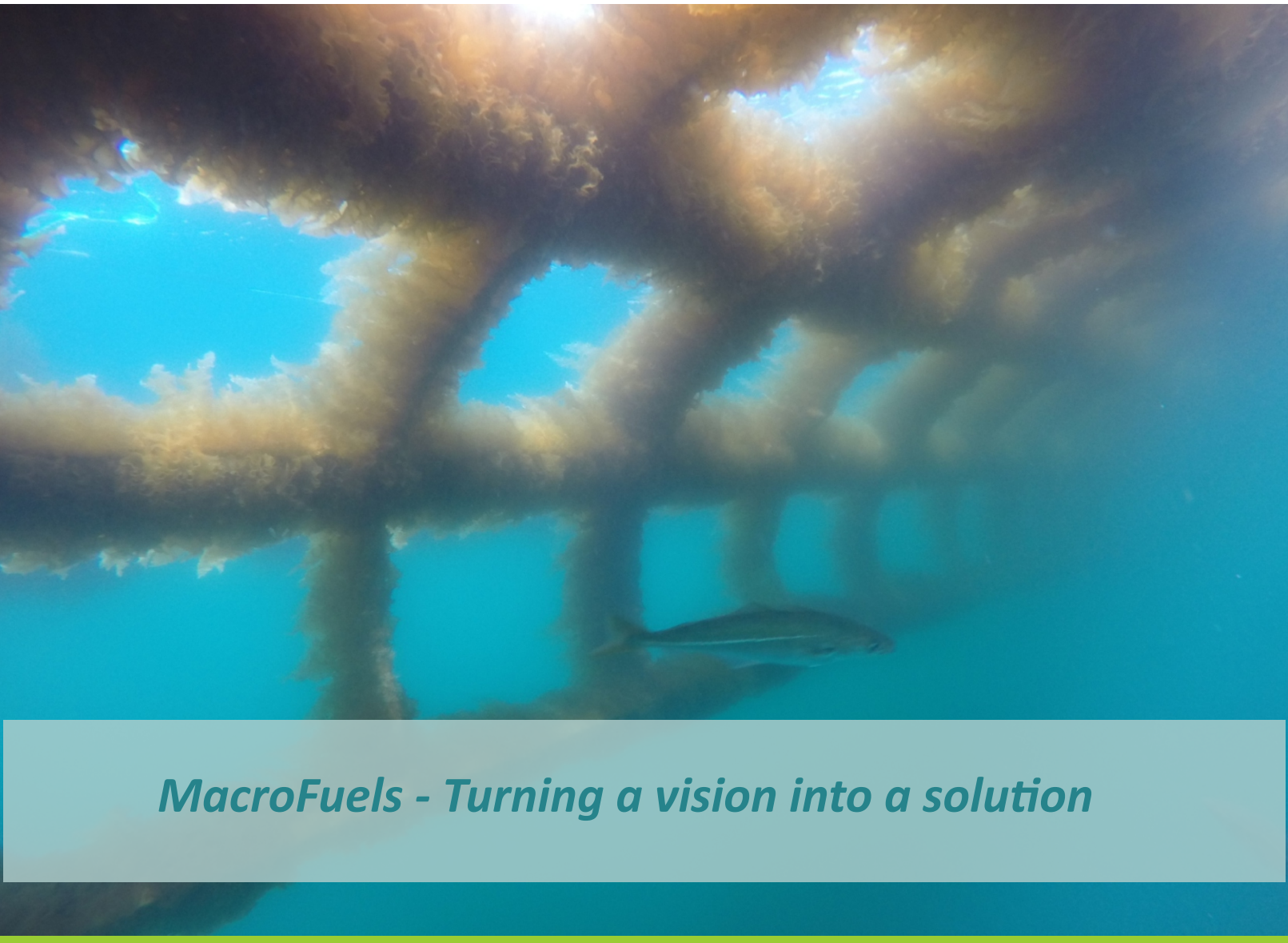
Third-Generation Biofuels from Seaweed

MACROFUELS



MacroFuels - Turning a vision into a solution

MacroFuels in a Nutshell

MacroFuels aims to produce advanced biofuels from macroalgae, commonly known as seaweed. The targeted biofuels are ethanol, butanol, furanics and biogas. The project will achieve a breakthrough in biofuel production from macroalgae by:

- Increasing biomass supply by developing a rotating crop scheme for cultivation of seaweed, using native, highly productive brown, red and green seaweeds, in combination with the use of advanced textile substrates resulting in a year round biomass yield
- Improving the pre-treatment and storage of seaweed and to yield fermentable and convertible sugars at economically relevant concentrations (10-30%)
- Increasing bio-ethanol and bio-butanol production to economically viable concentrations by developing novel fermenting organisms which metabolize all sugars at 90% efficiency
- Increasing biogas yield to convert 90% of the available carbon in residues by adapting the organisms to seaweed
- Developing thermochemical conversion processes of sugars to furan-based fuels
- Performing an integral techno-economic, sustainability and risk assessment of the entire seaweed to biofuel chain

MacroFuels will develop technology for the production of fuels that are suitable as liquid fuels or precursors thereof for the heavy transport sector as well as potentially for the aviation sector. MacroFuels will furthermore expand the biomass available for the production of advanced biofuels. Seaweed does not need fresh water, arable land or fertilizers to grow, which provides environmental benefits, and in addition has a high carbon dioxide reduction potential as well as reduces the demand for natural resources on land. The technology offers many novel opportunities for employment along the entire value chain.

Benefits and Impacts

The progress that will be achieved by MacroFuels will have significant impact on various economic fields, and – most importantly – paves the way towards a sustainable solution for biofuels that is not competing with arable land or food in contrast to 1st and 2nd generation biofuels derived from food-based crops and residuals. Thus, MacroFuels aims to make a substantial contribution towards renewable energy from photosynthesis and towards the goal set by the European Union of 10% of the transport fuel of every EU country to come from renewable sources such as biofuels by 2020.

✓ MacroFuels permits the use of new feedstock sources that do not compete directly or indirectly with resources for food or feed production.

✓ MacroFuels converts seaweeds more efficiently to biofuels.

✓ MacroFuels enables a favourable energy balance, as well as a significant potential for cost reduction, which will permit our targeted fuels to eventually compete favourably with fossil or 1st and 2nd generation equivalent fuels.

✓ MacroFuels performs a robust and reliable multi-criteria assessment, including environmental and social benefits, with respect to current technologies, notably in terms of GHG performance, energy balance, efficient use of natural resources, decentralised energy production, and job creation in rural areas, as well as a secure and affordable energy supply in Europe or worldwide.

✓ MacroFuels stimulates stakeholder dialogues and international collaboration.

✓ MacroFuels improves innovation capacity.

Advanced cultivation

To produce biofuels, the total annual production of seaweeds will need to be expanded by orders of magnitude, from the current 14 Mton (wet basis). In Europe, macroalgae cultivation is still in its infancy, with a limited number of commercial farms. Today's state of the art cultivation of seaweed is based on long lines with seeding lines twisted around them. Yields are typically 1-6 kg per running meter per year.

MacroFuels will significantly increase yields by utilising cultivation textiles' with optimised chemical and morphological characteristics, combined with a rotating crop process allowing for year-round harvesting. With this approach we target yields of 25 kg seaweeds (wet weight) per m^2 per year. Basis for year round cultivation will be the patented and award-winning advanced textile-based substrates developed within the AT~SEA project which received funding under the European 7th Framework Programme.

Storage and Logistics

Storage and logistics are an integral part of the proposed process and here MacroFuels adopts a two pronged approach. MacroFuels will develop containers, so-called flexitanks, which are flexible, large storage containers based on coated textile developed in the FP7 project AT~SEA. Flexitanks will allow for the temporary storage of harvested seaweed at sea and for later onward transport. AT~SEA already demonstrated that hundreds of kilograms of wet seaweed can be stored for months in such containers at sea, near the cultivation site. Within the MacroFuels project, we will further develop this seaweed storage concept for large volumes (up to 25 m^3) and different seaweed species. We will also investigate if certain pre-treatment steps can be performed in these flexitanks.

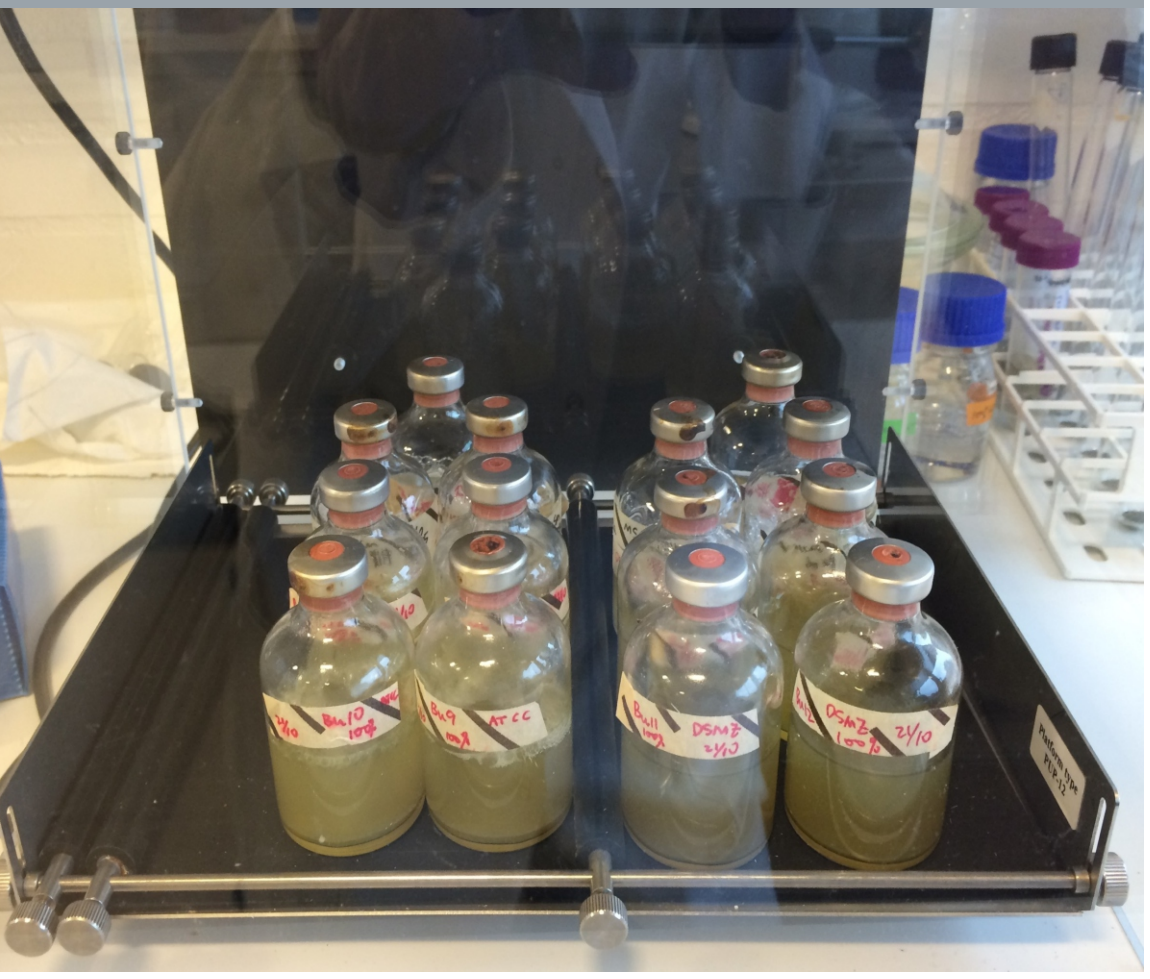
MacroFuels aims to demonstrate a novel storage concept using 25m^3 flexible storage tanks and transporting the stored seaweed over a distance of 2 km at sea. MacroFuels will integrate storage with pre-treatment by ensiling, which yields fermentable sugars without further pre-treatment. These methods allow for the year-round production of biofuels.

Pre-treatment and fractionation

Pre-treatment and fractionation yields sugar streams, which are to be converted to advanced biofuels. The objective of pre-treatment is the production of concentrated sugar streams suitable for fermentation or thermochemical conversion. Pre-treatment concepts will be developed to allow for local flexible processing of the seaweeds, depending on the conversion technology selected. Combinations of enzymatic and chemical pre-treatments will be developed, including mesophilic and thermophilic enzymatic hydrolysis of alginates, ulvans, C5 and C6 sugar polymers.

Acetone, butanol and ethanol (ABE) and ethanol production

For the production of butanol as biofuels, MacroFuels aims for the conversion of 90% of all the sugars to liquid biofuel precursors. Microbial strains able to degrade and ferment the sugar polymers to a mix of acetone, butanol and ethanol (ABE) will be developed, eliminating the need to use enzymes in pre-treatment of the seaweeds and realising a more economic process.
The production of ethanol as a first stage liquid energy carrier will be improved by developing a process based on gentle pre-treatment in combination with optimised enzyme mixtures for full hydrolysis of sugar polymers to monomers, and further conversion to ethanol at a minimum of 4% for the end concentration. C6 sugars (glucose and mannose) will be fermented by yeast, and other sugars by thermophile bacteria, at an efficiency of at least 90%.



Anaerobic digestion

Developing efficient anaerobic digestion (AD) processes adapted for processing the residues from fermentation and thermochemical conversions will further improve the energy balance of the entire MacroFuels production chain. MacroFuels aims at the conversion of at least 90% of the total carbon present in the residues to biogas containing 60% methane.

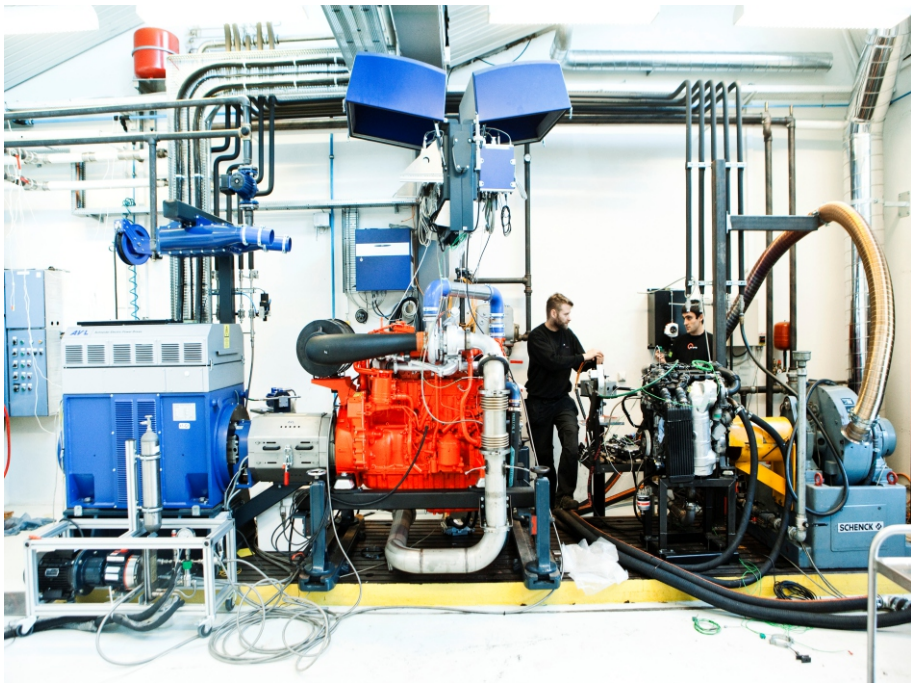
Thermochemical conversion routes

The thermochemical conversion routes aim to produce furanics-based fuels from seaweed specific carbohydrates. Furanics refer to compounds which have a furan ring in their structure. The production of furfural from alginic acid has been demonstrated at analytical scale, i.e. mg/experiment, and we aim to further develop this step to a continuous laboratory scale at the kg/hr scale.

Furfural can then be used as an intermediate for the production of fuels. Furthermore, we aim to implement Avantium's innovative fractionation scheme in the production of the furanics-based biofuels chain from three different carbohydrates (e.g. alginate, laminaran and rhamnose) at the kg scale.

Economic viability and sustainability

MacroFuels will determine the economic viability of the seaweed to biofuel production chains by using accurate verified experimental data obtained under relevant conditions. The data from the assessment will be used in a feed-back loop to further inform the experiments, thus ensuring that the chances of commercial implementation are maximised.



Valorisation of the side- and waste-streams

Side- and waste-streams will be valorised by screening them for high value marketable components and identifying the most viable products. We will further assess the proteins liberated during the entire process for their use to augment feed supply in the EU, as well as the mineral streams for use as inorganic fertilizer in terms of primary, secondary and trace elements. This assessment will result in a potential value and market for these streams.

Fuel assessment under realistic conditions

Fuel assessment under operating conditions will be performed by utilising the DTI fuel assessment capabilities. Fuel (mixtures) will be prepared and tested in the relevant engines to assess the suitability of these fuels under different realistic transport conditions.

Techno-economic and sustainability assessment

As part of MacroFuels, a multi-criteria assessment of the sustainability of substituting conventional, fossil-based transportation fuels and currently available biofuels with seaweed-derived fuels will be performed. The sustainability assessment will take into account economic, environmental, social, health and safety, and risk aspects and will consider the entire value chain of the transportation fuels using a life cycle comparison approach.

Our project team

The MacroFuels consortium brings together specialists along the entire chain of biofuel production, from seaweed cultivation up to fuel testing *via* fuel production. Feedback loops between the experts ensure crosspollination of ideas, concepts and insights. The cultivation, pre-treatment and conversion experts are further complemented by experts in the field of sustainability assessments, risk analysis and mitigation, commercial deployment and IP monetisation, as well as communication.

Contact

Anna-Belinda Bjerre - Coordinator
Danish Technological Institute
Gregersensvej
2630 Taastrup
Denmark
Tel: +45 72 20 20 00
Email: anjb@teknologisk.dk

Jaap Van Hal - Projective Executive
Energy Centre of the Netherlands
P.O. Box 1, Westerduinweg 3,
1755 ZG Petten
The Netherlands
Ph: +31-(0)88-5154297
Email: vanhal@ecn.nl

www.macrofuels.eu

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