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BLUE BIOECONOMY – TOWARDS A STRONG AND SUSTAINABLE EU ALGAE SECTOR

Accompanying the document

COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS

Towards a Strong and Sustainable EU Algae Sector

{COM(2022) 592 final}

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Glossary

Term or acronym	*Meaning or definition*
ABO	Algae Biomass Organization
B2B	Business-to-business
B2C	Business-to-consumer
BBF	Blue Bioeconomy Forum
CEN	European Committee for Standardization
CFP	Common Fisheries Policy
CMO	Common Market Organisation
COP26	UN Climate Change Conference (Conference of the Parties, COP)
EABA	European Algae Biomass Association
EC	European Commission
EFSA	European Food Safety Authority
EGD	European Green Deal
EMFAF	European Maritime Fisheries and Aquaculture Fund
EMFF	European Maritime and Fisheries Fund
ESIF	European Structural and Investment Funds
FAD	Fish Aggregating Devices
HRAP	High Rate Algal Pond
IMTA	Integrated multi-trophic aquaculture
LCA	Life-cycle assessment
MS	Member States
MSP	Maritime spatial planning
PBR	PhotoBioReactors
OPC	Open Public Consultation
SME	Small and Medium-sized Enterprises
YOY	Year-on-year

1. Introduction: The Potential of Algae in Europe

1.1. Scope

This document provides supporting information to the development of the European Commission Communication "Blue Bioeconomy[1] - Towards a Strong and Sustainable[2] EU Algae Sector[3]" (hereafter: "EU Algae Initiative"). The EU Algae Initiative will aim to unlock the algae potential in Europe by increasing sustainable production, ensuring safe consumption and boosting innovative use of algae and algae-based products. This will help to achieve the objectives of the European Green Deal, the transition to a green, circular self-sufficient and carbon neutral EU, post Covid-19 recovery and mitigation of economic crisis resulted by Russia's military aggression against Ukraine. In this vain, this Staff Working Document aims to: **Identify valid, well-founded and realistic policy solutions** and **actions** based on best available science, information, good practices and views provided by the relevant algae sector representatives during the stakeholder consultation process.

This staff working document takes due account of previous analyses, recommendations, studies and guidelines of the Blue Bioeconomy and algae sector[4].

1.2.What are algae?

Algae is a common name for a group of taxonomically unrelated organisms sharing a number of traits. Algae include cyanobacteria, eukaryotic microalgae and seaweeds (or macroalgae). Common traits are: oxygenic photosynthesis (use of visible light to fix CO2 with oxygen release), chlorophylls as main photosynthetic pigment, lack of differentiated tissues, primary producers in aquatic ecosystems. There are exceptions because some algae can grow in the dark using simple organic compounds and some algae do not possess photosynthetic organelles so are unable to perform photosynthesis[5].

[1] The "blue bioeconomy", includes any economic activity associated with the use of renewable aquatic biological resources to make products. Examples of such products include novel foods and food additives, habis, nutraceuticals, pharmaceuticals, cosmetics, materials (e.g. clothes and construction materials) and energy. Businesses that grow the raw materials for these products, that extract, refine, process and transform the biological compounds, as well as those developing the required technologies and equipment all form part of the blue bioeconomy. European Commission., 2020. Directorate-General for Maritime Affairs and Fisheries, Blue bio-economy: situation report and perspectives, Publications Office. Available at: https://data.europa.eu/doi/10.2771/053734

[2] If done right, algae cultivation goes beyond the notion of sustainability – it is regenerative by nature, where "regeneration" is the ability of an ecosystem – specifically, the environment and its living population – to renew and recover from damage. Regeneration refers to ecosystems replenishing what is being eaten, disturbed, or harvested. Regeneration's biggest force is photosynthesis which transforms sun energy and nutrients into plant biomass.

[3] The most notable sub-sector in Blue Bioeconomy is the algae sector (Blue economy report 2022)

[4] Provided in (non-exhaustive list) the: the Blue Bioeconomy Forum Roadmap, Pegasus-Phycomorph Seaweed Aquaculture Guidelines, Blue economy reports 2018-2022, Blue bioeconomy reports 2018 and 2020 , in Seaweed for Europe's report, SUBMARINER Roadmap beyond 2021 (includes macroalgae, marine biotechnology, and sea multi-use recommendations and national and trans-national Baltic Sea Region projects e.g. Macro-cascade, GRASS, Alliance, ERA-NET Marine Biotehnology etc.), The Seaweed Manifesto, Lloyd's Register Foundation (2020), AAC Recommendation Seaweed, EnAlgae – several guiding documents and infosheets about algae; Protecting seagrass through payments for ecosystem services; Seaweed aquaculture cultivation challenges ecosystem services; Seaweed Cultivation in Scotland: A Guide; Practical Guidances for the Sustainable Ocean Principles, UN Global Compact; Policy brief Future of seaweed aquaculture industry; Brief on algae biomass production, ASC seaweed standard; Impact assessment study to support the development of EU Algae Initiative; the current Status of the Algae Production Industry in Europe: An Emerging Sector of the Blue Bioeconomy

[5] European standard EN 17399:2020 defines algae as a functional group of organisms consisting of microalgae, macroalgae, cyanobacteria and Labyrinthulomycetes.

Although there is a vast range of algae species – with estimates suggesting 72,500 species[6] – global production focuses on five genera accounted for more than 95% of world seaweed cultivation production[7], including the well-known Japanese kelp, nori and wakame[8,9]. In Europe, the main species farmed and already sold on the European market are Saccharina latissima, Alaria esculenta and Ulva sp. On a smaller scale and for niche markets, there are also: Porphyra spp., Palmaria palmata, Codium tomentosum, Gracilaria gracilis and Laminaria digitata[10], while for microalgae the species produced by most enterprises are *Chlorella* sp. and *Nannochloropsis* sp.

The coastal EU waters are colonized by a strong diversity of wild populations of algae with a total of **1550 different seaweed species**[11], of which only 23 are currently included as food or food supplements in the EU Novel Food catalogue[12].

Additionally, algae are key organisms in coastal ecosystems that provide habitat, food, reproductive areas and shelter to species from different levels of the food web[13]. In fact, about 50% of the photosynthesis on Earth occurs in seaweeds and microscopic algae floating in the oceans[14] absorbing a range of excess inorganic nutrients from the ocean, including nitrogen and phosphorus[15], as well as other compounds such as CO_2[16]. Research is currently conducted on the carbon storage potential of algae, leading some to speak of a forthcoming "Seaweed Revolution"[17], although carbon storage needs to be further explored[18].

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[6] How Many Species of Algae are There? Guiry, M., 2012. Journal of Phycology, 48(5), pp.1057-1063.

[7] Laminaria/Saccharina (35.4 percent); Kappaphycus/Eucheuma (33.5 percent); Gracilaria (10.5 percent); Porphyra/Pyropia (8.6 percent); and Undaria (7.4 percent), FAO, 2019 data

[8] The Global Status of Seaweed Production, Trade and Utilization. - FAO, 2018. Volume 124. GLOBEFISH Food and Agriculture Organization of the United Nations.

[9] Seaweeds and microalgae: an overview for unlocking their potential in global aquaculture development. FAO, 2021

[10] Michèle Barbier, Bénédicte Charrier, Rita Araujo, Susan L. Holdt, Bertrand Jacquemin & Céline Rebours (2019) PEGASUS - PHYCOMORPH European Guidelines for a Sustainable Aquaculture of Seaweeds, COST Action FA1406 (M. Barbier and B. Charrier, Eds), Roscoff, France. https://doi.org/10.21411/2c3w-yc73

[11] European seaweeds under pressure: Consequences for communities and ecosystem functioning. Mineur, F., Arenas, F., Assis, J., Davies, A., Engelen, A., Fernandes, F., Malta, E., Thibaut, T., Van Nguyen, T., Vaz-Pinto, F., Vranken, S., Serrão, E. and De Clerck, O., 2015. Journal of Sea Research, 98, pp.91-108.

[12] Algae as food and food supplements in Europe Araujo, R., Peteiro, C., 2021., EUR 30779 EN, Publications Office of the European Union, Luxembourg.

[13] Potential effects of kelp species on local fisheries. Bertocci, I., Araújo, R., Oliveira, P. and Sousa-Pinto, I., 2015. Journal of Applied Ecology, 52(5), pp.1216-1226.

[14] The majority of this production is from oceanic plankton - drifting plants, algae, and some bacteria that can photosynthesize. One particular species, Prochlorococcus, is the smallest photosynthetic organism on Earth. But this little bacteria produces up to 20% of the oxygen in our entire biosphere. That's a higher percentage than all of the tropical rainforests on land combined (NOAA, 2022) Available at: https://oceanservice.noaa.gov

[15] Seaweed Aquaculture for food Security, Income Generation and Environmental Health in Tropical Developing Countries World Bank Group, 2016; Development and objectives of the PHYCOMORPH European Guidelines for the Sustainable Aquaculture of Seaweeds Barbier, M., Charrier, B., Araujo, R., Holdt, S., Jacquemin, B. and Rebours, C., 2022. Phycomorph European Guidelines for a Sustainable Aquaculture of Seaweeds.

[16] Sequestration of macroalgal carbon: the elephant in the Blue Carbon room. Krause-Jensen, D., Lavery, P., Marba, N., Masque, P. and Duarte, C., 2018. Biology Letters, 14 ; Important contribution of macroalgae to oceanic carbon sequestration. Ortega, A., Geraldi, N.R., Alam, I. et al., 2019. Nat. Geosci. 12**,** 748–754.

[17] Lloyd's Register Foundation. (2020). Seaweed Revolution: A Manifesto for a sustainable future (V. Doumeizel, ed.)

[18] A seaweed aquaculture imperative to meet global sustainability targets Duarte, C.M., Bruhn, A. & Krause-Jensen, D. 2021. Nat Sustain.; Testing the climate intervention potential of ocean afforestation using the Great Atlantic Sargassum Belt.. Bach, L.T., Tamsitt, V., Gower, J. et al., 2021. Nat Commun 12**,** 2556.

1.3.Algae sector – the most notable EU Blue Bioeconomy sector

While in Eastern Asia algae have been an integral part of human diets for centuries, in Europe they are mainly considered as niche[19] or novel food product. Low in fat and rich in dietary fibres, micronutrients and bioactive compounds[20], algae are often portrayed as **healthy and low-calorie food**, with some species known for having particularly high protein content[21]. The biochemical compounds and properties make algae a valuable ocean material, paving the way for a growing number of potential commercial applications also outside the food industry: **animal/fish feed and feed additives, medical devices, pharmaceuticals, nutraceuticals, fertilisers, plant biostimulants, bio-packaging, cosmetics or biofuels**[22] (see Figure Nr.1)[23].

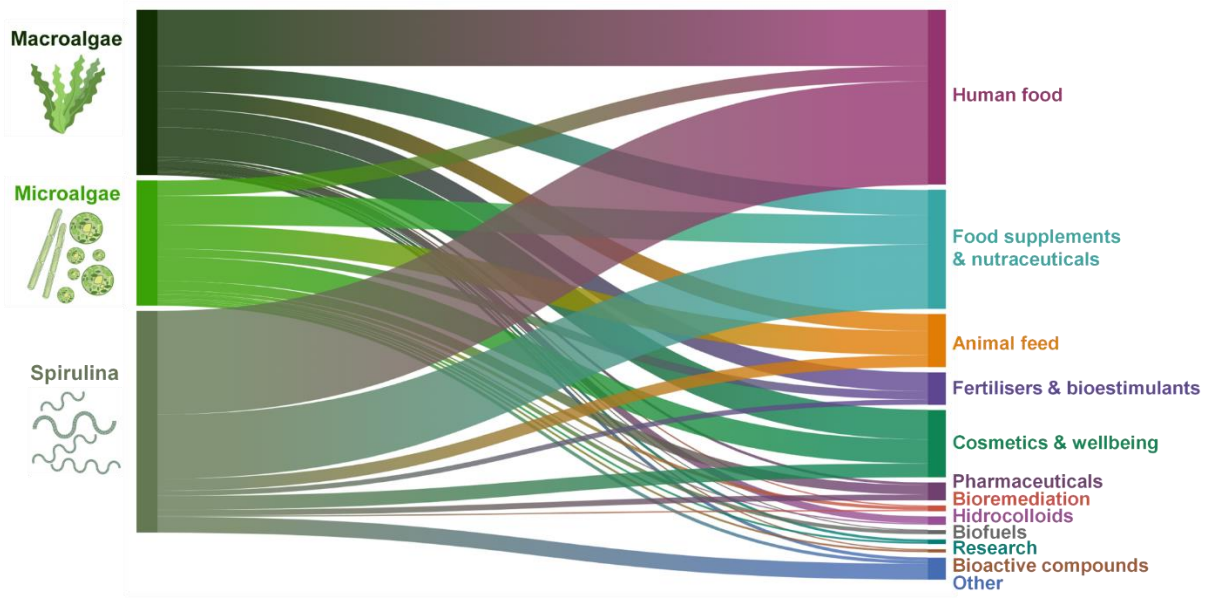

Figure 1. Potential commercial applications of algae in Europe[24]

Beyond these examples, algae biomass has many more **innovative applications** that are being developed or scaled, including textile fibres, laundry detergents, construction materials, biochar for soil

[19] A good or service with features that appeal to a particular market subgroup. A typical niche product will be easily distinguished from other products, and it will also be produced and sold for specialized uses within its corresponding niche market. Niche products are more expensive than non-niche products. Examples of niche products are organic food, expensive, high quality coffee etc.

[20] Bioactive Compounds in Seaweed: Functional Food Applications and Legislation. Holdt, S.L. and Kraan, S. (2011). Journal of Applied Phycology, 23, 543-597.

[21] *Palmaria palmata* (also known as dulse), and *Porphyra tenera* (Holdt and Kraan, 2011).

[22] 61% of seaweed production companies in Europe direct their biomass production to food uses (36% as human food, 15% for food-related uses like supplements and nutraceuticals and 10% for feed). The 39% remaining are dedicated to cosmetics and well-being products (17%) and all other applications such as fertilizers and biostimulants (11%). For microalgae producing companies, these shares are similar: 56% or food uses and 44% non-food (with a higher relative importance of pharmaceuticals). Source: An overview of the algae industry in Europe. Producers, production systems, species, biomass uses, other steps in the value chain and socio-economic data, Vazquez Calderon, F., Sanchez Lopez, J.Guillen, J., Avraamides, M. editors, Publications Office of the European Union, Luxembourg, 2022, ISBN 978-92-76-54516

[23] Comparative proteomics reveals proteins impacted by nitrogen deprivation in wild. Garnier M, Carrier G, Rogniaux H, et al., 2014.; Sustainable Seaweed Aquaculture Full Recommendations. Barbier, Michele, et al., 2019.

[24] An overview of the algae industry in Europe. Producers, production systems, species, biomass uses, other steps in the value chain and socio-economic data, Vazquez Calderon, F., Sanchez Lopez, J.Guillen, J., Avraamides, M. editors, Publications Office of the European Union, Luxembourg, 2022, ISBN 978-92-76-54516

improvement and carbon dioxide removal[25] or methanation that converts the biomass into biogas. On the other hand, leakage of agricultural nutrients into the aquatic ecosystems can cause periodic blue-green algae blooms with negative consequences on coastal ecosystems (through oxygen depletion and the creation of anaerobic conditions) and that also cause concerns for human health. This latter example demonstrates that by removing nutrients (causing eutrophication) from coastal marine waters we can bring waters them back into productive value chains thus turning coastal marine pollution into business opportunities.

European Algae Biomass Association (EABA) estimates a turnover in algae products in EEA countries of more than €350 million in 2018 (including transformation), by considering both companies and jobs. This estimate reaches more than €400 million[26] when including equipment companies and R&D companies. In algae turnover data estimates, care should be taken by considering bulk biomass and transformed products, as algae product value (after transformation) greatly exceeds the value of bulk biomass (see figure Nr.2).

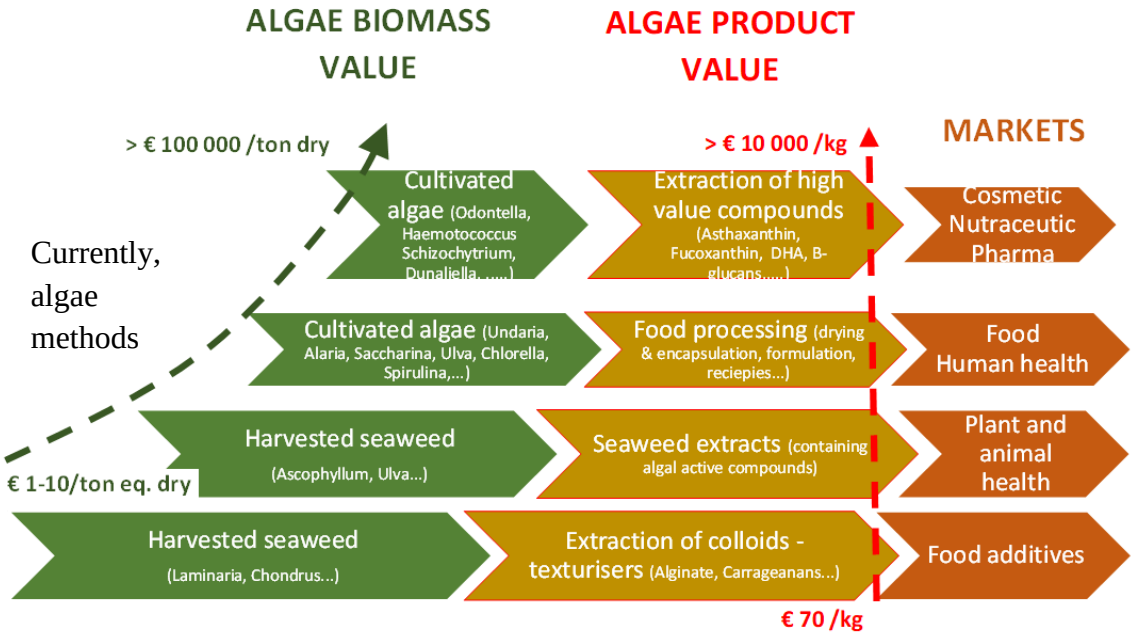

Figure 2. Current EU algae value chains[27]

Currently, the main algae production methods in the EU are laid down in figure Nr. 3 below. Main algae production volumes (according to the available data) in Europe and globally are provided in the Table 1 below.

[25] Biochar from commercially cultivated seaweed for soil amelioration. Roberts, D., Paul, N., Dworjanyn, S., Bird, M. and de Nys, R., 2015. Scientific Reports, 5(1) ; A Review on Application of Seaweed in Construction Industry. International Journal of Emerging Technology and Advanced Engineering. Praveena, R. and Muthadli, A., 2016., [online] 6(9) ;Focus on Fibres: Sustainable Seaweed Fabric... Seacell Ross, 2017. [Blog] The Sustainable Fashion Collective ; Seaweed Bacteria Could be the Answer to Environmentally Friendly Laundry Days. Gatten, E., 2020. The Telegraph, [online].

[26] JRC estimates show a turnover of EUR 328 million (including processing) plus EUR 1 trillion of services (including technology providers, R&D, consultancy and trader/exporters. This values include macro, micro and spirulina. The estimates also show around 2 000 people employed in the production and processing of macro, micro and spirulina plus 3 900 people in service enterprises.

[27] Source: EABA

Figure 3. Main algae production methods in Europe

France is the largest farmed seaweed producer in the EU, and only reported a production volume of 500 tonnes in 2016[28]. Seaweed farming of most species (*Laminaria*, *Alaria*, *Undaria*, *Saccharina etc*) requires the mastering of the reproductive life cycle (seeding, growing and harvesting), although some other species (*Ulva*, *Porphyra*, etc.) can also grow and multiply by themselves (undergo vegetative reproduction). Seaweed is mainly farmed out at sea but can also be produced in open ponds with direct access to sea water. Microalgae on the other hand are produced on-land in open or closed systems. In open systems, usually in Open Raceway Ponds (ORP) stirred by a paddle wheel, the growth medium is in direct contact with the atmosphere. Closed systems are usually designed as Photobioreactors (PBR) - horizontally or vertically arranged tubes or panels with high volumetric productivity and controlled conditions - or as fermenters – to benefit from the ability of microalgae to grow in the dark on sugars (heterotrophic production) - both with access to seawater for marine species or freshwater for freshwater species[29]. As of April 2022, **a total of 187 algae and 212 *Spirulina*[30] production plants (at sea and on-land) have been identified throughout the EU**[31,24]. Among those algae plants, 57% produce macroalgae and 43% microalgae (by number of production plants, not the production volumes). The largest number of companies are based in France, followed by Spain, Italy, Germany and Ireland. In other European countries (namely Faroe Islands, Greenland, Switzerland and the UK), there are 57 production plants (47 macroalgae, 8 microalgae and 2 Spirulina) have been mapped (Figure 4).

[28] Towards sustainable European seaweed value chains: a triple P perspective, S W K van den Burg, H Dagevos, R J K Helmes, *ICES Journal of Marine Science*, Volume 78, Issue 1, January-February 2021, Pages 443–450.
[29] Brief on algae biomass production, Araujo, R., Lusser, M., Sanchez Lopez, J. and Avraamides, M. editor(s), Publications Office of the European Union, Luxembourg, 2019.
[30] *Spirulina* is the most commonly produced cyanobacteria globally and whether dried or prepared as a food or food additive, is a rich source of many vitamins and minerals
[31] JRC algae database. Joint Research Centre and Bioeconomy Country dashboard – EC's Knowledge Centre for Bioeconomy

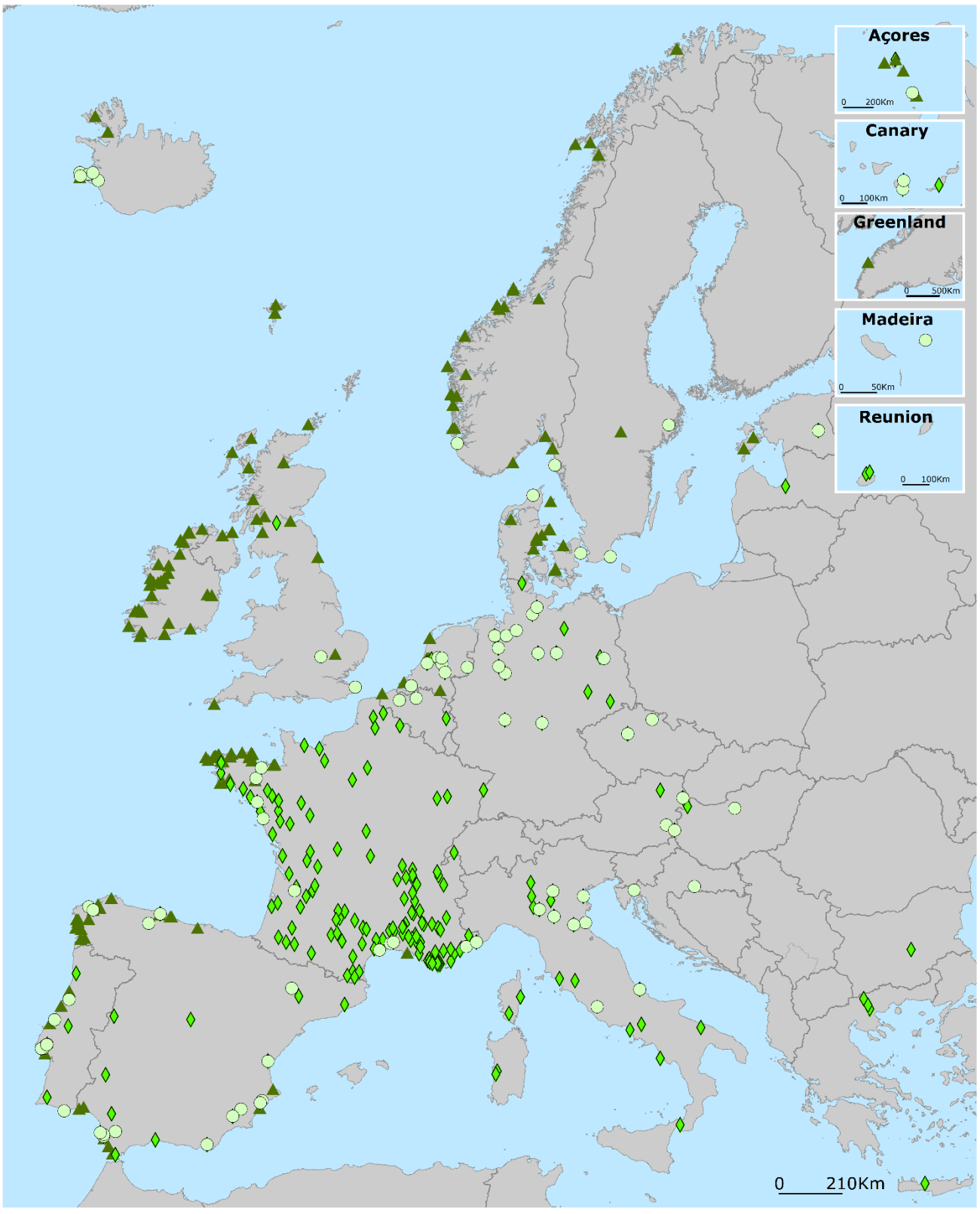

Figure 4. Macroalgae, microalgae and Spirulina production plants in Europe (April 2022).[28]

Table Nr.1. Algae production volumes in Europe and globally

Algae[6] type	**Production methods**	**European volumes (2020)**	**Global volumes**
Seaweed (or macroalgae)	Wild harvesting (boat and handpicked)	300 000 tonnes wet weight per annum (or 37 000 tonnes eq. of dry weight per annum)	1.09 million tonnes of wet weight in 2015[32]
	Seaweed farming at sea (long lines)	~ 600 tonnes of wet weight per annum (or ~45 tonnes eq. dry weight per annum)	35.76 million tonnes of wet weight in 2019[9]
	Seaweed farming on-land[33]		
Microalgae	In open raceway ponds or photobioreactors	~ 100 tonnes of dry weight per annum	56 456 tonnes of wet weight in 2021[34]
Cyanobacteria	In open raceway ponds or photobioreactors	~120 tonnes of dry weight per annum	
Labyrinthulomycetes	In open raceway ponds or photobioreactors	No data	

Looking forward, algae are a promising ocean resource, largely untapped in Europe that offers an **enormous potential** for a variety of food and non-food uses. These have the potential to contribute to mitigate the impact of global challenges such as climate change, environmental degradation, biodiversity loss, and unsustainable food production while creating new business opportunities for Europe. Figure Nr.4. outlines how the EU Algae Initiative can contribute to achieving the objectives of the European Green Deal. The production of algae mitigates climate change by, for example, mitigating CO_2, absorbing phosphorous and nitrogen[14]. Food applications of algae products can contribute to the Farm to Fork Strategy[35] and more sustainable and innovative food systems. Additionally, non-food applications of algae, such as for the production of biofuels[36] can help achieve sustainable energy objectives.

Nevertheless, to unlock algae potential in the EU a cross-cutting and realistic strategy needs to be put in place to address current problems from scaling up the production, reducing costs, developing innovative technologies until improving knowledge about potential risks to the environment or human health and impacts from algae products and production processes (see heading 2 below) by achieving objectives (heading 4), proposed policy solutions, and corresponding actions points (heading 5 below).

[32] The Global Status of Seaweed Production, Trade and Utilization. FAO, 2018. Globefish Research Programme. Volume 124.
[33] In open raceway ponds or photobioreactors
[34] Seaweeds and microalgae: an overview for unlocking their potential in global aquaculture development. Cai, J., Lovatelli, A., Aguilar-Manjarrez, J., Cornish, L., Dabbadie, L., Desrochers, A., Diffey, S., Garrido Gamarro, E., Geehan, J., Hurtado, A., Lucente, D., Mair, G., Miao, W., Potin, P., Przybyla, C., Reantaso, M., Roubach, R., Tauati, M. & Yuan, X. 2021. FAO Fisheries and Aquaculture Circular No. 1229. Rome, FAO.
[35] COM(2019) 640 final, 11.12.2019
[36] Are algae ready to take off? GHG emission savings of algae-to-kerosone production, Prussi M., Weindorf W., Buffi M., Sánchez López J., Scarlat N. 2021. Applied Energy

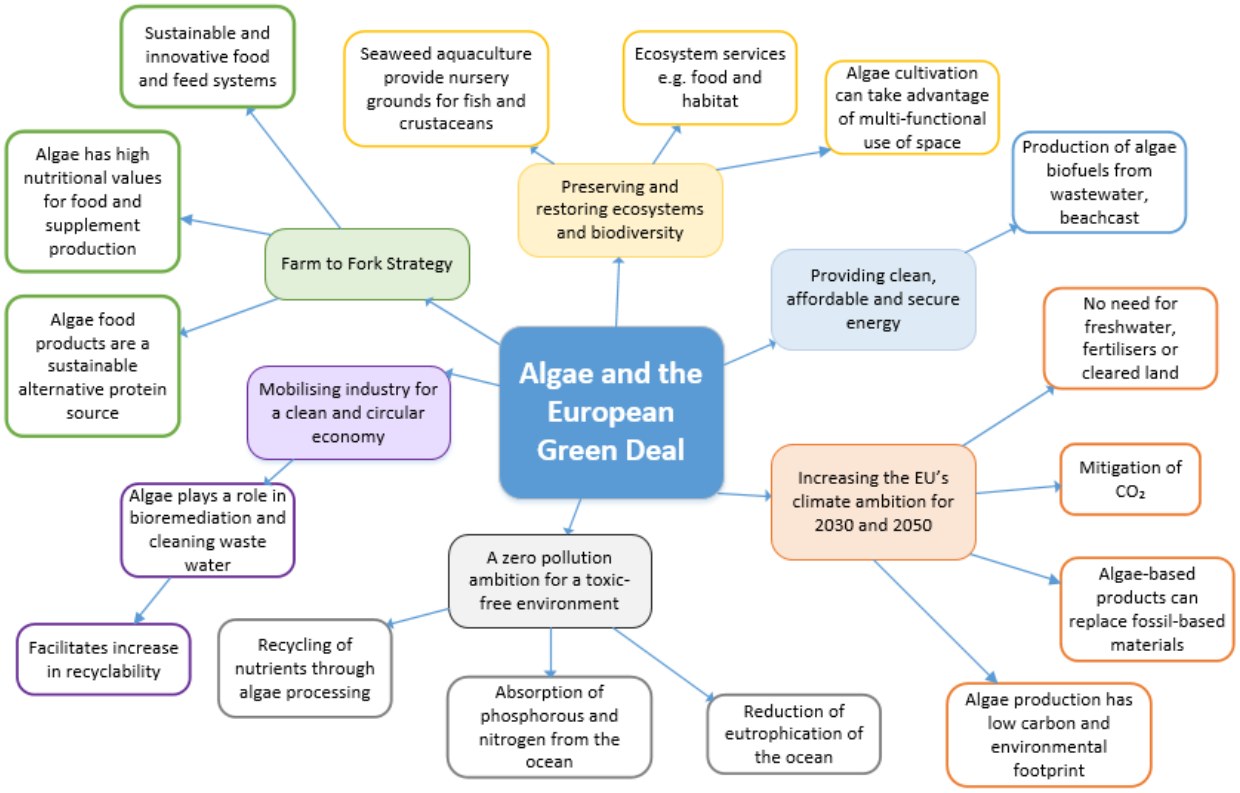

Figure 4. Algae in the European Green deal

Why algae are an untapped resource in the EU?

While today's EU algae sector remains small, the conditions are favourable to grow it into an innovative sector within the EU Blue Bioeconomy. Figure Nr. 5 provides an overview of the EU demand for algae and algae-based products. As the EU is a top global importer of seaweed products in terms of value (€554 million in 2016)[37], there is clearly a strong demand for seaweed in the EU which is only set to increase in line with health and sustainability trends[9]. Seaweed for Europe estimates that European demand for seaweed will reach €3.0 – 9.3 billon in 2030 across all segments, with feed, food and biostimulants being the largest[34]. For example, the demand for Chlorella and Spirulina is growing in Europe, and it is expected that the European market for **Chlorella** will grow at a compound annual growth rate (CAGR) of **6.4%** to 2025[38]. The CAPR for the European market of **Spirulina** is expected to grow with **8.7%** to 2025. There is a growing vegetarian and vegan population in the EU; currently there are around 75 million vegetarians and vegans living in the EU[39]. This number is expected to increase in the coming years and leads to a growing market and increase in demand for plant-based food products, including algae. Additionally, the ageing population in the EU and increasingly health-conscious consumers are drivers for an increase in demand for algae food products, such as spirulina and chlorella based products. Moreover, EU coastal regions have been

[37] Hidden Champion of the Ocean: Seaweed as a Growth Engine for a Sustainable European Future. Seaweed for Europe, 2021.
[38] Entering the European market for seaweed or marine algae. CBI Ministry of Foreign Affairs, 2021.
[39] The European market potential for seaweed or marine algae. CBI Ministry of Foreign Affairs. 2021.

recognized as a fertile ground and with high opportunity areas for the algae sector to thrive. The Atlantic Ocean and the North Sea indeed provide ideal natural conditions for seaweed cultivation due to their cold, nutrient-rich waters[40], and researchers believe that Europe has vast areas suitable for seaweed and macroalgae cultivation[41]. Besides, data show that China, having 13 000 km coastline with actual cultivation area of 136 223 ha (1362 km2), has cultivated 20.1 Mio tons of algae in 2019. At the same time, EU-27, with its 66 000 km coastline and 5 mio km^2 of marine area (where 141 000 km^2 are near-shore area (0-1 nautical mile from coastline) and 715 000 km^2 territorial waters (0-12 nautical miles from coastline)) has an annual cultivated seaweed amount of less than 1000 t[42]. If the EU algae potential is to be unlocked, by 2030, one-third of algae products in the global market could be produced by the EU suppliers[34]. This increase in production would create around 85,000 jobs and would remove thousands of tonnes of phosphorus and nitrogen annually and would mitigate up to 5.4 million tonnes of CO_2 emissions per year.

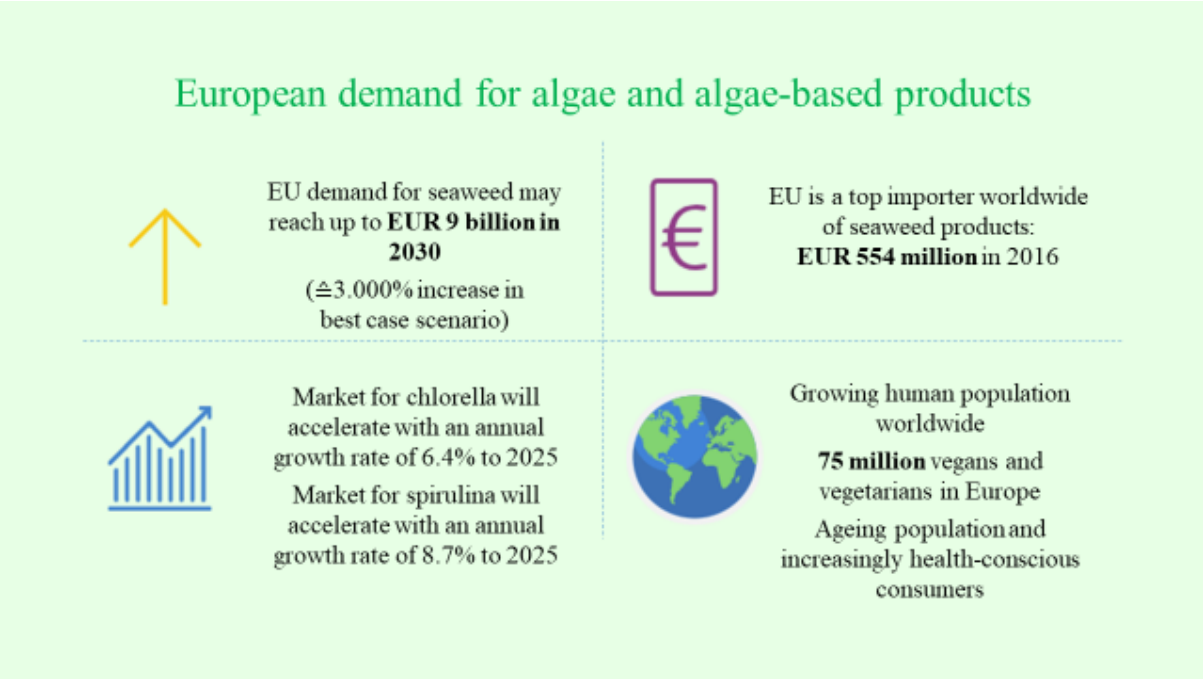

Figure 5. Expected growing demand for algae products

1.4.Political context

As aquatic resources, algae fall under the European Commission's Fisheries and Maritime Affairs policy. More specifically, the algae sector, as part of the **blue bioeconomy**, is considered an evolving and growing innovative sector of the **blue economy** providing new prospects and creating jobs. Algae

[40] Recent Pace of Change in Human Impact on the World's Oceans Halpern, B.S., Frazier, M., Afflerbach, J., Lowndes, J.S., Micheli, F., O'Hara, C., et al. (2019. Science Reports, 9, Article No. 11609.
[41] Global Potential of Offshore and Shallow Waters Macroalgal Biorefineries to Provide for Food, chemicals and Energy: Feasibility and Sustainability. Lehahn, Y., Nivrutti, I., Golberg, A., 2016.
[42] Spatial Analysis of Marine Protected Area Networks in Europe's Seas II. Agnesi, S., Annunziatellis, A., Chaniotis, P., Mo, G., Korpinen, S., Snoj, L., Tunesi, L., Reker, J., 2020.

cultivation falls under the notion of aquaculture, which is shared competence[43] between the EU Member States and European Commission (the latter performs an ″open method of coordination‟[44]). The EU algae initiative will be implemented as an initiative complementary to national legal acts and policies

The **EU's new approach to the sustainable blue economy**[45] recognizes the role of algae in delivering on the **European Green Deal**[46] objectives to 'build a climate-neutral, green, fair and social Europe' and develop innovative, healthy and sustainable food systems, and a sustainable and circular bioeconomy[47]. The document also sets an action to develop a dedicated EU Algae initiative[48] in 2022. The various types of algae production fall under the **Common Fisheries Policy** (CFP), covering both harvesting of marine biological resources and aquaculture. The new **Strategic Guidelines for Aquaculture**[49] recognize algae's potential as alternative protein source for sustainable food and feed systems and in promoting aquaculture systems with lower environmental impact. As renewable biological resources, algae are also a small but growing part of the European Commission's **Bioeconomy Strategy** [50], setting out the Commission's priorities for economic activities based on renewable biological resources from land and sea and acting as a cross-sectoral policy framework to ensure optimum use of biological resources, as well as identification and resolving of potential trade-offs. The strategy is also related and fits within the objectives of the **Clean planet for all (decarbonisation strategy)**[51], which aims to improve the productivity of aquatic and marine resources to capture the full range of opportunities of the bioeconomy in tackling climate change. The Bioeconomy strategy development in EU regions report[52]outlines that Spain, France, Belgium Denmark, Italy and Germany have bioeconomy strategies that include aquatic biomass from fish, aquaculture production and algae. Additionally, Spain and Germany have highlighted blue growth and blue biotechnology respectively in their regional bioeconomy strategies[53]

[43] EUR-Lex - 12016E004 - EN - EUR-Lex (europa.eu); FAQ EU competences and Commission powers (europa.eu)
[44] Aquaculture policy (europa.eu); Open method of coordination - Wikipedia,
[45]Sustainable Blue economy communication (COM(2021) 240 final (17-5-2021) recognizes potential of algae to provide viable and sustainable alternative food and feed materials and to produce other bio-based products. Algae-based food and feed production in the EU is a major opportunity for the development of a sustainable food sector that will alleviate environmental pressures exerted by agriculture, aquaculture, and fisheries. Animal feed produced from microalgae can help reduce catches of wild fish. Producing algae in the sea can help remove excess carbon, nitrogen and phosphorus from water. The Commission will also explore the potential of cell-based seafood as an innovative and sustainable alternative.
[46] Available at: European Green Deal
[47] The EU Blue Economy report 2022.European Commission, Directorate-General for Maritime Affairs and Fisheries, Addamo, A., Calvo Santos, A., Guillen J., et al.., 2022.
[48] To adopt a dedicated initiative on algae in 2022 to support the development of the EU's algae industry. The initiative will facilitate the authorisation of algae as novel foods by cutting application costs, facilitate market access, increase consumer awareness and acceptance of algae products and close gaps in knowledge, research and innovation;
[49] Available at: EU Blue Farming
[50] Available at: Bioeconomy Strategy
[51] Available at: Clean planet for all
[52] Available at: Bioeconomy Strategy Development in EU Regions
[53] Pays de la Loire region (France) published one sectoral strategy on algae: Regional roadmap for the microalgae sector. Andalusia (Spain) has 1 regional bioeconomy strategy embedded in blue growth: Bases for an Andalusian strategy to promote business activity in the field of the blue economy. The Canary Islands (Spain) have three bioeconomy strategies embedded in blue growth: Canary Islands Blue Economy Strategy 2021-2030.

On 22 June 2022 the Commission adopted its proposal for **EU legally binding nature restoration targets**[54], with the objective in particular to restore ecosystems capable of removing and storing carbon and preventing and reducing the impact of natural disasters. Algae's potential for carbon uptake, recycling and sequestration and nature-based solution towards the impact of natural disasters could help achieve these targets. Connected are the Commission's initiatives ─on the certification of carbon removals and adopted communication on sustainable carbon cycles with algae carrying potential towards the objectives by removing and storing carbon and nutrients from marine ecosystems in their production cycle[55]. Overall, enhanced EU production and use of algae will help to ensure sustainable food and farming systems, economic circularity and bio-based products.

Algae cultivation should also consider and can contribute to marine ecosystem conservation and restoration, where the EU puts forward various legislations with a positive bearing on EU ecosystems. The **Habitats Directive**[56], **Marine Strategy Framework Directive**[57] and the **Water Framework Directive**[58] aim to conserve and ensure good environmental status of EU waters to protect marine life, including algae, from the cumulative pressures of climate change and other anthropogenic pressures[57]. Furthermore, all Directives specify that developments, including algae cultivation, should not lead to negative ecosystem impacts (e.g. ecosystem-based management of human activity

While algae are referred to in various pieces of EU legislation, there is currently no dedicated EU policy focused specifically on algae. Most relevant legal acts are further elaborated in the subheading 1.5, while a more comprehensive overview of algae related legislation is provided in Annex X. Within the EU, some Member States already recognise the potential of algae by introducing algae cultivation into national strategic documents like **National Strategic Aquaculture Plans, Marine Spatial Plans and/or National Bioeconomy Strategies**[59].

At international level, the possible capacity of algae to store and sequester carbon provides an opportunity to help reach greenhouse gas emission reduction targets set under the **Paris Climate Agreement**[60] . In addition, a scaled algae industry shows opportunities to contribute to nearly the entire **Sustainable Development Goals** (SDGs)[61,62] agenda, from coastal communities' empowerment and ocean regeneration to low-impact food systems. Under the **Convention of Biological Diversity** (CBD), the **Nagoya Protocol** aims to preserve the genetic diversity of ecosystems by increasing cooperation among stakeholders involved in access to and benefit-sharing for genetic resources (e.g. resource exchange, collaborative research, inclusion of local and/or indigenous knowledge)[10].

[54] Proposal for a Regulation of the European Parliament and of the Council on nature restoration, COM(2022) 304 final of 22.6.2022.
[55] Available at: Sustainable Carbon Cycles
[56] Available at : Habitats Directive
[57] Available at : Marine Strategy Framework Directive
[58] Available at : Water Framework Directive
[59]As of April 2022, ten Member States have dedicated bioeconomy strategies (Austria, Finland, France, Germany, Ireland, Italy, Latvia, the Netherlands, Portugal and Spain) and seven Member States (, Croatia, Czechia, Hungary, Lithuania, Poland, Slovakia, Sweden) are in the process of developing a dedicated strategy at national level (European Commission's Knowledge Centre for Bioeconomy country dashboard and EU Bioeconomy Strategy Progress Report, forthcoming).
[60] The Paris Agreement
[61] Available at: Sustainable Development Goals
[62] Available at: Algae2030 (algonauts.org)

2. Problem definition

2.1.Overview of problem definition

The **Blue Bioeconomy Forum Roadmap**[63] published by the Blue Bioeconomy Forum[64] at the end of 2019 and after an extensive consultation process of around 300 stakeholders, identified 14 problems, structured around 4 domains: (1) Policy, environment and regulations; (2) Finance and business development; (3) Consumers and value chains and (4) Science, technology and innovation. This sub-heading is a follow-up of the above roadmap and takes into account latest developments.

A number of problems were identified with regards to the current EU algae sector and the potential for sustainable growth of the sector. Figure Nr.7 outlines the most significant problems of the current EU algae sector, and the resulting specific and general objectives to address these problems. The specific and general objectives are explained in more detail in chapter 4.

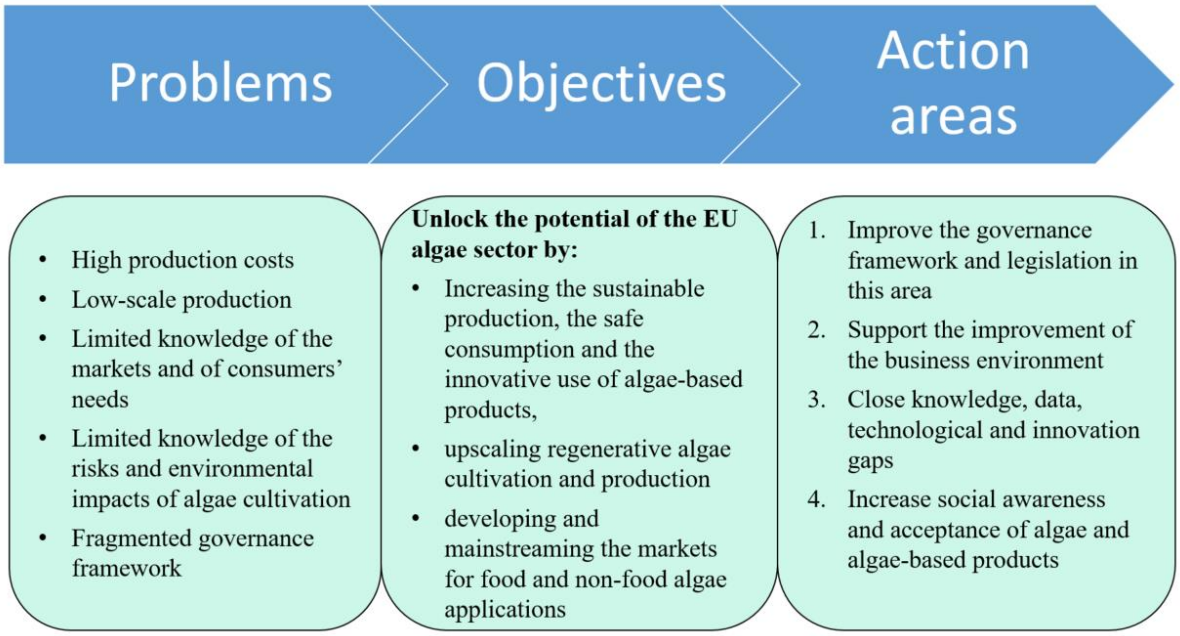

Figure 7. Problems, objectives and proposed action areas for the EU Algae Initiative.

2.2. Low production volumes

Nowadays, 99% of algae production volumes in the EU depend on seaweed harvesting from wild populations at sea[65]. Although well managed and based on advice from national scientific bodies, algae harvesting from the wild will not be able to sustain the growing demand for algae products in the future. Farmed seaweed represents roughly only 1% of the algae biomass in the EU, while globally, there is an opposite trend, where 99% of global seaweed production comes from farming practices. **Upgrading**

[63] Available at: Blue Bioeconomy Forum Roadmap

[64] DG MARE of the European Commission and the Executive Agency for Small and Medium Sized Enterprises (EASME) initiated the Blue Bioeconomy Forum (BBF) in 2018 to bring together industry, public authorities, academia, finance and civil society in order to strengthen EU's competitive position, exploit the potential of renewable resources and ensure the sustainable use of the resources of the emerging blue bioeconomy. The aim of the BBF was to develop a common understanding of the current status of blue bioeconomy in the EU and to collectively identify strategic developments, market opportunities, appropriate financial assistance, regulatory actions and research priorities.

[65] 68% of the macroalgae production enterprises in the EU harvest from wild stocks[24]

and accelerating sustainable seaweed cultivation systems is crucial to achieve successful increase of seaweed production volumes in the EU. Long and cumbersome process do deploy a farm (i.e. access to maritime space) is one of the causes of low production. In addition, current competition for marine space for various activities can be tackled via the modification of the national Maritime Spatial Plans (MSP) in the Member States with well-integrated seaweed farming. However, this will need to be done without jeopardizing the environmental, economic or social objectives on which current maritime spatial planning is based, and following a careful assessment of trade-offs and co-benefits.[66]

Although microalgae cultivation amounts are currently negligent in the EU (estimated 350 t yearly), microalgae cultivation in photobioreactors (71%) which are closed on-land systems[67] have a potential of substantial scale-up of the production without a maritime space requirements and limited land needs. Additionally, 19% of microalgae is produced in open ponds and 10% is produced in fermenters.

Whereas 83% of companies producing Spirulina use open-ponds. European production volumes are minor but the economic value of the resulting products is notably compared to seaweed. **Cultivation of microalgae requires specific infrastructure, valuable equipment and manpower which make the production costs relatively high**. Upscaling microalgae production systems can reduce costs but need space and considerable investments, which, at a producer's level is very challenging.

In general terms, when addressing algae cultivation, species selection and improvement as well as metabolic enrichment strategies can provide solutions to not only increase biomass volumes but also increase the proportion of interesting valuable compounds within the algae. Although a longer process, **upstream knowledge (research in genomics, metabolomics etc.) is essential to provide solid knowledge-based solutions.** Moreover, the EU already possesses a sound research basis but technology transfer should be strongly supported, besides investments and space.

2.3. High production costs

Cultivating algae in the EU is costly today. This explains why most products are not competitive on the global market and confines them to niche markets. Strategies to be more cost efficient and to have more optimised processes can be deployed individually (to reduce energy and water consumption, increase automation and nutrient recycling, etc.), but globally, the following strategies are currently being implemented to reduce production costs:

- Upscaling algae production systems can reduce costs but would need more space and considerable investments. The latter could be achieved without any risk if the downstream market was secure and stable. Fluctuating market prices and the unstable position of niche markets make investments risky at a producer's level.

- Developing advanced biorefinery technologies to valorise each fraction of the algae biomass can increase the global value of the incoming algae biomass and in effect the cost-effectiveness of algae

[66] As emphasised by the Bioeconomy Progress Report: 'Bioeconomy Policy: Stocktaking and future developments', integrated land and sea use assessments are essential to ensure environmental integrity, provide good biosphere stewardship, and finally develop sustainable biomass strategies

[67] Current Status of the Algae Production Industry in Europe: An Emerging Sector of the Blue Bioeconomy. Araujo et al., 2021.

cultivation. However, not all algae biomass fractions are marketable. Bringing more novel algae species to the EU market in line with the Novel Food Regulation needs to be continued (e.g. via the EU4Algae project).

2.4. Limited knowledge of market and consumers

In the EU, algae-based products have been consumed for decades without explicit knowledge of the consumers. Today, consumer awareness towards natural ingredients and plant-based products is increasing, and has slowly expanded the diversity of other algae food and high value health products besides the simple low value texturisers.

However, algae-based food is not traditionally consumed in the EU and there is a large proportion of consumers who are not ready or even willing to integrate algae in their staple diet. **Awareness on exceptional nutritional benefits[5,19,38,40] and low environmental footprint[38,35]** and acceptance of algae products should be raised to the EU citizens in order to **boost the demand.** At the moment, potential consumers have limited knowledge on how to prepare algae-based recipes, about the consumption of algae products, and on the potential risks that may arise due to the presence of certain compounds (for seaweed: iodine, heavy metals, inorganic arsenic), and simply where to buy products.

The business-to-business markets are often unaware on potential algae uses ranging from animal feed to compostable or edible biopackaging, to algae-based textiles, tissues and pigments, cosmetics, or plant biostimulants to support the growth of organic agriculture practices. They are also often unaware on low environmental and carbon footprint of algae production and products.

Besides social awareness and consumer acceptance to boost the demand, connections between suppliers and buyers need to be improved. For instance, harmonized prices and clear commercial channels to buy algae biomass could enable algae products to reach buyers who are willing to experiment with the products on untapped markets.

2.5. Limited knowledge on risks and impacts of an expanded algae production

To ensure that the algae sector develops sustainably, it is important to understand potential impacts of a developing algae industry (as supported by the results of the Open Public Consultation that ended August 2021, see Figure Nr. 8 below). Besides the Life Cycle Analysis, which provides comparative scenarios indicating the process with highest environmental impact and steps how to act on them (notably used for microalgae production), more detailed and consistent measurements need to be performed, such as the impact on local biodiversity, environmental footprint and proposals for compensation measures (notably used for seaweed production).

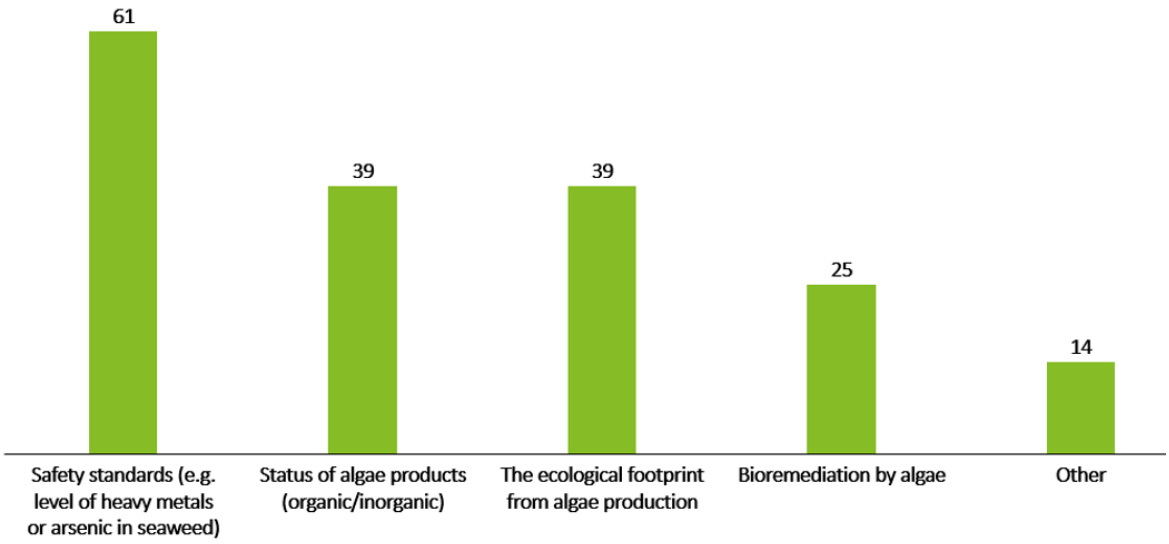

Figure 8. Areas that should be governed at the EU level (number of responses to the OPC).

There is also a need to increase knowledge on environmental benefits of seaweed aquaculture, such as carbon and nutrients capture and carbon sequestration. Harmful impacts on local ecosystems, such as reduced genetic diversity need to be considered (have already been reported in Chile, Tanzania). Also, potential darkening of ocean colour (e.g. due to eutrophication) leading to higher heat absorption and hence ocean warming[68] needs to be assessed. Therefore, more studies and monitoring programs are needed to better understand and assess potential negative effects and proposing risk mitigation strategies. The latter may help to increase the acceptance of algae products by consumers in the EU.

2.6. Fragmented governance framework[69]

Seaweed aquaculture at sea or algae cultivation on land need to comply with different national regulations (licensing, access to marine space, species to be farmed) depending on the EU Member States, EU rules (food safety, fertilising products etc), industry standards etc.

Although scientists recommend not to shift species from one marine area to another or not to spread the same seedlings in different areas in order to prevent potential mono-clonal escapes replacing natural wild populations, such situations may happen. This may distort local genetic diversity.

Access to marine space can be allocated to the aquaculture production, provided the national MSP allow it and the license is temporary for an agreed time frame. Licensing processes, including the validity duration of the license and its renewal terms, are managed entirely by the national authorities and vary significantly from country to country. The licensing process can be intermittent, multi-step and resource-intensive, which makes it a barrier for setting up new investments.

[68] Testing the climate intervention potential of ocean afforestation using the Great Atlantic Sargassum Belt, Bach, L.T., Tamsitt, V., Gower, J. et al., 2021. Nat Commun 12**,** 2556.

[69] **Governance framework** (for the purpose of this document) reflects the interrelated relationships, factors, and other influences upon EU public sector (national authorities and European Commission). Governance frameworks structure and delineate power and the governing or management roles. They also set rules, procedures, and other informational guidelines. In addition, governance frameworks define, guide, and provide for enforcement of these processes. These frameworks are shaped by the goals, strategic mandates, financial incentives, and established power structures and processes of the EU public sector.

Regarding more downstream legislation, there are differences between the EU Member States in terms of certain, non harmonised at EU level, food safety measures such as not exceeding iodine thresholds in algae biomass before commercialization. **Such differences between countries have created discords between suppliers and buyers across borders and lead to commercial tensions**.

3. Why should the EU act?

3.1. Legal basis and context

The Treaty on the Functioning of the European Union (TFEU) provides for the following distribution of responsibilities between the EU and the Member States in areas relating to algae:

1) The European Union has **exclusive competence** with regard to the conservation of marine biological resources within the framework of the common fisheries policy[70] (see Article 3 (1d) TFEU)[71];

2) The European Union **shared competence** with the Member States in matters of agriculture[72] and fisheries[73] (including aquaculture, thus covering the production of seaweed, the common organization of the markets in fisheries) to the exclusion conservation of living marine resources (see **Article 4 (2d) TFEU**)[74], and Union policy will contribute to pursuing objectives in the main areas of:

- Common public health safety concerns for the aspects defined in the TFEU;
- Consumer protection (Article 4 (2k) TFEU);
- Environment (Article 191 TFEU)[75].

There is currently a lack of harmonized algae-related legislative framework between Member States. This section provides an overview of the EU regulatory framework applicable to algae from their production or collection to their processing into food, feed, pharmaceuticals, chemicals and other products. Some EU regulations are relevant for all types of algae, namely those that deal with aquatic resources, renewable biological resources and anthropogenic pressures on the environment. Other policies and regulations are only applicable to one phase of the value chain, such as the Common Fisheries Policy (cultivation or wild harvesting) or rules on food packaging, and various rules apply to specific products, e.g. additives in feed. Overall, algae industry needs to be aware of various rules and regulations (as outlined in this sub-heading and Annex 5).

Product safety and consumer protection are the priority when considering bringing new algae products to the EU market. For organic algae, labelling and production, EU level rules are set up. In seafood, producers need to consider maximum allowed levels of **iodine, heavy metals** and other **contaminants.** In algae as foods also high concentrations of contaminants may occur, but so far occurrence data have been lacking to allow the establishment of maximum levels in food, in order to

[70] Regulation (EU) No 1380/2013 of the European Parliament and of the Council of 11 December 2013 on the Common Fisheries Policy*:* includes rules on the capture of marine resources and aquaculture (including freshwater aquaculture), thereby covering the various types of algae production.
[71] Available at: Article 3 (1d) TFEU
[72] Available at: agriculture
[73] Available at: fisheries
[74] Available at: Article 4 (2d) TFEU
[75] Available at: article 191 TFEU

protect EU consumers against the health risks from those contaminants (in particular high concentrations of heavy metals) in algae. Maximum allowed levels are available for contaminants in feed and fertilisers. Obtaining health claims for algae-based foods may be an extensive process as strong substantiation of any health benefits is needed. In addition to the rules on products, the algae business is strongly impacted by the elements of the general regulatory environment such as agricultural/aquacultural subsidies, aquaculture licensing, public procurement criteria, tax schemes, and trade agreements. Needless to say, not every single rule will apply to every single algae producer or processor, depending on their production methods, final products and size of the operation[76, 77].

For the cultivation of algae for food and feed, various legal acts are in place. Compliance with EU food safety legislation[78] sets out basic legislative principles for algae products to ensure safe human nutrition and to protect consumer interests. Furthermore, new algae food products entering the EU market might fall under the **Novel Food Regulation**[79]and would require authorisation by the European Commission, The Novel Food legislation applies to foods and ingredients that were not consumed significantly in the EU before May 15, 1997. As the algae industry is an emerging sector in the EU and demand for algae biomass is rising for a variety of products, new algae species will most probably need to get a Novel Food authorization before being allowed to enter the EU market and be included in the Union List of authorised novel foods.

Macroalgae have a long history of usage in the production of thickening and gelling agents applied as additives in food, cosmetics, and pharmaceuticals. The Regulation on **food additives**[80] regulates their use and contains a list of authorized food additives. It includes eight macroalgae-derived additives under codes E401-E407a. Commission Regulation **on specifications for food additives**[81] further specifies the origin, composition, and usage of the accepted additives. Several novel or underutilized macroalgae species could be used for production of food additives, although they would not be accepted as food or food ingredients. In addition to the traditional macroalgae-derived thickening and gelling agents, macroalgae contain pigments, antioxidants, and bioactive compounds, the properties and potential applications of which are under active research[82]. However, any novel macroalgae-derived phytochemicals intended for use as food additives, require an authorization before their entry into the EU market.

The EU has, furthermore, issued a **Recommendation on the monitoring of metals and iodine**[83] in seaweed, halophytes, and products based on seaweed (through a specific list of species). These monitoring data are needed to establish maximum levels on the basis of the 'As Low As Reasonably

[76] European Union Legislation and Policies Relevant for Algae. Leinemann F., Mabilia V., 2019.
[77] European Union legislation on macroalgae products. Lähteenmäki-Uutela, A., Rahikainen, M., Camarena-Gómez, M.T. et al, 2021.
[78] Available at : EU food safety legislation
[79] Available at : Novel Food Regulation
[80] Available at: Regulation (EC) No 1333/2008
[81] Available at: Regulation (EU) No 231/2012
[82] Bioactive Compounds in Seaweed: Functional Food Applications and Legislation. Holdt, S.L. and Kraan, S., 2011.
; Recovery and utilization of seaweed pigments in food processing. Current Opinion in Food Science. Aryee A, Agyei D, Akanbi T., 2018. Current Opinion in Food Science 19:113–119. ; Source, extraction, characterization, and applications of novel antioxidants from seaweed. Jacobsen C, Sørensen AD, Holdt S, Akoh C, Hermund D., 2019. Annu Rev Food Sci Technol 10:541–568. Available at:
[83] Available at : recommendation on the monitoring of metals and iodine

Achievable' principle, in order to limit the adverse health effects for consumers. Algae used in animal feed/feed additives do not need pre-market authorization, but do have to comply with **regulation on feed hygiene**[84], **marketing of feed**[85], **undesirable substances in feed**[86] and **feed additives**[87]. As mentioned earlier, the Commission shares competence with Member States in this regard.

When used in **pharmaceuticals**, algae need authorization through centralized procedures, under the EU Medicine Agency. Algae used as sources of fine chemicals, botanical extracts and active substances or for speciality high-value applications in pharmaceutics and medicine fall under the main legislation for chemicals in the EU: the **Regulation on the Registration, Evaluation, Authorisation and Restriction of Chemicals)**[88]. The Cosmetics Regulation (EC) No. 1223/2009 is addressing concerns for human health, and REACH - for environmental concerns of substances used in cosmetics. The EU **Fertilising Products Regulation**[89] harmonises the rules for EU fertilising products, giving these products access to the EU single market. However, national legislations (with different rules) may apply in parallel, and regulate "national" fertilising products in national markets.

Algae cultivation itself falls within the area of aquaculture (Article 34 of the CFP regulation)[90], where the Commission establishes non-binding Union strategic guidelines on common priorities and targets for the development of sustainable aquaculture. Therefore, the inclusion of algae cultivation within **multiannual national strategic aquaculture plans** falls to the responsibility of Member States, along with regulating algae licensing, marketing and production requirements. In order to obtain the 'organic' label, algae producers need to comply with the **Organic regulation**[91] and additionally require an **Environmental Impact Assessment (EIA)**[92] with thresholds determined by each Member State individually. Furthermore, the EU encourages Member States to include algae objectives in their national/regional spatial plans under the **Maritime Spatial Planning (MSP) Directive**[93] promoting sustainable development and encouraging coexistence of different sectors in the marine area.

Finally, algae production can be integrated into other industrial activities, e.g. wastewater treatment and industrial CO_2 capture. In this regard, relevant algae products can fall under the remit of the **Waste Framework Directive (WFD)** and specifically under End-of-waste criteria[94]. A revision of the WFD is underway for 2023.

Some of the main legal references related to the seaweed aquaculture are laid down in Figure Nr. 6 below.

[84] Available at : regulation on feed hygiene
[85] Available at : marketing of feed
[86] Available at : undesirable substances in feed
[87] Available at : feed additives
[88] Available at: REACH
[89] Available at : Fertilising Products Regulation
[90] Available at : Article 34 of the CFP regulation
[91] Available at : organic regulation
[92] Available at: Environmental Impact Assessment
[93] Available at: Maritime Spatial Planning Directive
94 Available at: End-of-waste criteria.

Figure 6. Overview of legal acts relevant to seaweed aquaculture[95]

An elaborative overview of existing and forthcoming initiatives and explanation of their relevance to algae is provided in Annex 5.

3.2. Is it necessary for EU to act?

The European Union can only act in areas according to a division of responsibilities set in EU treaties (See 3.1 above). The **EU Blue Bioeconomy**, including the algae sector, plays an important role in achieving **European Green Deal** objectives and **Sustainable Development Goals** (SDGs). A growing global population, exhaustion of resources, environmental pressures, and climate change, require a modified approach to our food systems. To overcome these challenges, new sustainable ways to feed a rapidly growing global population are essential. The European Commission's Group of Chief Scientific Advisors elaborated in its 2017 "Food from the Oceans" advice[96] how the ocean offers untapped potential to meet global food demand through direct food production or biomass harvest. The production and processing of food from the ocean, such as algae and other new marine resources can help provide sustainable food products, animal feeds and non-food products. The European Commission intends to play a key role in the development of a regenerative EU algae sector.

As part of the **Farm to Fork Strategy**, the Commission aims to "launch a process to identify new innovative food and feed products, such as seafood based on algae"[35]. In addition, the Commission stresses the need for well-targeted support to the algae industry to develop its potential as a sustainable food system.

Currently, the lack of harmonization between Member States poses obstacles to the rapid and successful development of an algae sector in the EU. These may be the licensing procedures, access to marine

[95] Design: Michèle Barbier, Institute for Science and Ethics
[96] Food from the oceans : how can more food and biomass be obtained from the oceans in a way that does not deprive future generations of their benefits?. European Commission, Directorate-General for Research and Innovation, Group of Chief Scientific Advisors, Publications Office, 2017,

space including multi-use, spatial planning, carrying capacity of EU marine waters, competition between countries, access to algae seeds, guidelines around algae-origin biostimulants, organic production and labelling, traceability, origins control, and preserving, protecting and improving the quality of the environment, etc.

Not taking action at this stage would mean a missed opportunity for Europe in terms of creating an algae industry sector creating new and quality jobs in coastal regions, helping to restore ocean health and biodiversity, making low carbon footprint products etc. Not improving the traceability of bulk biomass and algae-based products can create consumer suspicion on the products origin and production methods, which will hinder the downstream market and confine the products to niche markets (as it is today). Not ensuring environmental sustainability of up scaled algae production systems, through fundamental knowledge, is likely to lead to potential drawbacks on local ecosystems and create social controversy. **By acting, the EU can seize the opportunity to address these potential drawbacks, and not only respond to the increasing demand for algae, but also provide a safe, sustainable (economic and environmental) and competitive resource for the growing EU and international market.**

3.3. Would there be an added value of an EU action?

Coordinated action at EU level is necessary to unlock the algae potential and to enforce environmental, health, food, social and economic benefits that algae sector will provide. In respect of the subsidiarity mentioned, the EU must thus act in those areas and across EU maritime regions.

The goal is to integrate algae into the national policies, be thoughtful of the algae sector's complexities and specificities, and promote its integration into internal markets. It is essential that the homogeneous political approach does not replace national policies, but complements them and harmonizes the rules on the use of algae as food and non-food products. Similarly, national legislation and licensing requirements necessary to carry out algae-related activities will have to be harmonized to facilitate intra-EU algae sector developments. Clear regulations in the sector would eliminate barriers to new investors and young entrepreneurs to enter the sector, and will increase its broader visibility and recognition.

The growth of the sector will be fostered when new products are continuously developed and introduced into the market. This can be promoted through EU level actions by helping innovation and simplifying the authorization procedures for new foods. The improved labelling and European standards of algae and algae products would certainly lead to a better competitive position for EU algae producers and processors, compared to algae producers from outside the EU, and would push the request for products of EU origin. This would also establish consumer confidence in the products, and make it easier for producers to adhere to standards when labelling is done in a coherent way.

4. The EU Algae Initiative and its objectives

One strong value added of a dedicated EU Algae Initiative lays in the coordinated supervision of the existing and additional actions listed in previous sections. The unlocking of the EU algae industry will indeed emerge from this system-level approach that will create synergies between this long list of

complementary actions. This integration and coordination is key to ensure smart economic stewardship of EU budget by avoiding duplication and maximising knowledge sharing across these actions.

The set-up of the Algae Initiative can be done in a cost-efficient way given that many of these actions are already planned, budgeted or already being implemented. The Algae Initiative can indeed:

- Leverage existing programs and actions directly contributing to the algae agenda (cf section 5.1). EU4Algae can for instance be a powerful amplifying channel to engage the algae community and disseminate knowledge generated by the Algae Initiative.
- Collaborate with adjacent EU programs that can also contribute to the algae agenda, for instance collaborating with EU4Ocean and their literacy and awareness campaigns to promote algae, or with Blue Invest to present algae companies to investors.
- Officialise the "algae interest group" that exists across DGs and make it the network of focal points for the Algae Initiative
- Activate DG MARE budget already validated in the Work Programme and that could be allocated to funding new actions listed in section 5.2

However, to make the EU Algae Initiative successful, some additional enablers will be required:

1. Clear allocation of Commission resources to play this coordination role across existing and new actions listed in this document, under the official mandate of the Algae Initiative, signalling to other DGs that the Algae Initiative will be in charge of creating synergies across them on algae-related topics and programs.
2. Engage with Horizon Europe to shape proposals aligned with the new actions proposed in section 5.2, as long as they are consistent with workstreams defined by Horizon Europe plan and roadmap.

Assess possibility to unlock additional budget in 2023 and 2024 for additional actions from section 5.2 that cannot be funded and resourced by all other mechanisms listed above.

4.1. General objectives

The **main goal,** and 10-year vision**,** is to **unlock algae potential in the EU by increasing sustainable production[97], safe consumption[98] and innovative use of algae products in the EU**.

Unlocking the algae potential in the EU by developing a thriving, strong and sustainable EU algae sector would contribute to strengthening the EU economy and limit dependency on imports of raw materials and nutrients from other parts of the world. The Covid-19 pandemic and recently started Russia's military aggression against Ukraine reinforce the case for diversifying the production of key raw materials in the EU and making this production sustainable. A thriving EU algae industry would also be a key contributor to the European Green Deal and a flagship and source of inspiration for other

[97]Sustainable production and consumption can be defined as production and use of products and services in a manner that is socially beneficial, economically viable and environmentally benign over their whole life cycle Sciencedirect

[98] Algae products intended for consumption on the EU market shall correspond to the "safe products" definition laid down in the Directive 2001/95/EC of 3 December 2001 on general product safety

industries to become more regenerative, innovative and socially exemplary, with thousands of good jobs created, notably in coastal communities.

Positive impacts on the people, nature and the economy - described in the next chapter - would be unleashed and will contribute to addressing key ocean (acidification, biodiversity loss, pollution, habitat destruction) and socio-economic (self-sufficiency, unemployment, obesity and malnutrition etc.) challenges of our time.

4.2. Specific objectives

Specific objectives to implement the general objective above are:

1. To **upgrade**[99] and **upscale regenerative algae cultivation and production** throughout the EU
2. To develop and mainstream the markets for **food and non-food algae applications.**

Algae food applications, for instance, algae sold in supermarkets and prepared in restaurants should become accessible to a wide variety of EU consumers. For non-food applications, EU-sourced algae should become a mainstream sustainable raw material and feedstock across various sectors ranging from animal feed, agriculture, textile, cosmetics, nutraceuticals, packaging, etc.

Increasing the capacity of algae production (and hence the whole value chain) in the EU is essential for reaching such a target. Seaweed for Europe estimated (in their most ambitious scenario) that the European seaweed production capacity could reach 8 million tons fresh weight by 2030 (currently: 0.3 million tons fresh weight per year) [34] to supply around a third of a EUR 9 billion European seaweed market.

In this **2030 target vision**, fundamental research in algae genetics, genomics and metabolomics has built the required knowledge for biodiscovery, strain selection and ability to stabilize the quality and increase the productivity of biomass, but also to increase the productivity of inherent compounds of interest (e.g. high value bioactives). Research and long-term monitoring programs deployed within production sites at sea (seaweed) have improved knowledge on environmental services of algae production regarding nutrients uptake, ecosystem services, and the role of algae as a nature-based climate solution. This research also provided conclusive information regarding the positive and negative environmental impacts, essential for guiding aquaculture and hence ensuring environmental sustainability of seaweed cultivation. Improved and new algae cultivation and processing systems and methods have been tested, validated and scaled, leveraging technological breakthroughs, for instance regarding biomass stabilization, full value transformation (e.g. via biorefineries) and technology integration (e.g. industrial symbiosis) to guarantee economic viability of the produced algae. Public and private capital would have been raised to fuel this research innovation and infrastructure development.

In this target 2030 vision, algae would not be any more a niche industry in the EU:

- Algae production would be siginificantly scaled up, and would be environmentally friendly and economically viable and sustainable;
- Innovative products would be available on the market, in the broadest range of applications.

[99] Upgrading is the process of replacing a product with a newer version of the same product

- Algae products placed on the EU market would be safe and their health benefits would be substantiated, recognized and praised for (for food, feed and non-food applications);
- The industry would develop in a socially fair and resilient way and would leave no-one behind.

To deliver this ambitious (and sustainable) growth in EU algae production and new products development within the next decade, many structuring enablers need to be deployed across the theme of research, technology innovation, policy reforms, capital mobilised, improved governance and awareness and acceptance raising.

4.3. Operational objectives

To reach the specific objectives presented above, the following operational objectives have to be achieved.

4.3.1. **Improve and harmonize governance and legal frameworks.**

Algae sector would benefit from harmonized governance throughout the EU, involving common legal procedures, monitoring and quality thresholds with the final goal to deliver an EU label guaranteeing safe and traceable biomass or algae-based products.

Among others this objective implies development of **common guidelines** regarding algae cultivation and commercialization as well as integrate algae-related provisions into **national governance frameworks** (e.g. **maritime spatial plans)**. For instance, development of centralized guidelines for new algae farmers in the Member States to be performed. Specific actions may look at addressing access to algae cultivation sites at sea (these diverge between countries) as well as at safe concentration limits of certain compounds (e.g. iodine) required before commercialization (also differ across the countries). Another example would be to draw an intra-EU policy on organic production of microalgae. Improved governance also implies improved licensing and access to space procedures, improved industry standards and necessary legal changes.

4.3.2. **Support the improvement of business environment.**

Well-functioning and growing business landscape and environment are crucial for an effective growth of a regenerative algae sector. Some of the actions to implement under this objective are bringing **more algae species to the EU market** by considering industry collaboration for preparing novel food dossiers and by discovering species that are used as a traditional food in the EU Member States. Reorientation of fishers careers to regenerative ocean farmers through a pilot projects could be encouraged. Support could be provided to algae producers and transformers to attain existing EU quality labels, which can provide a price premium to their respective products and help to achieve economic sustainability. Implementation of the **EU4Algae project** will promote partnerships and knowledge exchange, will accelerate the development of a regenerative, equitable and climate-friendly algae industry in the EU by fostering stakeholder collaboration (for further details see sub-heading 5.1).

4.3.3. **Increase social awareness and acceptance**

EU consumers and ordinary citizens often are not aware about the multiple benefits algae cultivation may bring ranging from marine ecosystem regeneration until creating low-carbon products and generating blue economy jobs. **Social awareness** of algae and algae products needs to be increased to boost the demand and knowledge of the EU Blue Bioeconomy sector through, for example, educational

programmes at schools, seaweed cooking shows or by conducting a consumer behaviour and preferences analysis on algae products.

4.3.4. Closing knowledge, research, technological and innovation gaps

Implementing this objective is key to succeed with implementing the general objective above. Algae sector in the EU has rather limited availability of algae-related data (production and socio-economic data)[24],[100]. There is a need to develop innovative equipment able to increase and stabilise productivity and quality levels such as large scale efficient and optimized production systems, automation equipment, monitoring probes with control command systems, nutrient recycling, etc. which can reduce unpredictable biomass loss but can also reduce labour costs. This equipment could be sound for downstream processes like biorefineries able to treat algae biomasses of macro- and microalgae. There is also a need to **remove systemic innovation barriers** and accelerate algae innovation and market access etc.

5. Ongoing and proposed policy actions

The algae sector is currently a niche sector in the EU on a development trajectory given the advantages of algae products and consumer demand, e.g. algae foods. However, as described in Chapter 1 to unlock the algae potential in the EU Blue Bioeconomy, without compromising on sustainability and safety issues, a policy intervention to support and regulate the sector needs to be considered. This chapter describes and explains **(1) existing and ongoing algae-related actions and (2) proposes a range of new policy actions** structured around 4 specific objectives described above.

As indicated earlier, algae industry sector is at the early development stages therefore there is no or very minor regulatory measures. The existing ones are very fragmented and mentioning in sectoral legal acts of "algae" is either minor or inexistent (see sub-heading 1.5 and Annex 5 for more details on the legal algae-related context). As the development of algae cultivation mostly falls within the remit of the aquaculture, which is managed by the EU Member States, currently there is minor scope for further legislative changes to support the development of algae sector. After a careful review of the potential legislative changes with algae sector experts, stakeholder groups (see the results of the stakeholder consultation in Annex 2 and 3) and based on collective knowledge of the Commission, a possible future amendment of the scope of the fertilising products regulation (Regulation (EU 2019/1009) to allow more algae related materials could be considered. However, any proposal for such an amendment should be duly supported and justified by an in-depth technical assessment of the market potential, the agronomic efficiency and the safety of certain algae materials when used in fertilising products. Existing and ongoing algae-related actions

This sub-heading describes the ongoing support to the algae sector, which is provided not in a targeted strategic way, but more as part of the wider Green Deal Strategy. By continuing "business as usual" algae-related calls could be still released, funded, contracted and implemented, while the regulatory framework could be improved e.g. as part of Sustainable Blue Economy Strategy. To understand how the algae-sector will look like in 3-5 years without the Algae initiative, we have to throw light on the

[100] Report on the Community of Practice Workshop: Algae production in Europe: status, challenges and future developments. European Commission's Knowledge Centre for Bioeconomy.

expected outcomes of the current algae-related initiatives that are in an implementation and planning phase. Consequently, in the following paragraphs, the most important initiatives that can influence the algae sector (2021-2022) are presented. These initiatives (non-exhaustive list) are: EU4Algae, current EU funding calls (Horizon 2020, Horizon Europe, BBI-JU, EMFF, ERDF, etc.), business support mechanisms (Blue Invest, private financing, etc.), initiatives that contribute to the knowledge base, like the Commission's Knowledge Centre for Bioeconomy, the JRC's biomass study, as well as specific algae-related studies, ocean literacy and awareness raising initiatives etc.

5.1.1. European Algae Stakeholder Forum (EU4Algae)

EU4Algae project was kicked off in February 2022 to run for three years. The project aims to support EU algae innovation and market access, contributing to increasingly sustainable production of algae, ensuring safe consumption and boosting innovative use of algae and algae-based products in the EU. EU4Algae consortium consists of some leading European algae organizations[101] that already have a network of some 300 algae sector stakeholders.

EU4Algae contractor will deliver the following (non-exhaustive list):

- Create an EU-wide collaborative algae sector network – **EU Algae stakeholder forum (EU4Algae)**
- Review and compile existing **national incentives**, **best practices and procurement mechanisms** facilitating the development of algae businesses and increasing demand for algae products
- Examine current national policies and forward planning for potential introduction of **financial incentives** on the price of algae and algae-based products in the Member States
- Compile information on **business support actors, initiatives and mechanisms** in the Member States to support collaboration and broader knowledge sharing at the EU level
- Will examine future **EU research and innovation needs** to enhance the potential of algae, including the nutritional benefits of algae, the development of new algae-based products, new business models and emerging algae applications at the initial phase of research
- Consider setting up an online **Algae Intelligence and Innovation corner** on the EU4Algae website with an updated **periodic list of EU funding sources** for algae-related projects
- Support the addition of **new algae species** to the **Novel Food Catalogue**
- Aggregate actual algae-related funding calls to make them available for the algae sector stakeholders
- Review and analyse state of the art knowledge on quantifying ecosystem services of algae-based on bioremediation and **carrying capacities of EU waters** for seaweed aquaculture and marine permaculture, and **impacts** of cultivation, restoration and harvesting on marine ecosystems.

[101] EURA, European Algae Biomass Association (EABA), Seaweed for Europe, sPRO (Submariner network), Technopolis Group

5.1.2. Algae-related EU funding calls

A number of existing funding calls are already supporting the development of algae sector. Among others, these are Horizon 2020, Horizon Europe, BBI-JU/CBE-JU calls, blue economy window calls (EMFF), ERDF and other EC funding calls already awarded or programmed. While EU4Algae project mentioned above will aggregate the actual funding calls and make them available to the stakeholders, below are few examples of recent calls.

One of the 5 key action areas of the **EU research framework program Horizon Europe** is the mission "Restore our ocean and waters by 2030". The objective of this Mission is to restore by 2030 the health of one of our most precious shared resources: our ocean and waters. Alongside Horizon Europe the Mission also mobilises the European Maritime Fisheries and Aquaculture Fund (EMFAF), InvestEU and other EU programmes. Together, they will provide around €500 million in seed funding during 2021-2023. Along with Member State contributions and private funding, this will create a big and lasting impact. In a nutshell, this means to: (1) protect and restore marine and freshwater biodiversity and ecosystems, (2) eliminate pollution, and (3) make the blue economy carbon-neutral and circular. So far there have been released or planned following funding actions where **algae** are explicitly mentioned in the description or scope:

- Unlocking the potential of algae for a thriving European blue bioeconomy[102]
- Building alternative protein-friendly sustainable and healthy food environments[103]
- Innovative food from marine and freshwater ecosystems[104]
- Filling knowledge gaps on nutritional, safety, allergenicity and environmental assessment of alternative proteins and dietary shift[105]
- Novel, non-plant biomass feedstock for industrial applications[106]
- Photosynthesis revisited: climate emergency, "no pollution and zero-emission" challenge and industrial application[107]
- Environmental services: improved bioremediation and revitalization strategies for soil, sediments and water[108]

Circular Bio-based Europe Joint Undertaking (CBE JU) – the successor of Bio-based industries Joint Undertaking (BBI JU) will launch the algae-related calls (Annual Work Programme 2021-22) on 22 June 2022. **BBI-JU** has funded between 2014 and 2020 some ten algae-related projects. Some examples are provided below.

SPIRALG was a successful aquatic biomass project, aiming to demonstrate the sustainable feasibility of biorefining of EU produced Spirulina biomass in the agro-food and health sectors.

[102] HORIZON-CL6-2021-CIRCBIO-01-09 – Total funding: 18 mio EUR, 9 Mio per project, 2 projects. Deadline: 01 Sep 2021
[103] HORIZON-CL6-2022-FARM2FORK-01-07: Total funding: 12 Mio EUR, 12 Mio per project, 1 project. Deadline: 15 Feb 2022
[104] HORIZON-CL6-2022-FARM2FORK-02-05-two-stage: Total funding: 18 mio EUR, 6 Mio per project, 3 project. Deadlines: 15 Feb 2022 (First Stage), 06 Sep 2022 (Second Stage)
[105] HORIZON-CL6-2021-FARM2FORK-01-12: Total funding: 11 Mio EUR, 11 Mio per project, 1 project. Deadline: 01 Sep 2021
[106] HORIZON-CL6-2021-CIRCBIO-01-05: Total funding: 12 Mio EUR, 6 Mio per project, 2 projects. Deadline: 01 Sep 2021
[107]HORIZON-CL6-2022-CIRCBIO-02-04-two-stage: Total funding: 6 Mio EUR, 6 Mio per project, 1 project. Deadlines: 15 Feb 2022 (First Stage), 01 Sep 2022 (Second Stage)
[108] HORIZON-CL6-2021-ZEROPOLLUTION-01-10: Total funding: 11 mio EUR, 5,50 Mio per project, 2 projects. Deadline: 01 Sep 2021

The **REDWine** project will demonstrate the technical, economic and environmental feasibility of using the CO2 rich gas generated during the red wine fermentation and winery liquid effluent to support the production of Chlorella biomass and extracts. The **SCALE** project (2021-2025) will build and operate a first-of-its-kind flagship plant producing ingredients with high nutritional value derived from the untapped microalgae diversity, for food, food supplements, feed and cosmetics sectors, through economically-sound processes and in an environmentally friendly way. **ALEHOOP** project (2020-2024) will demonstrate - at pilot scale - the feasibility of recovering low-cost dietary proteins from algae-based and plant residual biomass sources, namely seaweed and the by-products of vegetables production using biorefineries. **MULTI-STR3AM** project (2020-204) will develop a sustainable multi-strain, multi-method, multi-product microalgae biorefinery integrating industrial sidestreams to create high-value products for food, feed and fragrance. **NENU2PHAR** project (2020-2024) will develop a viable sustainable and biodegradable alternative to the existing petrochemical-based plastic.

European Maritime and Fisheries Fund (EMFAF) has funded a number of algae-related projects. These projects cover a range of different algae related topics and target different ways to promote the sustainable algae sector in the EU. For example, the AlgaeDemo[109] project aims to demonstrate large-scale seaweed cultivation at open sea and quantify the environmental effects of seaweed cultivation. The Biogears[110] project supports the eco-friendly offshore aquaculture sector by developing prototypes of biogears for use in the mussel and seaweed sector. To promote the sustainable production of biopesticides for agriculture produced from microalgae biomass, EMFAF funds the innovative ALGAENAUTS[111] project. The objectives of the KELP-EU[112] project are to enable the EU blue circular economy through innovative, sector-leading seaweed biorefinery. EMFAF funded Algama[113] to launch a project named 'Seafood Algternative' aimed at producing fish substitute from algae to develop the algae sector and to preserve marine life. Additionally, the ULVAFARM [114] project was funded to promote large scale sea cultivation of green seaweed. Besides, the AFRIMED [115] aims to develop, implement and promote a protocol to restore damaged pl forests in the Mediterranean Sea.

EIT Climate-KIC is a Knowledge and Innovation Community (KIC), working to accelerate the transition to a zero-carbon, climate-resilient society. To achieve above Climate KIC features innovative algae start-ups (e.g. Swedish algae factory[116]), success stories (Microalgae biorefinery 2.0 project[117]) or innovations (MiAlgae project[118])

EIT Food accelerates innovation to build a future-fit food system that produces healthy and sustainable food for all. EIT Food invests in projects, organisations and individuals that contribute to the healthy and sustainable food system. It unlocks innovation potential in businesses and universities and create

[109] Available at: AlgaeDemo
[110] Available at: Biogears
[111] Available at: Algaenauts
[112] Available at: Kelp-EU
[113] Available at: Algama foods
[114] Available at: ULVAFARM
[115] Available at: AFRIMED
[116] Available at: Climate-KIC
[117] Available at: Microalgae Biorefinery project
[118] Available at: MiAlgae project

and scale start-ups to bring new technologies and products to market. It also equips entrepreneurs and professionals with the skills needed to transform the food system, and educate and inspire the next generation. The forthcoming 2022 call, among others, includes the focus area **Sustainable aquaculture** aiming to promote new emerging sustainable production systems and aquaculture species and will cover adaptation of existing systems to new species or production of species in currently underexploited areas e.g. to scale up of systems for production, harvest, and processing of **seaweed**.

- Innovative food from marine and freshwater ecosystems[119]
- Filling knowledge gaps on nutritional, safety, allergenicity and environmental assessment of alternative proteins and dietary shift[120]
- Novel, non-plant biomass feedstock for industrial applications[121]
- Photosynthesis revisited: climate emergency, "no pollution and zero-emission" challenge and industrial application[122]
- Environmental services: improved bioremediation and revitalization strategies for soil, sediments and water[123]

5.1.3. Strategic guidelines for the sustainable development of EU aquaculture

The updated "Strategic guidelines for the sustainable development of EU aquaculture" (2021)[124], include recommendations for the development of alternative aquaculture and food systems, incl. algae, in multi-annual national strategic aquaculture plans for the next period (2020-2030) and simplification of administrative procedures, mostly regarding permit application processes. The Strategic Guidelines have identified the challenges and obstacles for algae production in the EU due to complex and not harmonised legislation and propose solutions for national countries to overcome these. The EMFAF programmes will support Member State's efforts to develop sustainable aquaculture, including alternative aquaculture sectors, in line with the EU strategic guidelines during the 2021-27 programming period. The programmes' strategy and actions are assessed to ensure they address the specific needs of the sector and for consistency with Member states' multiannual national strategic plan, as aligned with the EU strategic guidelines.

The suggested solutions include: simplification, streamlining and harmonising, where possible, of legislation and administrative guidance on aquaculture for new licences or licence renewals; a 'one-stop-shop' system for aquaculture licences; longer-term licensing, include an obligation to monitor report data, and sanctions for non-compliance, including licence revocation.

Strategic guidelines have also stressed the importance of coordinated spatial planning principles and have listed a scope of topics the planning has to consider for algae aquaculture:

[119] HORIZON-CL6-2022-FARM2FORK-02-05-two-stage: Total funding: 18 mio EUR, 6 Mio per project, 3 project. Deadlines: 15 Feb 2022 (First Stage), 06 Sep 2022 (Second Stage)
[120] HORIZON-CL6-2021-FARM2FORK-01-12: Total funding: 11 Mio EUR, 11 Mio per project, 1 project. Deadline: 01 Sep 2021
[121] HORIZON-CL6-2021-CIRCBIO-01-05: Total funding: 12 Mio EUR, 6 Mio per project, 2 projects. Deadline: 01 Sep 2021
[122]HORIZON-CL6-2022-CIRCBIO-02-04-two-stage: Total funding: 6 Mio EUR, 6 Mio per project, 1 project. Deadlines: 15 Feb 2022 (First Stage), 01 Sep 2022 (Second Stage)
[123] HORIZON-CL6-2021-ZEROPOLLUTION-01-10: Total funding: 11 mio EUR, 5,50 Mio per project, 2 projects. Deadline: 01 Sep 2021
124 Available at: Strategic guidelines for the sustainable development of EU aquaculture

1. The development of offshore algae farming, special areas for organic aquaculture and the integration of suitable aquaculture activities into protected areas, e.g. Natura2000;
2. The development of combined forms of aquaculture, algae with mussels and fish – IMTA, and seek for synergies and multi-use of space at sea, e.g., combining offshore wind parks and seaweed.
3. Promote algae (micro- and macro-algae) ecosystem services including in ponds and wetlands;
4. The adaptation of algae cultivation to climate change and mitigation of climate change impacts (e.g. carbon capture)

5.1.4. Algae business support mechanisms

The Commission have developed certain business support mechanisms where algae industry could benefit from. Two of the existing ones are outlined below

BlueInvest is up and running and aims to boost innovation and investments in sustainable technologies for the blue economy, by supporting readiness and access to finance for early-stage businesses, SMEs and scale-ups. It is enabled by the European Maritime and Fisheries Fund. Among other actions, Blue Invest has compiled a project pipeline that currently lists 12 micro- and macroalgae related projects[125]. BlueInvest organises regular pitching events for SMEs in front of investors to increase the chances of getting funding. Algae projects have been featured quite remarkably e.g. the BlueInvest Info day 28 March 2022[126] includes pitches of 4 algae companies and annual the Algaeurope 2021 conference[127] included the BlueInvest session with pitches of 5 algae companies.

Aquaculture Assistance Mechanism (2022-2024) will support in the implementation of the EU strategic aquaculture guidelines by providing logistic, administrative and technical support and by enhancing cooperation between Member States and stakeholders for the development of sustainable aquaculture in the EU (2021-2030). This includes the support to the seaweed aquaculture and to the promotion and development of the Integrated Multi-Trophic Aquaculture in the EU Member States.

5.1.5. The European Commission's Knowledge Centre for Bioeconomy

The Knowledge Centre for Bioeconomy[128] is a European Commission initiative on better knowledge management for policymaking on the bioeconomy. It is coordinated by the Commission's Joint Research Centre (JRC). It pulls together knowledge and expertise on different elements of the bioeconomy, including **algae**[129] and from different sources in order to assess the status, progress and impact of the bioeconomy and support science-based policy making.

5.1.6. Algae related studies and projects

Apart from the EU4Algae, mentioned above, some other studies contribute to the development of algae sector (non-exhaustive list):

[125] Available at : BlueInvest algae related projects
[126] Available at: BlueInvest info day pitches
[127] Available at: BlueInvest session pitches
[128] Available at: https://knowledge4policy.ec.europa.eu/bioeconomy
[129] Available at: https://knowledge4policy.ec.europa.eu/bioeconomy/topic/algae-biomass_en

1. **Shellfish, Algae and Nutrients** (2022-2023/4) will assess the potential of shellfish and algae to recycle nutrients and to estimate the greenhouse gas emissions generated by their production, will develop digital maps that must provide complete coverage of EU seas.
2. **Algae & Climate** (2022-2023) will estimate the nutritional yield of various algae species, the proportion of an animal feed that can be displaced by algae, the costs and greenhouse gas emissions of algae production benchmarked against land-based crops, the land area that could be used for inland production of algae.
3. The **JRC's Biomass Mandate**[130] aims to provide data, models and analyses on EU and global biomass supply and demand and its environmental, social and economic sustainability. It covers all sources of biomass, including from **algae** and all uses.

5.1.7. Ocean literacy and awareness raising

Supported by the European Commission, the **European Ocean Coalition (EU4Ocean)**[131] connects diverse organisations, projects and people that contribute to **ocean literacy** and the sustainable management of the ocean. The coalition is made up of three components: a **Platform** for organisations and individuals engaged in Ocean Literacy initiatives, a **European Youth Forum for the Ocean** and a **Network of European Blue Schools**. During its third year of the implementation, EU4Ocean is becoming a reference forum for Ocean Literacy in Europe. Public engagement in Ocean related themes e.g. in schools, exhibitions, conferences etc. have been existing for years, but now there is an umbrella for European Ocean Literacy. Gathering many actors in Europe (research organisations, youth, schools etc.), the benefit for the algae sector is tapping into a huge network of local "influencers", and people working with the end-users of algae products. Algae offers huge opportunity for food, feed, pharmaceuticals, biopackaging, etc. but these opportunities often are not known to civil society. Co-developing awareness and dissemination projects with these local actors (translators) would benefit the algae sector in the long-term."

Taste the ocean[132] is a campaign from the EU with top chefs across Europe to encourage consumers to buy and enjoy sustainable fish and seafood. Cooking with seaweed will be explored during the next episodes of the #TasteTheOcean campaign.

Supported by the European Commission, **Euronews** have monthly **''Oceans''** episodes featuring many Blue economy and ocean related aspects. Two episodes[133] so far have already featured algae as a sustainable future alternative.

5.1.8. Algae related industry standards

European Standards are needed to assure safety of algae products, to ensure that products and materials are tailored-made for their purpose, promote the interoperability of products and services, facilitate trade by removing trade barriers, promote common understanding of a product etc. To develop algae-

[130] Available at: https://knowledge4policy.ec.europa.eu/projects-activities/jrc-biomass-mandate_en
[131] Available at: | Maritime Forum (europa.eu)
[132] Available at: Taste The Ocean (europa.eu)
[133] Available at: Will seaweed save the world? | Euronews

related standards the European Committee for Standardization (CEN)[134] has established a dedicated technical committee **CEN/TC 454 – Algae and Algae products**[135]. The committee has a work in progress and so far has delivered a range of industry **standards**[136] and **technical reports**[137]. Further development of necessary standards is important for successful development and scaling up of the algae industry and in particular a common harmonisation with International Standardization Organization (ISO), FAO and other International associations (ABO, ISAP) on that matter.

5.2. Coordinated additional enablers – new proposed policy actions

Annex 1 lists additional proposed policy actions taking a systems approach, i.e. addressing in parallel different levers to boost a sustainable EU algae sector. These are cost-effective actions bucketed by themes around improvement of the governance framework, improvement of business environment, social awareness and acceptance, knowledge, research, technology and innovation as well as technology transfer.

These actions are meant to be performed in parallel. They will require additional resourcing to be delivered and implemented successfully (funding and staffing), and most importantly to be piloted in a coordinated fashion so the compendium of algae actions contributes to a meaningful, integrated objective under the EU Algae initiative.

6. Conclusions and recommendations

A thriving EU algae industry may become a key contributor to the European Green Deal and its flagship initiatives: decarbonisation, zero pollution, circularity, biodiversity, sustainable food. The sector may also become a source of inspiration for other industries to become more regenerative, innovative and socially exemplary, with thousands of high quality jobs created, for instance, in coastal communities. Recent Commission-led initiatives like the new approach for a Sustainable Blue Economy and the EU Strategic Aquaculture Guidelines recognize the potential of algae.

According to the evidences provided in this document, algae sector has a huge potential in the EU. To unlock the algae potential there is a need to upscale regenerative algae cultivation and production throughout the EU, and to develop and mainstream the markets for food and non-food algae applications. Once the above is achieved the EU security of supply of algae biomass, strategic autonomy from imports and smooth functioning of the algae sector will be ensured.

However, the broad range of problems (outlined in the heading 2) limits development of EU algae sector.

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[134] CEN is an association that brings together the National Standardization Bodies of 34 European countries. CEN provides a platform for the development of European Standards and other technical documents in relation to various kinds of products, materials, services and processes.

[135] Available at: CEN/TC 454 - Algae and Algae Products

[136] Terms and definitions (EN 17339), Identification of the biomass of microalgae, macroalgae, cyanobacteria and Labyrinthulomycetes - Detection and identification with morphological and/or molecular methods (EN 17477), Methods for the determination of productivity of algae growth sites (EN 17480)

[137] Specifications for chemicals and biofuels sector applications (CEN/TR 17739), - Food and feed applications: General overview of limits, procedures and analytical methods (CEN/TR 17559), Specifications for cosmetic sector applications (CEN/TR 17611), Specifications for pharmaceutical sector applications (CEN/TR 17612), Cosmetic applications (CEN/TR 17611:2021), Pharmaceutics applications (CEN/TR 17612:2021)

A number of ongoing actions (listed in sub-heading 5.1 above) contribute to a certain extent to the development of the EU algae sector, but not in a coordinated manner. A coordinated approach is needed where existing actions are supplemented by additional policy actions taking a systemic approach.

Specific attention should be devoted to proactively addressing potential concerns of EU citizens regarding environmental sustainability of large scale-seaweed cultivation and food safety of algae products (contaminants, iodine, bromine, etc).

Recommendation:

Based on the evidences outlined above, it is recommended that the Commission elaborates and adopts a cross-cutting EU Algae Initiative that (1) takes into account and brings forward best available science, knowledge, data and practices; (2) considers and proposes realistic enablers for algae sector to take off, (3) integrates existing algae-related actions; (4) addresses potential environmental and food safety concerns, (5) raises awareness and acceptance of algae products in the EU.

1. ANNEX 1: Proposed policy actions with explanations

Table below provides a list of the suggested policy actions structured around 4 action areas:

***Action area 1*: Governance framework and legislation**

Guidelines		
Policy actions proposed	*Implementation*	*Responsible body*
1. The Commission in close collaboration with relevant stakeholders will develop a **new algae farmers toolkit**	Why: a centralized toolkit set by the EU are useful for new algae farmers (those who start new business or intend to change from e.g. fishing activities to algae cultivation) and to better understand development of new regenerative algae production farms. The toolkit will be a practical guide for the development of new regenerative algae farms throughout the entire value chain, including cultivation, harvesting, processing, logistics, labelling of algae and algae based products as well as licensing and permits, existing standards, Best Available Technologies (BAT), good practices and other relevant aspects for seaweed, microalgae and cyanobacteria. How: 1. By contracting the establishment of a new algae farmers toolkit 2. Tailoring the toolkit to each EU marine region	European Commission (MARE), Industry

National procedures and governance		
Policy actions proposed	*Implementation*	*Responsible body*
The Commission will call Member States authorities to simplify **national licensing procedures** and **governance** for algae cultivation	Why: Current licensing procedures often are fragmented, complex, labour-intensive and lengthy. Simplification is needed to facilitate and speed up setting of algae cultivation, integrated multi-trophic aquaculture, multi-use or marine sites and co-exploitation of farming sites by multiple entities. Besides, improved transparency and efficiency of the procedures is needed. How: by (1) making inventory of existing national and regional algae licensing and permits procedures across the Member States; (2) setting a roadmap with recommendations for necessary governance changes; (3) implementing necessary governance (or legal changes) tailored to the specific Member States and maritime regions.	Member States, European Commission

	Commission will support this process by compiling best practices[138] and existing procedures across the Member States with the aim to streamline and harmonise national regulations.	
2. The Commission will work with Member states to facilitate access to marine space, identify optimal sites for seaweed farming and include seaweed farming and sea multi-use in the **Maritime Spatial Plans**	Why: To identify gaps and enabling factors for seaweed farm development in multi-use settings and to consequently facilitate establishment of such farms in multi-use of marine space settings, which is currently difficult. Use of existing monitoring data to identify suitable sites for macroalgae and multi-use systems. How: 1. As a follow-up to the current study of the EU MSP Assistance Mechanism on how Member States have dealt with (low-trophic) aquaculture and sea multi-use in their Marine Spatial Plans to commission a follow-up analysis (study) on how/whether seaweed farming is considered and supported in national MSPs (e.g. via the Blue Forum[139] activities). 2. Based on the new acquired knowledge e.g. findings of "Shellfish and Algae" study, analyse optimal conditions, develop criteria for optimal sites to include into national MSP plans.	European Commission (MARE) Member states

Standards		
Policy actions proposed	*Implementation*	*Responsible body*
3. The Commission will work with the European Standardization organization (CEN) to develop standard test, quantification and extraction methods for algae ingredients and contaminants	Why: Algae contain a range of useful active elements in the biomass, but their detection, quantification (e.g. chlorophyll) and consequent extraction (e.g. lipids) is challenging due to large range of testing methods. Food safety are some of the key concerns of European consumers as regards algae related products. A European standard is needed to establish a unified method to detect contaminants (incl. biofouling), iodine and heavy metals. How: By developing European standards with test, quantification and extraction methods for active ingredients in algae such as phycobiliproteins, fatty acids, polysaccharides, amino acids, proteins, lipids, vitamins, for detection and quantification of contaminants.	European Commission (ENER, MARE) CEN

[138] E.g. Seaweed for Europe Licensing Toolkit

[139] In particular, via the one of the Blue Forum key themes - Blue Life (use of the ocean for sustainable farming, fishing, biomass production, ocean life protection, sustainable human activities at sea)

4. The Commission will work with CEN to develop **algae biofuel standards** and a certification methodology for algae-biofuel products to be used in various transport sectors, particularly heavy road, aviation and maritime transport;	Why: Algae contain active elements in the biomass, like lipids, that makes them feasible for producing biofuels. A European standard is needed to establish unified methods for extracting biofuels and developing relevant certification methodology. How: By developing relevant European standards within the *CEN/TC 454 - Algae and algae products.*	European Commission (ENER, RTD), CEN

EU legislation		
Policy actions proposed	*Implementation*	*Responsible body*
5. The Commission will assess the market potential, efficiency and safety of algae materials when used in **fertilising products** and the need for amend Regulation (EU) 2019/2009 on EU Fertilising products to include algae materials	Why: (1) to facilitate use of materials recovered from algae grown on waste[140], or from algae which have themselves a waste status, in production of EU Fertilising Products[141] (2) to allow the use of certain cyanobacteria in the production of EU fertilising products How: 1. To clarify status of waste-grown algae whether algae grown in wastewater, or with waste input (e.g. off gas CO2 or ammonia) are considered to be a "waste" or "product" and identify "end of waste criteria" for algae with waste status 2. Review the exclusion of cyanobacteria [in Component material category (CMC) 2] in the regulation 3. Clarify the status of algae collected from the sea and identify "end of waste criteria" for algae collected from the coast[VI]. Develop "end of waste" criteria for recovered materials used in the production of fertilising products.	European Commission (GROW)

***Action area 2*: Supporting the improvement of business environment**

[140] At present, mechanically processed algae (no chemical processing or extraction) can be used under CMC2. Algae material collected from nature and which have waste status, e.g. floating algae removed from a canal, algae filtered from eutrophic waters, seaweed collected from beaches for tourism could be considered CMC 2 if they are harvested in such conditions as to contain negligible impurities. Algae can be used as input material to compost CMC3 and digestate CMC5. Four taxa of algae are currently authorised under CMC7 (biostimulants), but only if not processed (other than drying, freeze-drying) and potentially other taxa of algae or micro-algae could be added to this list. Materials processed from algae can be used in CMC1, but not if the algae is classified "waste". However, the status under CMC1 of materials processed from algae which are grown on waste streams (fed by nutrients from sewage, manure, etc.) is unclear.

[141] 'Fertilising product' means a substance, mixture, micro- organism or any other material, applied or intended to be applied on plants or their rhizosphere or on mushrooms or their mycosphere, or intended to constitute the rhizosphere or mycosphere, either on its own or mixed with another material, for the purpose of providing the plants or mushrooms with nutrient or improving their nutrition efficiency

Policy actions proposed	Implementation	Responsible body
6. The Commission will work with algae industry to examine algae market and propose **market stimulating mechanisms** to support and promote the technology transfer from research to market	Why: For algae sector to take off, a targeted support is necessary to tackle existing bottlenecks and facilitate procedures, access to funding, to obtain necessary knowledge, to develop technologies, boost innovation etc as well as support technology transfer from research to market How: the Commission will work with industry (e.g. via the EU4Algae platform) to identify feasible market support mechanisms and promote their implementation	
7. The Commission will prepare specific guidance to promote replacing **fish-based feed with algae-based feed**	Why: 18 mio tons of wild fish is processed into fish oil/meal for animal and fish feed, which algae may (partly) replace. How: The following actions could be examined as part of potential policy research/study: (1) Introduction of ambitious EU forage fish dependency ratio (FFDR) for aquaculture, combined with requirements to maintain the nutritional and health quality of the farmed fish, and respect the environmental objectives of the EU's 2030 Biodiversity Strategy and Farm-to-Fork Strategy. (2) Introduction of financial incentives for the uptake of algae-based fish feed[142]. (3) Make the "ALARA (as low as reasonably achievable)" principle more ambitious, which is essential to further lower the EU limit values for dioxins and Polychlorinated biphenyls (PCBs). (4) Introduction of minimum blend-in targets for sustainably-sourced, non-fish-derived EPA + DHA[143] in fish feed. (5) Introduction of algae-based fish feed as a sustainable activity in the future Sustainable Finance Taxonomy for sustainable fisheries and aquaculture (in future revisions).	European Commission, Industry
8. The Commission will work with algae industry and Member States to: • to identify valid and safe **alternatives** for	Why: use of algae for cleaning wastewater from nutrients and recycling of nutrients from algae has big potential but is not well-explored in the EU.	Industry, European Commission (AGRI, MARE,

[142] This can, for example, be done through; a) Introduction of differentiated import duties for imported salmon that is sustainably-sourced (e.g. with an FFDR < 1); b) Removal of tariffs for algae oil; c) Phasing out of subsidies for European forage fisheries while also maintaining a level playing field.

[143] Eicosapentaenoic acid (EPA) and Docosahexaenoic acid (DHA) are omega-3 fatty acids.

use of **nutrients and CO_2 from various sources** for microalgae cultivation and **organic certification** • **promote extraction of nutrients from algae biomass** • **support life cycle assessment of environmental and climate impact** of algae cultivation and production by considering the development of **monitoring methodologies and indicators** to measure environmental impact and sustainability from seaweed cultivation	Why: There is currently limited options of using different sources of nitrogen, phosphorus and CO2 to use as fertilisers in closed microalgae cultivation processes. Why: A quality accounting of the marine ecosystem services[144] and potential impact of seaweed cultivation on these ecosystems will help to track the performance of the sector towards achieving its sustainability goals[145]. Algae cultivation, if done properly, has a regenerative impact on the surrounding ecosystems. How: To clarify regulatory questions related to the "waste" status of inputs that are used to feed algae. Algae production can ensure synergy between wastewater treatment and nutrient removal, carbon capture and use of waste heat, and production of valuable materials and biomass energy. But only if regulatory questions are clarified (especially relating to waste-status of inputs used to "feed" algae)[59]. Consider the opportunities to develop test sites for removal of nutrient from side-streams. Demonstrate industrial symbiosis concepts to pilot phase, exchanging and recycling carbon, nutrients and energy among industrial activities (to consider existing best practices e.g. Kalundborg and Sötenas Symbiosis centres). To consider floating technologies for the cultivation of emergent macrophytes and halophytes as one option to remove nutrient from eutrophicated waters. Study the impact of floating wetlands not only on nutrient removal but also on other pollutants such as the bacterium *Escherichia coli*[146]. How: Based on the current work in progress (EGTOP, EABA working groups) and in close collaboration with relevant stakeholders (e.g. DG AGRI), EU4Algae to prepare recommendations for economically and legally viable nutrients and CO2 alternatives for organic microalgae cultivation	SANTE), EM ODNET

[144] Ecosystem services are defined as the gains acquired by humankind from surroundings ecosystems

[145] The Commission is going to propose the revision of the Regulation on European Environmental Economic Accounts (EEEA) to expand its coverage to include a new module on natural capital accounting, fully consistent with the UN framework. This is in line with the recommendation of the European Court of Auditors and the recent mid-term review of European Strategy for environmental accounts (ESEA) 2019-2023

[146] To consider exisiting studies such as innovation on the integration of a microalgae photobioreactor with macrophytes floating wetlands for waste water treatment (https://patents.google.com/patent/WO2015092093A1/en) and the bioenergy use of the biomass from floating wetlands for wastewater treatment has been also investigated (https://biomasscarbonpositive.eu/).

	How[147]: 1. To contract a study compiling existing monitoring good practices, methodologies and indicators of potential environmental impact from seaweed cultivation. Develop a system to ensure environmental monitoring practices and setup standards for obligatory monitoring and data for new farms	
9. The Commission will fund pilot project(s) supporting **reorientation of fisher's careers to regenerative ocean farming**	Why: Steady decline of fishing opportunities and degradation of marine aquatic habitats could be turned around, when fishers could switch from extracting marine activities to marine farming and marine habitat regeneration. This would provide new career and employment opportunities in coastal regions and contribute to regeneration of coastal marine habitats and fish resources. How: To contract pilot projects and to provide financial, training and infrastructural advice mechanisms to aid in the organization of the pilot projects through the existing funding mechanisms, such as EMFAF and Horizon Europe.	European Commission (MARE)
10. The Commission will enhance the targeted **support to innovative SMEs** and projects in the algae sector through the scaled-up activities of the **BlueInvest platform**	Why: Many algae start-ups and SME would benefit from public financing to de-risk their operations and attract private investors. Also, algae entrepreneurs would benefit from mentoring and acceleration/ incubation services to stress test their business models and help them professionalise their fundraising and access networks of private investors. How: This may include the delivery of market intelligence and strengthening capacities of investors to mobilise capital for high potential businesses/technologies, new coaching packages on sustainability for SMEs, and technical assistance to accelerate the closing of deals.	European Commission (MARE)
11. The Commission will facilitate cooperation at **sea basin and macroregional scale** by promoting innovative interregional	Why: Algae cultivation is currently negligent in the EU and its development needs to be supported. Growing conditions, species, national procedures etc are different across EU maritime regions and countries. Improved collaboration at the	European Commission (MARE)

[147] Improving Microalgae Research and Marketing in the European Atlantic Area: Analysis of Major Gaps and Barriers Limiting Sector Development. Judith Rumin, Raimundo Gonçalves de Oliveira Junior, Jean-Baptiste Bérard, and Laurent Picot ; Summary of results and policy recommendations for cultivation of algae in North West Europe for energy production (and potentially other non-energy products) - Arvaniti, Efthalia., 2016. Summary of Results and Policy Recommendations for Cultivation of Algae in North West Europe for Energy Production (and Potentially Other Non-Energy Products. EnAlgae. Available at: https://edepot.wur.nl/424045

partnerships (e.g. Blue Bioeconomy with focus on algae/shellfish), through the implementation of **Smart Specialisation Strategies and the dedicated 3S platform on Sustainable Blue Economy**	macroregional scale would help to better coordinate algae sector development efforts. How: By developing Smart Specialisation Strategies	

Action area 3: **Closing knowledge, research, technological and innovation gaps**

Knowledge		
Policy actions proposed	*Implementation*	*Responsible body*
12. The Commission will integrate algae sector knowledge into the **EU aquaculture assistance mechanism**	Why: As part of the proposed dedicated EU Aquaculture Assistance Mechanism, it is important to distinguish algae sector knowledge to facilitate easy access to information for relevant stakeholders, including Member States authorities. How: By implementing algae as an important aspect of the EU aquaculture assistance mechanism, to be, for example, included under: • Pillar 1 (website development): include a chapter dedicated to algae; • Pillar 3 (knowledge base development): consider a prominent place for algae; • Pillar 4 (technical expertise): consider a short background paper on algae; • Pillar 5 (trainings, conferences and workshops): algae topic (e.g. IMTA) to be included at one of the planned events	European Commission Aquaculture Assistance Mechanism
13. The Commission and relevant stakeholders will perform a study to gather better knowledge on the seaweed climate change mitigation opportunities (e.g. via seaweed cultivation and seaweed forest restoration) and role of	Why: Algae's potential to sequester carbon can potentially benefit the business case for algae production if carbon sequestration can be rewarded financially or otherwise. Why: algae use soluble carbon, phosphorus and nitrogen to grow, thus removing them from natural environments and consequently reducing ocean eutrophication and acidification. But the development of environmental services and market-based instruments is limited by the lack of solid data and knowledge as well as monetarization methods for services in relation to eutrophication and acidification.	European Commission, Member States

seaweed as blue carbon sinks	How: By contracting a study to examine the following: ● improving policy and legal arrangements to incorporate blue carbon as natural climate solution ● reviewing and investigating financial approaches and accounting tools for emissions and sequestration of greenhouse gases by algae and how it is affected by cultivation and use ● improving stewardship by incorporating indigenous knowledge and values; ● clarifying property rights; developing technologies (e.g. sensors) and computational tools (e.g. artificial intelligence, block-chain) for measuring blue carbon sequestration at low cost; and improving our understanding of lesser-known aspects of the blue carbon cycle (e.g. seaweed contributions). How[148]: To contract a study, preferably accompanied with real life data gathering from algae production systems, to 1. Obtain data on how much carbon and nutrients are taken up by seaweed during their growth process. Study shall gather information on available carbon sequestration projects[149] and data on exact carbon amounts sequestered in seaweed aquaculture and make scenarios based on life-cycle approach to showcase impacts. 2. Explore strategies for recycling industrial side-streams containing soluble mineral nutrients, like nitrogen and phosphorus e.g. from fermentation, food production, aquaculture, or anaerobic digestion activities, and also reusing captured CO2 produced by industrial activities, e.g. power plants, CHP, cement industry, food fermentation etc., to "feed" / "fertilise" algae production. 3. Explore the possibility to create a CO2 framework that contains mandates and economic and other incentives supporting development and deployment of algae-based technologies that upcycle industrial CO2 for production of	

[148] Based on the existing EU initiatives on Sustainable carbon cycles and Certification of carbon removals. Available at: Sustainable carbon cycles (europa.eu)

[149] Oceans2050 and Pilot projects like LIFE BIORest to establish norms to use algae for bioremediation; create regulatory framework to encourage the same across the EU

	energy, materials and food. Examples for better regulation of CO2 emissions include introduction of a carbon tax and a functional EU ETS. 4. Explore the potential to develop nutrient trading systems that include nutrient uptake by algae by commissioning a review study, examining practices such as the NutriTrade platform. 5. Develop a study to analyse existing and proposed (if any) compensation mechanisms and possible business models, and also assess the role of private sector and NGOs and get them involved, e.g. municipalities, industry, foundations.	
14. The Commission, in collaboration with research and academia will prepare guidance for a EU-wide approach for conserving seaweed biodiversity by maintaining and documenting European **seaweed strains in a centralized biobank's network or databank**	Why: Transition from decentralized, often poorly documented algae stock cultures to a centralized, easily accessible and open access databank will help promote food security and biosecurity, conserve biodiversity under the threat of climate change and prevent the extinction of local strains. How: By launching a study or project 1. To identify main organization(s)[150] able and willing to become centralized seaweed biobank organization (including IT capacity plus a seaweed scientists working together) 2. To elaborate a pathway of setting up a centralized network made up of regional biobanks, connected in a network to the centralized databank. The biobanks could be organized by regions (e.g. Baltic, North Sea, Iberian Sea, Norwegian Sea, Irish / British, Arctic, Mediterranean). 3. To follow two related objectives: (1) biobanking for applied purposes e.g. cultivation (at sea, in tanks), research, (2) Restocking, biodiversity conservation – identifying species and areas of high risk and major ecological importance[151]	European Commission Academia

[150] To consider the existing ones e.g. Alfred Wagner Helmholtz Institute, Microbial Resource Research Infrastructure

[151] Other specific tasks in establishing centralized biobanks may include:

- ➢ To consider establishing new biobanks that specifically address the following:
  - i. Taxa that are particularly difficult to cultivate and need specialized cultivation/cryopreservation methods (biodiversity aspect)
  - ii. Taxa that are under threat of climate change or have been identified as highly important for ensuring food security
- ➢ To consider establishing specific experts working groups on
  - i. identifying taxa of commercial interest
  - ii. On establishing a conservation plan of seaweed species and regions of high (e.g. due to climate change) and major ecological importance (eg by identifying regions of enhanced genetic diversity or species richness) and to promote isolation and preservation of strains in regional biobanks instead of local culture collections.
- ➢ To elaborate methods to follow in order to standardize and promote biobanking of seaweed strains.
- ➢ Identify EU Regulations and national governance frameworks to implement the Nagoya Protocol provisions into the database (requires legal advice)
- ➢ To identify possible incentives for scientists to contribute to the seaweed biobanks
- ➢ To identify potential educational, youth engagement and awareness raising initiatives

15. subject to European Food Safety Authority advice start discussions on the establishment of **maximum levels of contaminants and iodine in algae** and/or the adoption of a new monitoring Recommendation for algae species for which insufficient occurrence data for contaminants are available, in order to allow the establishment of maximum levels[152]**.**	Why: currently no maximum levels of contaminants and iodine and algae are set as well as no unified monitoring procedures are in place. This leads to very fragmented situation due to insufficient occurrence data in the Member states. How: when better monitoring data are available, proper examination and discussions with engagement of appropriate stakeholders will help to establish maximum levels and possibly adopt a new monitoring regulation	European Commission, Member States
16. The Commission and Member States will study existing monitoring schemes and available data of **seaweed harvesting from wild and beachcast** on the EU coasts	Why: Wild harvesting of seaweed and beach-cast collection are important business activities which will remain a good source of biomass and economic opportunity for various applications, knowledge development, economic activities e.g. combined with coastal tourism, stewardship for native species and biodiscovery. However, wild harvesting needs to be properly monitored to remain sustainable and even regenerative for natural ecosystems. How: To study and evaluate existing wild seaweed harvesting and beached seaweed collection practices, species, marine regions, data monitoring schemes, etc. The study should foster a joint interpretation of targets set by relevant EU Directives (Natura 2000, WFD, MFSD etc.) with regard to "harvesting" marine resources (e.g. macroalgae, beach cast). The study will provide conclusions and recommendations for sustainable harvesting and beachcast collection of seaweed, broken down by species, marine regions, collection/harvesting methods and valid mechanisms to gather real data on harvested and collected seaweed amounts.	European Commission

Research

[152] In view of the health risks related to the possible occurrence of high concentrations of heavy metals in certain algae species, the discussions on maximum levels and monitoring will also be linked to discussions on the need for consumption advice regarding the consumption of certain seaweed species

Policy actions proposed	*Implementation*	*Responsible body*
17. The Commission will support via Horizon Europe and other EU research programs the development and innovations on new and improved **algae processing systems and novel production methods for high-value compounds traditionally sourced from algae** (e.g. biorefineries, precision fermentation, cell-free systems), processing algae into circular biobased products for multiple applications	Why: The potential of biorefinery to process the algae in (multiple) valuable products is not fully used. Lab-scale experiments with biorefineries are often not up scaled and never realize full transition from experimental research to commercial uptake. Microalgae cultivation in photobioreactors has high potential but to scale up the production, further costs reduction and energy saving technologies are needed. How: By taking stock of existing R&I projects to identify specific development and innovation needs in algae processing that include for instance: 1. Logistics, pre-processing/pre-treatment 2. Lessons learned from cross-cutting macro- and microalgae value chains. 3. Develop concepts to scale up biorefineries on boats on de-centralised/centralised processing. 4. Robust systems that can handle seasonal fluctuations and multiple seasonal streams of biomass. 5. Processing of seaweed beach-cast and other microalgae for production of biogas and digestate through anaerobic digestion. 6. Promote open access pilot-sites for prototyping and testing at scale and couple them with SME innovation vouchers and mentoring services e.g. Smart Pilots, Alliance etc. 7. To look at the energy-saving technologies and strategies, as well as scale up and cost reduction of photoautotrophic production systems in photobioreactors.	European Commission
18. The Commission together with the Member states will support via Horizon Europe and other EU research programs the development of improved scalable **algae cultivation systems** (e.g. IMTA, multi-use, offshore cultivation, photobioreactors and	Why: Various innovative algae cultivation systems are considered by the sector but lack of evidence on functionality and feasibility (for example high costs and technical adaptability to off shore conditions) hamper use of these. How: By examining national policies and by identifying specific research and development needs, for instance, to be funded via Horizon Europe, with specific attention for 1. Development of scalable technical solutions for cultivation and harvesting of macroalgae incl. elevator farming, harvesting, automation and digital solutions, that improve operational management, reduce cost, increase safety (occupational) and quality.	European Commission Member States

algaeponics) or methods (e.g. cellular mariculture, and macroalgae in tanks) contributing to solving current technical constraints of macroalgae and microalgae production systems	2. Innovation Actions focusing on development of large-scale offshore cultivation systems and multi-use systems, building on results of the H2020 multi-use projects, UNITED[153], MUSICA[154]. 3. Innovation actions to investigate site-specific solutions with varying combinations of fish, algae and mussel farming at one site in order to find optimal technical and economical solutions 4. Innovations Actions to support and bring IMTA to the market, building upon projects such as IMPAQT, and algaeponics on land. 5. Research, Development and Innovation actions exploring the concept of cellular mariculture and macroalgae production in tanks. 6. Improvement of microalgae production systems and development of new systems. 7. Promote open access pilot-sites for prototyping and testing at scale and couple them with SME innovation vouchers in exchange of mentoring services concepts that have been implemented in e.g. Smart Pilots[155], Blue Bio Value Accelerator[156] etc.	
19. The Commission will address **algae biofuel-specific** technological and systemic challenges and identify market take up measures in Horizon Europe.	Why: For algae biofuels specific challenges occur based on specific product and market characteristics How: Research and Innovation actions to address specific challenges and opportunities for algae biofuels exist e.g. in the following areas: Carbon fixation and conversion efficiency, harvesting and logistics, cost effectiveness, energy efficiency, socio-economic and environmental sustainability of cyanobacteria/microalgae and macroalgae production systems. This can be supported by market uptake measures and a systemic analysis of challenges and opportunities for algae biofuel uptake in specific transport sectors (e.g. aviation/maritime), and evaluation of necessary financing schemes.	

Data		
Policy actions proposed	*Implementation*	*Responsible body*

[153] H2020 UNITED project: https://www.h2020united.eu/
[154] H2020 MUSICA project: https://musica-project.eu/
[155] Available at: SmartPilots | Interreg Europe
[156] Available at: Acceleration 2021 - Blue Bio Value

20. The Commission will prepare an overview of the **availability of algae-related data** (e.g. production, employment, turnover and other socio-economic data) and issue recommendation regarding **centralising the source** for such data	Why: The availability of good quality data for the algae sector in the EU (production and socio-economic data) is currently limited[157]. A centralized data source consisting of all algae-related data would be useful while conducting research in the field, and is critical in monitoring and evaluating the impact of various measures implemented by the Member States and the European Union to support the development of the algae sector. How: (1) Contract a feasibility study for improving the availability of, and establishing a central source for algae related data (input/output data algae cultivation, production, turnover and employment); (2) Liaise with JRC to leverage current efforts on improving the data for algae and related products across member states collected so far, (3) ensure coordination with the activities undertaken under the Data Collection Framework.	European Commission, Member States

Action area 4: **Increasing social awareness and acceptance**

Towards consumers		
Policy actions proposed	*Implementation*	*Responsible body*
21. The Commission will support raising consumer awareness by: A. doing a **consumer behaviour and preference analysis**[158] of the perceptions of algae-based products; B. launching a fact-based **EU-wide and/or, where relevant, regional or local**	Why: Awareness around application, use, qualities, benefits, potential risks, and potential of algae products among buyers and consumers in the sector is lacking. Action could help in the development of markets for algae food products. How: - To compile an overview of **algae and seafood related communication campaigns** funded/led by the EU by hosting the information on an EU hosted online environment where local and EU-wide communication campaigns are shown; - To support the development and launch multi-media (internet, TV, radio) and multi-lingual campaigns across	European Commission

[157] European Market Observatory for fisheries and aquaculture products (EUMOFA), Data Collection Framework, report on the Community of Practice Workshop: Algae production in Europe: status, challenges and future developments, European Commission's Knowledge Centre for Bioeconomy, JRC Data catalogue (https://data.jrc.ec.europa.eu/collection/id-00363), EUROSTAT's Fisheries and Aquaculture data

[158] E.g. using the Eurobarometer - a collection of cross-country public opinion surveys conducted regularly on behalf of the EU Institutions since 1974.

communication campaign(s) to promote the variety of applications and benefits of algae-based products[159];	the member states to increase outreach towards EU consumers	
22. Raise the sustainability profile of algae-based products in the EU sustainable food labelling framework, including in marketing standards for fisheries and aquaculture products and green public procurement initiatives envisaged as part of the Farm to Fork Strategy.	Why: Algae cultivation processes and algae products are having low or even negative carbon footprint. To move towards zero-carbon EU, there is a need to establish financial support mechanisms to low carbon production as comparing to carbon-intensive production. To establish such mechanisms (e.g. green procurement) there is a need to map good practices in the EU and beyond to inspire national authorities for change. Consumer attitudes towards algae products, how they choose their option from the available possibilities and their level of awareness about the various applications of algae are unknown. Understanding consumer perceptions of seaweed products in order for companies in the sector to respond to these preferences would be key. How: To contract a study to investigate green procurement support mechanisms in the Member States to invest in algae farming projects or subsidize algae products taking into account the regenerative nature of the algae cultivation (reduction of excess nutrients, carbon, improved water quality etc.). To consider also potential of public-private partnerships. To collect consumer data and preference trends[160] and publish the insights on an EU hosted platform (Ex: Potential candidates for hosting include the page on consumer market demands[161] or the page on consumer outcomes[162]). To explore designing and implementing a simulated **online store** for the purpose of testing consumer preferences for algae and algae-based products. This tool will collect and provide data on user choices regarding the variety of product types, origin, presentation, packaging and flavour.	European Commission (MARE), Member States

[159] Could be combined with targeted awareness-raising actions, such as setting up an algae cooking contest to increase consumers' engagement and awareness.
[160] Could be a separate study or collaboration with existing consumer behaviour analysis organisations e.g. Eurobarometer
[161] Available at: Market studies | European Commission (europa.eu)
[162] Available at: Consumer scoreboards | European Commission (europa.eu)

23. The Commission, together with the EU4Ocean platform and Member States will promote awareness raising actions with schools and universities in the area of Blue Bioeconomy and innovative solutions for regenerative aquaculture	Why: Presenting fact-based information related to algae to pupils and young students can help in raising awareness and sparking vocational interest at an early age (15-23 years old). How: For school levels: • organize science symposia (like the European Schools Science Symposium[163]) with focus on algae and related topics; • promote the Handbook for the European Blue Schools[164] to encourage students to pursue projects in algae and related topics; Link blue schools with blue Universities, Zoos, Aquarius etc. and promote algae farming and blue biotechnology, and algaepreneurship as upcoming career sectors. (ERASMUS+ funding on algae and blue bioeconomy?). For university levels: • In-depth programs focusing on innovations around algae production, processing and bio-entrepreneurship/ algaepreneurship can be given at university[165]	Member States, European Commission EU4Ocean

[163] Available at: European Schools Science Symposium
[164] Available at: Handbook for the European Blue Schools.
[165] An initiative in the Mediterranean region that could be supported is BlueSkills initiative from Italy Algeria Maritime Cluster which focuses on capacity building on blue economy topics by collaborating with universities https://ufmsecretariat.org/wp-content/uploads/2019/03/Project-Snapshot-BlueSkills-1.pdf

2. ANNEX 2: STAKEHOLDER CONSULTATION SUMMARY

2.1. Introduction and overview of the consultation strategy

Stakeholder consultation to support EU Algae initiative included public consultations[166] and open public consultation (12 weeks), targeted interviews, stakeholder surveys and 5 webinars to support the EU Algae Initiative.

2.1.1. Consultation scope and objectives

The objectives of the stakeholder consultation were to:

- Collect facts, views and opinions on current challenges in algae production and consumption and options and preferences for resolving them;
- Ensure all voices are heard with adequate representation of all stakeholder groups – industry, public authorities, civil society, research; academia, NGOs, EU citizen etc.
- Gather further information, including roadmaps, policy briefs, studies and analysis of policies, actions and technologies.
- Various consultation stages and actions aimed to obtain a comprehensive stakeholder view on the different policy options and necessary actions to unlock EU algae potential.

For the targeted stakeholder interviews and surveys, the balanced set of stakeholders was established in terms of algae value sectors, types of organizations and geographical regions. The consultation strategy aimed to target different relevant algae sector representatives e.g. suppliers, producers, processors, end-users, research, academia, sector organisations, non-governmental organisations and MS authorities, all major sea-basins e.g. Atlantic, Mediterranean Sea, North Sea, Baltic Sea, Black Sea and main producing Member States e.g. France, Spain, Portugal, Ireland, Germany, Netherlands, Denmark, Belgium etc.

2.1.2. Selection of consultation activities & their accessibility

Consultation activities were structured in a way to have a cascading effect and a possibility to validate the results of previous consultations with the consecutive ones.

Policy actions (laid down in Annex 1) were drafted according to the results of all consultation activities.

A comprehensive consultation of citizens and stakeholders took place as follows:

(1) Feedback on the inception impact assessment of the initiative (21 December 2020 - 18 January 2021) Link

(2) A 12-week public consultation via the Commission's *Have Your Say* Portal took place 19 May 2021 - 11 August 2021

(3) Various targeted stakeholder consultations (first half of 2021) as follows:

- Interviews (19) targeting different sectorial representatives (suppliers, producers, processors, end-users, research, sector organisations and MS authorities)

[166] Have Your Say Portal

- Surveys targeting mostly umbrella/business organisations;
- Webinars/virtual discussion (5) on various intervention areas (provisional topics: *improving governance framework, supporting the functioning of the market, improving business environment, increasing social awareness and acceptance, closing knowledge, research and technological and innovation gaps*).

As a result of the consultations, the following reports were prepared:

(1) A factual summary of the public consultation that is published at the Commission's Have Your Say Portal website and
(2) A consultation summary report that is an analysis of all consultation activities corresponding to the Algae initiative (this Annex).

2.1.3. Summary /overview on consultation activities by stakeholder groups and indicative timing

Consultation activity Indicative planning **Stakeholders**	Feedback period on IIA 1st Q 2021	12-weeks public consultation 2nd Q 2021	Targeted interviews 2-3 Q 2021	Written surveys 2-3 Q 2021	5 webinars 2-3 Q 2021	Post-study consultations
EU citizens	x	x			X	
Algae industry	x	x	x	x	X	
Business organizations	x	x	x	x	X	
Public authorities	x	x	x	x	X	
Research	x	x	x	x	X	
Academia	x	x	x	x	X	
NGOs	x	x		x	X	

2.1.4. Consultation webpage & communication activities

The general description of the EU Algae initiative together with the inception impact assessment (IIA) and public consultation results is published at the Commission's *Have Your Say* Portal. The

communication about the consultation activities, key deliverables and actions was performed via Europa website[167] and various social media tools e.g. LinkedIn, Facebook, Twitter.

2.2. Consultation Activities and Tools

To gather input for refining the policy actions, an online public consultation was launched, several stakeholders throughout the value chain were interviewed and three webinars were organised. The summary of the responses to the public consultation, the interviews and the key outcomes from the webinars are elaborated below. First, the responses from the public consultations, together with the input generated from the interviews are discussed, whereafter an overview of the webinars is shown. A more detailed description of the responses from the stakeholders is available in Annex 3 – Stakeholder consultation results.

2.2.1. Characteristics of the respondents

108 respondents provided their input to the online public consultation (PC) published on the EU Survey portal which took place from 19th of May to 11th of August 2021. Out of the 108 respondents in the PC, **56%** of them were written **in English**, **14% in Spanish**, **16% in French, and 6% in Dutch**. Additionally, there were contributions in the following languages: **Croatian, Estonian, Greek, Italian, Romanian, and German**.

As visualised in Figure 1, 31 out of 108 participants indicated that they participated on behalf of a company/business organisation and 26 participants on behalf of an academic/research institution.

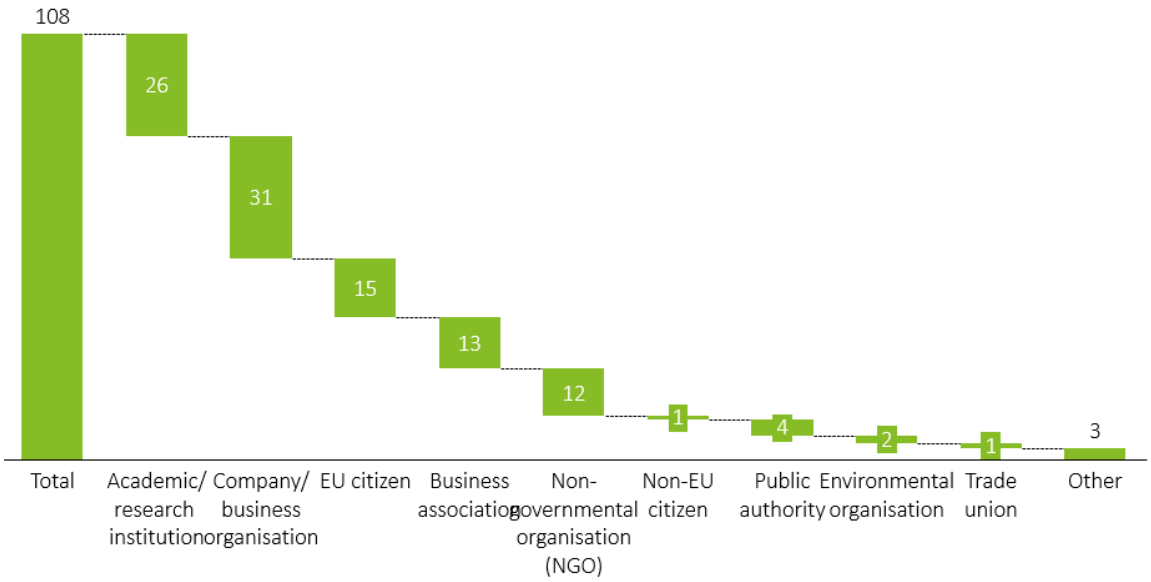

Figure 1 Distribution of respondents among affiliation with organisation

This public consultation received a balanced number of responses, in terms of the organisation sizes of respondents and brought together 30% of large organisations (250 employees and more), 30% of micro

[167] News item on the public consultation results on the inception impact assessment (IIA).

(1 to 9 employees) organisations, 17% of small and 9% of medium sizes organisations. 16 respondents indicated as 'other'.

The distribution of the respondent's country of origin is balanced throughout the European Union. Respondents originate from in total 24 countries: sixteen countries within the EU, four in Europe, but not in the EU, and four countries outside continental Europe. Out of the 108 respondents, 23 originate from France, 19 from Spain, and 11 from Belgium. The other respondents were spread over 21 different countries.

To gain insights on the spread of respondents within the value chain of the algae sector, respondents indicated their organisation's role in the value chain. As visible in figure 2 below, 40 out of 108 participants are active in algae production, and 43 out of 108 are active in R&D organisations (please see Annex 3 for more details).

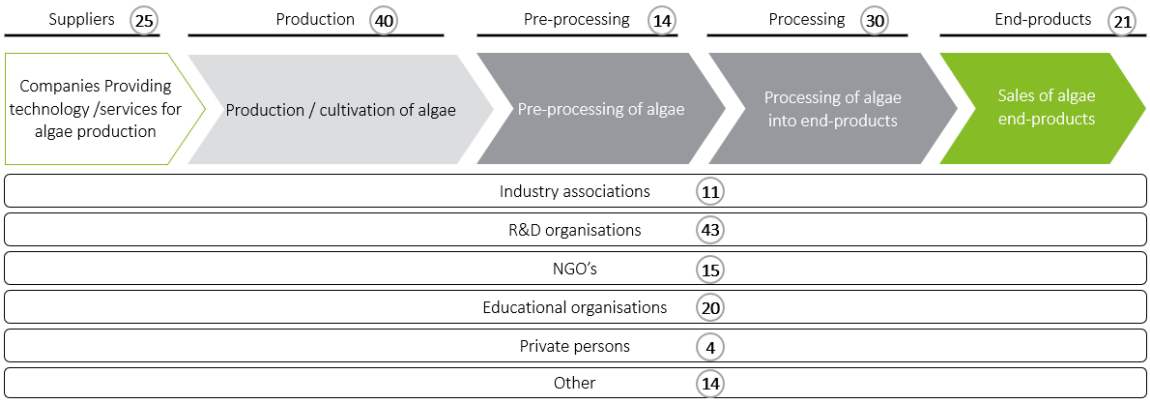

Figure 2 Organisation's role/relevance in the algae industry

For the **stakeholder interviews**, in total **19 stakeholders** were interviewed from **seven different EU Member States**. Seven stakeholders originate from France, six stakeholders originate from the Netherlands, and the others from Italy, Spain, Portugal, Ireland, or Greece. The stakeholders are active in all parts of the European algae value chain. Suppliers, producers, end-users as well as authorities, business organisations, and universities were interviewed for this stakeholder consultation. Some of the stakeholders are part of large organisations, where others are active in smaller businesses. In terms of their focus on micro- or macroalgae, the stakeholders were evenly spread.

2.3. Webinar on Novel Foods regulation for algae and algae-based products

As part of the stakeholder consultation, three webinars were organised where multiple stakeholders with different views were invited to participate. The first webinar took place on the 22nd of June 2021. The topic of this webinar was "Novel Foods regulation for algae and algae-based products."

The objective of this webinar was, among others, to share information on relevant topics to the industry and engage stakeholders by providing room for discussion in the webinar. Above all, the webinar was held to gather input from different stakeholders within the sector to use as input for the impact assessment

The webinar was organized with expert presentations followed by break-out sessions with participants (see the agenda in figure 3 below). The webinar started with an opening by DG MARE and an introduction to the objectives by Deloitte. The webinar ended with a Q&A session.

Time	Topic	Speaker
09.30 – 09.35	Opening - Introduction by the Commission	Maris Stulgis – DG MARE
09.35 – 09.45	Introduction to the study objectives	Gurvinder Arora – Deloitte
09.45 – 10.00	Session 1: Novel Foods regulation for algae	Takis Daskaleros – DG SANTE
10.00 – 10.30	Breakout 1: Challenges for Novel Foods regulation	
	15-minute Break	
10.45 – 11.00	Session 2: JRC's report on algae in the context of Novel Foods	Rita Araújo – Joint Research Centre
11.00 – 11.45	Breakout 2: Building the Novel Foods catalogue	
11.45 – 12.00	Q&A	
12.00	End of the webinar	

Figure 3 Agenda webinar on Novel Foods regulation for algae and algae-based products

In the first webinar, ~90 people participated from all over Europe. Participants originated from all parts of the value chain, from algae producers to processors to business organisations.

The first session was presented by DG SANTE. An overview of the Novel Foods regulation and its authorisation process was presented. Also, a short introduction to the Novel food catalogue was given. The topic of the first breakout was "challenges for Novel Foods regulation. The challenges that were discussed were the high cost of the Novel Foods approval process and the lengthy duration it takes to get a new species allowed on the market. Consensus between the participants to the webinar existed about the importance of regulations for food safety throughout the EU.

The second session was presented by the Joint Research Centre (JRC) and titled "JRC's document on algae in the context of Novel Foods". In the session, participants were informed about the work the JRC is doing in the algae domain, including identifying algae that are currently listed in the Novel Food Catalogue[168] and algae species that may have a history of consumption in the EU before 15 May 1997 and could therefore be potentially added to the Novel Food Catalogue. In the second breakout, participants indicated which species they would like to see added to the Novel Foods catalogue and if this is not possible, to be authorised as Novel Foods.

2.4. Webinar on Support the functioning of the EU algae markets

The second webinar took place on the 28th of June. The topic of this webinar was "Support the functioning of the EU algae markets"

[168] Latest report on Algae as food and food supplements in Europe available at: https://publications.jrc.ec.europa.eu/repository/handle/JRC125913.

The objective of this webinar was, as well as the first one, to share information on relevant topics, engage stakeholders by providing room for discussion, and gather input from different stakeholders within the sector to use as input for the impact assessment. The focus of this webinar, in particular, was on the business side of the algae sector.

The webinar consisted from an expert presentation of the topic, followed by a breakout session where participants were given the opportunity to discuss the topic at hand. The webinar started with an opening by DG MARE and an introduction to the objectives by Deloitte. The webinar ended with a Q&A session (see the agenda in Figure 4 below).

Time	Topic	Speaker
14.00 – 14.05	Opening - Introduction by the Commission	Maris Stulgis – DG MARE
14.05 – 14.15	Introduction to the study objectives	Gurvinder Arora – Deloitte
14.15 – 14.40	Session 1: EABA's view on the EU algae market	Jean-Paul Cadoret – EABA / ALGAMA
14.40 – 15.10	Breakout 1: Current challenges in consumer acceptance and possible solutions	
	5-minute Break	
15.15 – 15.40	Session 2: An entrepreneur view of the European algae market	João Navalho – Necton
15.40 – 16.15	Breakout 2: Discussion on what entrepreneurs in the European algae sector need	
16.15 – 16.30	Q&A	
16.30	End of the webinar	

Figure 4 Agenda webinar on Support the functioning of the EU algae markets

In the second webinar, ~100 people participated from all over Europe. Participants originated, as well as in the first webinar, from all parts of the value chain.

The first session was presented by the European Algae Biomass Association (EABA). EABA presented their view on the EU algae market – starting with an overview of the European micro-and macroalgae market, among others, the number of companies, total turnover, total biomass production, direct jobs, and research groups. This was followed by an insight into EABA's work. The topic of the first breakout was challenges and solutions in consumer acceptance of algae and algae-based products. Some of the challenges that were discussed: the taste, high price, and smell. Some of the solutions that were discussed: targeted communication, a hero product that can be used to show how great algae are, and administration support.

The second session was presented by João Navalho – President of Necton. The session was titled "An entrepreneur view of the European algae market". In the session, Mr. Navalho gave an insight into the state of affairs of his company. He then gave an overview of what he believed to be the bottlenecks in the sector. In the second breakout, participants indicated what entrepreneurs in the European algae sector need to succeed and grow their business**. Some of the input gathered**: clear and simple

administrative procedures for facilities and products, reduction of the regulatory burden, subsidising the Novel Foods application process, and novel technologies to reduce production costs.

2.5. Webinar on Algae in Europe – Data collection and market information initiatives

The third webinar took place on the 8th of July. The objective of this webinar was, as well as the first two webinars, to share information on relevant topics, engage stakeholders by providing room for discussion, and gather input from different stakeholders within the sector to use as input for the impact assessment. The focus of this webinar, in particular, was on data collection of algae and algae-based products.

The webinar consisted of two parts. Each part included one session, where one or two expert(s) presented their topic, followed by a breakout where participants were given the opportunity to discuss the topic at hand. The webinar started with an opening by DG MARE and an introduction to the objectives by Deloitte. The webinar ended with a Q&A session (See the webinar agenda in Figure 5 below).

Time	Topic	Speaker
14.00 – 14.05	Opening - Introduction by the Commission	Maris Stulgis – DG MARE
14.05 – 14.15	Introduction to the study objectives	Gurvinder Arora – Deloitte
14.15 – 14.40	Session 1: European statistical data collection on aquatic plants	Marjo Kasanko & Alois Hoenig – Eurostat
14.40 – 15.10	Breakout 1: Role of the sector in data collection	
	5-minute Break	
15.15 – 15.40	Session 2: Key challenges in data collection for algae and algae-based products	Rita Araujo – JRC
15.40 – 16.15	Breakout 2: Benefit of high-quality data towards algae sector	
16.15 – 16.30	Q&A	
16.30	End of the webinar	

Figure 5 Agenda webinar on Algae in Europe – Data collection and market information initiatives

In the third webinar, ~60 people participated from all over Europe. Participants originated, as well as in the first two webinars, from all parts of the value chain.

The first session was presented by Eurostat and titled "European statistical data collection on aquatic plants". An overview of data which is collected throughout the years was given within three topics: catches & landings, aquaculture production, and trade data. The topic of the first breakout was the potential role of the European algae sector in data collection. Potential roles that were discussed were: reporting on reliable data and conduct research on consumer preference and perceptions of algae.

The second session was presented by JRC. The session was titled "Key challenges in data collection for algae and algae-based products"[169]. In the session, JRC gave an overview of the data which they collected over time and touched upon some of the key challenges in the process of data gathering. In the second breakout, participants indicated what the benefits could be of high-quality data towards the European algae sector. **Some of the input gathered**: Better data could provide higher income, diversification of activities and products, it could create a deeper understanding of the real value and impact of this sector, and it could provide better information to potential investors.

2.6. Validation webinars of the environmental impact screening and the economic and social impact

As part of environmental impact screening and the economic and social impact, two validation webinars were organised. In these webinars, multiple stakeholders with different views were invited to participate. The first webinar took place on the 22nd and the second webinar on the 24th of September 2021. Both webinars had a duration of 1.5 hours and in each, approximately 40 people participated. The objective of the webinars was to collect input from the participants on the performed environmental impact screening and the economic and social impact.

The webinar consisted of two parts. The first part included an introduction to the initiative, and to the impact screening and was followed up by a breakout session where participants could choose to discuss the microalgae or macroalgae-related measures. The webinars ended with final remarks.

Time	Topic	Speaker
14.00 – 14.05	Opening and welcome	Gurvinder Arora – Deloitte
14.05 – 14.10	Introduction to the initiative by the Commission	Maris Stulgis – DG MARE
14.10 – 14.20	Presentation to introduce the economic and social impact assessment	Deloitte
14.20 – 15.25	Breakout: economic and social impact assessment	Macro- and microalgae groups
15.25 – 15.30	Final remarks	
15.30	End of the webinar	

Figure 6 Agenda validation webinar

In the breakouts, the participants were presented with a selection of the proposed policy measures. Per measure, the different impacts were presented. For the environmental impact screening, these were the impacts of the thirteen indicators. For the economic and social impact, this was the qualitatively economic and social impact and the impact on the growth of the revenue and employment of the sector.

[169] Some more insights on the status, challenges and future developments of algae production data can be found at https://knowledge4policy.ec.europa.eu/publication/report-community-practice-workshop-algae-production-europe-status-challenges-future_en.

Input gathered during the webinars demonstrated that the methodology in general and impact of specific proposed measures is sometimes confusing. In particular:

1. Participants indicated that several measures are not clear and should be formulated more specifically.
2. Specific impacts assigned to measures are not reliable if measures are not clear.
3. Estimation of the quantitative impact per each measure does not make much sense, as each measure wouldn't develop in isolation but in a complex and interlinked environment

3. ANNEX 3: STAKEHOLDER CONSULTATION RESULTS

3.1. Main stakeholder feedback

3.1.1. General responses regarding the algae sector

Respondents indicated the policy areas that should, according to them, be prioritized within the sustainable growth of the EU algae sector in the future. Of the ten available options to select, the area which was rated the highest – with a 4,6 – was **potential contribution of algae towards environmental sustainability**. **Access to space and water** was rated the lowest, on average 3,6, by the respondents. In the interviews, several stakeholders mentioned that the increasing of consumer awareness and acceptance is one of the most important developments in the EU algae sector in the near future. Additionally, several of the interviewees mentioned that **consumer awareness** is one of the challenges their respective organisations face nowadays. This is in line with the high rating, of a 4,4, of this area of prioritisation in the PC. Only one stakeholder, a Portuguese microalgae producer, mentioned that currently awareness is growing faster than production. Several interviewees mentioned **access to funding/financing** as a game-changer to benefit the development of the sector – which is in line with the rating of a 4,4 of 'availability of funding' in the PC.

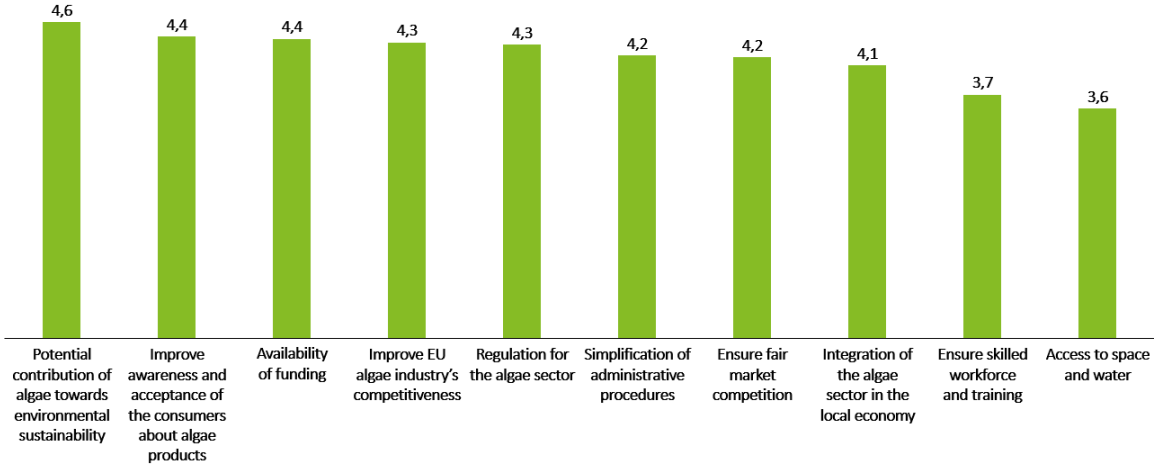

Figure 7. Areas that should be prioritized in the EU algae sector

Thereafter, the respondents indicated the application of algae perceived as the most promising for the growth of the sector. Respondents could indicate multiple applications. 74 out of 108 respondents indicated that algae as **human food and food ingredients** are for them the most promising potential. 50 out of 108 participants indicated that **animal/fish feed and ingredients** are most promising. **Bioremediation** as promising potential was indicated by 44 respondents. Also, eight respondents indicated that for them the most promising potential was something not listed in the options, namely nutraceuticals, bio- or biobased materials, biofuels, bioplastic, and/or bioenergy. The interviewees agreed on food and feed presenting the most promising potential for algae use.

3.1.2. Responses on the five objectives and potential regulatory measures

For each objective that respondents indicated as being important several potential measures were presented to them as part of a subsequent set of consultation questions. Participants then indicated, on a scale from 1 to 5 (**1 = not important, 5 = very important**) the perceived importance of each of the measures associated with the objectives. In figure 8 the average rating of respondents' answers to this question is shown.

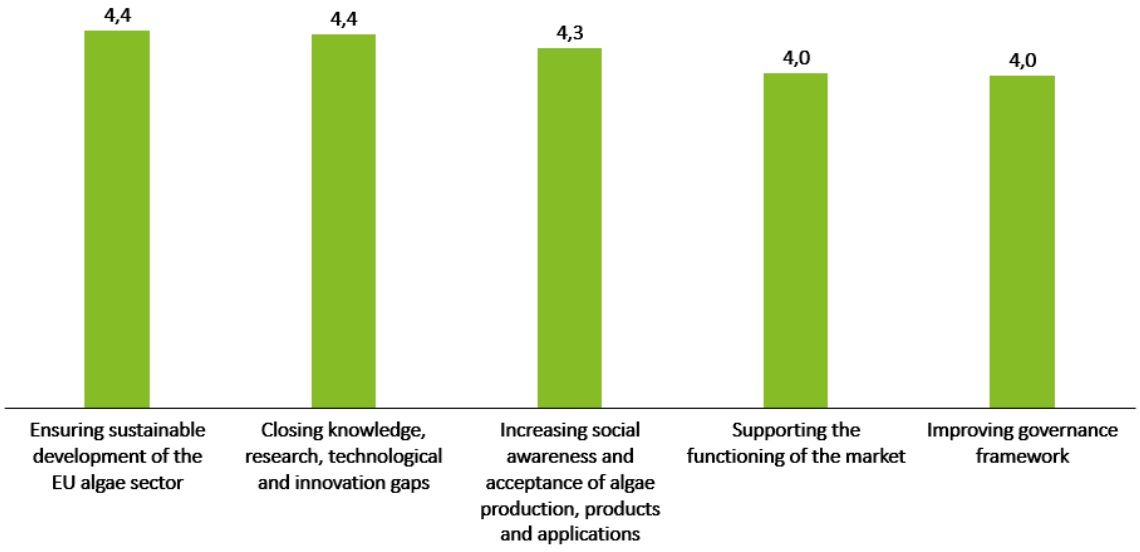

Figure 8. Importance of the objectives to unlock the EU algae sector's potential

The responses gathered per objective are provided below along with the responses on regulatory measures. The participants rated (on a 1 to 5 scale) all presented measures and were given the opportunity to propose additional measures. The participants indicated the measures that would generate the highest economic social and environmental impact, per objective and could choose multiple measures per objective. The output resulting from these questions is also displayed per objective. The summary of the responses also distinguishes micro-and macroalgae affiliated respondents. Input from respondents who are affiliated with both micro- as well as macroalgae is spread evenly between micro-and macroalgae output – 50% for each.

3.1.3. Objective 1. Improving governance framework

For objective 1, five potential measures were proposed to the participants. These were:

- Guidelines for sustainable production of algae, and sustainable harvesting of seaweed
- Guidance on large scale cultivation of algae in multi-use settings (e.g. combination with windfarms, include in local Maritime Spatial Planning, etc.)
- Standardisation of algae product specifications (built on existing standards and standards under development)
- Recommendations for harmonised licensing of seaweed farms
- Recommendations for labelling of sustainable, safe, and/or organic algae products

Standardisation of specifications for algae production methods was perceived as being the most important to the microalgae sector with a rating of 4,4. By the macroalgae sector, recommendations for labelling of sustainable, safe, and/or organic algae products are seen as most important, with a rating of 4,5.

Additional measures mentioned by participants were reviewed and one topic recurred several times; seven of the 35 respondents that indicated the need of additional measures suggest that there should be equal conditions and opportunities for algae products from the EU and imported ones. Therefore, the following measure was added: implement a mechanism to ensure a fair market.

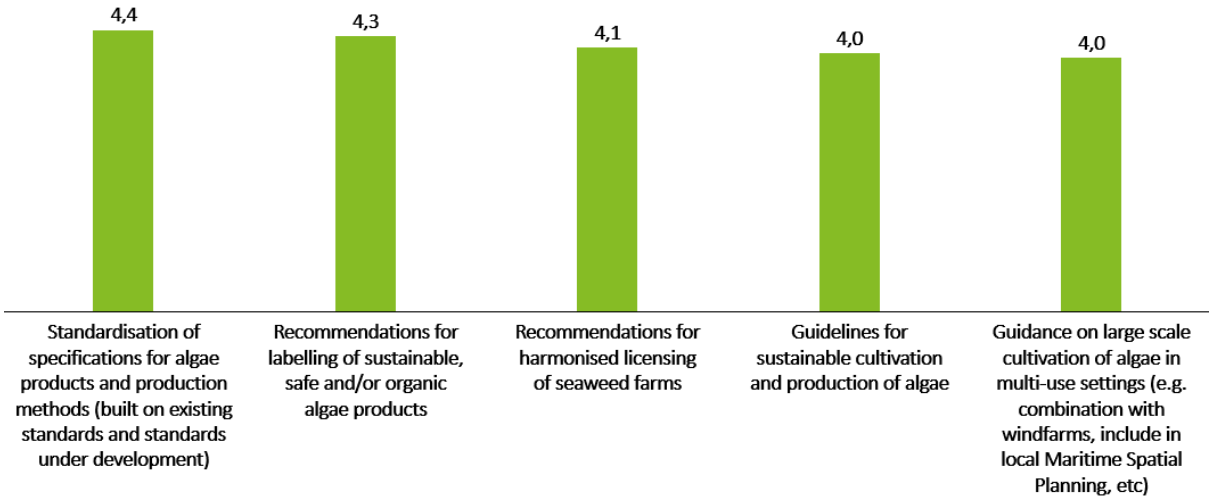

*Figure 9. Importance of proposed measures for improving the governance framework (**microalgae**)*

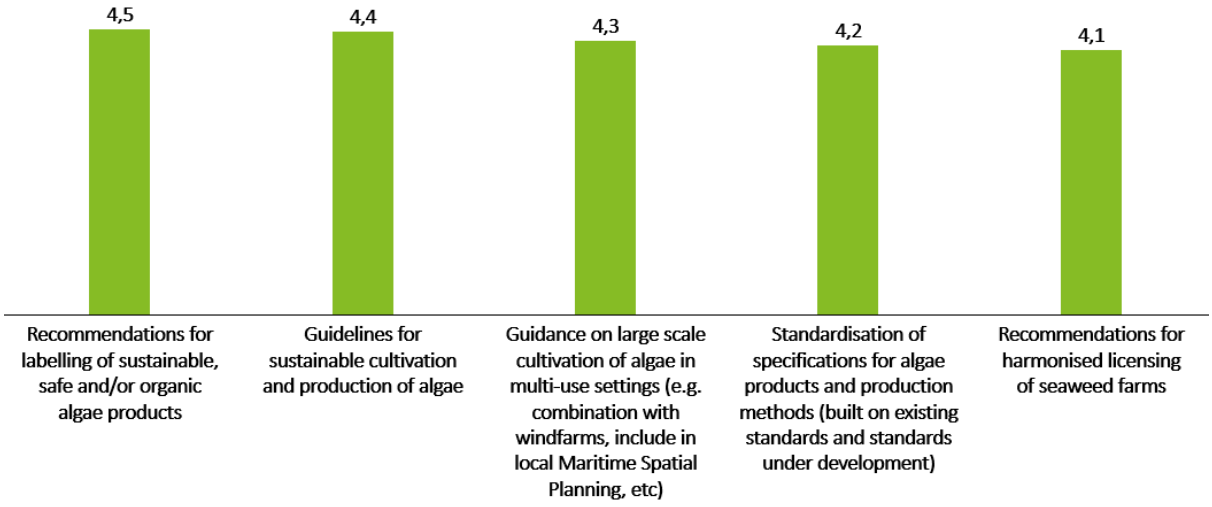

*Figure 10. Importance of proposed measures for improving the governance framework (**macroalgae**)*

Then, participants indicated which topics, in their opinion, should be managed at the EU level. The list of proposed topics include:

- Safety standards (e.g. level of heavy metals or arsenic in seaweed)
- Status of algae products (organic/inorganic)
- The ecological footprint from algae production
- Bioremediation by algae
- Any others

The number of times participants picked one of the topics, is displayed in figure 11. As can be seen, participants picked the topic of **safety standards** the most – 61 times (over 56% of the participants picked this topic). Fourteen participants suggested additional topics that should be governed at the EU level.

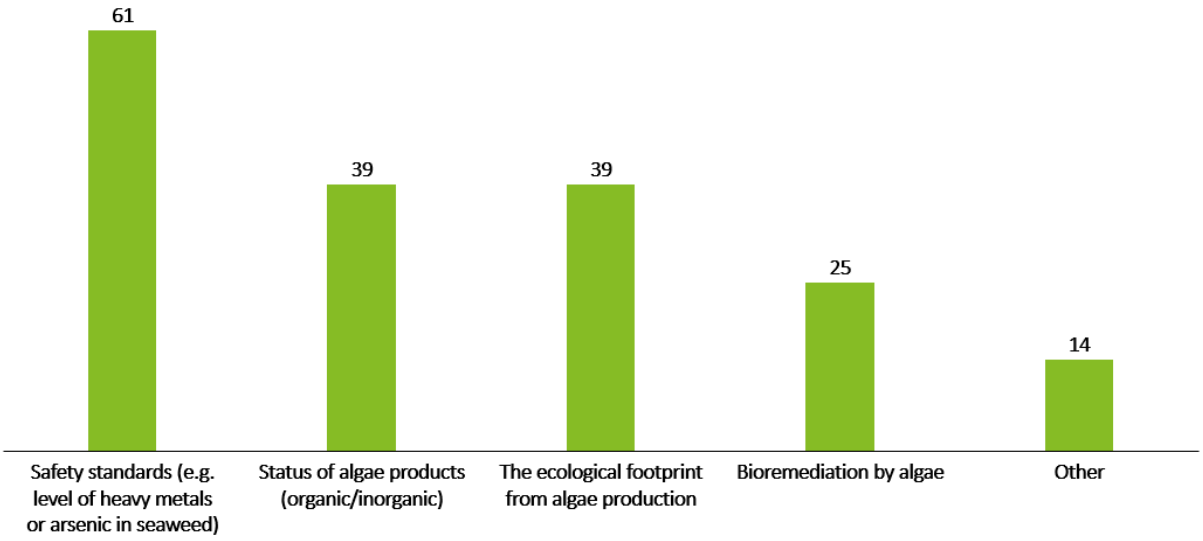

Figure 11. Topics that respondents consider to best be governed at EU level

Furthermore, the participants identified the proposed measures that would potentially have the highest impact. 66 out of 108 (=61%) participants indicated this objective (improving governance framework) as an important objective and therefore provided further elaboration on the potential impact of the measures. Most of the microalgae affiliated respondents (36) indicated that standardisation of specifications for algae products and production methods would have the highest impact (see figure 12

below). Most of the macroalgae affiliated respondents perceived guidelines for sustainable cultivation and production of algae as the measure with the highest impact (see figure 13 below).

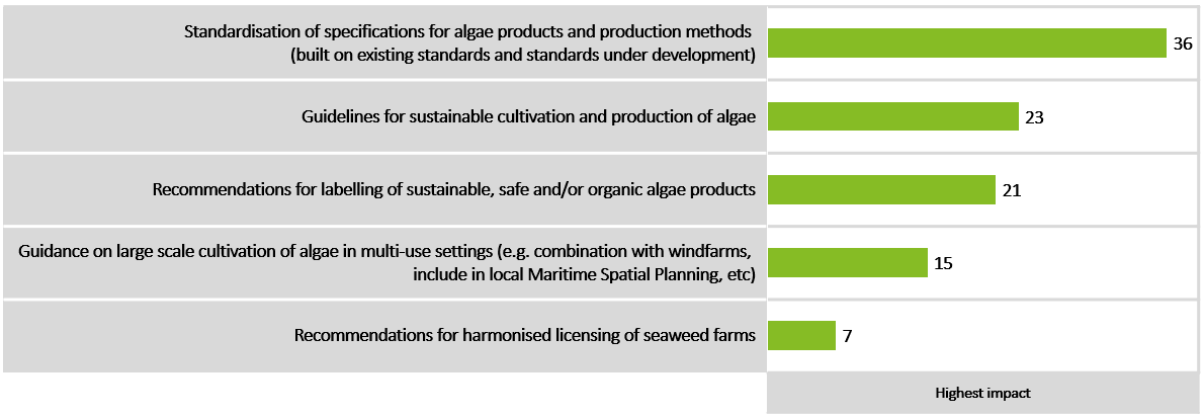

Figure 12. Highest impact from proposed governance framework changes (microalgae)

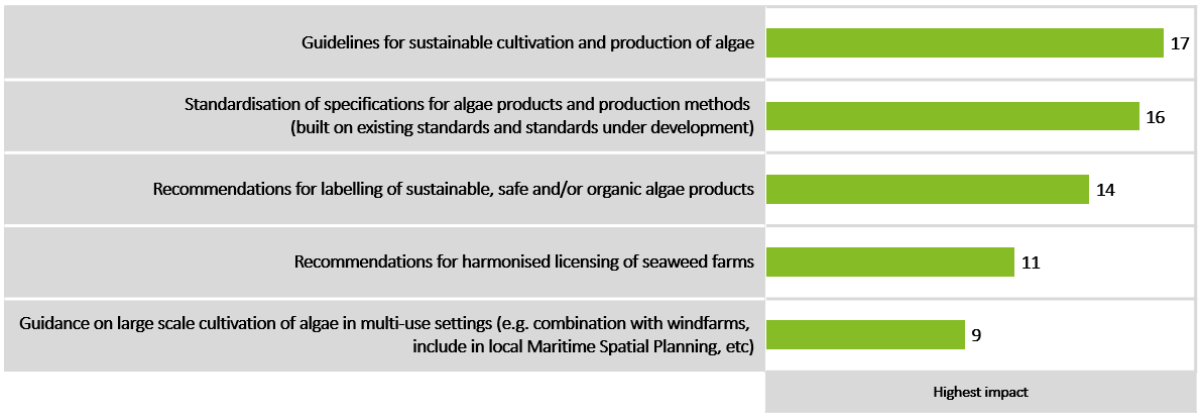

Figure 13. Highest impact from proposed governance framework changes (macroalgae)

In the interviews, a recurring theme was that algae are classified differently in several Member States. In some Member States (micro)algae belong to the group of aquaculture and related activities whereas in some Member States algae is added to agriculture and related activities. This classification creates unclarity as the regulations needed for algae may not align fully with other aquaculture and agriculture activities. The interviewed stakeholders indicate that harmonising industry standards throughout the EU would be beneficial for the sector, including a separate classification for algae and algae-related activities. This corresponds to the high rating of the standardisation measures as visualised in figures 10, 12, and 14.

3.1.4. Objective 2. Supporting the functioning of the market

For the second objective, eight different measures were proposed to the participants. These measures were:

- Introduce well-targeted and easy accessible financial support that will accelerate the development of the EU's blue bioeconomy and algae sector

- Support the development of market-based instruments to monetize bioremediation and other ecosystem services based on algae production
- Develop European standards for safety and environmental sustainability to use throughout the EU algae sector
- Increased government procurement of algae-based products
- Support/assist the industry to bring new algae species to the market under the Novel Food Regulation
- Increase in demand by raising awareness on the benefits of seaweed
- Support technological developments
- An EU innovation prize for the macroalgae and microalgae industry

On average, the participants affiliated with microalgae rated the measures about the introduction of well-targeted and easy accessible financial support and to support the industry to bring new algae species to the market under the Novel Foods Regulation the highest – both with a scoring of 4,5 (see Figure 14 below). The participants affiliated with macroalgae rated the measures about support technological development and support the industry to bring new algae species to the market under the Novel Foods Regulation the highest – both with a scoring of 4,4 (see Figure 15 below).

19 respondents mentioned that overly restrictive regulations on EU level and unclear and/or lacking legislation on a national level is the most striking barrier that prevents the EU algae sector from sustainable growth. Also, numerous respondents, 16 in total, believe the lack of awareness – and therefore ignorance of the potential of algae and low market acceptance – is the most striking barrier preventing the EU algae sector from sustainable growth.

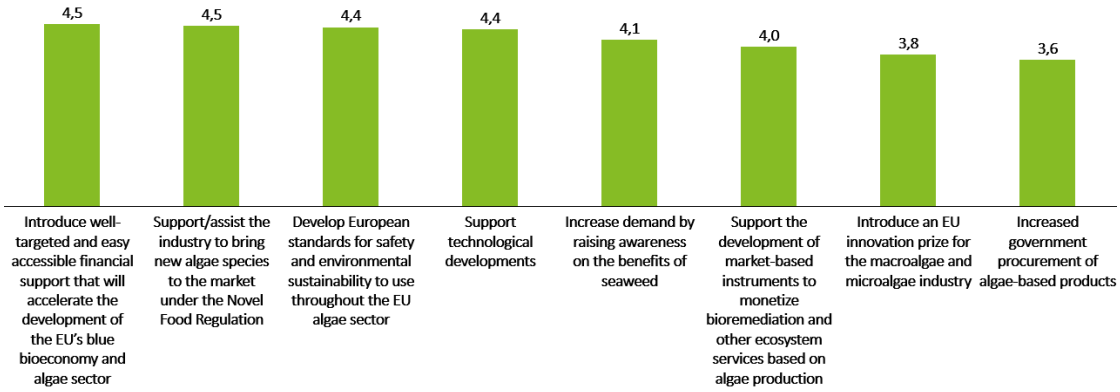

Figure 14. Importance of proposed measures for supporting the functioning of the markets (microalgae)

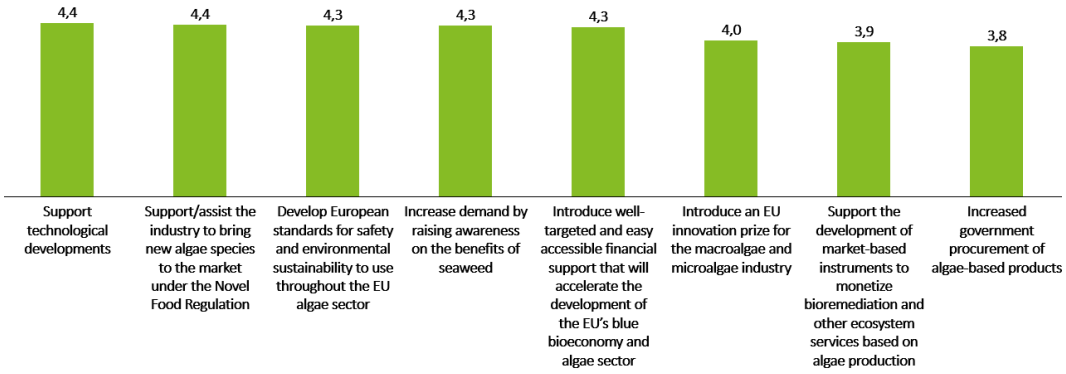

Figure 15. Importance of proposed measures for supporting the functioning of the market (macroalgae)

76 out of 108 (70%) respondents indicated supporting the functioning of the market as an important objective and therefore provided further elaboration on the potential impact of the measures. 32 of the microalgae affiliated participants indicated that they thought that the introduction of well-targeted and easy accessible financial support would have the highest impact. Most of the macroalgae affiliated respondents (17) indicated that the measure to develop European standards for safety and environmental sustainability would have the highest impact (see Figures 16 and 17 below).

Figure 16.Highest impact from Supporting the functioning of the market (microalgae)

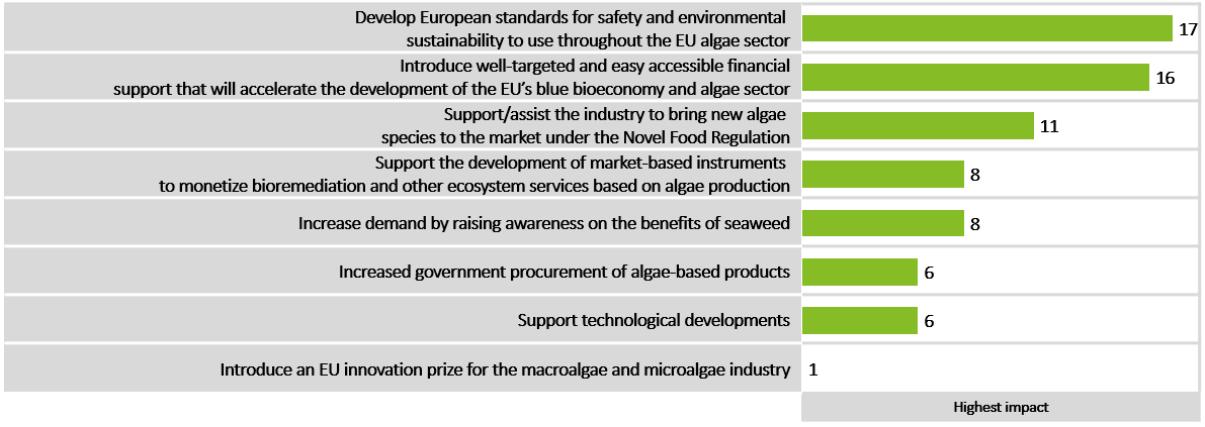

Figure 17. Highest impact from Supporting the functioning of the market (macroalgae)

The Novel Foods process and associated costs were a much-discussed topic in the interviews. Several of the interviewees mentioned that, for the rather small companies they represent, it is impossible to bear the costs and the risks of going through the Novel Foods process. Therefore, these stakeholders suggested that the EU should support them in obtaining Novel Food authorizations. This finding corresponds to the high rating of the measure 'support/assist the industry to bring new algae species to the market under the Novel Food Regulation' visualised in figures 15 to 18. Also, the high rating of the measure 'increase demand by raising awareness on the benefits of seaweed' visualised in figures 15 to 17 corresponds well to the findings from the interviews.

3.1.5. Objective 3. Ensuring sustainable development of the EU algae sector

For the objective of ensuring sustainable development of the EU algae sector, the PC proposed the participants six different measures. These were:

- Create an EU wide sector organisation/network
- Create and maintain a web-based one-stop-shop for EU algae stakeholders for knowledge, good practices sharing, mapping of funding, algae project results, etc
- Create and maintain an assistance mechanism for EU algae stakeholders
- Identify and assess specific needs and availability of investment funding for innovation, technology, infrastructure, knowledge and skills development
- Mapping and keeping an up-to-date EU funding sources overview for EU algae sector
- Support to start-ups in the algae sector in accessing the value chain, including contacts with others companies, knowledge institutes and/or regulators

The measures were rated, on average, from a 3,7 to a 4,4. The measure with the highest rating, for the microalgae (scoring of 4,4) and macroalgae (scoring of 4,2) industry respectively, is to identify and assess specific needs and availability of investment funding for the sector and to give support to start-ups in the algae sector (see Figures 18 and 19 below).

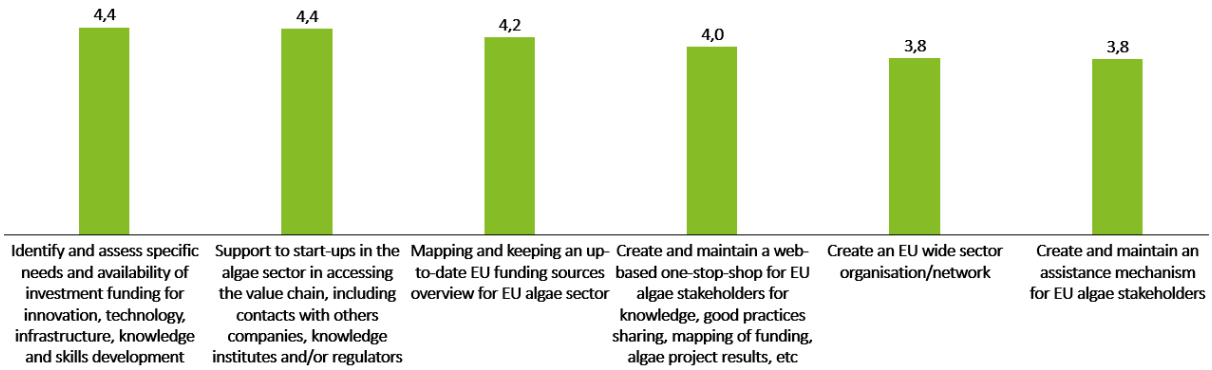

Figure 18. Proposed measures to ensure sustainable development of the EU algae sector (microalgae)

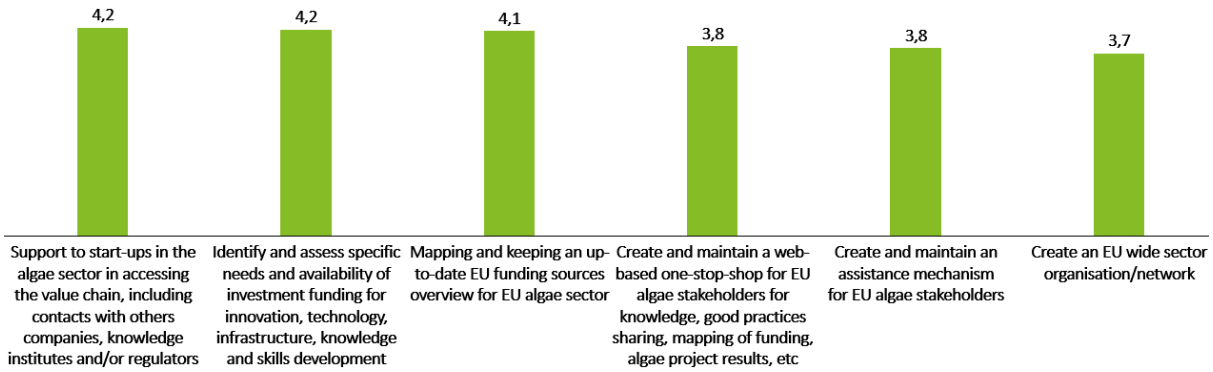

Figure 19. Proposed measures to ensure sustainable development of the EU algae sector (macroalgae)

92 out of 108 (=85%) participants indicated the sustainable development of the EU algae sector as an important objective and therefore provided further elaboration on the potential impact of the measures. 38 microalgae-related respondents identified the measure about the needs and availability of investment funding as having the potential highest impact. 18 macroalgae-related participants identified the measure about the needs and availability of investment funding as having the potential highest impact. Not many participants think of creating an EU-wide sector organisation/network as something which can create potentially high impact. This measure received also the lowest average rating.

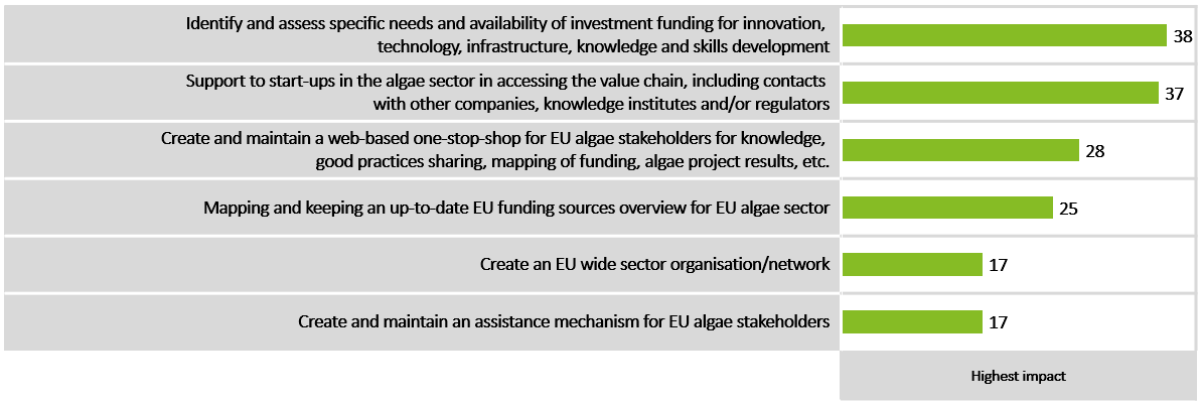

Figure 20. Highest impact from Ensuring sustainable development of the EU algae sector (microalgae)

Figure 21. Highest impact from ensuring sustainable development of the EU algae sector (macroalgae)

3.1.6. Objective 4. Increasing social awareness and acceptance

For this objective, participants were given the possibility to rate seven different measures. These were:

- EU wide communication campaign(s) of benefits on human health of algae food products
- EU wide communication campaign on environmental, social and commercial benefits of algae products
- Support and promote eco-labelling of sustainable, safe and/or organic algae products
- Publication of guidance for stakeholder consultations
- Inclusion of algae production into maritime spatial planning processes
- Support Member States and their Nutrition Centres to provide attractive information on algae
- Support the algae sector at European and global conferences such as UN Climate Change Conference (COP26) and World Economic Forum

The measures were on average rated from a 3,8 for the lowest score to at 4,5 for the highest. The measure with the highest rating, from microalgae-related respondents, is about setting up an EU-wide communication campaign to highlight the benefits on human health of algae-based products. For macroalgae-related respondents, the measure to create EU-wide communication campaigns on the environmental, social, and commercial benefits of algae products received the highest rating. The measure of which the participants thought as being the least important is about the publication of guidance for stakeholders on awareness and acceptance of algae, for microalgae-related respondents. For macroalgae-related respondents, this was the measure to support Member States and their nutrition centres to provide attractive information on algae (see Figures 22 to 25 below).

Out of the respondents that believe additional measures should be incorporated for this objective (17), six mentioned they believe that training courses on algae, especially education in school for younger generations should be incorporated. This observation is assimilated in refining the policy options of the objective on closing knowledge, research, technological and innovation gaps.

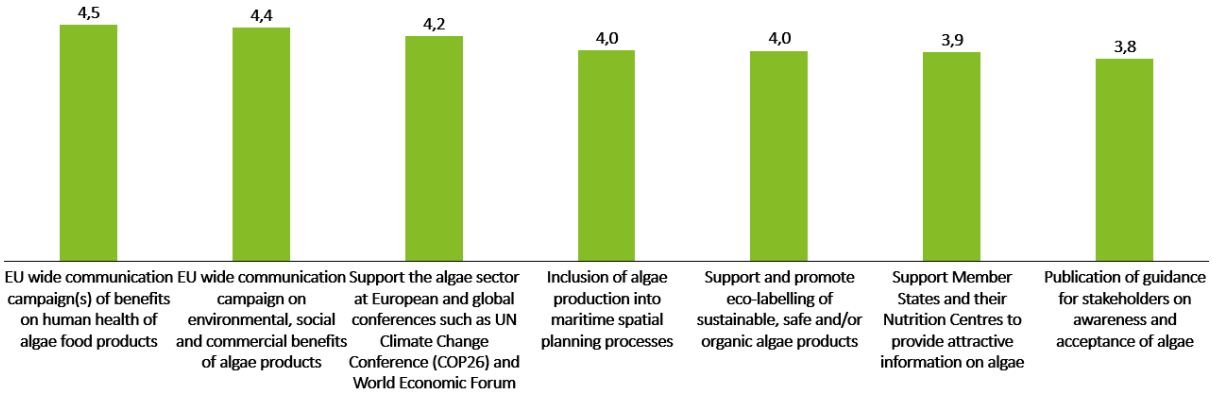

Figure 22. Proposed measures to increase social awareness and acceptance (microalgae)

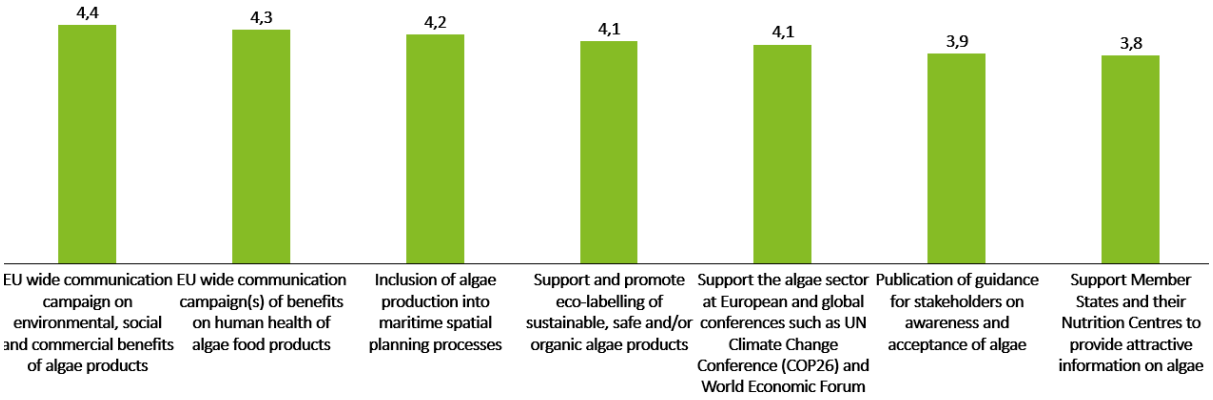

Figure 23. Proposed measures to increase social awareness and acceptance (macroalgae)

81 out of 108 (75%) participants indicated increasing social awareness and acceptance as an important objective and therefore provided further elaboration on the potential impact of the measures. Both the measures about the EU-wide communication campaign of benefits on human health and environmental, social, and commercial benefits of algae products were perceived as having the highest potential impact by the micro-and macroalgae-related respondents.

Figure 24. Highest impact from Increasing social awareness and acceptance (microalgae)

Figure 25. Highest impact from Increasing social awareness and acceptance (macroalgae)

As mentioned before, several interviewees mentioned that it is important to increase social awareness and acceptance of algae throughout the EU. Although many agree on the importance of social awareness, not all agree on the execution of it. Three out of the six interviewees who talked about this subject believe that the sector itself should undertake action to improve awareness and acceptance of

algae. The other three interviewees think that the EU should support marketing to improve societal awareness and acceptance. Interviewees agree, however, on the point that campaigns should focus on classifying algae as a healthy product.

3.1.7. Objective 5. Closing knowledge, research and innovation gaps

For the objective around closing the knowledge, research and innovation gaps, nine measures were proposed in the PC. These were:

- Developing improved algae cultivation systems (integrated multi-trophic aquaculture, offshore cultivation) or methods (e.g. cellular mariculture) contributing to fighting the current technical constraints in the production systems and consequently upscaling production volumes
- Developing improved algae processing systems (biorefineries), processing algae into multiple products and for multiple applications
- Establishing a monitoring framework, targets and methodologies for (1) quantifying ecosystem services (e.g. carbon sequestration, blue carbon credits, nutrients uptake), (2) carrying capacities of EU waters for seaweed aquaculture and marine permaculture and (3) impacts of cultivation, restoration and harvesting on marine ecosystems
- Research to strengthen the potential nutritional benefits of algae
- Research to deliver new innovative algae-based products
- Targeted support to industry helping to move from research/demonstration stage to the market
- To support higher education programs in the area of blue biotechnology and innovative solutions for algae cultivation
- Fund doctoral theses in the area of innovative solutions, knowledge, data or good practices on the blue bioeconomy and algae

Participants rated these measures, on average, from a 3,7 to a 4,6 as shown in figures 26 and 27. The measure about support to move from research/demonstration stage to the market, for microalgae-related respondents, and the measure about developing algae processing systems, for macroalgae-related respondents, received the highest ratings – a 4,6 and 4,4 respectively.

36 out of 64 (=56%) participants who answered the question about what specific actions could help to improve the collaboration among academia, research, and industry, indicated that networking events and hubs for ideas exchange could help improve collaboration. Therefore the measure “initiate network events, to connect stakeholders, and hubs to exchange ideas between industry and academia” was added to the policy measures for this objective.

93 out of 108 (=86%) participants indicated closing the knowledge, research, and innovation gaps as an important objective and therefore provided further elaboration on the potential impacts of the measures. Most of the microalgae-related participants thought that the measure about research to deliver new innovative algae-based products would generate the highest impact. Of the macroalgae-related participants, the measure of developing improved algae cultivation systems or methods, contributing to fighting the current technological constraints in the production systems and consequently upscaling production volumes is perceived as the one with the highest potential impact.

None of the participants indicated that research on safe and secure algae production methods in closed systems would have the highest impact.

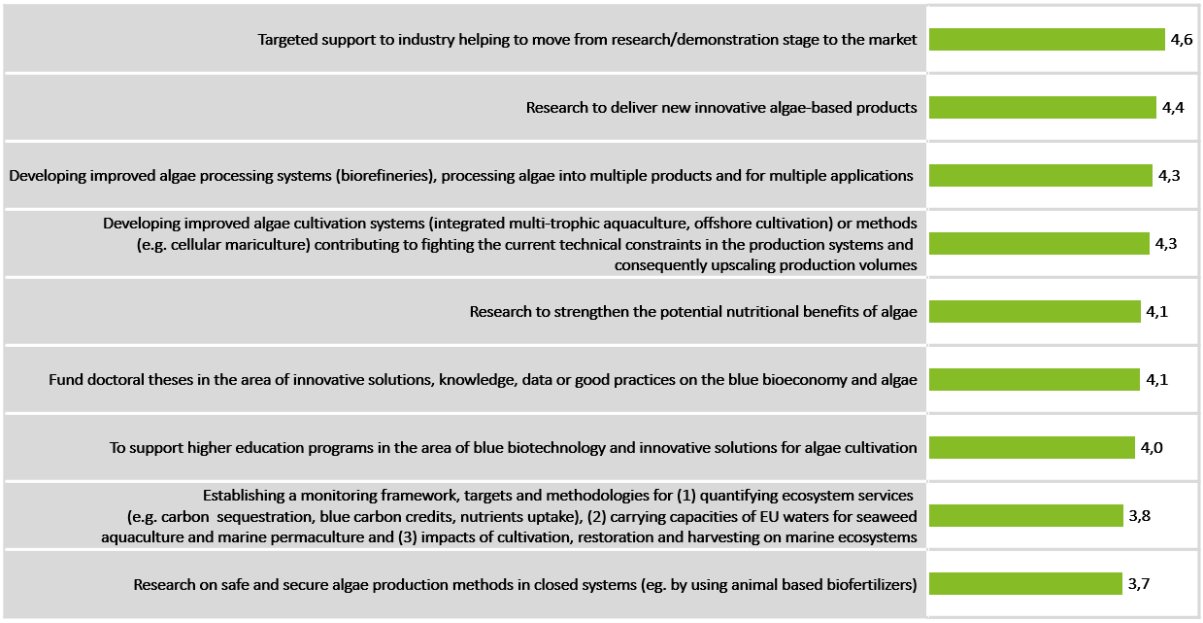

Figure 26. Proposed measures for closing knowledge, research and innovation gaps (microalgae)

Figure 27. Proposed measures for closing knowledge, research and innovation gaps (macroalgae)

Figure 28. Highest impact from closing the knowledge, research and innovation gaps (microalgae)

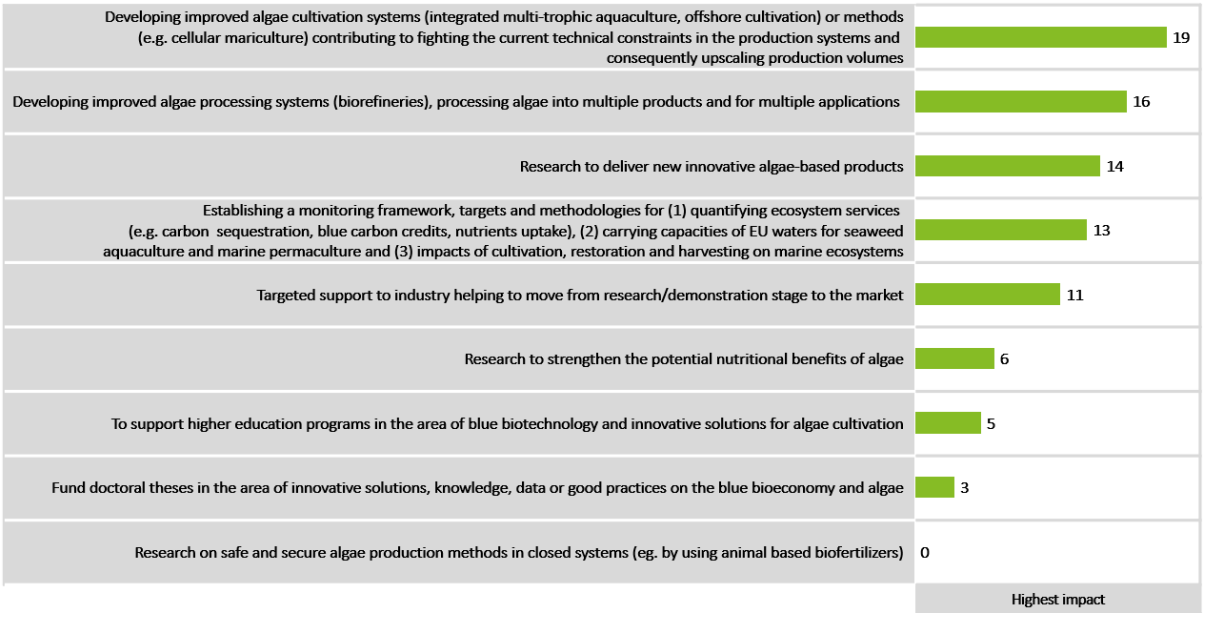

Figure 29. Highest impact from closing the knowledge, research and innovation gaps (macroalgae)

One of the recurring themes in the interviews was that there should be going more funds to research into the application of algae, the production of algae, domestication of foreign species, and nutritional benefits of algae. Although the measure 'Research to strengthen the potential nutritional benefit of algae' was not perceived as creating the highest impact by a lot of respondents to the PC – 14 in microalgae and 6 in macroalgae, the measures about developing improved cultivation systems and processing systems and the measure 'Research to deliver new innovative algae-based products' were perceived as generating the highest impact by a lot of respondents to the PC.

4. ANNEX 4: OVERVIEW OF EU LEGAL REFERENCES PERTAINING TO ALGAE

Legislation / Initiative	Objective	Relevance to algae
	A. Overarching Legal Frameworks	
Treaty on the Functioning of the European Union (TFEU)	This Treaty organizes the functioning of the Union and determines the areas of, delimitation of, and arrangements for exercising its competence.	Specifies that the European Union: 1. has **exclusive competence** in the conservation of marine biological resources under the **common fisheries policy**; 2. and **shares competence** with Member States on agriculture and fisheries (including aquaculture, common fisheries market organization), thereby covering the various types of algae production, excluding the conservation of marine biological resources, in the principal areas of: - Common safety concerns in public health matters; - Consumer protection; - Environment (TFEU, Article 191).[170]
Common Fisheries Policy	The CFP ensures that fishing and aquaculture activities are environmentally sustainable in the long-term, and are managed in a way that is consistent with the objectives of achieving economic, social and employment benefits, and of contributing to the availability of food supplies.	Under the CFP, Member States share competence in the area of aquaculture and fisheries, including the cultivation and wild harvesting of algae. In line with the CFP, the EU delivered strategic guidelines for a more sustainable and competitive EU aquaculture, which aims to boost the development and competitiveness of the aquaculture sector. The guidelines include plans and guidance for the use of aquatic plants in aquaculture.
	B. Algae for food and feed	

[170] Article 191 on the Environment states that Union policy on the environment shall contribute to pursuit of the following objectives:
- preserving, protecting and improving quality of the environment.
- Protecting human health.
- Prudent and rational utilisation of natural resources.
- Promoting measures at international level to deal with regional or worldwide environmental problems and in particular combating climate change.
- Union policy shall aim a t high level protection – precautionary principle – preventive action should be taken and environmental damage should as a priority be rectified at source and that the polluter should pay.
- Harmonisation measures answering environmental protection requirements shall include a safeguard clause allowing Member States to take provisional measures.

Food safety regulation	Food safety regulation sets out basic principles to protect safe human nutrition and consumer interests. Within the EU, food regulation envelops specific regulations under the following topics: • Rules on food hygiene which set standards to be met for the premises, transport conditions, waste, water supply, personal hygiene of workers and heat treatment processes • Rules on safe food packaging including those on plastic, cellulose and recycled plastic packaging where relevant • Rules on food labelling. • Rules on contaminants in foods which set the maximum levels of metal toxins and contaminants allowed in food • Rules on nutritional and health claims which any claim made on a food label in the EU is clear, accurate and substantiated, enabling consumers to make informed and meaningful choices	Algae harvested or cultivated for human consumption must comply with the specifications set out under the food safety regulation. Algae are exempted to take regard of rules on food labelling unless algae are sold unprocessed.
Novel food Regulation (NFR) / Regulation (EU) 2015/2283	The NFR requires a pre-market authorisation before novel foods (foods for which a history of consumption before 15 May 1997 cannot be documented) can be placed on the EU market. Business operators wanting to place a food on the EU must assess and determine its novel food status of their foods. In case of doubt they shall consult with the Member State on which they first intend to place the food on the market. Applications for the authorization of novel foods must be submitted to the European Commission and authorisation is granted by the Commission on the basis of a positive safety assessment of the novel food by the European Food Safety Authority .	The regulation is applicable to all foods classified as 'novel food', which applies to a variety of micro- and macroalgae produced for food or food supplements (Araujo and Peteiro, 2021) for which a history of consumption before 15 May 1997 cannot or has not been documented New algae substances are required to request authorisation under the regulation before entering the market.
Novel Food Catalogue (NFC)	The NFC is a non-legally binding data base reflecting the views of Member States on the novel food status of foods that have been considered and discussed over the years. This list is non-exhaustive, and serves as orientation whether a product will need authorisation under the Novel Food Regulation. A food item listed in the NFC may have one of the following statuses: novel, not novel, not novel in food supplements or subject to an ongoing novel food status consultation. If a product is not included, it should not necessarily be considered as novel but as an item whose status was either not previously discussed or to which a consultation request has not been launched yet (Araujo and Peteiro, 2021)[12].	Any algae species categorised as novel need to be authorized in correspondence with the Novel Food Regulation. If an algae is listed in the NFC as being not novel or not novel in Food Supplements, it can be placed on the market for the corresponding application (either as food or in Food Supplements).

EU Recommendation 2018/464	Under the EU recommendation, concentrations of arsenic, cadmium, iodine, lead and mercury in seaweeds and halophytes are monitored to establish maximum levels for food/food supplements in which no harmful effects for human health are indicated.	To set the maximum allowed levels of iodine, heavy metals and other contaminants in seaweed, halophytes and products based on algae, Member States in cooperation with food and feed business operators are asked to monitor the presence of these substances over the years 2018, 2019 and 2020.[171]
Regulation (EC) No 1924/2006	This regulation, also known as the claims regulation, sets out the framework for using nutrition and health claims in the EU. The claims regulation requires that only permitted nutrition and health claims may be used on the EU market, which are listed in the Annex of the Claim regulation and are in conformity with the conditions of use accompanying them and concerning health claims. Member States carry the responsibility to enforce food law and monitor and verify that relevant EU requirements are fulfilled by food business operators.	Algae may be used in food products due to their high nutritional profile, and should therefore conform to the claims regulation regarding vitamins, minerals and fatty acids (there are no authorised health claims regarding amino acids) if any reference is made to nutritional and health claims of algae use in a product.
Regulation (EU) No 68/2013 / Regulation (EC) No 1831/2003	In the EU, products used for animal nutrition are classified either as feed materials or feed additives. Feed materials do not require a pre-market authorisation, but do need to comply with regulation on feed hygiene, rules on the marketing of feed, undesirable substances in feed (under Directive 2002/32/EC) and rules on feed additives. Feed additives are products used in animal nutrition with the purpose of improving the quality of feed and the quality of food from animal origin, or to improve the animals' performance and health, e.g. providing enhanced digestibility of the feed materials. Feed additives may not enter the EU market unless authorization is given following a scientific evaluation showing that the additive has no harmful effects on human and animal health and on the environment. Therefore, feed additives regulation provides rules on the supervision and labelling of feed additives to ensure good practices and effective functioning of the internal market.	Algae are used as fish and animal feed and in feed additives in aquaculture, agriculture and for pets due to their nutritional profile (amino acids, vitamins, minerals and essential fatty acids). The cultivation or harvesting of algae for animal feed does not need pre-market authorisation, but do need to comply with specified regulations. The Commission shares competence with Member States in this regard. Regulation (EU) No 68/2013, the Catalogue on feed materials, lists the various types of algae and good practice principles on the use of chemical impurities and processing aids.

[171] -For mercury in seaweed already an MRL is set under the pesticides legislation (Reg. (EC) No 396/2005) (with possibility of revision). -For cadmium in food supplements, which contain dried seaweed, in regulation (EC) No 1881/2006 a maximum level is set (with possibility of revision).

Regulation 1832/2021 (OJ L385, 29/10/2021)	Establishes a good nomenclature to meet, at one and the same time, the requirements of the Common Customs Tariff, the external trade statistics of the Union, and other Union policies concerning the importation or exportation of good.	Algae-products that are imported from countries (outside the EU) fall under specific trade tariffs. - Under the regulation, seaweeds and other algae, fresh, chilled, frozen or dried, whether or not ground, fall under HS[172] heading 1212 of the nomenclature and have 0% MFN[173] tariff. - Seaweeds and other algae products prepared or preserved by processes such as cooking, roasting, seasoning or adding sugar fall under Chapter 20 – classified as preparations of other parts of plants, and various MFN tariff may apply to algae-related products.
	C. Algae for non-food uses	
Directive 2001/83/EC / Regulation (EC) No 726/2004	The directive gives the provisions laid down by law, regulation or administrative action relating to medicinal products for human use, including use of specific substances, labelling and advertising for different types of medicine. In the EU, medicinal products may be authorised by a centralised procedure, run by the EU Medicine Agency or through a mutual recognition procedure with the medicinal product authorised in a single Member State at first and then starting a process of recognition of that authorisation in other Member States. Clinical trials are regulated by EU legislation under Regulation (EU) No 536/2014.	Algae are used within the field of pharmaceuticals, given their wide range of bioactive compounds (Dmytryk et al., 2017). Therefore, algae use in medicinal products are regulated through the specified directive and regulation, and need to be authorised for use.
Regulation on the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH)[174]	REACH is the main regulation regarding legislation for chemicals in the EU. It provides a comprehensive set of rules applicable to chemical substances and compounds, and places the responsibility of managing the associated risks onto the industry. Under the regulation, any company manufacturing or importing one ton or more of a substance needs to register with the European Chemicals Agency (REACH,	Algae can be used as sources of **fine chemicals, botanical extracts and active substances** in several applications (e.g. astaxanthin, phyco-cyanin, fucoxanthin and numerous speciality high-value applications in pharmaceutics, medicine and cosmetics), wherefore their use may fall under the REACH regulation.

[172] Harmonized System (HS): standardized numerical classification of trade products. The system is used to assess which duties and tariffs apply to specific types of products when imported (EC HS).
[173] The Most Favoured Nation (MFN): principle under the WTO specifies that under the WTO agreements, countries cannot normally discriminate between their trading partners. Grant someone a special favour (such as a lower customs duty rate for one of their products) and you have to do the same for all other WTO members (WTO).
[174] In relation, there is Directive 1223/2009/EC, which gives the provisions related to cosmetics regulation, setting rules for the substances and mixtures intended for cosmetic use, to ensure that cosmetic products shall be safe for human health.

	Article 6). Substances manufactured or imported for the purposes of research and development do not need to be registered for 5 years. On the contrary, substances that pose high risks cannot be used until an authorisation is issued and the applicants are asked to analyse the feasibility of substitution (REACH, article 55).	
Fertilising Products Regulation / Regulation (EU) 2019/1009	Harmonises the requirements for EU fertilising products produced from primary or secondary raw materials, opening up new possibilities for production and marketing on the single market. The regulation sets harmonised limits for a range of contaminants, such as cadmium contained in phosphate fertilisers. The regulation provides provisions only for EU fertilising products, and allows Member States to maintain national legislations to regulate fertilising products marketed on national markets.	EU fertilising products may only contain materials that comply with the Component Material Categories (CMC). There are various CMCs covering algae: CMC1, CMC2, CMC3, CMC4, CMC5.[175] Therefore, algae, algae parts or algae extracts may be used in fertilising products if they comply with the requirements of the respective CMCs, and the resulting fertilising product complies with all relevant provisions.
Directive 2018/2001	This directive gives the provisions related to the use of energy from renewable sources. It set binding targets on the share of renewable energy in energy consumption and in the transport sector.	Algae can be used as sources for the production of biogas for transport and advanced biofuels.
	Algae cultivation and multi-use of space	
Marine Spatial Planning Directive	Application of an ecosystem-based integrated approach to spatial planning of the maritime environment, ensuring the sustainable economic development and ecological protection of maritime and coastal areas.	The use of maritime space for multiple purposes, including algae cultivation, requires integrated planning of space usage by potentially competing activities.
Organic Regulation / Regulation (EU) 2018/848[176]	The Organic Regulation (repealing and replacing Council Regulation (EC) No 834/2007 and applicable since January 1st 2021) provides the basis for the sustainable development of organic production and its positive effects on the environment, while ensuring the effective functioning of the internal market in organic products and fair competition,	Algae producers aiming to obtain the 'organic' label need to comply with production rules specified in Regulation (EU) 2018/848. Within the rules, a distinction is made between the collection and cultivation of algae. The Organic Regulation signifies that harvesting

[175] - CMC 1: all algal extracts ; REACH registration of such extracts is mandatory. Extracts originating from waste are excluded
- CMC 2: algae, algae parts and algal extracts having undergone no other processing than cutting, grinding, milling, sieving, sifting, centrifugation, pressing, drying, frost treatment, freeze-drying or extraction with water or supercritical CO2 extraction. Blue-green algae are excluded.
- CMC 3: compost generated by the aerobic composition of algae or algae parts (waste or non-waste). Algae materials shall be unprocessed or processed only by manual, mechanical or gravitational means, by dissolution in water, by flotation, by extraction with water, by steam distillation or by heating solely to remove water, or which are extracted from air by any means.
- CMC 4: digestate generated by the anaerobic digestion of algae or algae parts grown for the production of biogas. Blue-green algae are excluded.
- CMC 5: digestate generated by the anaerobic digestion of algae or algae parts (waste or non-waste). Algae materials shall be unprocessed or processed only by manual, mechanical or gravitational means, by dissolution in water, by flotation, by extraction with water, by steam distillation or by heating solely to remove water, or which are extracted from air by any means.

[176] **Regulation (EC) 710/2009**: lays down rules for the implementation of organic regulation (organic aquaculture and seaweed production).

	thereby helping farmers to achieve a fair income, ensuring consumer confidence, protecting consumer interest and encouraging short distribution channels and local production. Those objectives should be achieved through compliance with general and specific principles and general and detailed production rules applicable to organic production	of wild algae should not significantly affect the natural stability of the ecosystem in the collection area. Algae cultivation shall use sustainable practices throughout the supply chain to ensure the maintenance of a wide gene pool and no use of fertilizers in open cultivation processes.[177] Algae can be harvested wild and cultivated in accordance with those provisions, and can be labelled organic when respecting such rules.
Regulation (EC) No 1893/2006	The regulation establishes the statistical classification of economic activities to reflect the technological development and structural changes of the EU economy to inform and contribute more comparable and relevant economic data to establish better economic governance at both Community and national level. The different economic activities are categorised under NACE codes.	Algae cultivation can occur in different practices, macroalgae cultivation (in open marine environment or closed systems), and microalgae and cyanobacteria cultivation in closed systems. These different practices fall under various NACE codes, which specifies the licensing requirement under which the producers are required to operate.[178]

[177] **2.2. Production rules for algae**

2.2.1. The collection of wild algae and parts thereof is considered as organic production provided that:

(a) the growing areas are suitable from a health point of view and are of high ecological status as defined by Directive 2000/60/EC, or are of equivalent quality to:

— the production zones classed as A and B in Regulation (EC) No 854/2004 of the European Parliament and of the Council (1), until 13 December 2019, or

— the corresponding classification areas set out in the implementing acts adopted by the Commission in accordance with Article 18(8) of Regulation (EU) 2017/625, from 14 December 2019;

(b) the collection does not affect significantly the stability of the natural ecosystem or the maintenance of the species in the collection area

2.2.2. The **cultivation of algae** shall take place in areas with environmental and health characteristics at least equivalent to those outlined in point 2.2.1(a) in order to be considered organic.

In addition the following n rules shall apply:

(a) sustainable practices shall be used in all stages of production, from the collection of juvenile algae to harvesting;

(b) to ensure that a wide gene-pool is maintained, the collection of juvenile algae in the wild shall take place on a regular basis so as to maintain and increase the diversity of indoor culture stock;

(c) fertilisers shall not be used, except in indoor facilities, and only if they have been authorised pursuant to Article 24 for use in organic production for this purpose

[178]

Activity	NACE section	NACE division	NACE group	NACE class
Seaweed cultivation at sea	A	03	03.2 (Fishing and aquaculture)	03.21 (Marine aquaculture)
Seaweed cultivation in ponds	A	03	03.2 (Fishing and aquaculture)	03.22 (Freshwater aquaculture).
Microalgae cultivation with salt water (in in open raceways of photobioreactors)	A	03	03.2 (Fishing and aquaculture)	03.21 (Marine aquaculture)
Microalgae cultivation with freshwater (in open raceways of photobioreactors)	A	03	03.2 (Fishing and aquaculture)	03.22 (Freshwater aquaculture)

	D. Conservation and preservation of the marine environment	
Habitats Directive	Promote biodiversity by protecting natural habitats and species, contributing to the sustainable development of ecosystems at the EU level.	Safeguard natural habitat types, including various algae species that are present in coastal and halophytic habitats. In particular seas and tidal areas with reefs. The development of aquaculture, and thus algae, should be compatible with the environmental protection stipulated in this Directive.
Marine Strategy Framework Directive	Achieve Good Environmental Status of the EU's marine (open) waters (by 2020) and to protect the resource base upon which marine-related economic and social activities depend.	The cultivation and harvesting of algae should not affect in a negative impact on the biodiversity and intertidal ecosystems and sea-floor integrity, should not contribute to the introduction of invasive species, and should not contribute to eutrophication in marine waters.
Water Framework Directive [179]	Achieve good environmental status for all ground and surface waters (rivers, lochs, transitional waters, coastal waters and groundwater) in the EU.	Aquaculture, including algae, development should not negatively affect the biodiversity of macrophytes and phytobenthos or increase eutrophication in ground and surface waters.
Environmental Impact Assessment Regulation / Directive 2011/92 EU and amendment 2014/52/EU	Establish and harmonise procedures for the environmental impact assessment (EIA) of private and public projects, which are likely to have significant effects on the environment (principles, minimum requirements, assessment content).	When regarded as having a significant impact, algae related project, both in marine ecosystems and on-land), are subject to an EIA. All new algae farms producing over 20tonnes a year, and wishing to acquire an 'organic' label are also subject to an EIA.
Waste Framework Directive	The Directive sets out basic waste management principles to manage waste's impact on human health and the environment and comply with re-use and recycling objectives. It explains basic concepts and definitions of waste, recycling and recovery.	Algae related materials may be categorised as ''waste'' or ''non-waste''. The status of algae related materials does not fall under the EU, but is determined the Member States along with the implementation of

Processing and preserving fresh seaweed and microalgae/cyanobacteria	C	10	10.2	10.20 (Processing and preserving of fish, crustaceans and molluscs).
Retailer or wholesaler buying seaweed or microalgae biomass to manufacture products	G	46 (wholesale) or 47 (retail)	46.3 (wholesale) 47.2 (retail)	46.38 (wholesale) 47.29 (retail)
Importing algae products from 3rd countries?	G	Depends on the product	Depends on the product	Depends on the product

[179] Collectively, the HB, MSFD, WFD specify that the collective pressure of human activity, including algae cultivation or harvesting, does not compromise the good environmental status (GES) or capacity of marine ecosystems to respond to change.

		provisions in the Waste Framework Directive. Therefore, algal material considered ‘’waste’’ in one Member State might be considered as ‘’by-product’’ in another.
Invasive Alien Species Regulation / Regulation on alien and locally absent species in aquaculture	The Invasive Alien Species Regulation sets measures on the prevention and management of the introduction and spread of non-indigenous and invasive alien species into the environment. Related is the Regulation on alien and locally absent species in aquaculture, which establishes a framework governing aquaculture practices in relation to alien and locally absent species to asses and minimise the possible impact of these and any associated non-target species on aquatic habitats – contributing to sustainable development of the sector.	The cultivation of algae species in open marine environments may result in the introduction of alien species, which can become invasive species. Examples show that introduction of algae species can have a negative impact on coastal ecosystems. Therefore, algae cultivation sites should consider potentially invasive species in the production process, as they may have negative impacts on native species and ecosystems overall (Barbier et al., 2019).
List of Invasive Alien Species of Union Concern	Core of the Alien Species Regulation is the List of Invasive Alien Species of Union Concern, which includes species that are subject to restrictions and measures (on keeping, importing, selling, breeding and growing) set out in the Regulation. Member States are required to take action on pathways of unintentional introduction, to take measures for early detection and rapid eradication of these species, and to manage species that are already widely spread in their territory. Member States can also propose additional species for inclusion in the Union List.	Currently, the Union List does not include any marine species. National lists of invasive alien species of Member States do include several seaweed (macro algae) species, which need to be followed by algae producers. Furthermore, harmonisation between EU Member States on alien invasive species would help manage/monitor/prevent impacts due to the open-nature of marine environments.
	E. Algae-related policy initiatives	
Certification of carbon removals	This initiative is in the pipeline and proposes EU rules on certifying carbon removals. It will develop the necessary rules to monitor, report and verify the authenticity of these removals. The aim is to expand sustainable carbon removals and encourage the use of innovative solutions to capture, recycle and store CO2 by farmers, foresters and industries. This represents a necessary and significant step towards integrating carbon removals into EU climate policies. (Feedback period from 7th February 2022 – 2nd May 2022)	Algae cultivation carries the potential for carbon removal from marine ecosystems, and therefore the development of the algae industry can contribute to the goal to capture, recycle and store CO2. Currently, the European Commission is conducting several studies (one of these is an *Algae and Climate Study*) to assess the potential of algae to contribute to carbon uptake, removal and sequestration to quantify algae’s ability to contribute to EU objectives under the European Green Deal.

Nature restoration targets (impact assessment approved by regulatory scrutiny board)	The initiative proposes legally binding EU nature restoration targets to reverse biodiversity loss and restore degraded ecosystems (i.e. with high importance for biodiversity), in particular those areas with most potential to remove and store carbon and to prevent and reduce the impact of natural disasters. Legislative proposals towards restoration targets should include ecosystem-, habitat- and species specific targets, and restoration should contribute to biodiversity as well as to climate change mitigation and adaptation, and stressing the importance of ensuring non-deterioration of restoration ecosystems.	Algae cultivation has the potential to contribute to goals set under the nature restoration targets, as it can support various ecosystem services when managed appropriately: absorption of excess nutrients and organic matter, improvement of water quality, CO2 uptake.
Sustainable Carbon Cycles - carbon farming (communication adopted)	To achieve carbon objectives set on an international and EU level, sustainable and climate-resilient carbon cycles must be established through three key actions: 1.Reduce the reliance on carbon: switch to circular economy and renewable energy. 2.Recycle carbon from waste streams, from sustainable sources of biomass or directly from the atmosphere. 3.Upscale carbon removal solutions that capture CO2 from the atmosphere and store it for the long term, either in ecosystems through nature protection and carbon farming solutions or in other storage forms through industrial solutions while ensuring no negative impact on biodiversity or ecosystem deterioration Proposes carbon farming as a business model for healthier ecosystems, in which farming will be a green business model that rewards land managers for taking up improved land management practices resulting in increased carbon sequestration, dead organic	As specified under the initiative *Certification of carbon removals*, algae have the potential to contribute to nutrient removal and CO2 uptake in their production cycle. In addition, algae cultivation is perceived as a viable alternative to traditional fishing and aquaculture, and is highlighted as a blue farming alternative. Therefore, algae cultivation can help the transition into new forms of low trophic food systems (EU Sustainable Aquaculture Guidelines).
A New Approach for a Sustainable Blue Economy	This communication takes a systematic view that integrates ocean policy into our Europe's new economic policy. Our ocean, and the 'blue economy' it supports, is indispensable to achieving the transformation set out in the European Green Deal. Therefore, the communication sets out a detailed and realistic agenda for the blue economy to play a major role in achieving EGD objectives, and aims to connect the green and blue policies, while extending the approach beyond EU borders into international ocean governance.	- New algae-based food and feed products in the EU market – a major opportunity for the development of a sustainable food sector. - Algae-based food can alleviate environmental pressures exerted by agriculture, aquaculture, and fisheries. - Algae production at sea removes excess carbon, nitrogen and phosphorus from water. - Commission will also explore the potential of cell-based seafood as

		an innovative and sustainable alternative.
Strategic guidelines for a more sustainable and competitive EU aquaculture	These guidelines form the main pillar of strategic coordination of aquaculture policy in the EU. In line with the European Green Deal and Farm to Fork Strategy, the guidelines offer a common vision for EU Member States and all relevant stakeholders to contribute to an aquaculture sector that is: 1) competitive and resilient; 2) ensures the supply chain of nutritious and healthy food; 3) reduces the EU dependency on seafood imports; 4) creates economic opportunities and jobs; 5) becomes a global reference for sustainability.	The aquaculture guidelines refer to the algae sector in multiple ways: - Refers to the EU Algae Initiative to address the challenges and opportunities of algae farming and propose concrete action. - Refers to Farm to Fork Strategy: the Commission will 'set out well-targeted support for the algae industry, as algae should become an important source of alternative protein for a sustainable food system. - Algae as an alternative protein for sustainable feed systems. - Promoting other aquaculture systems with lower environmental impact, such as: IMTA and lower trophic species (e.g. algae farming).

5. Annex 5: Expected impacts of a strong and sustainable EU Algae sector

In a keynote speech at European Maritime day, 20 May, 2021, Commissioner Sinkevičius announced that a new algae initiative to be launched in 2022 will *"unlock the potential of the EU algae sector, which provides cheap, nutrient-rich proteins from the oceans and can be grown in combination with other activities, such as offshore wind."*[180] This official recognition and support of the EU algae sector as a regenerative industry spearheading the European Green Deal builds on a growing collection of evidence that algae can generate multiple positive benefits for people, nature and the economy. This chapter hence first presents in more details the types of impacts that would be generated from a strong and sustainable EU algae sector if its potential was to be unlocked in the next decade, based on the current best available knowledge.

A strong and sustainable EU Algae sector is expected to generate multiple positive impacts on nature, people and the economy in the next 5 to 10 years if its potential is to be unlocked. The overview of potential impacts presented below builds on latest scientific knowledge to date.

5.1. Potential environmental impacts.

Given the characteristics of algae cultivation and its versatility of use cases, algae is a powerful ally to address simultaneously multiple environmental challenges, ranging from climate change, marine biodiversity loss and eutrophication, overfishing, coastal habitats degradation, plastic pollution or soil erosion. This sub-heading evaluates potential environmental impacts of algae production and algae products.

5.1.1. Environmental impacts of algae production.

Macroalgae (seaweed) production

Current macroalgae production in the EU predominantly takes place by harvesting of wild stocks. The sustainability of this practice is under debate and increasingly subject to strict management plans. Aquaculture production of seaweed is presently ongoing in 13 EU countries and is still at an early stage of development[181] but growing. In the future, the development of sustainable seaweed aquaculture is seen as the preferred pathway to scale up the EU production. Macroalgae cultivation is expected to occur in near-shore or offshore locations using line systems or alternative production systems. Cultivation may be combined with wind turbine parks in multi-use systems[182] or integrated with other types of aquaculture incl. cultivation of fish in so-called Integrated Multi Trophic Aquaculture (IMTA) systems (see Figure 30. below).

[180] European Commission. "Commissioner Sinkevičius Keynote Speech at European Maritime Day, 20 May, 2021, Den Helder, Netherlands – European Commission."

[181] Current Status of the Algae Production Industry in Europe: An Emerging Sector of the Blue Bioeconomy. Araújo Rita, Vázquez Calderón Fatima, Sánchez López Javier, Azevedo Isabel Costa, Bruhn Annette, Fluch Silvia, Garcia Tasende Manuel, Ghaderiardakani Fatemeh, Ilmjärv Tanel, Laurans Martial, Mac Monagail Micheal, Mangini Silvio, Peteiro César, Rebours Céline, Stefansson Tryggvi, Ullmann Jörg., 2021. Frontiers in Marine Science, 7.

[182] Mussel and Seaweed Cultivation in Offshore Wind Farms: An Opinion Survey. Michler-Cieluch, Tanja, and Silvia Kodeih., 2008. Coastal Management, vol. 36, no. 4, pp. 392–411.

Figure 30. Main Seaweed aquaculture and microalgae production methods

Sustainable scale-up of the EU macroalgae production would have multiple benefits on the environment. Indeed, unlike for equivalent land-based food or materials, seaweed production generally does not require any freshwater, fertiliser or other external inputs. There is also no need to repurpose or clear land – a necessary practice for terrestrial crops which often results in the disruption and displacement of biodiversity or, in the worst cases, its complete loss (for example through deforestation). In addition, seaweed plays a central role in providing critical ecosystem services. It forms an integral part of a complex ocean food web and offers habitat, nursery grounds and shelter for different ocean species, contributing to restoring marine biodiversity. Seaweed supplies oxygen to and increases the pH of the water it grows in, and so reduces both the hypoxia that occurs with eutrophication, and ocean acidification – a problem that is becoming ever more acute with current global warming trajectory. Seaweed also dissipates wave energy and prevents coastal erosion. Besides, seaweed absorbs a range of inorganic nutrients from the ocean, including nitrogen and phosphorus, often found in excess in coastal areas due to agriculture run-offs. Lastly, seaweed is expected to have a beneficial carbon footprint, where emissions due to production are likely to be at least offset by sequestration of carbon from the sinking of detached seaweed fragments to the bottom of the ocean, creating a carbon sink.

In spite of all these proven environmental benefits, some impacts of seaweed farming (including negative ones) still need to be further evaluated by rigorous scientific studies in collaboration with the industry and policy makers to prevent any unintended effects while scaling up the production. This includes for instance a better quantification of the fluxes between carbon sequestered and carbon emitted by production processes; a better assessment and mitigation plans of potential risks associated with large scale seaweed farming in terms of nutrients uptake or impact on seabed and local biodiversity; or the analysis of the net impact of seaweed onshore farming (in land-based tanks) given the high energy consumption and land-use. Below are given 3 macroalgae use-cases to have a more complete picture of macroalgae processing into the products

Use-case 1: Macroalgae being used for food

With a more developed macroalgae industry, it is suggested that protein from fish might be replaced to some extend by macroalgae protein. This will translate in a reduction of pressure on fish and may support the fish stock recovery. If macroalgae products are used to replace terrestrial crops for consumption, like soy, it will also reduce the pressure on terrestrial areas and thus have a positive environmental impact.[183] Whereas the savings in carbon emissions from replacing animal-based proteins with seaweed have been proven, it gets more complicated with other vegetables, like soy or palm oil. Here, life cycle analysis for each product will give insight into the net carbon balance, taking into consideration the currently high fuel consumption for macroalgae cultivation. However it needs to be ensured that an increased consumption of algae would not adversely affect the health of EU consumers, possibly related to the presence of high concentrations of contaminants (in particular heavy metals) in algae.

Use-case 2: Macroalgae being used for animal feed

It has been widely criticised, that with a declining fish stock available in our oceans, wild fish is being caught only to be transformed to fishmeal and fed to farmed fish. Another source of feed for these farms is soybeans which also have a high carbon footprint whose production is sometimes driving to deforestation. Yet, the first results of studies show that it is possible to replace soy- or fish protein in animal feed with macroalgae depending on the protein content, the fatty acids, and the aminoacidic profile.[184] Similar to use-case 4, if macroalgae replaces terrestrial crops for animal feed it has the same positive impact on the environment by a possible increase in terrestrial biodiversity, reduction of pressure on terrestrial land. Comparisons of LCA for each product need to be made to determine the net carbon balance of each product and thus its impact on the environment.

Various studies confirm that the addition of macroalgae to ruminants' diets can reduce CH4 emissions, with a reported reduction of over 80%.[185] While some studies show a negative impact on animal health, product quality, and residues[186], some other evidence demonstrates that animal health and product quality is not compromised at the minimum effective feed inclusion levels of certain seaweeds[187], thus further research and in vivo studies are required to strengthen the evidence base of the effectiveness of using seaweed as feedstuffs to reduce enteric emissions.

Use-case 3: Macroalgae being used for bioremediation

[183] Environmental impacts of protein-production from farmed seaweed: comparison of possible scenarios in Norway. Koesling Matthias, Pvadsheim Nina P, Halfdanarson Jon, Emblemsvag Jan, Rebours Celine. 2021. Journal of Cleaner Production volume 307.
[184] Strategic considerations for establishing a large-scale seaweed industry based on fish feed application: a Norwegian case study Emblemsvåg, J., Kvadsheim, N.P., Halfdanarson, J. 2020. Appl Phycol 32.
[185] Red seaweed (Asparagopsis taxiformis) supplementation reduces enteric methane by over 80 percent in beef steers. Roque BM, Venegas M, Kinley RD, de Nys R, Duarte TL. 2021. PLOS ONE 16(3)
[186] Safety and Transfer Study: Transfer of Bromoform Present in Asparagopsis taxiformis to Milk and Urine of Lactating Dairy Cows. Muizelaar W, Groot M, van Duinkerken G, Peters R, Dijkstra J. 2021. Foods 10(3).
[187] Benefits and risks of including the bromoform containing seaweed Asparagopsis in feed for the reduction of methane production from ruminants. Glasson, C.R.K., Kinley, R.D., de Nyys, R et al. (2022). Algal Research (64) 102673.

This use-case *reiterates* the generic impacts of cultivation that were already stated above, the capacity to take up nitrogen and phosphorus and to capture CO_2. It is still important to focus on these "generic impacts" here once again, since according to the online public consultation of this document, the bioremediation quality of macroalgae was the third important use for them. This shows the growing awareness about the importance of circularity in our economy and the regeneration of our ecosystems.[188] The nutrient uptake (N,P), can play a role in a circular economy approach[189], by closing the gap between ocean and land industries with using feeding on the nutrients from the wastewater and growing consumable goods.

Microalgae (and cyanobacteria) production

In the EU, PhotoBioReactors (PBRs) are the most common type of system used for microalgae production (71%) while open ponds and fermenters represent 19% and 10% of the total production units respectively[190]. For *Spirulina* the predominant technology used is open ponds (sometimes placed in a greenhouse). Thus, in the future use-cases for the EU, the closed systems including PBRs as well as fermenters are most likely to remain dominant (>70%) since most development can be expected there. Some growth may occur of open systems (e.g. for Spirulina) or hybrid systems combining PBR or fermentation technology to produce inoculum coupled to a photoautotrophic system (open or closed) for the grow-out phase of production. Important to acknowledge, that PBRs don't require much space for biomass production, which reduces the overall pressure on land and sea space. Overall, the energy consumption in PBR's is a point for consideration in the environmental assessment. In the microalgae sector considerable attention is aimed at energy-saving technologies and strategies, as well as scale up and cost reduction of photoautotrophic production systems. Furthermore, we can expect an expansion of commercial heterotrophic algae production seeing the technical advantages and the potential for scale up while reducing production costs and the expected environmental benefits. Microalgae production can also have other environmental benefits if using agricultural by-products or agro-industrial effluents as a source of nutrients, helping valorising waste and recycling nutrients from other bio-industries (e.g., dairy industry, brewery effluents, sugar cane, etc.). In addition, the closed systems allow a clear monitoring of the CO2 consumption. In the future, the issue will be scrutinized and will impact LCA as well as services costs calculation. Below are given 3 microalgae use-cases to have a more complete picture of microalgae processing into the products.

Use-case 4: Microalgae being used in food and food ingredients

According to Araujo et al. food supplements and nutraceuticals (24%), cosmetics (24%), and feed (19%) are the main current application areas of microalgae biomass. The use of microalgae and *Spirulina* in food and as food ingredients is a major application area. This refers particularly to the use of whole algae biomass (e.g. *Spirulina*, *Chlorella*) as a food supplement / nutraceutical. Furthermore, other species are produced and used for their content of valuable, functional food components including

[188] Habitat value of bivalve shellfish and seaweed aquaculture for fish and invertebrates: Pathways, synthesis and next steps. Theuerkauf, SJ, Barrett, LT, Alleway, HK, Costa-Pierce, BA, St. Gelais, A, Jones, RC. 2021. Aquac 14.
[189] Opportunities and limitations for the introduction of circular economy principles in EU aquaculture based on the regulatory framework. Regueiro, L, Newton, R, Soula, M, et al. 2021. J ind Ecol.
[190] Current Status of the Algae Production Industry in Europe: An Emerging Sector of the Blue Bioeconomy. Araújo, R., Vázquez Calderón, F., Sánchez López, J., et al. (2021). Front. Mar. Sci., 27.

Dunaliella (beta-carotene), *Haematococcus* (astaxanthin), *Nannochloropsis* (omega fatty acid EPA). Algae may be produced via fermentation or photoautotrophically. Developments are ongoing to expand the use of microalgae in human food as a source of proteins and oils. It is expected that the use of microalgae as a source of food ingredients will grow considerably in the coming decades (data from OPC this study). In the EU, any novel microalgae species or product needs to undergo a pre-market authorisation through the Novel Food regulation before it can be placed in the food market. The use of microalgae in human food as an alternative source of omega oils and proteins may reduce the amount of fish used for human consumption and reduce the terrestrial area in use e.g., for production of edible oils including palm oil [191,192,193]. The achieved reduction of carbon emissions by using algae products instead of conventional products is dependent on the production process and on the actual products that are replaced. At the current stage of development microalgae products may or may not have lower environmental impacts than conventional products, unless we can make more efficient systems, reduce energy use, and increase productivity[194]. Seeing the current stage of fermentative production, we can expect that fermentative production of food ingredients will strongly increase in the future.

Use-case 5: Microalgae being used in feed and feed ingredients

Today a range of microalgae species are used as an ingredient in aquaculture feeds and animal feed[195]. The application of microalgae as a functional ingredient in aquafeeds is considered a potential growth area. This refers in particular to algae as an alternative source of omega oils EPA and DHA as an alternative for fish oils or krill oil and for bioactive components that enhance the immune system of cultivated fish[196]. Microalgae are used as a component in formulations for larvae and juvenile feeds. Besides aquafeed, potential microalgae applications in the feed industry are considered for pets, horses, poultry, pigs and other animals.

Microalgae have a suitable amino acid profile for this application area and good digestibility as well as an interesting lipid profile including long chain omega fatty acids. Currently limitations exist regarding the present production scale and costs[197]. Another interesting application area is the use of algae as an ingredient in pet food. Sustainability of algae products in feed must be documented. For example a study comparing algal meal with soybean meal showed that large-scale soy meal production was significantly lower, mainly as a result of the energy-intensive algae cultivation stages. A sensitivity analysis showed that the resource footprint of algal meal production could be comparable with soy

[191] Food commodities from microalgae. Current Opinion in Biotechnology. Draaisma et al, 2013. Volume 24, Issue 2, April 2013, Pages 169-177.

192 Commercial application of microalgae other than as biofuels: a brief review. J.J. Milledge. Rev Environ Sci Bio-Technol, 10 (2011), pp. 31-41

[193] Micro-algae as a source of protein. E. Becker. 2007. Biotechnol Adv, 25, pp. 207-210

[194] Comments from validation webinar #4 this project.

[195] The role of microalgae in the bioeconomy. F. Gabriel Acien Fernandez, et al, 2021. New Biotechnology 61 (2021) 99-107.

[196] Magnificient - Algae project

[197]Food and feed products from micro-algae: Market opportunities and challenges for the EU. Vigani, M., Parisi, C., Rodríguez-Cerezo, E., Barbosa, M. J., Sijtsma, L., and Ploeg, M. 2015. Food Sci. Tech. 42, 81–92.

meal when, overall, the areal biomass productivity increases, electricity production is based on renewable sources and the energy consumption of the cultivation is reduced[198].

Use-case 6: Microalgae being used in non-food applications

Today a major non-food application area of microalgae extracts is in the area of cosmetics. The cosmetic industry is applying microalgae for skincare and regeneration products, anti-aging, and protection from UV radiation[199].

Several other non-food applications have been suggested for microalgae and/or are under development[200]. A major emerging application of microalgae is for use as biofertiliser or plant biostimulants to enhance the productivity of agriculture and horticulture crops and reduce the use of synthetic fertilisers[201]. Other emerging applications include microalgae based bio-materials, waste water treatment and CO_2 biofixation and the production of bioenergy. The potential application of oil-enriched microalgae for biofuels has been researched extensively. However stand-alone biofuel production is to date not feasible due to an unfavourable energy balance and high production costs. Yet, for certain biofuels e.g. kerosene for aviation, algae represent a better bio-based solution than other traditional biomass feedstocks in terms of energy balance and GHG savings, as long as certain conditions for their cultivation, such as high process optimisation, nutrient recycling and use of renewable energy to meet input demand, are met[202]. An option to improve this could also be to develop algae biorefineries producing multiple products next to biofuels[203].

Application of microalgae systems for bioremediation has been developed e.g. for the removal of nutrients from municipal wastewater (effluent polishing). Recently, the project AlgaeLinkages was conducted in Mexico aimed at the purification of effluent from greenhouses coupled to the use of the produced microalgae biomass in poultry feed[204].

Overall, we can conclude that a proper assessment of environmental impacts requires the performance of Life Cycle Assessment (LCA) studies using appropriate (ISO) methodology comparing specific applications / reference products with input from real data gathered with standardised metrics obtained at least pilot scale production level or full-size plant level[205].

[198] Environmental sustainability analysis of a protein-rich livestock feed ingredient in The Netherlands: Microalgae production versus soybean import. Sue EllenTaelma, Steven De Meester, WimVan Dijk Vamilsond Silva, Jo Dewulf. 2015. Resources, Conservation and Recycling, Volume 101, Pages 61-72.
[199] The role of microalgae in the bioeconomy. F. Gabriel Acien Fernandez, et al, 2021. New Biotechnology 61, 99-107.
[200] The promising future of microalgae: current status,challenges, and optimization of a sustainable and renewable industry for biofuels, feed, and other products. Khan, M.I., Shin, J.H. & Kim, J.D. 2018.. Microbial Cell Factories, 17: 36.
[201] Microalgae: New Source of Plant Biostimulants. Colla, G., Rouphael, Y. (2020). Agronomy, 10(9), 1240;
[202] Are algae ready to take off? GHG emission savings of algae-to-kerosene production. Prussi et al., 2021. Applied Energy (304), 15.
[203] The role of microalgae in the bioeconomy. F. Gabriel Acien Fernandez, et al, 2021. New Biotechnology 61 (2021) 99-107.
[204] Stimulating the circular economy for food production in central Mexico: integration of greenhouse cultivation, land-based aquaculture and microalgae production systems. Sijtsma, L.; Boedijn, A.; Kals, J.; Muizelaar, W.; Appelman, W. 2020, Wageningen Food & Biobased research.
[205] Comments from validation webinar #4 this project.

5.1.2. Environmental impacts of algae products.

Algae products can generate multiple environmental benefits, especially when they are providing substitutes to conventional products associated with a high ecological footprint, as long as they are produced sustainably and with a minimised carbon footprint. This applies to the current main applications of algae: food and food supplements, animal feed, cosmetics or fertilising products; as well as to emerging applications e.g., bio-packaging.

Algae as food and food supplements

Developments are under way to expand the use of microalgae in human food as a source of proteins and oils. The use of microalgae in human food as an alternative source of omega oils and proteins could drastically reduce the amount of fish used for fish aquaculture and human consumption and reduce the terrestrial area in use e.g. for production of edible oils including palm oil[206]. Besides, macroalgae is increasingly becoming popular as a food product, providing alternative (local) vegetables or being used in vegetarian or vegan meat alternative (e.g. seaweed-based burgers, fake tuna, etc.).

The reduction in carbon emissions achieved by using algae products instead of conventional food products will of course depend on the production process and on the actual products to be replaced. For meat or fish species under overfishing pressures, the benefit is quite clear; for vegetables, detailed LCAs will need to be conducted (e.g. to assess the origin and cultivation methods).

Algae as animal feed

Algae is historically implemented in the aquaculture industry as the indispensable feed for aquatic larvae. The major research and development in microalgae rearing was intended to provide feed to these shrimp and fish larvae. More recently, the use of micro and macroalgae has been investigated to reduce the environmental footprint of finfish aquaculture, where one of the major ecological impacts comes from the fish meal and the fish oil industry to feed the farmed fishes. Fish meal is also often prepared from soybeans, which in many cases is imported and associated with deforestation. Fish oil (and some of the fish meal) is currently mostly coming from forage fisheries, increasingly challenged on the sustainable management of the stocks being fished. First results of studies show that it is possible to replace soy or fish protein in animal feed with micro-macroalgae depending on the protein content, the fatty acids, and the aminoacidic profile[83]. The application of microalgae as a functional ingredient in aquafeed is also part of this strategy. This refers in particular to algae as an alternative source of long chain polyunsaturated fatty acids like EPA and DHA to replace fish oils or krill oil, and for bioactive components that enhance the immune system of farmed fish or as probiotics[84].

In addition to aquafeed, micro- and macroalgae are increasingly used in animal feed as raw material and in feed additive mixes to improve gut health, stimulate the immune system of pets, horses, poultry, pigs, cows and other animals. More recently, various studies confirm that the addition of macroalgae

[206] Food commodities from microalgae. Draaisma et al., 2013. Current Opinion in Biotechnology, Volume 24, Issue 2, pp. 169-177.; Commercial application of microalgae other than as biofuels: a brief review J.J. Milledge., 2011. Rev Environ Sci Bio-Technol, 10, pp. 31-41. ; Microalgae as a source of protein' E. Becker., 2007. Biotechnol Adv, 25, pp. 207-210

to ruminants' diets can reduce methane emissions, with a reported reduction of over 80%[207]. Impact on animal health, product quality and residues, however need to be furthered researched.

Algae as fertilising products

Seaweed has been used in the EU to fertilise land for centuries. A whole new generation of fertilising products exists out of algae and support the development of organic agriculture and the transition out of chemical fertilisers. There are companies[208] in the EU that are selling these products since 30 years. Green microalgae and certain seaweed species are for instance be used as biostimulants to enhance soil fertility and plant growth. Research on the use of cyanobacteria as a plant biostimulant and soil conditioner has also proven the potential of these organisms for sustainable agriculture and several European companies are ahead on this field.

Algae as cosmetics

In adapting themselves to new environments, macro and microalgae produce a wide variety of secondary (biologically active) metabolites which cannot be found in other organisms. Several of them have been studied for their antiaging effects on skin, including antiphotoaging, antifree radical activity, moisturisation, and collagen biosynthesis. In fact, algae are rich sources of biologically active metabolites such as polysaccharides, carotenoids, phlorotannins present in green, red, brown algae, or in microalgae, and represent attractive source to fight against the skin aging process. They have the potential to decrease oxidative stress and increase skin cellular longevity in human skin, the examples are numerous[209].

Innovative applications

Other emerging applications for microalgae include microalgae-based biomaterials, waste water treatment and CO_2 biofixation, and the production of bioenergy. Bioremediation services, especially uptake of nitrogen and phosphates in areas affected by eutrophication, is also a promising use case for seaweed, and was therefore ranked third in importance as a use case during the Online Public Consultation. A whole new range of material applications out of seaweed are being explored by a growing number of innovative start-ups and could generate substantial environmental benefits. Proof of concepts and demonstration products are now widely available for seaweed based bio packaging, either edible or home compostable, and could contribute to reducing plastic leakage into the ocean and reduce the packaging CO2 footprint. In the same spirit, several start-ups are developing seaweed-based textiles and yarn to reduce the micro plastics leakage associated with synthetic garments.

5.2. Potential social impacts

A strong and sustainable EU algae sector is expected to have a strong positive social impact, in terms of job creation, quality of jobs and health benefits.

[207] Red Seaweed (Asparagopsis Taxiformis) Supplementation Reduces Enteric Methane by over 80 Percent in Beef Steers. Roque, Breanna M., et al., 2021. PLOS ONE, vol. 16, no. 3.
[208] E.g. Goëmar
[209] Marine algae as attractive source to skin care, Free Radical Research. Jean-Yves Berthon, Rachida Nachat-Kappes, Mathieu Bey, Jean-Paul Cadoret, Isabelle Renimel & Edith Filaire., 2017., 51:6, 555-567.

5.2.1. Job creation.

According to the latest data available, the algae industry in the EU-27 employs 5,380 people, with the entreprises involved in algae-related services (including technology providers, R&D entreprises, consultancy entreprises, and traders/exporters) being the largest contributors to this employment[210]. The first social benefit of the EU algae initiative will be mechanical: the growth of the EU algae production and the development of new product applications will create new jobs all along the value chain. Numerous jobs requiring a multitude of skillsets will need to be created, from technical experts in hatchery, production or harvesting, to manufacturing jobs in processing and supply chains. Development of the algae sector will also create job opportunities in sales and in technology companies.

5.2.2. Quality of jobs

The algae industry in the EU predominantly generates full time jobs (81%) rather than seasonal (19%) while in terms of gender, the sector is quite balanced: male employees dominate (62%) over female employees (38%)[55].With the right level of ambition, the EU algae sector can aspire to not only create employment opportunities, but actually foster high quality jobs, that give back to employees and their local communities. This aspiration might manifest through the creation of jobs for young people struggling in the job market, the ongoing upskilling of employees, and investments in the local community. The localisation of jobs created is also important for the EU context, where a considerable share of the employment opportunity is likely to manifest in coastal and rural areas, often facing higher levels of unemployment. Seaweed farming can also become a part time job for existing ocean users like oysters or mussel farmers, or fishers, and help them generate additional income streams making them less exposed to unexpected shocks (e.g., oyster disease, oil price increase, etc.). When integrated into the agricultural system in a circular manner, microalgae production also represents an alternative of new value chains for agricultural farmers to obtain low-volume and high added-value products.[211]

Strengthening the supply chain for the EU algae industry could in itself deliver further social benefits. Today, a significant share of algae used in the EU is imported, leaving the supply chain vulnerable to unexpected shocks – the COVID crisis has demonstrated how significant this can be for many different industries. As the EU domestic sector grows however, distances within the seaweed value chain will shorten and supply sources will diversify, making the supply chain more resilient. This trend will better protect downstream players in the seaweed value chain and ancillary industries from volatility in the global algae market and could therefore enhance job security.

5.3. **Health benefits.**

Algae have multiple health benefits through food and pharmaceuticals applications.

[210]An overview of the algae industry in Europe. Producers, production systems, species and socio-economic data. Vazquez Calderon et al., 2022. JRC Technical Report (forthcoming).
[211] Algae and their potential for a future bioeconomy, landless food production, and the socio-economic impact of an algae industry. Ullmann, J. and Grimm. D. (2021). Organic Agriculture volume 11, pages 261–267 (2021).

5.3.1. Food

Nutrient-dense and low in fat, algae are often portrayed as healthy and low-calorie food. Spirulina, has already entered the category of superfoods in the early 90s, when the World Health Organization designated it as the "best food of the future" to fight malnutrition worldwide. Most seaweed species are characterised by elevated levels of dietary fibres and minerals, and low lipid levels. Seaweed are also characterised by their antioxidant activities and their content of polyphenolic compounds. In addition to their nutritional benefits, edible seaweed species found on the coasts of the EU are used for enhancing the flavours of a variety of products. Development of consumption of algae food products in the EU will therefore contribute to healthier dietary habits as regards calory, nutrients and fibre intake, and can eventually help in limiting non-communicable diseases like diabetes, often associated with unhealthy diets. However, due to the possible presence of high concentrations of contaminants (in particular heavy metals), which are known to cause serious adverse health effects it needs to be ensured that the health risks of algae consumption are not higher than the benefits. In any case consumption advice would be needed to limit the consumption of the algae species, which contain the highest concentrations of contaminants.

5.3.2. Pharmaceuticals

Macroalgae are increasingly being explored as sources of bioactive compounds for pharmaceutical applications. There is growing research leveraging neuroprotective effects of certain algae compounds, useful in the treatment of neuro-degenerative diseases such as Alzheimer's and Parkinson's. Other compounds displayed anti-ulcer and anti-viral properties. Anti-cancer or anti-inflammatory and immunomodulatory activities are also being actively researched.

5.4. Potential economic impacts

According to the latest data available, the algae industry in the EU-27 a total turnover (2016-2020 average) of EUR 1,211 million[55] (i.e. <0.01% of EU economy's total Gross Domestic Product). A thriving EU Algae sector will without doubt have a positive impact on the EU economy, with a contribution to EU GDP that could amount to several billion euros in the next decade. Most importantly the EU algae sector could become the success story that embodies the ambition of the European Green Deal to reinvent the EU economy with more sustainable, climate friendly and resilient industries. Recent international crisis like the Covid-19 pandemic or the war in Ukraine have demonstrated that globalized value chains can be put at risk, resulting in shortages of raw materials or food, or massive increase in commodity prices. The development of the EU Algae industry will bring solutions and resilience to the EU economy by diversifying production of vital raw materials within EU borders, increasing EU self-sufficiency of raw materials and high added-value products and limiting the need for imports.

Besides, even though the EU algae industry is still small compared to Asia competition, there is in the EU a solid basis of academic networks, industry knowledge, and innovative start-ups that can develop an edge in terms of algae technologies (precision farming, bio-refinery and extraction of high value

compounds, digital platforms, etc.), that could eventually lead to export opportunities for the EU algae companies.