MacroFuels Project

FACTSHEET

Fuel Production and Road Performance

Findings from the MacroFuels Horizon 2020 research and innovation project

www.macrofuels.eu

Sustainable biofuels from seaweed

The need to decarbonise transport and aviation is becoming more urgent by the year as these are the only sectors in Europe that show increasing GHG and CO_2 emissions, for example emissions from aviation have doubled since 1990.[1] European strategies predict a strong role of advanced biofuels in the decarbonisation of heavy transport and aviation.[2,3] While for passenger cars the electrification of transport is a likely scenario, for heavy transport, shipping and aviation a much higher dependency on liquid fuels can be expected for the coming decades.[4] MacroFuels foresees that seaweed can a sustainable bio-based feedstock for liquid transportation fuels. Seaweeds, or macroalgae, are the fast growing organism and only need CO_2, sunlight and the nutrients already present in the seas. Seaweeds can be naturally high in sugars, which makes them suitable for the production of advanced biofuels.

Biofuels production

In the first biorefinery step, sugars are released from the seaweed by a process called hydrolysis. The obtained sugar solution needs to be purified to remove salts and other impurities that can affect the next conversion steps. Depending on the desired product, different conversion routes can be chosen. MacroFuels explored both fermentation and thermochemical conversion routes.

Fermentation of seaweed @ WFBR

Fermentation of seaweed @ DTI

Thermochemical conversion of seaweed @ TNO

In the fermentative route, yeast was used to convert the sugars (glucose and laminarin) from brown seaweed (*Saccharina latissima)* into ethanol. It was also shown that specific bacteria are able to ferment sugars from the brown and red seaweed (*Palmaria palmata*) into an ABE mixture (acetone/butanol/ethanol). Water is removed to obtain a pure butanol or ethanol that can be blended with petrol or diesel for conventional cars.

During thermo-chemical conversion, the sugars of the red seaweed are converted to furfural, which is a precursor for a range of biofuel compounds. For example, furfural can react with butanol (from the ABE fermentation, mentioned above), in order to produce fuel additives (octane boosters).

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[1] https://www.eea.europa.eu/articles/aviation-and-shipping-emissions-in-focus

[2] https://ec.europa.eu/energy/en/topics/renewable-energy/renewable-energy-directive

[3] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52018DC0773

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

To improve the utilisation of the biomass, side streams from the fermentation and thermochemical routes were successfully digested to biogas, which is an important energy carrier for heating and electricity.

During the project the MacroFuels consortium produced:

- ✓ 10 liter ethanol
- ✓ 8 liter butanol
- ✓ 2.5 liter furan-derived fuel booster

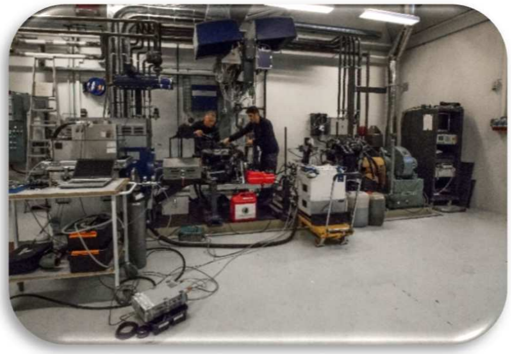
Engine testing – laboratory and on-road

The biofuels produced by the MacroFuels consortium were mixed to an 'E10' type fuel using conventional petrol without added ethanol. The obtained fuel blends were tested for engine performance both on an engine dynamometer, and on a chassis dynamometer in the lab and during real driving emission testing according the European PEMS[5] procedures. The PEMS directive sets a very strict framework for how the test should be conducted and distributed over different types of roads.

The tested fuels showed excellent engine performance, fully equivalent to commercial petrol. No difficulties where discovered during cold start, any of the load points or during on-road operation. All measured emissions are within the regulations for commercial fuels.

Fuel tests performed as part of MacroFuels included:

- ✓ Cylinder pressure measurements
- ✓ Combustion quality
- ✓ Emissions, including NOx, CO, CO2, SO2 and particulates
- ✓ Engine behaviour and emissions during a WLTP6 test procedure
- ✓ Real driving emission test on a 80 km PEMS route



Engine dynamometer test @DTI

Real driving emission testing with PEMS @DTI

A short film of the PEMS test car drive is accessible via the MacroFuels websitewww.macrofuels.eu

[5] *Portable Emission Measurement System*

[6] *Worldwide harmonized Light vehicles Test Procedure*

Technology and economy

During the MacroFuels project, all seaweed conversion steps were performed with conventional equipment with adaptations to manage the characteristics of seaweed as biomass feedstock. This shows that biofuel production from seaweed is technically feasible.

- ✓ Different biofuels were produced from seaweed
- ✓ Road tests showed good performance of seaweed-based fuel blends
- ✓ Emissions of seaweed-based fuel blends were within regulatory limits

After demonstration in the laboratory, the process was scaled up to multi-litre scale, which showed that each step has specific challenges. Most important challenges foreseen based on the MacroFuels results are:

- ✗ Current estimated seaweed cultivation costs are too high for economic fuel production
- ✗ Seaweed contains a lot of water and salts, increasing costs for fuel production
- ✗ Composition of seaweed varies with cultivation site, season and species, which poses challenges for logistics and biorefining business case

Outlook

The world fuel demand is high and to have sufficient impact once fully developed the MacroFuels concept is ultimately expected to be a large-scale operation. At the current state-of-the-art, 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 and would yield 1200 kton seaweed (dry weight basis) each year.

MacroFuels has demonstrated the technical viability of the production of biofuels from seaweed: such biorefinery could yield 104 kton of biofuel (from the ABE route) and 32 kton of biomethane each year. However, economic biofuel production at relevant scale depends mainly on biomass production and requires:

- ✓ Scale up of seaweed production and handling
- ✓ Reduction of seaweed cultivation costs
- ✓ Optimizing biofuel yields
- ✓ Combining biofuels with co-production of high-value products

To improve the sustainability of the seaweed platform, we think that seaweed utilisation for food and high value chemicals (*e.g.* pharma, materials) needs to go hand-in-hand with and pave the way for a seaweed-to-biofuels platform. Further research is required as upscaling from laboratory to bench and full scale will pose challenges in seaweed logistics, handling, storage and processing.

Project Identity

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Consortium

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

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