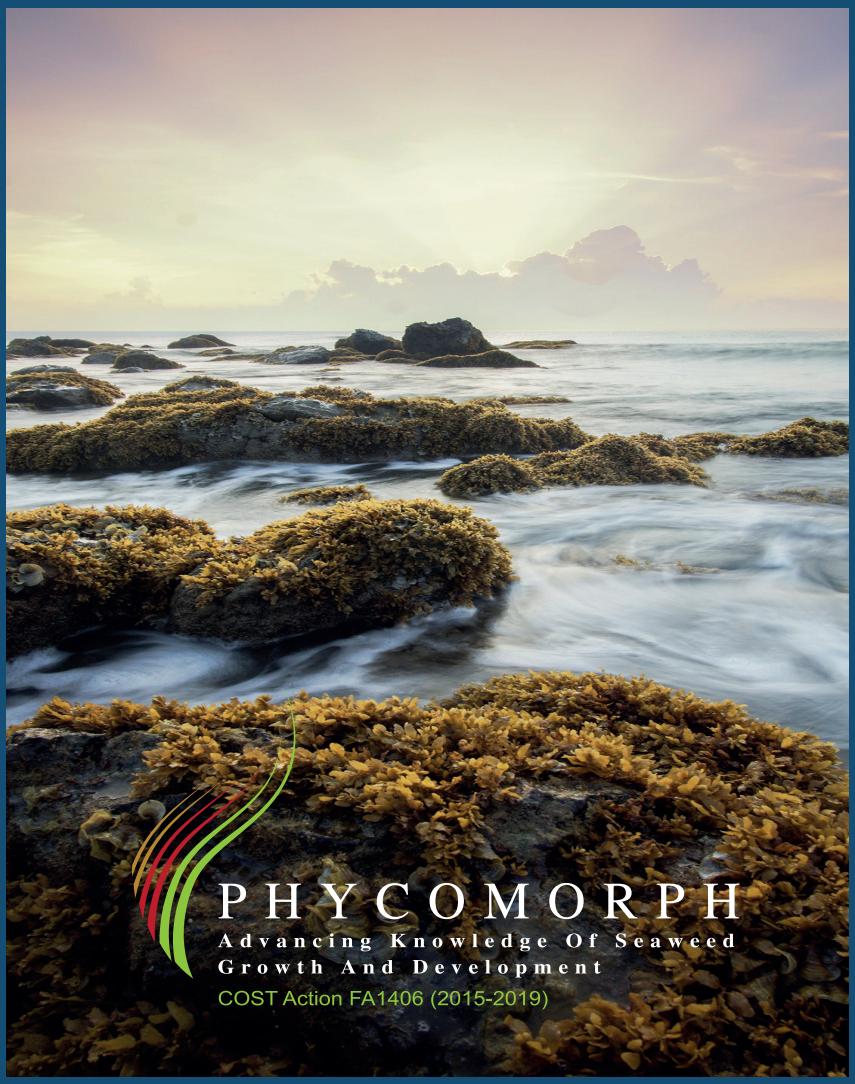
KEY FACTS

PEGASUS

PHYCOMORPH EUROPEAN GUIDELINES FOR A SUSTAINABLE AQUACULTURE OF SEAWEEDS



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EUROPEAN COOPERATION IN SCIENCE & TECHNOLOGY

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PHYCOMORPH COST ACTION FA1406

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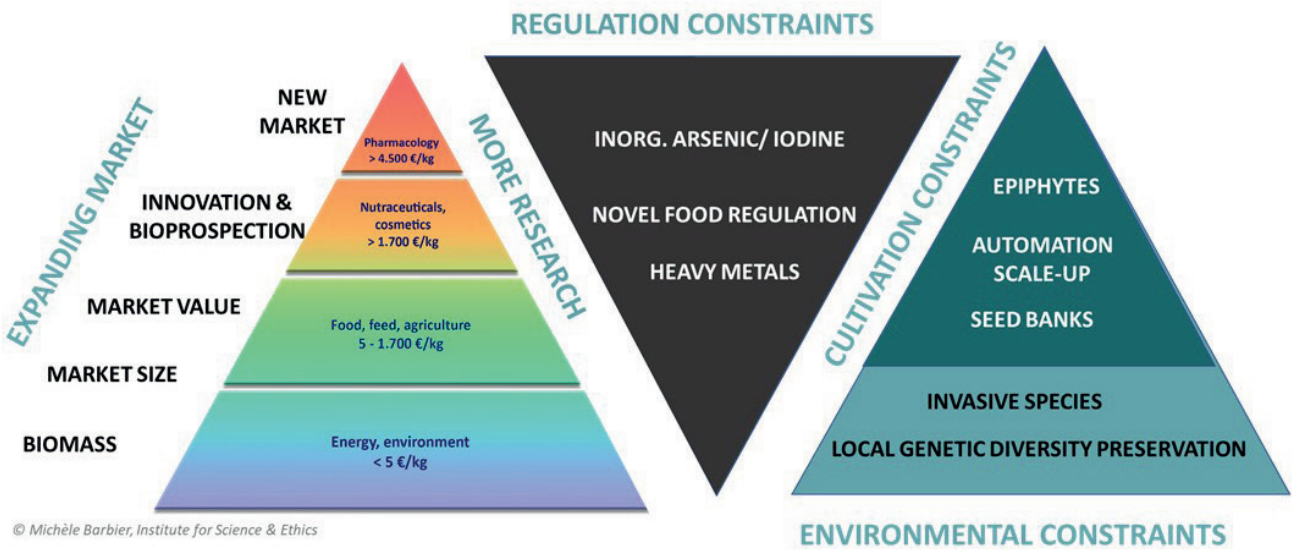
CHALLENGES FOR SUSTAINABLE SEAWEED AQUACULTURE DEVELOPMENT IN EUROPE

Seaweed are plant-like organisms, playing a key ecological role in coastal ecosystems: support of food web, coastal protection of erosion, bioremediation by removal of nitrogen or phosphate and possible pollutants and CO_2 sequestration. They are also a promising bioresource for the future and the demand for high-value seaweed-derived compounds (cosmetics, food) is on the rise in Europe. This sector is multidimensional with economic, environmental dimensions, technological, legal and marketing dimensions implying fruitful exchanges and collalboration between all stakeholders – industry, farmers, researchers and policy-makers.

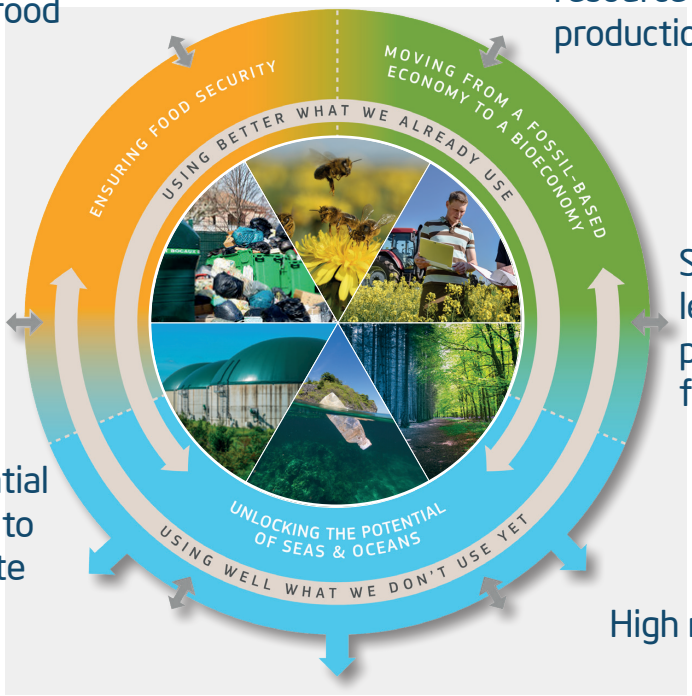
PEGASUS provides scientific recommendations based on the identification of the challenges and bottlenecks currently preventing this sector's development to support the related economy while preserving our environment.

The challenges are various: market size, environmental constraints and the preservation of local genetic diversity, the need for more research – both fundamental and applied –, regulations on food quality, heavy metals or alien species, and cultivation constraints ranging from automation to epiphytism issues as represented in the figure.



The PEGASUS guidelines should be considered as expert advice aiming to help all stakeholders in the sector to understand the different aspects of seaweed aquaculture and identify the key points and critical steps.

SEAWEED AQUACULTURE FITS IN THE STRATEGY OF THE EUROPEAN BIOECONOMY AND CAN ADDRESS SUSTAINABLE DEVELOPMENT CHALLENGES.



Opportunities for sustainable supply of food

Towards a low-carbon and resource-efficient energy-production system

Seaweed businesses less vulnerable to price and market fluctuations

Promising potential for contributing to mitigating climate

High rates of innovation

1 NO POVERTY

3 GOOD HEALTH AND WELL-BEING

5 GENDER EQUALITY

12 RESPONSIBLE CONSUMPTION AND PRODUCTION

13 CLIMATE ACTION

IMPORTANT ECOLOGICAL ROLE

2% of sea surface

70% world's CO_2 uptake

SEAWEED KEY FACTS

SEAWEED GLOBAL PRODUCTION

30 MT/year

8.1 billion € / year

50 countries

SEAWEED-CULTIVATION PROCESS

14 LIFE BELOW WATER

The potential challenges in cultivation are the risk of introduction of alien species as well as the risk of transmission of parasites and pathogens to wild populations, the impact of escapees, the preservation of the local biodiversity, the loss of best cultivar and the management of waste.

NON INDIGENOUS SPECIES
They can act as vectors of introduction for new pathogens or pest organisms and can modify the local genetic diversity.

INTEGRATED MULTITROPHIC AQUACULTURE
IMTA is a promising co-cultivation system but its development requires further research to optimise the technique. A framework, as an integral part of local Maritime Spatial Planning should be set up for guiding the spatial organisation of open-sea aquaculture so as to maximise production while minimising impacts on the environment.

BREEDING PROGRAMMES?
Cultivars are plants obtained by artificial selection (breeding). To obtain the best cultivar, strains are chosen for their traits of interest and increasing their yield as well as their robustness is required for farming. Well-planned and -designed breeding and selection programmes will help to achieve the goal of long-term sustainability but require further research to determine the appropriate conditions for cultivation given the high risk of genetically modified individuals escaping into the wild.

It is essential to **preserve** local **genetic diversity**

Actions promoting the preservation of European marine biodiversity

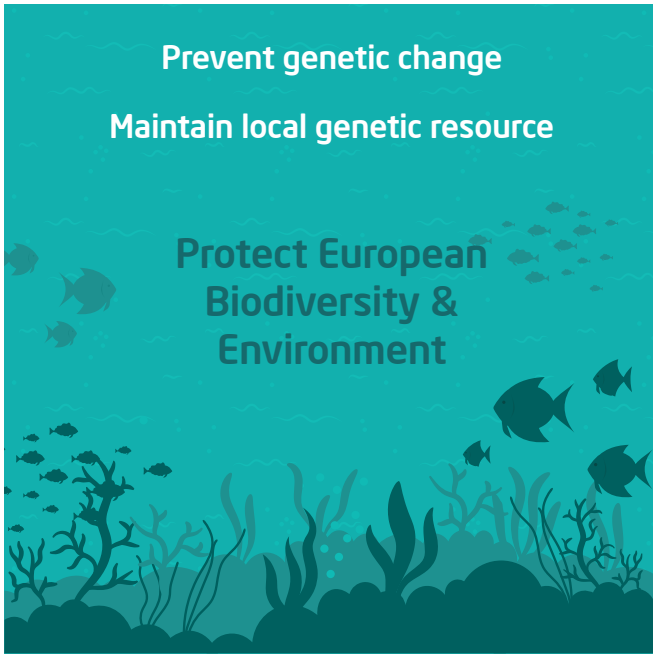
Sourcing from indigenous species

Consider seaweed reproduction

More research on breeding & selection programmes under controlled conditions

More research on pests & diseases

More research on impact on the environment



Choose best location for cultivation

More research on the biology of seaweeds and gene flow, connection with the environment

Assess impact of introduced species on the environment

Reconsider some regulations on alien species and some European regulations / directives

SEAWEEDS FOR FOOD

2 ZERO HUNGER

THE FOOD MARKET IS PROMISING, EVEN IN WESTERN COUNTRIES, BUT A NUMBER OF EXISTING BOTTLENECKS IN LEGISLATION CAN HINDER MARKET DEVELOPMENT.

29 species of seaweeds (brown, red and green) are accepted as food in Europe, some are imported and some more are consumed. A complete list of seaweed species authorised as food in Europe is needed. Seaweeds are known for their nutraceutical, bioactive food, or superfood but scientific and clinical studies are needed for risk-benefit analyses, including chemical risk assessments.
Research on high iodine content, heavy metals, and nutrients must be pursued for ensuring food safety and the threshold values of different contaminants for seaweed as food, and specifically, the inorganic arsenic threshold for feed legislation should be updated.

The preservation of seaweeds for food is important and best storage procedures/ industrial-classification codes should be defined. New compounds are extracted from seaweed and should be evaluated by the Commission Implementing Regulation (EU) 2017/2470. Species must be clearly and specifically identified to guarantee the source of compounds extracted for the market.

Seaweed are rich in fibers, pigments, polyphenols, minerals (Na, K, P, Ca, Mg, I, Fe) and vitamins (A, B1, B2, B6, B12, C, D, E). They produce texturising agents: carrageenan, agar-agar, alginates and some species (e.g. *Porphyra*) contain 40% proteins. Seaweed have low Na/K ratio and low lipid (50% PUFA).

PUBLIC AWARENESS MUST BE INCREASED

A VOCABULARY TO DESCRIBE THE FLAVOUR OF SEAWEED NEED TO BE DESCRIBED

Nutritional value: general studies are furthermore needed on red, green and brown seaweeds to evaluate the long-term effects of preservation treatments while alternative treatment solutions should also be investigated.

Novel food list: an official list of all seaweed species accepted as food should be compiled so that producers, companies and other stakeholders can consult an updated list, promoting a simplification of procedures. Transparent overview of seaweed accepted as food (both authorized before and after 15 May 1997) is needed.

ECONOMY AND INDUSTRY

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

THE DEVELOPMENT AND SUPPORT OF THE INDUSTRY NEED INVESTMENT AND ADAPTED RESEARCH PROGRAMMES

In Europe, seaweed cultivation is still in its infancy. A clear understanding of current European seaweed production is needed including standardisation of biomass production and quality assessment. Investment are needed to support automation and mechanisation of the cultivation proccess.

Cultivation yield depends on seasonal and geographic variabilities. The optimal conditions favorising best growth and production of high-valued chemicals and flavours all in a cost-effective way need to be seeked for the development of the industry.

To improve the production yield, scientific knowledge on seaweed genetics is needed to better understand species' life cycles and control their reproduction and growth. The final aim is to control breeding and selection programmes to preserve the environment.

> Seaweed biomass, after harvesting, must be stabilised to ensure high-value components and bioactive substances. Stabilisation alternatives and optimal procedures to prepare biomass are needed.

Research programmes flagged to provide more understanding on the biology of seaweed.

	Challenges	More research to
Biology of Seaweeds	Conservation of species of interest	Develop cryopreservation methods
	Improve strains of interest through breeding and selection programmes	Understand genetic compatibility and genome interactions
	Cultivation of new species under artificial conditions	Understand the parameters that control fertility & reproduction
	Improve production of juvenile seaweeds	
	Improve the shape, texture and content of seaweeds	Understand the impact of environmental factors (biotic and abiotic) on phenotypic traits of interest
	Prevent epiphytes, diseases and pest blooms	

INTEGRATED EUROPEAN GOVERNANCE

17 PARTNERSHIPS FOR THE GOALS

TECHNICAL STRUCTURES FOR CULTIVATION, REFERENCE TECHNICAL CENTRES AND CERTIFICATION CONSORTIUM STRUCTURES ARE NEEDED

Environmental issues regarding invasive species: a list of alien species of economic interest in Europe should be established as well as their risks for the environment (update the Annex 4 of EU Regulation 708/2007).

Traceability, organic certification: the notion of local strains for a specific market requires appellations of controlled origin. Traceability would define these appellations. Certification procedures need to be implemented.

Food safety: bottlenecks that hamper the market development have been identified in European legislation. Legislation on contaminants such as heavy metals and issues on iodine and inorganic arsenic should be addressed in seaweed "as food". The monitoring of heavy metals, iodine, arsenic etc. could remove market barriers and provide clear updated regulation on the threshold values of different contaminants.

Arsenic: the total arsenic threshold value is at present a market barrier. Feed legislation needs to be updated as does legislation on seaweed as food. It is now possible to distinguish harmful inorganic arsenic from organic arsenic.

Iodine: the high concentrations of iodine accumulated in some of the large brown seaweeds are market barriers. More knowledge is needed on chemical form and bioavailability of seaweed iodine. New methods for the detection of different chemical forms should be developed.

Research programmes necessary for improving cultivation

Challenges and needs for the Industry	Recommendations
	Governance
Secure food security: inorganic arsenic, iodine, heavy metals	Update the threshold values of contaminants and define these for seaweed as food, as well as a common standard on dry- or wet-weight basis
Food preservation to maintain consistent content and improve organoleptic properties	Set up certification centres
Unknown impacts of post-harvest handling (preservation treatments) on the seaweed's quality and quality stability (nutrient content, organoleptic properties) Stabilisation of seaweed biomass	Implement best practices/industrial-classification codes developed in collaboration with companies and national / European authorities
Various certification processes for organic certification in different EU countries	Harmonise organic certification across EU
Attract consumers	Increase public awareness, create a vocabulary to describe the flavour of seaweed

This document is based on work undertaken by COST Action FA1406 "PHYCOMORPH" (2015-2019).

COST (European Cooperation in Science and Technology) is a funding programme for research and innovation networks that enables researchers to set their interdisciplinary research network in Europe and beyond. Our Actions help connect research initiatives across Europe and enable scientists to grow their ideas by sharing them with their peers. By creating open spaces where people and ideas can grow, COST unlocks the full potential of science.

The main aim of PHYCOMORPH is to unify a scattered European research landscape to enable a step-change in the basic knowledge of macroalgal reproduction and development, and to ensure appropriate and efficient transfer to R&D and Innovation Institutes dedicated to the development of aquaculture techniques, in tune with current needs in Europe and worldwide. These guidelines are balanced and long-term recommendations assembled by a group of PHYCOMORPH experts (http://www.phycomorph.org).

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PHYCOMORPH
Advancing Knowledge Of Seaweed Growth And Development
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PEGASUS
Phycomorph European Guidelines for a Sustainable Aquaculture of Seaweeds