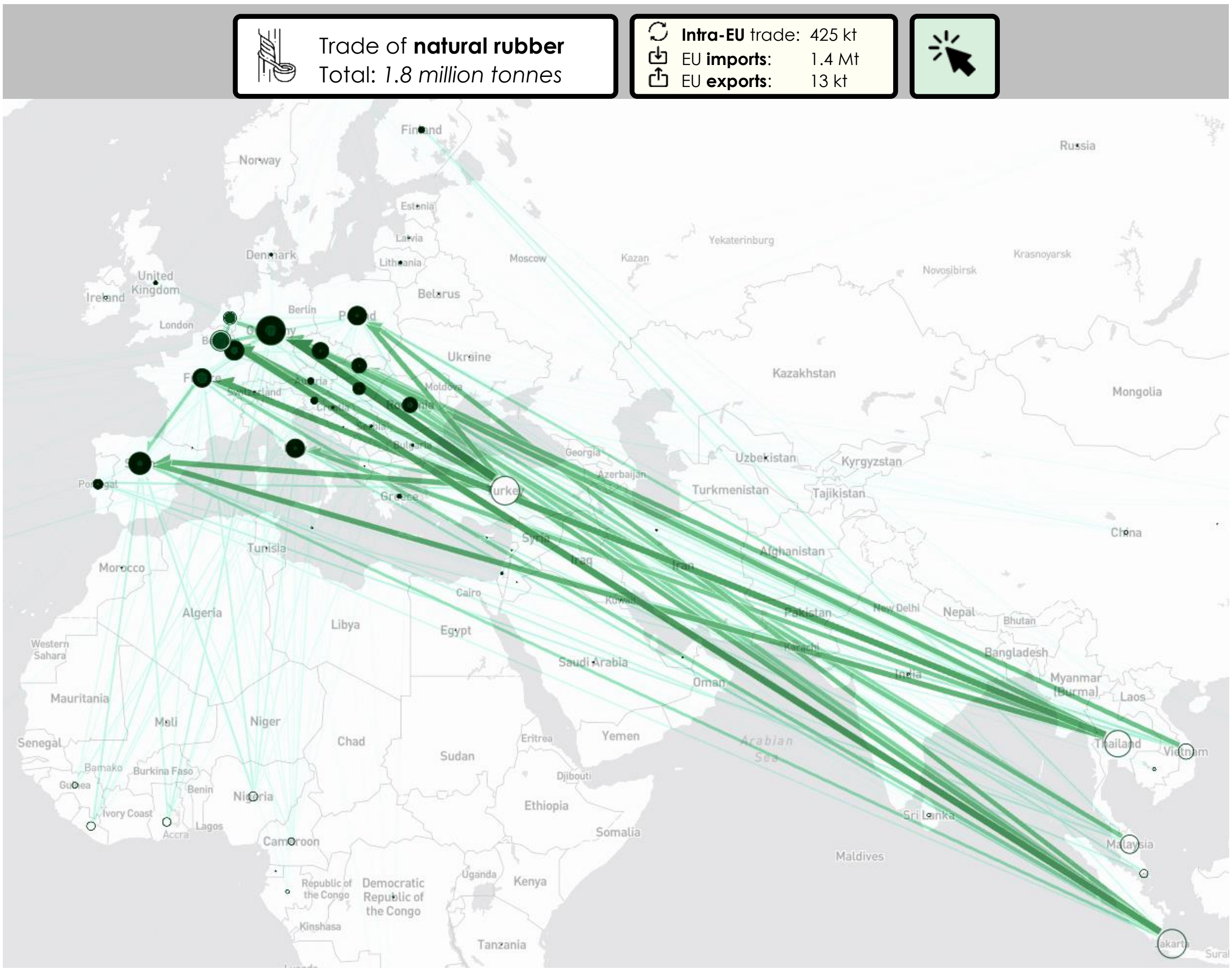

Figure 37, EU trade of natural rubber

3.6 Algae

Algae production in the EU totalled 287 390 tonnes in 2019, about 0.8% of global production. Of this, only a small share (0.12%) originates from microalgae, while the vast majority comes from macroalgae. Global algae production mostly occurs in Asia (97%), with over half occurring in China. Global microalgae biomass production was estimated to be around 56,456 tonnes in 2019, of which 0.63% was produced in Europe. The largest producers of macroalgae in the EU are France, Ireland, and Spain; while this is Spain, Germany, France and Italy for microalgae production[25].

The total trade of seaweed and other algae fit for human consumption is shown in Figure 38. The EU traded 8 thousand tonnes of seaweed and algae in 2021, of which 5.5 thousand tonnes were traded within the EU, 2 thousand tonnes were imported, mostly from Asia, and half a tonne was exported to countries outside of the EU. The EU's main importers are Germany (1.5 kt), Spain (1 kt), and Austria (0.8 kt). The largest EU exporters are the Netherlands (1.2 kt), Germany (1.1 kt), and Ireland (1 kt). The EU's main trading partner outside of the EU is China, which exported 1.1 thousand tonnes of seaweed and algae to the EU.

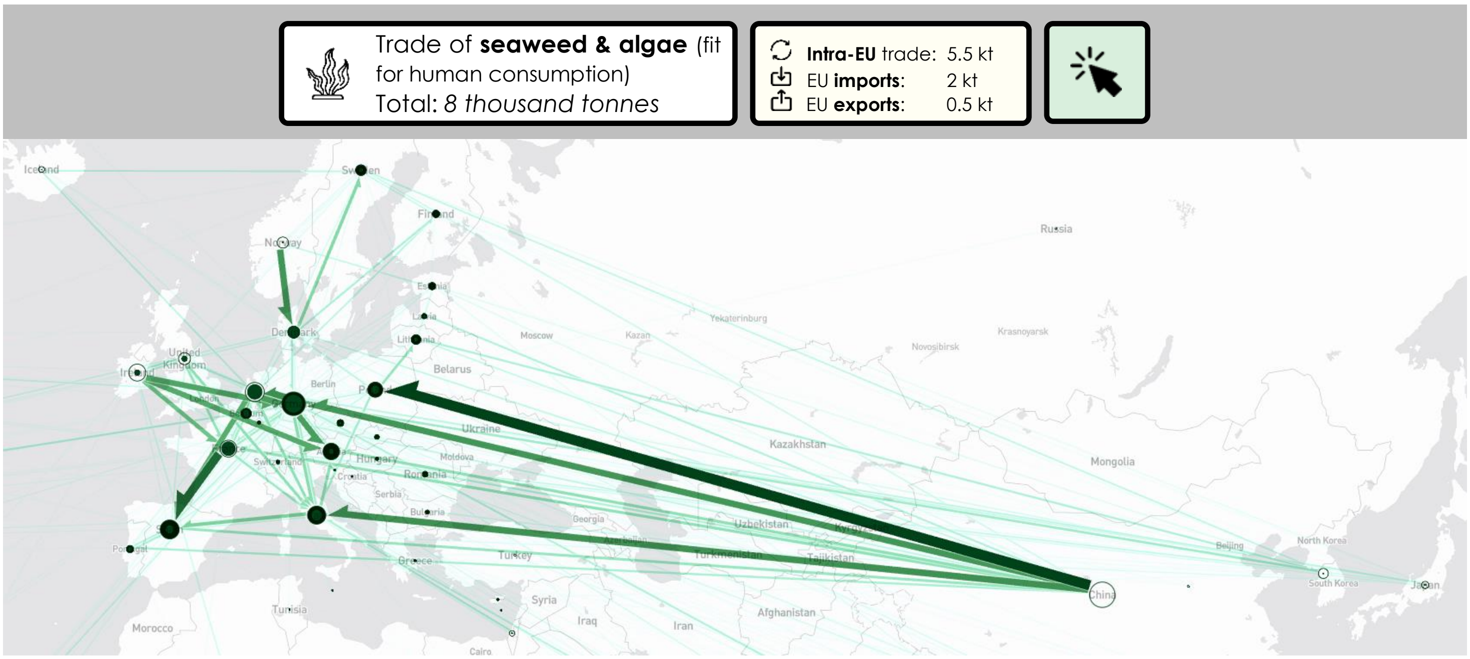

Figure 38, EU trade of seaweed and other algae

While most macroalgae production is based in the North Atlantic, microalgae production is mostly land-based and occurs in photobioreactors (71%), ponds (19%) and fermenters (10%). Microalgae can be used for various applications, including food supplements, nutraceuticals, cosmetics and feed[26].

Microalgae can be used to produce omega-3 fatty acids, such as eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). These fatty acids are commonly produced from fish oils but can also be produced from microalgae species such as nannochlorpsis, phaeodactulum, nitzschia, schizochrytium and cryptocodinium[27].

[25] https://www.europarl.europa.eu/RegData/etudes/STUD/2023/733114/IPOL_STU(2023)733114_EN.pdf
[26] https://www.europarl.europa.eu/RegData/etudes/STUD/2023/733114/IPOL_STU(2023)733114_EN.pdf
[27] https://www.sciencedirect.com/science/article/pii/S2211926421003830

3.7 Straw

In 2021, the EU produced almost 300 million tonnes of cereals for the production of grain. As can be seen in Figure 39, the largest producers of these cereals are France, which had a production of almost 67 million tonnes, and Germany with a production of 42 million tonnes. The most commonly produced cereals are wheat and spelt, of which 130 million tonnes were produced in 2021 in the EU, followed by grain maize (73 Mt), barley (52 Mt), oats (7.5 Mt) and rye (8.4 Mt).

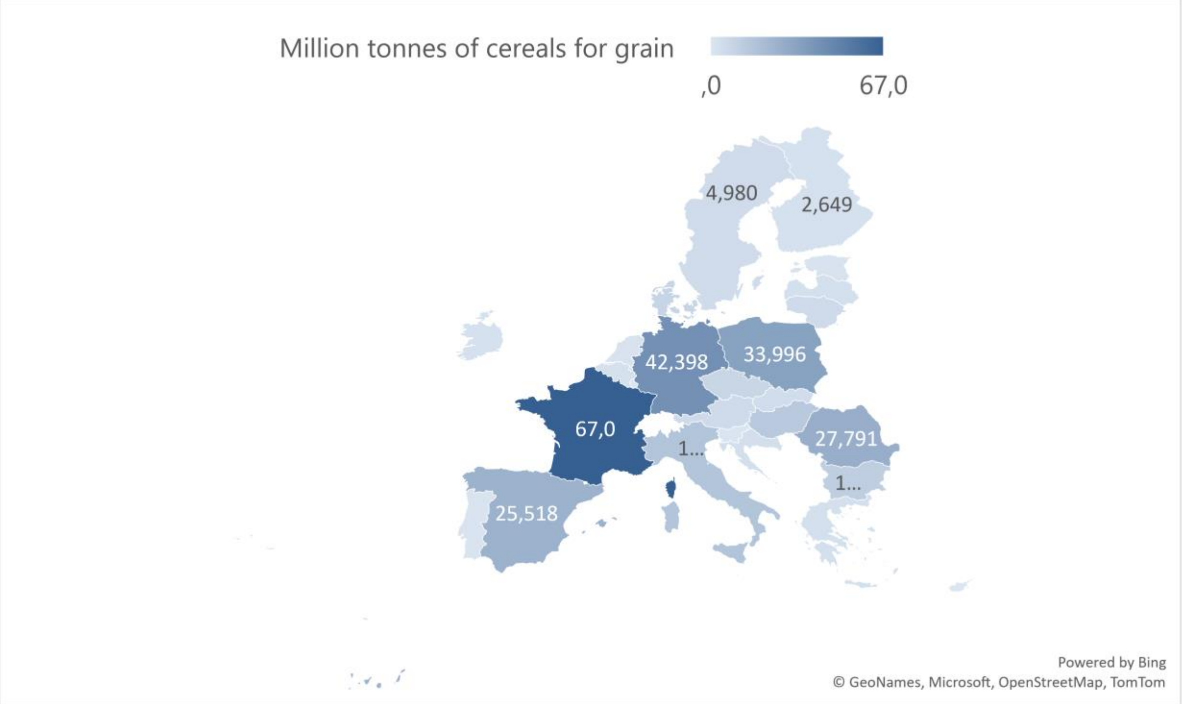

Figure 39, EU production of cereals for grain production, data from Eurostat

Straw is an agricultural by-product from cereal grasses such as wheat, oats and rye. Straw, the dry stalk from these cereals, is seen as a by-product and is mostly used for animal bedding and feed but can also be used for various bio-based applications, such as insulation materials[28].

In 2021, the EU traded about 2.3 million tonnes of cereal straw. As can be seen in Figure 40, a large share of this (1.4 million tonnes) was traded within the EU, with the majority of trade happening between the Netherlands, Germany, and France. The EU imported a little over 10 thousand tonnes in 2021 and exported over 830 thousand tonnes of cereal straw in the same year. The two largest trading partners outside of the EU are Saudi Arabia, which imported about 244 thousand tonnes of cereal straw, mostly from Spain, and Switzerland, which imported over 400 thousand tonnes of cereal straw, mostly from Germany and France. Within the EU, the largest importer is by far the Netherlands (630 kt), followed by Portugal (173 kt) and Germany (153 kt). The largest EU exporters of cereal straw are Spain (717 kt), France (536 kt) and Germany (367 kt).

[28] https://wawheat.org/growing-for-the-future/what-is-wheat-straw-used-for

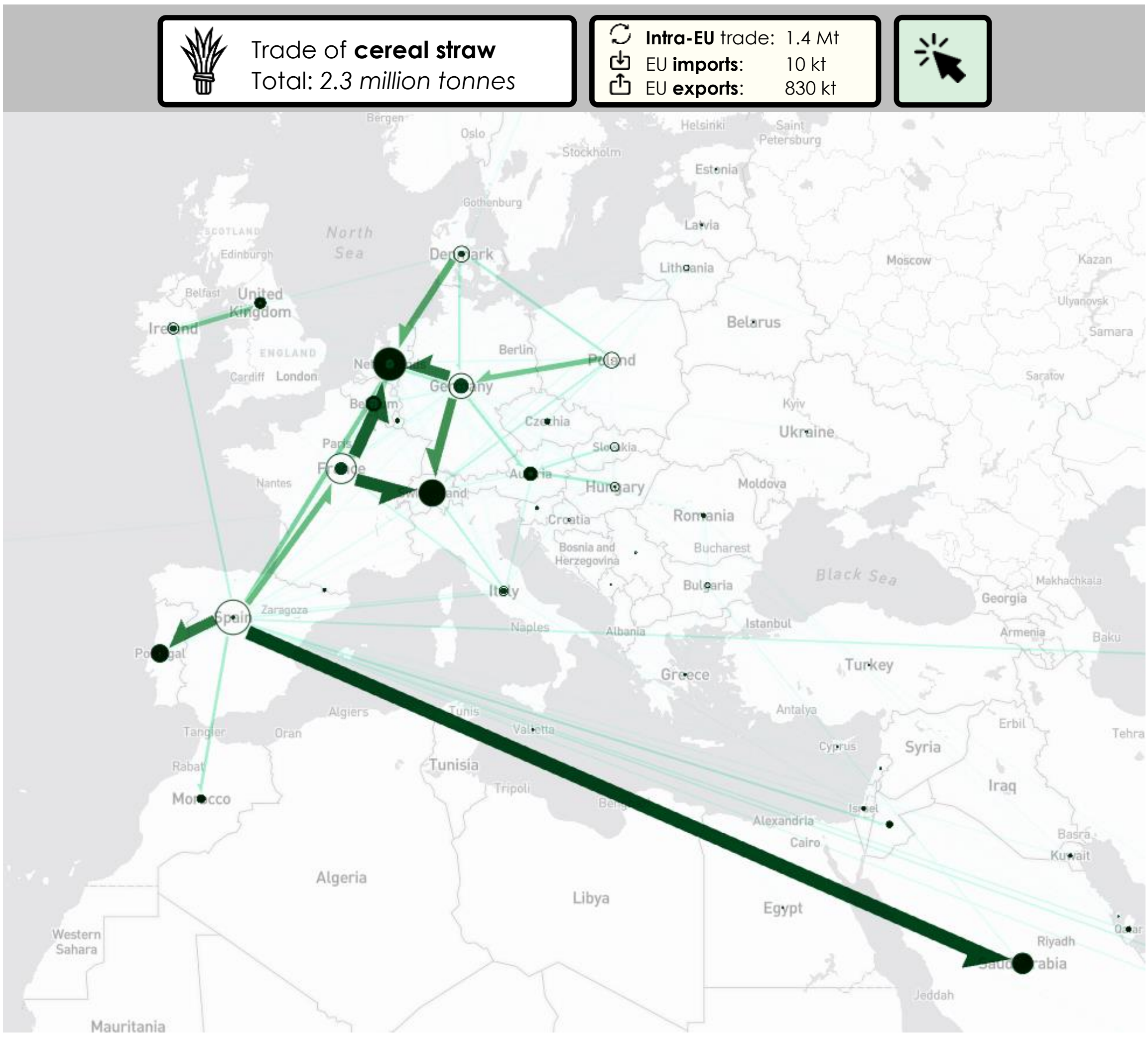

Figure 40, EU trade of cereal straw

Considering the EU's production of cereal crops is almost 300 million tonnes, the trade of 2.3 million tonnes of straw can be considered low. Straw is often used at the farm and due to it being a bulky and relatively low-value product, it might not be cost-effective to trade straw outside of the region of production. This could explain the trade of straw across borders being fairly low.

3.8 Summary of trade biological resources

The trade data of biological resources presented in Chapter 3 is summarized in Table 3. The table shows the total trade of the different categories of biological resources 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) are also shown.

Table 3, Summary trade data of biological resources

	Trade of biological resources *(thousand tonnes)*	***Total EU trade***	***Intra-EU***	***EU imports***	***EU exports***	***Largest importers (from EU countries)***	***Largest exporters (to EU countries)***
Sugar	*Sugar beets*	**914**	569	1	318	Czech, Switzerland, Croatia	Germany, Slovakia, Latvia
	Beet sugar	**173**	132	4	38	Israel, Spain, Italy	Austria, France, Germany
	Sugar cane	**1.4**	0.5	0.6	0.3	Belgium, Netherlands, UAE	Germany, Egypt, Vietnam
	Cane sugar	**2429**	328	2018	83	Italy, Spain, Belgium	France, Germany, Poland
	Sugar (all)	**8143**	5358	1884	901	Italy, Spain, Belgium	Germany, France, Poland
Starch	*Potatoes*	**9088**	8012	602	474	Belgium, Netherlands, Spain	France, Germany, Netherlands
	Potato starch	**1195**	519	7	719	Netherlands, United States, South Korea	Germany, Netherlands, Denmark
	Corn	**35753**	13687	3481	18585	Spain, Italy, Netherlands	Ukraine, Romania, France
	Corn starch	**899**	667	66	165	France, Germany, Italy	Spain, France and Germany
Oil	*Sunflower seeds*	**3959**	2949	455	555	Bulgaria, Netherlands, Spain	Romania, Bulgaria, France
	Sunflower & Safflower oil	**3146**	1289	1575	282	Netherlands, Spain, Italy	Ukraine, Bulgaria, Hungary
	Rapeseed & colza	**13852**	7782	5589	481	Germany, France, Belgium	Australia, Ukraine, Netherlands
	Rapeseed & colza oil	**2462**	1753	330	379	Netherlands, Belgium, China	Germany, France, Netherlands
	Palm nuts and kernels	**7**	2	0	5	United Kingdom, Ireland, Italy	Ireland, France, Greece
	Palm kernel oil	**674**	50	568	50	Germany, Netherlands, Spain	Malaysia, Indonesia, Papua New Guinea
	Palm oil	**8075**	1713	6142	220	Netherlands, Italy, Spain	Indonesia, Malaysia, Netherlands
Other	*Natural rubber*	**1806**	425	1368	13	Germany, Spain, Netherlands	Indonesia, Turkey, Thailand
	Cereal straw	**2269**	1428	10	830	Netherlands, Switzerland, Saudi Arabia	Spain, France, Germany
	Algae (human consumption)	**8**	6	2	0	Germany, Spain, Austria	China, Netherlands, Germany

The trade data presented in Table 3 has also been visualized and is shown in Figures 41, 42, 43, and 44. Figure 41 shows the EU trade of the various sugar crops, Figure 42 the EU trade of starch crops, Figure 43 of oil crops, and Figure 44 of other crops, namely natural rubber, cereal straw and algae.

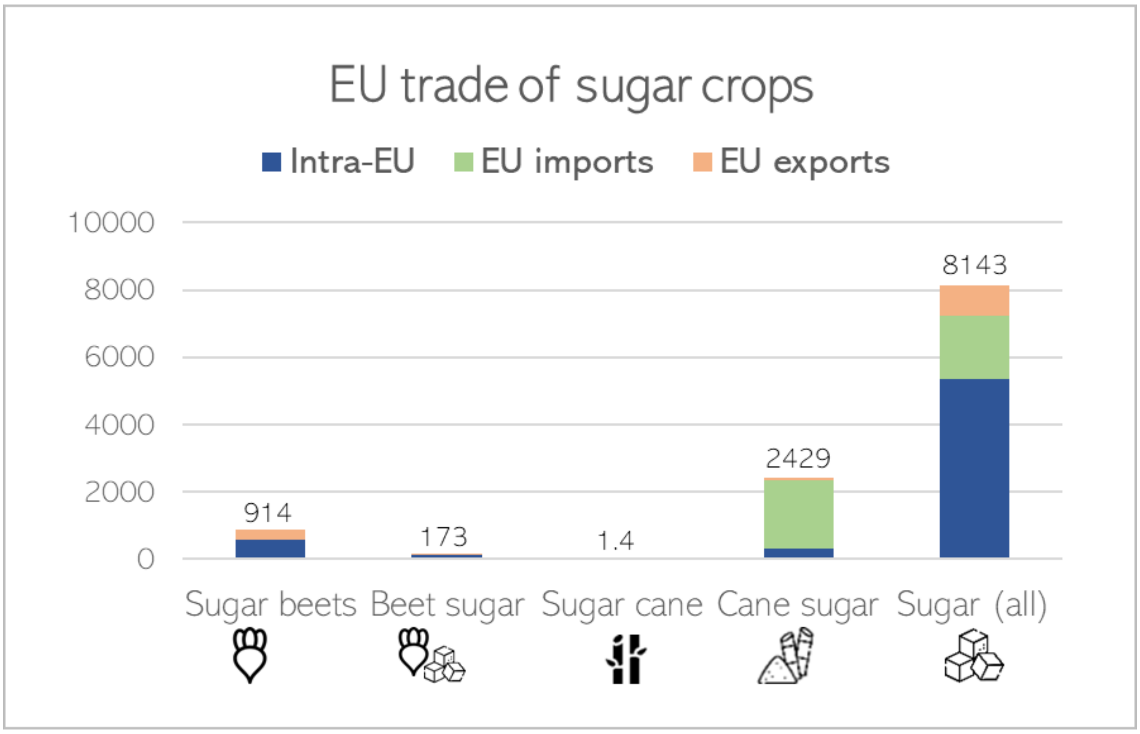

Figure 41, EU trade of sugar crops (thousand tonnes)

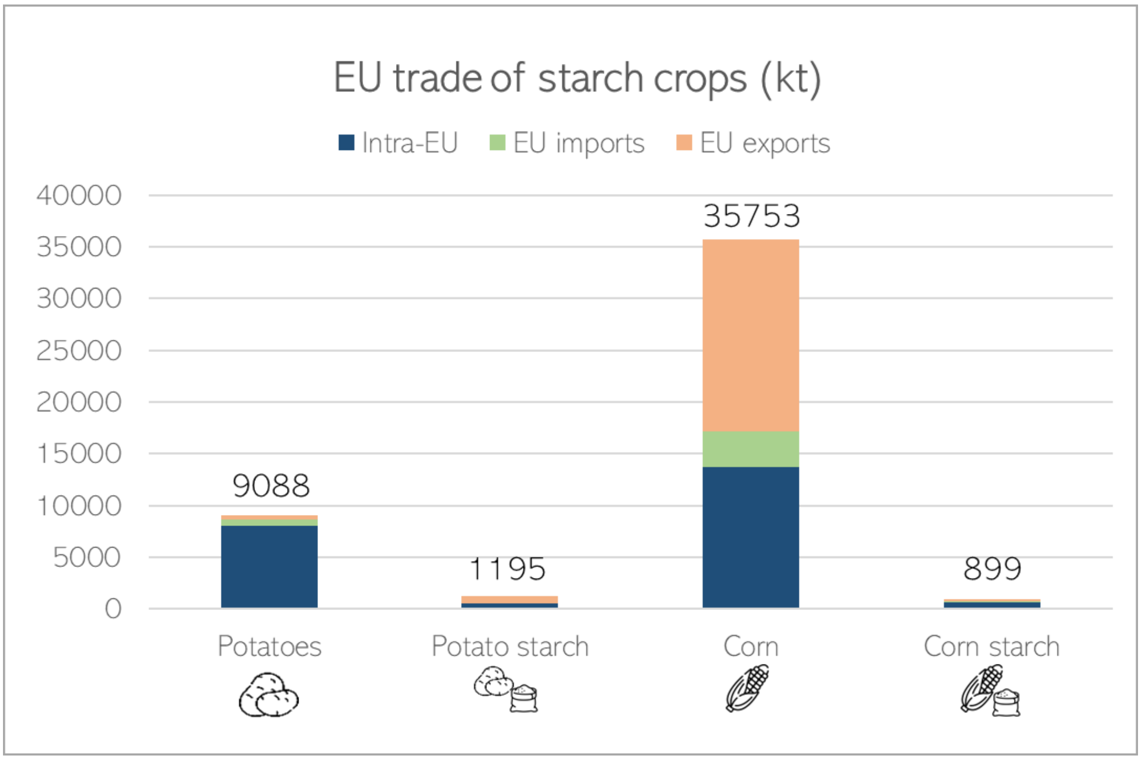

Figure 42, EU trade of starch crops (thousand tonnes)

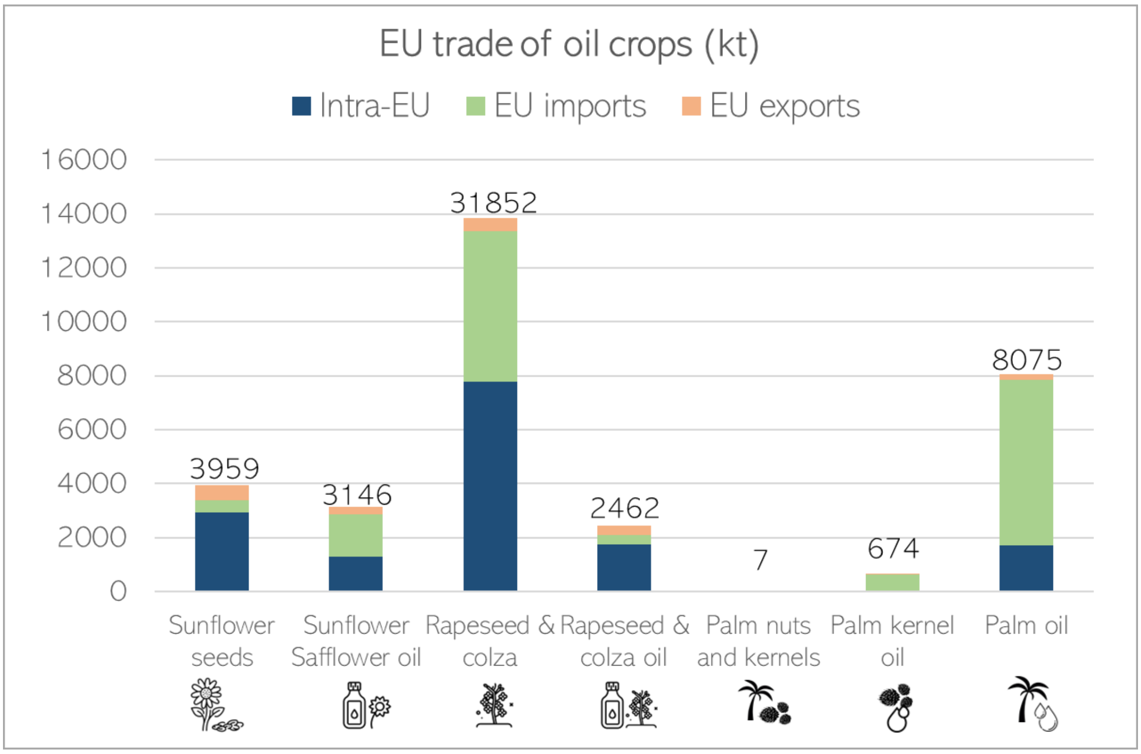

Figure 43, EU trade of oil crops (thousand tonnes)

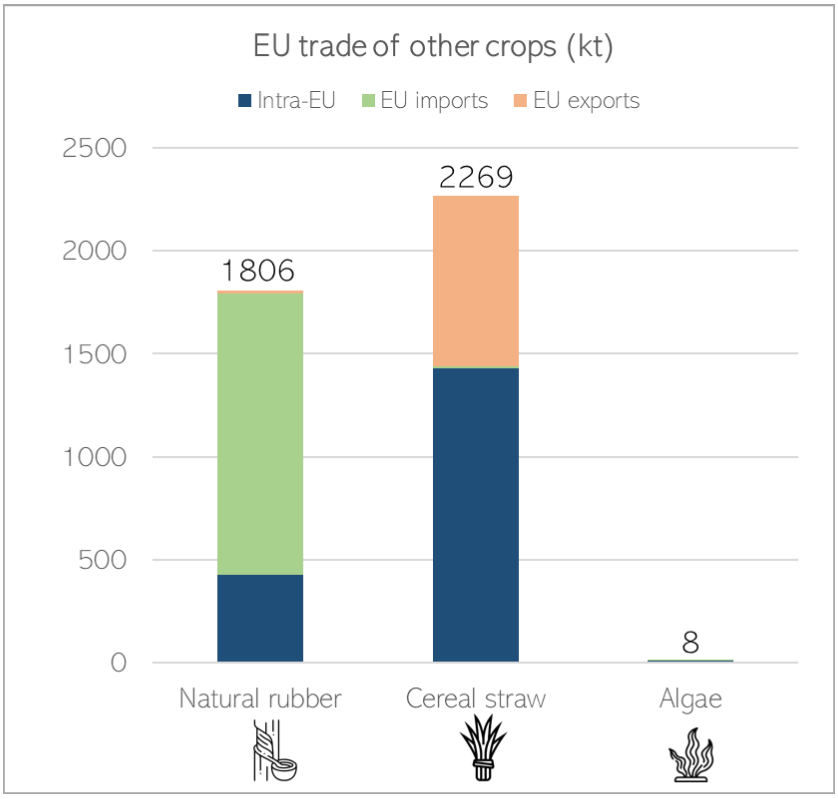

Figure 44, EU trade of other crops (thousand tonnes)

4 Bio-based dedicated chemicals

This chapter describes the value chains and trade flows of the dedicated bio-based chemicals. These bio-based chemicals do not have a fossil counterpart, 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 bio-based chemicals included in this chapter are lactic acid, polylactic acid, palmitic acid, and algal fatty acids. A summary of the main trade data of these bio-based chemicals can be found at the end of the chapter.

4.1 Lactic acid/PLA

Value chain description

Polylactic acid (PLA) is a biopolymer produced from lactic acid. It is used as bio-degradable packaging material, and as filament in 3D printing, amongst others.[29] The lactic acid required for the production of PLA is derived from starch crops (e.g. corn) and sugar crops (e.g. sugar cane). The corresponding value chain is depicted in Figure 45:

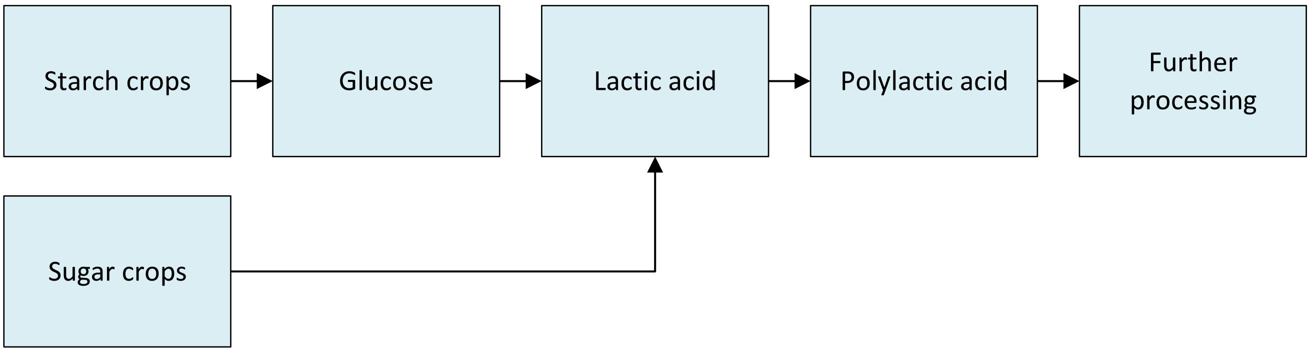

Figure 45: Polylactic acid value chain

Production locations

The world's largest lactic acid producer is Corbion Purac, while the largest PLA producer is Natureworks.

Natureworks, a joint venture between Cargill and PTT Global Chemical, has a lactic acid plant in the US with a capacity of 180 thousand tonnes of lactic acid, as well as a PLA manufacturing plant with a capacity of 150 thousand tonnes[30]. The company has also announced the construction of a new PLA manufacturing complex located in Nakhon Sawan, Thailand, with a capacity of 75,000 tonnes. The construction should be completed in the second half of 2024[31].

Futerro, a subsidiary of the Belgian Galactic group, operates an 80-thousand-tonne lactic acid plant in China, as well as a PLA plant with a capacity of 30 thousand tonnes per year. Futerro has also announced its plans to construct a PLA biorefinery with a production capacity of 75 thousand tonnes in France[32].

The Dutch company Corbion is one of the world's largest producers of lactic acid and its derivatives. The company has several production plants around the world, including in the US, Netherlands, Spain, Brazil and

[29] TotalEnergies Corbion, About PLA, https://www.totalenergies-corbion.com/about-pla/ Accessed August 24th, 2023
[30] https://www.natureworksllc.com/about-natureworks
[31] https://www.natureworksllc.com/about-natureworks/news-and-events/press-releases/2023/2023-02-02-natureworks-celebrates-construction-milestone-in-thailand
[32] https://www.futerro.com/news-media/futerro-aims-set-new-fully-integrated-pla-biorefinery-normandy-france

Thailand. Of these plants, the Thailand site is the largest, as it has a capacity of 100 thousand tonnes of lactic acid per year.

For the production of polylactic acid, Corbion has formed a joint venture with Total Energies. TotalEnergies Corbion has set up a 75-thousand-tonne-capacity PLA plant in Rayong, Thailand[33]. Total Corbion announced the construction of a second PLA plant to be built in France, but this plan was recently called off[34]. Corbion has also built a new lactic acid plant at the Rayong site, with a capacity of 125 thousand tonnes. The new plant is expected to be completed by the end of 2023[35].

The locations and production capacities of the identified production plants can be found in Table 4.

Table 4, Identified lactic acid and PLA production plants

Company	**Location**	**Lactic acid capacity (ktonnes/year)**	**PLA capacity (ktonnes/year)**
Natureworks	United States	180	150
Futerro	China	80	30
Corbion	US, Netherlands, Spain, Brazil	Unknown	
Corbion	Thailand	100	
TotalEnergies Corbion	Thailand		75
Total		**360**	**255**

[33] https://totalenergies.com/media/news/press-releases/thailand-total-corbion-pla-starts-its-75000-tonnes-year-bioplastics-plant
[34] https://www.sustainableplastics.com/news/corbion-calls-french-pla-bioplastics-plant
[35] https://www.corbion.com/-/media/Corbion/Files/Annual-reports/corbion_annual_report_2021_final.pdf

Trade flows

Figure 46 shows the EU trade of lactic acid. The EU's biggest importers of lactic acid are the Netherlands (28 kt), Germany (27 kt) and Belgium (23 kt). Outside of the EU, the biggest importer is the United States, which imported 21 thousand tonnes of lactic acid from the EU in 2021. The EU's biggest exporters of lactic acid are the Netherlands (79 kt), Belgium (44 kt) and France (29 kt). Outside of the EU, the biggest exporter is Thailand, which exported 12 thousand tonnes of lactic acid to the EU, primarily to Spain.

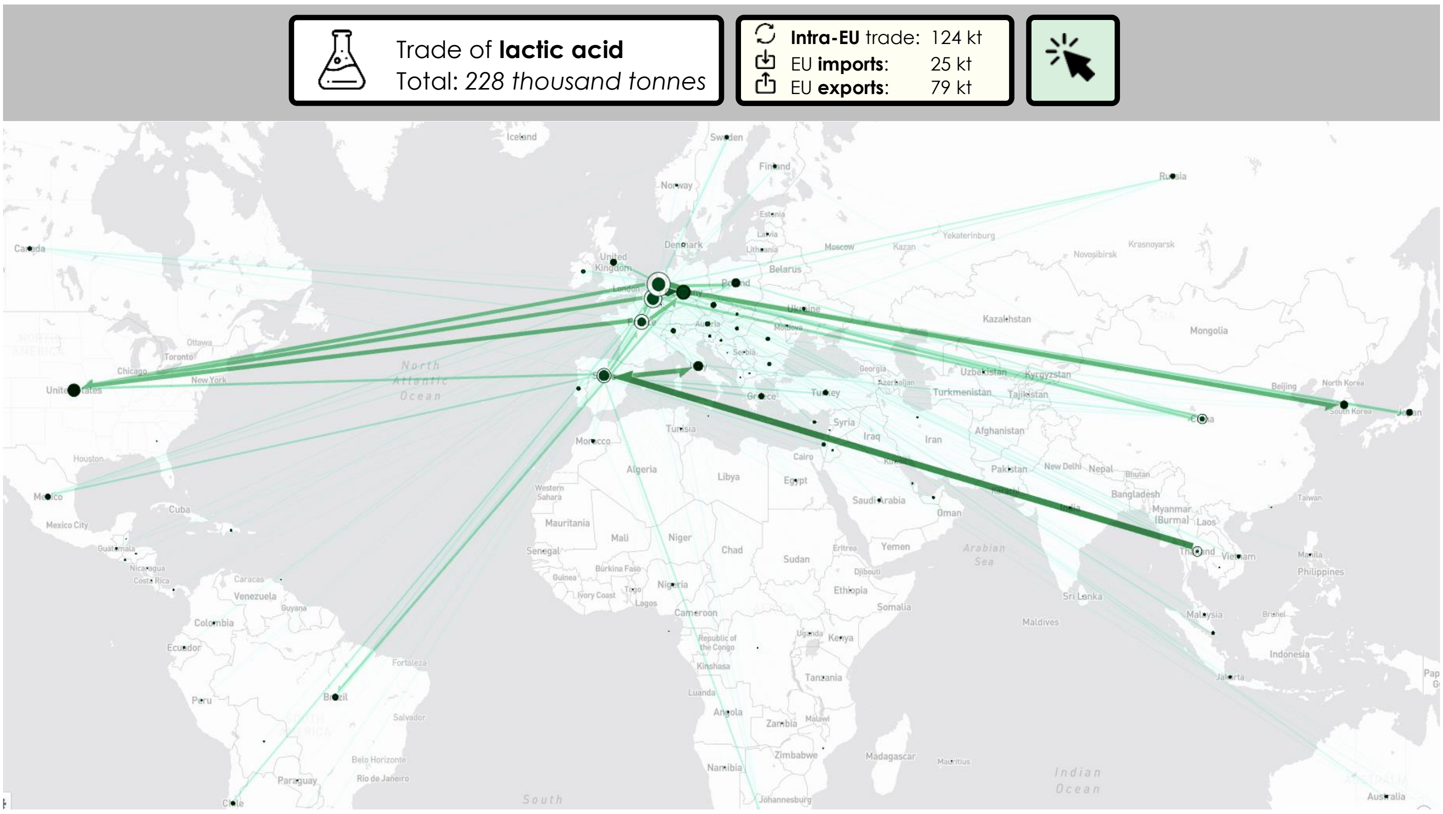

Figure 46, EU trade of lactic acid

Figure 47 shows the EU trade of polylactic acid (PLA). The biggest EU importers of PLA are the Netherlands (60 kt), Germany (28 kt) and Italy (23 kt). The EU's biggest exporter of PLA is by far the Netherlands (57 kt), followed by Belgium (3 kt) and Germany (3 kt). The two biggest exporters of PLA globally are the United States, which exported 51 thousand tonnes of PLA to the EU in 2021, and Thailand, with 17 thousand tonnes. As mentioned before, the Dutch company Corbion is the world's largest producer of lactic acid and has a large lactic acid and polylactic acid plant located in Thailand. This explains the exports of lactic acid and PLA from Thailand to the Netherlands. Additionally, the world's largest producer of PLA, Natureworks, is located in the United States, explaining the large PLA exports from the United States.

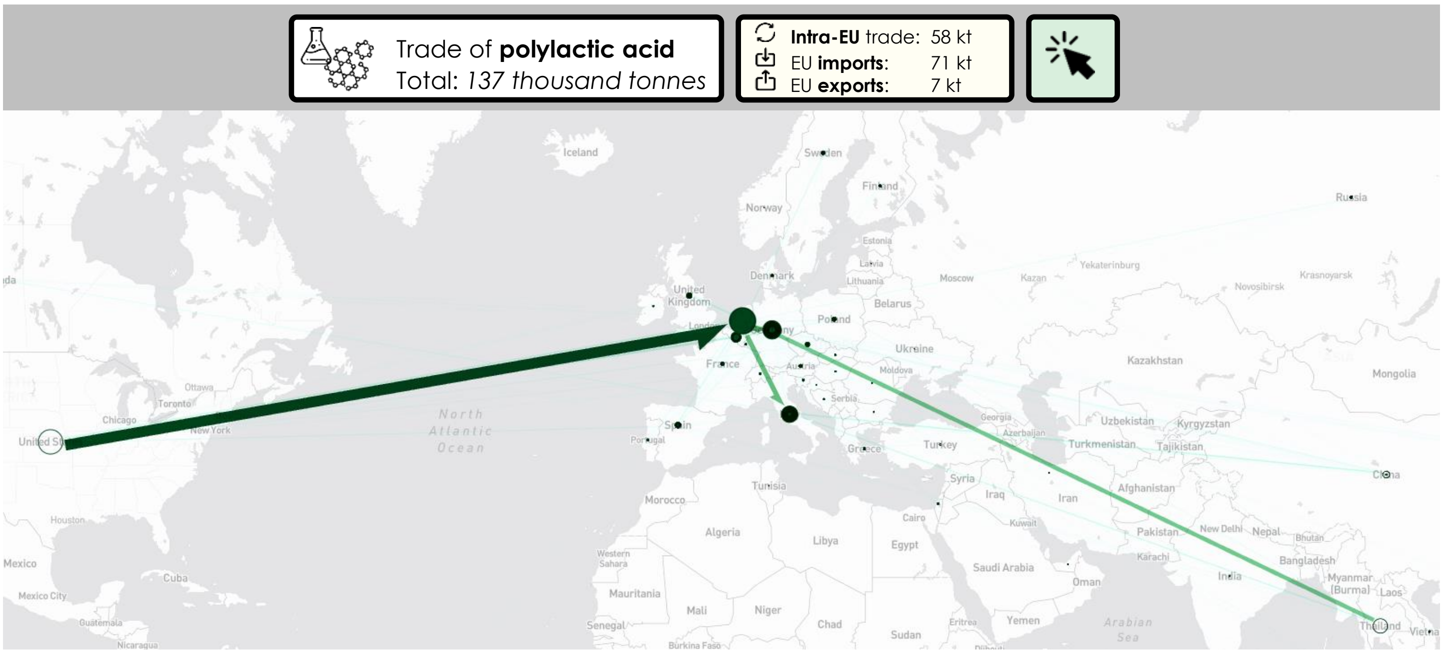

Figure 47, EU trade of polylactic acid (PLA)

4.2 Palmitic acid

Value chain description

Palmitic acid is obtained through the hydrolysis of triglycerides derived from palmitic acid. These triglycerides are found in palm oil, amongst others. Hydrolysis of palm oil also results in the production of glycerine as a by-product (Figure 48). Subsequent reaction of palmitic acid with a base, results in the formation of soap (sodium palmitate). Performing hydrolysis in an alkaline environment, results in the direct formation of soap (and glycerine) from palm oil. Both the one- and two-step conversion of palm oil in soap is known as saponification.

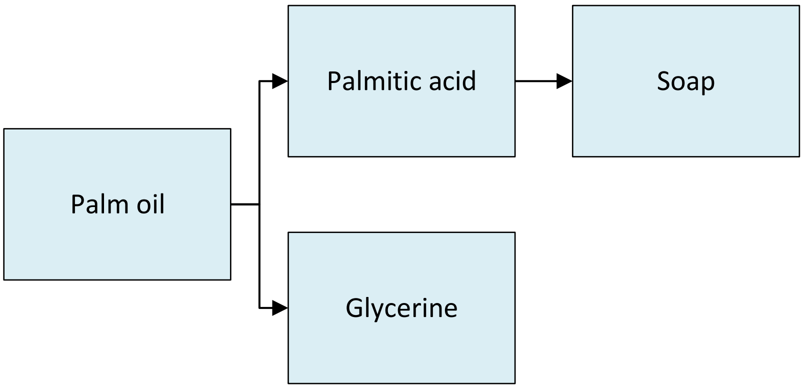

Figure 48, Palmitic acid value chain

Trade flows

Figure 49 (on the next page) shows the EU trade flows of palmitic acid. Similarly to the trade flows of palm oil, the majority of palmitic acid is imported from Malaysia and Indonesia, the world's largest producers of palm oil. The largest EU importers of palmitic acid are the Netherlands (17 kt), Spain (14 kt) and Germany (10 kt). The EU's largest exporters of palmitic acid are Germany (15 kt), Spain (3 kt) and Italy (3 kt). Outside of the EU, the biggest trading partners are Indonesia, which exported over 21 thousand tonnes of palmitic acid to the EU, and Malaysia, with almost 19 thousand tonnes of exports to the EU.

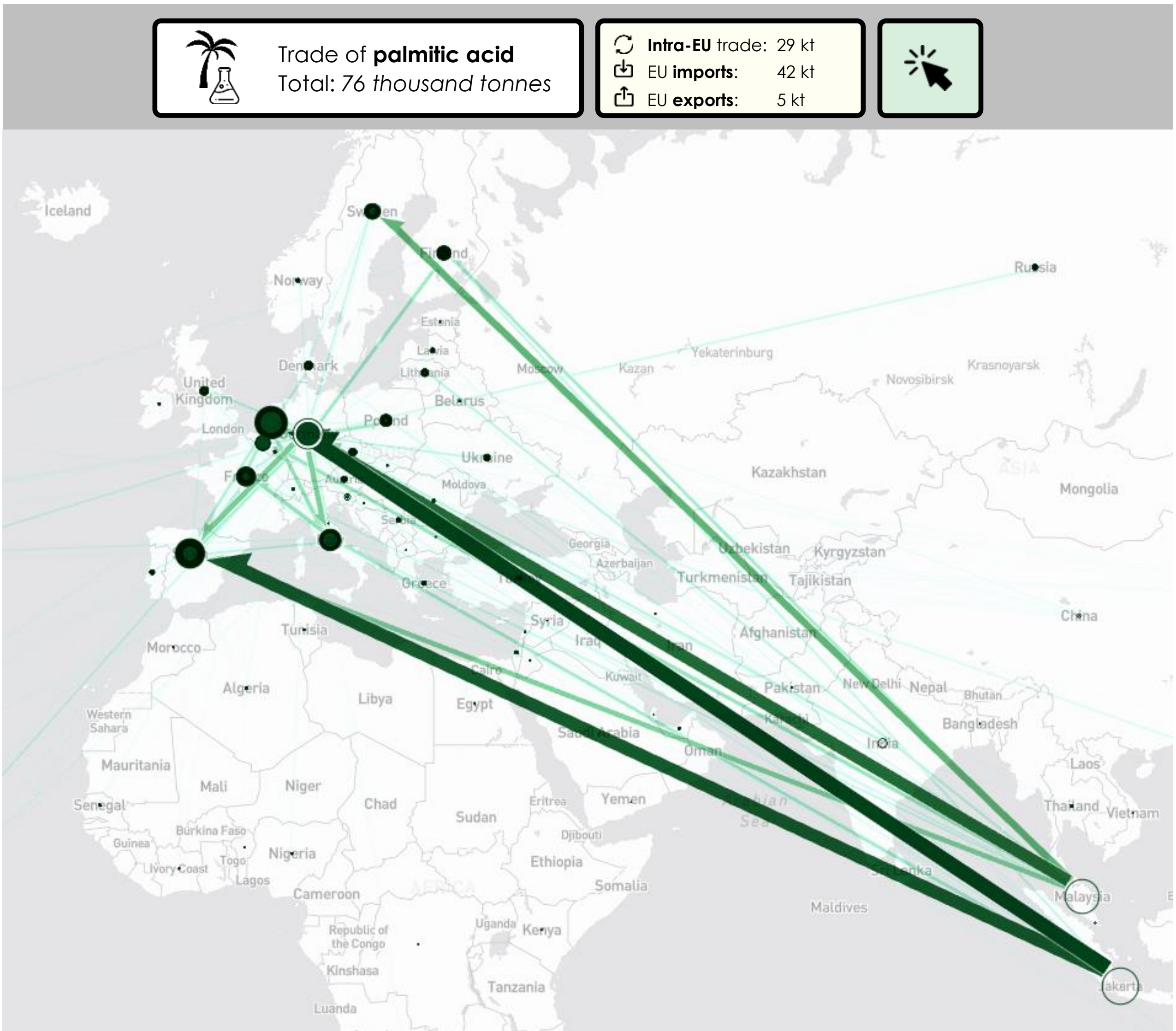

Figure 49, EU trade of palmitic acid

4.3 Algal fatty acids

Value chain description

Algae are aquatic organisms. Each species of algae has its own unique properties, depending on the algae's living environment. Their size ranges from one cell (called microalgae) to large multicellular organisms that are visible to the naked eye (macroalgae). [36] Currently, selected algae species are used for the production of algal fatty acids. These algal fatty acids serve different purposes, such as the production of biodiesel, as fish feed or as an alternative source for fish-based essential fatty acids. [37,38] In this report, it is focused on the production of omega-3 fatty acids eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). EPA and DHA are produced through fermentation of sugar [38, 39] by specific micro-algae, [39, 40] followed by algae harvesting, fatty acid extraction and purification. [37]

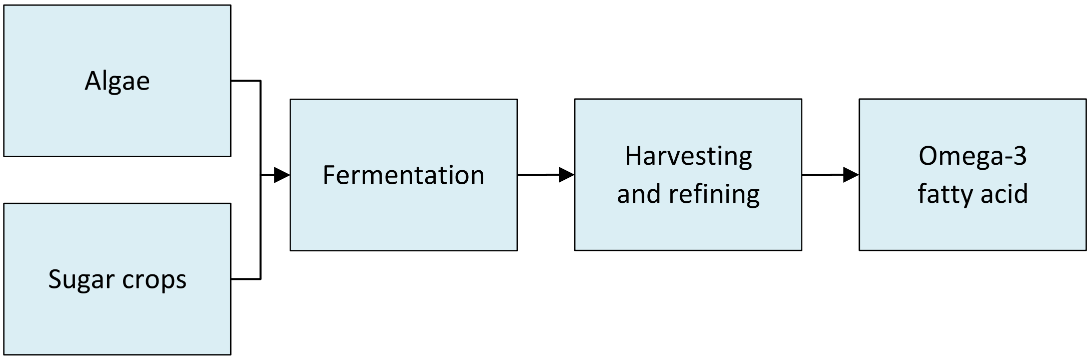

Figure 50, Algal fatty acid value chain

Production locations

As was mentioned before, the EU only accounts for a small share (<1%) of global algae production. The majority of algae produced is also macroalgae, rather than microalgae. The largest producers of microalgae in the EU are Spain, Germany, France and Italy[41]. The most commonly produced species of microalgae are 'Chollera sp.', 'Nannchloropsis sp.' and 'Haematococcus pluvialis'.

While most macroalgae production is based in the North Atlantic, microalgae production is mostly land-based and occurs in photobioreactors (71%), ponds (19%) and fermenters (10%). Microalgae can be used for various applications, including food supplements, nutraceuticals, cosmetics and feed[42].

Microalgae can be used to produce omega-3 fatty acids, such as eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). These fatty acids are commonly produced from fish oils but can also be produced from microalgae species such as nannochlorpsis, phaeodactulum, nitzschia, schizochrytium and cryptocodinium[43].

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[36] R.A. Andersen et al, Algae, *Encyclopedia Britannica*, https://www.britannica.com/science/algae, accessed on September 13 2023.
[37] W. Chen et al, 2023, Microalgal polyusaturated fatty acids: hotspots and production techniques, Frontiers in Bioengineering and Biotechnology, 11, 1146881, DOI: 10.3389/fbioe.2023.1146881.
[38] Corbion, AlgaPrime™ DHA, https://www.corbion.com/Products/Algae-ingredients-products/AlgaPrimeDHA, accessed on September 13 2023.
[39] Veramaris, 2022, Sustainable development report 2022
[40] Jongerius Ecoduna, FAQ, https://jongerius-ecoduna.at/en/faq/, accessed on September 13 2023.
[41] https://www.europarl.europa.eu/RegData/etudes/STUD/2023/733114/IPOL_STU(2023)733114_EN.pdf
[42] https://www.europarl.europa.eu/RegData/etudes/STUD/2023/733114/IPOL_STU(2023)733114_EN.pdf
[43] https://www.sciencedirect.com/science/article/pii/S2211926421003830

Global algal DHA and EPA production is estimated to be approximately 200,000 tonnes. In Europe, the company AlgaeCytes produces about 50,000 tonnes in Germany[44], while Veramaris, a joint venture between DSM and Evonink has a production of an estimated 20,000 tonnes in the Netherlands[45]. Furthermore, ADM produces 60 thousand tonnes of animal feed in the United States, that contains at least 24% DHA[46]. Additionally, Corbion has a production plant in Brazil, with an initial production capacity of 110 thousand tonnes of algal oil for DHA/EPA extraction, which could be expanded to 330 thousand tonnes[47]. Lastly, in China, Hubei Fuxing Biotechnology Co. produces about a thousand tonnes of algal oil[48], while Runke Bioengineering Co. has a production capacity of three thousand tonnes per year[49].

Table 5, Production locations algal fatty acids

Company	Location	Capacity (ktonnes/year)
Europe		***70***
AlgaeCytes	Germany	50[50]
Veramaris (DSM & Evonink)	Netherlands	20[51]
Other		***128***
ADM	United States	14[52]
Corbion	Brazil	110-330[53]
Hubei Fuxing Biotechnology Co.	China	1[54]
Runke Bioengineering Co.	China	3[55]
Total		**198**

[44] https://algaecytes.com/2021/10/22/algaecytes-limiteds-project-to-build-its-first-commercial-production-plant-in-dessau/
[45] https://www.veramaris.com/what-we-do-detail.html
[46] https://thefishsite.com/articles/algal-producer-ups-dha-ante
[47] https://www.acs.org/pressroom/newsreleases/2013/april/microalgae-produce-more-oil-faster-for-energy-food-or-products.html
[48] https://www.fuxingbiotechnology.com/about-us.html
[49] https://file.echemi.com/upload/eu/files/DHAAlgaeOilMarketReport.pdf
[50] https://algaecytes.com/2021/10/22/algaecytes-limiteds-project-to-build-its-first-commercial-production-plant-in-dessau/
[51] https://www.veramaris.com/what-we-do-detail.html
[52] https://thefishsite.com/articles/algal-producer-ups-dha-ante
[53] https://www.acs.org/pressroom/newsreleases/2013/april/microalgae-produce-more-oil-faster-for-energy-food-or-products.html
[54] https://www.fuxingbiotechnology.com/about-us.html
[55] https://file.echemi.com/upload/eu/files/DHAAlgaeOilMarketReport.pdf

Trade flows

Using the data from Table 5, a geographical indication of the production sites of algal fatty acids was made and presented in Figure 51. While there is no data available on the trade of algal fatty acids, the geographical distribution and size of identified production sites could help identify relevant trade flows.

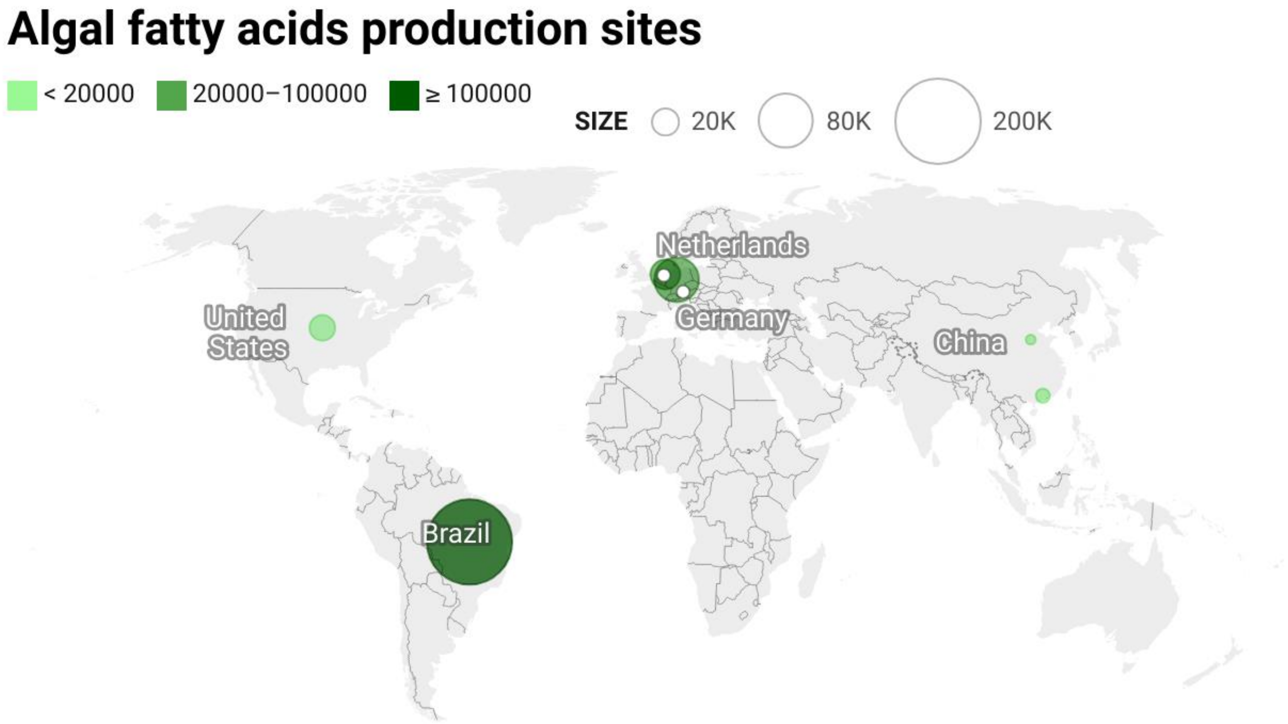

Figure 51, Production locations algal fatty acids

4.4 Summary of data bio-based dedicated chemicals

The trade data presented in Chapter 4 is summarized in Table 7. 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. The trade data from Table 7 is presented in Figure 52.

Table 6, Summary trade data bio-based dedicated chemicals

Dedicated chemicals *(thousand tonnes)*	***Total EU trade***	***Intra-EU***	***EU imports***	***EU exports***	***Largest importers (from EU countries)***	***Largest exporters (to EU countries)***
Lactic acid	228	124	25	79	Netherlands, Germany, Belgium	Netherlands, Belgium, France
Polylactic acid (PLA)	137	58	71	7	Netherlands, Germany, Italy	Netherlands, United States, Thailand
Palmitic acid	76	29	42	5	Netherlands, Spain, Germany	Germany, Netherlands, Spain
Algal fatty acids		-	Extra-EU production: 128	EU production: 70		Found producers: Germany, Netherlands, United States, Brazil, China
Natural rubber	1,806	425	1,368	13	Belgium, Netherlands, Germany	Indonesia, Turkey, Thailand

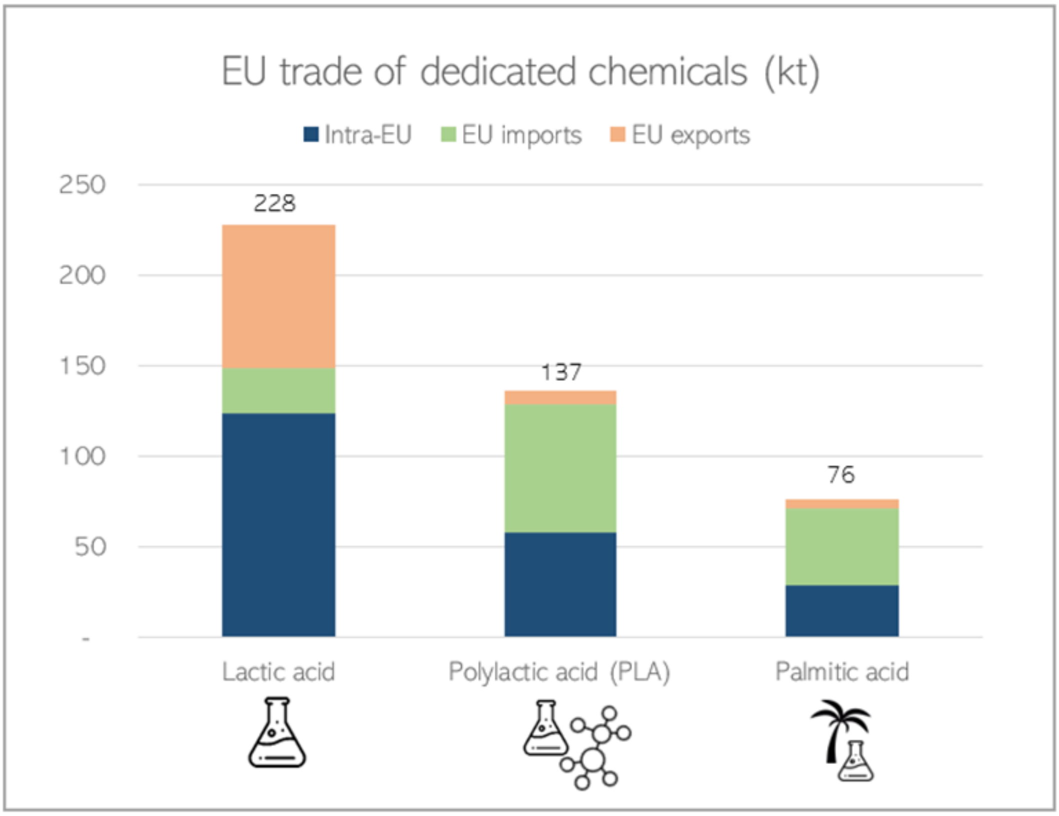

Figure 52, EU trade of bio-based dedicated chemicals

5 Bio-based drop-in chemicals

This chapter describes the value chains and trade flows of the drop-in bio-based chemicals. These bio-based chemicals have a fossil counterpart, 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 included in this chapter are 1,4-butanediol, ethylene, ethylene glycol, propylene glycol, polyurethane, epichlorohydrin, and polypropylene. A summary of the main trade data of these bio-based chemicals can be found at the end of the chapter.

5.1 1,4-Butanediol

Value chain description

1,4-butanediol (BDO) is used as a solvent as well as an intermediate for the production of plastics and other chemicals. Bio-based production of BDO occurs through the fermentation of sugars (Figure 53).[56]

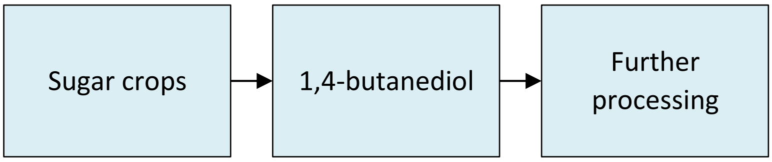

Figure 53, Bio-based 1,4-butanediol value chain

Production locations

1,4-Butanediol, primarily used to manufacture plastics, elastic fibres and films[57], can be produced from bio-based feedstocks. The main bio-based routes include the direct fermentation of sugars, as well as the fermentation of sugars to produce and hydrogenate succinic acid[58]. The global 1,4-butanediol market is estimated to be around 3.3 million tonnes in 2022[59]. Of this, about 19% or 635 thousand tonnes is produced in Europe[60].

Genomatica, a US-based company, has developed a bio-based process technology for 1,4-butanediol through the fermentation of sugars (GENO BDO). Using this process, the Italian company Novamont produces 30,000 tonnes of bio-BDO, which are used in various products, such as fruit and vegetable bags, mulch film and coffee capsules[61]. The Chinese company Shandong Landian Biological Technology produces between 20 and 50 thousand tonnes of bio-BDO using succinic acid[62]. Lastly, bio-BDO is produced at the facility of SK Geo Centric in the Republic of Korea, where it acts as an intermediate for the production of a biodegradable plastic[63].

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56 Novamont, 2016, Opening of the world's first industrial scale plant for the production of butanediol via fermentation of renewable raw materials, https://www.novamont.com/eng/read-press-release/mater-biotech/ Accessed on August 22, 2023

57 https://www.sciencedirect.com/topics/biochemistry-genetics-and-molecular-biology/1-4-butanediol#:~:text=1%20Chemical%20route-,1%2C4%2DBDO%20is%20an%20important%20raw%20material%20in%20manufacturing,)%2C%20and%20GBL%2C%20respectively.

58 https://biorrefineria.blogspot.com/2021/06/Biobased-1-4-butanediol-BDO.html

59 https://www.chemanalyst.com/industry-report/butanediol-market-657

60 Own calculations using: https://www.grandviewresearch.com/industry-analysis/1-4-butanediol-market, https://www.polarismarketresearch.com/industry-analysis/europe-1-4-butanediol-bdo-market and https://www.chemanalyst.com/industry-report/butanediol-market-657

61 https://www.novamont.com/eng/read-press-release/mater-biotech/

62 https://topic.echemi.com/a/asias-first_322725.html

63 https://skinnonews.com/global/archives/8350, accessed on August 23, 2023

BASF, one of the world's largest producers of fossil-based BDO has also signed a license agreement with Genomatica for the production of 75,000 tonnes of bio-BDO using the GENO BDO process[64]. However, the company has not yet announced the construction of any commercial-scale production plants and is believed to only be producing on a batch scale[65]. Qore, a joint-venture between Cargill and HELM, has announced the construction of a bio-BDO plant with a capacity of 65,000 tonnes in the United States, using Genomatica's GENO BDO process. The plant should be completed and operational in 2024. Qore is marketing its bio-BDO under the QIRA brand. LYCRA has signed an agreement with Qore for the production of bio-based spandex, which uses bio-BDO as one of its main ingredients. The bio-based LYCRA fibres will be produced in Singapore starting in 2024[66]. The China-based company Kingfa has built a plant with an annual capacity of 10,000 tonnes of bio-BDO from succinic acid per year, which should be operational by the end of 2023[67].

Current production of bio-based 1,4-butanediol is thereby estimated to currently be around 50 to 80 thousand tonnes globally, of which 30 thousand tonnes in Europe. As mentioned before, the global production of 1,4-butanediol is estimated to be around 3.3 million tonnes, while this is 635 thousand tonnes in Europe.
As such, the global bio-based share is estimated to be around 2%, while this is 5% in Europe. Would the planned projects also be realized, global production of bio-based 1,4-butanediol would increase to over 200 thousand tonnes, which would lead to a global bio-based share of 6.1%.

Trade flows bio-based

As the bio-based 1,4-butanediol market is considered to be relatively small, limited information about its production and trade is available. Figure 54 shows the current and planned production sites of bio-BDO.

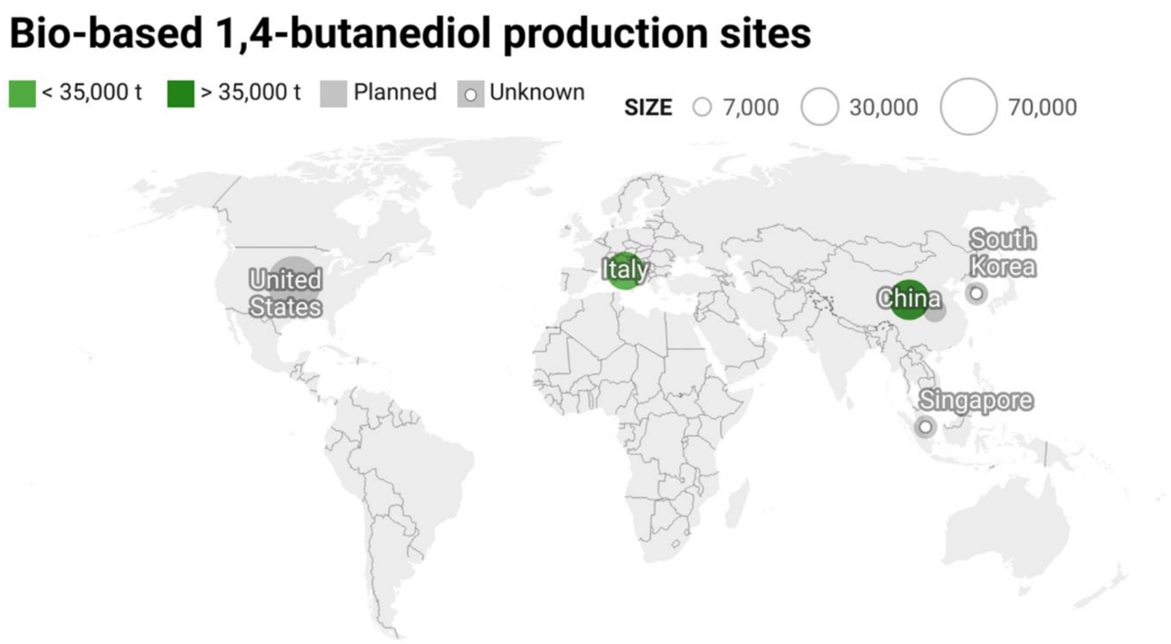

Figure 54, Bio-BDO production sites

[64] https://www.basf.com/global/en/media/news-releases/2015/09/p-15-347.html
[65] https://biorrefineria.blogspot.com/2021/06/Biobased-1-4-butanediol-BDO.html
[66] https://greenchemicalsblog.com/2022/10/03/bio-bdo-and-succinic-acid-updates/
[67] https://topic.echemi.com/a/asias-first_322725.html

There is also trade data available for bio-based 1,4-butanediol. However, since this data does appear to be limited and does not match with the found production locations and volumes. Figure 55 gives an overview of the trade data of bio-based 1,4-butanediol. It shows that the EU's biggest importers are the Netherlands (18 kt), Belgium (7 kt), and Germany (3 kt). The EU's biggest exporters are the Netherlands (4 kt), Germany (3 kt), and Belgium (2 kt). By far, the EU's largest trading partner is Saudi Arabia, which exported almost 22 thousand tonnes of bio-BDO to the EU in 2021. However, no production plant of bio-BDO could be found in Saudi Arabia. Saudi Arabia could be a re-exporter of the product, however, no data on this could be found.

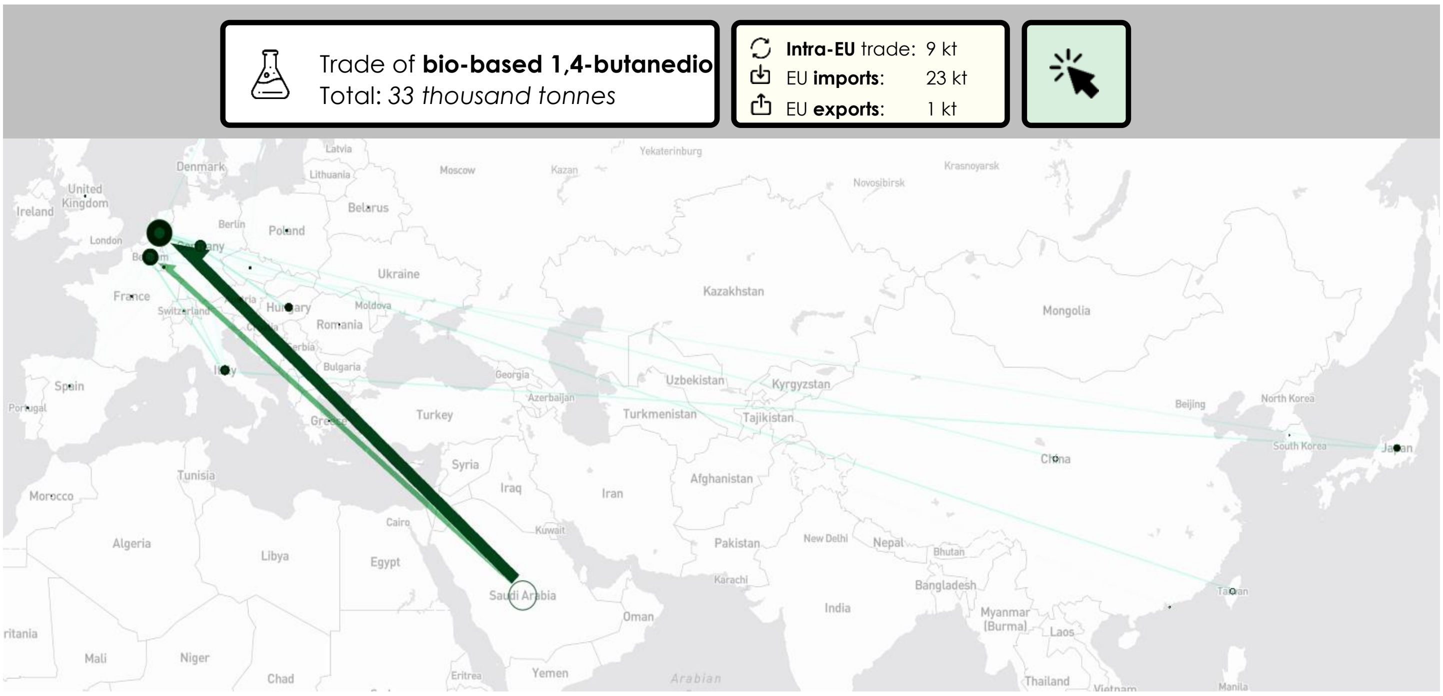

Figure 55, EU trade of bio-based 1,4-butanediol

5.2 Ethylene

Value chain description

Ethylene is a widely used commodity chemical and acts intermediate for the production of many other chemicals. Its bio-based counterpart is produced from sugars, as well as through steam cracking of bio-naphtha and other bio-based hydrocarbons (Figure 56).

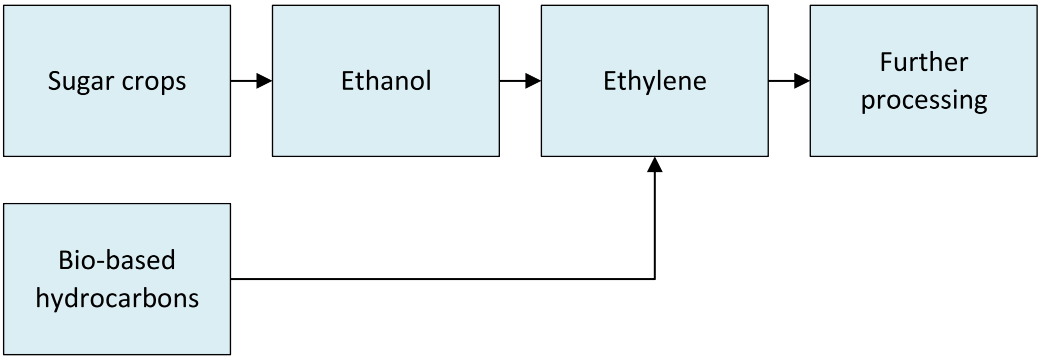

Figure 56, Bio-ethylene value chain

Production locations

Within the EU, on-demand production of bio-based ethylene occurs through the mass-balance approach by BASF,[68] Borealis,[69] and Versalis,[70] amongst others. Outside the EU, a large share of the bio-ethylene production occurs at Braskem's facilities, which use bio-ethylene for the production of bio-polyethylene, amongst others. Braskem's facilities in Brazil have a capacity of 260 thousand tonnes of bio-based ethylene, which is produced using ethanol from sugar cane[71]. Also in Brazil, Dow operates a bio-ethylene plant with a production capacity of 350 thousand tonnes per year[72]. Dow has also announced a supply agreement with New Energy Blue for bio-based ethylene produced from agricultural residues[73]. Also in Brazil, Solvay Indupa produces about 60 thousand tonnes of bio-ethylene for the production of PVC.

India Glycols produces bio-ethylene as an intermediate during bio-ethylene glycol production, [and] so does Greencol Taiwan. Bio-ethylene is produced as an intermediate for bio-ethylene oxide by Croda.

Finally, SCG Chemicals Company Limited and Braksem announced their plans in 2023 to build a bio-ethylene plant in Thailand, with a capacity of 200 thousand tonnes. The bio-ethylene is meant to be used in the production of polyethylene[74].

[68] BASF, The Mass Balance Approach, https://www.basf.com/global/en/who-we-are/sustainability/we-drive-sustainable-solutions/circular-economy/mass-balance-approach.html, accessed on August 21st, 2023
[69] Borealis, 2020, Borealis to gain International Sustainability & Carbon Certification for all its European polyolefin production sites, https://www.borealisgroup.com/news/borealis-to-gain-international-sustainability-carbon-certification-iscc-plus-for-all-its-european-polyolefin-production-sites Accessed on August 21st, 2023
[70] Eni Versalis, 2021, Versalis: new certified product range for sustainability, https://www.eni.com/assets/documents/press-release/migrated/2021-en/02/PR-Versalis-ISCC-Plus.pdf, accessed on August 21st, 2023
[71] https://www.braskem.com.br/europe/news-detail/braskem-expands-its-biopolymer-production-by-30-following-an-investment-of-us-87-million
[72] https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2013/IRENA-ETSAP-Tech-Brief-I13-Production_of_Bio-ethylene.pdf
[73] https://corporate.dow.com/en-us/news/press-releases/dow-and-new-energy-blue-announce-collaboration-to-develop-renewa.html
[74] https://greenchemicalsblog.com/2023/08/18/green-pe-coming-soon-in-thailand/

Current production of bio-based ethylene is thereby estimated to currently be around 700 thousand tonnes globally. As the global production of ethylene is estimated to be around 223.86 million tonnes[75], this would mean the bio-based share of ethylene is around 0.3%.

Trade flows

As ethylene is a drop-in chemical, with both a bio-based and fossil-based alternative, there is no specific data available about the trade flows for the bio-based alternative. Figure 57 shows the trade flows of all ethylene, including both the bio-based and fossil-based counterparts. It should be taken into account that of these trade flows, an estimated 0.3% of ethylene is estimated to be bio-based, and the remaining 99.7% is estimated to be fossil-based. As the bio-based share is relatively low, the trade flows presented might not be representative of the trade of bio-based ethylene.

Taking the estimated bio-based share of 0.3% and a total EU trade of 2.9 million tonnes of ethylene, resulted in an EU trade figure of 8.7 thousand tonnes of bio-based ethylene.

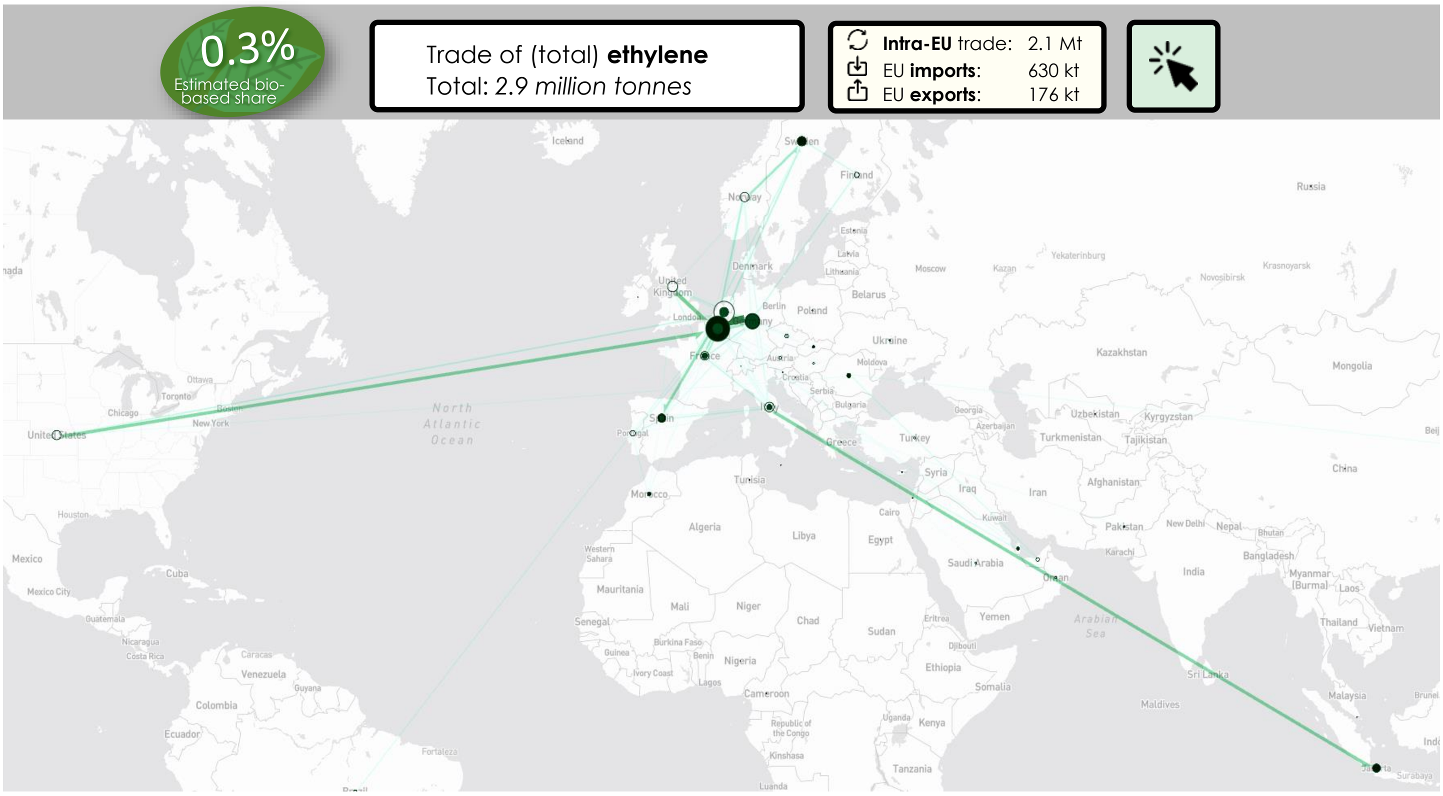

Figure 57, EU trade of total ethylene (fossil and bio-based)

The identified production sites of bio-based ethylene are mapped in Figure 58. While the exact trade flows of bio-based ethylene, the geographical distribution of production sites can help determine the relevant bio-based trade flows.

[75] https://www.offshore-technology.com/comment/asia-global-ethylene-capacity-2027/

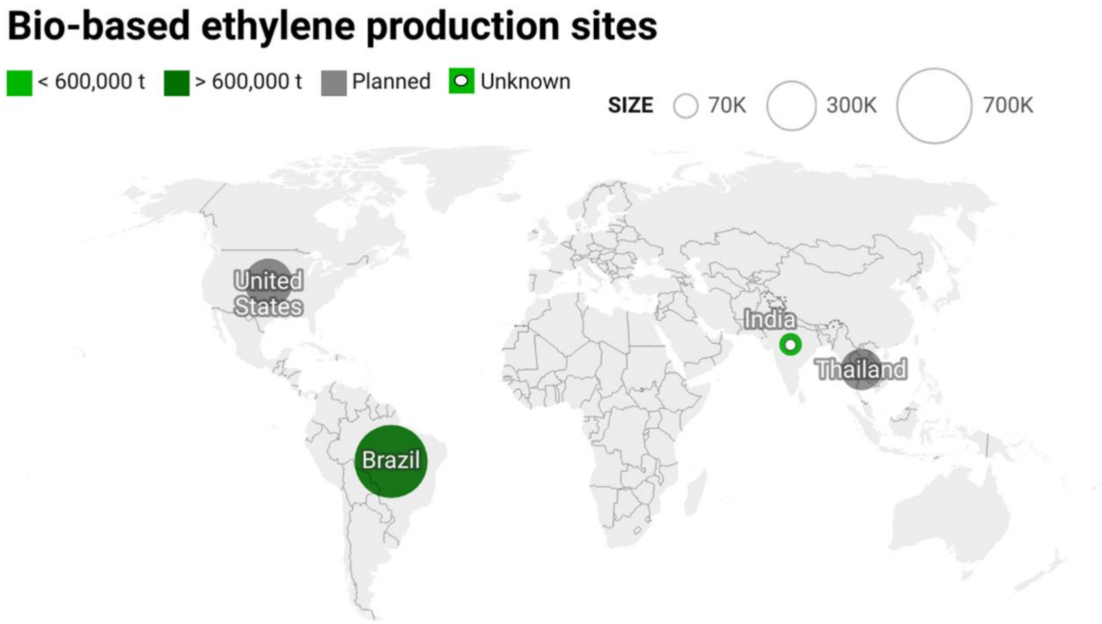

Figure 58, Identified production locations of bio-based ethylene

5.3 Ethylene glycol

Value chain description

Bio-based production of ethylene glycol occurs through the conversion of sugar crops in subsequently ethanol, ethylene, and ethylene-glycol (Figure 59). Alternatively, bio-based ethylene glycol can be produced through steam cracking of bio-based hydrocarbons and subsequent conversion of ethylene into ethylene glycol. Ethylene glycol is widely used as an anti-freeze agent, and also acts as an intermediate for the production of poly(ethylene terephthalate) (PET) and poly(ethylene glycol) (PEG), amongst others. Both bio-based ethylene glycol and ethylene glycol of fossil fuel origin are also known as mono-ethylene glycol (MEG).

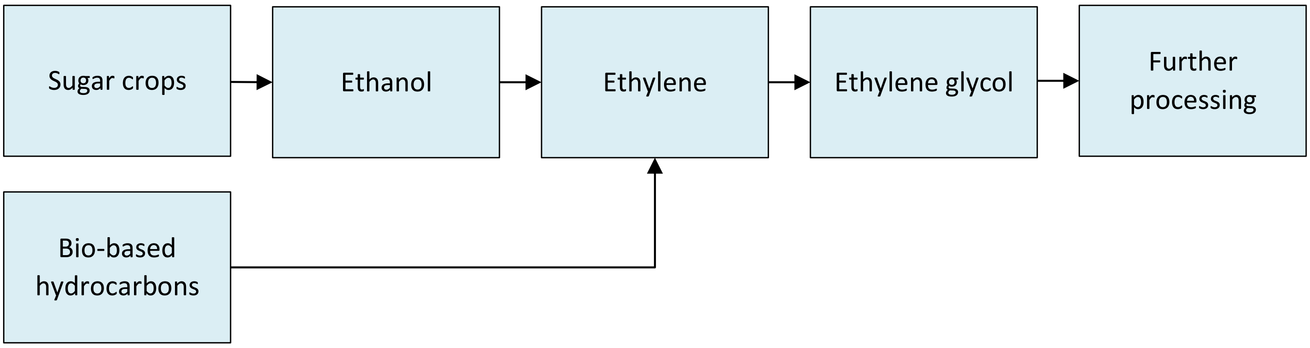

Figure 59, Bio-ethylene glycol value chain

Production locations

Commercial-scale bio-based ethylene glycol production mainly occurs outside the EU, at the facilities of India Glycol Ltd, with a production capacity of 175 thousand tonnes[76]. In addition, Greencol Taiwan might be producing bio-ethylene glycol, though information about this facility is very limited. Also, Global Bio-Chem lists bio-ethylene in its portfolio, yet it is unclear if it still produces bio-ethylene glycol as most of Global Bio-Chem's activities in the corresponding polyol segment are suspended.[77]

Inside the EU, Clariant might be producing bio-ethylene glycol on a commercial scale, acting as an intermediate for the production of bio-based poly(ethylene glycol).[78] Next to this, demonstration-scale plants for bio-based ethylene glycol production exist within the EU and are operated by Avantium in the Netherlands,[79] and a joint venture of Braskem and Haldor Topsoe in Denmark.[80] Several companies have announced commercial production of bio-based ethylene glycol within the EU, including UPM together with

[76] India Glycols Ltd, Ethylene glycols (MEG, DEG and TEG), https://www.indiaglycols.com/divisions/ethylene_glycols.htm, accessed on November 13th, 2023
[77] Global Bio-Chem Technology Group Company Limited, Annual Report 2022, http://media-globalbiochem.todayir.com/20230424174801527110700180_en.pdf, accessed on August 21st, 2023
[78] Clariant, 2022, Clariant launches 100% bio-based surfactants range driving the transition towards renewable carbon, https://www.clariant.com/en/Corporate/News/2022/02/Clariant-launches-100-biobased-surfactants-range-driving-the-transition-towards-renewable-carbon, accessed on August 23rd, 2023.
[79] Avantium, Technologies, https://www.avantium.com/technologies/, accessed on August 21st, 2023
[80] Braskem, 2020, Braskem and Haldor Topsoe achieve first production of bio-based MEG from sugar, https://www.braskem.com.br/news-detail/braskem-and-haldor-topsoe-achieve-first-production-of-bio-based-meg-from-sugar, accessed on August 21st, 2023

HAERTOL Chemie for 2024, Avantium together with Cosun for 2025,[81] and Braskem together with Haldor Topsoe for 2026.

Global production of ethylene glycol is estimated to be around 28 million tonnes[82]. Assuming the production of bio-based ethylene glycol to be around 200 thousand tonnes, the bio-based share of ethylene glycol is estimated to be around 0.7% of total production.

Trade flows

As ethylene glycol is a drop-in chemical, with both a bio-based and fossil-based alternative, there is no specific data available about the trade flows for the bio-based alternative. Figure 57 shows the trade flows of all ethylene glycol, including both the bio-based and fossil-based counterparts. It should be taken into account that of these trade flows, less than 1% of ethylene glycol is estimated to be bio-based, as such, the total trade flows presented might not be representative of the trade of bio-based ethylene glycol.

Taking the estimated bio-based share of 0.7% and a total EU trade of 1.9 million tonnes of ethylene glycol, resulted in an EU trade figure of 13 thousand tonnes of bio-based ethylene glycol.

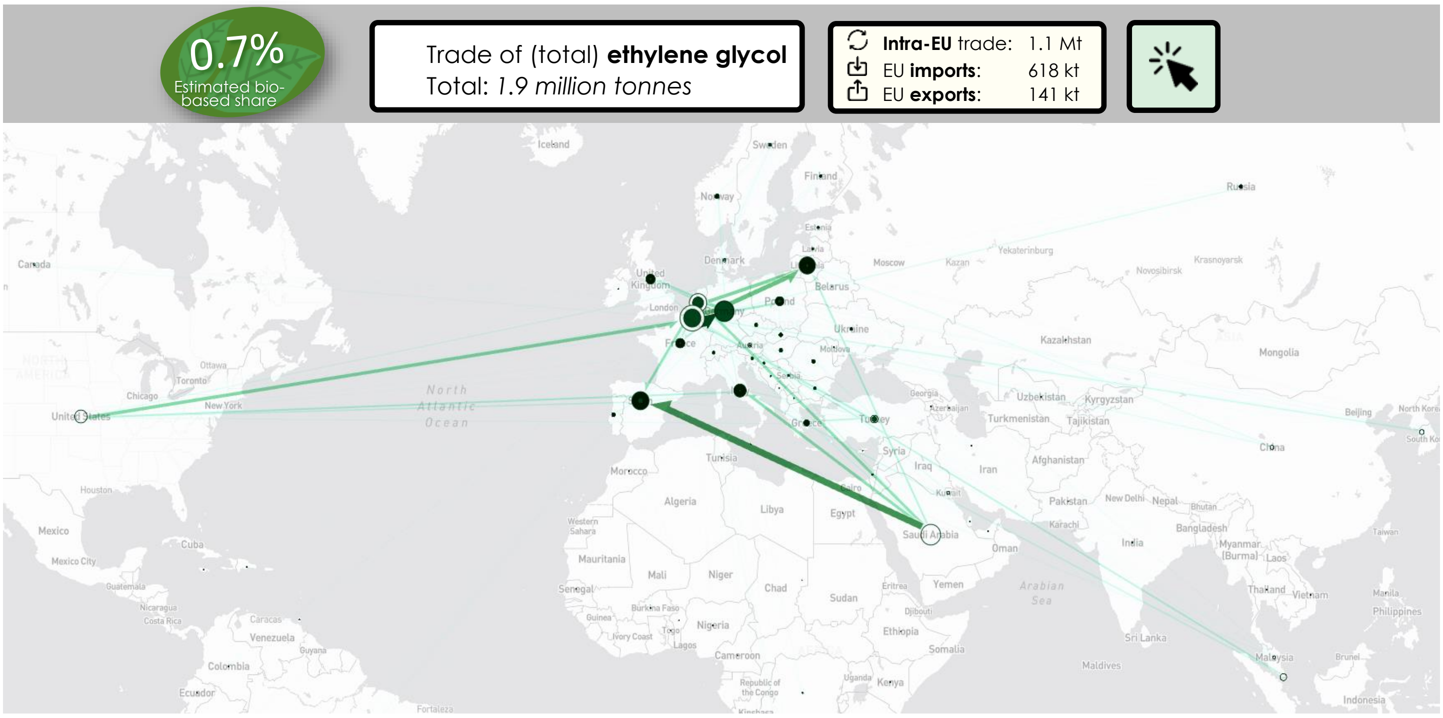

Figure 57, EU trade of total (fossil and bio-based) ethylene glycol

[81] Avantium, 2021, Cosun Beet company and Avantium join forces with the ambition to produce plant-based glycols from sugars, https://www.avantium.com/wp-content/uploads/2021/04/20210422-Cosun-Beet-Company-and-Avantium-join-forces-with-the-ambition-to-produce-plant-based-glycols-from-sugars.pdf, accessed on August 21st, 2023

[82] https://www.sciencedirect.com/science/article/abs/pii/S1385894723024300

5.4 Propylene glycol

Value chain description

Propylene glycol has many different applications, such as an antifreeze and de-icing agent, or as a chemical building block for the production of polyester resins, amongst others. It is produced from glycerol by means of hydrogenolysis. Glycerol, in turn, is obtained as a by-product during biodiesel production, or is obtained through hydrolysis of oil crops, oil wastes and oil residues (see Figure 60).[83] Other biobased propylene glycol production methods utilize starch or wood-based sugars as feedstock.[84, 85, 86] Propylene glycol is also known as monopropylene glycol (MPG) and 1,2-propanediol.

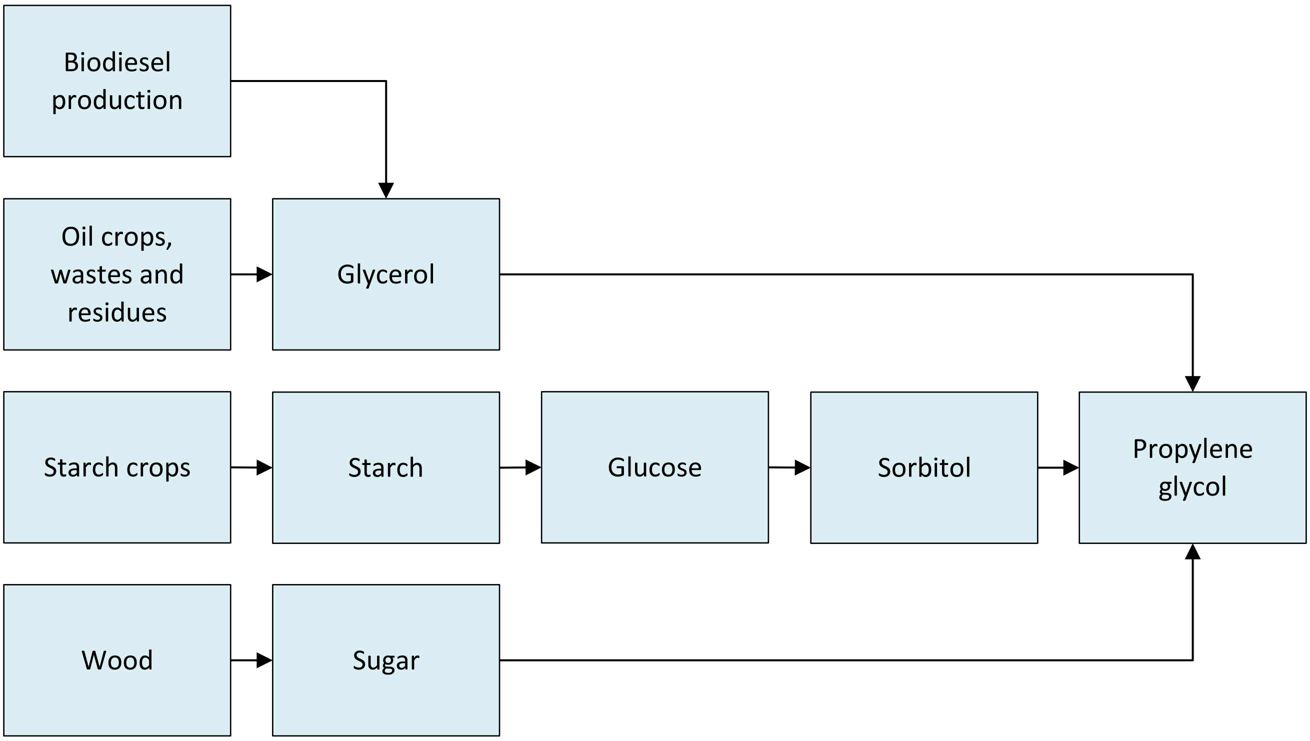

Figure 60, Propylene glycol value chain

[83] R. Platt et al., 2021, EU Biorefinery outlook to 2030, DOI: 10.2777/103465.
[84] Global Bio-chem, Corn-Based Biochemical products (downstream), http://www.globalbiochem.com/html/bus_product_cornbased.php, accessed on September 19 2023
[85] Global Bio-chem, 2004, Global Bio-Chem makes technological breakthrough using corn to produce “environmental friendly” polyol products, http://www.globalbiochem.com/download/press_release/20041027.pdf
[86] UPM Biochemicals, Building a state-of-the-art biorefinery in Leuna, https://www.upmbiochemicals.com/about-upm-biochemicals/biorefinery-leuna/, accessed on September 19 2023

Production locations

The EU produced a total of 574 thousand tonnes of propylene glycol in 2021, of which an estimated 50,000 tonnes were bio-based. As such, the bio-based share of propylene glycol in the EU is about 8.7%.

Bio-based propylene glycol production occurs in Belgium, where Oleon produces about 20,000 tonnes[87], and in Poland, where PKN ORLEN produces 30,000 tonnes[88]. In North America, ADM produces about 100,000 tonnes[89] and Cargill/Ashland 65,000 tonnes of bio-based propylene glycol[90]. Additionally, UPM Biochemicals has built a biorefinery in Leuna, Germany, which should be operational by the end of 2023. The biorefinery will have a capacity of 220,000 tonnes of biochemicals, including bio-monopropylene glycol and bio-monoethylene glycol[91]. Additionally, Green Glycols, a joint venture between GBE and ChemCom, will produce 40,000 tonnes of bio-based propylene glycol in the Netherlands starting in 2025[92].

Table 7, Bio-based propylene glycol production in the EU and North America

Company	Location	Capacity (ktonnes/year)
Europe		***50***
Oleon	Belgium	20
ORLEN	Poland	30
North America		***165***
ADM	USA	100
Cargill / Ashland	USA	65
Total		**215**

As can be seen in Table 7, the current production of bio-based propylene glycol is estimated to be around 50 thousand tonnes in Europe, and 215 thousand tonnes globally. The total production of propylene glycol is estimated to be 633 thousand tonnes[93] in Europe and 2520 thousand tonnes globally[94]. As such, the bio-based share is estimated to be 7.9% in Europe and 8.5% globally.

[87] https://pubs.acs.org/doi/pdf/10.1021/acssuschemeng.3c01018
[88] https://www.orlen.pl/en/sustainability/transition-projects/ORLEN-Group-Hydrogen-Strategy-2030/News-about-hydrogen/ORLEN-Poludnie-launches-production-of-eco-friendly-green-glycol
[89] https://pubs.acs.org/doi/pdf/10.1021/acssuschemeng.3c01018
[90] https://investor.ashland.com/static-files/5501164e-a802-441d-a8fd-d6402677b55b
[91] https://www.upmbiochemicals.com/biorefinery/
[92] https://www.prnewswire.com/news-releases/ethos-asset-management-inc-usa-announces-deal-with-greenglycols-green-glycols-bv-to-develop-a-biompg-production-facility-in-the-netherlands-301784850.html
[93] Spekreijse, Jurjen, Tijs Lammes, Claudia Parisi, Tévécia Ronzon and Martijn Vis (2019) Insight into the European market of bio-based chemicals. Analysis based on ten key product categories. European Commission, Joint Research Centre (JRC), Directorate for Sustainable Resources. JRC115202
[94] https://publications.jrc.ec.europa.eu/repository/handle/JRC124141

Trade flows

As propylene glycol is a drop-in chemical, with both a bio-based and fossil-based alternative, there is no specific data available about the trade flows for the bio-based alternative. Figure 61 shows the trade flows of all propylene glycol, including both the bio-based and fossil-based counterparts. It should be taken into account that of these trade flows, an estimated 7.9% of propylene glycol that is produced in Europe is bio-based, and the remaining 92.1% is estimated to be fossil-based. Relatively small amounts of propylene glycol are imported from countries outside of Europe.

Taking the estimated bio-based share of 8% and a total EU trade of 527 thousand tonnes of propylene glycol, resulted in an EU trade figure of 42 thousand tonnes of bio-based propylene glycol.

Figure 61, EU trade of (fossil and bio-based) propylene glycol

The production sites of Table 7 can also be mapped in order to better understand the trade flows of bio-based propylene glycol. Figure 62 visualizes the data shown in Table 7 using a proportional symbol map, showing current production locations in green and future sites in grey, using different size circles to represent the production capacity of the sites, located in Belgium, Poland, and the United States and future sites planned in Germany and the Netherlands.

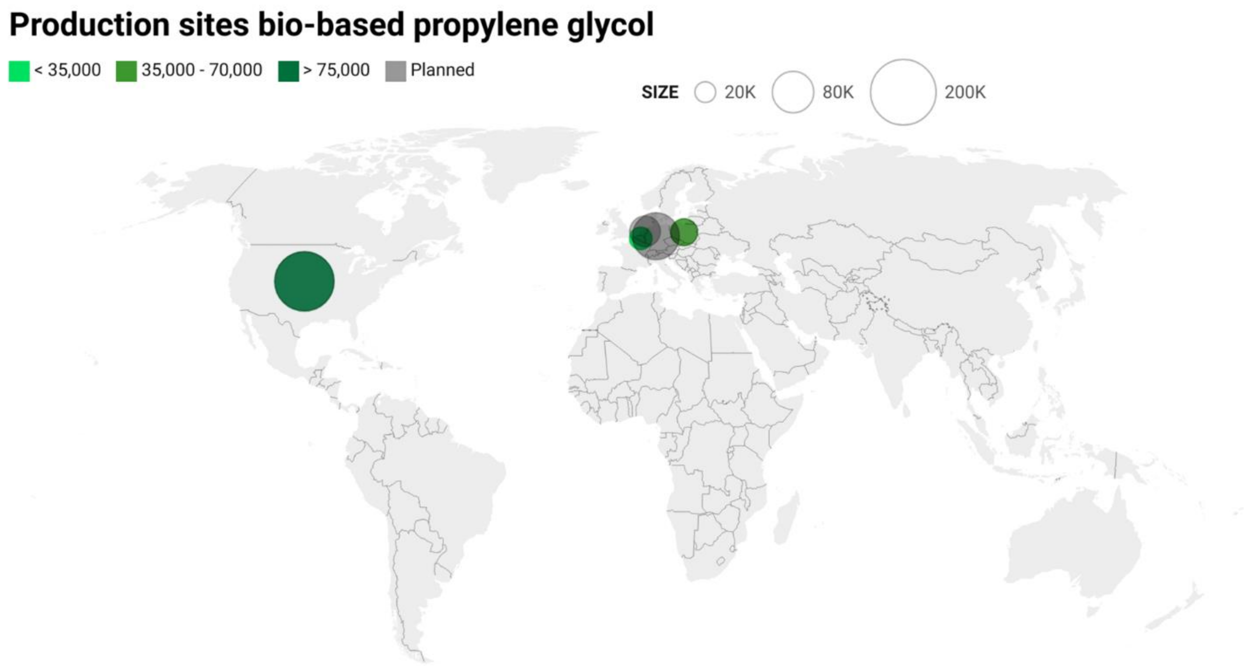

Figure 62, Production sites of bio-based propylene glycol

5.5 Polyurethane

Value chain description

Polyurethane is a collective name for a wide range of polymers obtained from reacting a polyol with a diisocyanate. Depending on the selected reactants and their corresponding characteristics, many different materials are obtained which are used in a wide range of applications. The use of two different reactants, each with its own production processes, results in an extensive value chain. Figure 63 shows a segment of this value chain, starting at the reactants that are required to obtain the polyol and diisocyanate. In turn, the polyol and diisocyanate are reacted to obtain the desired polyurethane. Although the figure shows a polyether polyol and methylene diphenyl diisocyanate (MDI) as the starting point for polyurethane production, many other types of polyols and diisocyanates are used in industry.

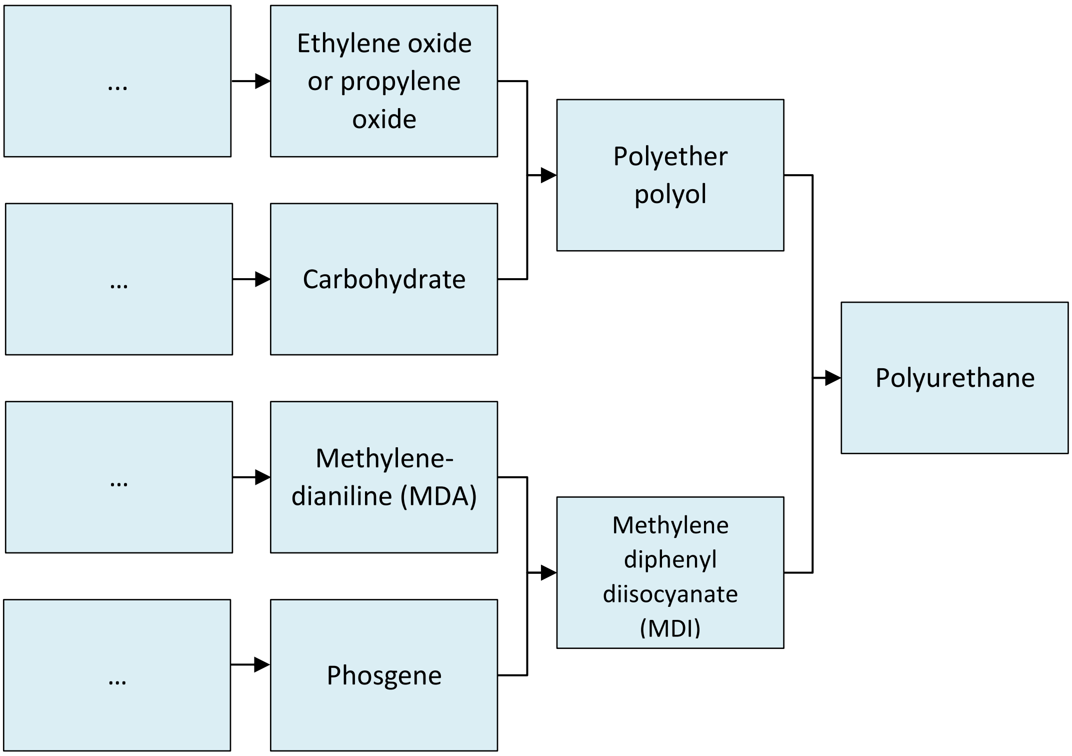

Figure 63, A segment of the polyurethane value chain

Production locations

The EU produced about 2.5 million tonnes of polyurethane in 2021, of which half was produced in Germany.

Polyurethanes are prepared by reacting two components: a polyol and an isocyanate. While the isocyanate is almost exclusively derived from petrochemical feedstocks, the polyol component can be produced from bio-based resources, such as castor, sunflower, rapeseed and soybean oil[95]. In order to produce (partially) bio-based polyurethane, polyether or polyester polyols should be produced from bio-based resources, or oleochemical polyols should be produced from vegetable oils.

- Sucrose, sorbitol and 1,3-propanediol can be used to produce polyether polyols.
- Succinic acid, adipic acid, ethylene oxide and propylene glycol could be produced using bio-based feedstocks and used as polyester polyols.
- Vegetable oils, such as soybean, castor, sunflower and rapeseed oils, can be used to produce vegetable oil-based polyols.

Bio-based polyurethane forms a small market. The global bio-based polyurethane market was estimated at 1.6 thousand tonnes in 2013, which was then expected to expand to 2.5 thousand tonnes in 2020[96].

The production, trade and consumption of bio-PUR could not be determined due to a lack of data. As the total expected production is estimated to be around 2,500 tonnes, the lack of data is not surprising. However, several companies producing partially bio-based polyurethane products were found. Covestro produces the partially bio-based PUR Impranil® eco[97]. Epaflex produces partially bio-based thermoplastic polyurethanes and Huntsman Polyurethanes has developed partially bio-based polyurethane products for the automotive and footwear industries[98][99].

Additionally, it was found that several companies produce bio-based polyols to be used in polyurethanes. Cargill produces polyols for polyurethanes from soybean oil, called BiOH. BASF produces Sovermol, a vegetable oil-based polyol[100]. Vertellus produces a polyol called POLYCIN, produced from castor oil[101].

Using the estimated global production of bio-PUR of 2.5 thousand tonnes, and a total production of polyurethane of almost 25 million tonnes in 2022[102], the bio-based share of polyurethane is estimated to be small, at around 0.01%.

[95] https://www.uu.nl/sites/default/files/copernicus_probip2009_final_june_2009_revised_in_november_09.pdf
[96] https://bioplasticsnews.com/2015/02/13/bio-based-polyurethane-pu-market-analysis-and-forecasts-to-2020/
[97] https://www.bio.org/sites/default/files/legacy/bioorg/docs/1030AM-%20Natalie%20Bittner.pdf
[98] https://www.epaflexpolyurethanes.com/products/tpu/epamet-tpus-bio-based-thermoplastic?id=67
[99] https://www.huntsman.com/docs/Documents/PU_Automotive_Bio_Based_Technologies.pdf
[100] https://www.basf.com/hk/documents/en/products-industries/paint-coating-industry/BASF_Sovermol_brochure.pdf
[101] https://vertellus.com/products/polycin-polyol-series/
[102] https://www.globenewswire.com/en/news-release/2022/10/5/2528659/0/en/Global-Polyurethane-Market-to-Worth-USD-91-2-Billion-by-2028-China-Produces-32-of-the-Global-Polyurethane-Industry-Vantage-Market-Research.html

Trade flows

As polyurethane is a drop-in chemical, with both a bio-based and fossil-based alternative, there is no specific data available about the trade flows for the bio-based alternative. Figure 64 shows the trade flows of all polyurethane, including both the bio-based and fossil-based counterparts. It should be taken into account that of these trade flows, an estimated 0.01% of polyurethane is estimated to be bio-based, and the remaining 99.99% is estimated to be fossil-based. As such, these trade flows might not be representative of the trade of bio-based polyurethane. Taking the estimated bio-based share of 0.01% and a total EU trade of 1.1 million tonnes of ethylene glycol, resulted in an EU trade figure of 110 tonnes of bio-based polyurethane.

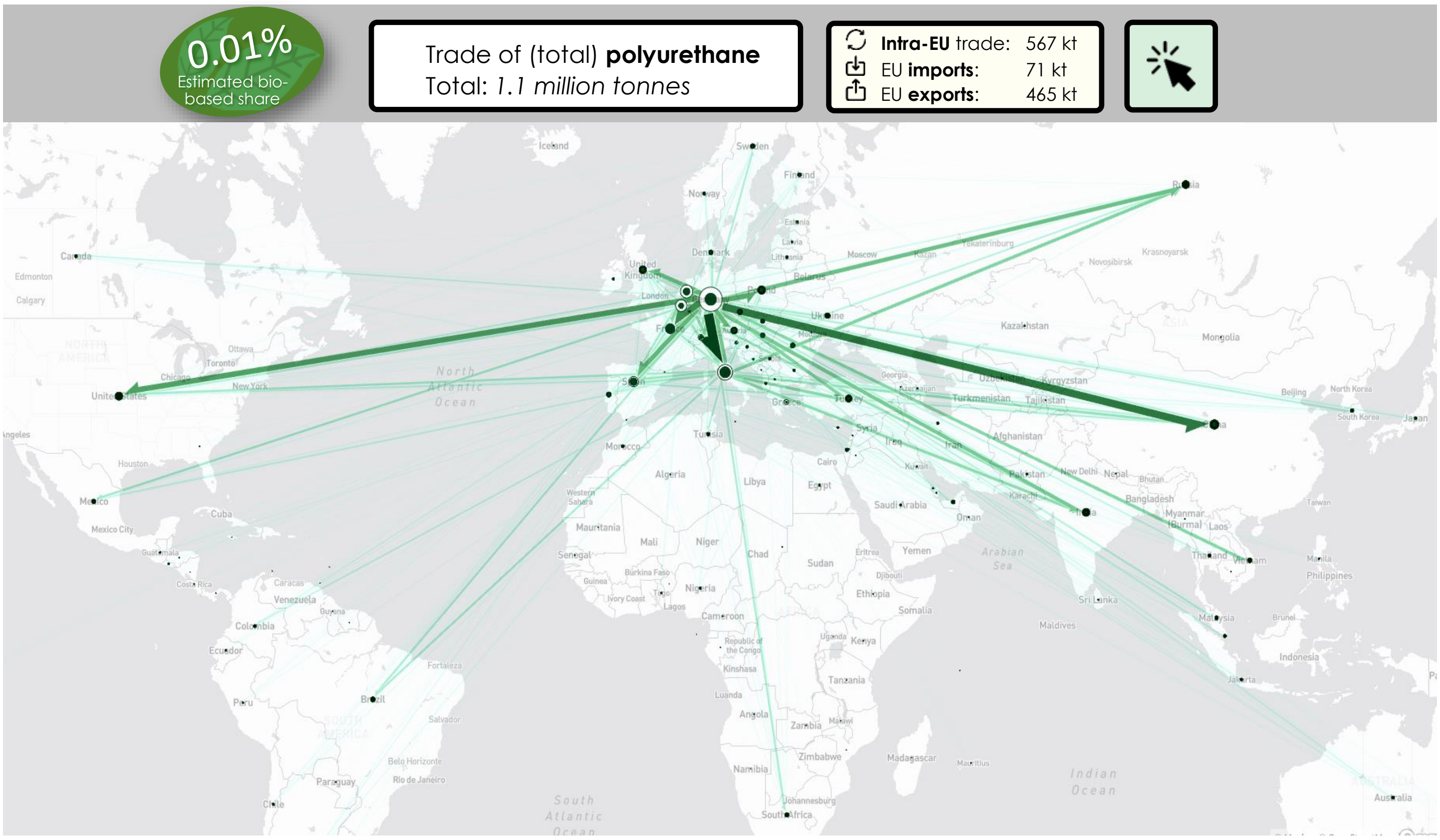

Figure 64, EU trade flows of (bio-based and fossil-based) polyurethane

5.6 Epichlorohydrin

Value chain description

Epichlorohydrin is an important intermediate for the production of epoxy resins. Its partially bio-based counterpart is produced from glycerine and hydrochloric acid. The glycerine is obtained as a by-product from bio-diesel production.[103] With each reactant having its own production process, the epichlorohydrin value chain is quite extensive. Figure 65 shows the segment of relevance for this study.

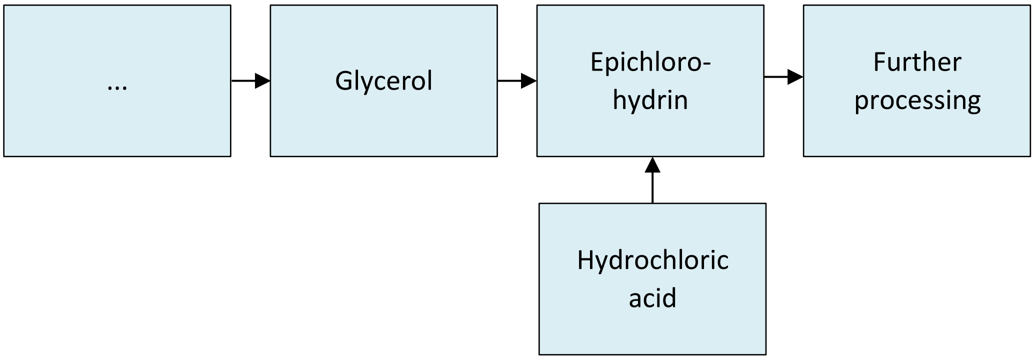

Figure 65, A segment of the bio-epichlorohydrin value chain

Production locations

About 90% of ECH output goes into the manufacture of epoxy resins. Epichlorohydrin can be produced using propylene and either acetic acid or chlorine but is increasingly more often produced using a new method with glycerine, a by-product from the production of bio-diesel.

INOVYN produces bio-ECH in its locations in Tavaux, France and Rheinberg, Germany, acquired from Solvay. These two locations have a total capacity of 50,000 tonnes per year[104]. In Czechia, Spolchemie produces bio-ECH with a capacity of 30,000[105]. In China, Jiangsu Yangnong Chemical Group produces 60,000 tonnes and Yihai Kerry (Wilmar Int.) 100,000 tonnes per year[106]. Advanced Biochemical Thailand, a part of the AGC group (previously Solvay) has an annual production of 120,000 tonnes[107].

Table 8, Production locations bio-based ECH

Company	Location	Capacity (ktonnes/year)
Europe		***80***
INOVYN	France, Germany	50
Spolchemie	Czechia	30
Asia		***280***
Jiangsu Yangnong Chemical Group	China	60
Yihai Kerry (Wilmar Int.)	China	100
Advanced Biochemical Thailand (AGC)	Thailand	120
Total		**360**

[103] B.M. Bell et al., 2008, Glycerine as a renewable feedstock for epichlorohydrin production. The GTE Process, Clean Soil Air Water, 36, p.657 – 661, DOI: 10.1002/clen.200800067
[104] Pagliaro, Mario. (2017). Glycerol: The renewable platform chemical.
[105] https://greenchemicalsblog.com/2012/09/14/biobased-ech-growing-rapidly/
[106] Pagliaro, Mario. (2017). Glycerol: The renewable platform chemical.
[107] https://bioenergyinternational.com/abt-increases-bio-based-epichlorohydrin-ech-capacity-to-120-000-tpa/

Additionally, several companies are planning to build bio-based epichlorohydrin plants. In 2021, Haiwan Chemical announced that it will be building the world's largest glycerol-based epichlorohydrin plant with an annual capacity of 150,000 tonnes, in Qingdao, China[108].

In 2018, the French company Technip Energies acquired Solvay's glycerine-to-epichlorohydrin technology[109]. In the same year, Technip signed an agreement with India-based Meghmani Finechem Ltd for a plant with an annual capacity of 50,000 tonnes of ECH from glycerine[110]. Additionally, OCIKUMHO, a joint venture between Technip and the Malaysian company OCIM, signed an agreement in 2022 to build a plant with a capacity of 100,000 tonnes of ECH from glycerine in Malaysia[111].

Hexion plans to add 25,000 tonnes of glycerine-based epichlorohydrin to its site based in Pernis, the Netherlands in 2024[112].

Using the data from Table 8, the bio-based production of epichlorohydrin is estimated to be around 80 thousand tonnes in Europe and 360 thousand tonnes globally. Total production of epichlorohydrin, including fossil-based production, is estimated to be 265 thousand tonnes in Europe[113] and 2.16 million tonnes in 2022[114]. As such, the bio-based share of epichlorohydrin is estimated to be 30% in Europe and 17% globally.

[108] https://mcgroup.co.uk/news/20220316/epichlorohydrin-market-opportunities-challenges.html
[109] https://www.technipfmc.com/en/media/news/2018/03/technipfmc-acquires-epicerol-technology-from-solvay/
[110] https://www.technipfmc.com/en/media/news/2019/10/technipfmc-announces-first-technology-license-for-epichlorohydrin-from-renewable-feedstock-in-india/
[111] https://www.bioplasticsmagazine.com/en/news/meldungen/20220518-epicerol.php
[112] https://www.mrchub.com/news/397228-hexion-to-add-epichlorohydrin-capacity-at-pernis
[113] https://publications.jrc.ec.europa.eu/repository/handle/JRC112989
[114] https://www.statista.com/statistics/1245160/epichlorohydrin-market-volume-worldwide/

Trade flows

As epichlorohydrin is a drop-in chemical, with both a bio-based and fossil-based alternative, there is no specific data available about the trade flows for the bio-based alternative. Figure 64 shows the trade flows of all polyurethane, including both the bio-based and fossil-based counterparts. It should be taken into account that of these trade flows, an estimated 30% of epichlorohydrin produced in Europe is estimated to be bio-based, and the remaining 70% is estimated to be fossil-based. The EU imports relatively small amounts of epichlorohydrin from countries outside of Europe, where the bio-based share is estimated to be lower, around 17%. Estimating that the 17 thousand tonnes of EU imports have a bio-based share of 17%, while intra-EU trade and EU exports have a bio-based share of around 30%, the bio-based share of the EU traded epichlorohydrin is around 28.6%.

Taking this bio-based share of 28.6% and the total EU trade of 160 thousand tonnes of epichlorohydrin, resulted in an EU trade figure of 46 thousand tonnes of bio-based epichlorohydrin.

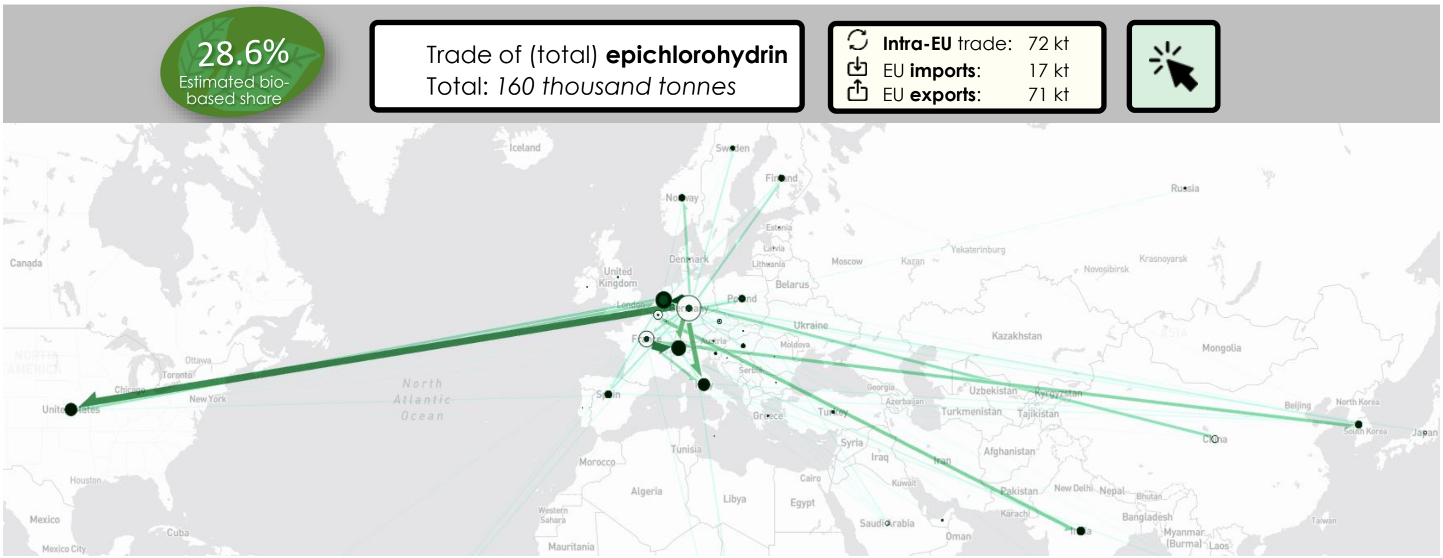

Figure 64, EU trade of total (fossil and bio-based) epichlorohydrin

The production sites of bio-based epichlorohydrin (presented in Table 8) are visualized in Figure 66. The figure shows the production locations and capacities of the identified companies. While the exact trade flows of the bio-based epichlorohydrin are unknown, the geographical distribution of production sites can help determine the relevant bio-based trade flows.

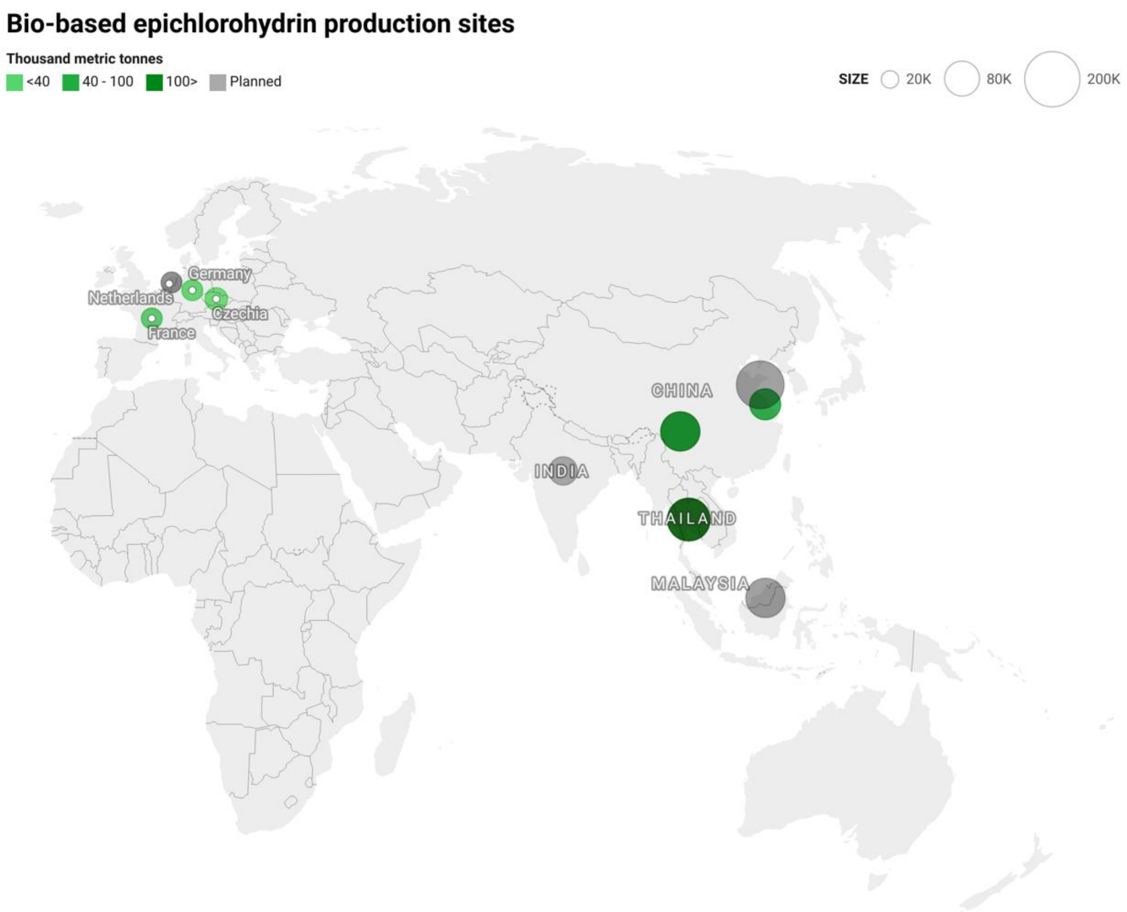

Figure 66, Production locations bio-based ECH

5.7 Polypropylene (PP)

Value chain description

Polypropylene is an extensively used commodity plastic, and finds its use in non-woven textiles, in packaging, in the medical field (syringes and petri dishes) and many other applications. Biobased polypropylene can be produced through many methods, [115, 116] of which two are identified to be applied on a commercial scale. The first method uses spent cooking oil as its feedstock. Cooking oil is refined to bio-based naphtha and subsequently cracked to obtain biobased propylene (see Figure 67).[115] Next, propylene is polymerized and biobased polypropylene is obtained. The second method involves the fermentation of sugar (derived from sugar cane) into ethanol, followed by dehydrogenation to obtain ethylene. Ethylene is subsequently converted into butene, and the following metathesis reaction of butene and ethylene results in the formation of propylene. Again the final step involves polymerization of biobased propylene into biobased polypropylene.

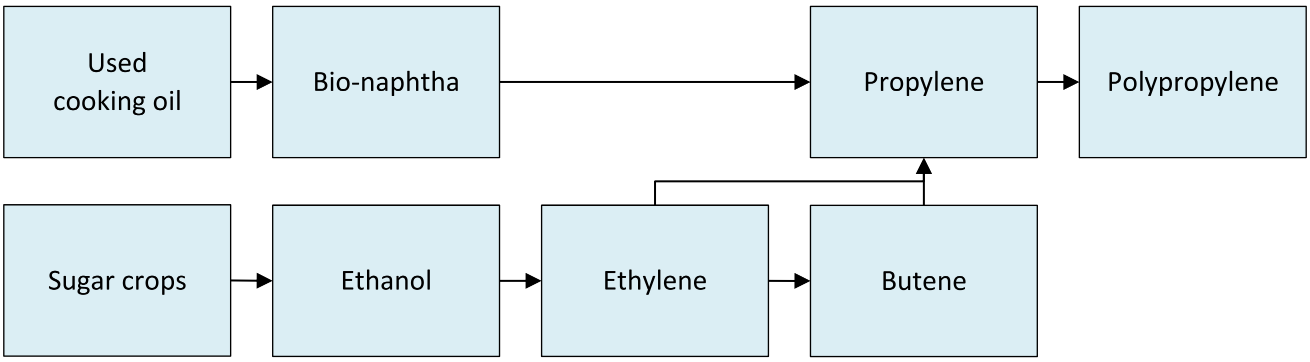

Figure 67, Bio-based polypropylene value chain

Production locations

According to European Bioplastics, global production of bio-based plastics was estimated to be 2.2 million tonnes in 2022, of which 26.5% was produced in Europe. A little less than 4% of bio-based plastics are polypropylene. As such, global bio-based polypropylene production would be around 86.5 thousand tonnes in 2022 according to European Bioplastics. Other sources report lower values, with market research reports stating that the global annual bio-based polypropylene production is about 28.91 tonnes[117]. The main drivers of the growth of bio-based plastics production are Polypropylene (PP), polyamide (PA), and polyethylene (PE). Polypropylene is estimated to have a 6% share of the 6.3 million tonnes of bio-based plastics produced in 2027. Total bio-based polypropylene production would then be around 378 thousand tonnes in 2027[118].

Neste has several partnerships for the production of bio-based polypropylene. LyondellBasell produces bio-based polypropylene using Neste's renewable hydrocarbons at its site in Wesseling, Germany[119]. The bio-based PP has a bio-based content of approximately 30%. While the exact production numbers of the project are unknown, it is of a scale of between 5 to 10 thousand tonnes annually[120]. Borealis also started producing bio-based polypropylene based on Neste-produced feedstock in Kallo and Beringen, Belgium[121]. IKEA and Neste have also started a pilot, in which waste and residues, such as cooking oil, are used to produce polypropylene (PP)

[115] C. Moretti et al, 2020, Environmental life cycle assessment of polypropylene made from used cooking oil, Published in Resources, conservation and recycling, 157, 104750, DOI: 10.1016/j.resconrec.2020.104750
[116] IEA Bioenergy, 2020, Bio-based chemicals – A 2020 update, available from: https://www.ieabioenergy.com/wp-content/uploads/2020/02/Bio-based-chemicals-a-2020-update-final-200213.pdf
[117] https://www.mordorintelligence.com/industry-reports/bio-based-polypropylene-market
[118] https://www.european-bioplastics.org/market/#
[119] https://www.plasticsnews.com/news/lyondellbasell-neste-making-bio-based-ldpe-pp
[120] https://biokunststofftool.de/materials/bio-pp/?lang=en#1549380148492-8a0fdf8c-09e3
[121] https://www.borealisgroup.com/news/borealis-producing-certified-renewable-polypropylene-at-own-facilities-in-belgium

and polyethylene (PE) plastic[122]. Mitsui Chemicals is also producing polypropylene using Neste's bio-based hydrocarbons as feedstocks.

The company SABIC also produces (partially) bio-based PP, mainly for packaging solutions which is applied in products by Nivea[123] and Mattel[124]. SABIC has a production plant for circular polymers in Geleen, the Netherlands[125].

In 2023, Braksem, a large producer of fossil-based polypropylene, announced that it is evaluating possibilities of producing bio-based polypropylene plastics from bioethanol in the US[126]. In the same year, Citroniq announced its plans to construct a bio-based polypropylene plant in the US, with an annual capacity of 450,000 tonnes. According to Citroniq, this is 20 times more than the current global production of bio-based polypropylene[127]. This would mean that the current global production levels are around 22,500 tonnes.

As such, the production of bio-based polypropylene is estimated to be between 22.5 and 86.5 thousand tonnes, which can increase to over half a million tonnes after the construction of the Citroniq plant. Global production of polypropylene (including both fossil-based and bio-based) is estimated to be around 97.65 million tonnes in 2022[128]. As such the bio-based share of polypropylene is currently between 0.023% and 0.089% and may potentially increase to over 0.5% of global polypropylene production.

122 https://www.neste.com/releases-and-news/renewable-solutions/ikea-and-neste-take-significant-step-towards-fossil-free-future
123 https://renewable-carbon.eu/news/beiersdorf-selects-sabic-certified-renewable-pp-for-new-nivea-packaging/
124 https://www.bioplasticsmagazine.com/en/news/meldungen/20220404-Mattel.php
125 https://www.sabic.com/en/newsandmedia/stories/our-world/sabics-circular-solutions-helping-to-address-key-sustainability-challenges
126 https://greenchemicalsblog.com/2023/01/19/braskem-mulls-bio-pp-plant-in-the-usa/
127 https://www.plasticstoday.com/automotive-and-mobility/bio-pp-capacity-beckons-usa
128 https://www.offshore-technology.com/energy/asia-global-polypropylene-capacity-2027/#:~:text=Global%20polypropylene%20capacity%20is%20poised,%2C%20an%20expansion%20of%2063%25.

Trade flows

As polypropylene is a drop-in chemical, with both a bio-based and fossil-based alternative, there is no specific data available about the trade flows for the bio-based alternative. Figure 68 shows the trade flows of all polypropylene, including both the bio-based and fossil-based counterparts. It should be taken into account that of these trade flows, less than 0.1% of polypropylene produced is estimated to be bio-based, and the remaining 99.9% is estimated to be fossil-based. As such, the data presented below might not be representative of the trade flows of bio-based polypropylene. Taking the bio-based share calculated before, of between 0.023% and 0.089% and the total EU trade of 7.5 million tonnes of polypropylene, resulted in an EU trade figure estimated to be between 172 thousand to 666 thousand tonnes of bio-based polypropylene.

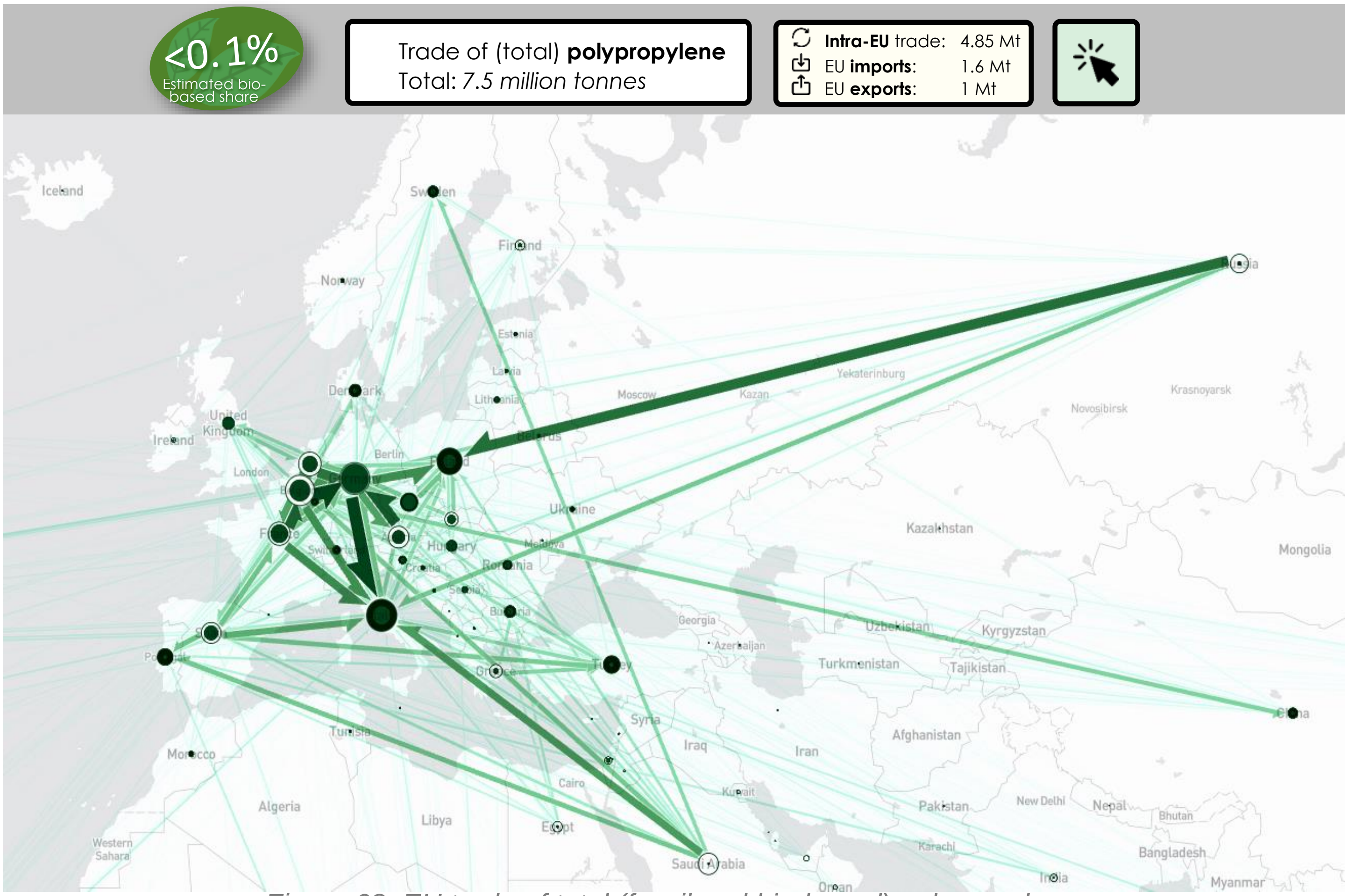

Figure 68, EU trade of total (fossil and bio-based) polypropylene

The companies producing bio-based polypropylene are mapped in Figure 69. While the exact production number is unknown for these companies, the geographical distribution of production sites can help determine the relevant bio-based trade flows.

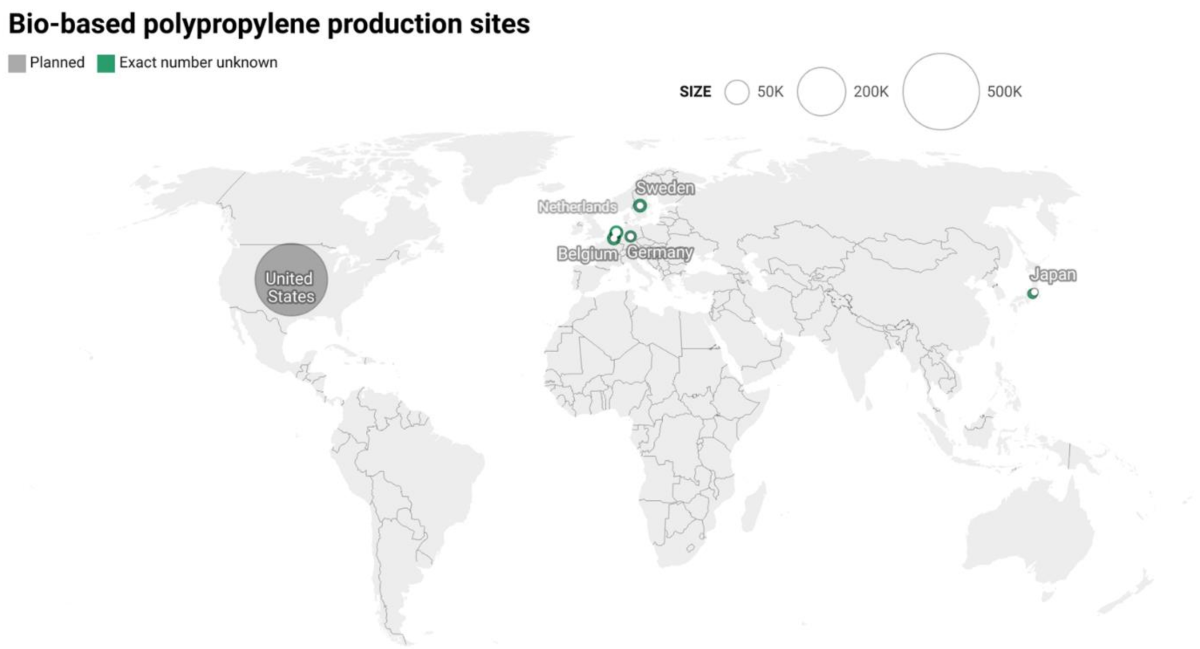

Figure 69, Production sites of bio-based polypropylene

5.8 Summary of trade bio-based drop-in chemicals

The trade data presented in Chapter 5 is summarized in Table 9. The table shows the total trade of the chemicals, the trade within the EU, and trade to and from countries outside of the EU. Additionally, estimations about the bio-based share of the chemicals were made and translated to estimations of bio-based trade figures. The largest importers and exporters (to/from the EU) are also shown, as well as known production locations for the bio-based drop-in chemical. The data from Table 9 is visualized in Figure 70.

Table 9, Summary trade data bio-based drop-in chemicals

Trade of drop-in chemicals *(thousand tonnes)*	**Total EU trade**	**Intra-EU**	**EU imports**	**EU exports**	**Largest importers (from EU countries)**	**Largest exporters (to EU countries)**
Ethylene	**2,929**	2,123	630	176	Belgium, Germany, Netherlands	Netherlands, Germany, Belgium
Bio-based share: 0.3%	**9**	6	2	1		*Known producers: Brazil, India*
Ethylene glycol	**1,867**	1,108	618	141	Germany, Belgium, Spain	Belgium, Saudi Arabia, Germany
Bio-based share: 0.7%	**13**	8	4	1		*Known producers: India*
Propylene glycol	**527**	388	30	109	France, Belgium, Netherlands	Germany, Netherlands, Spain
Bio-based share: 8%	**42**	31	2	9		*Known producers: United States, Poland, Belgium*
Polyurethane	**1,103**	567	71	465	Germany, Italy, France	Germany, Italy, Netherlands
Bio-based share: 0.01%	**0**	0	0	0		
Epichlorohydrin	**160**	72	17	71	Netherlands, Switzerland, United States	Germany, France, Netherlands
Bio-based share: 28.6%	**46**	21	5	20		*Known producers: China, Thailand, France, Germany, Czech Republic*
Polypropylene	**7,477**	4,842	1,604	1,030	Italy, Germany, Poland	Germany, Belgium, Netherlands
Bio-based share: 0.06%	**4**	3	1	1		*Known producers: Netherlands, Belgium, Germany, Sweden, Japan*

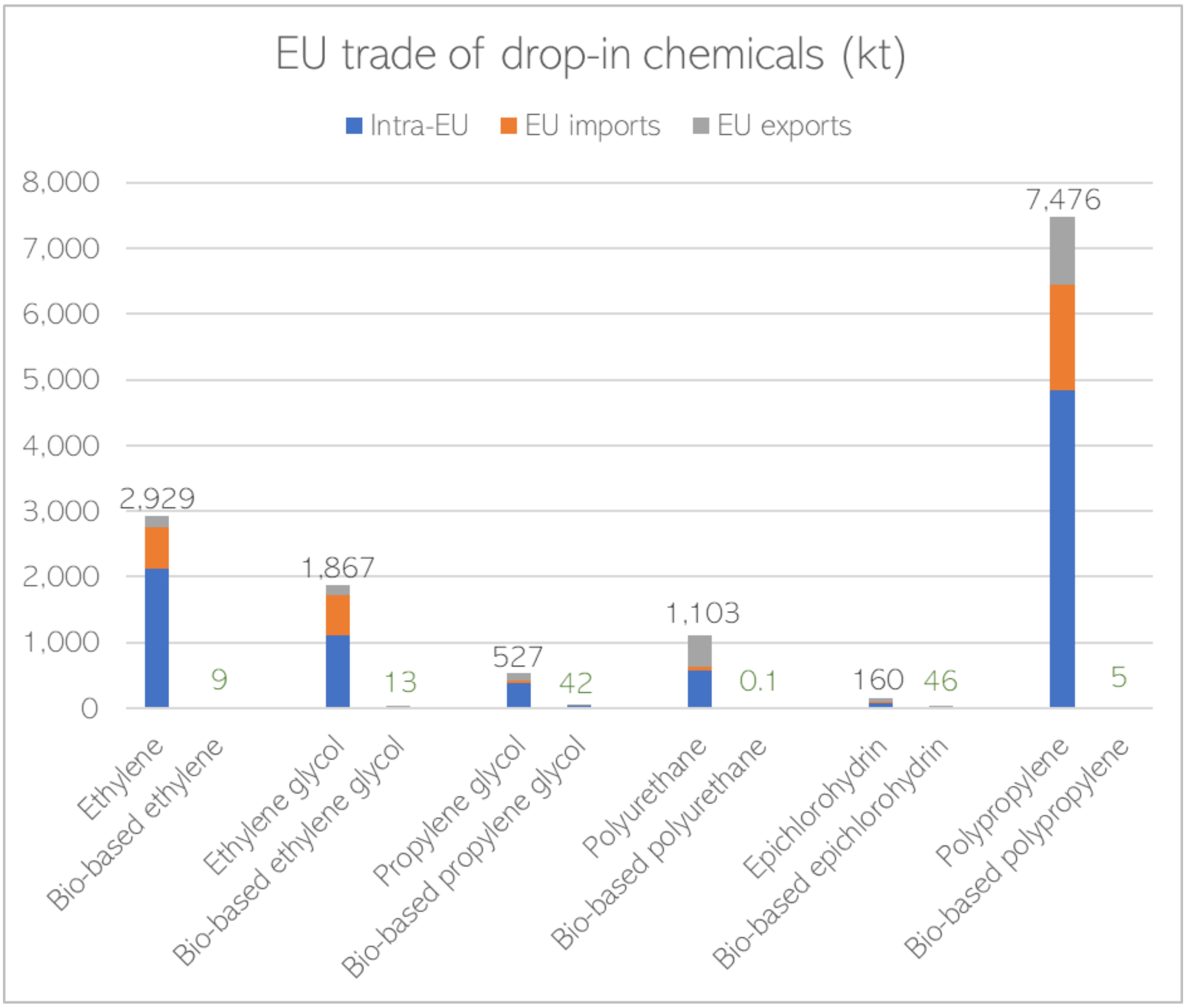

Figure 70, EU trade of bio-based drop-in chemicals (thousand tonnes)

6 Fibre-based products

This chapter gives an overview of the value chains and trade flows of the main fibre crops used for textiles, namely, cotton, flax, jute and hemp.

6.1 Flax

As is shown in Figure 71, Flax is made from fibres from the flax plant. These processed flax fibres, known as linen, are mostly (60%) used for clothes, (15%) for home textiles and (25%) for other apparel. The production of flax linen fibres is estimated at 1.1 million tonnes in 2021[129]. Approximately 85% of flax for linen is grown in European countries, with the biggest producer being France[130].

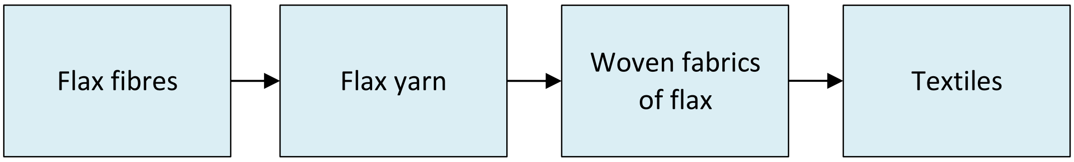

Figure 71, Value chain flax

6.1.1 Flax fibres

As can be seen in Figure 72, the production of flax in Europe is primarily occurring in France. In 2021, France produced over 678 thousand tonnes of flax. The second largest producer is Belgium, which produced 87 thousand tonnes, followed by the Netherlands with 11 thousand tonnes.

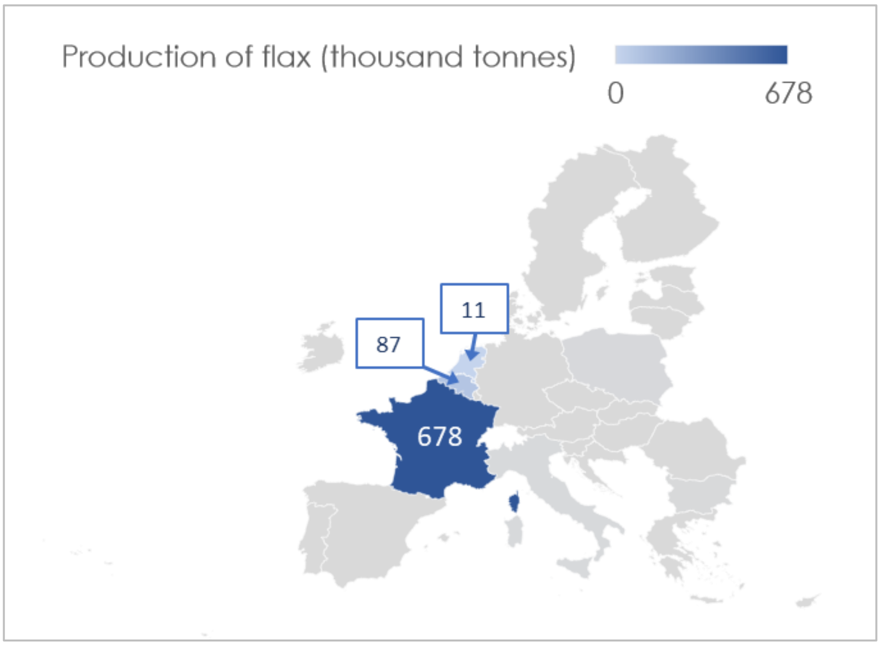

Figure 72, EU production of flax, data from Eurostat

The EU trade flows of flax, shown in Figure 73, also visualize France's role in the European flax market. The EU trades more than half a million tonnes of flax, of which over half is traded within Europe. Over 200 thousand

[129] https://www.moderndane.com/blogs/the-modern-dane-blog/what-is-flax-linen
[130] https://www.commonobjective.co/article/bast-fibres-size-of-production

tonnes are exported to countries outside of the EU, primarily to China. France exported about 145 thousand tonnes of flax to China, while Belgium exported 26 thousand tonnes. Within the EU, the biggest exporter is France, which exported almost 300 thousand tonnes in 2021, which is almost half of its production in the same year. The second biggest exporter is Belgium, which exported almost 180 thousand tonnes of flax, more than twice its annual production. The biggest EU importer is Belgium (128 kt), followed by the Netherlands (96 kt). This indicates that Belgium is also a major re-exporter of flax, which is to be expected since a lot of trade occurs in the Belgian harbours.

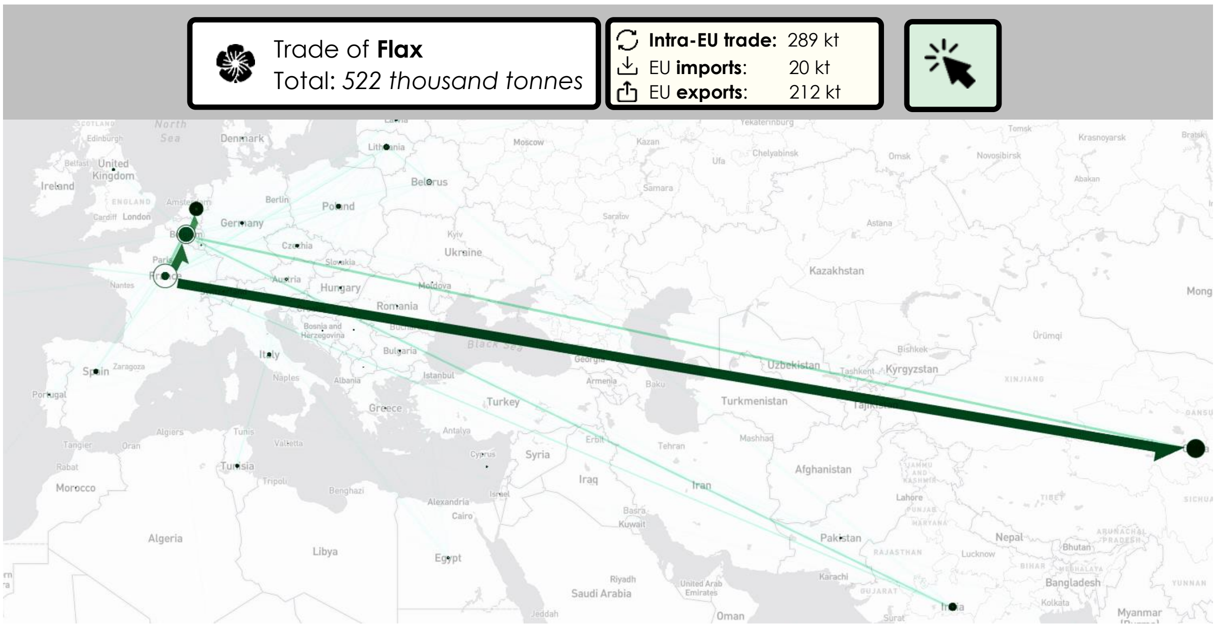

Figure 73, EU trade flows of flax

6.1.2 Flax yarn

As can be seen in Figure 74, the EU has an annual trade of about 27 thousand tonnes of flax yarn, which is relatively low. About half of this is traded within the EU and the other half is imported from countries outside of the EU, such as China and Tunisia. The largest EU importers of flax yarn are Italy (8.7 kt), Portugal (4.8 kt), and the Netherlands (4.4 kt). The largest EU exporters are Italy (3 kt), Poland (2.6 kt) and France (2.5 kt). The largest exporters outside of the EU are China (9.8 kt) and Tunisia (2.5 kt).

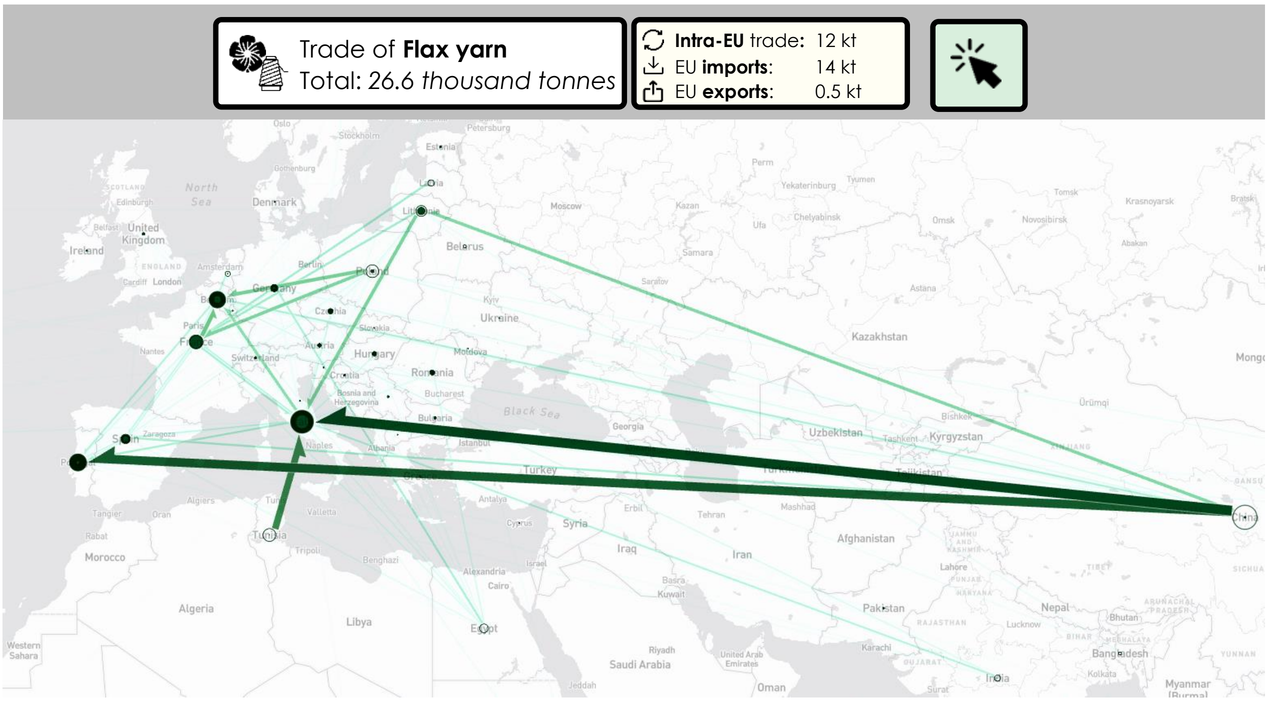

Figure 74, EU trade of flax yarn

6.1.3 Woven flax fabrics

As can be seen in Figure 75, the EU traded almost 30 thousand tonnes of woven flax fabrics in 2021. Of this, about half (14 kt) was imported from countries outside of the EU, 5.6 kt was exported, and 10 kt was traded within the EU. The EU's largest importers of woven flax fabrics are Italy (5.3 kt), Spain (4 kt) and Lithuania (2.3 kt). The EU's largest exporters of woven flax fabrics are Italy (3.7 kt), Belgium (2.7 kt), and the Netherlands (1.5 kt). Outside of the EU, the largest importer is the United States (1.4 kt), and the largest exporter is China (9 kt).

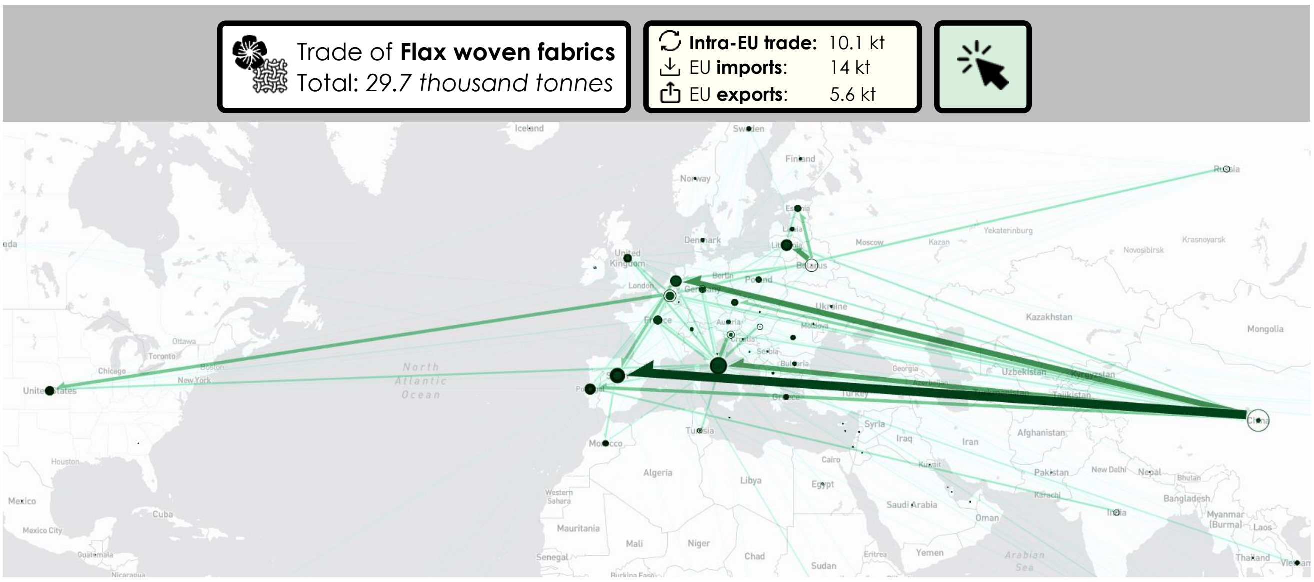

Figure 75, EU trade of woven flax fabrics

6.2 Hemp

Hemp is a species in the Cannabaceae family, with a very low level of THC and is primarily grown for industrial purposes. There are currently 75 different hemp varieties registered in the EU. Hemp production in the EU has increased rapidly in recent years, as it grew from 94 thousand tonnes in 2015 to 191 thousand tonnes in 2021.

As can be seen in Figure 76, the majority of the hemp produced in the EU originates from France. In 2021, France produced 141 thousand tonnes of hemp, followed by Poland with 15 thousand tonnes and the Netherlands with 13 thousand tonnes.

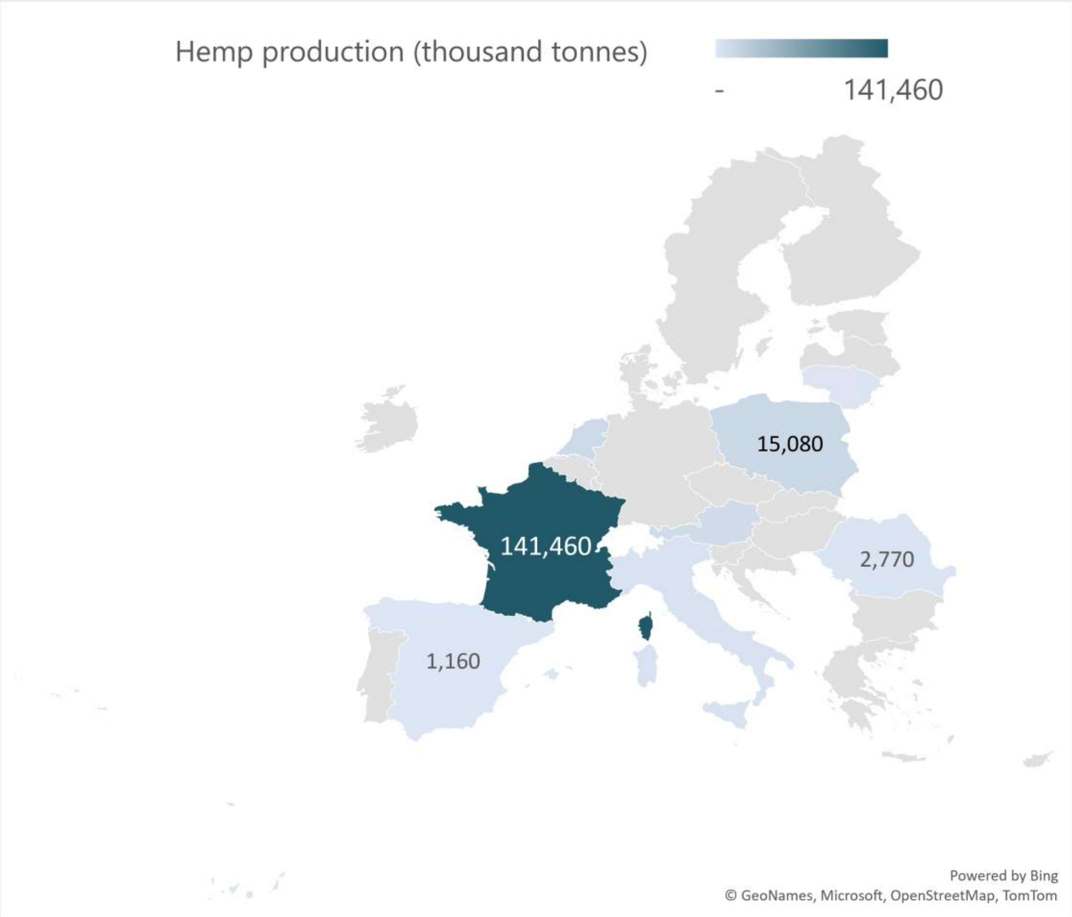

Figure 76, EU hemp production in 2021, data from Eurostat

Hemp fibres are used in various industries, including home textiles and apparel. Hemp fibres are also used to create hemp fibre paper and in the construction sector, where it is used to create lime hemp concrete, hemp wool and fibre-board insulation[131]. The production of hemp fibres for textiles is still relatively small with a market share of 0.2% of the entire fibre market. Hemp is estimated to have a global production value of 254,692 tonnes in 2021. As such, it is estimated that almost 75% of all hemp is produced in the EU.

[131] https://agriculture.ec.europa.eu/farming/crop-productions-and-plant-based-products/hemp_en

6.2.1 Hemp fibres

Figure 77 shows the EU trade of industrial hemp (Cannabis sativa L.). The EU traded 36 thousand tonnes of hemp in 2021, of which 31 thousand tonnes was within the EU, and 5 thousand tonnes was exported to extra-EU countries, such as the United States and China. The EU's largest importer is Spain (11 kt), the Netherlands (6 kt) and Germany (6 kt). Unsurprisingly, France is the largest exporter (19 kt), followed by the Netherlands (8 kt) and Germany (6 kt).

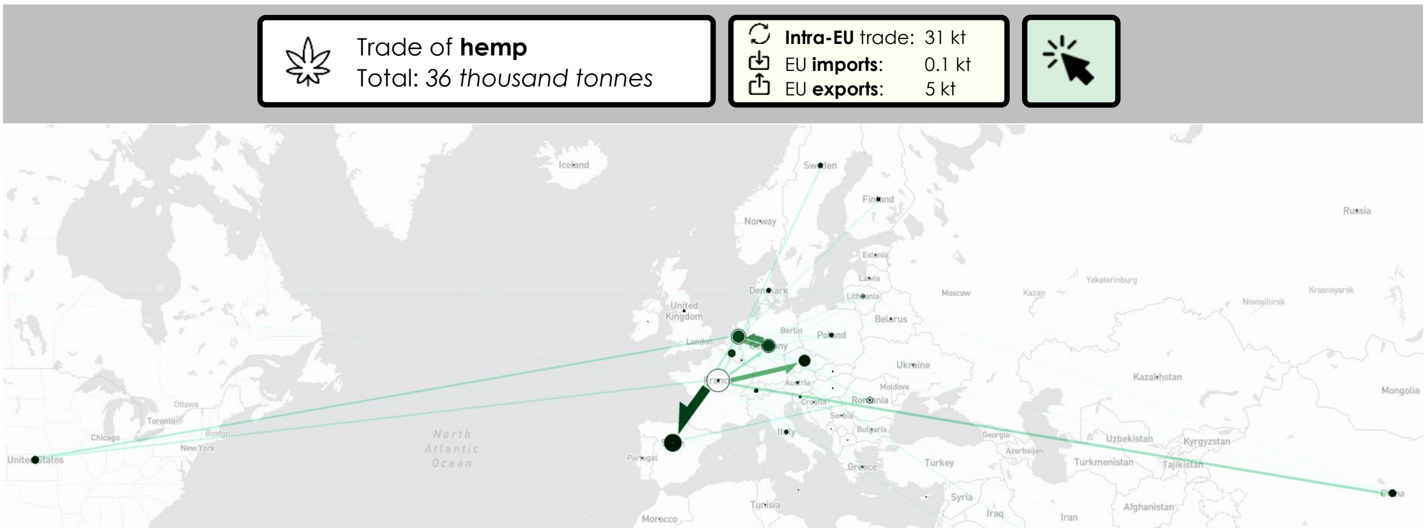

Figure 77, EU trade of industrial hemp

6.2.2 Hemp yarn

The hemp can then be spun into a yarn. Relatively small amounts of hemp yarn are being traded by the EU. In 2021, the EU traded 700 tonnes of hemp yarn, of which over half is imports, mostly from China. About 151 tonnes were traded within the EU and 187 tonnes were exported to extra-EU countries, such as the United States. The EU’s biggest importers of hemp yarn are Portugal (192 t), Italy (156 t) and the Netherlands (35 t). The EU’s biggest exporters are Romania (183 t), Germany (50 t) and Italy (41 t). Outside of the EU, the largest importer is the United States (181 t) and exporter is China (339 t). No data is available on the trade of hemp fabrics or textiles.

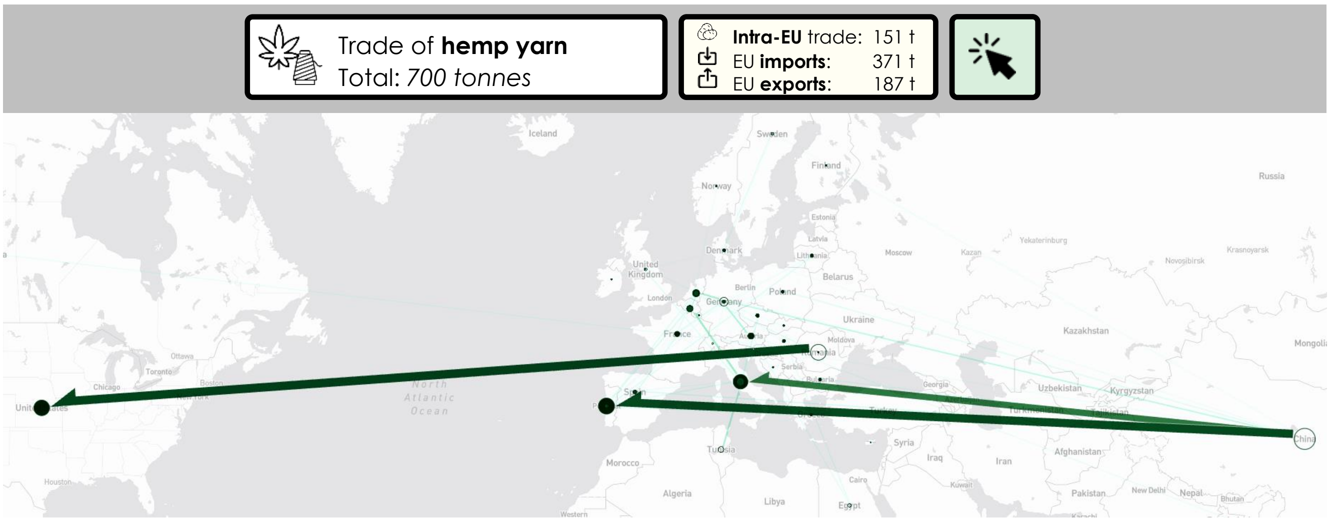

Figure 78, EU trade of hemp yarn

6.3 Jute

Jute is the second most commonly used plant fibre after cotton, with an annual production of 3.4 million tonnes globally. Jute originates from the bark of the white jute plant, as well as the tossa jute plant and is often used to make twine, ropes, matting and packaging materials such as sacks. Jute fibres can also be woven into other fabrics and blended with both natural and synthetic fibres[132]. The value chain of jute is presented in Figure 79.

The advantages of using bast fibres such as jute, flax and hemp are that they require small amounts of water and fertilizer and can grow on land that is unsuitable for food production. However, they are quite costly, and the spinning is known to be energy-intensive[133].

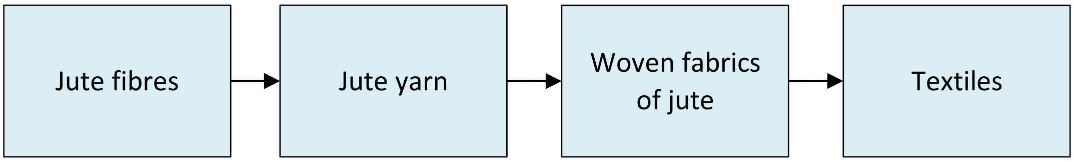

Figure 79, Value chain jute

Most of the world's jute production takes place in India and Bangladesh. India produces almost 2 million tonnes of jute annually and accounts for half of the world's exports of jute products. Bangladesh is also a major producer of jute, with an annual production of 1.3 million tonnes. These two countries are by far the largest producers. To put this into perspective, the number three producer of jute, China, has an annual production of less than 50 thousand tonnes of jute[134].

6.3.1 Jute fibres

In 2021, the EU traded 14.5 thousand tonnes of jute fibres. Of this, 9 thousand tonnes were traded within the EU, 5 thousand tonnes were imported, mostly from Bangladesh (4 kt), and half a tonne of jute fibres was exported to countries outside of the EU. The EU's largest importers of jute fibres are Germany (4 kt), Spain (2 kt) and France (2 kt). The largest EU exporters are Belgium (5 kt) and Germany (2 kt).

[132] https://www.fao.org/economic/futurefibres/fibres/jute/en/#:~:text=The%20Plant,July%2FAugust)%20to%20grow.
[133] https://ellenmacarthurfoundation.org/a-new-textiles-economy
[134] https://www.aristaexport.com/blog/top-jute-producing-in-the-world/

Figure 80, EU trade of jute fibres

6.3.2 Jute yarn

The jute fibres can then be spun into a yarn. As can be seen in Figure 81, in 2021, the EU traded 18 thousand tonnes of jute yarn, which is mostly imports (16.5 kt) from countries in Asia, such as India (4 kt) and Bangladesh (12 kt). The EU traded 1.5 thousand tonnes of jute yarn to other EU countries and exported 300 kg to countries outside of the EU. The EU's largest importers of jute yarn are Belgium (9 kt), Spain (2 kt), and Poland (2 kt).

Figure 81, EU trade of jute yarn

6.3.3 Woven fabrics of jute

The jute yarn can then be woven into a fabric. The EU traded 18 thousand tonnes of woven jute fabrics in 2021, which is primarily imported from India (11 kt) and Bangladesh (6 kt). Another 3.5 thousand tonnes of woven jute fabrics are traded within the EU and 1 tonne is exported to other countries. The EU's main importers of woven jute fabrics are the Netherlands (7 kt), Germany (6 kt) and Italy (2 kt). The EU's main exporters are Germany (3 kt), the Netherlands (1 kt) and Belgium (0.4 kt).

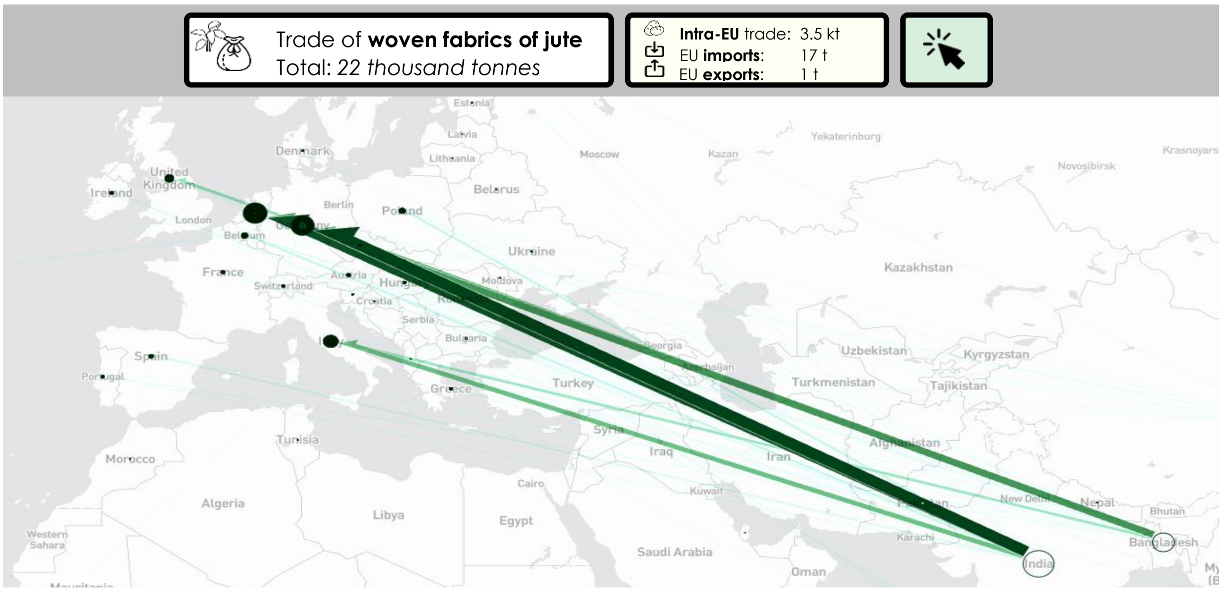

Figure 82, EU trade of woven fabrics of jute

6.4 Cotton

Cotton is cultivated mainly for its fibre, which grows around the cotton seed. [135] As shown in Figure 83, the cotton is ginned (seeds and fibres are separated) and the cotton fibre is then spun into the cotton fabric from which textiles are produced.

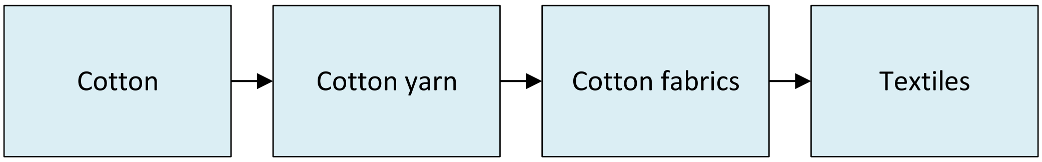

Figure 83, Cotton value chain

Cotton is sourced from the natural fibres of the cotton plant and is widely used in clothing, especially in t-shirts, jeans and underwear. Cotton fibres accounted for 22% of the global fibre market in 2021[136].

Cotton crops are mostly produced in dry tropical or sub-tropical climates. The main producers of cotton are India, China, the US, Brazil and Pakistan, together producing 75% of the world's cotton. As shown in Figure 84, the world's largest producer of cotton is China, which produced over 5.7 million tonnes of cotton in 2021, followed by India, with 5.2 million tonnes[137].

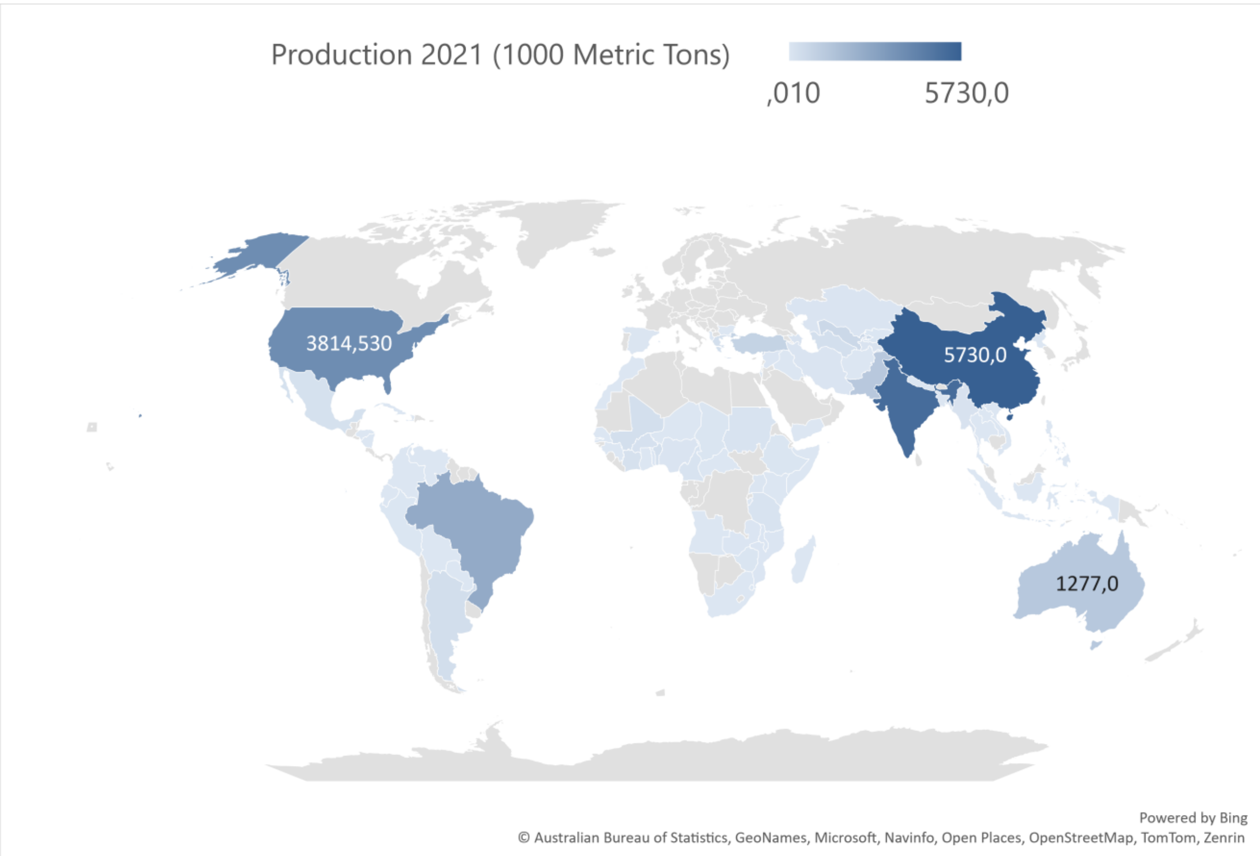

Figure 84, Global cotton production in 2021, data from World Population Review[137]

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[135] European Commission: Agriculture and rural development, https://agriculture.ec.europa.eu/farming/crop-productions-and-plant-based-products/cotton_en, accessed on August 25th 2023.

[136] https://www.fao.org/3/cc0308en/cc0308en.pdf

[137] https://worldpopulationreview.com/country-rankings/cotton-production-by-country

In the EU, cotton is almost exclusively produced in Greece and Spain. Greece has an annual production of 321,000 tonnes of cotton, of which almost half is ‘preferred cotton’. Preferred cotton has improved environmental and/or social sustainability outcomes and impacts compared to conventional cotton. Of Greece’s cotton production, 46% is ISCC-certified, and 0.6% is organic. Spain has an annual production of about 64,000 tonnes, of which 0.04% is organic and the other 99.96% is conventional cotton[138]. Nevertheless, cotton fibre produced in Europe is often exported and then re-imported as textiles, with 25% of the production returning to the European textile industry, which amounts to 40% of the domestic need. The value chain for cotton textiles commonly encompasses several countries. At each stage in the value chain (fibres, yarns, fabrics, textiles) import and export mass flows have to be considered.

6.4.1 Cotton fibres

Figure 85 shows the EU’s trade in cotton fibres. The total EU trade of cotton fibres is a little over half a million tonnes, which is relatively low. However, cotton is also traded in other forms, such as yarns, fabrics and textiles. A lot of cotton is processed into textiles in Asia, where it is also produced, before being exported to the EU.
Of the 541 thousand tonnes of EU trade of cotton fibres, 39 thousand tonnes are traded within the EU, 133 thousand tonnes are imported, and 370 thousand tonnes is exported to countries outside of the EU.
As was mentioned before, the only two countries in the EU that produce cotton on a larger scale are Greece (321 kt) and Spain (64 kt). Greece exported about 334 thousand tonnes of cotton in 2021, primarily to Turkey (217 kt) and Egypt (58 kt), where these fibres are likely to be further processed into yarn, fabrics or textiles. Spain exported about 36 thousand tonnes of cotton fibres in 2021, largely to Pakistan (10 kt) and Turkey (8 kt). The EU’s largest importers of cotton fibres are Italy (35 kt), Portugal (34 kt), and Germany (18 kt).

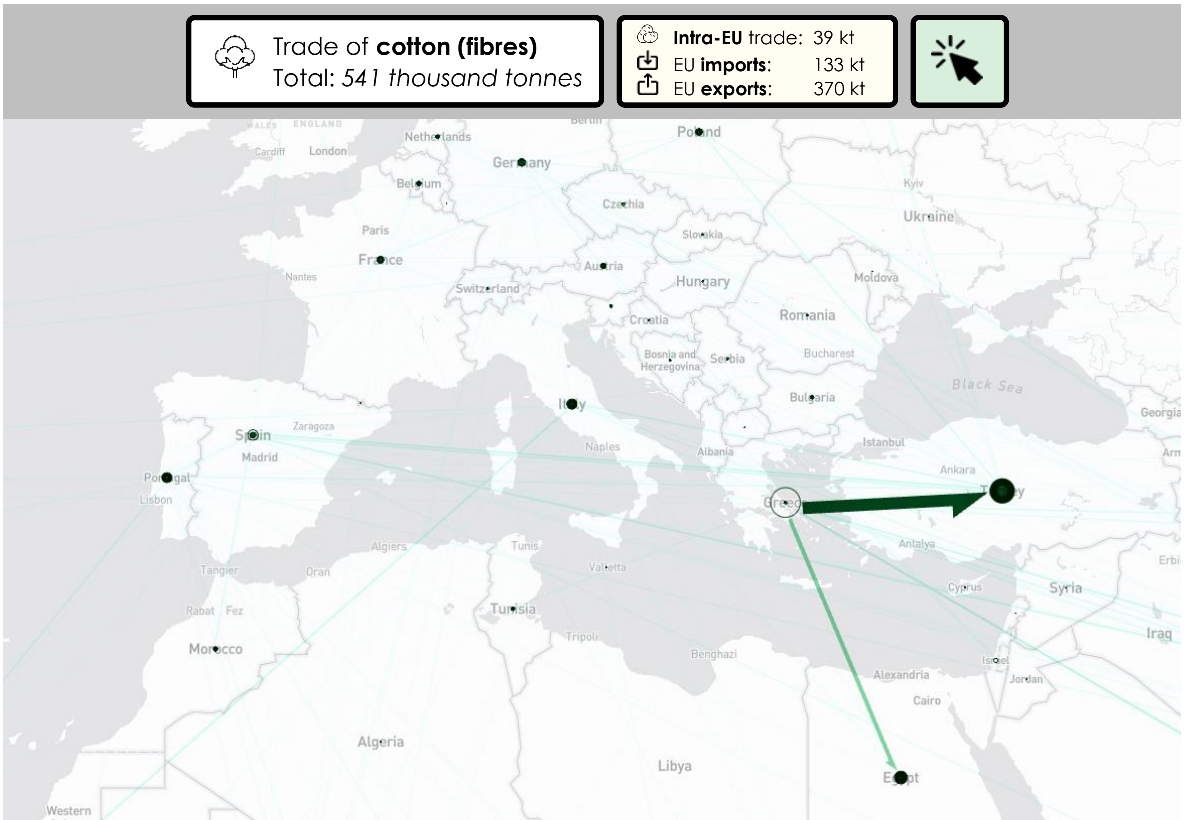


Figure 85, EU trade of cotton fibres

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

6.4.2 Cotton yarn

The cotton fibres can then be spun into a yarn. The EU traded about 400 thousand tonnes of cotton yarn in 2021, which is primarily imported from Asian countries. As shown in Figure 86, about 86 thousand tonnes of cotton yarn was traded within the EU, the EU imported 297 thousand tonnes and exported 14 thousand tonnes to countries outside of the EU. The EU's largest importers are Portugal (129 kt), Italy (75 kt) and Germany (46 kt). The EU's largest exporters are Spain (28 kt), Italy (22 kt), and Germany (14 kt). The EU's main trading partners are Turkey, which exported 130 thousand tonnes of cotton yarn to the EU, as well as other major exporters India (83 kt) and Pakistan (29 kt).

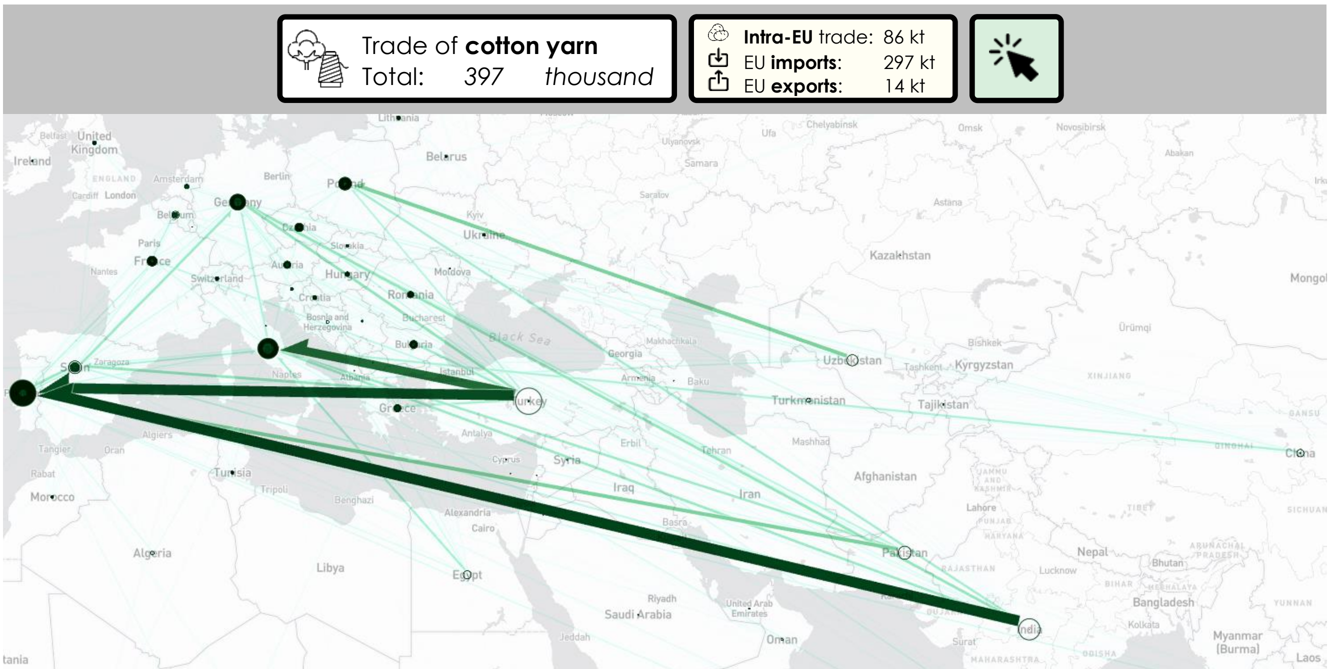


Figure 86, EU trade of cotton yarn

6.4.3 Woven cotton fabrics

The cotton yarn can then be woven into a fabric. As can be seen in Figure 79, in 2021, the EU traded a total of 336 thousand tonnes of woven cotton fabrics. Of this, 125 thousand tonnes were traded within the EU; 167 thousand tonnes were imported from countries outside the EU, mostly in Asia; and 45 thousand tonnes were exported to countries outside of the EU. The EU's main importers are Italy (59 kt), Belgium (36 kt), and Germany (33 kt). The EU's main exporters are Germany (32 kt), the Netherlands (30 kt) and Italy (29 kt). The EU's main trading partners are Pakistan, which exported 69 thousand tonnes of woven cotton fabrics to the EU, as well as Turkey (32 kt) and China (32 kt). The EU exported woven cotton fabrics to Northern Africa (Morocco and Tunisia), where these fabrics are likely processed into garments or other textile articles.

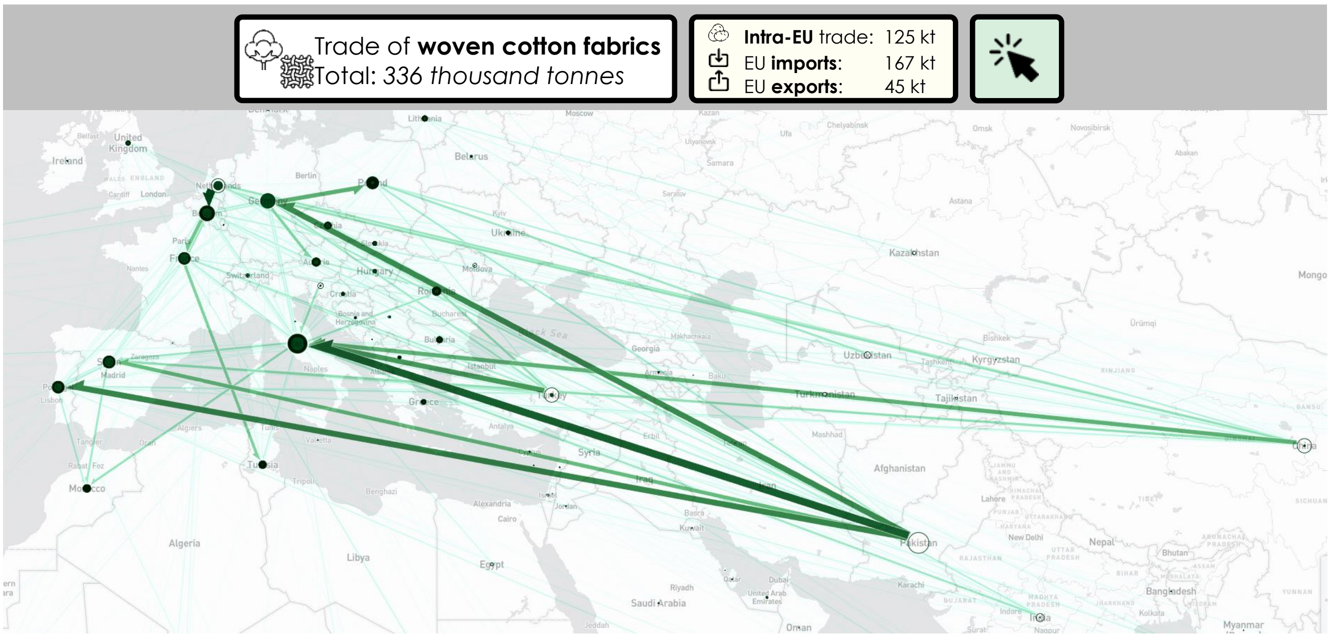


Figure 87, EU trade of woven cotton fabrics

6.5 Finished textile articles

Fabrics can be processed into textile articles. Most textiles are used to produce pieces of clothing, also known as garments. Textiles can also be used for various applications in the interior of homes, such as decorations, like curtains and carpets; or for comfort, like mattresses, sheets or blankets. Lastly, textiles can be used for various technical purposes. This includes protective clothing, medical textiles, transport textiles, industrial textiles, agrotextile and geotextiles.

Figure 88 shows the trade of all finished textile articles, also including textiles from materials other than cotton. In 2021, the EU traded over 16.6 million tonnes of finished textile articles. A large share of this (6.1 million tonnes) was traded within the EU. Over 7.4 million tonnes were imported from countries outside of the EU, mostly located in Asia, and 3.1 million tonnes were exported to countries all over the world.
The EU's largest importers of textile articles are Germany, which imported 2.6 million tonnes, as well as France (1.6 Mt), and the Netherlands (1.4 Mt). The EU's largest exporters are Germany (1.9 Mt), Netherlands (1.2 Mt), and Italy (0.9 Mt). The main exporters of textile articles to the EU are China (2.7 Mt), Bangladesh (1.2 Mt), and Turkey (1 Mt).

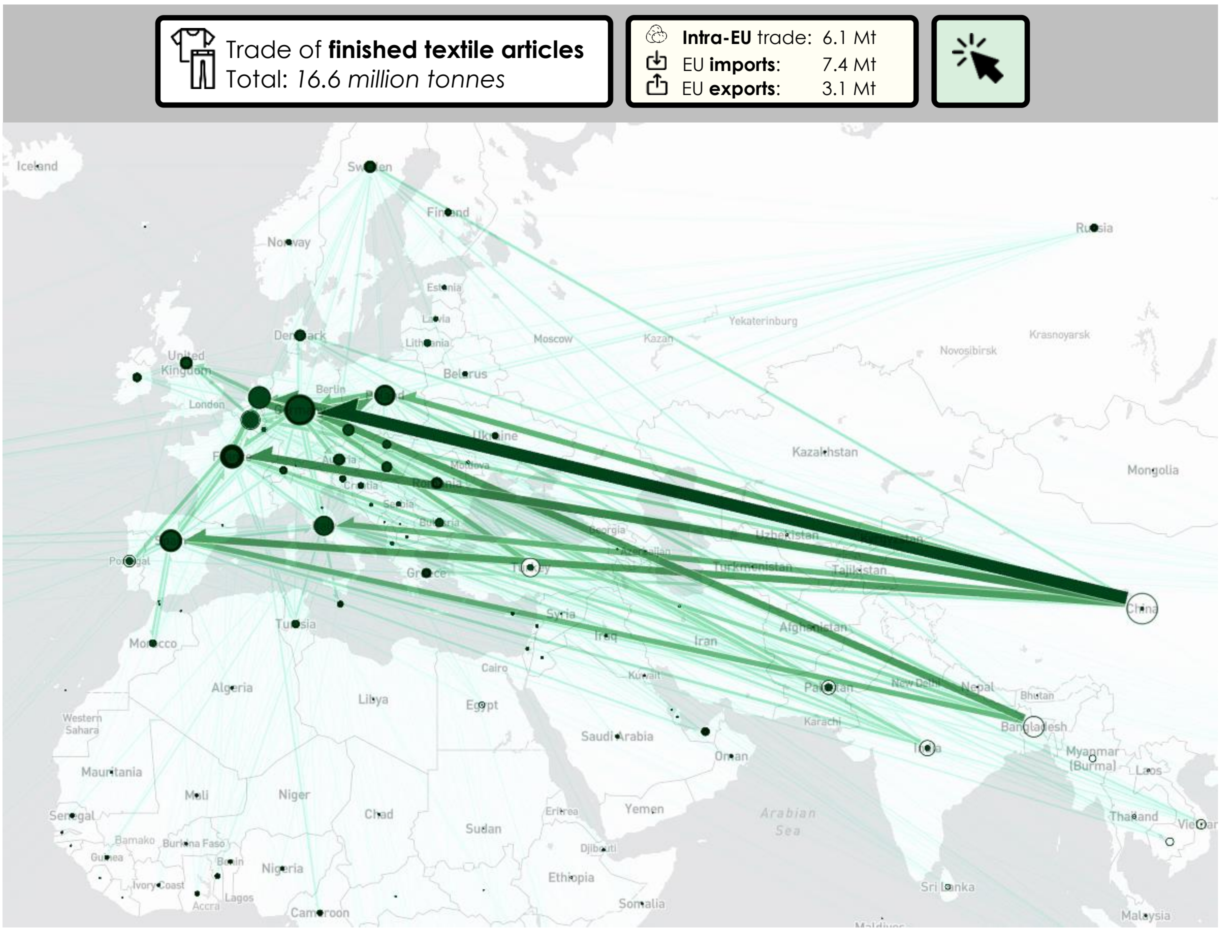


Figure 88, EU trade of finished textile articles

Using information from Textile Exchange[139] 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. As such the EU trade of cotton textile articles is estimated at 3.7 million tonnes, of which 1.3 million tonnes is traded within the EU, 1.6 million tonnes are imported, and 0.7 million tonnes is exported to countries outside of the EU.
- Jute is the second most commonly 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, with 183 thousand tonnes traded within the EU, 222 thousand tonnes imported, and 93 thousand tonnes exported.
- 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, with 61 thousand tonnes traded within the EU, 74 thousand tonnes imported, and 31 thousand tonnes exported.
- 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, of which 13 thousand tonnes is traded within the EU, 16 thousand tonnes imported, and 7 thousand tonnes exported.

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 of trade 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 importers (from EU countries)***	***Largest exporters (to EU countries)***
Finished textile articles	**16701**	6149	7442	3110	Germany, France, Netherlands	China, Germany, Netherlands
*Share cotton: **22%***	**3674**	1353	1637	684		*Large producers: China, India, United States*
*Share jute: **3%***	**501**	184	223	93		*Large producers: India, Bangladesh, China*
*Share flax: **1%***	**167**	61	74	31		*Large producers: France, Belgium, Netherlands*
*Share hemp: **0.22%***	**37**	14	16	7		*Large producers: France, Poland, Netherlands*

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

6.6 Summary of trade fibre crops and textiles

The trade data presented in Chapter 6 is summarized in Table 11. 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. The data from Table 11 is visualized in Figure 89 (on the next page). Additionally, Figure 90 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 11, Summary trade data fibre crops and textiles

Fibre & textile value chains *(thousand tonnes)*	***Total EU trade***	***Intra-EU***	***EU imports***	***EU exports***	***Largest importers (from EU countries)***	***Largest exporters (to EU countries)***
Flax fibres	**522**	289	20	212	China, Belgium, Netherlands	France, Belgium, Canada
Flax yarn	**27**	12	14	1	Italy, Portugal, Netherlands	China, Italy, Poland
Woven flax fabrics	**30**	10	14	6	Italy, Spain, Lithuania	China, Italy, Belgium
Cotton fibres	**541**	39	133	370	Turkey, Egypt, Italy	Greece, Spain, Turkey
Cotton yarn	**397**	86	297	14	Portugal, Italy, Germany	Turkey, India, Pakistan
Woven cotton fabrics	**336**	125	167	45	Italy, Belgium, Germany	Pakistan, Turkey, Germany
Industrial hemp fibres	**36**	31	0	5	Spain, Netherlands, Germany	France, Netherlands, Germany
Hemp yarn	**0.7**	0.1	0.4	0.2	United States, Portugal, Italy	China, Romania, Germany
Jute fibres	**15**	9	5	1	Germany, Spain, France	Belgium, Bangladesh, Germany
Jute yarn	**18**	2	16	0	Belgium, Spain, Poland	Bangladesh, India, Belgium
Woven fabrics of jute	**22**	4	17	1	Netherlands, Germany, Italy	India, Bangladesh, Germany
(all) finished textile articles	**16701**	6149	7442	3110	Germany, France, Netherlands	China, Germany, Netherlands

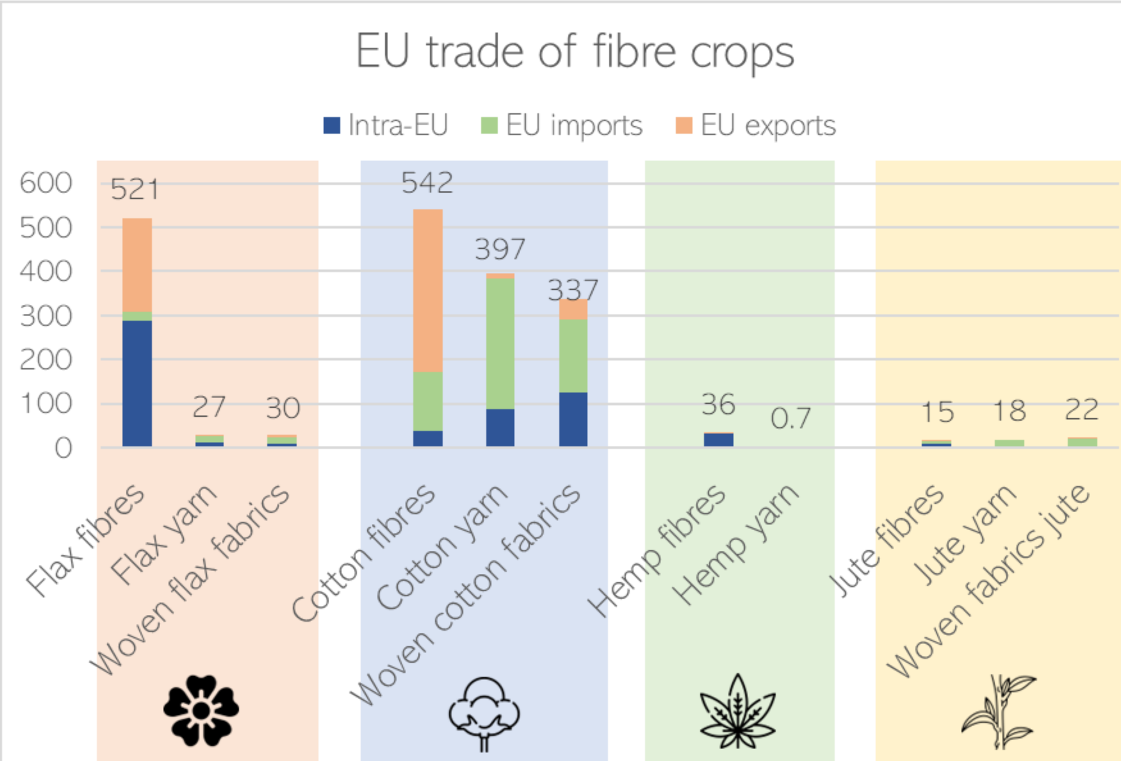


Figure 89, EU trade of fibre crops (thousand tonnes)

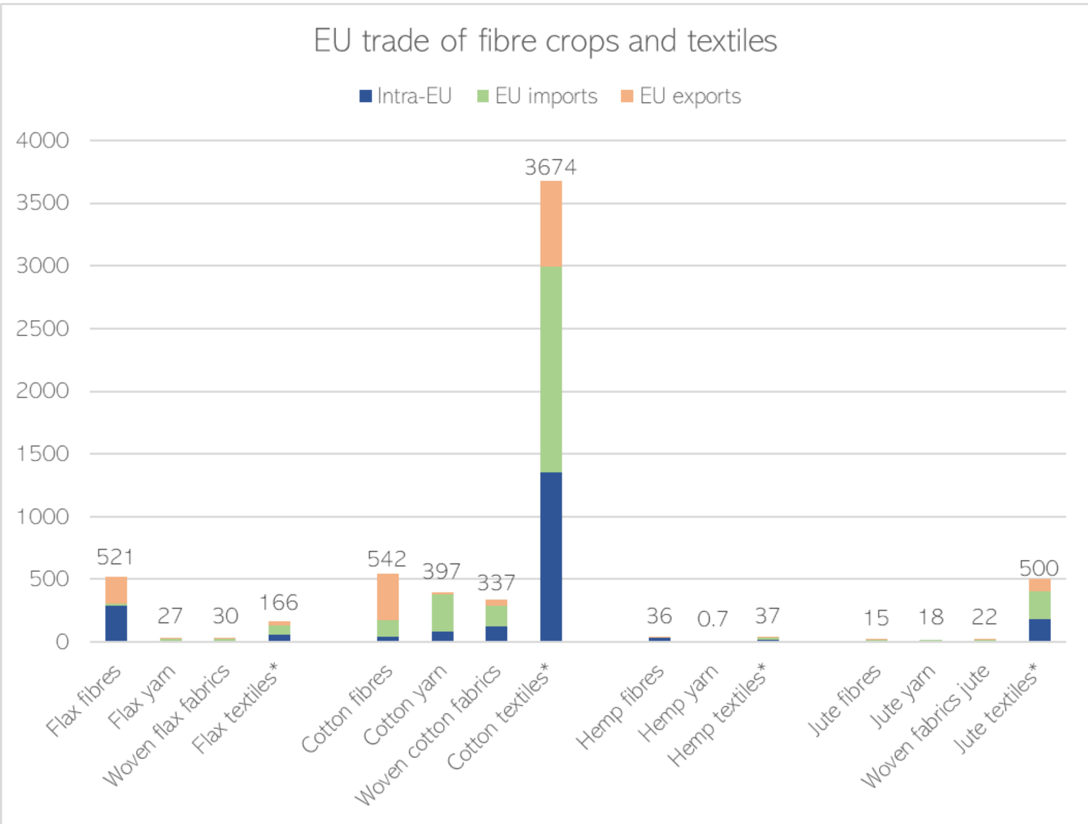


*Figure 90, EU trade of fibre crops and *estimations on trade of textile articles*

7 Wood-based products

This chapter gives an overview of the value chains of two wood-based products, sawn wooden products, and pulp and paper.

7.1 Sawn wooden products

Domestic and imported industrial roundwood is processed by sawmills into sawnwood by debarking, sawing lengthwise or by profile-chipping.

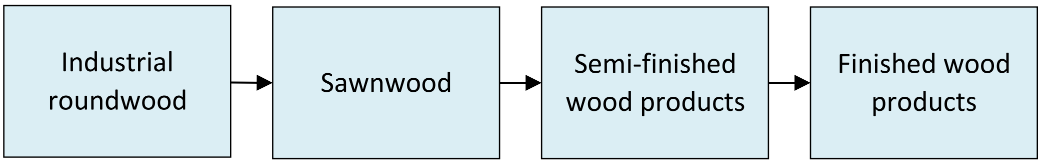


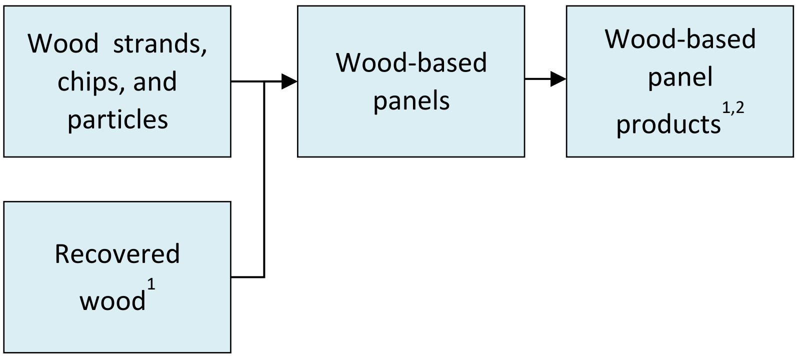
Figure 91, Sawnwood products value chain

Wood-based panel products: fibreboard and OSB

Wood-based panels are produced from wood fibres, wood particles and/or veneers that are bonded together with adhesives by plywood industries and particle board industries. Veneers are used by the plywood industry to produce plywood panels (not included in the selected materials). The particle board industry produces particle board (or chipboard), Medium Density Fibreboard (MDF), hardboard and Oriented Stranded Board (OSB) from small wood particles and other wood fibres (
Figure 92).

OSB is produced by compressing and gluing layers (wafers) of wood strands (flakes) that are coated with a water-resistant glue at different specific orientations into solid uniform OSB panels under heat and pressure. The different orientations provide strength and elastomechanical properties. These panels are then trimmed to the required dimensions of OSB products and packaged for distribution. The wood strands are long, thin chips that are produced from a variety of sources including wood from small logs, for example from thinning operations, sawmill residues and, in limited cases, also recovered wood.

MDF is produced by grounding wood chips or other wood into wood fibres. These wood fibres are blended with wax and an organic resin and bonded together in panels by applying heat and pressure. MDF is mostly produced from wood chips and other fibre sources.



1) Domestic, imports
2) Particle Board, Medium Density Fiberboard (MDF), Oriented Stranded Board (OSB), hardboard

Figure 92, Particle board value chain

Wood packaging materials: wooden pallets

Wooden pallets are produced and repaired by the wood packaging sector. Wooden pallets are produced from sawnwood strips, steel staples and nails. New pallets are used in pooled systems (closed-loop) or non-pooled systems (open-loop). Pooled pellets are built sturdier with better wood and nails and generally have a longer lifetime than non-pooled pellets[140]. At the end of life, pallets are dismantled for recycling or energy use.

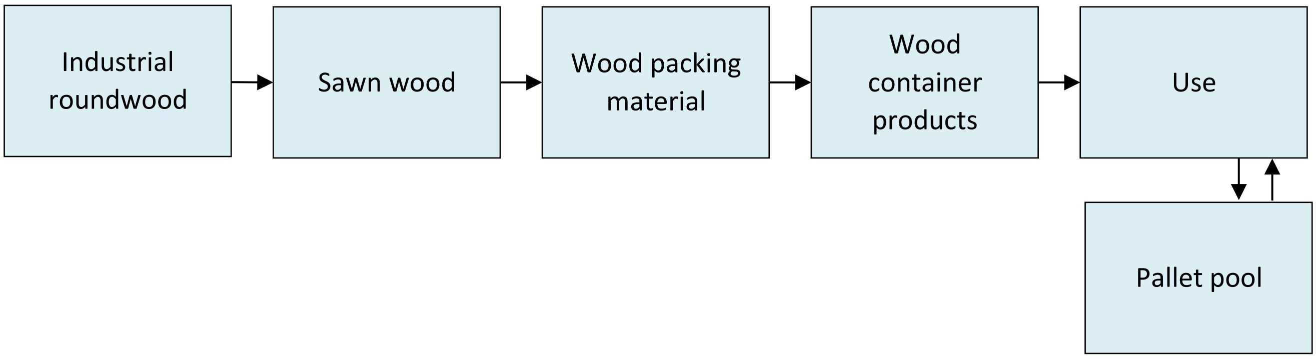


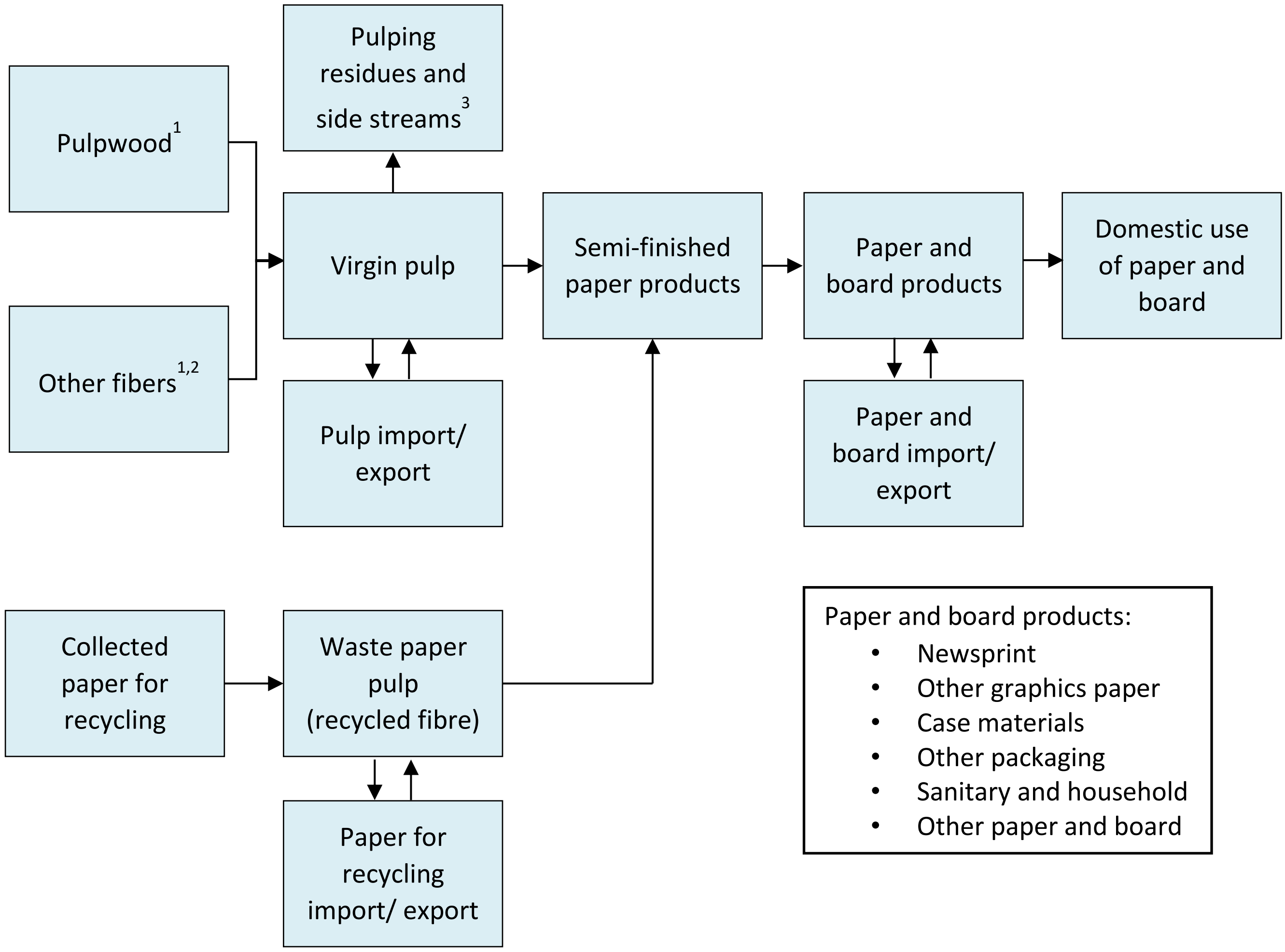
Figure 93, Pallets value chain

[140] BTG (2014) https://www.rvo.nl/sites/default/files/2014/11/cascading-wood-sector-final-report-btg.pdf

7.2 Pulp and paper

The pulp and paper value chain starts with the production and harvesting of pulpwood. Other fibres, such as straw, bamboo or bagasse are only used in small quantities in Europe (Figure 94). The pulp wood is processed in a pulp mill to separate the cellulose fibres from other wood components such as lignin. Pulping can be done by chemical processes (Kraft or sulphite), mechanical processes or a combination (semi-chemical pulping). The residues and side streams of the pulping process are increasingly used to produce bio-based products including fuels and materials (NC Partnering 2020)[141]. The virgin pulp is combined with recycled pulp produced from collected paper form recycling to produce different types of semi-finished paper sheets in paper mills. These sheets are converted into specific products through different processes, to produce paper and board products. Both integrated pulp and paper mills, that directly process wet pulp at the same site, and non-integrated pulp and paper mills, that use and sell their products on an open market are in operation. Some paper mills also produce finished paper products in the same mill, for example bags or paper tissues (CEPI 2021). All products in the pulp and paper value chain are traded: pulpwood and collected paper for recycling, dried pulp, semi-finished paper and board products and finished paper and board products.

[141] https://www.cepi.org/wp-content/uploads/2021/01/20-3362_BioRefineries_20210125_V2.pdf



1) Domestic removals, imports
2) Straw, bamboo, bagasse, etc.
3) Black liquor, tall oil, etc.

Figure 94, Pulp and paper value chain (based on CEPI 2022)[142]

The total production of paper and paper board in the EU27 was 87.44 Mt in 2021. Germany (26%), Italy (11%), Sweden (10%) and Finland (10%) are the largest producers of paper and paper board.

[142] https://www.cepi.org/key-statistics-2021/

Packaging paper and board

The value chain of packaging paper and board follows the general value chain of pulp and paper described above. However, the utilization of waste paper for recycling (use of recycled fibers as a percentage of total production), is substantially higher compared to other paper products such as graphic paper. In 2021, the utilization of paper for recycling was (CEPI 2021) :

- Case materials: 93.1%
- Carton board: 35.3%
- Wrappings and other packaging: 50%.

The total production of packaging paper and board in the EU27 was 52.85 Mt in 2021. Germany is the largest producer of packaging paper and board in the EU27 (26%), followed by Sweden (12%), Italy (11%), and France (9%).

Tall oil

Tall oil is produced from black liquor, a by-product of the chemical pulping processes (Kraft, sulphite). Black liquor contains the separated lignin stream of the pulping process, but also other dissolved components of wood, including extractives, hemicellulose and inorganic chemicals from pulping reactions (CEPI 2021). These extractives include fatty acid and rosin acid extractives and other neutral materials, or tall oil soap fraction in black liquor (

Figure 95). The soap is recovered by skimming from concentrated[143] black liquor when it becomes insoluble and floates (at black liquor concentrations of 20 - 25wt.% solids). The tall oil soap is processed into crude tall oil by acidulation, a process in which the tall oil soap reacts with a strong polar acid, mostly sulphuric acid in a continuous or batch reactor. After separation in the reactor, crude tall oil (CTO) can be used directly or further fractioned in Tall Oil Fatty Acids, Distilled Tall Oil, Tall Oil Rosins, and Tall Oil Pitch (Aro and Fatehi 2016)[144]. The CTO fractions can be used in several product application areas including chemicals, adhesives, coatings and fuels. The global availability of CTO is estimated to be 1.8 Mt in 2018, of which 82% is used for the production of chemicals and 18% for the production of transport biofuels[145].

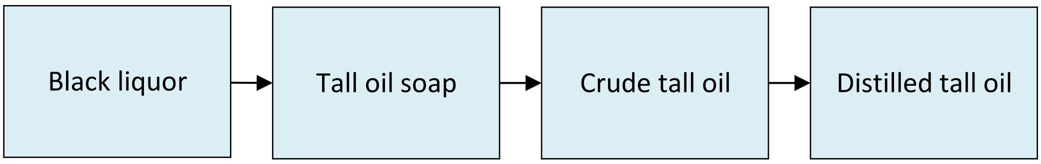


Figure 95, Tall oil value chain

[143] Black liquor from Kraft pulping has a solid concentration of 13-15 wt%.
[144] Aro, Thomas, and Pedram Fatehi. "Tall oil production from black liquor: Challenges and opportunities." Separation and Purification Technology 175 (2017): 469-480.
[145] Aryan, Venkat, and Axel Kraft. "The crude tall oil value chain: Global availability and the influence of regional energy policies." Journal of Cleaner Production 280 (2021): 124616.

8 Discussion and next steps

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. However, 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.

Also, for the products with a relatively small market (hemp yarn, bio-based 1,4-butanediol, etc.), for which there is trade data available, there is higher uncertainty of the trade data. Small deviations from the actual trade could lead to major changes in the total trade of these products. For example, while there is trade data available for bio-based 1,4-butanediol, this data does not correspond to the production locations found.

As such, the data can give a clear overview of the trade within the value chain and where certain steps in the bio-based value chain occur. However, the datasets might not always be complete and as the data is comprised of several declaring countries, differences in declarations can also occur as they can differ between countries.

While this deliverable gives the production and trade data of the value chains, qualitative data explaining certain flows and giving information on final products is still minimal. In Deliverable 3.3 'Trade flows of biological resources, bio-based materials and products', more qualitative information will be given, as well as the trade flows for the wood-based value chains, biowaste and compost. The information presented in this deliverable will also be used in the assessment of sustainability certification of bio-based value chains. Additionally, a differentiation between certified and non-certified production will be made in Deliverable 3.4 ‘Level of certification and labelling of biological resources, bio-based products and materials' with the help of the trade flow data. The Annex shows Milestone 4, the initial assessment of the level of certification and labelling of the selected value chains.

Annex: Milestone 4 'Assessing level of certification and labelling'

Contents

EXECUTIVE SUMMARY

Within the HARMONITOR project, different certifications schemes and labels (CSLs) are targeted, aiming at improving the effectiveness of these CSLs and their use as co-regulation experiment. In this context, this particular milestone report estimates the level of certification and labelling of various bio-based resources, bio-based materials, and bio-based chemicals produced within the EU. In case of apparent non-existent EU production rates, the major extra-EU producers are targeted.

The level of certification is estimated for a selection of CSLs, including ISCC Plus, Bonsucro, FSC and PEFC, amongst others. It appeared that it is challenging to find independent statistics about the level of certification of the targeted materials. For some bio-based resources and chemicals, the level of certification is estimated based on the information provided by the targeted CSLs. However, for many bio-based resources, the information required to estimate the certification level is lacking.

A.1 Introduction

A.1.1 Background

The project ‘Harmonization and monitoring platform for certification schemes and labels to advance the sustainability of bio-based systems’ (HARMONITOR) targets different certification schemes and labels (CSLs) in various sectors of the bioeconomy within the European Union, aiming at improving the effectiveness of these CSLs, and additionally the use of CSLs as co-regulation instrument.

This particular milestone report is related to task 3.3 of the project and focusses on the level of certification and labelling of biobased resources, and bio-based materials and products. The report uses the value chain inventory presented in HARMONITOR D2.1, and the corresponding selection of bio-based value chains presented in HARMONITOR D3.1 as its starting point, together with the trade data obtained within HAMONITOR task 3.2.

A.1.2 Goal

To determine the level of sustainability certification and labelling in percentage certified for a selection of the feedstocks and bio-based products listed in D2.1.

A.1.3 Scope

The level of certification and labelling is determined for a selection of feedstock and products listed in D2.1, focussing on intra-EU production. In case of apparent non-existent EU production rates, the major extra-EU producers are targeted. The assessment targets a selection of certification schemes and labels, see the Methodology chapter for further information.

A.2 Methodology

The materials and chemicals to be assessed for their level of certification and labelling are selected based on the value chains provided by HARMONITOR D2.1. Within D2.1, 16 value chains are presented that include many different bio-based products, including wood, cotton, and various bio-based chemicals, for example. The value chains from D2.1 are further specified, and the chemicals and materials that are assessed are indicated.

Next, the main producers of the targeted bio-based chemicals and materials are identified. Depending on the targeted chemical or material and available information, main producers are identified on country or company level. Initially, it is focused on intra-EU production, though in case of no or very little intra-EU production, the major extra-EU producers are targeted. Production data obtained within task 3.2 of HARMONITOR WP3 is utilized for this step, as well as information from the FAO amongst others.

Subsequently, the level of certification is determined for a selection of certification schemes and labels. In case of bio-based chemicals, ISCC Plus is selected. For sugar-derived bio-chemicals also Bonsucro is included. FSC and PEFC is targeted in case of wood derived products and natural rubber. For the latter also ISCC, Verified Carbon Standard and SAN are included. For cotton, flax and jute, general information about the certification level is given. Relevant information is acquired through the websites of the applicable CSLs. When possible, the level of certification is estimated by dividing the certified production capacity by the total amount of biobased production capacity of the targeted chemical or material.

A.3 Results

A.3.1 1,4-butanediol (BDO)

Value chain description

1,4-butanediol (BDO) is used as solvent as well as an intermediate for the production of plastics and other chemicals. Bio-based production of BDO occurs through the fermentation of sugars (Figure 96).[146]

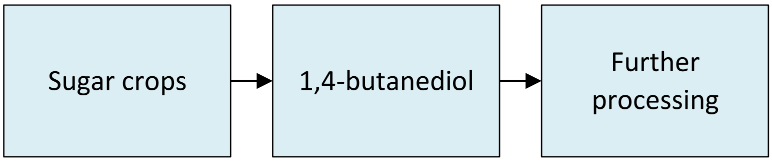


Figure 96: Bio-based 1-4-butane diol value chain

Production locations

Within the EU, one facility is known to produce bio-based BDO from sugars, operated by Novamont with a capacity of 30 kta.[56] Outside the EU, commercial production of bio-based BDO occurs at the facility of Shandong Land Biological Technology in China (20-50 kta),[147] and at the facility of SK Geo Centric in the Republic of Korea, where it acts as an intermediate for the production of a biodegradable plastic.[148] Other companies have announced to commence commercial bio-BDO production at the end of 2023 (Kingfa),[149] and in 2024 (Qore).[150] In addition, BASF is expected to be producing bio-BDO,[151] although it is unclear if the corresponding production location is in- or outside the EU.

Level of certification

The level of certification of bio-BDO is determined based on the number of certificates that are in place, as well as on the basis of the amount of certified bio-BDO versus non-certified BDO.

With respect to the level of certification on the basis of number of certificates, both Novamont, Shandong Land Biological Technology and BASF do not appear to hold ISCC or Bonsucro certificates for the corresponding processes. SK Geo Centric holds an ISCC Plus certificate for the production of bio- and bio-

[146] Novamont, 2016, Opening of the world's first industrial scale plant for the production of butanediol via fermentation of renewable raw materials, https://www.novamont.com/eng/read-press-release/mater-biotech/ Accessed on August 22, 2023

[147] Shandong Land Biological Technology, Bio-based 1-4 butanediol http://en.landbiotech.com/product/20.html, accessed on August 23, 2023

[148] SKinno News, 2021, SK Geo Centric and Kolon Industries launch eco-friendly biodegradable plastic PBAT, https://skinnonews.com/global/archives/8350, accessed on August 23, 2023

[149] Kingfa Technologies Ltd, Annual report 2021, https://www.kingfa.com/en/portal/article/index/id/7550/cid/986/type/pdf.html, accessed on August 23, 2023

[150] QIRA, 2021, Cargill and HELM partner to build $300M commercial-scale, renewable BDO facility https://www.myqira.com/qira-media/details/cargill-and-helm-partner-to-build-300m-commercial-scale-renewable-bdo-facility-first-in-the-us-to-meet-growing-customer-demand, accessed on August 23, 2023.

[151] BASF, Renewable BDO, https://chemicals.basf.com/global/en/Intermediates/Renewable/Renewable_BDO.html, and BASF, 2015, Joint News Release of BASF and Genomatica, https://www.basf.com/global/en/media/news-releases/2015/09/p-15-347.html, both accessed on August 23, 2023.

circular naphtha in bio- and bio-circular BDO. Apart from this, it is noted Novamont is a certified B corporation.[152] In addition, BASF does hold an ISCC certificate for the conversion of bio- and bio-circular methane, naphtha and pyrolysis oil in bio- and bio-circular butanediol, though this certificate appears to be applicable to a different conversion method compared to the technology listed on the product website.[151, 153]

Screening of the ISCC database for other companies holding certificates with respect to the production of bio-BDO indicates that also Lyondell (both in the Netherlands and the US) holds an ISCC Plus certificate for the production of bio-circular butanediol, although the corresponding production capacity is unclear. It should be noted that both BASF's and Lyondell's certificates list 'butanediol', which could relate to 1,4-butanediol, but also to its isomers.

In short, three out of five companies have acquired ISCC certification with respect to the production of bio-BDO (Table 12).

The level of certification of bio-based BDO on the basis of certified and non-certified production capacities could not be estimated due to the lack of data.

Table 12: ISCC Plus certificate holders for bio-BDO

Intra-EU	**Extra-EU**
BASF	Lyondell Chemical Company
Lyondell Chemie	SK Geo Centric

A.3.2 Polyurethane

Value chain description

Polyurethane is a collective name for a wide range of polymers obtained from reacting a polyol with a diisocyanate. Depending on the selected reactants and their corresponding characteristics, many different materials are obtained which are used in a wide range of applications. The use of two different reactants, each with their own production processes, result into an extensive value chain. Figure 63 (on the next page) shows a segment of this value chain, starting at the reactants that are required to obtain the polyol and diisocyanate. In turn, the polyol and diisocyanate are reacted to obtain the desired polyurethane. Although the figure shows a polyether polyol and methylene diphenyl diisocyanate (MDI) as starting point for the polyurethane production, many other types of polyols and diisocyanates are used in industry.

[152] Novamont, Impact Report 2022, https://www.novamont.com/public/Bilancio%20di%20sostenibilit%C3%A0/Novamont%20Relazione%20Impatto_0909_ENG.pdf

[153] ISCC-PLUS-Cert-DE129-35348573

Production locations

Inside the EU, production of bio-based polyurethane appears to be limited to a handful of companies. Most companies produce partially bio-based polyurethane, by choosing for a biobased polyol or diisocyanate, and by producing bio-based polyurethane on a mass-balance basis. The identified companies are: CIECH Pianki, Covestro, Epaflex, Huntsman Polyurethanes, NMC SA, Reckli GmbH, and Stahl.

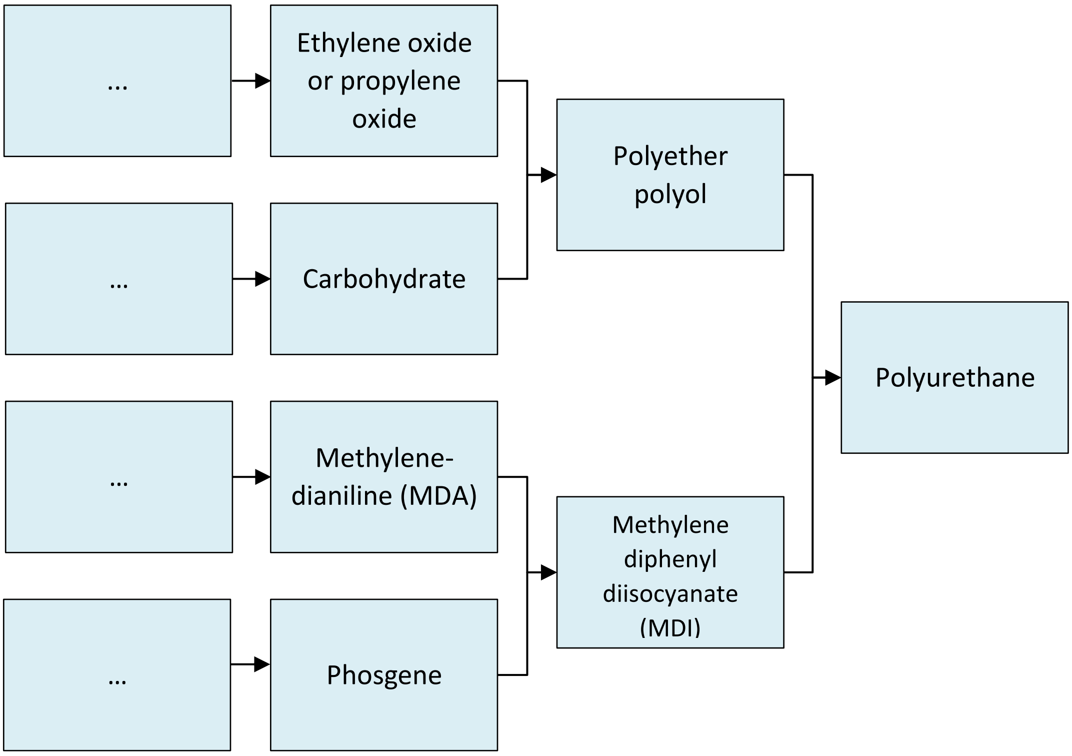


Figure 97: A segment of the polyurethane value chain

Level of certification

The level of certification of bio-based polyurethane is determined on the basis of the number of companies holding an ISCC certificate versus the number of companies that do not hold ISCC certification. From the eight companies that are identified to produce bio-based polyurethane, five companies have acquired ISCC certification (Table 13). Two of the companies with an ISCC certificate have acquired certification for the diisocyanate (Ciech Pianki and NMC SA), and the three remaining companies (Covestro, Reckli GmbH and Stahl) have acquired certification for both the polyol as well as the diisocyanate. Based on this analysis it appears that there is some extend of certification for the production of bio-based polyurethane.

Table 13: ISCC Plus certificate holders for bio-based polyurethane production

Intra-EU		**Extra-EU**
Ciech Pianki	Reckli GmbH	Not determined
Covestro	Stahl	
NMC SA		

A.3.3 Ethylene

Value chain description

Ethylene is a widely used commodity chemical and acts intermediate for the production of many other chemicals. Its bio-based counterpart is produced from sugars, as well as through steam cracking of bio-naphtha and other bio-based hydrocarbons (Figure 56).

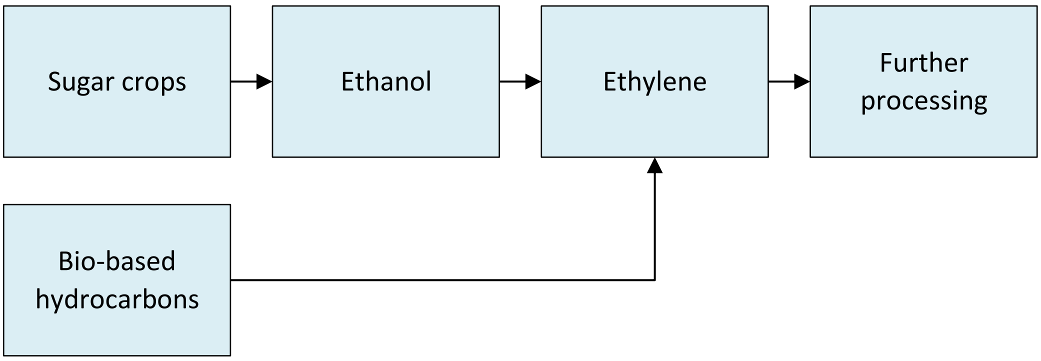


Figure 98: Bio-ethylene value chain

Production locations

Within the EU, on demand production of bio-based ethylene occurs through the mass-balance approach by BASF,[154] Borealis,[155] and Versalis,[156] amongst others. Outside the EU, a large share of the bio-ethylene production occurs at Braskem's facilities, which uses bio-ethylene for the production of bio-polyethylene, amongst others. India Glycols produces bio-ethylene as intermediate during bio-ethylene glycol production, so does Greencol Taiwan. Bio-ethylene is produced as an intermediate for bio-ethylene oxide by Croda.

Level of certification

The level of certification of bio-based ethylene is determined based on the number of certificates that are in place. Inside the EU, 14 different companies hold ISCC Plus certificates for the conversion of bio-based and bio-circular hydrocarbons to bio-based and bio-circular ethylene (Table 14). A few of these companies hold several of ISCC Plus certificates, related to different production facilities in different locations. Braskem and India Glycol hold ISCC Plus certificates for the production of bio-ethylene from bioethanol. These two companies also Bonsucro certificates (Table 15). Croda holds different certificates, although ISCC and Bonsucro are not on the list. Greencol Taiwan appears not to have ISCC Plus and Bonsucro certificates.

A total of 16 companies are identified to produce bio- or bio-circular ethylene on a commercial scale. Out of these 16 companies, 14 companies have acquired ISCC Plus (Table 14) and/or Bonsucro certification

[154] BASF, The Mass Balance Approach, https://www.basf.com/global/en/who-we-are/sustainability/we-drive-sustainable-solutions/circular-economy/mass-balance-approach.html, accessed on August 21st, 2023

[155] Borealis, 2020, Borealis to gain International Sustainability & Carbon Certification for all its European polyolefin production sites, https://www.borealisgroup.com/news/borealis-to-gain-international-sustainability-carbon-certification-iscc-plus-for-all-its-european-polyolefin-production-sites Accessed on August 21st, 2023

[156] Eni Versalis, 2021, Versalis: new certified product range for sustainability, https://www.eni.com/assets/documents/press-release/migrated/2021-en/02/PR-Versalis-ISCC-Plus.pdf, accessed on August 21st, 2023

(Table 15). The level of certification on the basis of tonne certified bio-ethylene versus tonne non-certified bio-ethylene could not be determined due to the lack of data.

Table 14: ISCC Plus certificate holders for bio-ethylene production

Intra-EU		**Extra-EU**
Basell	Raffinerie Heide	Braskem
BASF	Repsol Polímeros	India Glycol
Borealis	Sabic	
Dow	Shell	
INEOS	TotalEnergies	
OLEN	Total Petrochemicals	
OMV Deutschland	Versalis	

Table 15: Bonsucro certificate holders

Intra-EU	**Extra-EU**
Not applicable	Braskem
	India Glycol

A.3.4 Ethylene glycol

Value chain description

Bio-based production of ethylene glycol occurs through the conversion of sugar crops in subsequently ethanol, ethylene, and ethylene-glycol (Figure 99). Alternatively, bio-based ethylene glycol can be produced through steam cracking of bio-based hydrocarbons and subsequent conversion of ethylene in ethylene glycol. Ethylene glycol is widely used as an anti-freeze agent, and also acts as intermediate for the production of poly(ethylene terephthalate) (PET) and poly(ethylene glycol) (PEG), amongst others. Both bio-based ethylene glycol and ethylene glycol of fossil fuel origin are also known as mono-ethylene glycol (MEG).

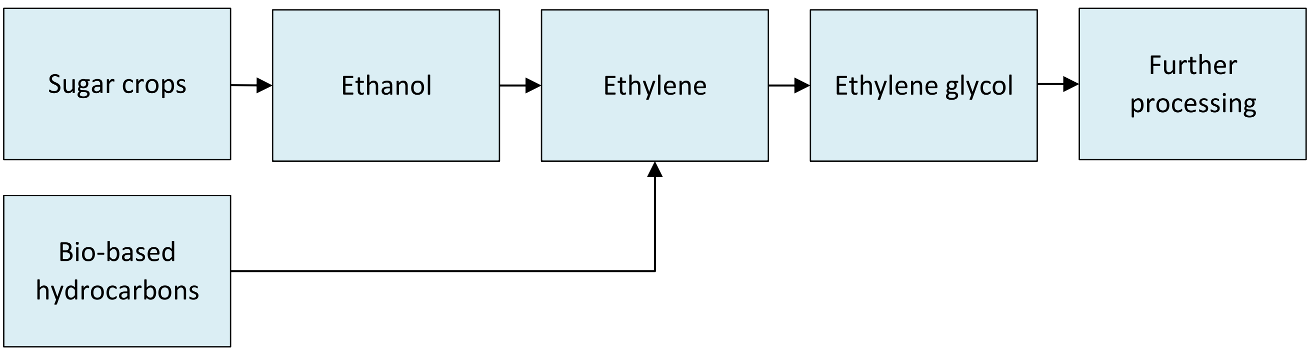


Figure 99: Bio-ethylene glycol value chain

Production locations

Commercial scale bio-based ethylene glycol production mainly occurs outside the EU, at the facilities of India Glycol Ltd. In addition, Greencol Taiwan might be producing bio-ethylene glycol, though information about this facility is very limited. Also Global Bio-Chem lists bio-ethylene in its portfolio, yet it is unclear if it still produces bio-ethylene glycol as most of Global Bio-Chem's activities in the corresponding polyol segment are suspended.[157]

Inside the EU, Clariant might be producing bio-ethylene glycol on a commercial scale, acting as intermediate for the production of bio-based poly(ethylene glycol).[158] Next to this, demonstration scale plants for bio-based ethylene glycol production exist within the EU and are operated by Avantium in the Netherlands,[159] and a joint venture of Braskem and Haldor Topsoe in Denmark.[160] Several companies have announced commercial production of bio-based ethylene glycol within the EU, including UPM together with HAERTOL Chemie for 2024, Avantium together with Cosun for 2025,[161] and Braskem together with Haldor Topsoe for 2026.

Level of certification

The level of certification of bio-based ethylene glycol is determined on the basis of the number of certificates that are in place. India Glycols Ltd. holds an ISCC Plus and a Bonsucro certificate. Both Global Bio-Chem and Greencol Taiwan appear not to have ISCC or Bonsucro certification in place. Clariant has obtained an ISCC Plus certificate for the conversion of bio-ethylene in bio-polyethylene glycol. Additional screening of the ISCC certificate database indicates that two other companies within the EU hold an ISCC Plus certificate for the production of bio-based ethylene glycol: BASF for the conversion of bio- and bio-circular hydrocarbons in bio- and bio-circular glycols, and Shell Chemical Europe for the conversion of bio- and bio-circular hydrocarbons in bio- and bio-circular ethylene glycol. Corresponding production capacities are unknown.

In conclusion, one company that produces bio-ethylene glycol on a commercial scale and another five companies that might produce bio-ethylene glycol on a commercial scale of where identified. Four out of the total of six companies hold ISCC (Table 16) and/or Bonsucro certification (Table 17), indicating that sustainability certification is applied to this product. However, on the basis of existing data it is not possible to quantify the volumes of certified bio-ethylene glycol and determine the level of certification on the basis of volume certified bio-ethylene glycol versus volume uncertified bio-ethylene glycol.

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157 Global Bio-Chem Technology Group Company Limited, Annual Report 2022, http://media-globalbiochem.todayir.com/20230424174801527110700180_en.pdf, accessed on August 21st, 2023

158 Clariant, 2022, Clariant launches 100% bio-based surfactants range driving the transition towards renewable carbon, https://www.clariant.com/en/Corporate/News/2022/02/Clariant-launches-100-biobased-surfactants-range-driving-the-transition-towards-renewable-carbon, accessed on August 23rd, 2023.

159 Avantium, Technologies, https://www.avantium.com/technologies/, accessed on August 21st, 2023

160 Braskem, 2020, Braskem and Haldor Topsoe achieve first production of bio-based MEG from sugar, https://www.braskem.com.br/news-detail/braskem-and-haldor-topsoe-achieve-first-production-of-bio-based-meg-from-sugar, accessed on August 21st, 2023

161 Avantium, 2021, Cosun Beet company and Avantium join forces with the ambition to produce plant-based glycols from sugars, https://www.avantium.com/wp-content/uploads/2021/04/20210422-Cosun-Beet-Company-and-Avantium-join-forces-with-the-ambition-to-produce-plant-based-glycols-from-sugars.pdf, accessed on August 21st, 2023

Table 16: ISCC Plus certificate holders for bio-ethylene glycol

Intra-EU	Extra-EU
BASF	India Glycol
Clariant	
Shell Chemical Europe	

Table 17: Bonsucro certificate holder for bio-ethylene glycol

Intra-EU	Extra-EU
Not applicable	India Glycol

A.3.5 Polylactic acid (PLA)

Value chain description

Polylactic acid (PLA) is a biopolymer produced from lactic acid. It is used as bio-degradable packaging material, and as filament in 3D printing, amongst others.[162] The lactic acid required for the production of PLA is derived from starch crops (e.g. corn) and sugar crops (e.g. sugar cane). The corresponding value chain is depicted in Figure 100:

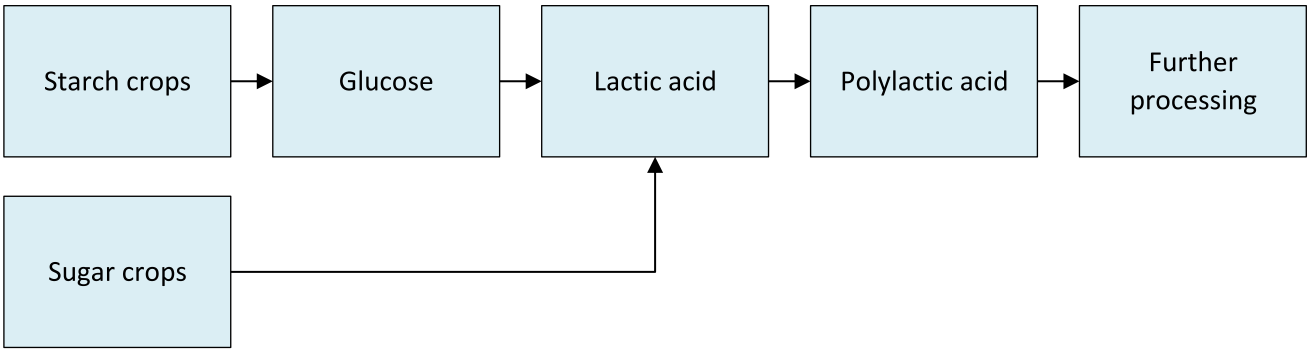

Figure 100: Polylactic acid value chain

Production locations

The major PLA production locations are located outside the EU. NatureWorks operates a PLA plant with a capacity of 150 kta located in the USA,[163] Futerro (part of Galactic) operates a PLA plant in partnership with BBCA Biochemical with a capacity of 100 kta located in China,[164,165] and the joint venture Total Energies Corbion has a plant with a capacity of 75 kta in Thailand.[166]

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[162] TotalEnergies Corbion, About PLA, https://www.totalenergies-corbion.com/about-pla/ Accessed August 24th, 2023
[163] NatureWorks, About NatureWorks, https://www.natureworksllc.com/about-natureworks, accessed on Augst 24, 2023
[164] Futerro, The Futerro story, https://www.futerro.com/
[165] K. Laird, Futerro launches fully integrated PLA plant in China, 2020, https://www.sustainableplastics.com/news/futerro-launches-fully-integrated-pla-plant-china, accessed on August 24,2023
[166] Total Energies, Thailand: Total Corbion PLA starts-up its 75,000 tonnes per year bioplastics plant, https://totalenergies.com/media/news/press-releases/thailand-total-corbion-pla-starts-its-75000-tonnes-year-bioplastics-plant, accessed on August 24, 2023

Inside the EU, the build of a PLA production location is announced by Futerro. [167] The plan of TotalEnergies Corbion to also build a PLA plant in Europe is cancelled recently. [168]

Level of certification

To determine the level of certification, the ISCC and Bonsucro databases are consulted first. NatureWorks is listed in the ISCC database and has obtained an ICSS certificate for the conversion of lactic acid to polylactic acid. No ISCC certification was found for the Futerro – BBCA Biochemical partnership and Total Energies Corbion. Screening of the Bonsucro database indicates that Purac Biochem (a Corbion company) holds a Bonsucro certificate. Indeed, the TotalEnergies Corbion website indicates that Bonsucro-certified PLA is available upon request.[169]

The level of certification is then determined on the basis of the amount of certified PLA versus total amount PLA produced by the major PLA producers. As TotalEnergies Corbion provides Bonsucro certification upon request, TotalEnergies Corbion's entire production capacity is assigned to the non-certified category, and a minimum level of certification is estimated. In addition, it is assumed that NatureWork's ISCC certificate is valid for NatureWork's entire production capacity. As such, the level of certification of PLA is estimated to be at least 54%.

A.3.6 Epichlorohydrin

Value chain description

Epichlorohydrin is an important intermediate for the production of epoxy resins. Its partially bio-based counterpart is produced from glycerine and hydrochloric acid. The glycerine is obtained as by-product from bio-diesel production.[170] With each reactant having its own production process, the epichlorohydrin value chain is quite extensive. Figure 101 (on the next page), shows the segment of relevance for this study.

Production locations

Within the EU, bio-based epichlorohydrin production takes place in France and Germany by INOVYN (50 kta in total),[171] and by Spolchemie in Czech Republic (30 kta).[172] Outside the EU, bio-based epichlorohydrin production takes place in China at the facilities of Jiangsu Yangnon Chemical Group (60 kt),[173] the facilities

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[167] Futerro, Futerro aims to set-up a new fully integrated PLA biorefinery in Normandy, France, 2022, https://www.futerro.com/news-media/futerro-aims-set-new-fully-integrated-pla-biorefinery-normandy-france, accessed on August 24th 2023

[168] K. Laird, Corbion calls off French PLA bioplastics plant, 2023, https://www.sustainableplastics.com/news/corbion-calls-french-pla-bioplastics-plant, accessed on August 24th, 2023

[169] TotalEnergies Corbion, Luminy® PLA portfolio, https://www.totalenergies-corbion.com/luminy-pla-portfolio/, accessed on August 24, 2023

[170] B.M. Bell et al., 2008, Glycerine as a renewable feedstock for epichlorohydrin production. The GTE Process, Clean Soil Air Water, 36, p.657 – 661, DOI: 10.1002/clen.200800067

[171] INOVYN, 2021, INOVYN bio-attributed epichlorohydrin, https://www.inovyn.com/news/inovyn-launches-worlds-first-commercially-available-grade-of-bio-attributed-epichlorohydrin/, accessed on August 28th 2023

[172] D. de Guzman, 2012, Biobased ECH growing rapidly, in Green Chemicals Blog, https://greenchemicalsblog.com/2012/09/14/biobased-ech-growing-rapidly/, accessed on August 28th 2023

[173] Pagliaro, 2017, C_3 monomers, in Glycerol: The renewable platform chemical, Elsevier, p. 29.

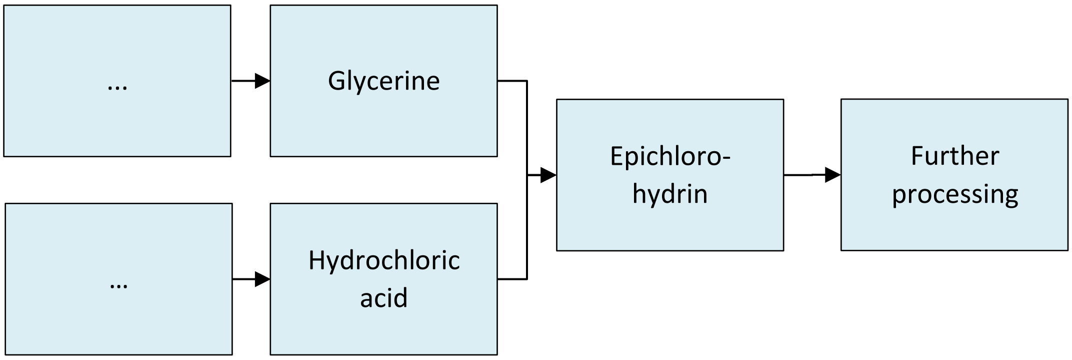

Figure 101: A segment of the bio-epichlorohydrin value chain

of Yihai Kerry (100 kta),[4] and the facilities of Dow Chemicals (150 kta).[174] Bio-based epichlorohydrin is also produced in Thailand at the facilities of Advanced Biochemical Thailand (120 kta).[175]

Level of certification

The bio-epichlorohydrin level of certification is determined considering ISCC certification. From the five companies listed to produce bio-epichlorohydrin, INOVYN has acquired ISCC Plus certification for the conversion of bio-circular glycerine into bio-circular epichlorohydrin. The majority stakeholder in Jiangsu Yangnon Chemical Group, Sinochem, also holds an ISCC Plus certification. However, the certificate details are not given, and it is unclear whether this particular certificate considers the production of bio-based epichlorohydrin. Another company in the Sinochem business family, Jiangsu Ruixiang Chemical, holds ISCC Plus certification for the conversion of bio-glycerine into bio-epichlorohydrin too. In this case it is unclear if the company produces bio-epichlorohydrin and in what quantities.

The level of certification of bio-based epichlorohydrin is estimated based on the amount of produced bio-epichlorohydrin with ISCC Plus certification versus the total estimated production of bio-based epichlorohydrin. Only INOVYN was included in the estimations, as it is not clear whether the companies in the Sinochem group of businesses hold ISCC Plus certificates that consider the production of bio-epichlorohydrin. As a result, the level of certification of bio-based epichlorohydrin is estimated to be 10%.

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[174] A. Barrett, 2014, Solvay and Bio Epoxy Production, in Bioplastics News, https://bioplasticsnews.com/2014/03/09/solvay-epoxy/, accessed on August 28th 2023.
[175] AGC, Bio-based epichlorohydrin, https://www.agcce.com/bio-based-epichlorohydrin/, accessed on August 28th 2023

A.3.7 Wood

Value chain description

For the wood value chain, forests and the (pre-)products sawn wooden products, fibreboard, wood packaging materials, and paper are considered separately.

Production locations

European forest accounts for 25% of the global forest area with the largest forest areas located in Sweden and Finland.[176]

Level of certification

According to FAOSTAT data,[177] Europe has 169 million ha certified forest area in 2020, accounting for around 38% of the forest area certified worldwide. For 2020, the FAOSTAT data on total forest area and the certified area suggest that 16.6% of the European forest area has an FSC and/or PEFC certificate and 10.7% of the worldwide forest area is certified. The largest certified forest areas in Europe are located in Finland and Sweden, which also have the largest total forest areas in Europe.

Wood products

Wood products production

Building material

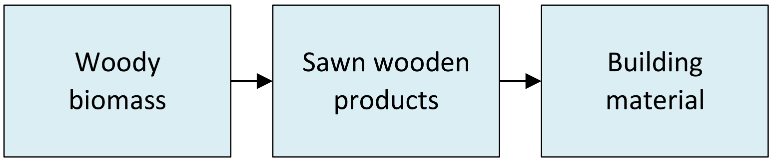

Figure 102: Wood to building material value chain

Softwood production in the EU is dominated by Germany, Sweden, Finland and Austria, while hardwood production is predominantly in Romania, France, and Germany.[178] FSC and PEFC, which are the key certification schemes for forests, have also reached the building sector,[179,180] but statistics on a level of certification are not available.

[176] FAOSTAT 15.1.1 forest area, https://www.fao.org/faostat/en/#data, accessed 28th of August 2023.
[177] FAOSTAT 15.2.1 forest area under an independently verified forest management certification scheme, https://www.fao.org/faostat/en/#data, accessed 28th of August 2023.
[178] EOS European organisation of the sawmill industry, https://unece.org/sites/default/files/2022-11/item-5-b-MELEGARI-sawnwood-overview.pdf, accessed 28th of August 2023.
[179] FSC construction, https://anz.fsc.org/construction, accessed 28th of August 2023.
[180] PEFC construction, https://pefc.org/for-business/supply-chain-companies/certify-your-construction-project, accessed 28th of August 2023.

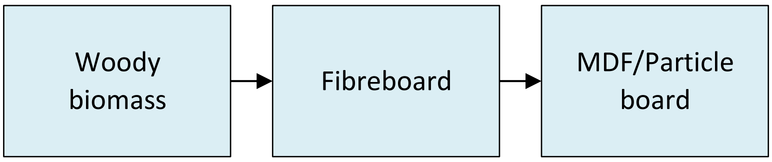

Figure 103: Wood to MDF/Particle board value chain

MDF/Particle board

Fibreboard includes different types of panels made out of wood fibres.[181] In 2021, the production and consumption of non-structural panels (particle- and fibreboard) in Europe was around 47 million cubic meters, additional imports and exports ranged around 10 million cubic meters each.[181]

Wood based packaging materials

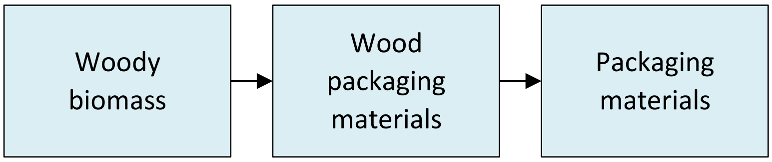

Figure 104: Wood to packaging materials value chain

Wood packaging materials are for example crates, pallets, and packing cases.

Paper

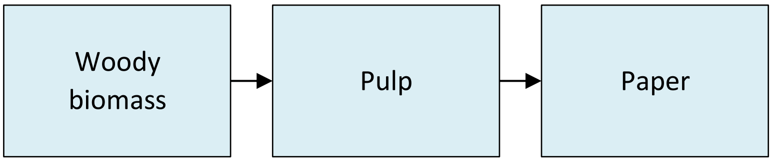

Figure 105: Wood to paper value chain

Europe produces a quarter of paper products worldwide[182] with almost 90% of the wood used for paper pulp production (107 million tonnes in 2022) coming from domestic sources.[183] Pulp production is dominated by Sweden (33% in 2022) and Finland (26% in 2022).[183] Collected recycling paper used for paper production amounts to additional 48 million tonnes in 2022.[183]

Level of certification

FSC and PEFC certification plays an important role also for wood products, the Forest Products Market Review[181] expects changes in in- and export patters due to FSC and PEFC terminating certificates for Russian and Belarus forests following the Russian war against Ukraine. Nevertheless, there is little aggregated data

[181] Forest Products Market Review, https://unece.org/sites/default/files/2023-02/2228765E_Inside_final_signa_red.pdf, accessed 28th of August 2023.

[182] Statista, https://www.statista.com/topics/7737/paper-industry-in-europe/#topicOverview, accessed 28th of August 2023.

[183] Cepi confederation of European paper industries, https://www.cepi.org/wp-content/uploads/2023/07/2022-Key-Statistics-FINAL.pdf, accessed 28th of August 2023.

on the overall level of certification of the wood product market, the individual certificates give not enough information to calculate shares.

Insulation material

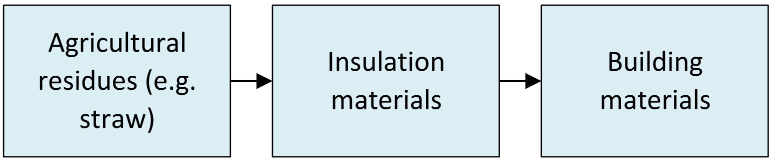

Figure 106: Agricultural residues to building materials value chain

No aggregated data on the level of certification of insulation material is available.

Rayon

Value chain description

Rayon is a bio-based product, obtained from cellulose. The cellulose finds its origin in biomass, and often wood is used as the cellulose source. The wood is shredded into chips and chemically treated, producing a cellulose rich pulp. After removal of the chemicals from the pulping process, the cellulose rich pulp is chemically and mechanically treated, and spun into fibres [184] Next, the fibres are spun into yarn and subsequently used to make rayon fabric (Figure 107).

Figure 107: Rayon value chain

Rayon can be obtained from many different cellulose sources and through different processes. Where in the USA rayon is used to indicate fibres made through the 'viscose process',[185] in this report it is used to indicate cellulosic fibres obtained from wood, independent of the production process applied to obtain the fibres.

Production locations

The main players in the area of rayon production inside the EU are identified to be Aditya Birla's Domsjö Fabriker, Cordenka, Kelheim Fibers, and Lenzing Fibers Corporation. Domsjö Fabriker converts wood into cellulose in Sweden. Cordenka produces rayon yarn from pulp in Germany and Kelheim Fibers converts wood pulp into fibres at its factory also in Germany. Lenzing converts wood into wood pulp and subsequently into rayon fibres. Lenzing's EU based facilities are located in Austria and Czech Republic.

[184] Lenzing, 2023, Focus paper Responsible production

[185] CIRFS, Viscose, https://www.cirfs.org/man-made-fibers/Fibre-range/viscose, accessed on August 29th 2023

Level of certification

All four companies listed in the previous paragraph have acquired FSC certification. Also other companies in the rayon value chain have acquired FSC certification. Consultation of the FSC product category 'P.1.7.4. Rayon and other synthetic fibres' gives about 800 entries, including both 'sites' and 'certificate holders' within the EU. The largest number of entries is found for German certificate holders and sites (435 entries) followed by Italy (245 entries). Other countries within the EU have less than 25 entries in this category.

A.3.8 Natural rubber

Value chain description

Rubber can be produced from natural or synthetic rubber, 75% of the global production are synthetic.[186] In the following, the value chain of natural rubber, produced from liquid tree sap of the rubber tree (Hevea brasiliensis) is considered.

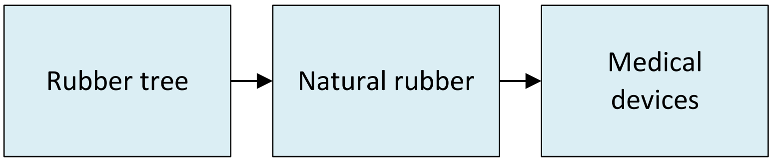

Figure 108: Natural rubber value chain

Production locations

The three largest producers of natural rubber in primary forms are Thailand, Indonesia, and Vietnam, accounting for 64% of the global production of around 14 million tonnes in 2021.[187] Natural rubber goods imported into the EU were mainly from Indonesia (28%), Cote d'Ivoire (23%), and Thailand (21%) in 2020.[188]

Level of certification

FSC and PEFC certify rubber trees, the global market share of certified rubber forest is around 2.6% in 2021.[189] None of the other schemes seem to certify rubber trees or natural rubber on a large enough scale to give out any statistics. Overall, there are only few individual projects listed in the databases (Table 18).

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[186] Erca European rubber chemicals association, https://erca.cefic.org/how-is-rubber-made/, accessed 25th of August 2023.

[187] FAOSTAT natural rubber in primary forms (production), https://www.fao.org/faostat/en/#search/natural%20rubber%20in%20primary%20forms, accessed 28th of August 2023.

[188] Statista, https://www.statista.com/statistics/411387/general-rubber-goods-eu-imports-source-distribution/, accessed 28th of August 2023.

[189] Textile Exchange Preferred Fiber & Materials Market Report 2022, https://textileexchange.org/app/uploads/2022/10/Textile-Exchange_PFMR_2022.pdf, accessed 25th of August 2023.

Table 18: Certification of natural rubber and rubber trees

CSL	SHARE/CERTIFICATE HOLDER	TYPE
FSC **PEFC**	2.6% of global market[17]	Rubber tree
ISCC	43 valid certificates for “rubber”, presumably including a large share of synthetic rubber	Mainly rubber producers, e.g. tires
VERIFIED CARBON STANDARD	Project in Guatemala	Rubber tree
SAN	Project in Cote d’Ivoire	Rubber tree

A.3.9 Cotton based textile

Value chain description

Cotton is cultivated mainly for its fibre, which grows around the cotton seed. [190] The cotton is ginned (seeds and fibres are separated) and the cotton fibre is then spun into cotton fabric from which textiles are produced.

Figure 109: Cotton value chain

Production locations

The estimated wood production of unginned seed cotton (containing both the seed and the fibre for textile production) was 73.7 million tonnes in 2021, with the largest production in China and India (each around 17 million tonnes) according to FAOSTAT.[191] India furthermore accounts for almost 50% of global organic cotton production.[192]

Cotton production in Europe is only a small sector with three countries growing cotton on around 320,000 ha and accounts for about 1% of the global production.[18] Nevertheless, cotton fibre produced in Europe is often exported and then re-imported as textiles, with 25% of the production returning to the European textile industry, which amounts to 40% of the domestic need.[193] The value chain for cotton textiles

[190] European Commission: Agriculture and rural development, https://agriculture.ec.europa.eu/farming/crop-productions-and-plant-based-products/cotton_en, accessed on August 25th 2023.

[191] FAOSTAT Food and Agriculture Organization of the United Nations, https://www.fao.org/faostat/en/#data/QCL, accessed on 25th of August 2023.

[192] TextileExchange Organic Cotton Market Report 2021, https://textileexchange.org/app/uploads/2021/07/Textile-Exchange_Organic-Cotton-Market-Report_2021.pdf, accessed on August 25th 2023.

[193] EUCOTTON European Cotton Alliance, https://eucotton.eu/wp-content/uploads/2022/09/dossier-press.pdf, accessed 25th of August 2023.

commonly encompasses several countries.[194] At each stage in the value chain (fibres, yarns, fabrics, textiles) import and export mass flows have to be considered.

Level of certification

Cotton

Of the global cotton production, the share which is certified by a voluntary sustainability scheme has increased from 2013 to 2016, when 14.1% of the total production were certified.[195] The most important certification schemes were the better cotton initiative (BCI), Cotton made in Africa (CmiA), Organic production and Fairtrade.[23] In 2018, 21% of the produced cotton are reported as sustainable[196] and in 2021, BCI alone states that more than 20% of the global production is certified by their standard.[197]

There are no statistics specifically for the export of sustainable cotton,[198] the shares of certified and non-certified cotton described above and subsequently exported to Europe are not accessible. For the Europe-grown cotton, the marketing campaign EUCOTTON states that production in Europe is sustainable and environmentally friendly by following the green pact, but no additional certification scheme is mentioned.[199]

Cotton fabrics

Cotton textiles on the EU market have often undergone a complicated value chain through multiple countries. Furthermore, of the more sustainably produced cotton, 75% is sold on as conventional cotton and not branded as sustainable cotton.[196] Information about certified textiles is not publicly available to calculate shares.[200] Common certificates for clothing include GOTS and fairtrade,[200] but their share of the European cotton textile market is not disclosed.

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[194] Köhler, Andreas, et al. *Circular economy perspectives in the EU textile sector*. Luxembourg: Publications Office of the European Union, 2021.

[195] International Institute for Sustainable Development (IISD), Global Market Report: Cotton, https://www.jstor.org/stable/pdf/resrep26555.pdf, accessed 25th of August 2023.

[196] Sustainable cotton ranking, https://sustainablecottonranking.org/market-update, accessed 25th of August 2023.

[197] 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.

[198] Centre for the Promotion of Imports from developing countries (CBI), Netherlands Enterprise Agency, https://www.cbi.eu/market-information/apparel/sustainable-cotton/market-entry, accessed 25th of August 2023.

[199] EUCOTTON, https://eucotton.eu/, accessed 25th of August 2023.

[200] Gossen, Maike et al. *Nudging Sustainable Consumption: A Large-Scale Data Analysis of Sustainability Labels for Fashion in German Online Retail.* Frontiers in Sustainability, 2022.

A.3.10 Flax and jute based textiles

Value chain description

For linen textile production, flax is cultivated, processed and spun into yarn with is subsequently used to produce the textile. Jute textile is produced from a variety of jute shrubs.

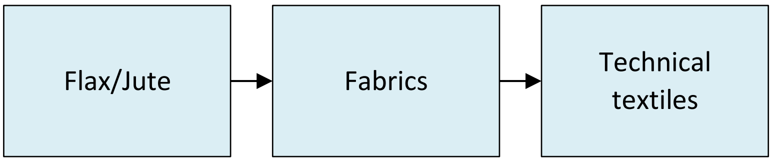

Figure 110: Flax/jute value chain

Production locations

Flax

The *Alliance for European Flax-Linen & Hemp* lists France as the largest producer in Europe (with 80% of the European production) and Europe as the producer of 75% of long fibres of flax in the world.[201]

Jute

For jute, the largest producing countries are India and Bangladesh, with no European country in the 10 largest producers.[202]

Level of certification

Flax

European Flax offers its own trademark certification (European Flax).[201] GOTS lists more than 900 entries for "linen",[203] but seems to give out no statistics on these certificates. Other certificates include OEKO-TEX, but statistics are not publicly available.

Jute

Data on jute certification is not available.

[201] The Alliance for European Flax-Linen & Hemp, https://allianceflaxlinenhemp.eu/en, accessed 25th of August 2023.
[202] https://www.worldatlas.com/articles/top-jute-producing-countries-in-the-world.html, accessed 25th of August 2023.
[203] Global Organic Textiles Standard, https://global-standard.org/find-suppliers-shops-and-inputs/certified-suppliers/database/search_results?total=905, accessed 28th of August 2023.

A.4 Discussion and outlook

This milestone report aims at estimating the level of certification of a selection of biobased resources, bio-based materials and bio-chemicals. It appeared that independent statistics about the level of certification of bio-based chemicals and materials are hard to find. In addition, the estimation of the certification level is limited by the information given by the corresponding CSLs. For certain CSLs, statistics are not (publicly) available or very general numbers are given. Other CSLs do provide further details about certification, although this information is not always complete.

To calculate the level of certification of several bio-based chemicals, the certified production capacity is required. However, no information on the certified amount of bio-based chemicals was found. Therefore, it is assumed that a company's full production capacity is certified in case a company has acquired an ISCC certificate. This assumption might result in an overestimation of the level of certification.

Fortunately, information about the level of certification for the major wood-based schemes is easy to acquire. However, moving further down the value chain, it is more challenging to find the information required to calculate the certification level. The latter is also valid in case of products made from natural rubber, cotton, flax and jute and for the bio-based chemicals. As a consequence, estimating the level of certification for an entire value chain is challenging.

The report estimates the level of certification based on a first selection of certification schemes and labels. This selection is not exhaustive, particularly for the bio-based chemicals. Hence, a next step in the assessment of the certification level of bio-based chemicals and materials would be to assess other certification schemes and labels. The longlist provided in Deliverable D2.1 could be used as starting point. Also, other chemicals and materials could be added, such as propylene, propylene glycol, algal fatty acid, tall oil and palm oil derived products.