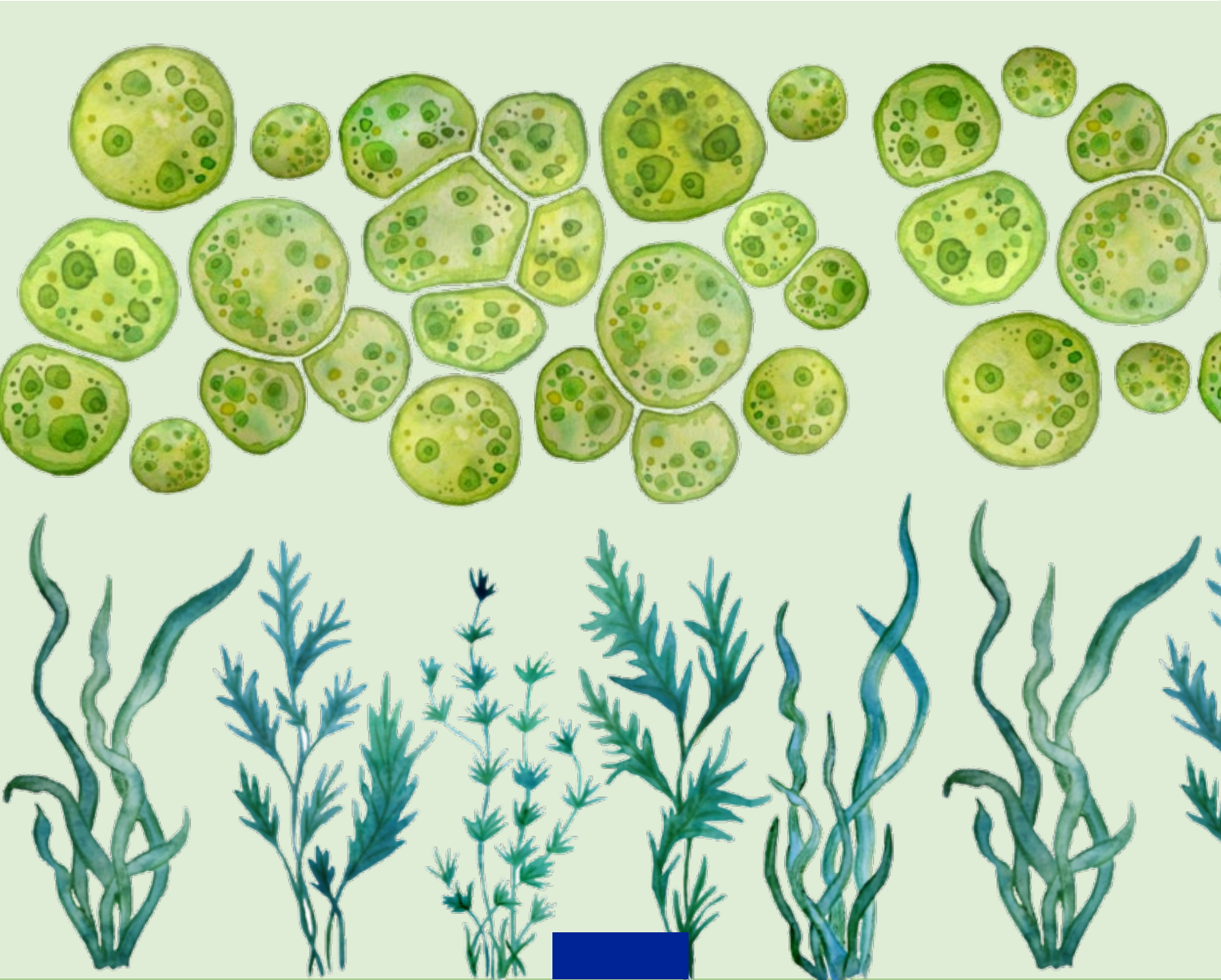
European Commission

Producers, production systems, species, biomass uses, other steps in the value chain and socio-economic data

An overview of the algae industry in Europe

The European Commission's Knowledge Centre for Bioeconomy



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Summary

Enhanced EU production and use of algae can help ensuring sustainable food and farming systems, economic circularity and bio-based products.[1] This potential of algae to provide viable and sustainable alternative food and feed materials and to produce other bio-based products is recognised in the Sustainable Blue Economy Communication[2] and other policy instruments.

The updated JRC algae industry database provides an improved overview on the algae industry sector in Europe based on information from 548 enterprises, based in 20 EU Member States as well as in Iceland, Norway, Switzerland, and the UK operating at different steps of the algae value chain: producing, processing, and services (which includes technology providers, R&D enterprises, consultancy enterprises, and traders/exporters).

Algae producing enterprises

At least 413 enterprises identified in this research are active in the production of algae biomass; most of them are also algae biomass processors. 153 enterprises produce macroalgae biomass in 166 production plants based in 13 European countries; 87 enterprises produce microalgae biomass in 89 production units based in 17 European countries; while the remaining 213 enterprises produce Spirulina in 216 production units based in 15 countries. These numbers include 40 enterprises producing two organism groups – either macroalgae and microalgae, microalgae and Spirulina, or macroalgae and Spirulina.

France is the country with the largest number of enterprises involved in algae production with 169 enterprises, followed by Spain, Ireland, Norway, and Italy with more than 20 algae producing enterprises in each country.

Macroalgae producing enterprises

Harvesting from wild stocks is the most common macroalgae production system (employed by 68% of the macroalgae enterprises) while aquaculture is less frequently used (32%). The harvesting is predominantly done manually (66% of the enterprises) and only 10% of the macroalgae enterprises that harvest does it mechanically. Aquaculture systems are mostly located at sea (68%), which include both coastal and offshore aquaculture and less frequently on land (20%). The specific production system for the remaining 12% of aquaculture enterprises is unknown.

From all the macroalgae produced in Europe, *Saccharina* spp. - mostly *Saccharina latissima* - is the genus most commonly produced (53 enterprises) followed by *Ulva spp.*, *Laminaria* spp. and *Palmaria* spp. -mainly *Palmaria palmata*- produced by 46, 45 and 42 enterprises, respectively. Other genera widely produced (by more than 20 enterprises) are *Fucus* spp., *Himanthalia* spp., *Alaria* spp., *Porphyra* spp., *Undaria* spp., *Chondrus spp.* and the species *Ascophyllum nodosum*. While some species are equally produced by aquaculture and harvested from the wild (e.g., *Saccharina* spp. and *Alaria* spp.), differences in the way certain macroalgae species are produced exist, namely for *Fucus* spp., *Palmaria* spp., *Laminaria* spp., and *Ulva* spp., which are predominantly harvested from wild stocks (86%, 82%, 79% and 68% of the enterprises producing them, respectively).

Microalgae producing enterprises

Photobioreactors is the main microalgae production system in Europe (employed by 61% of the microalgae enterprises). Open ponds is the second production system in terms of number of enterprises since it is used by 11% of them.

The microalgae species most largely produced (in terms of number of enterprises) is *Chlorella* spp. (27 enterprises, 31%), followed by *Nannochloropsis* spp. (24 enterprises, 28%).

[1] Inception impact assessment 'Blue bioeconomy - towards a strong and sustainable EU algae sector' https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12780-Blue-bioeconomy-towards-a-strong-and-sustainable-EU-algae-sector_en

[2] (COM(2021) 240 final. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52021DC0240.

Spirulina producing enterprises

Open ponds is the main Spirulina production system in Europe (employed by 65% of the microalgae enterprises). Photobioreactors follows, being used by 13% of the Spirulina producing enterprises.

Biomass uses

The food and feed sectors, which include human food, food supplements, and nutraceuticals and animal feed, are the main markets for macroalgae biomass in terms of number of the number of supplying enterprises (almost 60%). Cosmetics (18%) and fertilisers and biostimulants (11%) follow as most common macroalgae biomass uses.

The food and feed sectors are the main markets also for microalgae since more than 54% of the microalgae enterprises allocate their biomass to this sector (23% to food supplements, 19% to animal feed and 12% to human food). Cosmetics and wellbeing products are also a prominent sector (19% of the enterprises), followed by pharmaceuticals (8%) and fertilisers and biostimulants (7%).

The commercial uses of the Spirulina biomass are mainly human food, and food supplements and nutraceuticals, accounting together for 76% of the enterprises. Other minor uses of this biomass are cosmetics and wellbeing products (6% of the enterprises), animal feed (5%), pharmaceuticals (3%), fertilisers and biostimulants (2%) and bioremediation (1%).

Other steps in the algae value chain

In addition to algae producing enterprises, the European algae industry also includes enterprises operating in other steps of the algae value chain such as processing enterprises and different services (e.g., technology providers, consultancies and trader/exporters of algae biomass and products). Many enterprises are involved in several steps of this value chain. Similarly to producers, enterprises processing and in the services sectors deal with more than one single group of organisms.

Socio-economic data

Due to the limited data available in official statistics and private business databases and directories and the relatively low response rate to the surveys conducted, and due to the lack of disaggregated data for enterprises having also non-algae business streams, turnover and employment data may not be considered as precise estimates.

Turnover of the algae value chain

This study estimates that the total turnover (2016-2020 average) generated by the enterprises whose core business is the production and processing of algae biomass and the provision of related services amounts to EUR 161.4 million in the EU-27 (excluding FO and GL) and EUR 30 million in the other European countries mapped (CH, IS, NO and UK plus FO and GL).

Enterprises producing and processing algae biomass generate the largest turnover (EUR 130.6 million) while those only producing (EUR 27.3 million) and those producing, processing and providing services (EUR 26.9 million) follow.

Enterprises dealing only with macroalgae are the largest contributors to this turnover (EUR 129.5 million) followed by microalgae enterprises (EUR 31.6 million). In the case of Spirulina, the turnover from its dedicated enterprises alone reaches almost EUR 20.4 million. The remaining (EUR 9.9 million) is generated by enterprises which produce, process and provide services for more than one species group.

Enterprises in France and Ireland generate the largest turnover (EUR 75.9 million and EUR 40.4 million, respectively).

Employment of the algae value chain

The algae-dedicated enterprises (whose core business has been identified as being algae-related) in the EU-27 employ 1,852 people. According to the same data, other European countries covered (CH, IS, NO, UK plus FO and GL) employ in total another 288 people.

Enterprises involved in the production and processing of algae employ the majority of workers with 1,161 employees. Enterprises producing, processing algae biomass and providing related services follow with 559 people employed.

By organism group, enterprises dedicated solely to macroalgae employ the largest number of people in Europe, with almost 1,068 employees. Enterprises only dealing with microalgae follow in terms of people employed with 544 employees.

The employment generated by the enterprises with algae as the main business stream, is the highest in France and Ireland (478 and 385 people, respectively).

Full time jobs are predominant within the industry (81%) and male employees are predominant (62%) over female. Furthermore, 55% of the people employed in the algae sector are younger than 41 years old.

Dissemination

The data presented in this report can be accessed in a raw form[3] or explored further in a visual form[4], both available through the Knowledge Centre for Bioeconomy.

[3] https://data.jrc.ec.europa.eu/collection/id-00363
[4] https://knowledge4policy.ec.europa.eu/visualisation/bioeconomy-different-countries_en#algae_prod_plants

1 Introduction

The term 'algae' comprises a wide range of taxa of photosynthetic organisms with more than 72 500 estimated species[5]. About 80% of algae species are uni-cellular and are called microalgae while the remaining 20% are pluri-cellular and are called macroalgae or seaweeds. Macroalgae are macroscopic organisms that vary in size from millimetres to lengths of up to 70 m, as is the case for some kelp species[6]. Moreover, the genus Arthrospira, (commercially known and referred hereafter as Spirulina)[7], is a cyanobacteria that has been traditionally used in Western human nutrition since the 1970s and is frequently considered, from the industry and consumer perspective, as "algae" (e.g., CEN/TC454, 2020)[8].

Algae can play an important role in the production of sustainable food, feed, materials and energy while certain forms of algae aquaculture can offer many ecosystem services (e.g., the absorption of excess nutrients and organic matter from the environment or the conservation and restoration of ecosystems and biodiversity). They, therefore, have a potential to contribute to the transition to a green, circular and carbon-neutral EU economy. This potential is acknowledged in the European Green Deal (European Commission, 2019) and other related EU policy initiatives including the Farm to Fork (European Commission, 2020), the Sustainable Blue Economy Communication (European Commission, 2021a), the strategic guidelines for a more sustainable and competitive EU aquaculture (European Commission, 2021b) and Bioeconomy (European Commission, 2018) Strategies.

Algae biomass has been explored for centuries by coastal communities as a source of fertiliser, cattle feed and human food. However, over the past decades, the development of new algae-biomass-based applications (feed and food supplements, nutraceuticals, pharmaceuticals, third-generation biofuels, biomaterials and bioremediation services, see section 4) has led to an increase and diversification in the market for these resources[9], leading during the last decade to an increase of 150% in the number of new algae producing enterprises[6]. Indeed, algae together with ocean renewable energy and blue biotechnology are considered as emerging innovative sectors of the blue economy[10].

Despite the potential contribution of algae resources and of the broader algae sector to the mentioned European policy priorities, a comprehensive and robust knowledge base related to algae that could underpin these policies is currently lacking. As a first building block for this knowledge base, the data on production volumes in the EU has important knowledge gaps while the existing data are characterised by large uncertainty.

For example, available data from FAO are limited to the production of macroalgae (seaweed) and cover only 9 countries in Europe (Table 1).

Table 1. Seaweed production in 2019 (tonnes wet weight).

Country	Seaweed harvested from wild	Seaweed aquaculture	Total seaweed production
France	51,300	176	51,476
Ireland	29,500	42	29,542
Iceland	17,533		17,533
Norway	163,080	117	163,197
Rest of Europe (5 countries)	5,524	217	5,741
Russian Federation	8971	10,573	19,544
TOTAL Europe	275,908	11,125	287,033

Source: Cai et al., (2021).

[5] Barsanti, L. and Gualtieri, P. (2014) Algae: Anatomy, Biochemistry, and Biotechnology. CRC Press, 2014. https://doi.org/10.1201/b16544.
[6] Araújo, R., Brief on algae biomass production, Lusser, M., Sanchez Lopez, J. and Avraamides, M. editor(s), Publications Office of the European Union, Luxembourg, 2019, ISBN 978-92-76-12271-5, doi:10.2760/665775, JRC118214. https://publications.jrc.ec.europa.eu/repository/handle/JRC118214.
[7] Vonshak, A., and Tomaselli, L. (2002). "Arthrospira (Spirulina): systematics and ecophysioiogy," in The Ecology of Cyanobacteria: Their Diversity in Time and Space, eds B. A. Whitton and M. Potts (Dordrecht: Springer), 505–522. doi: 10.1007/0-306-46855-7_18. https://link.springer.com/chapter/10.1007/0-306-46855-7_18.
[8] CEN/TC454 (2020). EN 17399: 2020 "Algae and Algae Products-Terms and Definitions". CEN/TC 454 - Algae and Algae Products. European Committee for Standardization.
[9] Barbier, et al., 2016, https://doi.org/10.21411/2c3w-yc73.
[10] European Commission (2021c). The EU Blue Economy Report. 2021. Publications Office of the European Union. Luxembourg. https://blueindicators.ec.europa.eu/published-reports_en.

Similarly, available data on the economic value of algae (i.e., macroalgae, microalgae and the cyanobacteria Spirulina), are limited to aquaculture production, which is only a small share of macroalgae production and cover only few EU Member States, as shown above (Table 2).

Table 2. Summary data on aquaculture production of algae biomass and its economic value in the EU in 2019.

Group of organism	Weight (tonnes)	Value	Where
Macroalgae	more than 260	€4 million	mostly in France, Spain, Ireland and Portugal
Microalgae	5	more than €25 thousand	France and Bulgaria
Spirulina	almost 350	€8.5 million	France and Greece

Source: Extracted from FishStatJ, FAO 2022.

The JRC algae database presented and analysed in this report aims to provide an improved overview on the algae industry sector in Europe, based on information from the European enterprises operating at different steps of the algae value chain in Europe. For the producing enterprises, we present the updated data collected on location of the production units, production systems used, species produced, and uses of the biomass produced, as well as novel socio-economic data on employment and turnover.

These data available, now thanks to the JRC algae database, offer a more comprehensive source of knowledge and information on the sector to enhance the knowledge base and inform EU policies. Likewise, stakeholders, researchers and the society at large can access the data as publicly accessible raw data and explore them further in a visual form through the Knowledge Centre for Bioeconomy and the (EMODnet) Human Activities Portal.

2 Data collection and analysis methodology

The data and analysis presented in this report are based on new data collected to update the existing JRC algae database on the algae[11] producing industry in Europe as well as to extend it to post-production steps in the algae value chain (biomass processors, services, etc.) and with other data beyond production (socio-economic data) [12].

The data collection followed the steps and sources of information detailed below:

Step 1: The list of algae producing enterprises in the existing JRC algae database was extended with a customised list of algae enterprises involved in other steps of the value chain, obtained from the European Algae Biomass Association (EABA[13]) and whose information could be confirmed (see next steps below).

As explained in Araújo et al., (2021)[14], the algae enterprises were classified in three categories according to the data availability and certainty: i) level 1, enterprises that confirmed the information through direct contact; ii) level 2, enterprises with which direct contact could not be established but with web information of sufficient quality to be included in the database; iii) level 3: enterprises with which direct contact could not be established and for which the information that could be retrieved from the website was not of sufficient quality to be included in the database.

This classification was taken into account in step 2:

Step 2: A specifically designed set of 4 surveys (using the EUSurvey online platform[15]) was launched to all enterprises (i.e., the ones already registered in the database as well as to the new enterprises identified) following the status and type of company.

Survey 1 (Annex 1): for all enterprises with information previously confirmed in the producers' database (level 1).

Survey 2 (Annex 2): for macroalgae and microalgae enterprises with information still not confirmed in the producers' database (level 2) and for all level 3 enterprises. The difference between surveys 1 and 2 was that in the former, the enterprises were only asked to indicate whether they had any change on their data provided before (e.g., species produced, location of the production unit and number of employees) besides the new data related to the other steps of the value chain, as well as information on production volumes, end products in the market, and main markets in geographical terms. Survey 2 included questions on the main information (i.e., year of establishment, location of the production unit, number of employees with gender balance and age distribution data, species produced, production method, and commercial uses of the biomass) besides the questions on new data.

Survey 3 (Annex 3): for Spirulina enterprises with information still not confirmed in the producers' database (level 2). Survey 3 was different from surveys 1 and 2 in the part covering the main information, as the answer options for species and production method are specific for this organism group.

Survey 4 (Annex 4): for the new non-producing enterprises in the customised list of algae enterprises involved in other steps of the value chain obtained from EABA (see step 1 above). Survey 4 did not include the questions relative to the production step, but only the year of establishment and the information on employment, besides the data on the step of the value chain, organism group of focus, percentage of business focused on algae, and main markets in geographical terms.

Out of 760 enterprises contacted, a total of 103 replied to the surveys (i.e., 14% response rate).

[11] The JRC algae database includes macroalgae (also known as seaweed), microalgae and the cyanobacteria Spirulina.
[12] The JRC algae database collects data for 20 Member States from the EU-27, namely AT, BE, BG, HR, CZ, DK (including Faroe Islands – FO - and Greenland - GL), EE, FI, FR, DE, EL, HU, IE, IT, LT, LV, PT, ES, SE and NL plus 4 additional European countries (namely IS, NO, CH, UK). Data for FO and GL are reported separately from DK, unless stated otherwise.
[13] https://www.eaba-association.org/en
[14] Araújo, et al., 2021. https://www.frontiersin.org/articles/10.3389/fmars.2020.626389/full.
[15] https://ec.europa.eu/eusurvey/

Step 3: For the enterprises that did not reply to the survey, a thorough desk research of their specific websites was carried out to consolidate the list of algae companies within the database (adding the new enterprises, removing those that had ceased operations, etc.) and to complete the missing data.

Step 4: Between the steps 1–3 mentioned above, the information available for each enterprise in the Orbis database[16] was extracted to obtain the associated socioeconomic data (turnover, no. of employees, and other economic indicators: P/L before tax (profit/loss), P/L for period [=Net income], cash flow, total assets, fixed assets, current assets, costs of employees, depreciation & amortization, R&D expenses). This information was included in the resulting database, if applicable. The enterprises for which the information in the Orbis database was searched included the enterprises in the producers' database (level 1 and 2), in the customised list of algae enterprises involved in other steps of the value chain extracted from EABA, and also for the producing enterprises of level 3. As this step was done in parallel with steps 1-3, thus, before the consolidation of the resulting database, all the enterprises were searched in case they would eventually become part of the database.

It should be noted that, in the specific case of Spirulina, the 'Fédération des Spiruliniers de France' provided a specific list of the Spirulina producers registered in France, which were also included in the JRC algae database. For this reason, information on Spirulina producing companies may be more complete compared to other countries.

Furthermore, the following aspects related to the analysis and presentation of the data collected would be important to clarify:

One single enterprise may run production and processing plants in several European countries. For the results that are presented by country in this report, enterprises are assigned to the European country where the headquarters are based according to the information provided and confirmed by the enterprises (in the surveys or by contact through email), and according to the contact information available on the enterprises' websites when the address was not confirmed by the enterprise.

Data on the uses is based on information from the algae producing enterprises, collected through the surveys and desk research. The biomass uses were classified as detailed in section 4, following the categories established in Araújo et al., (2021)[14]. It should be noted that enterprises may be supplying algae biomass to multiple uses or markets in which case multiple biomass uses for each enterprise were registered in the database. It should be also highlighted that the values reported on biomass uses refer to the number of enterprises and do not reflect the volumes of biomass dedicated to each use.

As further explained in Section 6, socio-economic data for each algae enterprise has been collected from the surveys as well as from the Orbis database, namely annual data on turnover and employment for the period 2016-2020 (the last five years available)[17]. The Orbis database does not include socio-economic data for all the 548 enterprises identified: turnover data could only be collected for 252 enterprises and employment data could only be collected for 242 enterprises[18].

Whilst data from Orbis should cover a calendar year (January - December), a number of exceptional cases that did not meet that requirement were identified and treated as shown in Table 3.

[16] Orbis - Company information across the globe - BvD (https://orbis.bvdinfo.com/version-2021416/orbis/Companies/Login?returnUrl=%2Fversion-2021416%2Forbis%2FCompanies)

[17] As the surveys were considered a more accurate and targeted source of information than the Orbis database, the employment data coming from the surveys was, when available, preferred to that from Orbis.

[18] Data was not always available for all the years within the time-period considered. In these cases, the latest data from the time-period was considered for the analysis.

Table 3. Approach followed for data available in Orbis that did not correspond to a calendar year.

EXCEPTION	APPROACH FOLLOWED
Data is for less than 9 months	Not included in the database
Data is for 12 months ending in or before June	Value is moved to previous year
Data is for 12 months ending after June	Value stays in present year
Data is for more than 12 months	Split value between total number of months and multiply per 12, then: a) If data ends in or before June: value is moved to previous year b) If data ends after June: value stays in present year
There is no end month, it is only indicated the year	Value stays in present year

Since annual turnover and employment data were not available for each year in the reference period (2016-2020), an average value for each enterprise was calculated and then aggregated.

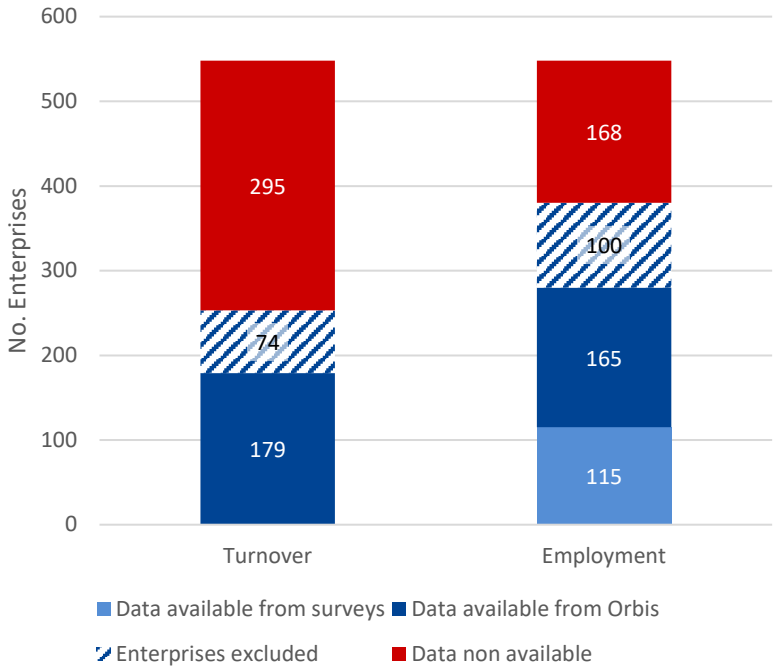
Many of the enterprises identified (especially most of the enterprises involved in post-production steps) have business streams other than those related to algae. In some of them, the algae-related activities represent the primary business of the enterprise, while for some others they represent a secondary business stream. Since the Orbis dataset does not disaggregate the turnover and employment data by business stream, a precise estimation of the share of turnover and employment created exclusively by the algae-related activities was not feasible. Furthermore, annual economic reports and other business directories[19] providing economic data were consulted, but no proxies could be found to estimate the share of the total business focused on algae in the identified enterprises. To overcome this limitation, each enterprise was assigned a best estimate of the 'share of business dedicated to algae' for each enterprise (between 0% and 100%), based on information available on the enterprises' websites (e.g., the different sectors they focus on, number of ingredients they process, type of products they sell on the online shops, etc.) using expert judgement. These shares were used to distinguish between the enterprises whose primary business stream is related to the algae sector (share of business dedicated to algae was equal to, or above 50%). For those enterprises, unless disaggregated data were available from the surveys, the compiled turnover and employment data were accounted fully (at 100%) and aggregated at country level. For the remaining enterprises (share of business dedicated to algae less than 50%) the turnover and employment data were not considered further in the analysis and the results presented in this report.

The aggregated socio-economic data presented in this report should thus be considered with the following important caveats:

- Approximately half of the enterprises identified in the JRC algae industry database do not have available data on turnover and approximately one third do not have available data on employment (red part of the bars in Figure 1). This results to underestimated aggregated values.
- The turnover and employment of enterprises for which algae-related activities represent only a secondary business stream were not included in the aggregated values (dashed part of the bars in Figure 1). This results to underestimated aggregated values.
- Unless disaggregated data were available from the surveys, the turnover and employment of enterprises for which algae-related activities represent a primary business stream were included fully in the aggregated values (blue part of the bars in Figure 1). This results to overestimated aggregated values.

[19] e.g. https://www.dnb.com/business-directory/, https://www.statista.com/, https://growjo.com/company/.

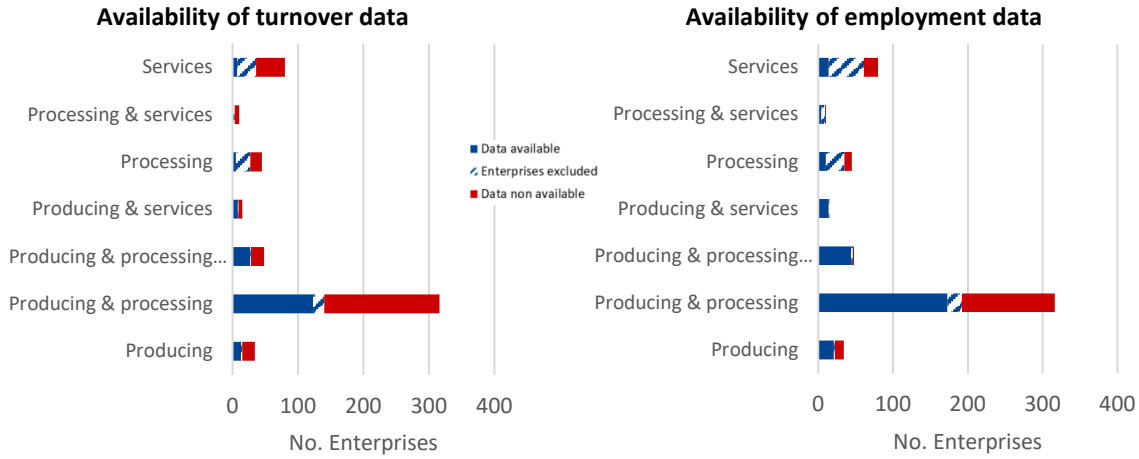
Figure 1. Number of enterprises for which turnover and employment data is available (from surveys and Orbis, light and dark blue, respectively); not accounted - due to a low algae business share (dashed blue); or not available (red).



Source: Own elaboration.

The low availability of turnover and employment data impacts the results related to all steps of the value chain (see Figure 2), but especially in the case of turnover of enterprises processing biomass and providing services, where 70% of the companies do not have data available.

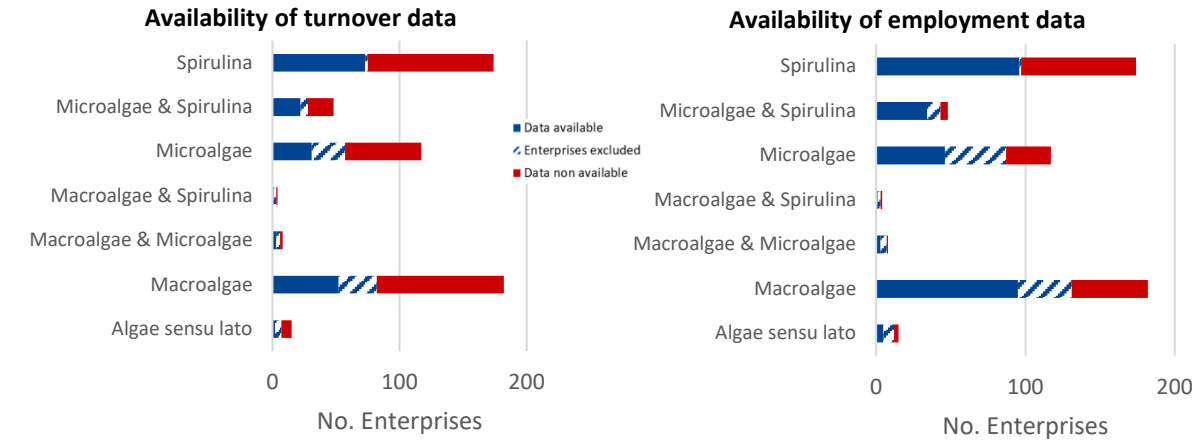
Figure 2. Number of enterprises for which turnover (a) and employment (b) data is available (blue); not accounted - due to a low algae business share (dashed blue); or not available (red) by step of the value chain.



a) b)

Similarly, the results for all the species group are impacted by the low data availability (Figure 3), most importantly the turnover of enterprises dealing with macroalgae and Spirulina, for which circa 50% of the enterprises have no associated data as well as for the employment of Spirulina enterprises, where 44% of which have no data available.

Figure 3. Number of enterprises for which turnover (a) and employment (b) data is available (blue); not accounted - due to a low algae business share (dashed blue); or not available (red) by species group.



a) b)

When looking at the results of turnover by country, the results should be considered with caution due to the extremely low data availability, especially for certain countries such as Faroe Islands, the Netherlands, Greece, Ireland and the UK, where around 90% of the enterprises do not have data available (Figure 4). The data on employment (Figure 5) are more complete except in the case of Faroe Islands. These limitations should be considered when interpreting the results provided in Figure 31 and Figure 34, e.g. in the case of the enterprises in the Netherlands, for which turnover data is not available in contrast to employment data. It is also worth noting the case of e.g. Finland, Greenland and Lithuania, where all the enterprises have turnover and employment data associated but, as algae was not considered its core business, they have not been accounted for in the final results.

Figure 4. Percentages of enterprises for which turnover data is available (blue), not accounted (dashed blue) and not available (red) by country.

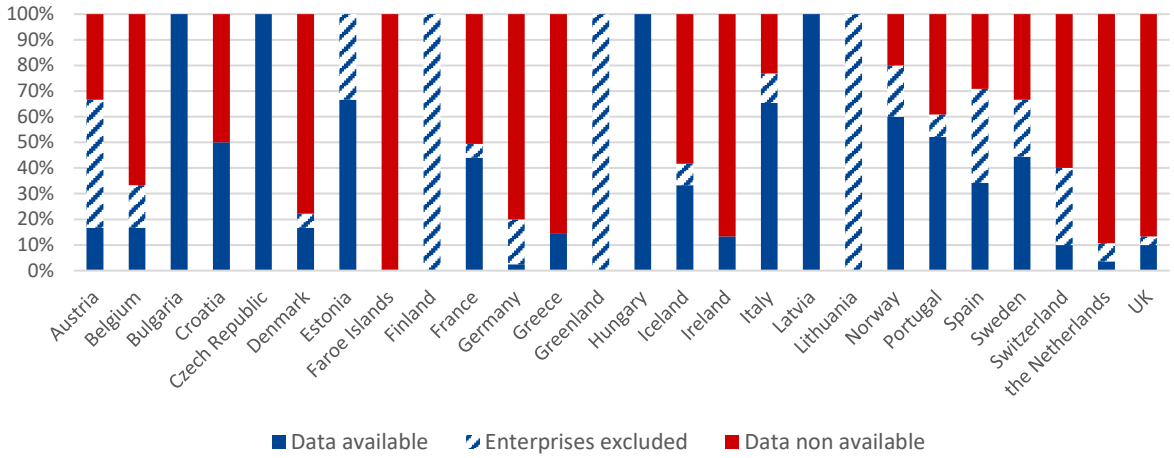
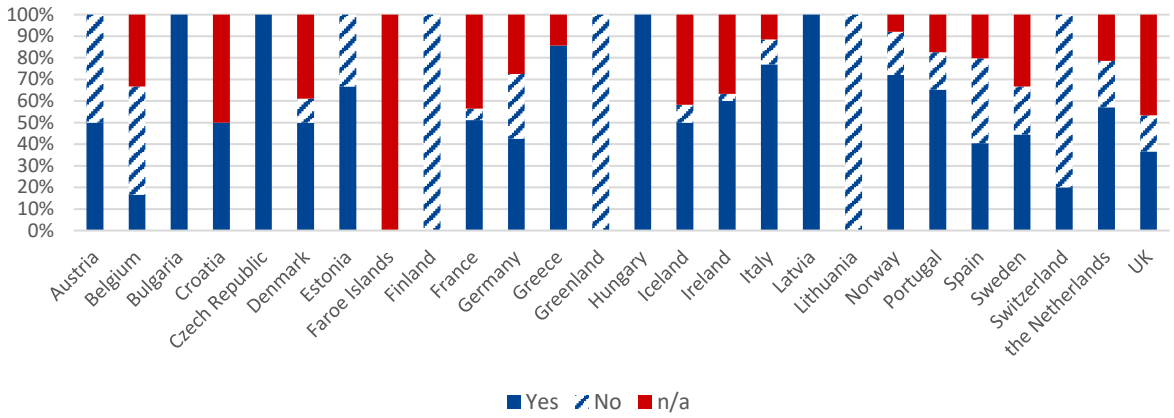


Figure 5. Percentages of enterprises for which employment data is available (blue), not accounted (dashed blue) and not available (red) by country.



The JRC algae database, described and analysed in this report, is available in the JRC Data Catalogue as a collection[3] composed by two datasets[20], one on the algae production industry in Europe and one with the consolidated socio-economic data. The following sections further describe the datasets and present their analysis.

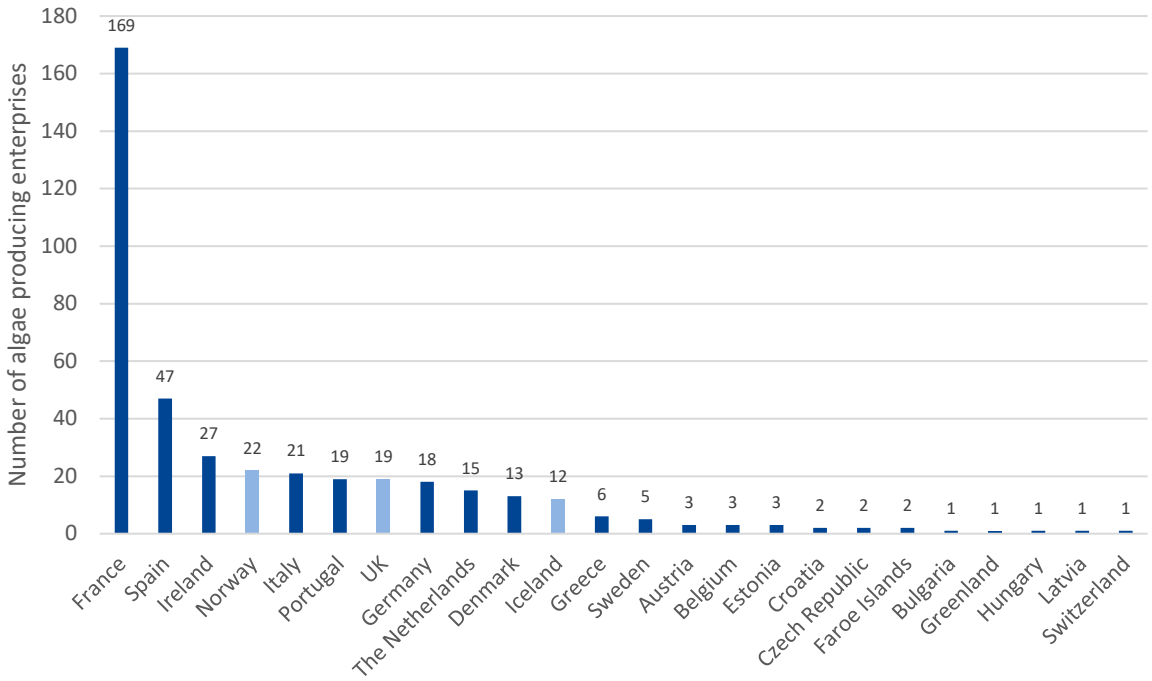
[20] https://data.jrc.ec.europa.eu/collection/id-00363 and https://publications.jrc.ec.europa.eu/repository/handle/JRC129053

3 Algae biomass production in Europe

The production of algae biomass has been increasing at a global scale[14]. Algae have traditionally provided an important source of food for numerous communities especially in Asia, and its consumption directly as food or as food supplements is becoming more common in western countries. Moreover, the number of commercial applications where algae biomass can be used has been increasing recently[21]. In Europe, macroalgae (or seaweed) have been traditionally harvested for centuries by some coastal communities to consume them as food and use them as animal feed and fertilizers[22]. According to some studies, the European bio-based industry landscape offers the potential for algae production to be a sustainable activity in economic terms[23]. The number of new algae producing enterprises in Europe has indeed been increasing in the last decades[14].

The updated JRC algae database[3] shows that there are currently 413 enterprises active in the production of algae biomass located in 24 European countries (20 MS from the EU-27, including Faroe Islands and Greenland, and also Iceland, Norway, Switzerland, and the UK)[12] (Figure 6).

Figure 6. Number of algae producing enterprises in the EU (dark blue) and other European countries (light blue) per country.



Source: Own elaboration.

It is important to note that the number of algae producing enterprises included in the JRC algae database may not represent all the enterprises active in the sector at the European scale, as the algae industry in Europe is very dynamic and the number of enterprises is constantly increasing[14]. Moreover, the enterprises included in the database are only those where available information was credible and of sufficient quality– i.e., either having their details confirmed by the own enterprise through the surveys or through direct communication by email, notification from external experts and consultants, or having a website updated and working correctly. In this context, the JRC algae database keeps record of producing enterprises that were identified but where the available data at the moment is incomplete or not confirmed. Many enterprises information and contact details

[21] Peteiro, C., (2018). https://link.springer.com/chapter/10.1007/978-981-10-6910-9_2.

[22] Guiry, M. D., and Morrisson, L. (2013), https://link.springer.com/article/10.1007/s10811-013-0027-2; Mouritsen, et al., 2013, https://link.springer.com/article/10.1007/s10811-013-0014-7; García Tasende and Peteiro, 2015, https://www.researchgate.net/publication/274868180_Explotacion_sostenible_de_las_macroalgas_marinas_Galicia_caso_de_estudio.

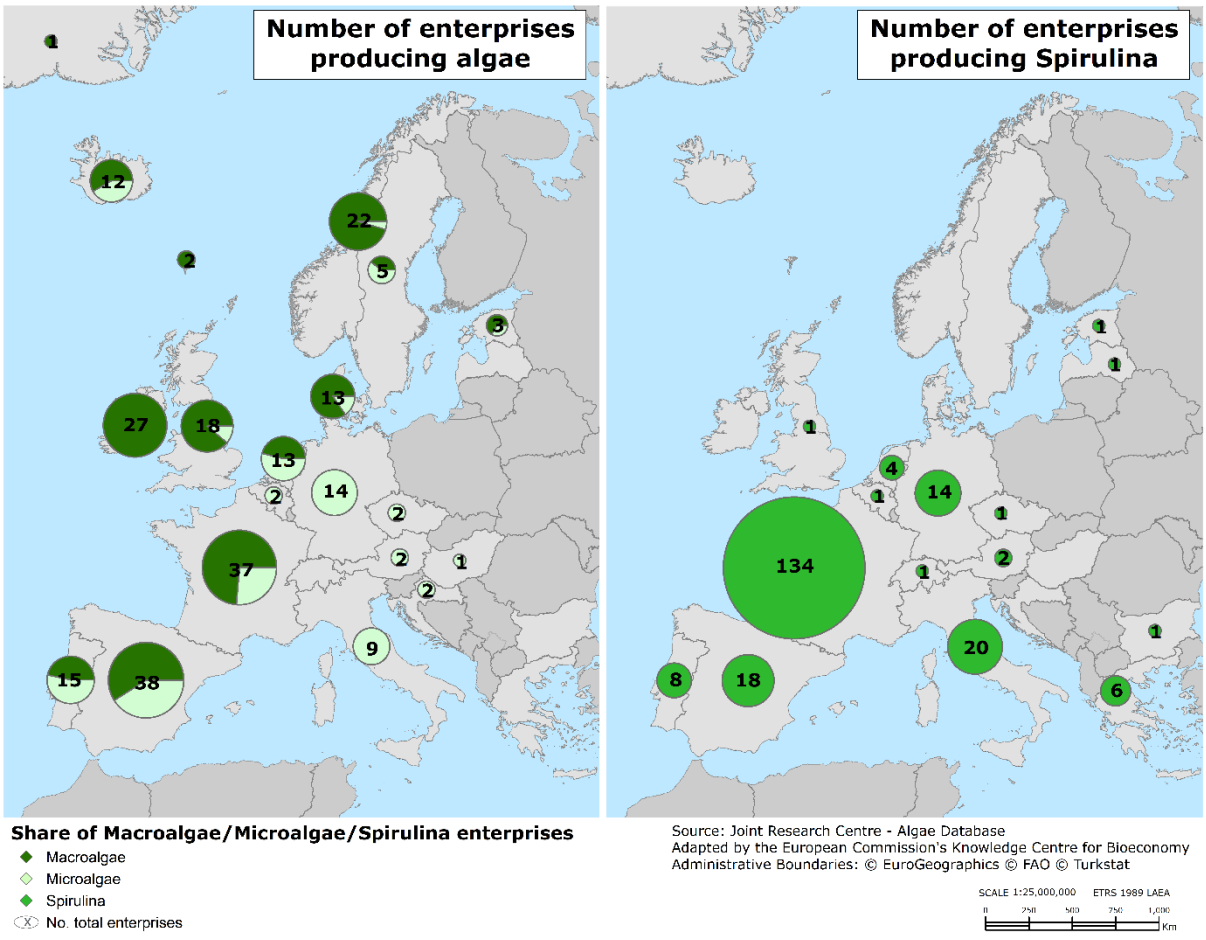
[23] Buschmann et al., 2017, https://www.tandfonline.com/doi/full/10.1080/09670262.2017.1365175; Hasselström et al., 2018, https://pubmed.ncbi.nlm.nih.gov/30041346/.

have been collected from the lists of EABA and, in the case of Spirulina producing enterprises from France, from the Fédération des Spiruliniers de France.

France is, with 169 enterprises, the country with the largest number of enterprises involved in algae production, mainly due to the large number of Spirulina producing enterprises that are active in the country (see section 3.3). The countries that follow with more than 20 algae producing enterprises are Spain, Ireland, Norway, and Italy (Figure 6). Most enterprises focus on the production of one organism group – macroalgae, microalgae, or Spirulina. However, there are 40 enterprises producing two groups – either macroalgae and microalgae, microalgae and Spirulina, or macroalgae and Spirulina.

Figure 7 shows the number of producing enterprises of macroalgae and microalgae as well as Spirulina in the European countries mapped.

Figure 7. Number of algae producing enterprises and the share between macroalgae and microalgae (left) and number of Spirulina producing enterprises (right).



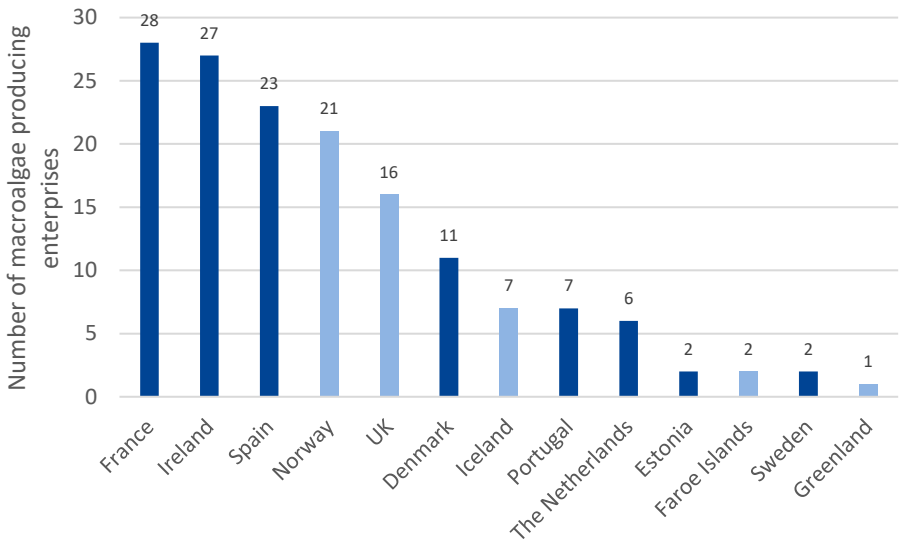
Source: Own elaboration.

In the following subsections of the report, the data for each organism group is presented in an aggregated form by country or by the total number of enterprises. The data on location of the production plants, production systems, species produced, and biomass uses are also analysed and presented.

3.1 Macroalgae

According to the data collected, there are currently 153 macroalgae producing enterprises based in 13 European countries. The countries with more presence of macroalgae producing enterprises are France, Ireland, Spain, and Norway (Figure 8).

Figure 8. Number of macroalgae producing enterprises in the EU (dark blue) and other European countries (light blue) per country.

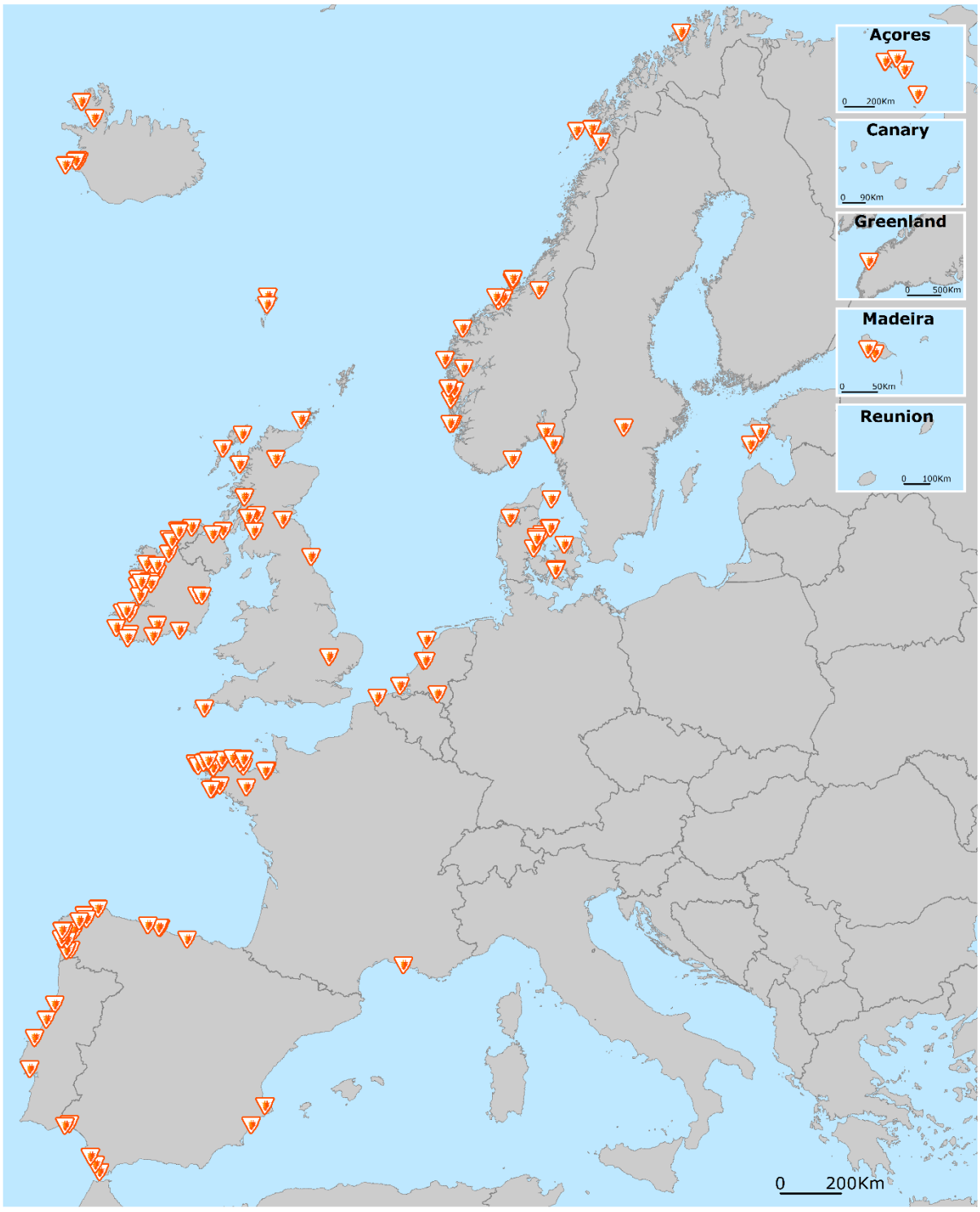


Source: Own elaboration.

3.1.1 Macroalgae production plants

There are in total 166 macroalgae production plants in Europe, operated by the 153 enterprises. Figure 9 shows the location of the production plants across Europe.

Figure 9. Macroalgae production plants (as of April 2022).



Source: Joint Research Centre & EMODnet Human Activities.
Adapted by the European Commission's Knowledge Centre for Bioeconomy
Administrative Boundaries: © EuroGeographics © FAO © Turkstat

Source: Own elaboration.

3.1.2 Macroalgae production systems

Macroalgae are harvested from wild stocks, or produced in aquaculture systems. Within the database, production systems are classified into manual or mechanical harvesting from wild stocks on the one hand, and aquaculture systems at sea, or land-based, on the other hand (Figure 11).

Manual harvesting is typically done by hand from the shore at low tide but also by diving. Mechanical harvesting is usually done with boats and custom-built devices[24] including rakes, trawlers, etc.

Aquaculture systems at sea can be further classified into coastal (i.e. located in coastal areas and shallow oceans[23]) and off-shore (located in specific infrastructures away from the coast line). Both off-shore and near the coast, sea-based cultivation is considered to have a relatively higher potential for scaling up the production volumes, subject to an adequate site-selection of the production facilities which may guarantee the suitable environmental conditions for biomass growth and cultivation[25]. However, this potential comes with associated issues that need to be considered, such as more variable yields[26], less control of the quality of the biomass, higher risks of diseases and pests[27] as well as vulnerability to environmental conditions (e.g., major storms, torrential rains)[28].

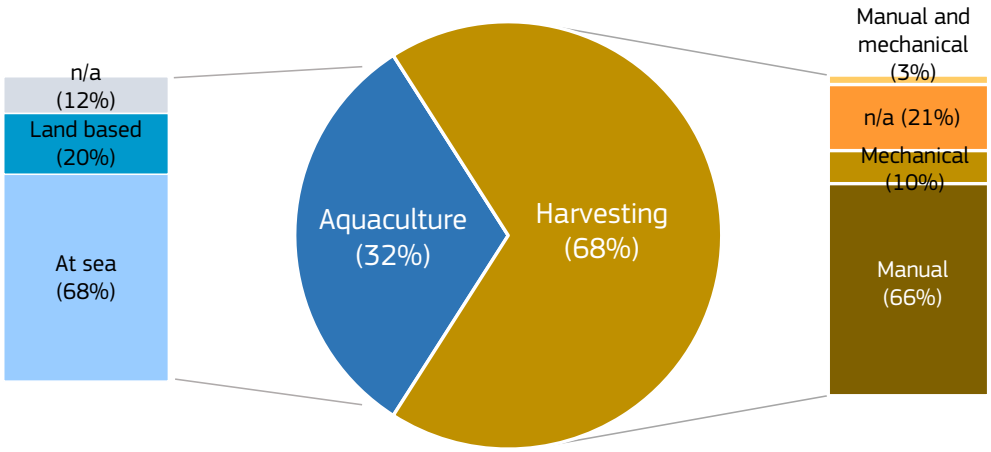
Land-based aquaculture systems, typically take the form of large tanks fed with marine water. This system offers a more controlled environment to produce algae biomass and a better control of the quality, and composition of the biomass, as well as standardisation, traceability and security, thus driving to a more consistent and stable biomass supply throughout the year[14]. Those systems are the most suitable for certain species (e.g. *Ulva* spp. and *Gracilaria*/*Gracilariopsis* spp.) and for specific high-value applications (e.g., functional products for human consumption, cosmetics, and pharmaceutics). However, land-based cultivation usually requires a higher availability of land, and has higher infrastructural and operational costs.

Figure 10. Different macroalgae production systems: a) mechanical harvesting of storm-cast material – ©Rasmus; b) land-based aquaculture © tonguy324; c) Offshore macroalgae aquaculture ©Seaweed Energy Solutions AS.

Figure 11 shows the share of the number of macroalgae producing enterprises by production system. It includes enterprises for which information on the specific production system is not available (n/a) but also enterprises using multiple production systems which are counted multiple times (one time for each production system).

[24] Mac Monagail et al., 2017, https://www.tandfonline.com/doi/full/10.1080/09670262.2017.1365273.
[25] Bruhn et al., 2016, https://www.int-res.com/abstracts/aei/v8/p619-636/; Peteiro et al., 2016, https://www.sciencedirect.com/science/article/pii/S2211926416300236; Barbier et al., 2019, https://doi.org/10.21411/2c3w-yc73.; Visch et al., 2020, https://www.sciencedirect.com/science/article/pii/S0025326X20300801.
[26] Titlyanov, E. A., and Titlyanova, T. V. (2010). https://link.springer.com/article/10.1134/s1063074010040012.
[27] Ward, et al., 2020. https://onlinelibrary.wiley.com/doi/10.1111/jwas.12649.
[28] Peteiro, et al., 2014. https://link.springer.com/article/10.1007/s10811-013-0096-2.

Figure 11. Share of macroalgae producing enterprises by production system used. Note: n/a = not available.



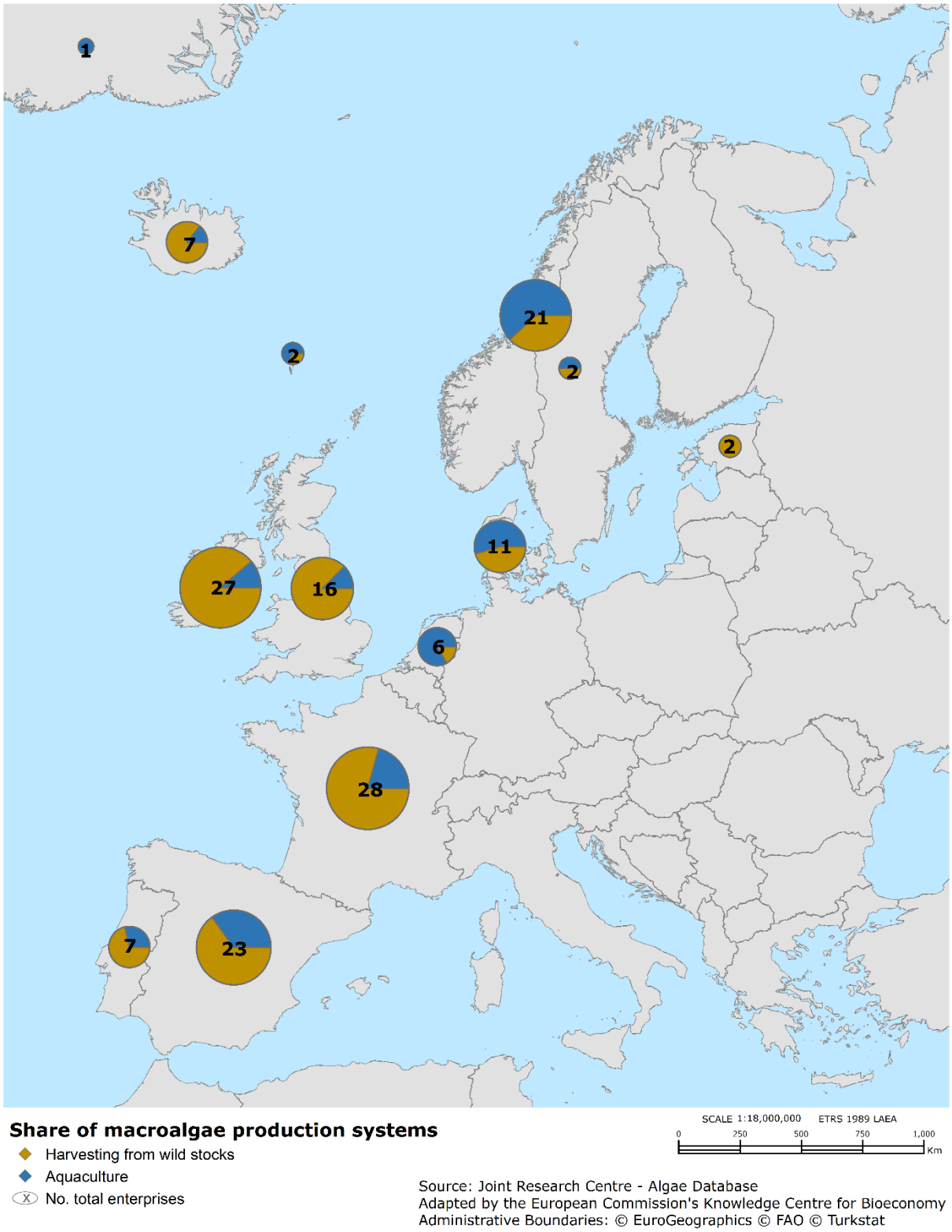
Source: Own elaboration.

Most enterprises produce macroalgae through harvesting (68%), while aquaculture is less frequently used (32% of the macroalgae producing enterprises). Manual harvesting is the predominant system (45% of all macroalgae producing enterprises, 66% of those harvesting). In fact, as the harvesting system has not been identified in 21% of the harvesting enterprises, that share might be even higher. Aquaculture at sea (which includes both coastal and offshore aquaculture) is predominant (68% of aquaculture enterprises) over land-based aquaculture (20%). The environment of the production system could not be identified in 12% of the macroalgae aquaculture enterprises.

The manual harvesting of macroalgae represented a traditional activity in some Atlantic coastal communities for centuries, becoming an important family activity and part of the cultural heritage that still continues nowadays[14], despite the recent advancements in harvesting technologies.

The distribution of the macroalgae production systems used by enterprises based in each country is shown in Figure 12. Harvesting from wild stocks is the main production system in most of the European countries mapped, except for Denmark, Faroe Islands, and Greenland, as well as in the Netherlands and Norway, where more than 50% of the producing enterprises use aquaculture.

Figure 12. Number of macroalgae producing enterprises and the share of the production systems used, by country.



Source: Own elaboration.

The production of macroalgae is frequently combined with other economic activities. Enterprises that harvest from wild stocks, either manually or mechanically, typically use their fleet and human power to land fish and other seafood, which can complement the revenues from the algae business, or indeed be their main economic activity.

Similarly, aquaculture of macroalgae may be also combined with the production of other seafood and related products. A key example is the Integrated Multi-Trophic Aquaculture (IMTA), which consists of the associated culture of several species from different trophic levels (2 or more). In these systems, farmers can combine the production of macroalgae with fed-species, like salmon, suspension feeders such as scallops and mussels, and/or organic deposit-feeders, such as sea cucumbers, to increase production efficiency and decrease waste[29]. IMTA allows uneaten feed and by-product particulate wastes and dissolved nutrients to be recaptured by extractive co-cultivars and converted into energy, feed, or fertilizer. Thus, IMTA is regarded as a potential mitigation approach, reducing the nutrients and organic matter inputs from finfish aquaculture[14].

3.1.3 Macroalgae species produced

According to the data collected from the macroalgae producing plants, *Saccharina* spp. - mostly *Saccharina latissima* - is the genus most commonly produced (53 enterprises), followed by *Ulva* spp. and *Laminaria* spp., produced by 46 and 45 enterprises, respectively (see Figure 13). Other genera widely produced (by more than 20 enterprises) are Palmaria spp. -mainly Palmaria palmata-, *Fucus* spp., *Himanthalia* spp., *Alaria* spp., *Porphyra* spp., *Undaria* spp., *Chondrus* spp. and the species *Ascophyllum nodosum* (Figure 14).

Figure 13. Some of the most produced seaweed species: a) Saccharina latissima ©ANGHI; b) Ulva lactuca © Elena Tcykina; c) Laminaria digitate © ChrWeiss.

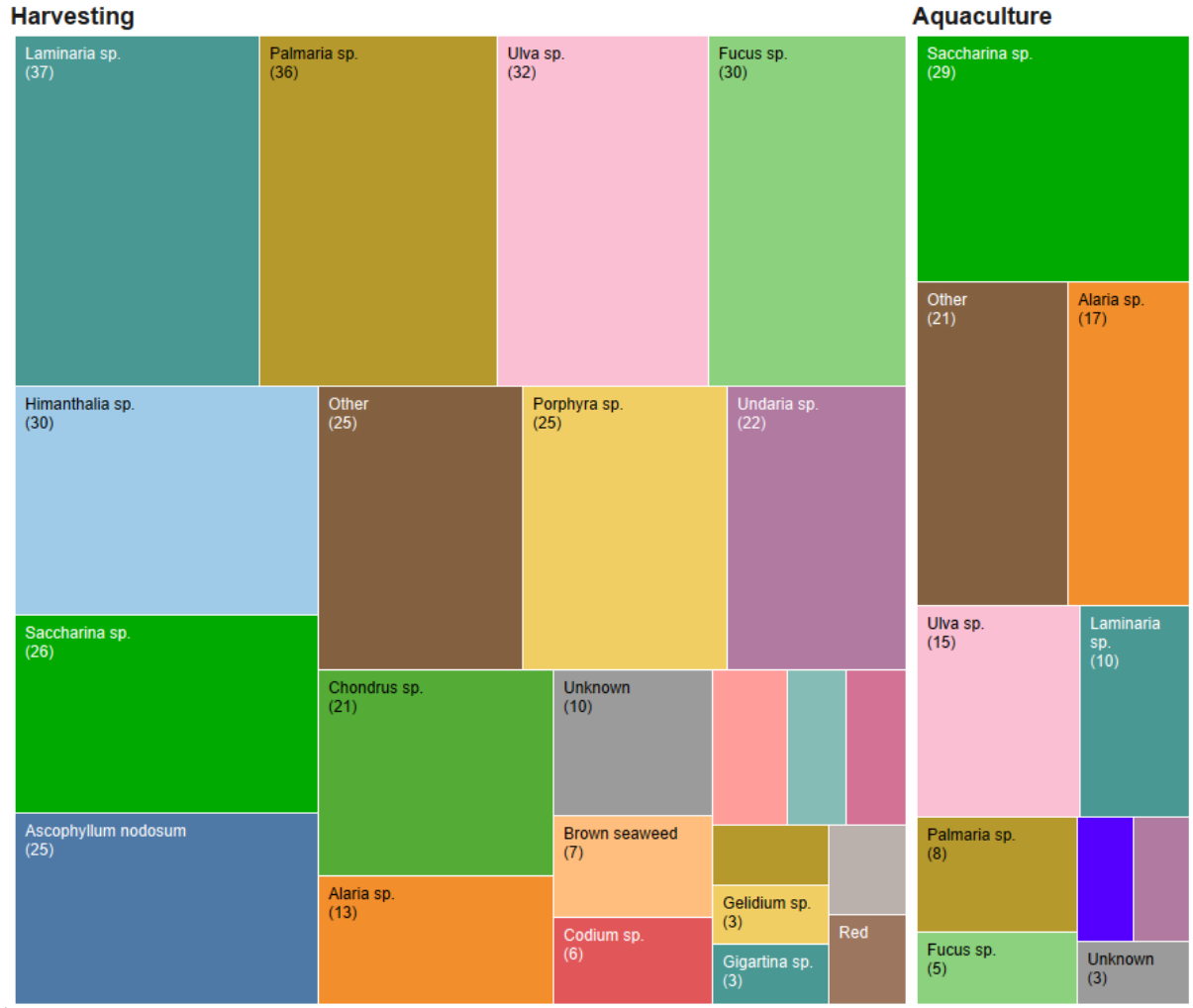
Most of the species are both farmed in aquaculture plants and harvested from the wild; for some species however, large differences between both production systems exist: while *Saccharina* spp. and *Alaria* spp. are equally produced by aquaculture and wild harvesting, seaweeds such as *Himanthalia* spp., *Ascophyllum nodosum* and *Chondrus* spp. are basically harvested (more than 90% of the enterprises producing them). *Fucus* spp., *Palmaria* spp., *Laminaria* spp., and *Ulva* spp., are also predominantly harvested (86%, 82%, 79% and 68% of the enterprises producing them, respectively).

Species that are produced more rarely (i.e., by only one enterprise) include many seaweeds, e.g., *Vertebrata lanosa, Ulvella lens, Caulerpa* spp., and *Asparagopsis* spp., produced in aquaculture systems and *Zonaria tournefortii*, *Cystoseira* spp., or *Chorda filum,* produced by wild harvesting.

In the JRC algae database, species were coded in broader groups, namely "Red seaweed" (phylum Rhodophyta), "Brown seaweed" (class Phaeophyceae), and "Green seaweed" (phylum Chlorophyta and phylum Charophyta) when the enterprise was not willing to disclose the species produced, or when the information from the website was not specific in this regard. Similarly, for 13 enterprises neither the species nor the group produced could be identified.

[29] Kleitouu et al., 2018. https://doi.org/10.1016/j.aquaculture.2018.02.035.

Figure 14. Macroalgae species produced through harvesting from wild stocks (left side) and aquaculture systems (right side), by number of enterprises (in brackets).

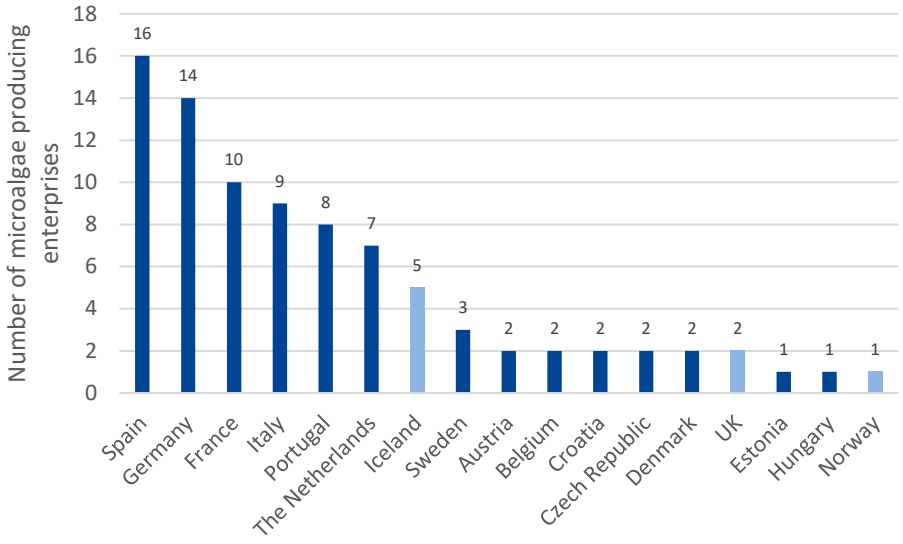


Source: Own elaboration.

3.2 Microalgae

According to the data collected, there are currently 87 microalgae producing enterprises based in 17 European countries. Spain and Germany are the countries that host more enterprises, with 16 and 14 enterprises, respectively (Figure 15).

Figure 15. Number of microalgae producing enterprises in the EU (dark blue) and other European countries (light blue) per country.



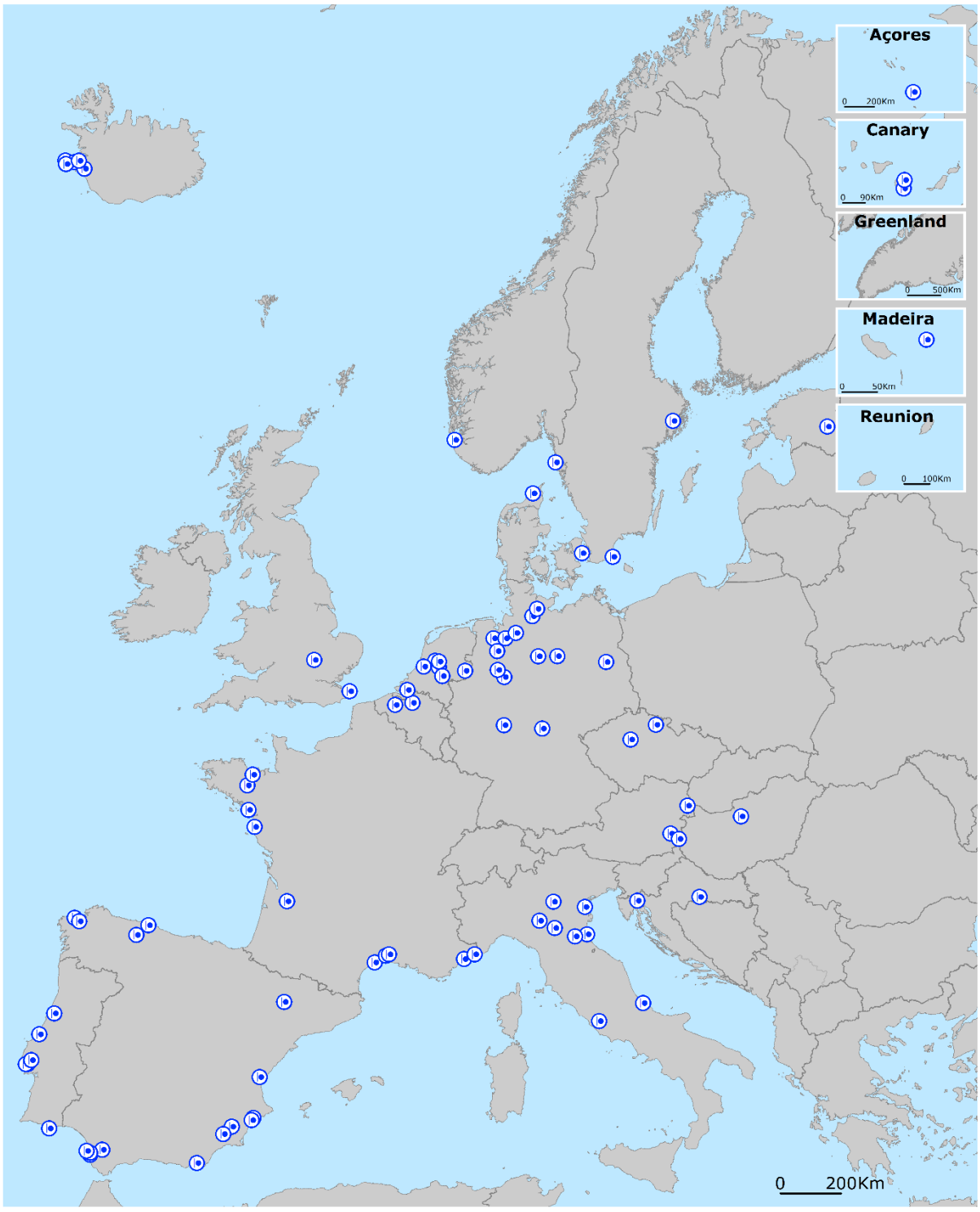
Source: Own elaboration.

3.2.1 Microalgae production plants

In total, there are 89 microalgae production units in Europe, operated by 87 enterprises.

Figure 16 shows the location of the production plants across Europe.

Figure 16. Microalgae production plants (as of April 2022).



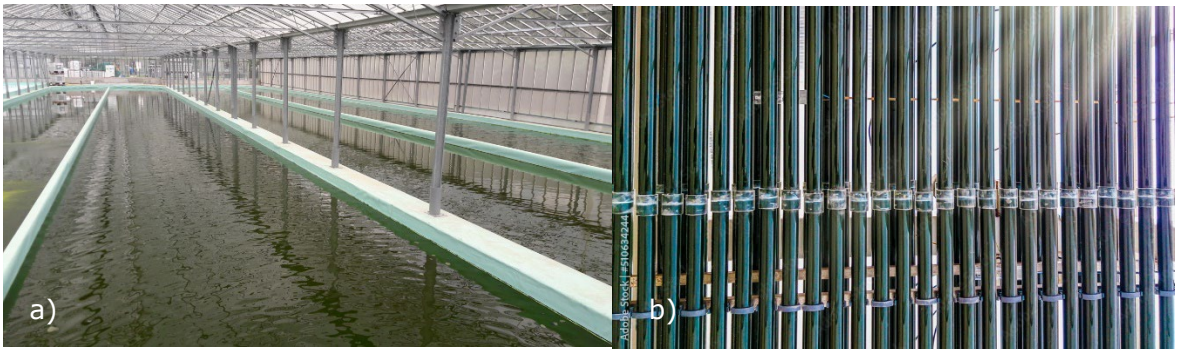
Source: Joint Research Centre & EMODnet Human Activities.
Adapted by the European Commission's Knowledge Centre for Bioeconomy
Administrative Boundaries: © EuroGeographics © FAO © Turkstat

Source: Own elaboration.

3.2.2 Microalgae production systems

Microalgae can be produced in open or closed systems. In open systems the growth medium is in direct contact with the atmosphere and can take the form of rectangular or circular ponds that are stirred mechanically, or of 'raceway ponds' which are stirred by a paddle wheel. On the other hand, in closed systems the growth medium is not in contact with the atmosphere in order to have more controlled conditions, including prevention of contamination, better control of the cultivation conditions (pH, temperature, nutrient supply, etc.), reduction of water use and CO_2 losses. The most common closed systems are those so-called photobioreactors (PBRs) and fermenters. PBRs consist either of horizontally or vertically arranged tubes, or vertically arranged panels while fermenters are stirred-tank reactors used to cultivate microalgae in heterotrophic conditions (in the dark on sugars). All these production systems can be used as single systems or a combination thereof.

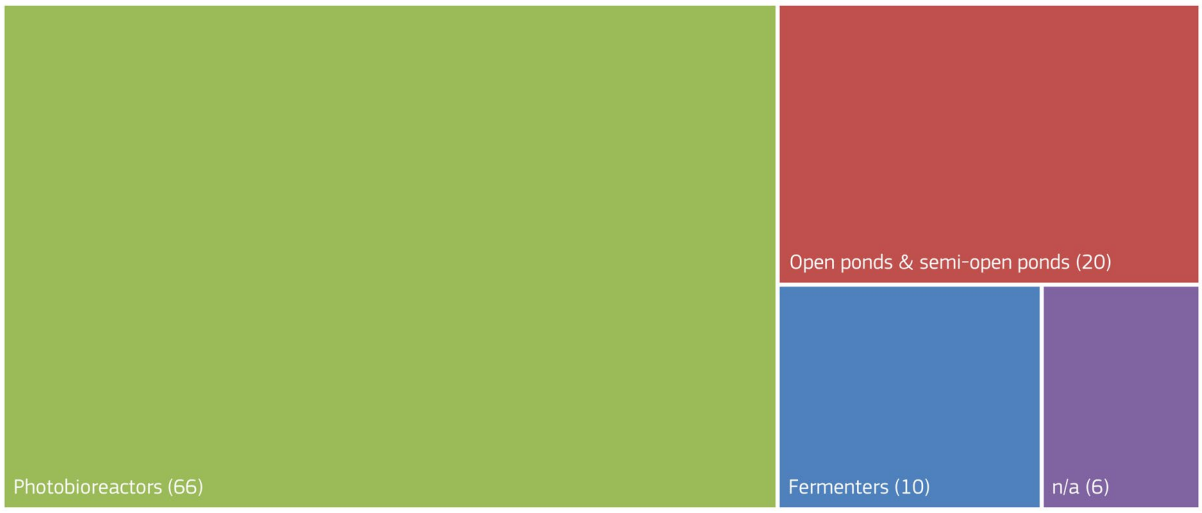
Figure 17. Examples of microalgae production systems: a) open pond microalgae production - © Archimede Ricerche, 2018; b) tubular photobioreactor – ©elif.



The number of enterprises using each production system can be seen in Figure 18.

The majority of the enterprises use photobioreactors to produce microalgae followed by open ponds.

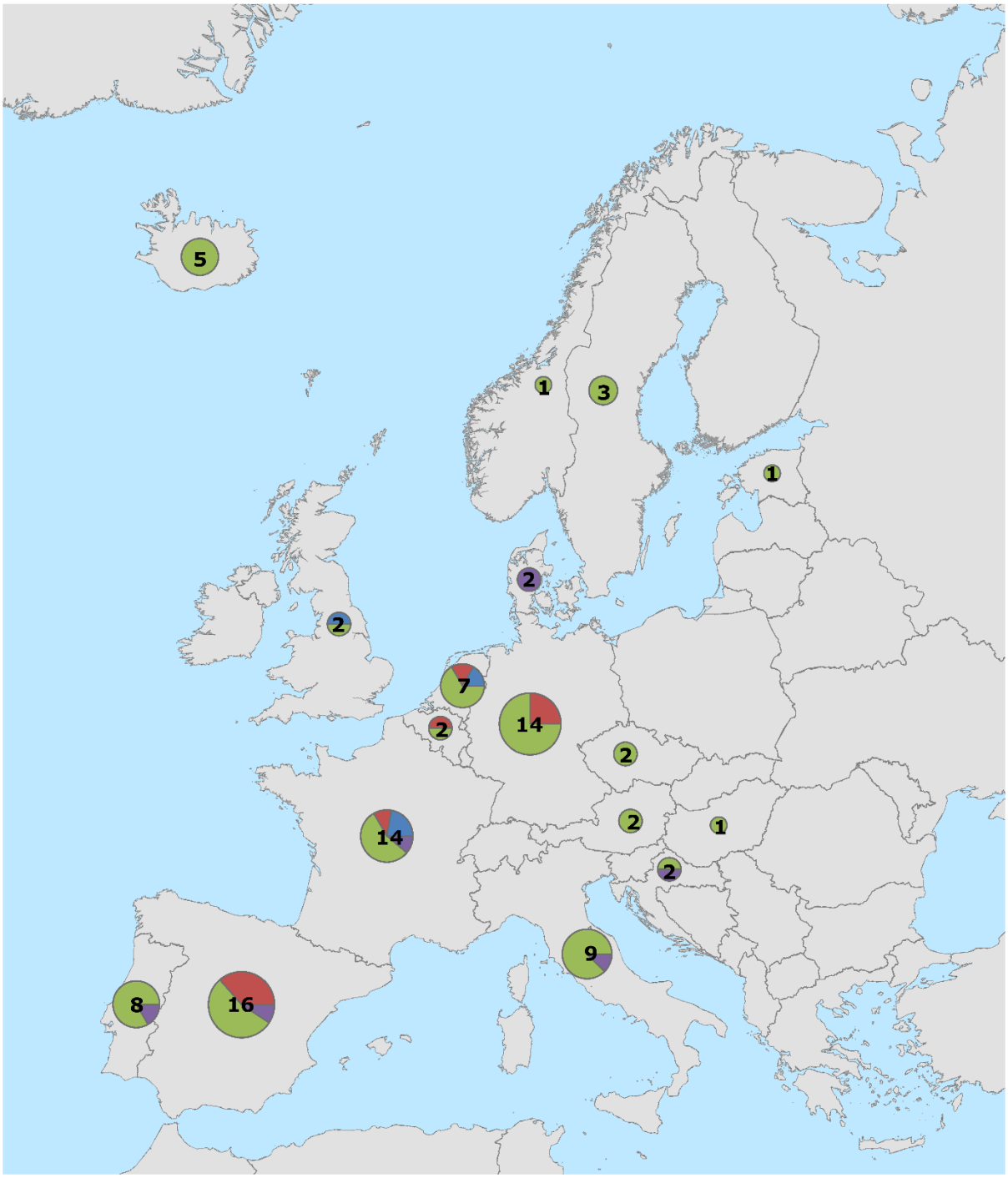
Figure 18. Microalgae species produced through different production systems by number of enterprises (in brackets). Note: a single enterprise may use more than one production system, in which case it is counted more than once in this graph.



Source: Own elaboration.

The distribution of the microalgae production systems used by companies based in each country is shown in Figure 19. Interestingly, photobioreactors are the main production system in all the European countries mapped except for Belgium and the UK, where it is equally used together with ponds and fermenters, respectively.

Figure 19. Number of microalgae producing enterprises and the share of the production systems used, by country.



Source: Own elaboration.

The production of microalgae represents a complex technological process that requires a high level of specialisation, thus its combination with other economic activities is not a common practice currently. However, recent research has been exploring the potential of integrating, in a circular manner, microalgae cultivation with

other agricultural and aquaculture systems[30] for the production of food[31] and feed (for e.g. fish), the bioremediation of wastewater[32], or waste streams from winery[33,34] or sludge from pig farms[35] or other livestock[36].

3.2.3 Microalgae species produced

The species produced by the largest number of enterprises are *Chlorella* spp. (27 enterprises, 31%), followed by *Nannochloropsis* spp. (24 enterprises, 28%) (Figure 20). Several species are produced by only one enterprise, e.g., *Rhodomonas* spp. and *Acutodesmus* spp. For visualisation purposes, those species were grouped under the category "Other". For 20 enterprises, the species produced could not be identified (Figure 21).

Figure 20. Some of the most produced microalgae species: a) *Chlorella* spp. © sinhyu; b) *Nannochloropsis oculata* © Malakootian, Hatami, Dowlatshahi, and Rajabizadeh (2016) licensed under the terms of the Creative Commons Attribution License (http://creativecommons.org/licenses/by/4.0).

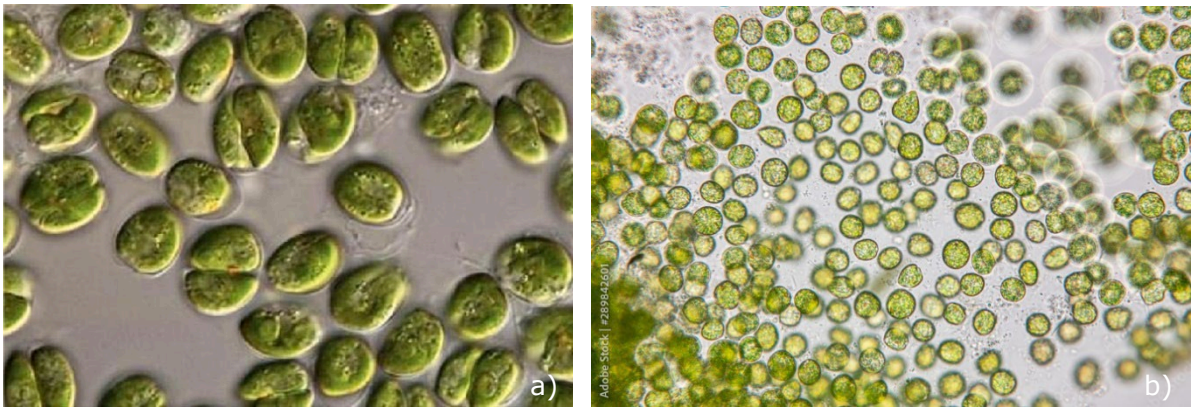
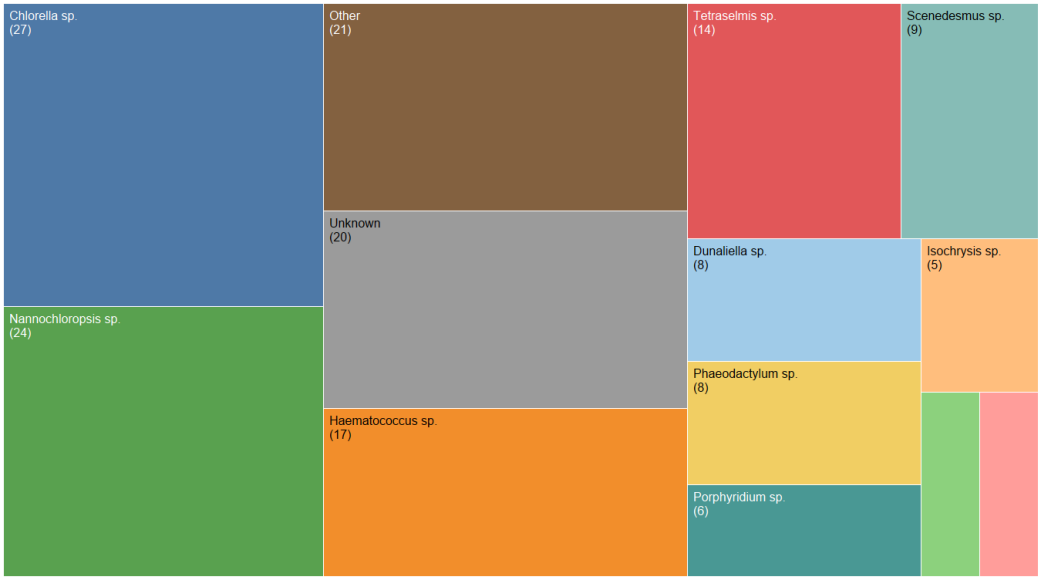


Figure 21. Microalgae species produced, by number of enterprises (in brackets).



Source: Own elaboration.

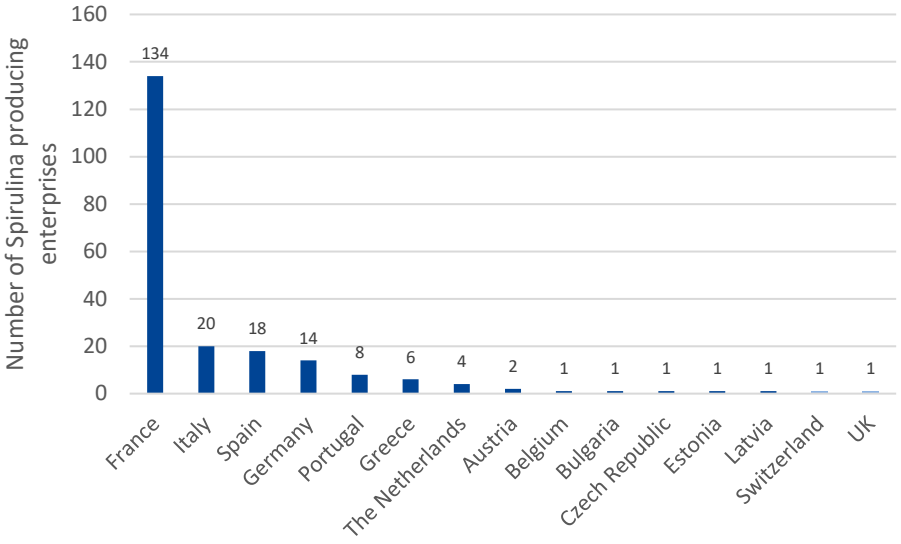
[30] Ullmann and Grimm, 2021. https://link.springer.com/article/10.1007/s13165-020-00337-9.
[31] Rahmann et al., 2020. https://link.springer.com/article/10.1007/s13165-019-00247-5.
[32] Singh et al., 2020. https://www.sciencedirect.com/science/article/pii/S0960852420305046.
[33] Higgins et al., 2018. https://doi.org/10.1038/s41545-018-0005-y.
[34] Marchao et al., 2021. https://www.sciencedirect.com/science/article/pii/S004313542100662X.
[35] Bai et al., 2012. https://link.springer.com/article/10.1007/s13593-011-0077-2; Veuthey et al., 2022. https://doi.org/10.1016/j.jwpe.2022.102869.
[36] López-Sánchez et al., 2022. https://www.sciencedirect.com/science/article/pii/S0301479722001852.

3.3 Spirulina

The JRC algae database also includes information and data on enterprises producing and processing Spirulina, a cyanobacteria which is frequently considered, from the industry and consumer perspective, as "algae" (e.g., CEN/TC454, 2020). Spirulina is the commercial name for the genus *Arthrospira*[7].

Currently the JRC algae database identifies 213 Spirulina producing enterprises based in 15 European countries (Figure 22). The majority of these enterprises (134) are based in France. Italy and Spain follow with 20 and 18 enterprises, respectively. With these numbers, France clearly dominates the Spirulina production in Europe, although it is important to note that that the list of enterprises based in France, mainly provided by the Fédération des Spiruliniers de France, may be more complete compared to other countries.

Figure 22. Number of Spirulina producing enterprises in the EU (dark blue) and other European countries (light blue) per country.

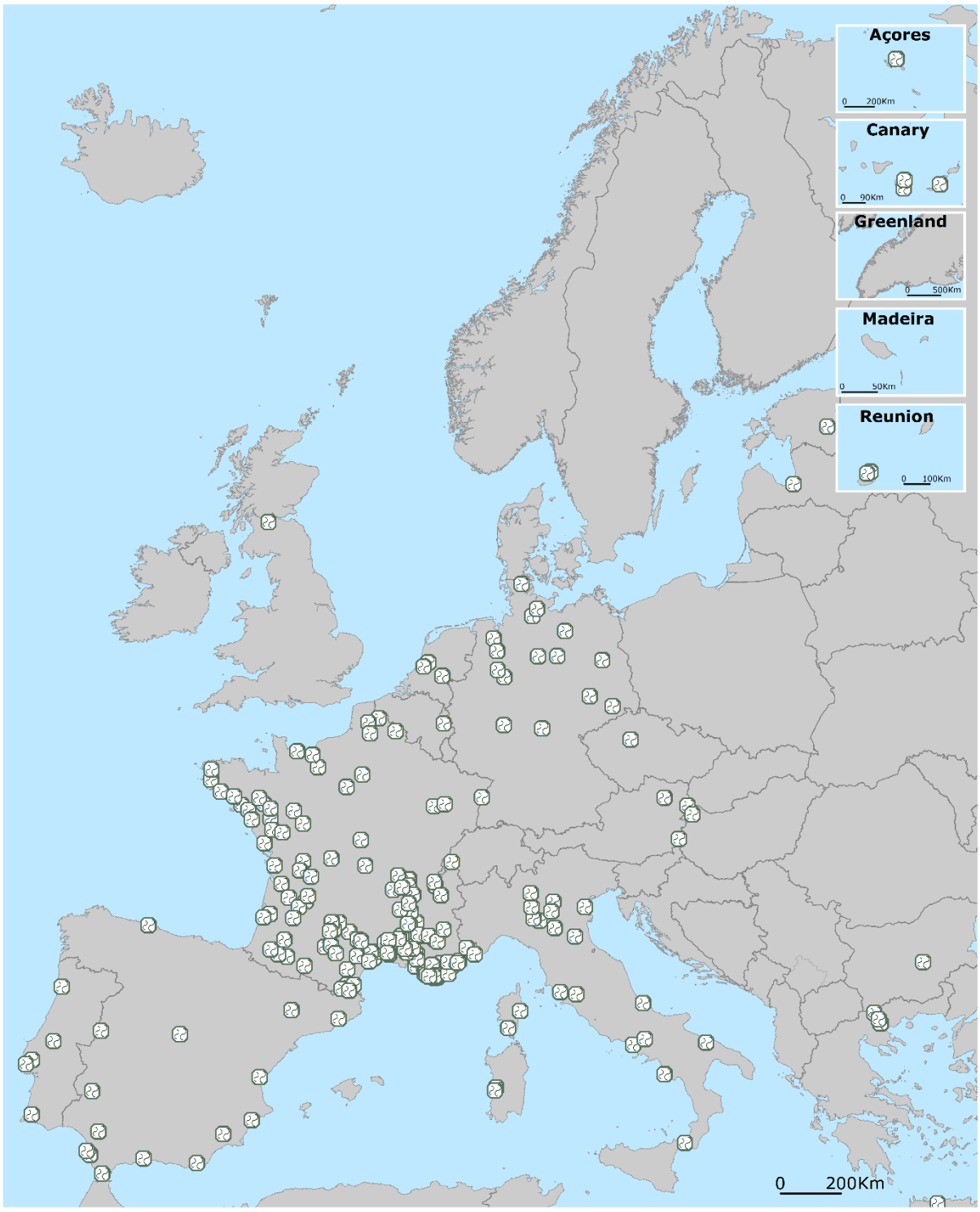


Source: Own elaboration.

3.3.1 Spirulina production plants

There are 216 production plants across Europe, operated by the 213 Spirulina producing enterprises (Figure 23).

Figure 23. Spirulina production plants (as of April 2022).



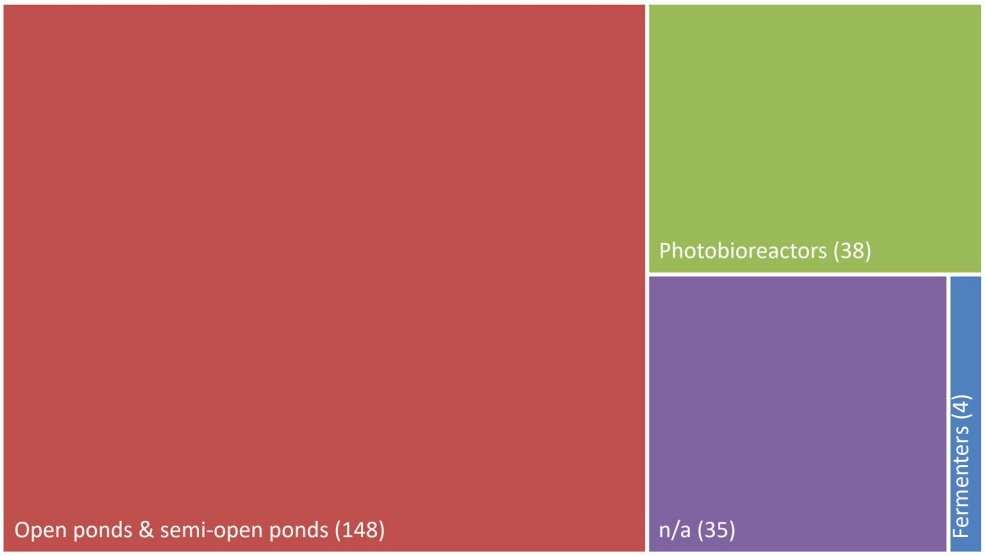
Source: Joint Research Centre & EMODnet Human Activities.
Adapted by the European Commission's Knowledge Centre for Bioeconomy
Administrative Boundaries: © EuroGeographics © FAO © Turkstat

Source: Own elaboration.

3.3.2 Spirulina production systems

There are different systems used for the production of Spirulina in Europe. Most of the enterprises (148) use open and/or semi-open ponds. Photobioreactors are also a common production system, used by 38 enterprises (Figure 24). As in the production of microalgae, a combination of different production systems is frequently used by European Spirulina-producing enterprises, especially photobioreactors and (open and semi-open) ponds. For 35 enterprises, the production system could not be identified.

Figure 24. Spirulina produced through different production systems by number of enterprises (in brackets). Note: a single enterprise may use more than one production system, in which it is counted more than once in this graph.

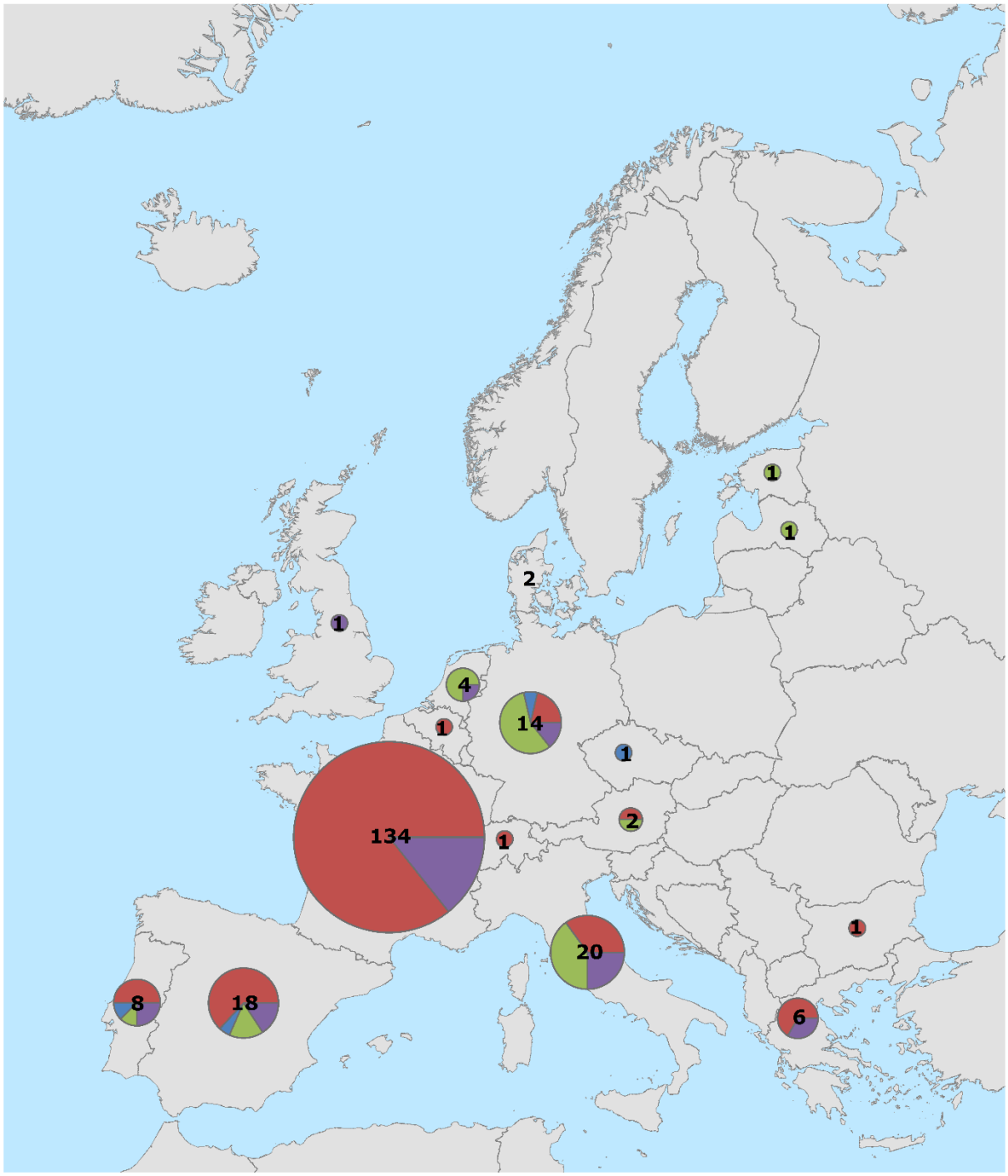


Source: Own elaboration.

The distribution of the Spirulina production systems used by companies based in each country is shown in Figure 25. Open and semi-open ponds are the main production system in most European countries (BE, CH, EL, ES, PT, FR, BG) while photobioreactors are also widespread in other countries (EE, LV, DE, NL, etc.).

Similarly to microalgae, Spirulina production and processing is a highly specialised technological process so its integration with other economic activities is not a common practice at present.

Figure 25. Number of Spirulina producing enterprises and the share of the production systems used, by country.



Share of Spirulina production systems

- Photobioreactors (X) No. total enterprises
- Ponds
- Fermenters
- n/a

SCALE 1:18,000,000 ETRS 1989 LAEA

0 250 500 750 1,000 Km

Source: Joint Research Centre - Algae Database
Adapted by the European Commission's Knowledge Centre for Bioeconomy
Administrative Boundaries: © EuroGeographics © FAO © Turkstat

Source: Own elaboration.

4 Uses of the algae biomass produced in Europe

In the case of macroalgae, human food is the use to which the largest number of producing enterprises supply biomass for (almost 34%), followed by cosmetics (18%), food supplements and nutraceuticals (15%), fertilisers and biostimulants (11%), and animal feed (10%). Thus, the food and feed sectors are the main markets for macroalgae biomass in terms of number of supplying enterprises (almost 60%). The macroalgae biomass is less frequently supplied to other uses such as those of pharmaceuticals, bioremediation, biofuels, research, and bioactive compounds (less than 2% of the European enterprises).

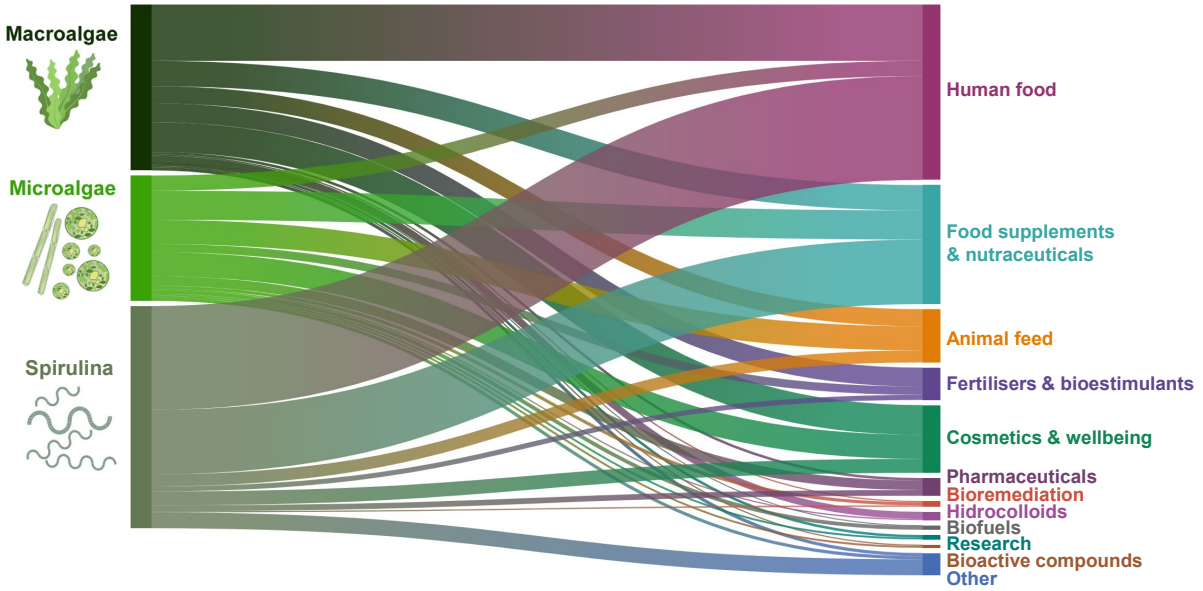
Similarly for microalgae, the food and feed sectors are the uses reported by more than 54% of the enterprises (23% to food supplements, 19% to animal feed and 12% to human food). Cosmetics and wellbeing products is also a prominent sector (19% of the enterprises), followed by pharmaceuticals (8%) and fertilisers and biostimulants (7%).

Spirulina has been traditionally part of western diets for decades, and it is considered nowadays as a "super food" due to its high nutritional value (Jung et al., 2019). Thus, the commercial uses of the Spirulina biomass are mainly human food, and food supplements and nutraceuticals, accounting together for 76% of the enterprises. Minor uses of this biomass are cosmetics and wellbeing products (6% of the enterprises), animal feed (5%), pharmaceuticals (3%), fertilisers and biostimulants (2%), bioremediation (1%) and other uses (remaining 7%).

Many algae producing enterprises supply biomass for multiple commercial uses. In these cases, all the biomass uses for each enterprise were registered in the database. It should be also highlighted that the values reported on biomass uses in these sections refer to the number of enterprises and do not reflect the volumes of biomass dedicated to each use (see section 2).

The commercial uses of the algae biomass produced by the enterprises in Europe is shown in Figure 26.

Figure 26. Algae biomass uses based on number of enterprises producing algae in Europe. Note: lines represent number of enterprises supplying biomass to the different uses (i.e., they do not represent biomass volumes).



Source: Own elaboration.

5 Other steps in the algae value chain

The JRC algae database includes data on other steps of the value chain besides the algae production and uses (both based on data from enterprises producing algae), in order to provide additional information about the algae value chain. The stakeholders identified in the post-production steps of the value chain beyond biomass producers are biomass processors, technology providers, R&D enterprises, consultancy, and traders / exporters. Most of the enterprises are actually part of several steps of the value chain, e.g., most of the producers are also processors.

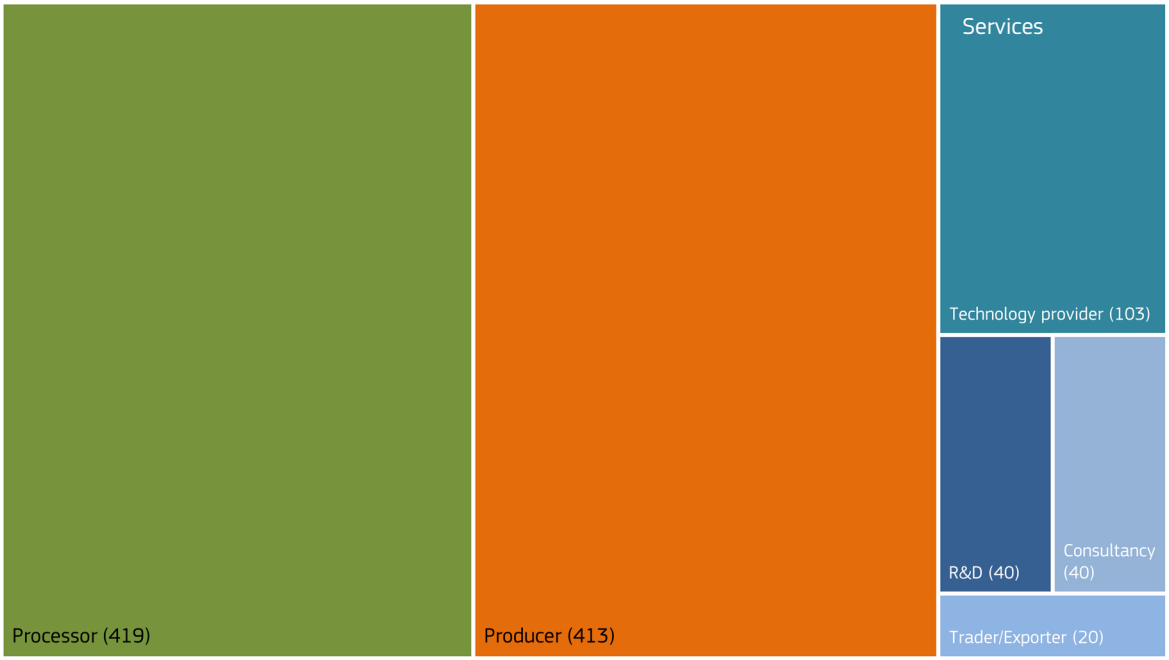
For analysis and visualisation purposes, the steps have been grouped in three categories as follows (Table 4):

Table 4. Categories in which the steps of the value chain are classified for the analysis of the data.

CATEGORY	STEPS IN THE VALUE CHAIN
Producing	Producer
Processing	Processor
Services	Technology provider; R&D; Consultancy; Trader/Exporter

Figure 27 shows the number of enterprises involved in the different steps of the value chain. It should be noted that many enterprises are involved in several steps of the value chain. In these cases, they have been accounted in each of the steps.

Figure 27. Steps of the algae value chain in Europe by number of enterprises, grouped by categories. Note: enterprises involved in multiple steps of the value chain are counted multiple times.

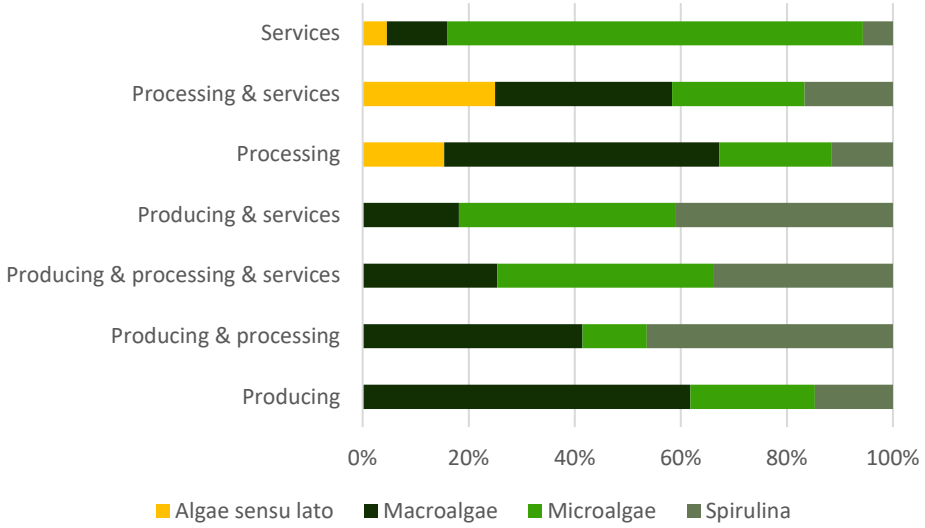


Source: Own elaboration.

Of the steps of the value chain considered, up to 419 enterprises are classified as biomass processors and 413 enterprises as producers. Of them, 364 enterprises are involved in both steps (i.e., are producers and processors). Related to services activities, 203 enterprises were classified as R&D (40), technology providers (103), consultancy (40) or trader/exporter (20).

Figure 28 shows the species group to which enterprises in different steps of the value chain associate their business to. From the production and processing steps, most of the enterprises identified are active in macroalgae and spirulina while in the other categories, the species group varies more. Interestingly, while on the other steps all the species groups are represented in a relatively balanced way, an impressive 86.3% of the identified enterprises working on services are dedicated to microalgae (12.6% of the total enterprises).

Figure 28. Share of enterprises by organism group and step of the value chain.



Source: Own elaboration.

6 Socio-economic data of the algae industry in Europe

The updated database includes data on turnover and number of employees from 2016 until 2020. As explained in Section 2, the data on turnover and employment was collected for each individual enterprise from the Orbis database. In the case of employment, data from the surveyed enterprises was complemented with data from Orbis. In the survey, data on gender balance and age distribution was also collected, but due to the low rate of responses, this data was not integrated eventually in the published database.

The available STECF[37] report data on the turnover (STECF, 2021), cost structure and employment on the algae sector refer to the aquaculture industry. But these data cover only France (macroalgae, microalgae and Spirulina), Spain (macroalgae, microalgae and Spirulina) and Portugal (macroalgae). The total production value in these countries was reported to be EUR 10.7 million in 2018 in the STECF report, which is in line with the EUR 12.5 million reported by FAO for the whole EU (Table 2).

The analysis of the STECF data shows that France, Spain and Portugal reported a total number of 156 algae aquaculture companies, 87% of them are micro-enterprises with fewer than five employees. The EU aquaculture (considering these countries) employs 509 persons, 399 in full time equivalent (FTE).

This data available from STECF shows that there is, indeed, a lack of knowledge on the socio-economic value of the algae industry in Europe, as only data from three European countries are considered and the data is related to the aquaculture sector as a whole (i.e., it may not differentiate between algae and other organisms produced by aquaculture).

The data reported in the following sections aims at partially filling this gap. However, the aggregated data may not be considered as precise estimates due to the limited data available in official statistics and private business databases and directories and the relatively low response rate to the surveys conducted, and due to the lack of disaggregated data for enterprises having also non-algae business streams (see section 2).

6.1 Turnover

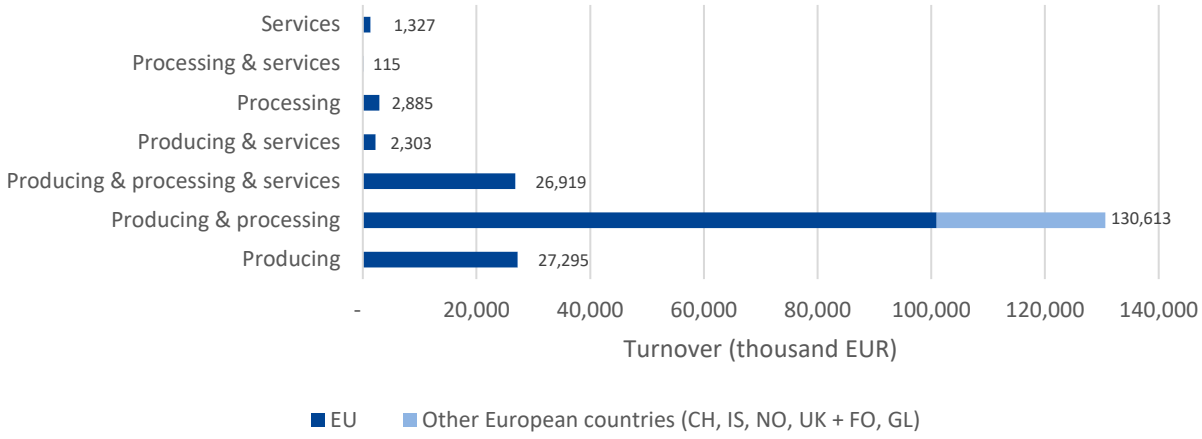
As explained in section 2, data for turnover for each enterprise and year (for the period 2016-2020) was collected from the Orbis database. Data was collected in US dollars ($) and expressed in EUR using the specific exchange rate for each year. The sum of the yearly average was calculated for each country (see section 2).

For the enterprises involved in several steps of the value chain, as it was not possible to break down the share of business for each step, the turnover values are provided in an aggregated form for combinations of steps. Similarly, the specific target organism group for certain enterprises could not be broken down. Thus, turnover values for those enterprises working with several organism groups are reported in an aggregated form for combinations of groups.

The total average available turnover in the five years considered per step of the value chain can be seen in Figure 29.

[37] Scientific, Technical and Economic Committee for Fisheries of the European Commission

Figure 29. Turnover (2016-2020 average) for the algae industry in the EU (dark blue) and other European countries (light blue) (including CH, IS, NO, UK plus FO and GL) per step of the value chain[38] grouped in categories. Please refer to section 2 for information on underpinning data availability.



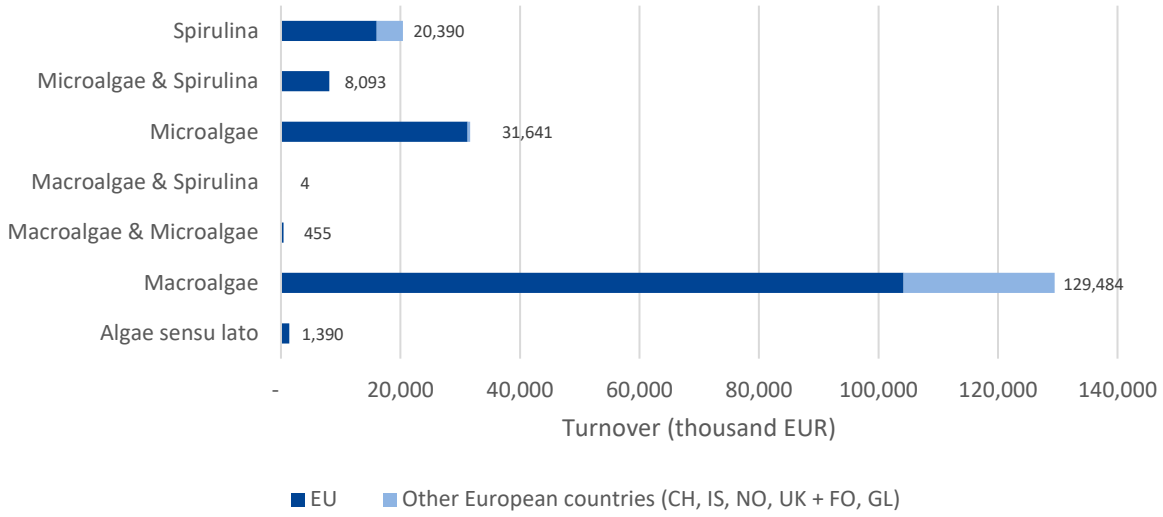
Source: Own elaboration.

The total turnover (2016-2020 average) generated by the identified companies from the algae industry is estimated at EUR 161.4 million in the EU[12] Member States (excluding FO and GL) and EUR 30 million in the other European countries mapped, respectively. Those enterprises that are both producing and processing algae contribute with the largest amount of turnover (around EUR 130.6 million). The enterprises involved only in the production of biomass and those involved in all three steps of the value chain generate EUR 27.3 million and EUR 26.9 million, respectively.

Figure 30 shows the total turnover by organism group, considering all countries and all steps of the value chain. As for enterprises involved in different organism groups, it is not possible to disaggregate the share of business by organism group, their turnover values are provided in an aggregated form. Furthermore, for certain enterprises, it was not possible to identify the target species group. For these enterprises, the category "algae sensu lato" was allocated.

[38] Many enterprises are involved in several steps of the algae value. For those enterprises, a breakdown could not be provided so aggregate values of combinations of steps are reported.

Figure 30. Turnover (2016-2020 average) in the EU (dark blue) and other European countries (light blue) (including CH, IS, NO, UK plus FO and GL) per organism group[39]. Please refer to section 2for information on underpinning data availability.



Source: Own elaboration.

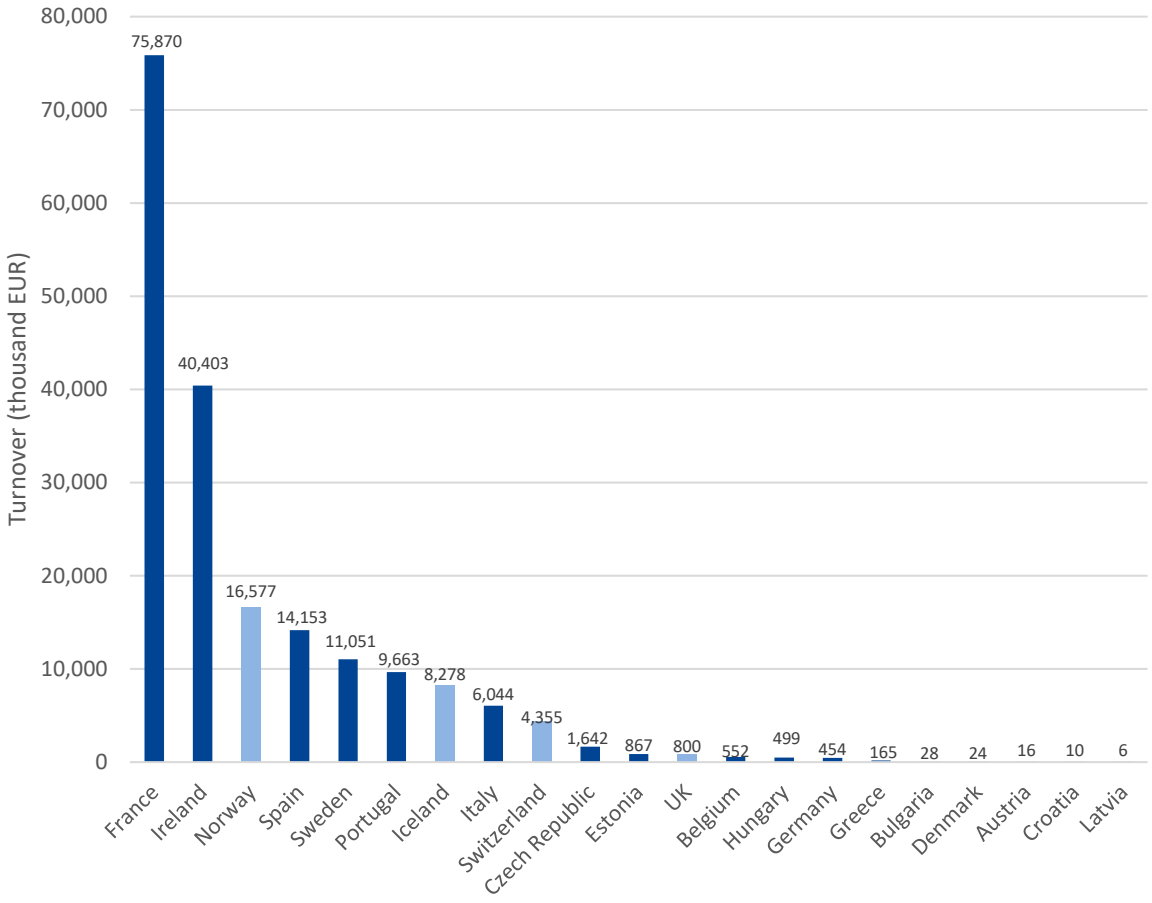
Macroalgae represent the organism group with highest turnover considering all steps of the value chain, as the turnover resulting from the enterprises dealing with them generate more than EUR 129.5 million € (Figure 30). Enterprises that focus on microalgae alone are in second place with regards to turnover generated, contributing with more than EUR 31 million. In the case of Spirulina, the turnover from its industry alone reaches over EUR 20 million while for the enterprises dedicating to the algae industry in general (algae sensu lato), the amount is over EUR 1.4 million.

The enterprises whose business is dedicated to more than one organism group generate a turnover amounting to EUR 8.1 million for microalgae and Spirulina enterprises, EUR 455 thousand for macro and microalgae enterprises and EUR 4 thousand for macroalgae and Spirulina companies (Figure 30).

The results disaggregated by country show that the enterprises with algae as the main business stream generate the largest turnover in France and Ireland, with EUR 75.9 million and EUR 40.4 million, respectively. Enterprises in Norway, Spain and Sweden follow with turnover values above EUR 10 million (Figure 31).

[39] Many enterprises target more than one species group. For those enterprises, a breakdown could not be provided so aggregate values of combinations of species are reported

Figure 31. Turnover generated by the algae (including macro, microalgae and Spirulina) enterprises by country in thousand euros. Please refer to section 2 for information on underpinning data availability.



Source: Own elaboration.

6.2 Employment

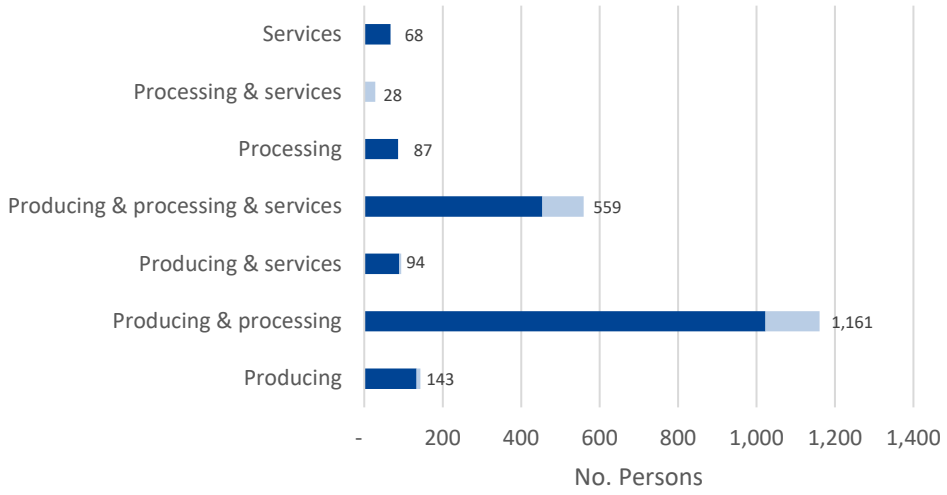
For the employment data, values of the number of employees in an enterprise coming from the surveys were prioritised as they are first-hand source of information. When data from surveys was not available, data collected from the Orbis database was used. Thus, the employment values indicated in the analysis correspond to the data of one year (i.e., not an average of several years), from the survey (preferably from the 2021 survey) or, otherwise, from the most recent year available in Orbis.

Twenty-two enterprises provided their employment data in the 2019 survey while forty-seven enterprises did so in 2021.

According to the data collected from the surveys and the Orbis database, the enterprises in the EU-27 with algae-related activities as the core business employ 1,852 people while in the other European countries mapped (CH, IS, NO, UK plus FO and GL), the employment generated amounts to 288 people. With regards to the employment data by step of the value chain, Figure 32 shows that the category of producing and processing algae biomass employs the majority of workers in the algae-dedicated enterprises in Europe, with 1,161 employees. Enterprises producing, processing biomass and providing algae-related services follow with over 559 people employed.

For the enterprises that are involved in several steps of the value chain, as it was not possible to break down the share of business for each step, the employment values are provided in an aggregated form (i.e., combinations of steps).

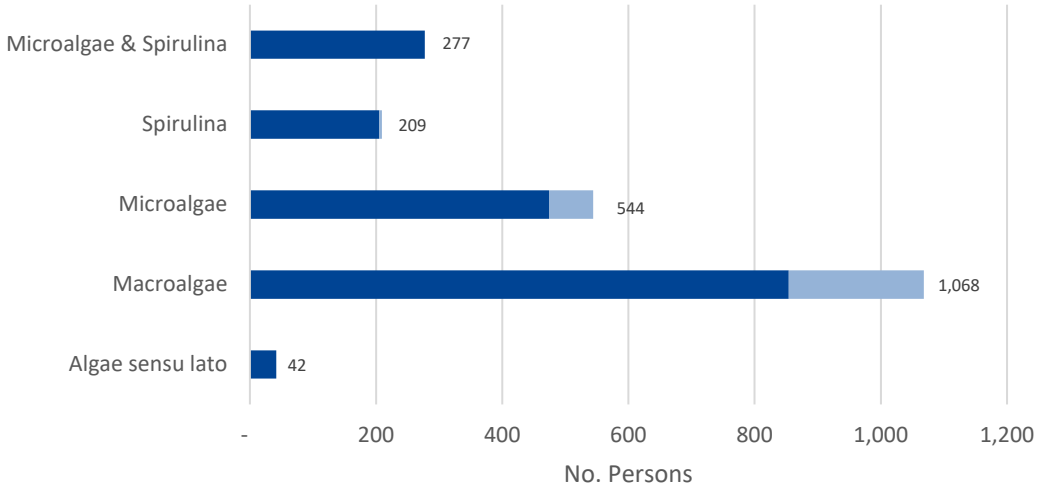
Figure 32. Number of employees by step of the value chain, considering all countries and organism groups. Please refer to section 2 for information on underpinning data availability.



Source: Own elaboration.

In the case of the employment data by organism group, considering all countries and steps of the value chain, enterprises dedicated solely to macroalgae employ the largest number of people in Europe, with almost 1,068 employees. Enterprises only dealing with microalgae follow in terms of people employed with 544 employees (Figure 33).

Figure 33. Available employment data per organism group. Please refer to section 2 for information on underpinning data availability.

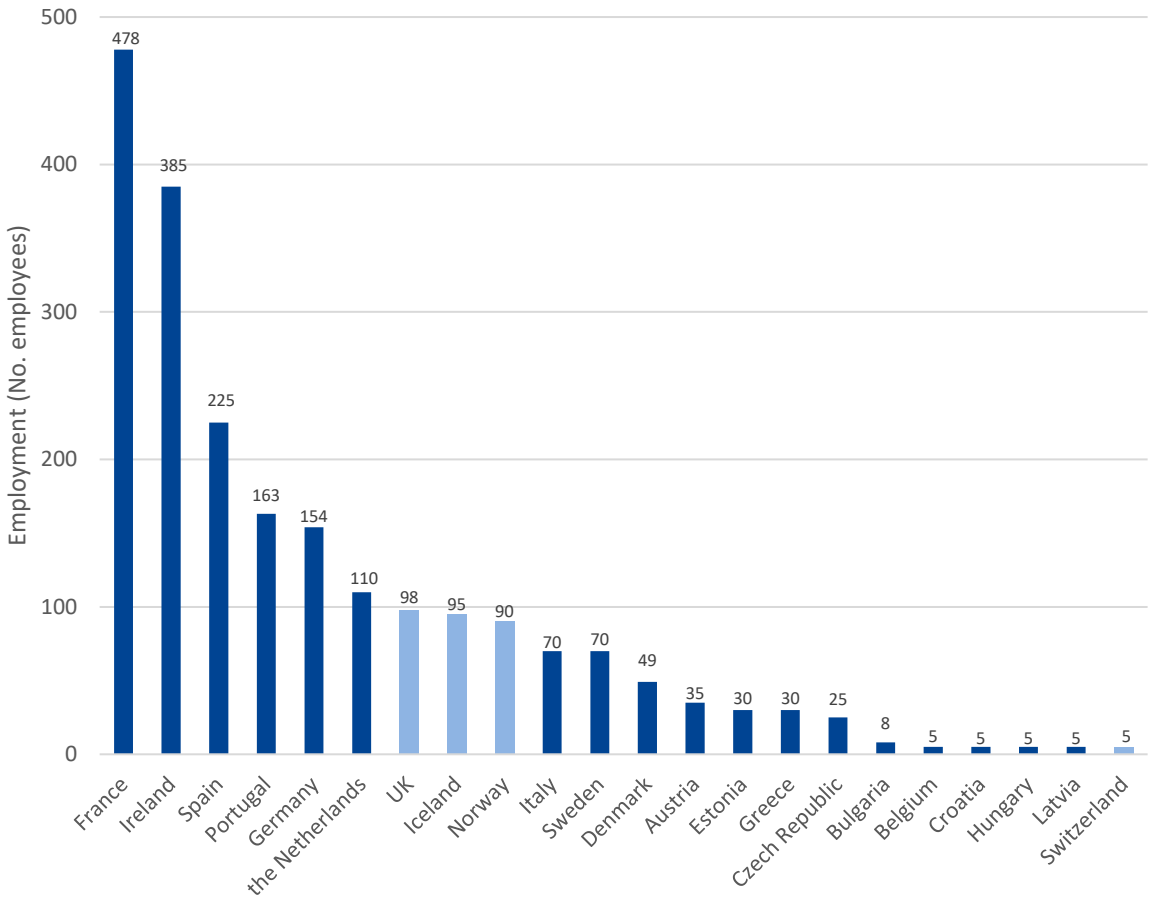


Source: Own elaboration.

Similarly to turnover values, the employment data available for enterprises that focus on more than one organism group could not be disaggregated. As Figure 33 shows, enterprises dedicated to both microalgae and Spirulina employ 277 people while the enterprises focused only on Spirulina employ 209 people.

The employment values disaggregated by country show that the enterprises with algae as the main business stream employ the largest number of people in France and Ireland with, 478 and 385 employees, respectively. Enterprises in Spain, Portugal Germany and the Netherlands employ more than 100 people in each of these countries (Figure 34).

Figure 34. Number of employees by country. Please refer to section 2 for information on underpinning data availability.

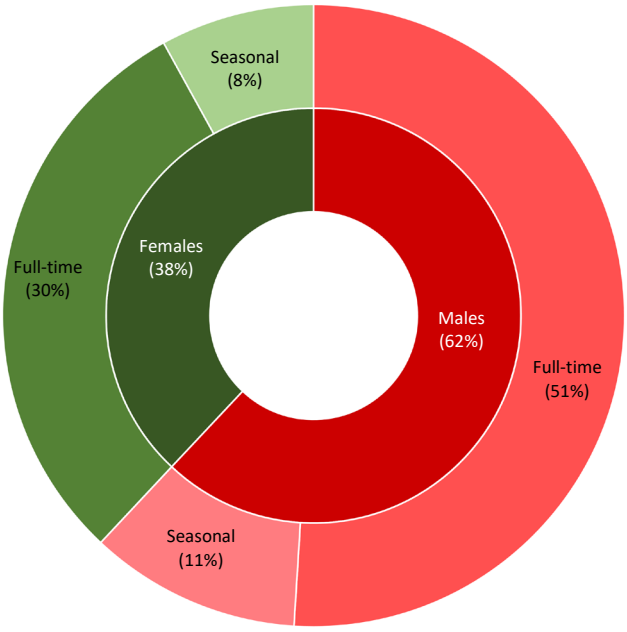


Source: Own elaboration.

6.3 Data on gender balance and age distribution

Information regarding gender balance, age distribution and temporary nature of contracts of the enterprises' employees was also collected through the surveys (see Annexes). Based on the data collected, full time jobs are predominant within the industry (81%), as Figure 35 shows. Male employees working in the algae sector in Europe are predominant (62%) over female (38%), for both full time and seasonal positions.

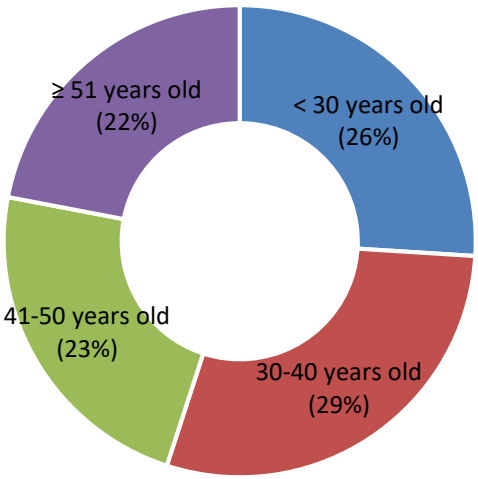
Figure 35. Share of gender by type of contract of the employees according to the replies to the 2021 survey.



Source: Own elaboration.

Regarding the age distribution of the employees in the sector, the following four age groups were considered: younger than 30 years old, between 30 and 40 years old, between 41 and 50 years old, and 51 years or older. According to the data collected, 55% of the people employed in the algae sector are younger than 41 years old and the distribution across these age groups is relatively balanced (Figure 36).

Figure 36. Share of employees by age group according to the replies to the 2021 survey.



Source: Own elaboration.

The results obtained from this data collection exercise regarding the employee profile in the algae sector are in line with those obtained by Nicheva et al., (2022) for the EU aquaculture sector, i.e., a typical employee in the EU aquaculture industry is male between 40 and 65 years old.

6.4 Other socio-economic data

In addition to the employment and turnover data from Orbis, other economic data were collected, when available, individually for each enterprise, for the time period from 2016 until 2020. These are:

P/L before tax (profit/loss)

P/L for period [=Net income]

Cash flow

Total assets

Fixed assets

Current assets

Costs of employees

Depreciation & Amortization

R&D expenses

Due to the low availability of that data and to the limitation to distinguish between the algae business streams from other business for the enterprises, the data were not further analysed in the present report.

7 Conclusions

Algae can play an important role in the production of sustainable food, feed, materials and energy, and therefore to the transition to a green, circular and carbon-neutral EU economy. Since 2017, the JRC has been collecting and analysing data on algae production and industry in Europe, as part of its work for the Commission's Knowledge Centre for Bioeconomy, in order to enhance the knowledge base for policymaking. Through this work, the JRC had compiled a comprehensive database on algae production systems, species produced, as well as on the location of the production units, disseminated through the Knowledge Centre for Bioeconomy[40] and the European Marine Observation and Data Network (EMODnet) Human Activities Portal[41]. The database also served as the basis for analysing the algae production industry in Europe[14].

Building upon this previous work, and based on new desk research, web-based surveys, direct exchanges with enterprises, consultations with stakeholders, and compilation and analysis of the Orbis database[42], the JRC algae database is updated with recent data on algae production, novel socio-economic data, in particular turnover and employment, and an extension to European enterprises that are part of the post-production steps of the algae value chain (processing of biomass and related services e.g., technology providers, R&D, consultancy, traders / exporters, etc.).

The updated JRC algae database includes 548 enterprises, based in 20 EU Member States (including Faroe Islands and Greenland) as well as in Iceland, Norway, Switzerland, and the UK. From those, 413 enterprises are active in the production of algae biomass whereas most of them are also active in the processing of algae biomass.

The JRC algae database also includes updated information on the location of algae production plants (macroalgae, microalgae and Spirulina), the production systems used, species produced and the uses of the biomass for each species group, as of April 2022. Furthermore, it integrates socio-economic data on turnover and employment for enterprises involved in different steps of the algae value chain. Due to the limited data available in official statistics and private business databases and directories and the relatively low response rate to the surveys conducted, and due to the lack of disaggregated data for enterprises having also non-algae business streams, that data may not be considered as precise estimates of the turnover or employment in the algae sector.

The data presented in this report can be accessed in a raw form[43] or explored further in a visual form[40], both available through the Knowledge Centre for Bioeconomy.

Despite the uncertainties and the scope for further data refinements the updated database fills some of the current knowledge gaps, allowing a more complete overview of the algae industry in Europe.

[40] https://knowledge4policy.ec.europa.eu/visualisation/bioeconomy-different-countries_en#algae_prod_plants
[41] https://www.emodnet-humanactivities.eu/view-data.php
[42] Orbis - Company information across the globe - BvD (https://orbis.bvdinfo.com/version-2021416/orbis/Companies/Login?returnUrl=%2Fversion-2021416%2Forbis%2FCompanies)
[43] https://data.jrc.ec.europa.eu/collection/id-00363

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List of abbreviations and definitions

DG RTD	Directorate General for Research and Innovation of the European Commission
EABA	European Algae Biomass Association
EC	European Commission
EEA	European Economic Area
EMODnet	European Marine Observation and Data Network
EU	European Union
EuroGeographics	Organization for Europe's National Mapping, Cadastral and Land Registration Authorities
FAO	Food and Agriculture Organization of the United Nations
FTE	Full Time Equivalent
IMTA	Integrated Multi-Trophic Aquaculture
JRC	Joint Research Centre of the European Commission
KCB	Knowledge Centre for Bioeconomy of the European Commission
MS	EU Member States
n/a	Not available/unknown
R&D	Research and Development
STECF	Scientific, Technical and Economic Committee for Fisheries of the European Commission
Turkstat	Turkish Statistical Institute
US	United States (of America)
UK	United Kingdom

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Annexes

Annex 1. Survey 1

Survey on the algae industry in Europe 2021

Fields marked with * are mandatory.

The data collected in this survey will be either publicly available (as specific information relative to the company), or used as underlying data for the JRC analysis. When publicly presented, the data used as underlying data for the analysis will be shown as aggregated results without any link to individual companies. Confidential data (e.g.production volumes) will be only presented in an aggregated form at the country level if data from more than 5 companies per country are available. Otherwise, the data considered as confidential will only be presented at EU level.

In case you have any update or change regarding the previous data provided please let us know. Some information (e.g. changes on company name, location of production site, species produced, production method, or biomass uses) will be publicly displayed on our visualization platforms (EMODnet, KCB country dashboards). Other information, (e.g. changes on jobs, gender balance, age structure and production volumes), will only be used as underlying data for the JRC analysis.

Each question in the survey contains a note specifying the kind of use of the information provided.

Lastly, we would like to inform you that it is not mandatory to answer the questions, except for the company name.
Thank you for your collaboration.

General Information

* Company name

To be publicly displayed on the visualization platforms.

Please indicate if you have any update or change regarding previous data provided (company name, location of production site, species produced, production method, biomass use). If the update or change is on jobs and related data, please see below:

To be publicly displayed on the visualization platforms.

Do you have any update or change on jobs (number, age structure and gender balance) in your company for 2021?

- Yes

- ○ No

New data

1 - Besides being algae biomass producers, does your company contribute to other steps of the algae value chain in Europe? If so, please specify from the list below:

This information will be publicly available.

- ☐ Algae biomass processors
- ☐ Technology providers
- ☐ Consultancy
- ☐ R + D (as a service)
- ☐ Traders/Exporters
- ☐ Other

2 - Can you indicate your company's approximate values of biomass production? (E.g. <1 tonne; 1-5 tonnes; 5-10 tonnes; 10-50 tonnes; >50tonnes). Please indicate if these values refer to wet or dry weight

Confidential data. To be presented in an aggregated form at the country level if data from more than 5 companies per country are available. Otherwise, it will only be presented at EU level.

3 - Does your company have end products in the market?

This information will be publicly available.

- ○ Yes
- ○ No

4 - Which are the main markets for your products?

Confidential data. To be presented in an aggregated form at the country level if data from more than 5 companies per country are available. Otherwise, it will only be presented at EU level.

- ☐ National
- ☐ EU
- ☐ Outside EU
- ☐ Equal share between some of the options above

Contact

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Annex 2. Survey 2

Survey on the algae industry in Europe 2021

Fields marked with * are mandatory.

The data collected in this survey will have two different uses, depending on the kind of information requested. Some information (e.g. company name, location of production site, species produced, production method, or biomass uses) will be publicly displayed as specific information relative to the company on our visualization platforms (EMODnet, KCB country dashboards). Other information (e.g. jobs, gender balance and age structure) will only be used as underlying data for the JRC analysis. When publicly presented this last mentioned kind of data will be shown as aggregated results without any link to individual companies. Confidential data (e.g.production volumes) will be only presented in an aggregated form at the country level if data from more than 5 companies per country are available. Otherwise, the data considered as confidential will only be presented at EU level.
Each question in the survey contains a note specifying the kind of use of the information provided.

Lastly, we would like to inform you that it is not mandatory to answer the questions, except for the company name and the address of the production site.

Thank you for your collaboration.

General Information

* Company name

To be displayed on the visualization platforms.

* Address of the production site

To be displayed in the visualization platforms.

Year when the company was established

To be used as underlying data for the JRC analysis. The results of this analysis will be always presented as aggregated information (without link to any individual company). We will use this specific information to show the temporal evolution of the algae production sector in Europe.

Jobs (number, age structure and gender balance)

1 - How many employees work currently in your company (2021)?

To be used as underlying data for the JRC analysis. The results of this analysis will be always presented as aggregated information (without link to any individual company).

- ○ 1 - 10
- ○ 11 - 20
- ○ 21 - 30
- ○ 31 - 50
- ○ More than 51

2 - Please indicate the gender and working time regime of your employees

To be used as underlying data for the JRC analysis. The results of this analysis will be always presented as aggregated information (without link to any individual company).

	Number of Females	Number of Males
Full-time		
Seasonal		

3 - Please indicate the age distribution of your employees

To be used as underlying data for the JRC analysis. The results of this analysis will be always presented as aggregated information (without link to any individual company).

	1- 10 employees	11 - 20 employees	21 - 30 employees	31 - 50 employees	More than 51 employees
Under 30 years old	○	○	○	○	○
30 - 40 years old	○	○	○	○	○
41 - 50 years old	○	○	○	○	○
More than 51 years old	○	○	○	○	○

Species produced, production method, and biomass commercial uses

1 - Which group/groups of organisms does your company produce?

To be displayed on the visualization platforms.

- ☐ Macroalgae
- ☐ Microalgae
- ☐ Spirulina

2 - Species produced

To be displayed on the visualization platforms.

3 - Which production method/methods does your company use?

To be displayed on the visualization platforms.

- [ ] Aquaculture
- [ ] Harvesting
- [ ] Photobioreactors
- [ ] Open ponds
- [ ] Semi open ponds
- [ ] Fermenters
- [ ] Pilot

4 - What are the commercial uses of the biomass produced by your company?

To be displayed on the visualization platforms.

- [ ] Human food
- [ ] Food supplements and nutraceuticals
- [ ] Animal feed
- [ ] Fertilizers
- [ ] Cosmetics
- [ ] Pharmaceuticals
- [ ] Bioremediation
- [ ] Hydrocolloid production
- [ ] Other

Additional data

1 - Besides being algae biomass producers, does your company contribute to other steps of the algae value chain in Europe? If so, please specify from the list below:

This information will be publicly available.

- [ ] Algae biomass processors
- [ ] Technology providers
- [ ] Consultancy
- [ ] R + D (as a service)
- [ ] Traders/Exporters
- [ ] Other

2 - Can you indicate your company's approximate values of biomass production? (E.g. <1 tonne; 1-5 tonnes; 5-10 tonnes; 10-50 tonnes; >50tonnes). Please indicate if these values refer to wet or dry weight

Confidential data. To be presented in an aggregated form at the country level if data from more than 5 companies per country are available. Otherwise, it will only be presented at EU level.

3 - Does your company have end products in the market?

This information will be publicly available.

- ( ) Yes
- ( ) No

4 - Which are the main markets for your company's products?

Confidential data. To be presented in an aggregated form at the country level if data from more than 5 companies per country are available. Otherwise, it will only be presented at EU level.

- ☐ National
- ☐ EU
- ☐ Outside EU
- ☐ Equal share between some of the options above

Contact

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Annex 3. Survey 3

Survey on the Spirulina industry in Europe 2021

Fields marked with * are mandatory.

The data collected in this survey will have two different uses, depending on the kind of information requested. Some information (e.g. company name, location of production site, species produced, production method, or biomass uses) will be publicly displayed as specific information relative to the company on our visualization platforms (EMODnet, KCB country dashboards). Other information (e.g. jobs, gender balance and age structure) will only be used as underlying data for the JRC analysis. When publicly presented this last mentioned kind of data will be shown as aggregated results without any link to individual companies. Confidential data (e.g.production volumes) will be only presented in an aggregated form at the country level if data from more than 5 companies per country are available. Otherwise, the data considered as confidential will only be presented at EU level.
Each question in the survey contains a note specifying the kind of use of the information provided.

Lastly, we would like to inform you that it is not mandatory to answer the questions, except for the company name and the address of the production site.

Thank you for your collaboration.

General Information

* Company name

To be displayed on the visualization platforms.

* Address of the production site

To be displayed on the visualization platforms.

Year when the company was established

To be used as underlying data for the JRC analysis. The results of this analysis will be always presented as aggregated information (without link to any individual company). We will use this specific information to show the temporal evolution of the algae production sector in Europe.

Jobs (number, age structure and gender balance)

1 - How many employees work currently in your company (2021)?

To be used as underlying data for the JRC analysis. The results of this analysis will be always presented as aggregated information (without link to any individual company).

- ○ 1 - 10
- ○ 11 - 20
- ○ 21 - 30
- ○ 31 - 50
- ○ More than 51

2 - Please indicate the gender and working time regime of your employees

To be used as underlying data for the JRC analysis. The results of this analysis will be always presented as aggregated information (without link to any individual company).

	Number of Females	Number of Males
Full-time		
Seasonal		

3 - Please indicate the age distribution of your employees

To be used as underlying data for the JRC analysis. The results of this analysis will be always presented as aggregated information (without link to any individual company).

	1- 10 employees	11 - 20 employees	21 - 30 employees	31 - 50 employees	More than 51 employees
Under 30 years old	○	○	○	○	○
30 - 40 years old	○	○	○	○	○
41 - 50 years old	○	○	○	○	○
More than 51 years old	○	○	○	○	○

Species produced, production method, and biomass commercial uses

1 - Which species does your company produce?

To be displayed on the visualization platforms.

- ☐ *Arthrospira platensis*
- ☐ *Arthrospira maxima*
- ☐ Other

2 - Which production method/methods does your company use?

To be displayed on the visualization platforms.

- ☐ Photobioreactors
- ☐ Open ponds
- ☐ Pilot

- [ ] Other

3 - What are the commercial uses of the biomass produced by your company?

To be displayed on the visualization platforms.

- [ ] Human food
- [ ] Food Supplements and nutraceuticals
- [ ] Animal feed
- [ ] Fertilizers
- [ ] Cosmetics
- [ ] Pharmaceuticals
- [ ] Bioremediation
- [ ] Hydrocolloid production
- [ ] Other

Additional data

1 - Besides being Spirulina biomass producers, does your company contribute to other steps of the Spirulina value chain in Europe? If so, please specify from the list below:

This information will be publicly available.

- [ ] Spirulina biomass processors
- [ ] Technology providers
- [ ] Consultancy
- [ ] R + D (as a service)
- [ ] Traders/Exporters
- [ ] Other

2 - Can you indicate your company's approximate values of biomass production? (E.g. <1 tonne; 1-5 tonnes; 5-10 tonnes; 10-50 tonnes; >50tonnes). Please indicate if these values refer to wet or dry weight

Confidential data. To be presented in an aggregated form at the country level if data from more than 5 companies per country are available. Otherwise, it will only be presented at EU level.

3 - Does your company have end products in the market?

This information will be publicly available.

- ( ) Yes
- ( ) No

4 - Which are the main markets for your company's products?

Confidential data. To be presented in an aggregated form at the country level if data from more than 5 companies per country are available. Otherwise, it will only be presented at EU level.

- [ ] National
- [ ] EU
- [ ] Outside EU
- [ ] Equal share between some of the options above

Contact

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Annex 4. Survey 4

Survey on the algae industry in Europe 2021

Fields marked with * are mandatory.

The data collected in this survey will have two different uses, depending on the kind of information requested. Some information (e.g. company name, location of production site, species produced, production method, or biomass uses) will be publicly displayed as specific information relative to the company on our visualization platforms (EMODnet, KCB country dashboards). Other information (e.g. jobs, gender balance and age structure) will only be used as underlying data for the JRC analysis. When publicly presented this last mentioned kind of data will be shown as aggregated results without any link to individual companies. Confidential data (e.g.production volumes) will be only presented in an aggregated form at the country level if data from more than 5 companies per country are available. Otherwise, the data considered as confidential will only be presented at EU level.
Each question in the survey contains a note specifying the kind of use of the information provided.

Lastly, we would like to inform you that it is not mandatory to answer the questions, except for the company name and the question to confirm whether your company is part of the algae value chain in Europe or not. In case of affirmative answer, then the address of the company is also requested as mandatory.

Thank you for your collaboration.

General Information

* Company name

To be displayed on the visualization platforms.

* Is your company part of the algae value chain in Europe?

- ( ) Yes
- ( ) No

Year when the company was established

To be used as underlying data for the JRC analysis. The results of this analysis will be always presented as aggregated information (without link to any individual company). We will use this specific information to show the temporal evolution of the algae production sector in Europe.

Jobs (number, age structure and gender balance)

1 - How many employees work currently in your company (2021)?

To be used as underlying data for the JRC analysis. The results of this analysis will be always presented as aggregated information (without link to any individual company).

- ○ 1 - 10
- ○ 11 - 20
- ○ 21 - 30
- ○ 31 - 50
- ○ More than 51

2 - Please indicate the gender and working time regime of your employees

To be used as underlying data for the JRC analysis. The results of this analysis will be always presented as aggregated information (without link to any individual company).

	Number of Females	Number of Males
Full-time		
Seasonal		

3 - Please indicate the age distribution of your employees

To be used as underlying data for the JRC analysis. The results of this analysis will be always presented as aggregated information (without link to any individual company).

	1- 10 employees	11 - 20 employees	21 - 30 employees	31 - 50 employees	More than 51 employees
Under 30 years old	○	○	○	○	○
30 - 40 years old	○	○	○	○	○
41 - 50 years old	○	○	○	○	○
More than 51 years old	○	○	○	○	○

Additional data

1 - Which step/steps of the algae value chain in Europe does your company contribute to?

This information will be publicly available.

- ☐ Algae biomass producers
- ☐ Algae biomass processors
- ☐ Technology providers
- ☐ Consultancy
- ☐ R + D (as a service)
- ☐ Traders/Exporters
- ☐ Other

2 - Which group of organisms are your company's services/products focused on?

This information will be publicly available.

- [ ] Macroalgae
- [ ] Microalgae
- [ ] Spirulina
- [ ] Algae sensu lato

3 - Which percentage of your company's business focus on algae?

Confidential data. To be presented in an aggregated form at the country level if data from more than 5 companies per country are available. Otherwise, it will only be presented at EU level.

- ( ) Less than 25%
- ( ) 25% - 50%
- ( ) 50% - 75%
- ( ) More than 75%
- ( ) 100%

4 - Which are the main markets for your company's services/products?

Confidential data. To be presented in an aggregated form at the country level if data from more than 5 companies per country are available. Otherwise, it will only be presented at EU level.

- [ ] National
- [ ] EU
- [ ] Outside EU
- [ ] Equal share between some of the options above

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