MacroFuels Project

# FACTSHEET

## Driving on Seaweed:

## Towards a production chain for sustainable transportation fuels from cultivated seaweed

**Key findings from the MacroFuels Horizon 2020 research and innovation project**

www.macrofuels.eu

## Why seaweed for sustainable transportation fuels?

There is an undisputed and urgent need to decarbonise the European transport sector.[1] For passenger cars, the electrification of transport is a likely scenario, but a high dependency on liquid fuels can be expected for transport, shipping and aviation.[2] This emphasises the need for sustainable biofuels that do not bear the risk of competing with food production or natural habitats by using land-based crops. In this context, cultivated seaweed is one of the very few feedstocks with the potential of being truly sustainable.

The MacroFuels consortium has investigated the complete chain from seaweed cultivation, harvesting and storage to conversion to fuels and fuel testing. The resulting processes were analysed based on social, environmental and economic effects. In addition, a life cycle assessment was made.

Compared to land-based biomass, seaweed:

- ✓ Grows without added nutrients, pesticides and fresh water
- ✓ Does not compete with land-use for food or valuable natural habitats, when cultivation sites are carefully selected

- ✗ Requires the development of new infrastructure
- ✗ Contains a lot of water, which influences fuel yields and processing technology

Seedlings growing on ropes

Seaweed growing on ropes

Seaweed harvesting

## Seaweed production and supply

Seaweed cultivation is a growing form of marine aquaculture. However, commercial seaweed cultivation is not yet employed at large scale within the European Union. In the MacroFuels concept, seaweed is cultivated and stored at sea, comparable to a sea-based agriculture, with no competition over land and without the need for fresh water,

---

[1] http://www.europarl.europa.eu/legislative-train/theme-resilient-energy-union-with-a-climate-change-policy/file-decarbonisation-of-road-transport

[2] DG MOVE - Expert group on future transport fuels *State of the Art on Alternative Fuels Transport Systems*

nutrients and pesticides. During the MacroFuels project, cultivation of four types of seaweed was optimised on ropes and nets. Important steps in the seeding and harvesting processes were automated. Another challenge is obtaining a continuous supply of seaweed, since the seasonal variation of the yield and composition of the crop leads to a relatively short optimal harvesting period. Various storage techniques were tested, in order to obtain a year-round supply of seaweed, and it was shown that ensiling (partial fermentation to lactic acid) is an effective way to store the seaweed. During the ensiling, the acidic environment preserves the seaweed. Ensiling bags were developed allowing for storage of seaweed at sea.

- ✓ Successful demonstration of seaweed cultivation at tonnes scale
- ✓ Ensiling allows for storage > 6 months and constant supply of seaweed
- ✓ Ensiling in bags allow for storage at sea without use of land space

- ✗ Yields are strongly dependent on environmental factors and crop management
- ✗ Some species, such as green seaweed are still challenging to cultivate

Seaweed harvester prototype

Ensiling bag in seawater

Ensiled seaweed

## Fuel production and road performance

In order to obtain fuel from seaweed, two (bio)-chemical steps are required. First, the sugars are released via a process called hydrolysis, which is assisted by enzymes or acid. Next, the sugars are converted to fuel components via fermentation or thermochemical conversion. During MacroFuels, both routes were investigated, yielding three fuel components, which were assessed by combustion and engine tests.

- ✓ MacroFuels produced
  - 10 litres of ethanol gasoline additives
  - 8 litres of butanol as gasoline alternative
  - 2.5 litres of furan-derived fuel booster

- ✓ MacroFuels performed road tests of 80 km driven using seaweed-derived ethanol and butanol

- ✗ Process optimization is required to make fuel production cost effective
- ✗ Seaweed processing is challenged by the high water and salt content

Fermentation tank @DTI

Seaweed lab @ TNO

Fuel testing @ DTI

## Efficient use of the biomass

In order to yield an efficient process, the complete biomass needs to be used. To achieve this, proteins were extracted from the remaining seaweed. Even the last residues were utilized by digestion to methane gas, which is a widely used energy source in industry.

- ✓ Proteins were isolated for feed applications
- ✓ Methane gas was produced from seaweed bio-refinery side streams

- ✗ Process optimization is required to make purification steps more efficient
- ✗ High water and salt content of seaweed limits fuel yields

## Sustainability assessment

A full sustainability analysis was performed taking into account social, environmental and economic aspects of fuel production from cultivated seaweed in Europe.
Social and environmental aspects that should be considered are:

- ✓ Job generation in cultivation and processing of seaweed
- ✓ Improved or new infrastructure to coastal areas
- ✓ Climate change mitigation potential through $CO_2$ uptake
- ✓ Accelerating recovery from coastal eutrophication via nutrient uptake
- ✓ Counteracts ocean acidification and oxygen depletion
- ✓ Carefully located seaweed farms can prevent coastal erosion

- ✗ Industrialisation of coastal regions
- ✗ Potential litter due to loss of cultivation materials in storms

The Environmental Life Cycle Assessment (E-LCA) has shown that the overall environmental footprint of the process for cultivated seaweed to fuel must be reduced. This can be achieved by sustainable cultivation and less energy and chemical intensive biorefinery methods. Several strategies to improve the environmental impact were proposed by the MacroFuels consortium:

- ✓ Innovation for upscaling and optimizing both cultivation and fuel production
- ✓ Investigate longer life-time materials and alternative cultivation systems
- ✓ Use of recycled materials for construction of the seaweed farm

## Fuel yields based on MacroFuels technology

The world fuel demand is high and to have sufficient impact once fully developed the MacroFuels concept is expected ultimately to be a large-scale operation. At the current stage, seaweed cultivation areas of 369 $km^2$ (equivalent to a 19x19 km plot) are needed for one single seaweed-to-fuels biorefinery. This farming area would occupy in total a plot equivalent to 81x81 km of sea surface area. This would yield 9130 ktons of fresh seaweed each year with 1200 ktons seaweed dry matter. Processing this in the seaweed biorefinery could yield: 104 ktons of biofuel and 32 ktons export biomethane each year.

## Potential market success and barriers

Large-scale seaweed cultivation and seaweed conversion to fuels are new technologies, which are in an early stage of development and related to high investment cost. There is a strong need for further development to allow for scaled production. Several strategies are selected to improve the economics of seaweed cultivation for non-food and fuel applications:

- ✓ Co-use maritime platforms, pursuing synergy in combining seaweed cultivation with wind parks and aquaculture will improve sustainability
- ✓ Research and innovation to support further upscaling.
- ✓ A cascading biorefinery approach is essential, where high-value products are targeted and fuels and methane are co-produced.

Further Fact Sheets on seaweed cultivation, environmental impacts, fuel production and social aspects are available on the MacroFuels website

www.macrofuels.eu/results-publications

## MacroFuels in numbers

- ✓ 200 kg of seaweed was harvested in Denmark
- ✓ 10 tonnes of seaweed was harvested in Scotland
- ✓ Cultivation of 4 species of seaweed was investigated
- ✓ 20 litre of seaweed derived fuel compound was obtained
- ✓ 80 km driven on seaweed derived fuels
- ✓ Biofuel production from cultivated seaweed has reached technology readiness level 5 (TRL5)
- ✓ Market readiness of seaweed-based fuels or fuel additives is envisaged for 2030.


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

This fact sheet 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.

Horizon 2020
European Union Funding
for Research & Innovation

## Project Identity


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

Dr. 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

Dr. 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** All MacroFuels Fact Sheets and other publications are available at: https://www.macrofuels.eu/results-publications.