MacroFuels Project

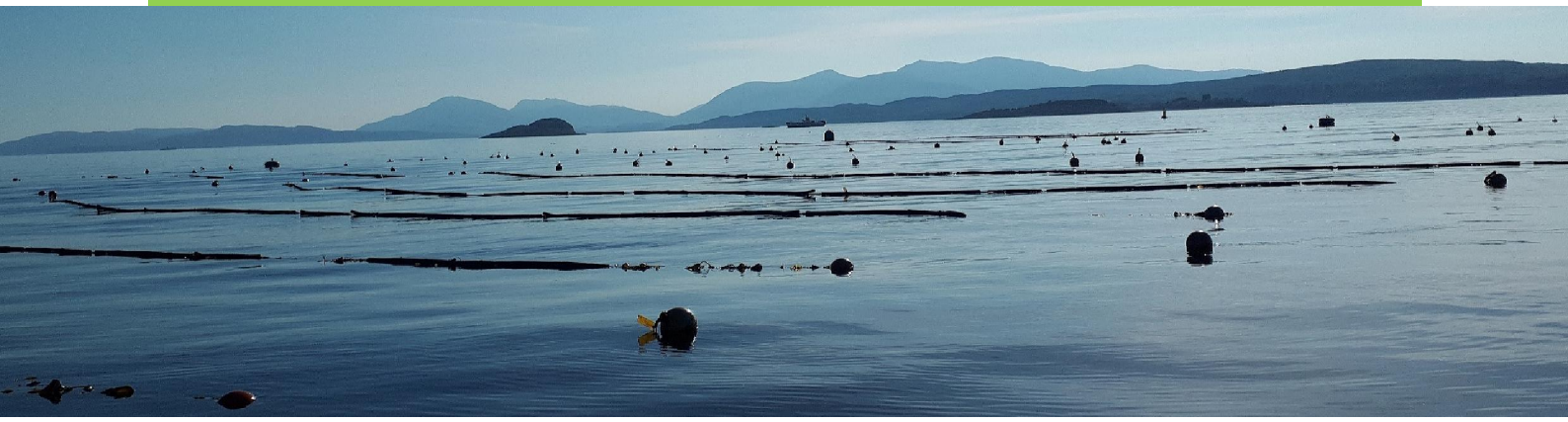
POLICYBRIEF

Seaweed as sustainable biomass for a European bioenergy sector

Findings and recommendations from the MacroFuels Horizon 2020 research and innovation project (www.macrofuels.eu)

Key Messages

1. Economic and environmental impacts of seaweed derived biofuels largely depend on cultivation scale, location as well as production design and valorization paths and need to be fully understood.
2. National authorities need robust overarching policies for giving permanent licenses for large-scale cultivation.
3. Environmental sustainability is vital for social acceptance of large-scale seaweed production, which is vital for economic success.
4. The long-term impact on the marine environment of large-scale seaweed cultivation is yet unknown, more research is needed.
5. Agreements are needed for acceptable limits of environmental changes where possible as basis for sensible monitoring and mitigation requirements from seaweed producers.



Challenges

Seaweed production is undergoing global expansion. With an annual production of 27.3 million tons in 2014 and a growth rate of 8% per year[1], seaweed aquaculture now comprises 27% of total marine aquaculture production. However, considering the process chain of seaweed from production through processing to final products, the growth of the actual seaweed production lags behind the demand of biomass for the many traditional and novel applications for this expanding crop.

One emerging application which shows a high potential for climate change mitigation is the conversion of seaweed species that are high in sugars into sustainable biofuels. The EU itself has called for the use of seaweed as a source of renewable energy: "Advanced biofuels, sourced from seaweed or certain types of waste, should represent at least 2.5% of energy consumption in transport by 2020"[2]. Furthermore, the EU for its revised Renewable Energy Directive (RED II), has proposed to gradually phase out crop-based biofuels from 7% in 2020 to 3.8% in 2030, effectively bringing the conventional biofuel use to pre-2008 levels[3].

The global biofuel production in 2017 (ethanol and biodiesel) totaled about 84 million tons.[4] If we aim to replace only 1% of the annual land-based biofuel production by seaweed-derived biofuel, approximately 1 million ton of biofuels have to be produced per year. This equals 27 million tons (wet weight) of seaweed, which equals the entire annual global seaweed production in 2014[5].

Those initial calculations highlight the need for Europe's move towards large-scale cultivation of seaweed to be able to meet the growing demands for this biomass. Further required technological modifications to make the seaweed-to-biofuel value chain economically viable include:

- ✓ The mechanization of seeding, deploying, cleaning and harvesting,
- ✓ Year-round cultivation of selected cultured species that are well-suited for biofuel production due to their high sugar contents, and
- ✓ Biorefinery by means of cascade processing that valorize high value components of seaweed biomass for biochemicals, pharmaceuticals, feed and food (supplements), fertilizer as well as biomaterials.

While this represents a great opportunity for economic growth and the creation of high quality workplaces in a sustainable industry in Europe, large-scale cultivation also

[1] FAO, 2016a
[2] http://www.europarl.europa.eu/pdfs/news/expert/infopress/20130906IPR18831/20130906IPR18831_en.pdf
[3] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32015L1513
[4] https://www.statista.com/statistics/274163/global-biofuel-production-in-oil-equivalent/
[5] The State of World Fisheries and Aquaculture 2016

raises new challenges for producers and the environment. Those challenges comprise:

- Uncertainties in national licensing practices for large-scale seaweed cultivation sites,
- Monitoring requirements for assessing and mitigating environmental, changes as results of industry level seaweed production
- The need for marine spatial planning to avoid competition in using the marine space, and
- Levels of social acceptance towards upscaled seaweed production.

Currently, the majority of seaweeds in Europe is produced at small scale. Large scale seaweed cultivation, harvesting and conversion to biofuels is a largely unexplored area. Clear reliable data on which policies can be based do not exist yet.
In several countries policy makers and regulators have however started to investigate setting in place a more defined set of rules covering seaweed cultivation. A rather advanced example is the Scottish Government Seaweed Cultivation Policy Statement[6] from 2017. However, even this policy statement mainly focuses on small scale seaweed cultivation and does not entail precise recommendations or measures for large-scale seaweed production (defined as cultivation sites that exceed 50 x 200m lines).

Key Findings

The research performed and results obtained in MacroFuels so far supports the existing insights that seaweed represents a highly interesting novel feedstock with great potential as regards the overall sustainability of the entire value chain from cultivation all the way through the conversion into biofuels and high value products.
However, to assure that the positive economic and environmental impacts that this biomass could bring about will be met and maximized, some pre-conditions will have to be met. This requires a deeper understanding of the key aspects that are described in detail in the following.

1. The long-term impacts of seaweed derived biofuels depend on seaweed production scales and best practices.

Today, there is a considerable discussion about the use of agricultural land for the growth of crops for food and/or for bioenergy uses (i.e. food/feed/energy nexus). Targeting the development of aquatic biomass for advanced biofuel production will eventually overcome those discussions and allow for more land cultivation solely applied for food for animals and humans by diverting cultivation for fuels production from land to sea. This is in line with recent EU initiatives.

[6] http://www.gov.scot/Publications/2017/03/1340/downloads

Seaweeds have great potential as sustainable biomass as they do not need any fresh water, arable land or fertilizers to grow. However, to be of interest for industries and to show any economic impact, the use of seaweed for the production of biofuels needs an increase of seaweed production by orders of magnitude as compared to the current production.

- ✓ Current research and piloting efforts across Europe will realistically enable the large scale production of seaweed as regards cultivation technologies and conversion process design.

An expansion of the industry that includes large scale cultivation projects will necessitate a more complete understanding of the scale dependent environmental and social changes. Seaweed producers, policy makers and public authorities need a sound knowledge base to fully understand the potential positive and negative impacts of seaweed production based on scale and cultivation design and to assess and manage any risks that could affect its overall sustainability.

2. European and national policies will create reliable frameworks and transparency for industries and large-scale cultivators.

One of the main reasons why no regulatory framework exists specifically for seaweed aquaculture is that the longer-term impact of large scale seaweed cultivation is still unclear at the moment. Reliable and usable databases on which policy makers can found long-term policies and legislations do not yet exist. This is particularly true for the long-term environmental effects of large-scale seaweed production. Current policies, such as the treaty of the North-Sea, the Water Framework Directive[7], the Marine Strategy Framework Directive[8] and other European and/or national policies and legislations that are relevant for the protection of the marine environment and the sustainability of its economic use have not been written with large-scale seaweed production in mind. Therefore the current European regulatory framework is rather unspecific and leads to uncertainties for economic actors in this field. Legislation and licensing practices in seaweed cultivation orient themselves on rules for established aquaculture at commercial level, such as salmon and mussels, although many of their cultivation parameters (e.g. nutrient inputs, visual impacts due to cages) vary significantly from seaweed aquaculture and therefore are not comparable. The lack of seaweed-specific policies, legislation and clear guidelines on how to integrate seaweed production in an ecosystems-based approach create barriers for investors in large-scale seaweed production and hamper long-term commitment of economic actors.

[7] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32000L0060&from=EN
[8] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32008L0056

The systematic collection and evaluation of environmental data and continuous dialogues with local communities at existing seaweed cultivation sites, be it for small economic or research and demonstration purposes. Openly accessible and easy-to-use knowledge on long-term impacts and best practices in scaling, locating and managing seaweed production sites will help European and national decision-makers to build future policies. Those should create the solid frameworks, for example for the selection of future locations for large-scale seaweed cultivation sites and for giving licenses to seaweed cultivators.

Integrating the knowledge in existing Marine Spatial Planning strategies at regional, national and European levels will further support policies on integrated marine infrastructures, instead of facing possible competition over the use of the marine space.

- ✓ Based on accessible and easy-to-use knowledge about the scale-dependent environmental and social impacts of large-scale seaweed operations, informed decisions can be made by authorities. This will facilitate the development of seaweed-specific policies, contribute to overarching strategies in marine spatial planning, and support the management of the marine space as an ecosystem instead of managing its economic uses in a fragmented way. Policies will create a sound basis for licensing practices, which will limit national fragmentation and uncertainties for investors and large-scale cultivators.

3. The support from a wider public can be secured for the long-term success of seaweed-production.

Only a few studies have been conducted on the public perception of aquaculture in general and there are hardly any systematic insights into public attitudes towards seaweed production. Currently, there seems to be the general assumption that the public perception towards seaweed as biomass is rather positive due to the 'green' reputation of seaweed. However, the attitude of the public, especially from local residents of seaweed production sites, might change with the scale-up of production techniques, automated harvesting processes and perceived environmental damages or fears of visual impacts or noise pollution. Studies on aquaculture that have been performed in the past indicated that there is a close link of public support or opposition and perceived environmental risks. However, a multitude of factors that affected perceptions were identified, ranging from awareness and knowledge levels, to credibility of information sources. A recent study on public perception at the Swedish West coast[9] distinguished between different types of aquaculture. Results of a conducted survey showed that the support towards aquaculture increased with the awareness level and with the

[9] https://link.springer.com/article/10.1007/s13280-017-0945-3

perceived economic opportunities that come with developed aquaculture.

Interviews, round-tables and surveys performed by MacroFuels with local residents of small-to-medium cultivation sites so far confirm the generally positive attitude towards seaweed aquaculture which seems to increase with the levels of understanding of the specifics of seaweed production. Dialogues revealed that the support towards industry-level seaweed production also increased with the prospects of economic growth in the region and local community development based on a growing seaweed industry. However, concerns have been expressed about uncertainties that come with the upscaling process, for example though the loss of cultivation material and the resulting pollution of beaches and habitats. Further conflicts over the use of the ocean space might occur with fisheries and local fishermen. Therefore, MacroFuels targets fishermen and fisheries associations for intense and continuous dialogues to discuss concepts of co-use, such as Integrated Multi-Trophic Aquaculture (IMTA).

- ✓ Dialogues with the public and especially with local residents of targeted seaweed production sites will not only maximise societal support for large-scale seaweed production, but also add valuable insight and local perspectives for economic actors in the seaweed industry. Policy makers could reinforce such intense public dialogues by making formats, such as round tables and citizen panels, mandatory parts of a large-scale licensing process. This could lead to social licenses for seaweed production, improving its sustainability even further.

4. Postulated positive environmental impacts of seaweed have to be further verified by research and more data has to be collected and evaluated.

In the past, many positive environmental impacts of seaweed have been postulated in scientific papers and by seaweed enthusiasts. While many positive effects can be verified and quantified, for example the ability of seaweed to capture of CO_2 and excess nutrients while growing without any fertilizer, the full environmental impacts of a large-scale seaweed production site are largely unknown. While the overall environmental assessment after taking all positive and negative effects into account might indeed be positive, individual environmental benefits and risks need to be better understood. This includes potential environmental risks from large-scale cultivation sites, such as the absorption of light, the possible depletion of CO_2 or nutrients, pests and diseases, the absorption of kinetic energy, the addition and loss of cultivation material, noise pollution or the interactions of the artificially created habitat with the natural flora and fauna. Understanding these factors in more detail will help to select the most suitable seaweed production sites in the future. As an example: While the absorption of kinetic energy of a seaweed production site might have positive impacts in an area that is vulnerable to erosion, it

might have damaging effects in a zone of low ocean energy in which changed water flows might lead to unwanted changes in water chemistries and ultimately also affect local primary production.

✓ Understanding the environmental impacts of large-scale seaweed production in more detail will allow to select the most suitable sites for cultivation and to maximise environmental benefits while keeping possible risks at a minimum level.

5. Agreed levels of environmental change due to large-scale production will be necessary to achieve a generally sustainable seaweed-based bioenergy and bioeconomy[10].

Based on current practices, it can be expected that each large-scale seaweed production site in the future will have a responsibility to demonstrate that existing conservation objectives will not be undermined and any potentially concerning environmental change predicted at the consenting stage are kept within acceptable limits throughout the lifetime of the site. It will be necessary for governing bodies to not use a zero-change approach towards environmental change as the creation of an artificial habitat like a large seaweed cultivation site will inevitably result in change. Instead, decision-makers could agree on levels of environmental change that are acceptable and that could trigger different site management options (i.e. mitigation). Targeted monitoring programs can then be designed to understand the likelihood that thresholds have been exceeded with a known degree of scientific certainty. This will also avoid forcing cultivators to collect monitoring data to assess the significance of changes against a hypothesis of 'no-change'. Setting vast monitoring obligations that are poorly defined and without first agreeing, where possible, levels of acceptable environmental charge will not only lead to excessive costs for operating a seaweed production site, which practically excludes SMEs as cultivators, it also facilitates the production of 'data-rich, information-poor' (DRIP) data[11]. This situation has been observed in other marine industries where current monitoring programs are extensive and costly yet many provide little useful data in relation to ecosystem-scale changes necessary for the assessment of 'impact'.

✓ In the context of seaweed cultivation, the consideration of acceptable thresholds on environmental change is extremely important given the great potential of creating many environmental changes that could be considered positive.

[10] Iona Campbell, Adrian Macleod, Christian Sahlmann, Luiza Neves, Jon Funderud, Margareth Øverland, Adam D. Hughes and Michele Stanley (2019). The development of seaweed farming in Europe - environmental impacts and prioritizing key knowledge gaps. Front. Mar. Sci., 22 March 2019 https://doi.org/10.3389/fmars.2019.00107

[11] Wilding, T. et al. (2017). Turning off the DRIP ("Data-rich, information-poor")–rationalising monitoring with a focus on marine renewable energy developments and the benthos. *Renew. Sustain. Energy Rev.* 74, 848–859.

POLICY RECOMMENDATIONS

1. Support the development of a European open and usable knowledge base on potential economic, environmental and social impacts resulting from large-scale seaweed production.

2. Establish a robust **policy framework** as orientation for European and national licensing bodies for large-scale seaweed cultivation sites.

3. Co-create European **best practice models and standards** for seaweed cultivation sites, based on latest findings from research projects and pilot sites.

4. Work towards **agreements on acceptable levels of environmental change** caused by large-scale seaweed production and suitable management options, instead of following a zero-change approach.

5. Introduce appropriate **benchmarks and thresholds for monitoring and risk assessment** needs to avoid overspecification of monitoring and data collection by seaweed cultivators that could prove too costly and deliver 'data-rich, information-poor' (DRIP) data.

6. **Initiate and facilitate dialogues** between various users of the marine space to counteract competition and instead promote synergies via multi-use marine energy infrastructures, ecosystem-based approaches and/or Integrated Multi-Trophic Aquaculture (IMTA) .

7. **Incentivise long-term investment** in the seaweed-based bioenergy sector in Europe by industries, potentially through subsidies of biofuels derived from aquatic biomass.

8. Reinforce dialogues with societal stakeholders, such as local residents and fishermen in future seaweed cultivation areas, by making **social licenses** a mandatory part of each seaweed cultivation site license.

MACROFUELS

www.macrofuels.eu

If you have any further questions and for further discussions, please contact us at:

r.clancy@eurida-research.com

Main contact: Rita Clancy, MacroFuels Communication Officer
Tel.: +43 (0) 663 0324 4114

Horizon 2020
European Union Funding
for Research & Innovation

This policy brief is part of the MacroFuels project. This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 654010.

Project Identity

Coordinators

Prof. Dr. Anne-Belinda Bjerre (Coordinator), anbj@teknologisk.dk
Danish Technological Institute, Denmark www.teknologisk.dk

Jaap van Hal (Project Executive), jaap.vanhal@tno.nl
ECN part of TNO, The Netherlands
https://www.tno.nl/en/focus-areas/energy/ecn-part-of-tno/

Communication

Rita Clancy (Dissemination Officer), r.clancy@eurida-research.com
EURIDA Research Management, Germany www.eurida-research.com

Bert Groenendaal (Exploitation Officer), bert.groenendaal@sioen.com
SIOEN Industries, Belgium https://sioen.com/en

European Commission

Agata Przadka, Innovation and Networks Executive Agency (INEA)

Consortium

Duration

January 2016 – December 2019

Budget

EU Contribution: 5 999 892,50 €

Website

MacroFuels policy papers and other publications are available at: https://www.macrofuels.eu/results-publications.