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JRC SCIENTIFIC INFORMATION SYSTEMS AND DATABASES REPORT

EU Biomass Flows

Update 2022

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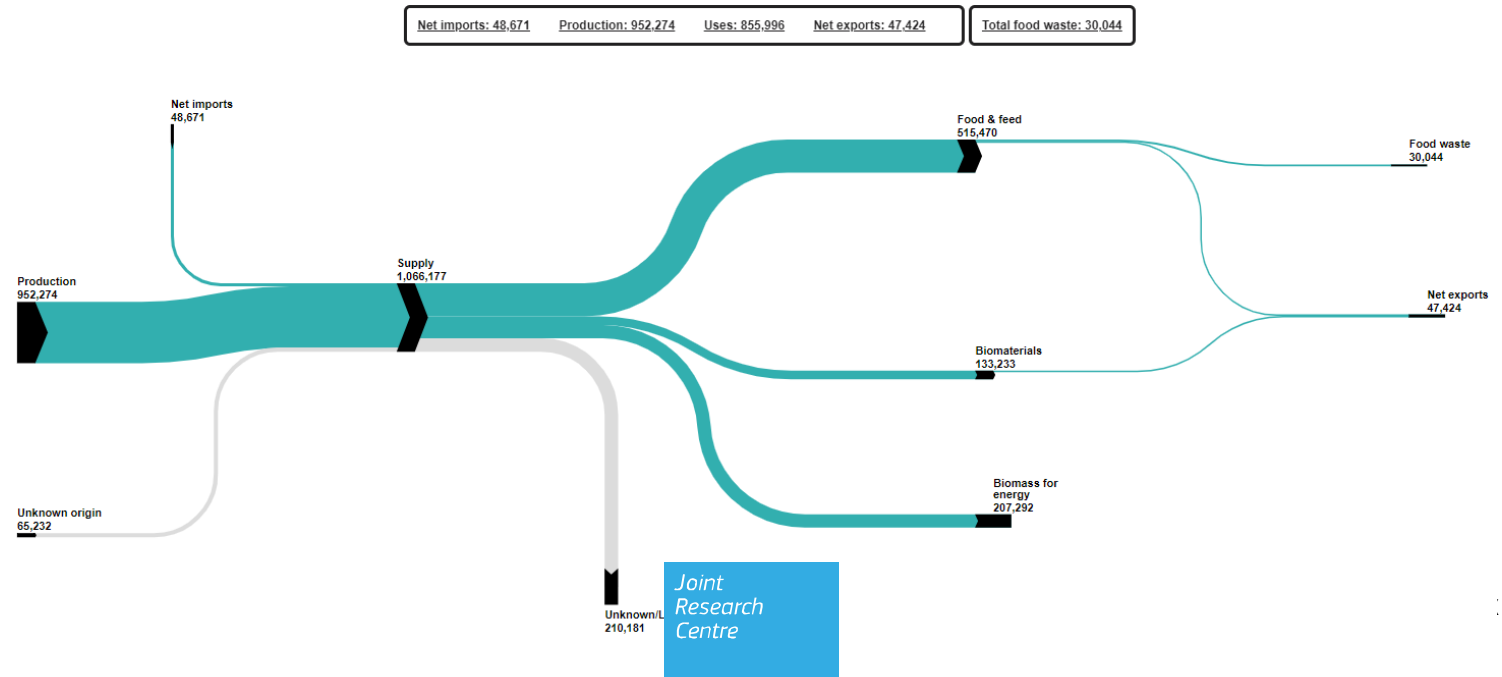
2022



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Contents

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The authors would also like to acknowledge the comments from the technical experts of the European Commission Inter-service Group following the JRC Biomass Study[2], as well as any feedback or comments provided by users.

[1] https://ec.europa.eu/eurostat/web/energy/energy-flow-diagrams
[2] https://ec.europa.eu/knowledge4policy/projects-activities/jrc-biomass-study_en

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Abstract

The **EU Biomass Flows** tool is a visualisation, in the form of Sankey diagrams, of the flows of biomass for each sector of the bioeconomy, from supply to uses including trade. It displays the harmonised data from the various Joint Research Centre (JRC) units contributing to the BIOMASS Assessment study of the JRC[3]. The diagrams enable deeper analysis and comparison of the different countries and sectors across a defined time series.

The first version of the tool was published in 2017 and has been used in multiple research activities and publications. A new version was released in 2020 on new software. This new version offers improved analysis capabilities and a better user experience, as well as increased granularity of data for some biomass types. It relies on the methodology to extract and integrate data developed for the first biomass visualisation tool.

In the past years, we have continued to improve on the data and design of the EU Biomass Flows tool. The most important changes of this new release are focused on four areas: migration to EU27 aggregation, redesign of the flows for woody biomass Update of the data with the latest available years and visualisation of food waste flows.

[3] https://ec.europa.eu/knowledge4policy/projects-activities/jrc-biomass-study_en; see also Ronzon et al. (2017).

1 Introduction

In the last few years, the European Commission has released multiple initiatives that continue to set out goals towards decoupling economic growth from resource use (The European Green Deal (European Commission, 2019)), protecting biodiversity (The Biodiversity Strategy (EC, 2020)), mitigating climate change (Stepping up Europe's 2030 climate ambition (EC, 2020b)) and, in general, increasing the economy's sustainability and circular use of resources (Farm to Fork Strategy (EC, 2020c)). In all these initiatives, biomass is a key resource.

In this context, and within the framework of the biomass Assessment Study, the JRC developed a methodology for the quantification of biomass and the analysis of its sources and uses. The results of this methodology can be visualised in the EU Biomass Flows tool in the form of Sankey diagrams (Gurria et al., 2017).

The tool is hosted in the JRC DataM Portal[4], in the Bioeconomy visualisation area[5]. It can be accessed directly using the following link:

https://datam.jrc.ec.europa.eu/datam/mashup/BIOMASS_FLOWS/index.html#

It is also part of the visualisations of the JRC Knowledge Centre for Bioeconomy[6].

The EU biomass Flows tool presents the flows of biomass for all European Union (EU) Member States (MS), as well as for the EU27 for a time period that varies depending on the source of biomass. It displays a series of Sankey diagrams that change according to the user's choices of year, country and trade type. The diagrams are shown in different levels of granularity, from aggregated biomass flows, regardless of the biomass origin, to detail sector specific diagrams. The diagrams shown can be used to analyse supply of biomass as well as uses of biomass within the three main use categories: food and feed, materials and energy production.

This document reviews the changes in the dataset and tool that have been implemented since 2020 (Gurria et al., 2020). Although there have also been multiple cosmetic changes, the main changes to the dataset and tool are focused on four areas: update of the dataset with the latest available years and full refresh of data, integration of food waste flows, migration to EU27 aggregation and redesign of the flows for woody biomass.

The next three chapters give an overview of the different sources and uses of biomass in the EU27. Supply is sourced from the primary sectors that traditionally produce biomass (agriculture, forestry and fisheries and aquaculture), as well as international trade. We consolidate the uses of biomass into three main categories: food and animal feed, biomaterials, and biomass for energy production. All international trade figures for this analysis are net trade values, as data in gross trade terms is not available for the EU27 in some sectors and comparison across sectors would therefore not be possible. These two chapters are an update of the insights published in Gurria et al. (2020).

Chapter 5 focuses on the changes introduced since the latest release. Chapter 6 presents the agricultural mid-term outlook commodity flows as a showcase for future oriented biomass flows. Chapter 7, finally, reviews some of the potential developments for the EU Biomass Flows tool.

Screenshots of the different biomass flows can be found in the Annex.

[4] https://data.jrc.ec.europa.eu/dataset/34178536-7fd1-4d5e-b0d4-116be8e4b124
[5] https://datam.jrc.ec.europa.eu/datam/area/BIOECONOMY; see also initial work by Ronzon, Santini and M'barek (2015b)
[6] https://ec.europa.eu/knowledge4policy/visualisation/biomass-flows_en

2 Biomass supply

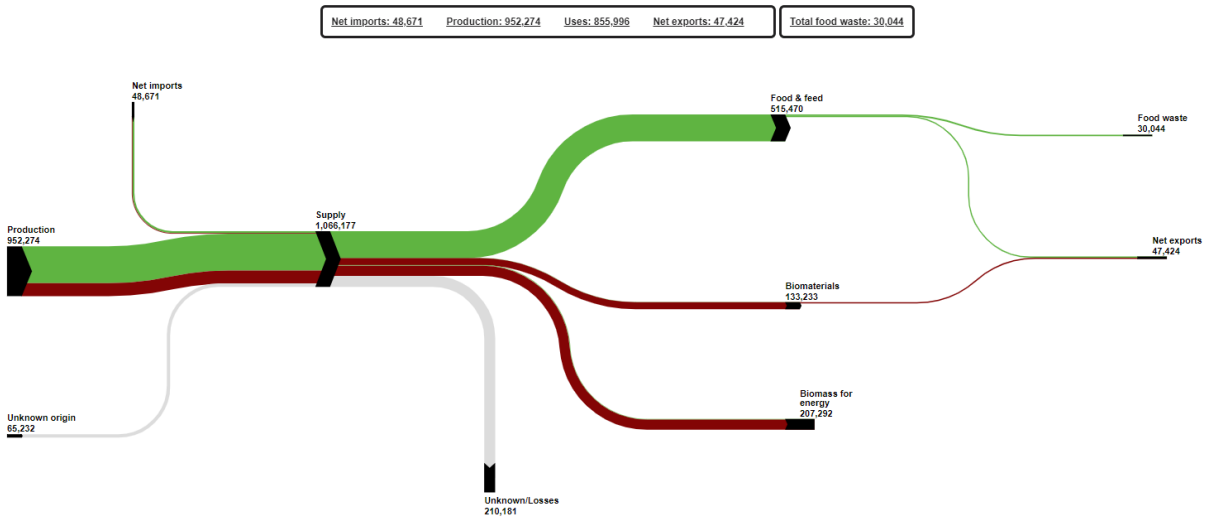
2.1 Overview

In 2017, the total supply of biomass in the EU27 added up to approximately 1 billion tonnes of dry matter (tdm). Almost 90% of this biomass was produced in the EU27, while 5% of the biomass supply was imported from extra-EU countries. The origin of 5% of the total biomass could not be identified.

The agriculture sector is the biggest producer of domestic biomass with 69% of the total (ranging from 20% in Finland to over 90% in Greece, Cyprus and Malta), followed by forestry with 31% of the dry matter content (from non-producing countries like Malta to over 80% in Finland). While the relative weight of the fishery sector is quite small (less than 1%), it is more important when considering economic or nutritional values.

Using the latest available complete sets of data (2018 for agriculture, 2017 for woody biomass and 2016 for fisheries and aquaculture) and considering net trade of products, we can analyse the major sources of biomass for each sector. In agriculture, crop production represents 68% of the biomass supply with grazed biomass (13%) and collected crop residues (12%) being closer in weight but representing much smaller portions. In the case of woody biomass, most of the primary woody biomass is harvested domestically, although there is wide variations among MS. As for the fisheries and aquaculture sector, the biggest source of biomass is imported fish and seafood (47%), followed by captured fish[7] (35%). 10% of the supply of aquatic biomass required to match the demand is of an origin that cannot be identified accurately.

Figure 1. Biomass flows by sector, EU27, net trade, latest available data (1000 tdm).



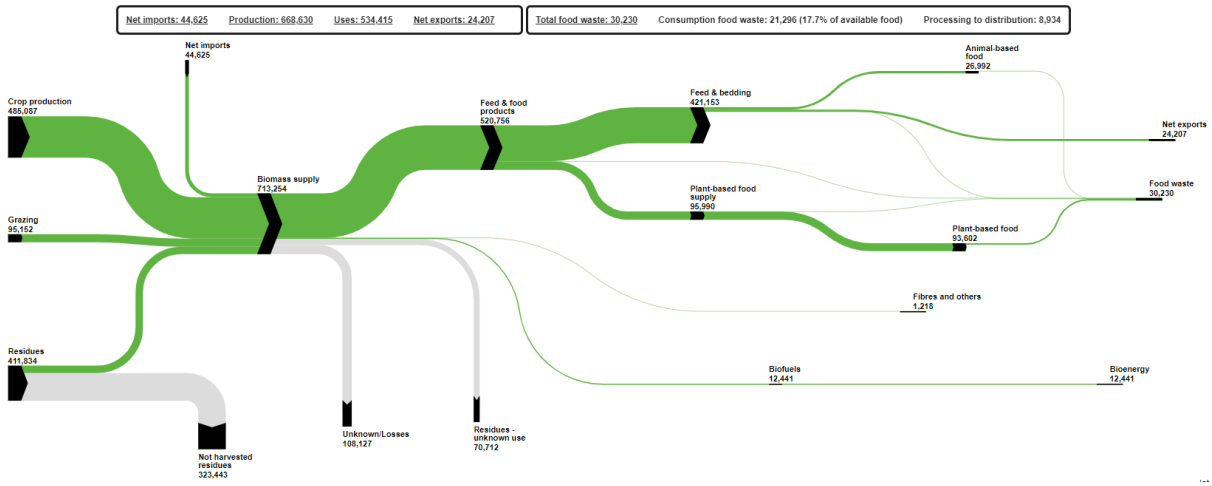
Source: Biomass Flows (DataM, 2022)

[7] Imported fish and seafood is a separate category because we currently have no data of whether its origin is capture fisheries or aquaculture.

2.2 Agriculture

In 2018, the EU27 agricultural biomass total supply (in net trade figures) amounted to approximately 713 million tonnes of dry vegetal biomass equivalents.

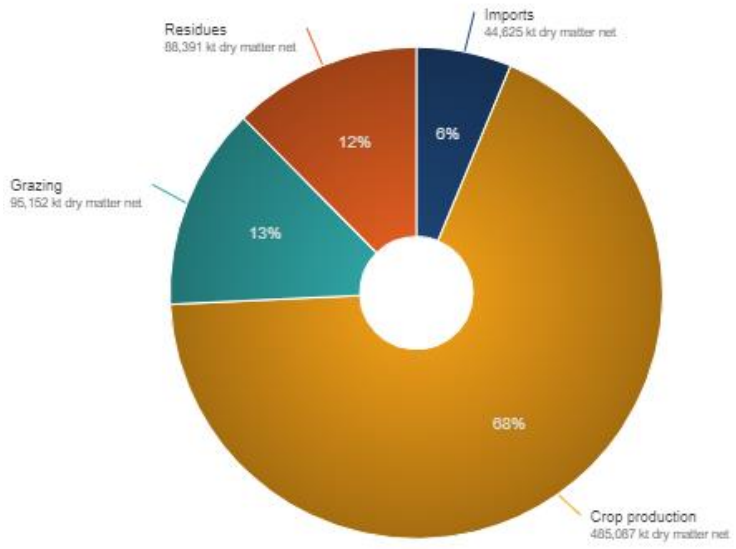
Figure 2. Biomass flows for agriculture, EU27, net trade, 2018 (1000 tdm).



Source: Biomass Flows (DataM, 2022)

This biomass is sourced in the form of crop production, harvested crop residues, grazed biomass and imports of agricultural products. The imports include live plants and animals, animal- and plant-based food items and other processed products of agricultural origin (e.g. leather products).

Figure 3. Sources of agricultural biomass, EU27, net trade, 2018.



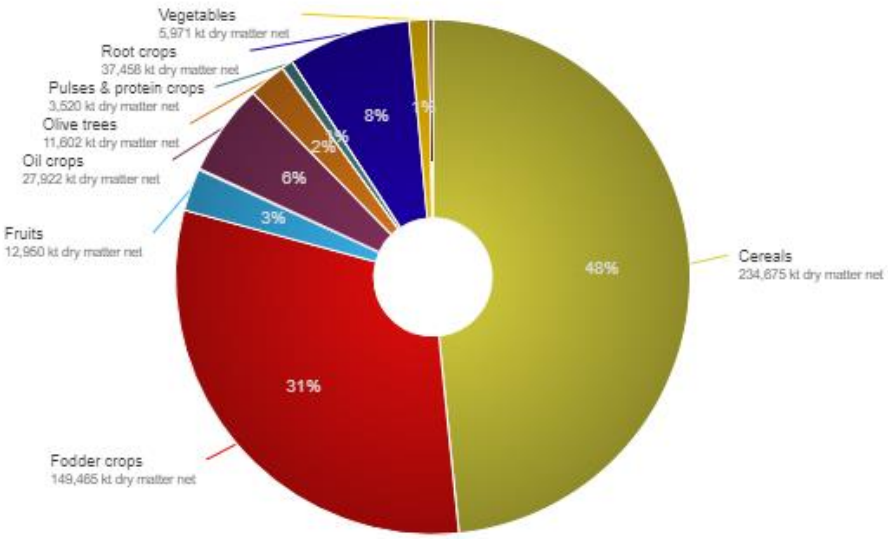
Source: Biomass Flows (DataM, 2022)

The crop production is estimated at 485 million tonnes of dry biomass in the EU27 and harvested crop residues provide an additional 88 million tdm of biomass. It should be noted that of these harvested residues, only an estimated 33% (29 million tdm) are used for feed. The remaining two thirds are used for other

purposes (biomaterials or energy), lost or discarded, but the quantity of biomass that is used for each purpose cannot be estimated at this point. 95 million tonnes of biomass are grazed in pastures and meadows.

Almost 50% of the crop dry matter produced in the EU27 in 2018 were cereals, followed by fodder crops (31%) and root crops (8%).

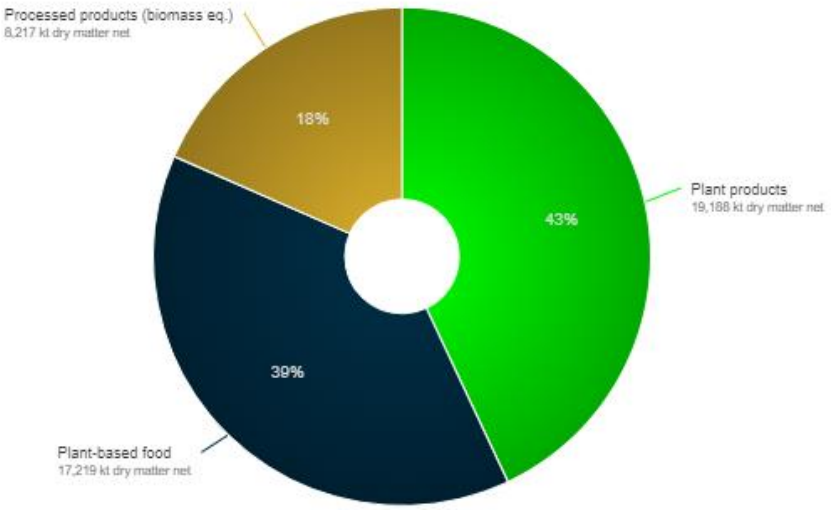
Figure 4. Crop production, EU27, net trade, 2018.



Source: Biomass Flows (DataM, 2022)

The EU27 has approximately 45 million tdm net imports of vegetal biomass equivalents, of which the biggest categories are plant products (live plants and vegetal raw material) and plant-based food. Processed products (biomaterials of agricultural origin, such as leather products) account for 18% of the net imports.

Figure 5. Agricultural imports, EU27, net trade, 2018.



Source: Biomass Flows (DataM, 2022)

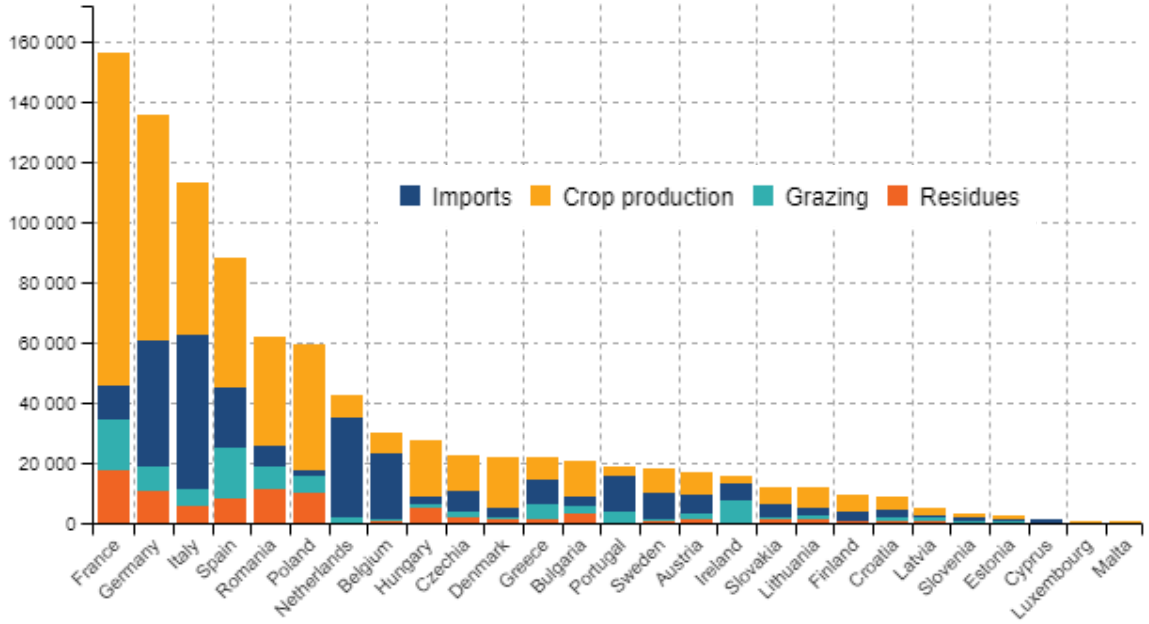
Figure 6 shows the total agricultural biomass supply (including crop and residue production, grazed biomass and imports). Following the 2008 economic crisis, agricultural supply in the EU27 has increased by over 12% (2010-2018), mainly due to a 14.5% increase in crop production.

Figure 6. Biomass supply from agriculture, EU27, net trade (1000 tdm).

Source: JRC EU Biomass Flows

France and Germany have the highest supply of agricultural biomass, while Italy and Germany are the largest net importers of agricultural biomass. They are followed by The Netherlands, who, as Belgium and Portugal, imports the majority of its agricultural biomass.

Figure 7. Biomass supply from agriculture, net trade, 2018 (1000 tdm).



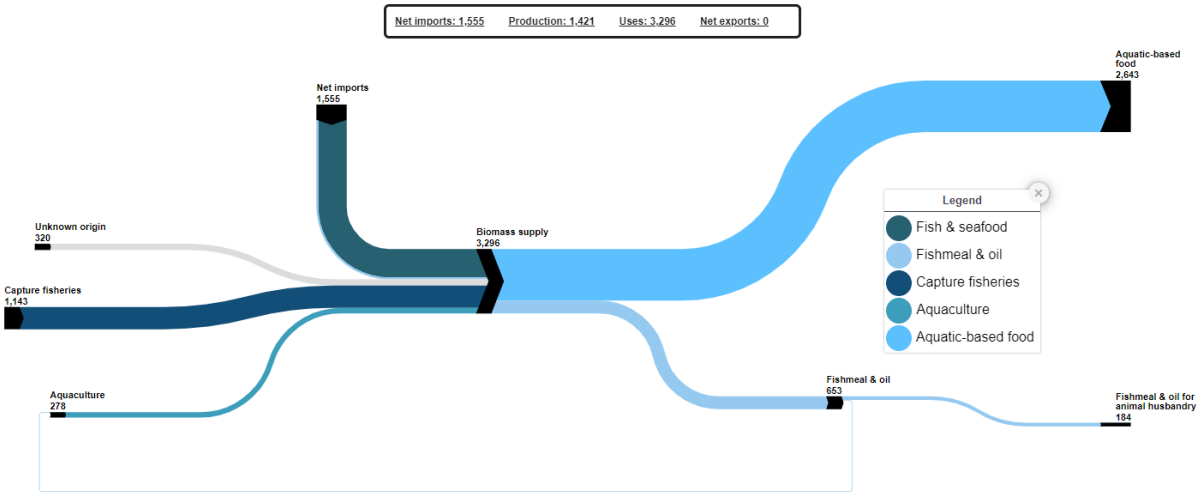
Source: Biomass Flows (DataM, 2022)

2.3 Fisheries and aquaculture

The fisheries and aquaculture dataset has been updated and enhanced with new data. The dataset now extends to 2016, although some of the categories had to be estimated using data from prior years so that complete flows could be created. More details are discussed in section 5.2.

EU27 production of seafood by capture fisheries and aquaculture was approximately 1.4 million tdm in 2016 with 1.1 million tdm originating from capture fisheries and 0.3 million tonnes tdm from aquaculture. EU27 net imports of seafood products amounted to approximately 1.6 million tdm (52% of the total biomass of known origin, slightly higher than the domestic sources of fisheries and aquaculture biomass at 48%).

Figure 8. Biomass flows for fisheries and aquaculture, EU27, net trade, 2016 (1000 tdm).



Source: Biomass Flows (DataM, 2022)

In terms of uses, most of the aquatic biomass is used for human consumption, with only 20% being used for fishmeal and oil.

2.4 Woody biomass

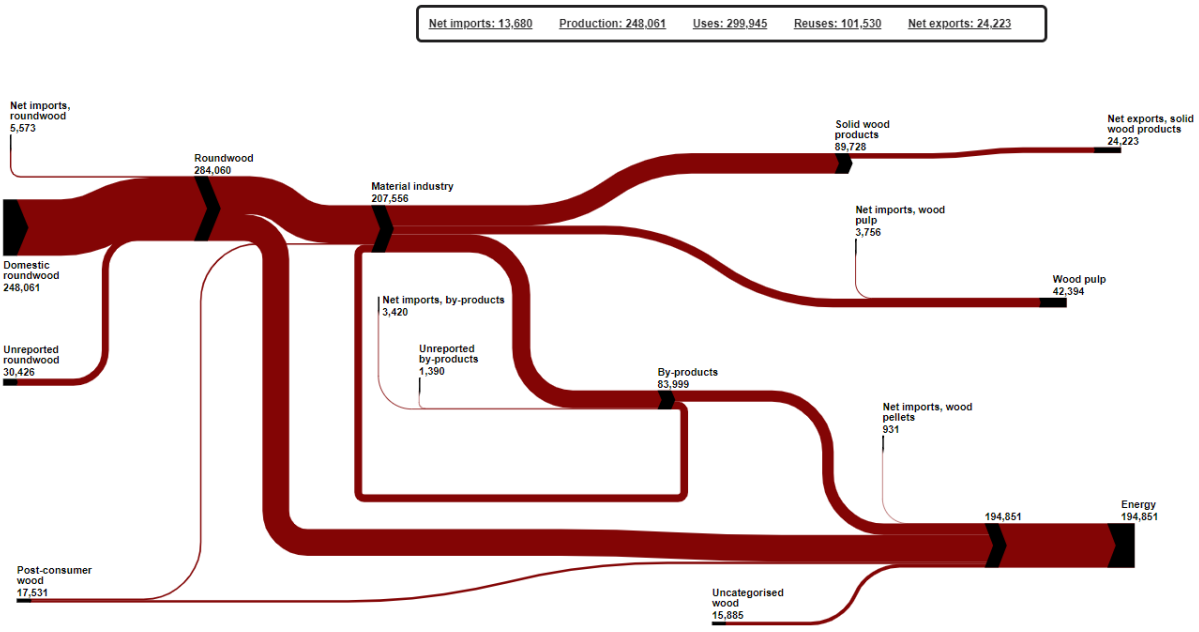
EU27 supply of roundwood was estimated at approximately 284 million tdm in 2017, of which at least 87% was sourced domestically. In the EU27, the biggest producer of roundwood is Sweden, followed by Germany and Finland.

This supply was complemented with 17 million tdm of post-consumer wood, 8 million tdm net imports of by-products, wood pulp and pellets, 15 million tdm uncategorised wood and 1 million tdm of by-products of unreported origin.

The total net imports of all woody biomass types are estimated to be approximately 13 million tdm.

Circular flows of biomass are key for woody biomass products, with wood often undergoing several cycles of reuse until it is disposed of (usually to produce energy). These circular flows are clearly visible in the new schema that has been implemented for the woody biomass sector.

Figure 9. Woody biomass flows in the-forest based sector, EU27, net trade, 2017 (1000 tdm).



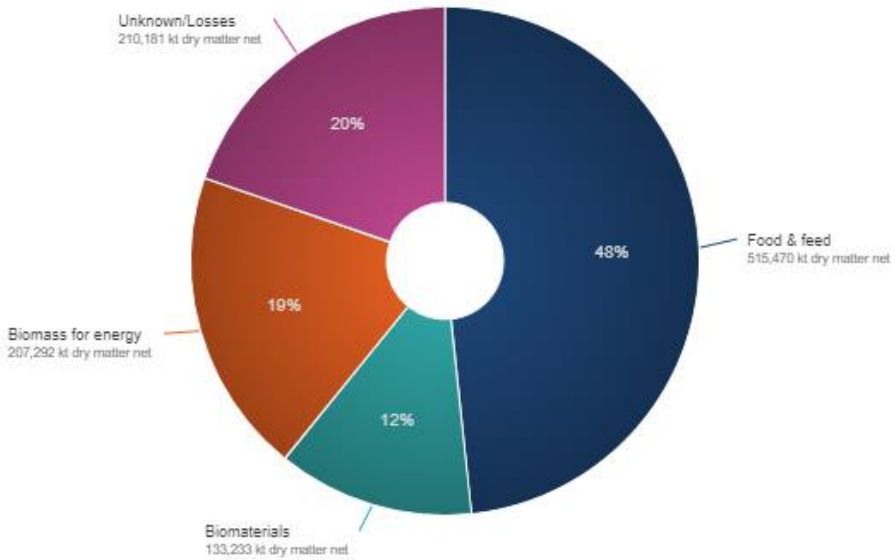
Source: Biomass Flows (DataM, 2022)

3 Biomass uses

3.1 Overview

Food and feed is the most important category in terms of biomass use, adding up to 48% of the biomass. However, due to large data gaps in terms of biomaterial and bioenergy uses of agricultural biomass, those two categories of uses are clearly under-estimated in this document. It is important to note that biogas and bioelectricity have not been considered for this study.

Figure 10. Composition of the EU27 biomass uses, net trade, 2017.



Source: Biomass Flows (DataM, 2022)

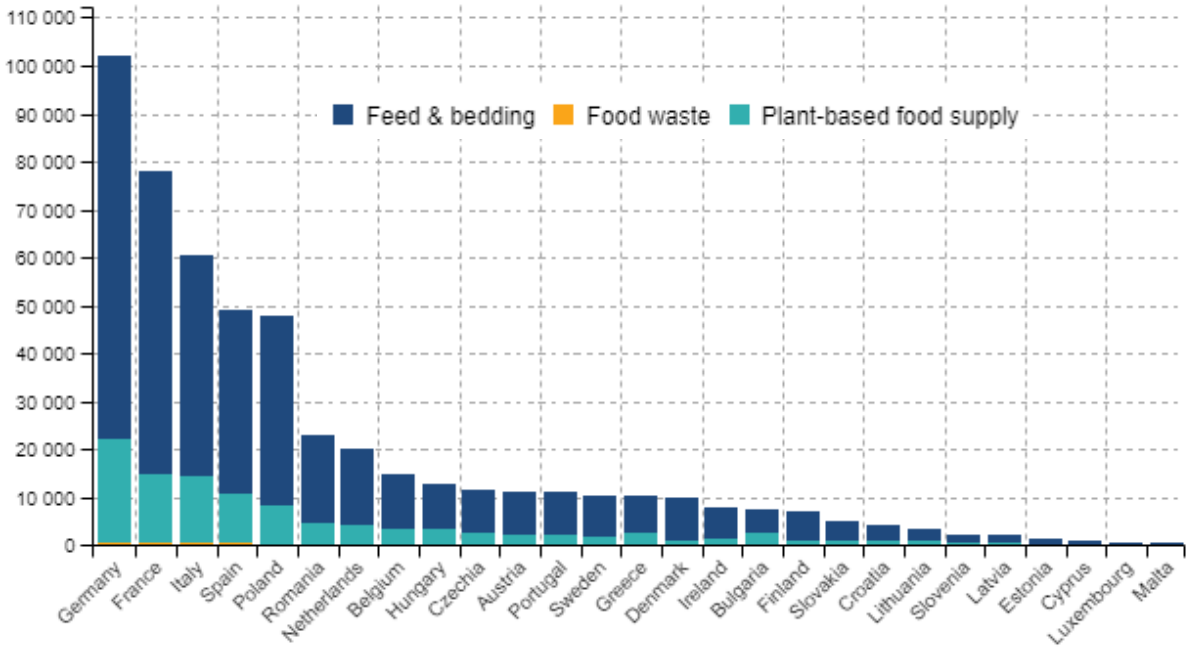
If losses or biomass for which a specific use cannot be estimated are not considered, approximately 60% of the available biomass is used for food and feed, with biomass for energy and biomaterials accounting for 24% and 16% of the identified biomass uses respectively.

3.2 Food and feed

The biomass used for food and feed products is almost entirely of agricultural origin. 73% of the total agricultural biomass supply (net trade, expressed in dry matter) was used as food and feed in 2018. Approximately 80% of the total biomass for food and feed uses is used as animal feed & bedding for the production of animal-based food (either for domestic consumption or for export), while the rest is directly consumed as plant-based food or is food wasted before consumption (vegetal biomass at the processing and manufacturing stage) (3%). One third of the collected crop residues is used for feed and bedding and horticulture purposes. The remaining two thirds are discarded or used in downstream sectors. How these two thirds are split into biomaterials and bioenergy uses cannot be quantified at this point.

Within the EU27, Germany (102 million tdm) and France (78 million tdm) were the biggest producers of food and feed. Figure 11 and Table 1 show the proportion of biomass dedicated to producing animal- or plant-based food in each country.

Figure 11. Food and feed uses, net trade, 2018 (1000 tdm).



Source: Biomass Flows (DataM, 2022)

Table 1. Biomass used for food purposes, net trade, 2018 (1000 tdm).

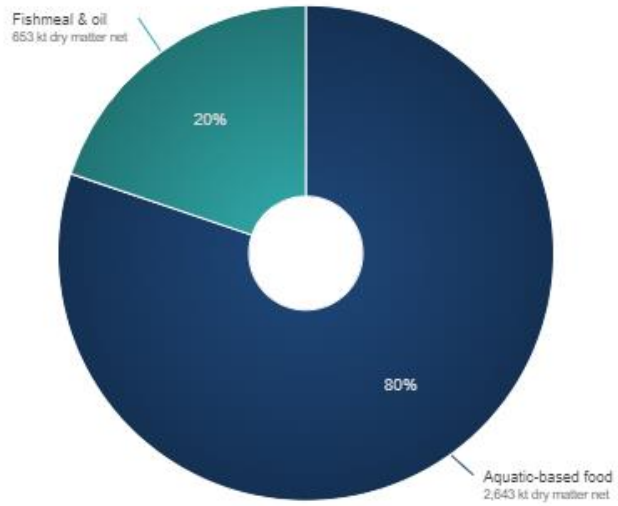
Country	Feed & bedding		Plant-based food supply		Total	% of EU27 Total
Germany	79 656	78%	21 674	21%	101 823	20%
France	62 796	81%	14 298	18%	77 798	15%
Italy	46 138	76%	13 664	23%	60 492	12%
Spain	38 188	78%	10 133	21%	49 015	9%
Poland	39 549	82%	8 221	17%	48 028	9%
Romania	18 166	80%	4 413	19%	22 846	4%
Netherlands	16 124	80%	3 780	19%	20 257	4%
Belgium	11 645	78%	3 100	21%	14 974	3%
Hungary	9 200	72%	3 428	27%	12 779	2%
Czechia	9 130	78%	2 557	22%	11 758	2%
Portugal	9 184	81%	2 057	18%	11 345	2%
Austria	8 851	79%	2 212	20%	11 202	2%
Greece	8 539	81%	1 935	18%	10 520	2%
Sweden	7 925	76%	2 310	22%	10 371	2%
Denmark	8 841	88%	1 161	12%	10 033	2%
Ireland	6 677	84%	1 183	15%	7 946	2%
Bulgaria	4 948	67%	2 397	32%	7 399	1%
Finland	5 937	84%	1 063	15%	7 039	1%
Slovakia	4 142	80%	997	19%	5 164	1%
Croatia	3 613	81%	793	18%	4 456	1%
Lithuania	2 669	74%	917	25%	3 603	1%
Slovenia	1 666	78%	451	21%	2 146	0%
Latvia	1 675	80%	392	19%	2 102	0%
Estonia	1 265	83%	256	17%	1 528	0%
Cyprus	765	76%	237	23%	1 009	0%
Luxembourg	603	82%	129	18%	736	0%
Malta	364	79%	93	20%	460	0%
Total	**408 256**	**79%**	**103 851**	**20%**	**516 829**	**100%**

Source: Biomass Flows (DataM, 2022)

The EU Biomass Flows tool also offers visibility on the nutrient share of the food consumed. These have been estimated following the methodology described by in Gurria et al. (2017 and 2021).

1% of the biomass dry matter that is used for food and feed is of aquatic origin. This is 80% of the biomass supply of fisheries and aquaculture.

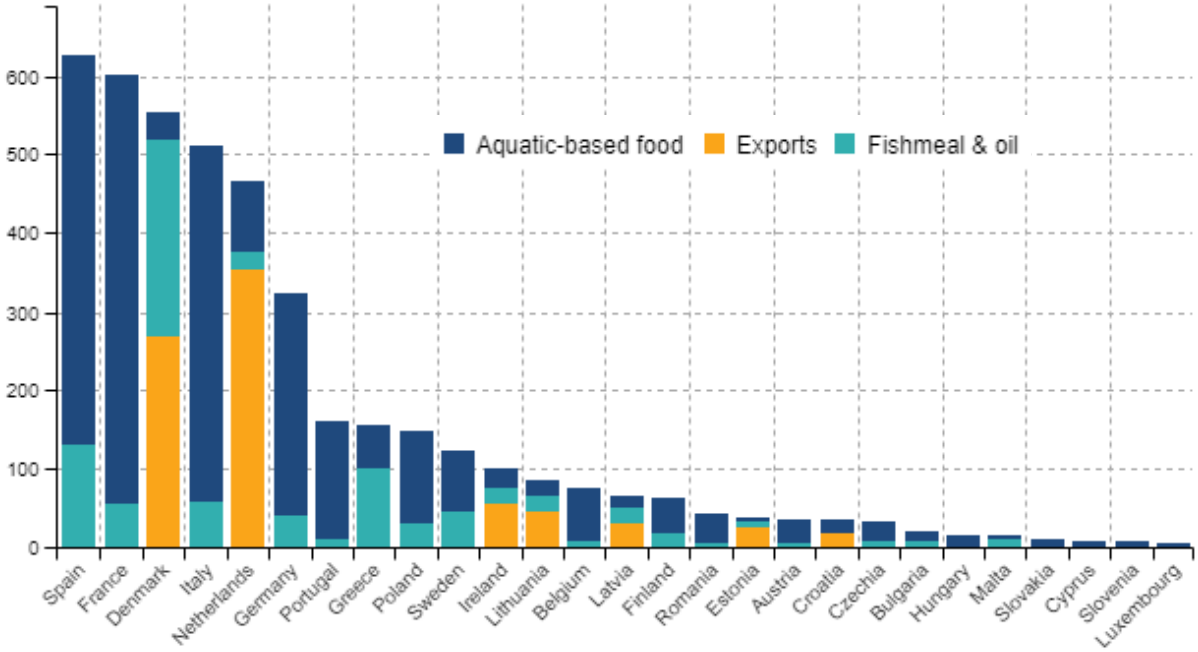
Figure 12. Aquatic biomass uses in the UE27, net trade, 2016.



Source: Biomass Flows (DataM, 2022)

Spain and France are the largest producers of aquatic-based food in the EU27. Denmark, on the other hand, is the biggest manufacturer of fishmeal and oil.

Figure 13. Aquatic biomass use by type and Member State, net trade, 2016 (1000 tdm).



Source: Biomass Flows (DataM, 2022)

3.3 Biofuels and biomaterials

Most of the biomass used as biofuels continues to be woody biomass. In 2017, 195 million tdm of directly or indirectly[8] gathered woody biomass were estimated to have been used for energy.

Other than updates for woody biomass, no changes have been made to the dataset for biomaterials and biomass for energy production.

It is important to note that, due to lack of data that can be integrated with the sources used for this analysis, many bioenergy pathways are missing (e.g. biogas production from biowaste).

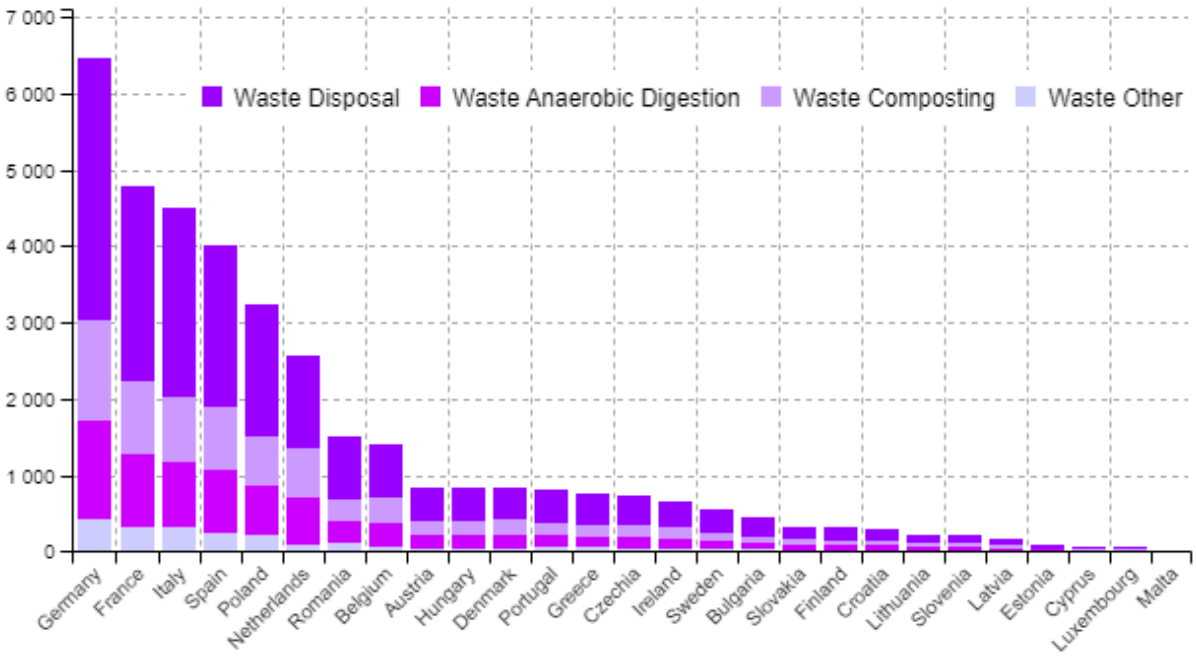
Almost all of the biomaterials also have an origin in forestry activities with the biggest component being solid wood products. In 2017, approximately 133 million tdm of biomass were used for bio-materials. Although a net importer of roundwood, the EU27 is a net exporter (24 million tdm) of solid wood products.

[8] From processed wood or as by- or co-product of industrial roundwood processing.

4 Food waste

Food waste in the EU27 is estimated to be approximately 30 million tdm in 2018. This figure includes waste from consumption of households and food services, waste during the processing and manufacturing, and retail and distribution stages, and animal-based food waste at the production stage. Vegetal food waste at the production stage has not been included (see section 5.3.4 for details). As expected, the MS with the largest populations also produce the biggest amounts of food waste.

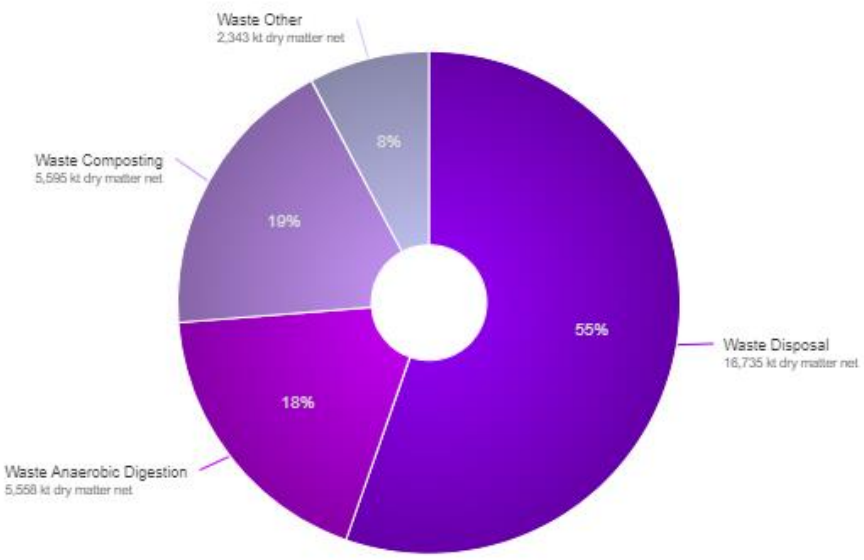
Figure 14. Food waste by destination and Member State, 2018 (1000 tdm).



Source: Biomass Flows (DataM, 2022)

Most of the food waste produced in the EU27 is destined for disposal in landfills, sewage or incineration (55%). Composting and anaerobic digestion are the other two main destinations of food waste (19% and 18% respectively). Finally, 8% of the waste is used in other ways such as home composting or food for pets.

Figure 15. Food waste by destination, 2018.



Source: Biomass Flows (DataM, 2022)

Most of the food waste occurs at the consumption stage. EU27 consumers wasted 21 million tdm of food in 2018. This is 17.7% of all food available for consumption.

5 Changes in the 2022 EU Biomass Flows tool

5.1 Agriculture and food

The data for agricultural biomass and food has been extended to include 2018 as well as completely refreshed with the latest Eurostat data. 2018 is now the reference year for the "latest data available" in the agriculture sector.

The methodology for estimation of biomass continues to be the one from the previous dataset. There have however been some changes in the data sources for the estimation of food biomass. As in the previous dataset, two FAOSTAT domains were used to calculate food demand. However, the time periods each of these two datasets are being used for have changed:
- Food balances (FBS) were used for data from 2014 on. This is now the source of data for all years starting in 2010.
- Food Balances (-2013, old methodology and population) (FBSH) are therefore now only used for the years 2008 and 2009.

5.2 Fisheries and aquaculture

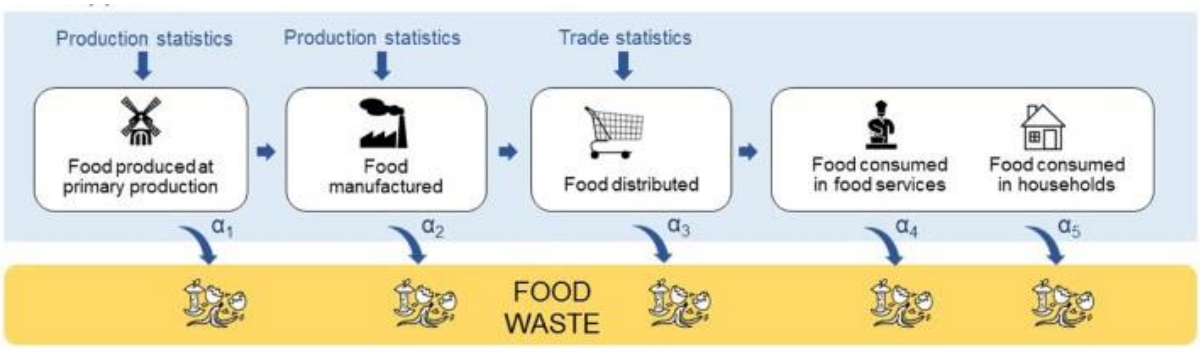
The data for fisheries and aquaculture biomass has been refreshed and extended to cover the period 2008-2016. 2016 is now the reference year for the "latest data available" in the fisheries sector.

The methodology and data sources have remained the same as in the previous dataset. However, the full time series shows some data gaps that have been mitigated as follows:
- Data for gross trade for the EU27 could not be found for all flows, as in some cases it was not possible to differentiate between intra- and extra-EU trade. Therefore, the EU27 gross trade diagrams have been disabled and no data will be shown if the options EU27 and gross trade view are selected.
- Fishmeal for aquaculture data is available only until 2012. Although generally decreasing, for the period 2000-2012 the quantities for fishmeal for aquaculture do not vary greatly overall. We have therefore decided to maintain the 2012 figure as default for the years 2013-2016 in order to be able to provide complete flows.
- Fishmeal for animal husbandry (fishmeal used to feed farm animals), has been estimated as the difference between the quantity of fishmeal for non-food uses and the quantity of fishmeal for aquaculture.

5.3 Food waste

We have used food waste data by the JRC D3 Land resources unit as our primary data source to incorporate food waste flows into the EU Biomass Flows tool. The methodology used for estimating food waste at each step of the food supply chain is explained in the food waste study published by De Laurentiis et al. (2021) and Caldeira et al. (2021). Both the food waste study and the EU biomass flows use FAOSTAT food balance sheets as their main source for available food supply.

Figure 16. Food waste at the different steps of the food supply chain.



Source: Grown and thrown: Exploring approaches to estimate food waste in EU countries. Caldeira et al (2021)

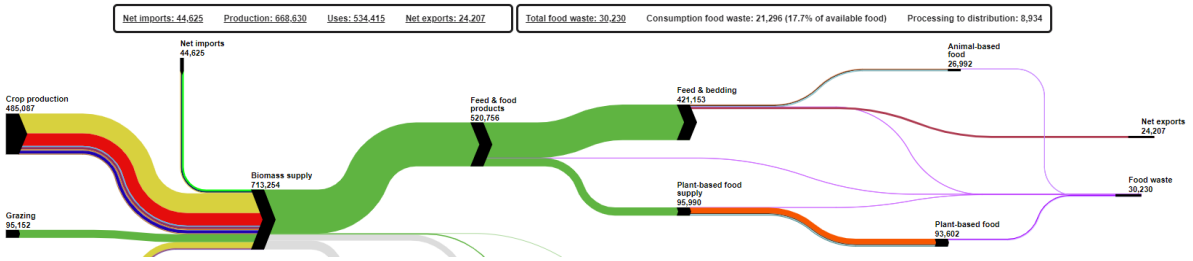
The biomass Sankey, however, is not developed to show all steps of the food chain, as it is meant to represent all kinds of different biomass types of various origins. In addition, food waste figures in the food waste study are provided in fresh matter, instead of dry matter as used in the EU Biomass Flows. Although the share of food waste out of the amount of food entering each stage of the supply chain in fresh matter (α in Figure 16) can be different than the share of the same waste in dry matter (e.g. waste of parts of vegetables may contain less water than what is consumed), the available data is insufficient to estimate the real weight of food dry matter waste. We have therefore made the assumption that the share of waste in fresh food is the same share as in dry matter of food biomass. Finally, food waste figures from the above mentioned study are provided as weight of product (e.g. dairy) instead of feed equivalents in the case of ABF (feed demand for the production of dairy products). Although a conversion to feed equivalents would be possible, waste figures are usually analysed in comparison to the available food. Using feed equivalents to estimate ABF waste could potentially cause confusion in the interpretation of the figures. We have therefore chosen to represent waste quantities as waste of final food products.

In order to integrate food waste flows in the EU Biomass Flows tool, we have calculated coefficients that represent the share of food waste for every year, every MS and the EU27, and each stage of the food chain. The food waste coefficients have been estimated for the main vegetal (cereals, fruits and nuts, oil crops, potatoes, sugar beets and vegetables) and animal (meat, dairy and eggs) food groups. Fish food waste has been excluded for this release but will be considered in future releases. The coefficients have then been applied to the corresponding food biomass figures in the EU biomass flows (vegetal and animal-based food).

Once the food waste quantity for every step of the food chain has been calculated, we have represented the food waste flows in the Sankey diagrams. All food waste flows converge into a food waste node so that we are able to show the total food waste figure for each diagram.

We have also included information on food waste in the info box shown at the top of the diagrams, both as the total food waste quantity and the food waste in the consumption stage and all other prior stages. A total food waste figure is also included in the info box at the aggregated biomass level (which shows all biomass flows regardless of origin).

Figure 17. Info box showing waste figures in the EU Biomass Flows.



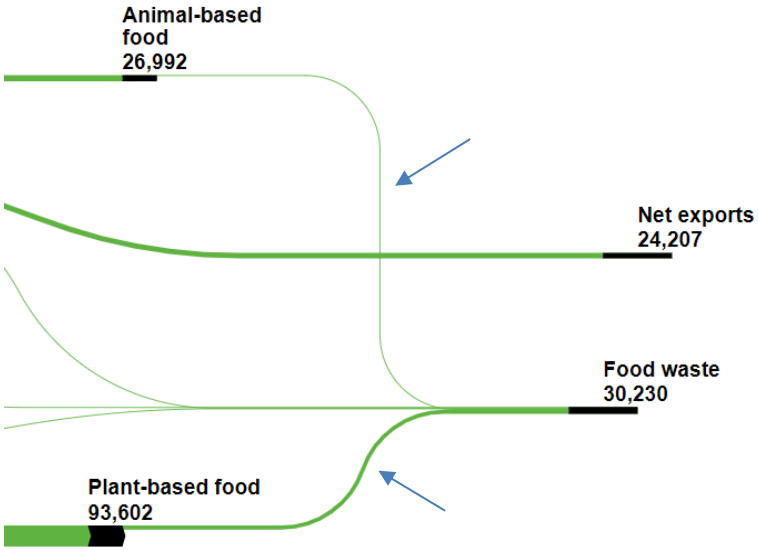
Source: Biomass Flows (DataM, 2022)

At the deepest detailed level of the agricultural flows, each of the food waste flows is in turn split into different types of waste treatment: disposal, anaerobic digestion, composting or other types of waste treatment. The coefficients have been calculated with the dataset mentioned above.

5.3.1 Consumption stage

Food waste at the consumption stage has been added as the final stage of the food chain. It is split in food waste of animal-based food (ABF) and food waste of plant-based food (PBF) origin. Consumption food waste is a direct flow from the estimated animal- and plant-based food quantities, as these quantities represent food available for human consumption, regardless of whether it is ultimately consumed or wasted.

Figure 18. Food waste flows at the consumption stage.



Source: Biomass Flows (DataM, 2022)

5.3.2 Retail and distribution stage

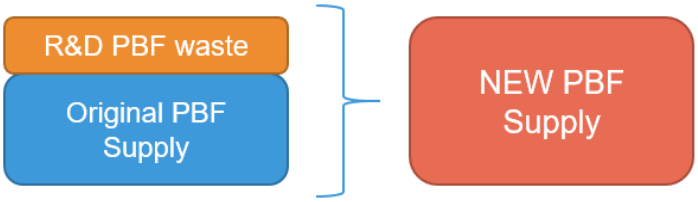
Vegetal food waste at the retail and distribution stage is estimated as a share of the PBF supply. PBF supply is the quantity of vegetal biomass that is needed to produce all vegetal food available for consumption by the population. PBF supply already takes food waste in the previous steps of the chain into account, as whatever is wasted in previous stages is no longer available for consumption. Therefore, we have increased the originally estimated PBF supply by the calculated food waste quantity.

$$\text{PBF waste}_{ij} = \text{Original PBF supply}_{ij} * \text{Vegetal food waste coefficient}_{ij}$$

$$\text{New PBF supply}_{ij} = \text{Original PBF supply}_{ij} + \text{PBF waste}_{ij}$$

Being i the selected year and j the selected MS or EU27.

Figure 19. New PBF supply calculation including retail and distribution vegetal food waste.



Source: Authors

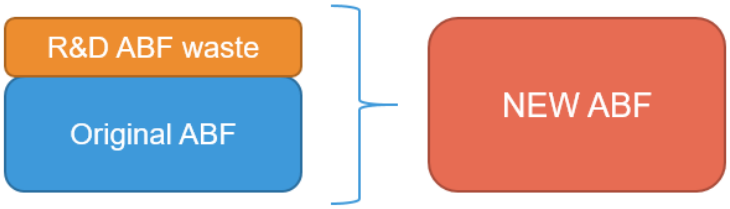
Similarly, ABF waste is estimated as a share of ABF available for consumption. Therefore, the originally estimated quantity has been increased by the food waste share at this stage.

$$ABF\ waste_{ij} = Original\ ABF_{ij} * Animal\ food\ waste\ coefficient_{ij}$$

$$New\ ABF_{ij} = Original\ ABF_{ij} + ABF\ waste_{ij}$$

Being i the selected year and j the selected MS or EU27.

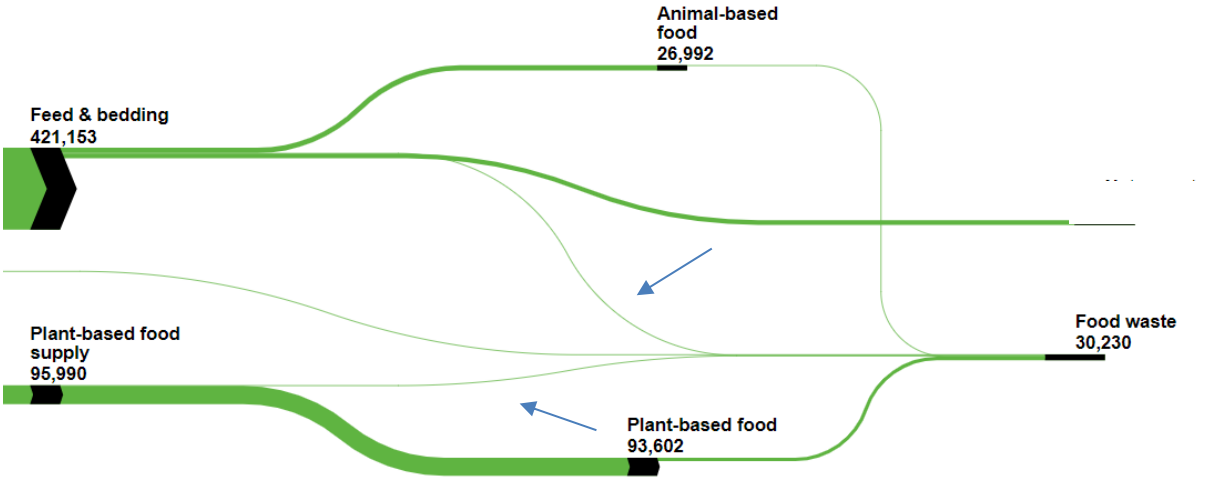
Figure 20. New ABF supply calculation including retail and distribution animal food waste.



Source: Authors

Both ABF and PBF waste flows converge at the total food waste node.

Figure 21. Food waste flows at the retail and distribution stage.

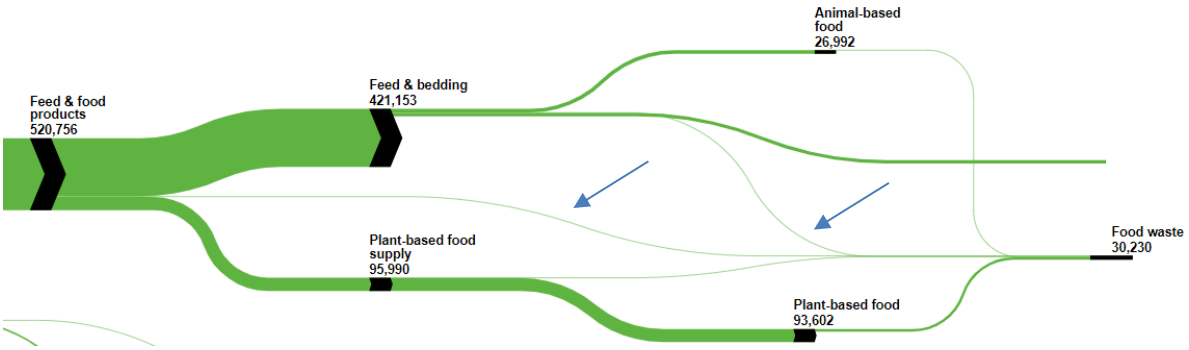


Source: Biomass Flows (DataM, 2022)

5.3.3 Processing and manufacturing stage

Waste that occurs at the processing and manufacturing stage is also already considered in the food supply quantity. The vegetal food waste for this stage is estimated as a share of the total feed and food products quantity.
In the case of ABF, the waste at the processing and manufacturing stage has been again estimated as a share of the ABF available for consumption in order to maintain coherence with the estimation of food waste as waste in final food products.
Similar to the retail and distribution stage, both PBF and ABF wastes at this stage increase the previously estimated feed & food products and feed and bedding (outgoing flow) biomass quantities respectively.

Figure 22. Food waste flows at the processing and manufacturing stage.



Source: Biomass Flows (DataM, 2022)

5.3.4 Production stage

Finally, for the production stage only ABF waste is considered, as in the EU biomass flows structure animal food production is a step that follows crop production, and therefore similar to a "processing" step. Crop production food waste has not been specifically included in the diagrams, as the crop production figures shown are economic food production and residues are shown separately. The unknown/losses flow should include post-harvest losses, but they cannot be differentiated for other supply of vegetal biomass that has no recorded use.

ABF waste joins all other stages of ABF waste, except for consumption, as a flow that is calculated multiplying ABF by its corresponding coefficient. All ABF waste flows are integrated in a flow that goes from "Feed & bedding" to "Food waste".

5.3.5 Waste destination

All waste flows have been split by destination type into four categories (anaerobic digestion, composting, disposal (which includes incineration, landfill and sewage) and other (such as pet food or home composting). The quantity of waste by destination has been calculated using coefficients from Corrado et al. (2020).

5.4 EU27

In 2020, the United Kingdom ceased to be a Member State of the EU. Although the data shown in the EU Biomass Flows is prior to this data, any analysis of biomass quantity performed for future studies requires EU27 data. Some of the data sources of the EU Biomass Flows tool have not migrated to the new EU27 until recently, and therefore a full dataset for the EU27 was not possible prior to 2022. All datasets that report data for EU27 have continued to be used in the same way than for the previous version of the tool, although the extraction of the data has been extended to include EU27.

5.5 Woody biomass

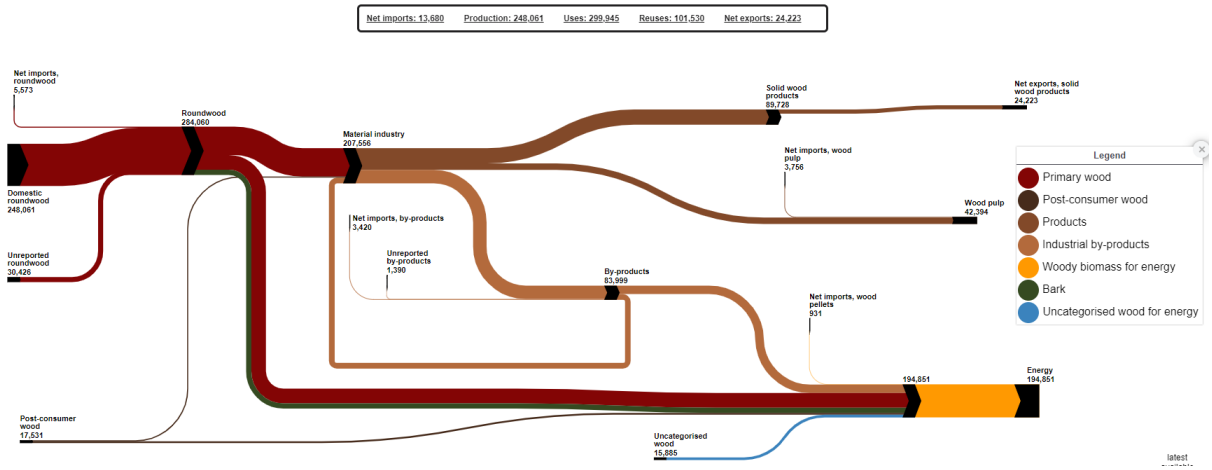
5.5.1 Redesign of woody biomass flows and new categorisation

Woody biomass from forests and other wooded land is used and re-used across complex and interlinked value chains. Woody biomass supply chains include the provision of primary wood from forests and other wooded land, industrial by-products, post-consumer wood and production of wood-based products and energy. The most important source of woody biomass is roundwood, which includes primary wood of any quality. Roundwood is used for the production of solid wood products and wood pulp, but also for energy (part of it is transformed into wood pellets and other agglomerates before being burnt). The two main sectors for woody biomass uses are industries of wood-based products and energy production, but they are not parallel processes. Indeed, industrial transformation of wood generates by-products that are again used as inputs for the production of other wood-based products or for energy generation. Both the material and energy sectors use not only primary wood, but also industrial by-products, that are directly output from manufacturing, and post-consumer wood that has been recovered after at least one life cycle.

Exploiting the new software capabilities to represent circular flows, the schema of the forest-based sector has been modified and designed to be more consistent with the actual biomass flows amongst the various wood processing steps. With this new schema the re-use of by-products from the wood processing sector can be shown not only for energy production, but also for material production. Wood pellets trade has been included in the new schema. Similar to the previous schema, the woody biomass flows end at semi-finished products because of lack of quantitative data for the finished wood products (e.g. furniture).

The schema shows that both of the main uses of woody biomass (i.e., material production and energy generation) exploit primary wood from forests and other wooded land, industrial by-products and post-consumer wood. The material production has been split into two main categories: solid wood products, which include sawnwood and wood panels, and wood pulp. The class “uncategorized wood” has been introduced in this schema for the energy sector to represent the burnt woody biomass of unknown quality/origin, even when counted in official statistics (figure 23).

Figure 23. Woody biomass flows in the forest-based sector, EU27, net trade, 2017 (1000 tdm).



Source: Biomass Flows (DataM, 2022)

5.5.2 Data sources

The time series of data on woody biomass supply, uses and flows in the forest-based sector spans from 2009 to 2017 and it is derived from international datasets and were converted to uniform units by using conversion factors. The last year of woody biomass flows is 2017 because of the availability of data in some datasets.
Data on production and trade of woody biomass are from the Joint Forest Sector Questionnaire (JFSQ) and Eurostat. Conversion factors and input-output coefficients concerning the production and trade of the main raw materials and by-products (i.e., roundwood removals and trade, wood pulp production and trade, industrial residues) that are used for the manufacturing of semi-finished wood-based products (i.e., sawnwood, wood-based panels, and wood pulp) and wood pellets are mainly from "Infro"5. For energy uses of wood, the main data source is the Joint Wood Energy Enquiry (JWEE), which also provides conversion factors and input coefficients for wood pellets production. The JWEE is complemented with data form the National Renewable Energy Action Plans Progress Reports (NREAP) (Table 2).

Table 2. Data sources used to estimate biomass flows in the forest-based sector.

Data source	Organization	Data
Joint Forest Sector Questionnaire (JFSQ)[9] (updated August 2021)	FAO, UNECE, EUROSTAT and ITTO	Production, imports and exports of wood removals and products
Eurostat database[10]	EUROSTAT	Wood pellets and other agglomerates from 2009 to 2011
Input/output coefficients[11]	Infro (Mantau)	Input/output coefficients for wood products and conversion factors
Forest product conversion factors for the UNECE region[12]	UNECE, FAO	Conversion factors
Joint Wood Energy Enquiry (JWEE)[13] (updated February 2021)	UNECE/FAO Forestry and Timber Section, IEA, EUROSTAT	Energy use of wood, conversion factors
NREAP Progress Reports[14]	EU	Energy use of wood

Source: Authors

These are the same datasets used for the last release of the Wood Resources Balance Assessments[15]. Interpolation strategies and conversion factors can be found in (Cazzaniga et al., 2021). They are also consistent with the new release of Sankey diagrams for the forest-based sector in (Cazzaniga et al., 2022). When available, data are strictly consistent with the official values without any outlier rejection.

Available data at MS-level have been aggregated to represent the EU values. Unfortunately, this cannot be done for the gross trade, because of the lack of consistent data on intra-EU trade.

[9] https://unece.org/forests/data-forest-products-production-and-trade
[10] https://ec.europa.eu/eurostat/data/database
[11] http://data.europa.eu/89h/a1f94d36-748d-48ef-81bd-f936c64e5800
[12] http://www.unece.org/fileadmin/DAM/timber/publications/DP-49.pdf
[13] http://www.unece.org/forests/jwee.html
[14] https://ec.europa.eu/energy/en/topics/renewable-energy/progress-reports
[15] https://knowledge4policy.ec.europa.eu/publication/wood-resource-balances_en

Despite the strong improvement in data quality and availability, especially in the last years, information is often incomplete and inconstant, so many gaps still remain. Hence, the input and output of the main nodes are generally imbalanced. Therefore, woody biomass flows include an estimate of the missing sources or uses in those nodes, estimated as the quantity required to reach a balance in each node. Missing flows are labelled as “unreported” quantities in the diagram. Charts and graphs have been disabled for this sector because the unreported category makes it difficult to provide an overall view of the woody biomass flows without additional analysis.

6 Future oriented biomass flows

One of the most common requests the EU Biomass Flows development team has received in recent years was the need for forward looking analysis of biomass flows. Unfortunately, the data required to create projections of biomass flows for all biomass types, in a way that can be integrated in the existing biomass flows' structure is not available.

There are, however, some markets for which flows of commodities in the coming years can be visualised. We have therefore created the agricultural outlook flows. These flows are commodity specific, future looking, quantified in different units and are more granular than the EU biomass flows. Therefore, and while they have been created with the same software and look very similar in structure and tool capabilities than the EU Biomass Flows, they are hosted in a separate dataset and visualisation page.

The data used to create the agricultural outlook flows are published every year in the medium-term outlook on the prospects for agricultural markets and income. You will find more information about the report in the Medium-term outlook web page:

https://ec.europa.eu/info/food-farming-fisheries/farming/facts-and-figures/markets/outlook/medium-term_en

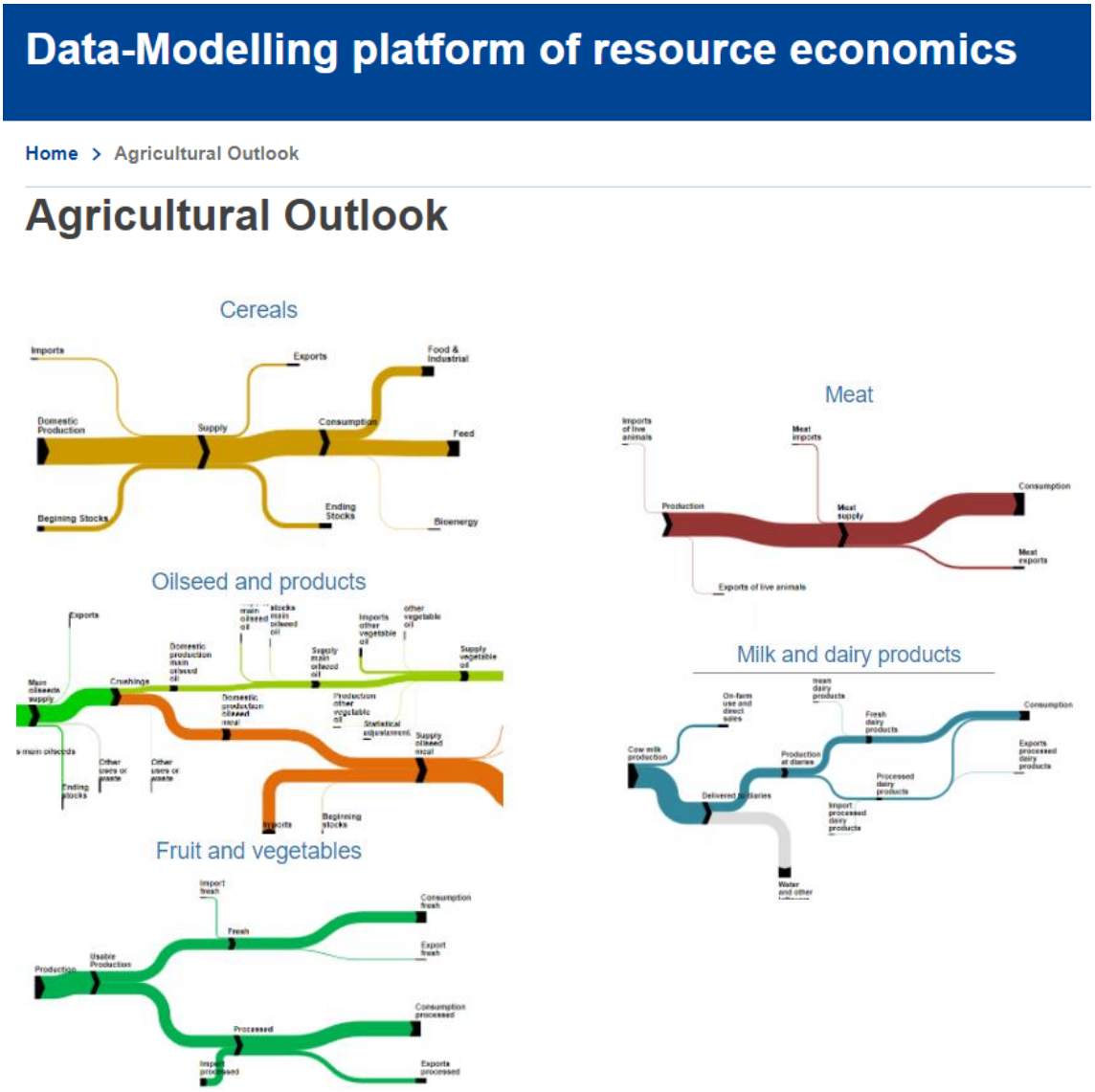
As is the case in the EU Biomass Flows tool, the agricultural outlook flows display a collection of Sankey diagrams, structured as a series of nodes connected by flows. The black nodes represent activities (e.g. imports, crushing, etc.), while the coloured flows indicate the inputs and outputs of different agricultural commodities (e.g. oilseeds, oil or meal). The width of each flow represents the quantity of each commodity in the flow.

These commodity flows are hosted in DataM, the Data-Modelling platform of resource economics created by the JRC. They can be accessed from a common entry page.

https://datam.jrc.ec.europa.eu/datam/mashup/AGRI_MTO_FLOWS/

There are 5 commodity flows: cereals, oilseeds and products, fruits and vegetables, meat and milk and day products.

Figure 24. Access page to the Agricultural medium-term outlook flows.

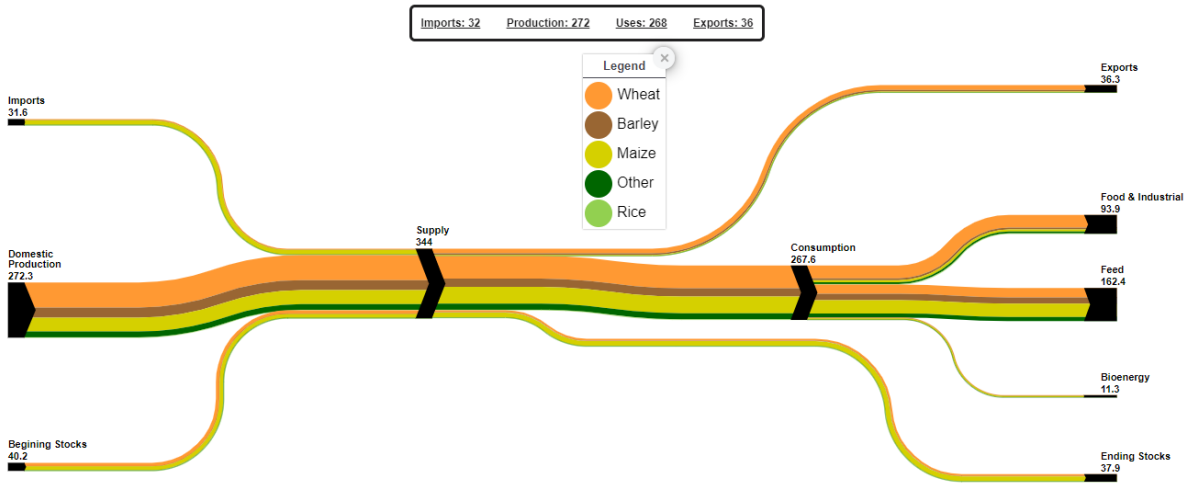


Source: Medium-term outlook commodity flows (DataM, 2022)

All flows show yearly data for the period 2005-2031 for the EU27 and have different levels of granularity that the user can navigate.

The cereal flow is shown in million tonnes of product weight, except for rice, which is measured in milled equivalent.

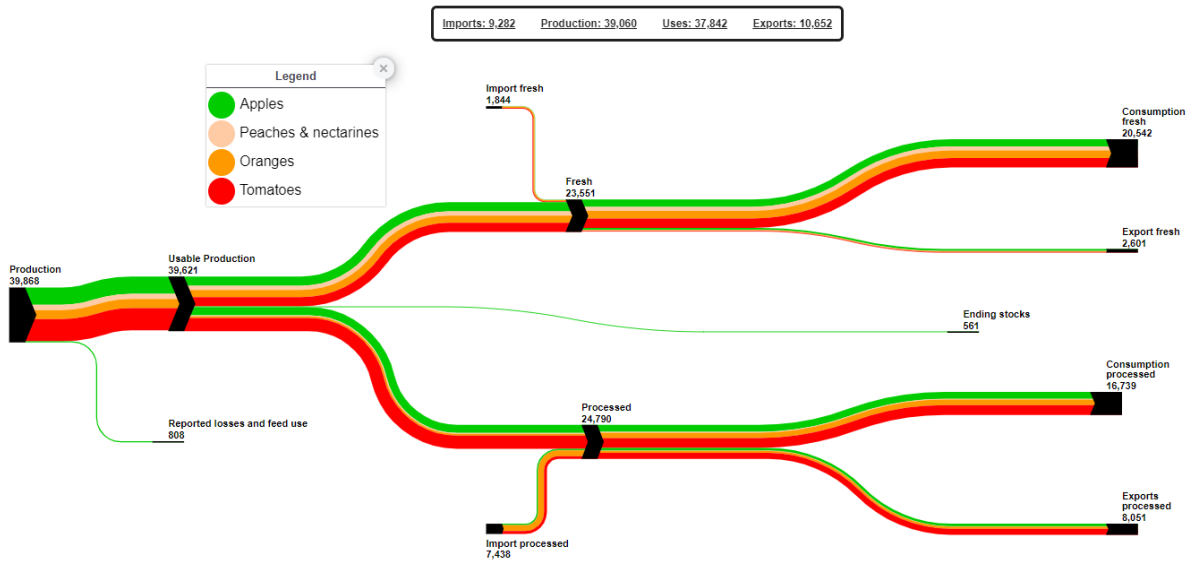
Figure 25. Cereal commodity flows, EU27, 2018.



Source: Medium-term outlook commodity flows (DataM, 2022)

Fruits and vegetables are shown in thousand tonnes of fresh equivalents. They include some of the main fruit and vegetable markets in the EU27: apples, peaches and nectarines, oranges and tomatoes.

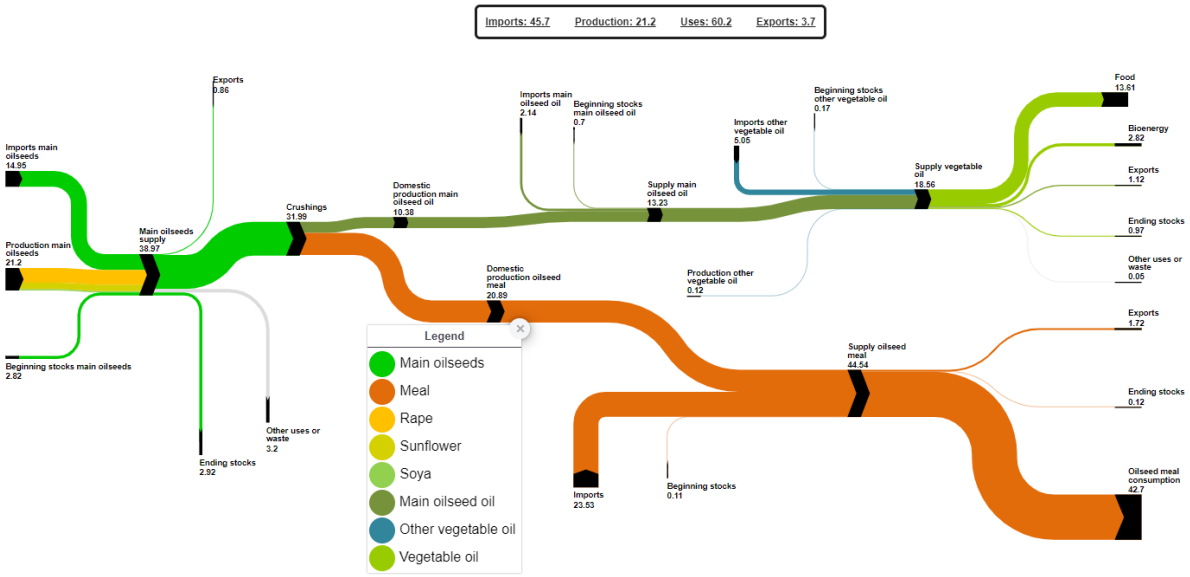
Figure 26. Fruits and vegetables commodity flows, EU27, 2018.



Source: Medium-term outlook commodity flows (DataM, 2022)

The oilseeds and products flow is shown in million tonnes of product weight. It displays how oil and meal are produced from oilseeds.

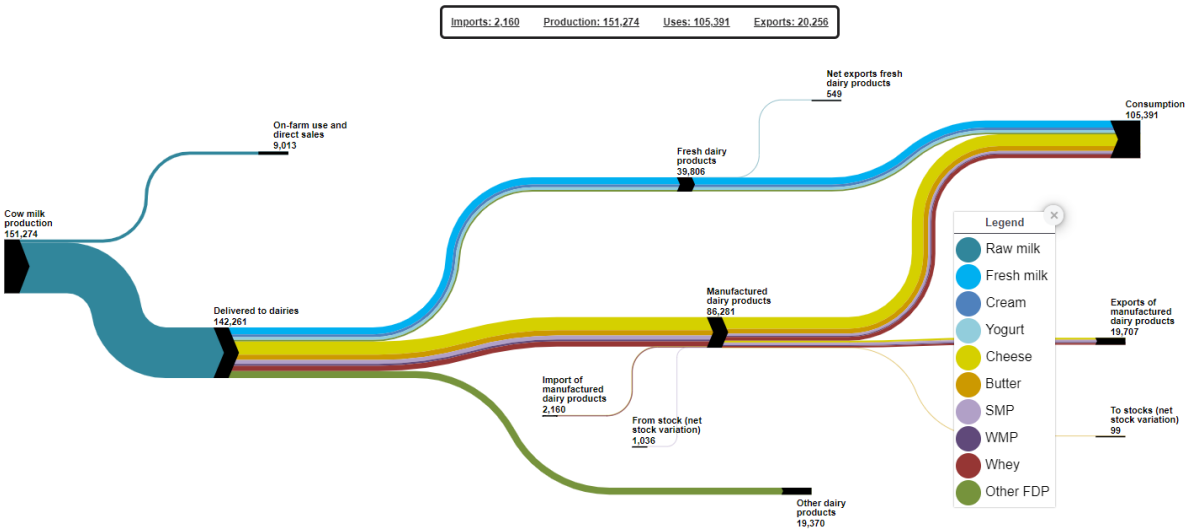
Figure 27. Oilseeds commodity flows, EU27, 2018.



Source: Medium-term outlook commodity flows (DataM, 2022)

The milk and dairy diagram is shown in thousand tonnes of milk equivalent to make flows of the different fresh and processed dairy commodities comparable.

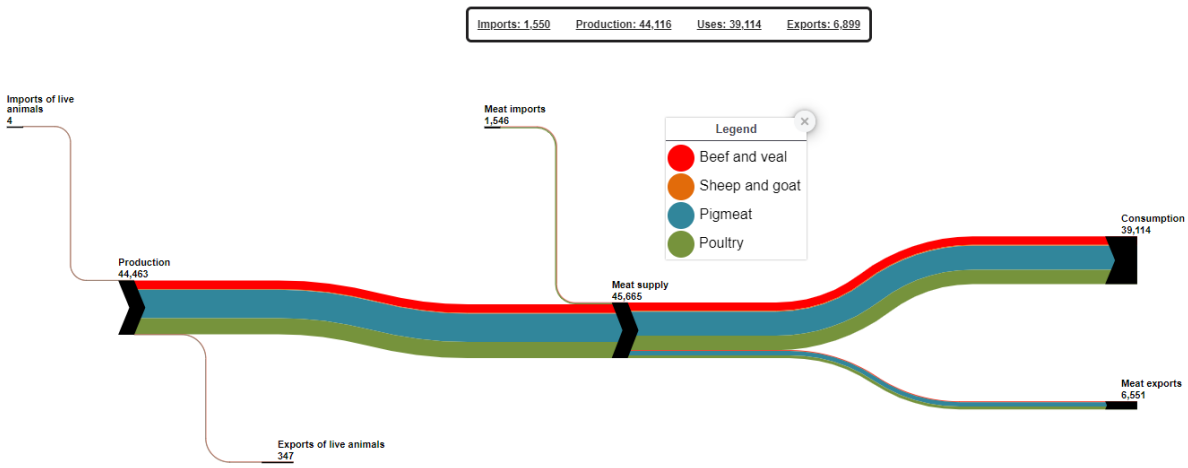
Figure 28. Milk and dairy products commodity flows, EU27, 2018.



Source: Medium-term outlook commodity flows (DataM, 2022)

Finally, the meat Sankey diagram is shown in thousand tonnes of carcass weight equivalent.

Figure 29. Meat commodity flows, EU27, 2018.



Source: Medium-term outlook commodity flows (DataM, 2022)

7 Planned improvements and future research opportunities

The widespread use of the EU and individual Member State biomass flow diagrams, as well as the recurrent mention of the biomass supply and demand assessment study in key EU policy documents, give evidence of the usefulness of this pioneer work as described also in Camia et al. (2018).
Since the first publication and provision of the biomass flow diagram (Gurria et al., 2017), many improvements have been implemented. However, data gaps in the time series, further break-down of biomass uses, full inclusion of circularity aspects and other desirable enhancements remain pertinent.
The following improvements will be considered in the coming years:

- Database update: the available data series are still very heterogeneous, ranging for the latest available year from 2011 to 2018.
- Other biomass categories: the inclusion of additional sources of biomass, such as algae, and uses not yet considered in the biomass flow, such as biogas, bioelectricity, other biomaterial etc.
- Future-oriented biomass flows: the inclusion of projections for the future biomass supply and use could help identify sustainability challenges and inform policy makers.
- New indicators: there are several potential indicators related to biomass to be included in a Sankey context, such as nutrition, wet weight, carbon, GHG emissions and monetary flows.
- As a further objective, coherence with other mass flow diagrams including biomass in a much higher disaggregation level should be looked at.

References

Caldeira C., De Laurentiis V., Ghose A., Corrado S., Sala S. (2021). Grown and thrown: Exploring approaches to estimate food waste in EU countries. Resources, Conservation and Recycling 168. doi:10.1016

Camia A., Robert N., Jonsson R., Pilli R., García-Condado S., López-Lozano R., van der Velde M., Ronzon T., Gurría P., M'barek R., Tamosiunas S., Fiore G., Araujo R., Hoepffner N., Marelli L., Giuntoli J., 2018. Biomass production, supply, uses and flows in the European Union. First results from an integrated assessment, EUR 28993 EN, Publications Office of the European Union, Luxembourg, ISBN978-92-79-77237-5, doi:10.2760/539520, JRC109869.

Cazzaniga N.E., Jonsson R., Pilli R., Camia A. (2019). Wood Resource Balances of EU-28 and Member States. EC Joint Research Centre, Publications Office of the European Union, Luxembourg.

Cazzaniga, N.E., Jasinevičius, G., Jonsson, R. and Mubareka, S., Wood Resource Balances of European Union and Member States - Release 2021, European Commission, 2021, JRC126552.

Cazzaniga, N.E., Jasinevičius, G. and Mubareka, S., Sankey diagrams of woody biomass flows in the EU – Release 2021, European Commission, 2022, JRC127989.

Corrado, S., Caldeira, C.; Carmona-Garcia, G., Körner, I., Leip, A., Sala, S. 2020. Unveiling the potential for an efficient use of nitrogen along the food supply and consumption chain. Global Food Security, Volume 25. ISSN 2211-9124, doi:10.1016.

De Laurentiis, V., Caldeira, C., Biganzoli, F. and Sala, S., Building a balancing system for food waste accounting at national level, EUR 30685 EN, Publications Office of the European Union, Luxembourg, 2021, ISBN 978-92-76-37828-0, doi:10.2760/1669, JRC124446.

DataM, 2022. Biomass Flows. https://datam.jrc.ec.europa.eu/datam/mashup/BIOMASS_FLOWS/

European Commission. 2010. COM 2020/2010. COMMUNICATION FROM THE COMMISSION EUROPE 2020. A strategy for smart, sustainable and inclusive growth. Brussels, Belgium.

European Commission. 2019. The European Green Deal. COM(2019) 640 of 11 December 2019. Available at: https://ec.europa.eu/commission/presscorner/detail/e%20n/ip_19_6691

European Commission. 2020. EU Biodiversity Strategy – Bringing nature back into our lives.. COM(2020) 380 of 20 May 2020. Available at:
https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52020DC0380&from=EN

European Commission. 2020b. Stepping up Europe's 2030 climate ambition – Investing in a climate-neutral future for the benefit of our people. COM(2020) 562 of 17 September 2020. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52020DC0562&from=EN

European Commission. 2020c. A Farm to Fork Strategy for a fair, healthy and environmentally-friendly food system. COM(2020) 381 of 20 May 2020. https://ec.europa.eu/energy/sites/ener/files/hydrogen_strategy.pdf

European Commission, DG Agriculture and Rural Development, Brussels. 2021. EU agricultural outlook for markets, income and environment, 2021-2031. Available at: https://ec.europa.eu/info/sites/default/files/food-farming-fisheries/farming/documents/agricultural-outlook-2021-report_en.pdf

EUROSTAT (2016) http://ec.europa.eu/eurostat

FAOSTAT (2016) http://www.fao.org/faostat

García-Condado, S., López-Lozano, R., Panarello, L., Cerrani, I., Nisini, L., Zucchini, A., Van der Velde, M. and Baruth, B., 2019. Assessing lignocellulosic biomass production from crop residues in the European Union:

Modelling, analysis of the current scenario and drivers of interannual variability. GCB Bioenergy, 11(6), pp.809-831

Gurria Albusac P, Ronzon T, Tamosiunas S, Lopez Lozano R, Garcia Condado S, Guillen Garcia J, Cazzaniga N, Jonsson K, Banja M, Fiore G, Camia A and M`barek R. Biomass flows in the European Union The Sankey biomass diagram – towards a cross-set integration of biomass . EUR 28565 EN. Luxembourg (Luxembourg): Publications Office of the European Union; 2017. JRC106502. doi:10.2760/22906

Gurria Albusac, P., Gonzalez Hermoso, H., Ronzon, T., Tamosiunas, S., Lopez Lozano, R., Garcia Condado, S., Ronchetti, G., Guillen Garcia, J., Banja, M., Fiore, G. and M`barek, R., Biomass flows in the European Union, EUR 30454 EN, Publications Office of the European Union, Luxembourg, 2020, ISBN 978-92-76-25378-5, doi:10.2760/14342, JRC122379.

Jonsson R., Cazzaniga N.E., Camia A., Mubareka S., 2020. Analysis of wood resource balance gaps for the EU-28. EC Joint Research Centre, Publications Office of the European Union, Luxembourg.

List of abbreviations and definitions

dm	Dry matter
EMFF	European Maritime and Fisheries Fund
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
IEA	International Energy Agency
JRC	Joint Research Centre
JRC C2	Joint Research Centre Unit C.2. Energy Efficiency & Renewables
JRC D1	Joint Research Centre Unit D.1. Bio-Economy
JRC D2	Joint Research Centre Unit D.2. Water & Marine Resources
JRC D3	Joint Research Centre Unit D.3. Land Resources
JRC D4	Joint Research Centre Unit D.4. Economics of Agriculture
JRC D5	Joint Research Centre Unit D.5. Food Security
JWEE	Joint Wood Energy Enquiry
ktoe	kilo tonnes of oil equivalent
m3	Cubic metres
MS	(EU) Member State
NFI	National Forest Inventory
NREAP	National Renewable Energy Action Plan
SWE	Solid wood equivalents
tdm	Tonnes of dry matter
UNECE	United Nations Economic Commission for Europe
WRB	Wood Resource Balance

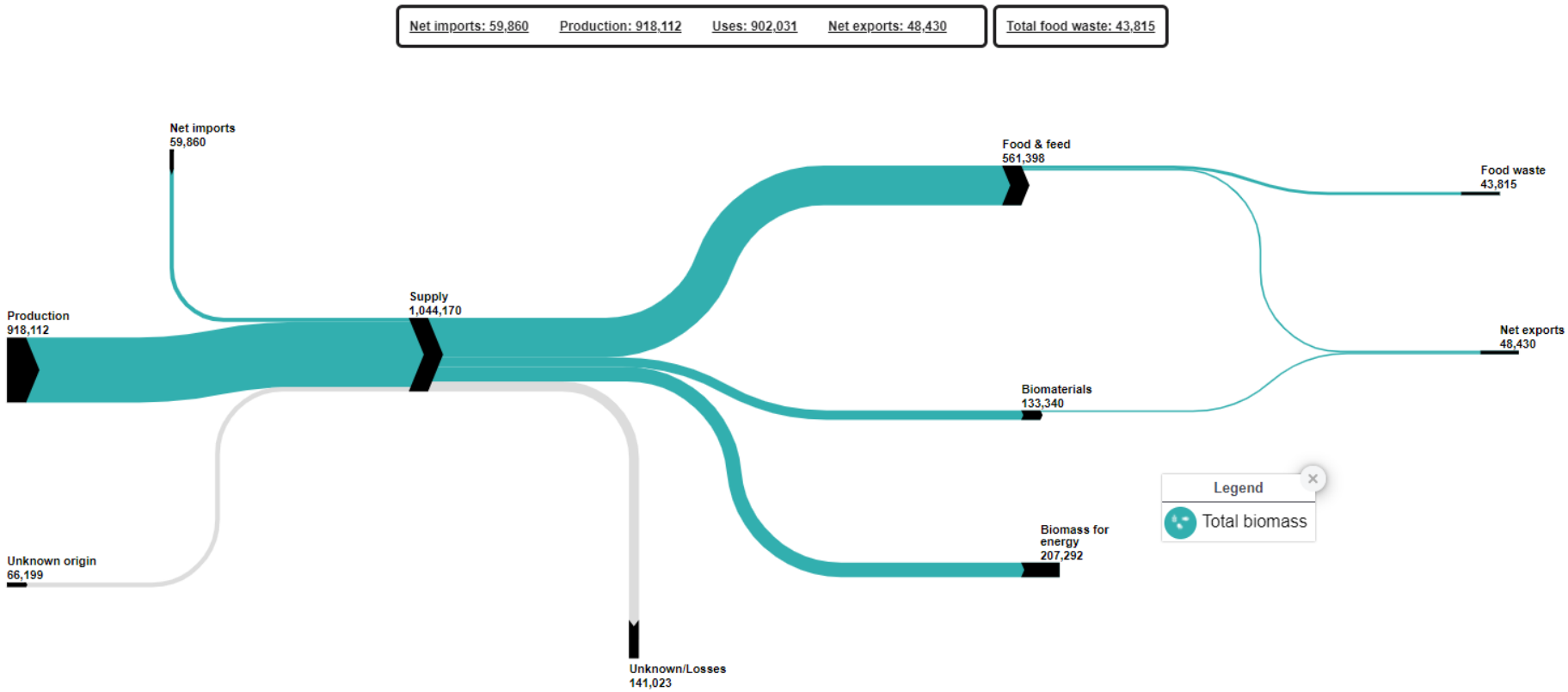
List of figures

List of tables

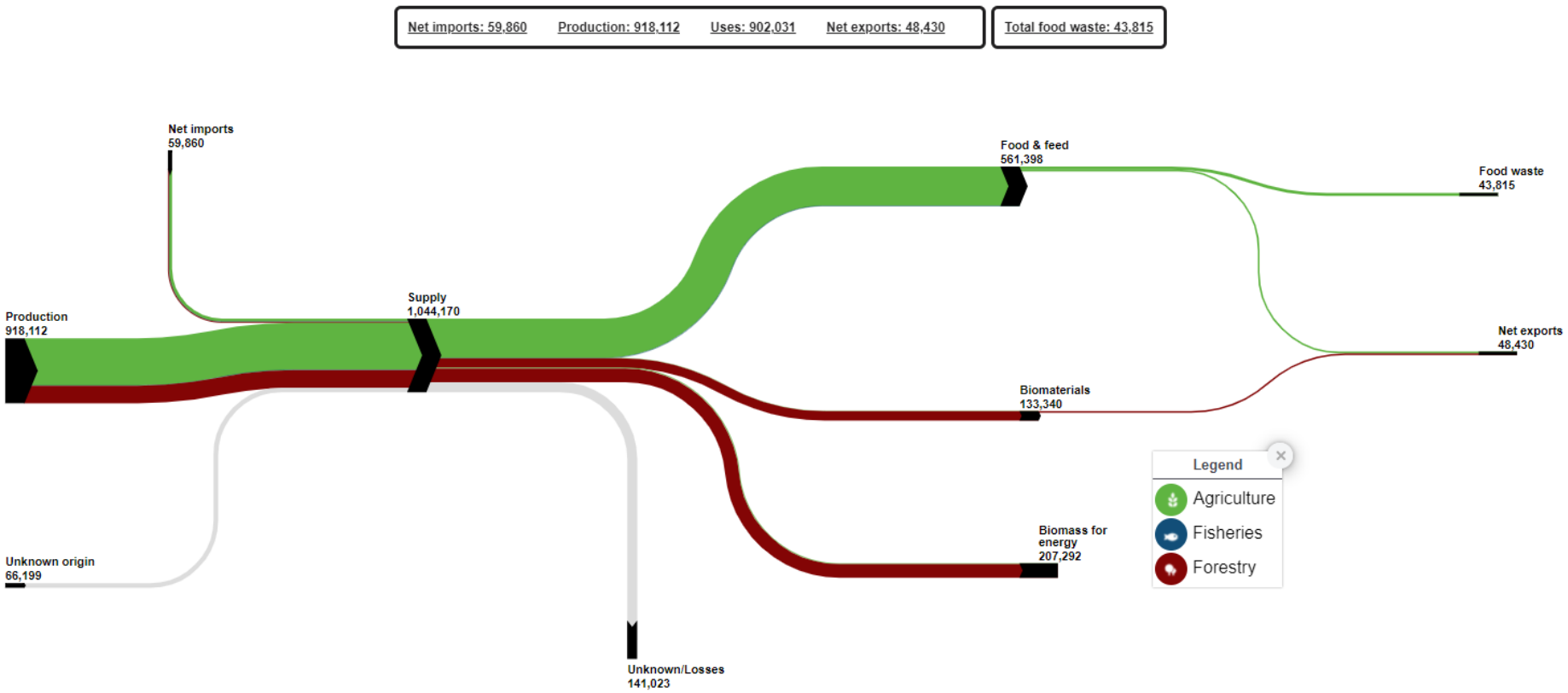
Annex: Screenshots of the EU Biomass Flows tool.

To offer a full cross-sector overview, these screenshots are created with the latest available data for each sector: 2018 for agriculture, 2017 for woody biomass, 2016 for fisheries and 2015 for biofuels.

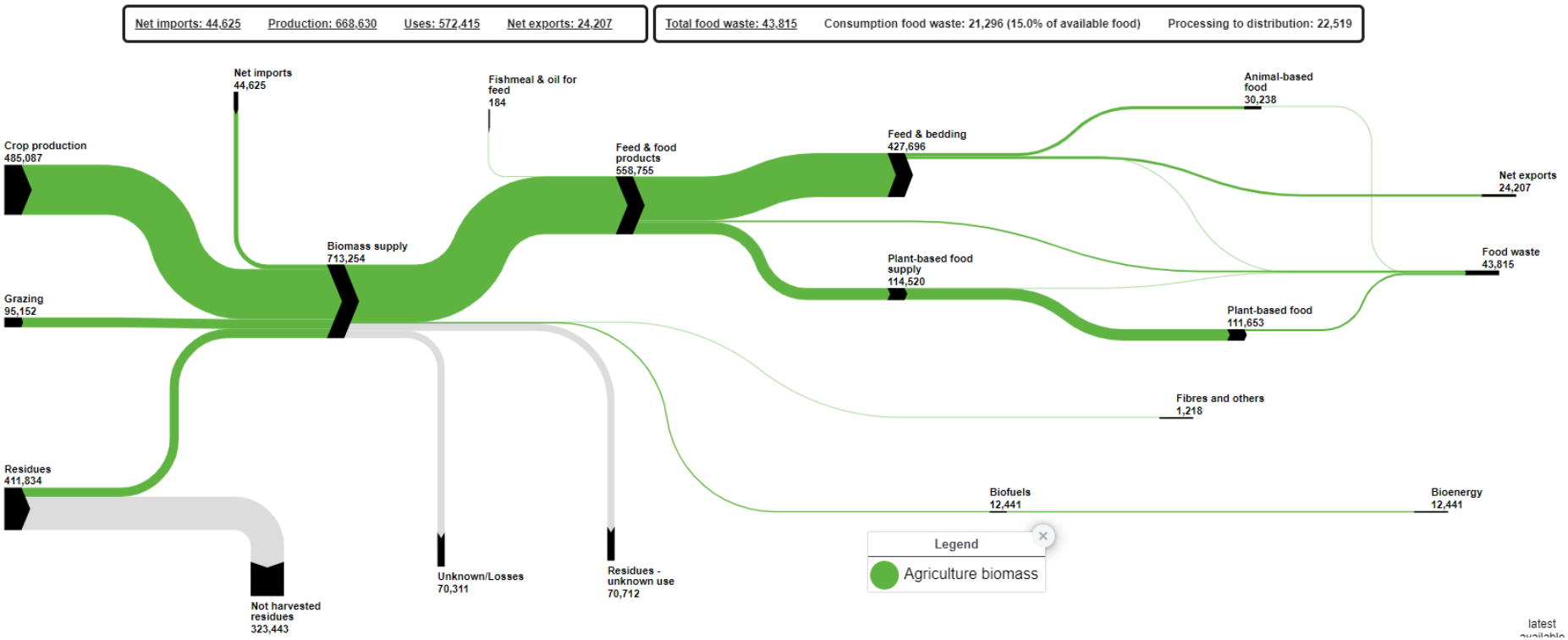
Total biomass in the EU27, net trade, latest available data



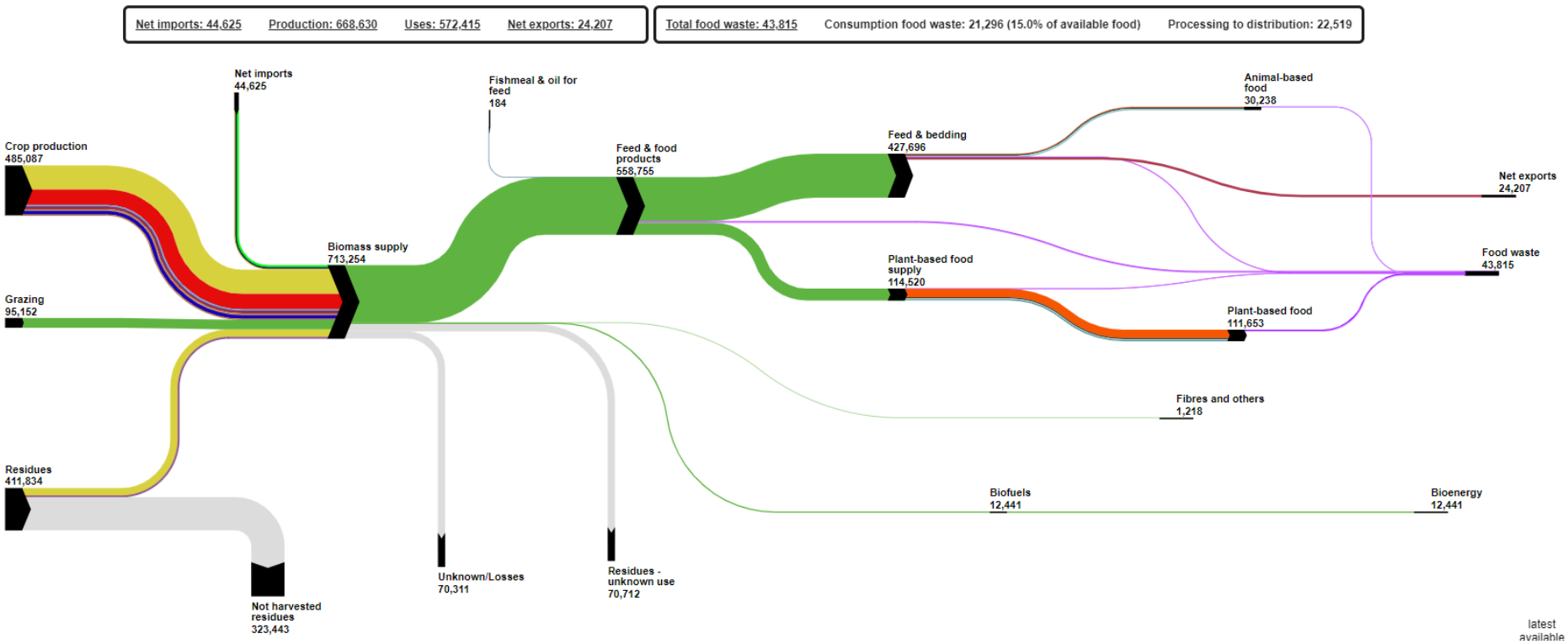
Total biomass by sector in the EU27, net trade, latest available data



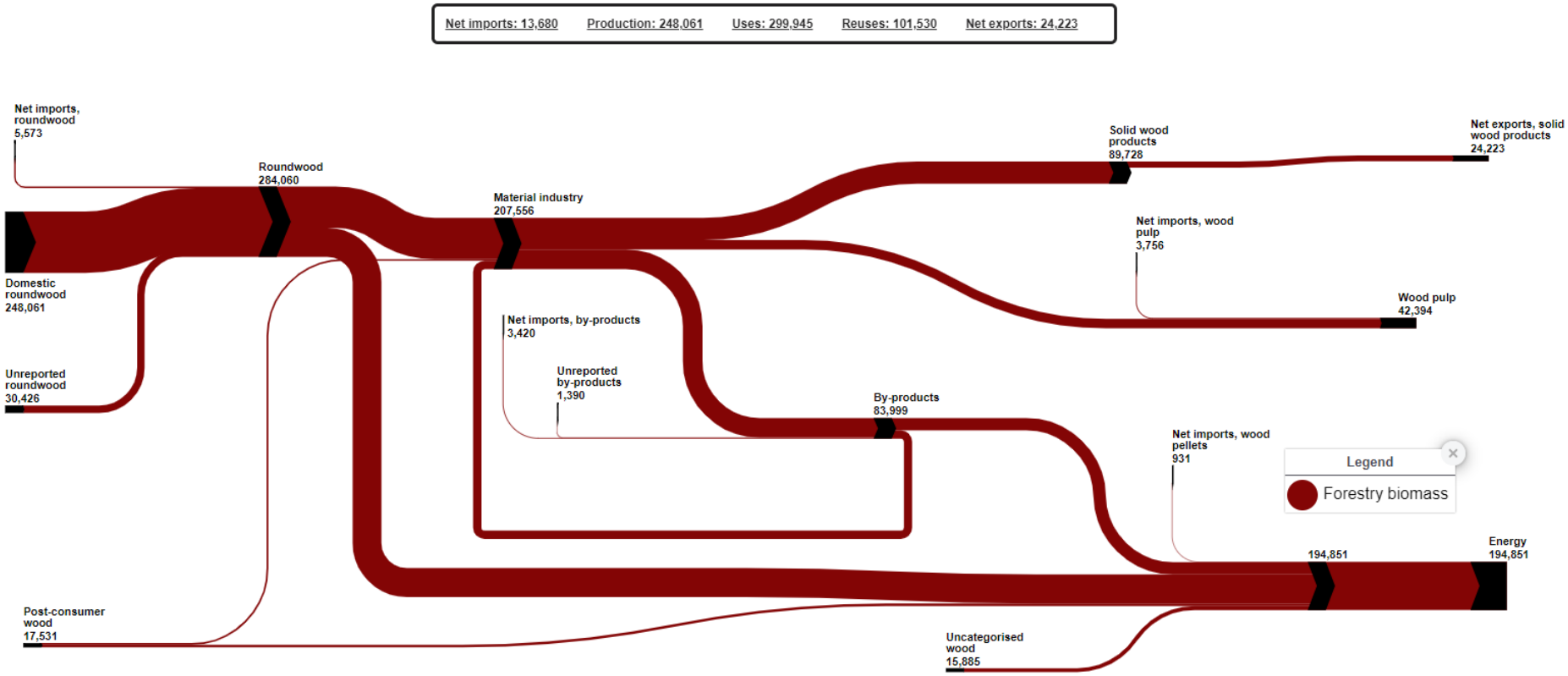
Total biomass from agriculture in the EU27, net trade, latest available data



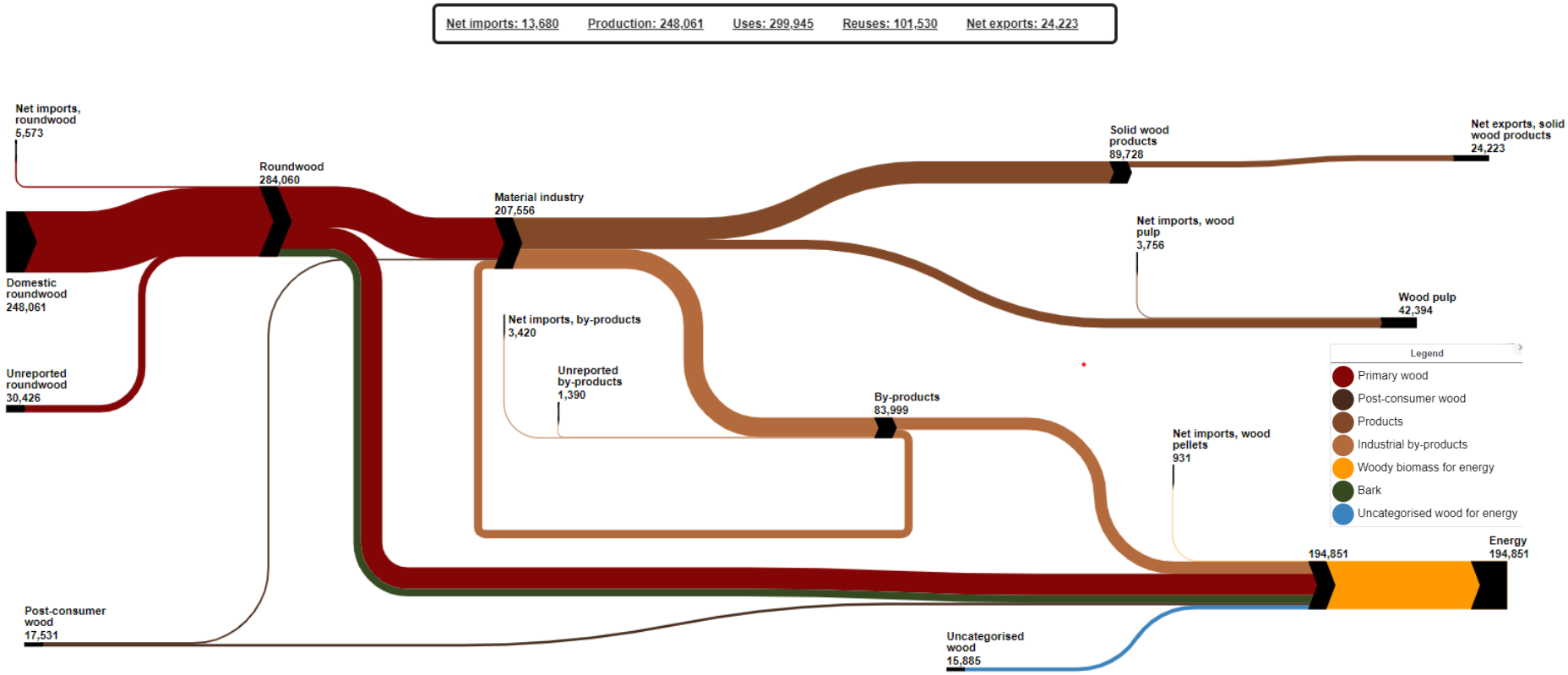
Total biomass from agriculture by type in the EU27, net trade, latest available data



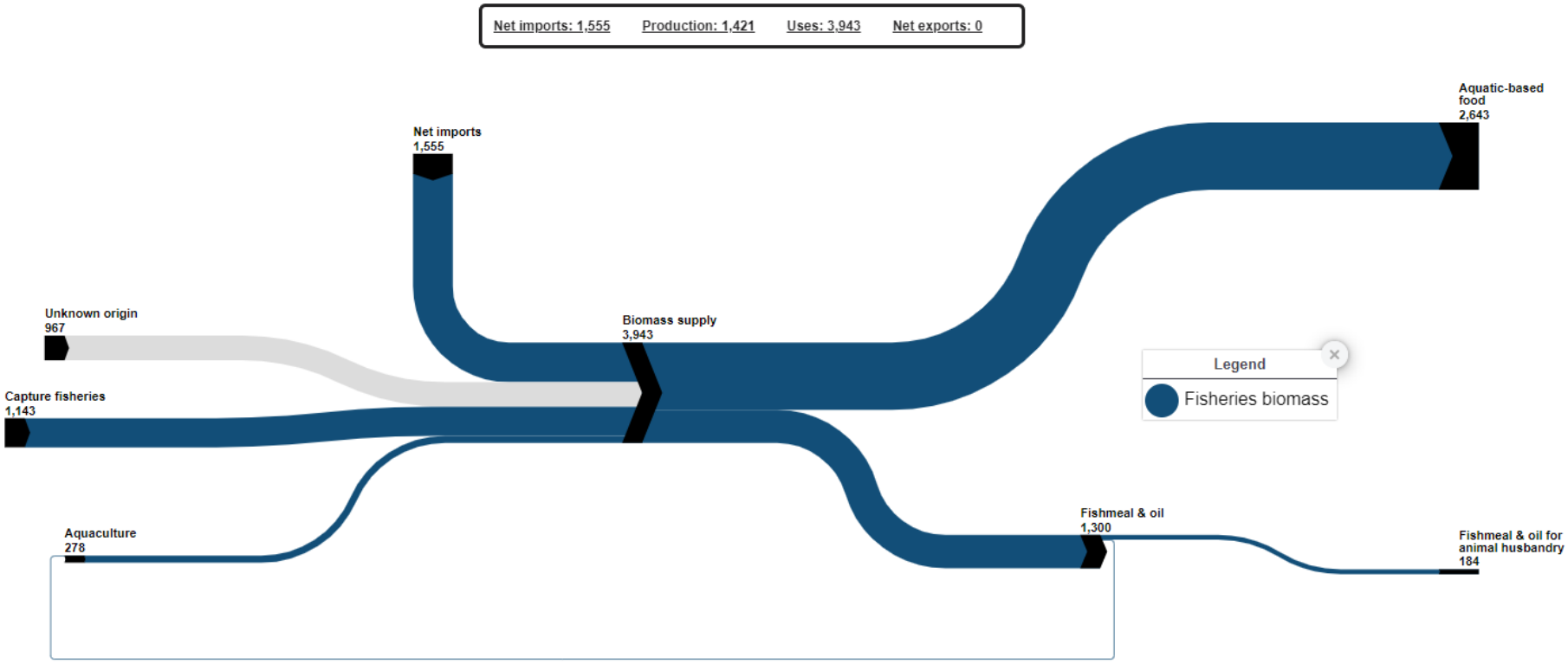
Total woody biomass in the EU27, net trade, latest available data



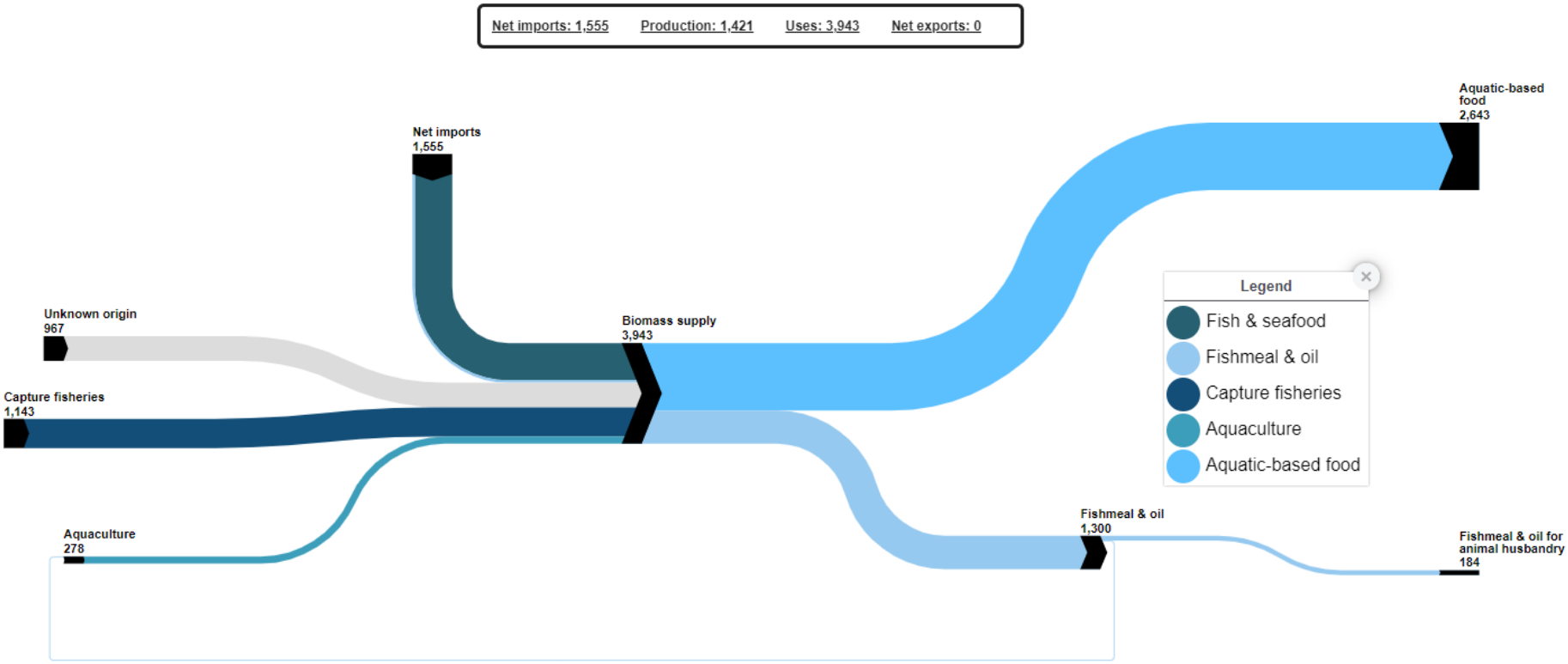
Total woody biomass by type in the EU27, net trade, latest available data



Total biomass from fisheries and aquaculture in the EU27, net trade, latest available data



Total biomass from fisheries and aquaculture by type in the EU27, net trade, latest available data



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