Driving on seaweed

Major achievements of the H2020 MacroFuels project towards producing biofuels from macroalgae

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✓ Links to resources throughout this presentation.

✓ You can also visit our virtual TNO Biomass programme booth for a chat!

Main Objective

MacroFuels aims to develop technologies to produce **advanced liquid biofuels from seaweed** for transportation.

The targeted biofuels are ethanol, butanol, furanics and biogas.

Main Objective

Sun, CO_2, no added fertilizer

Advanced cultivation

Advanced harvesting and Logistics

Advanced pre-treatment

Advanced (bio)chemical conversions

Advanced biofuels

Concept

Advanced cultivation
Rotating crop scheme, year around harvesting
Automated harvesting concept

Pretreatment and fractionation
Economic feasible storage
Enzymatic and chemical hydrolysis to yield fermentable sugars

Improved biofuel production
Fermentation of algal sugars to bio- ethanol and butanol
Conversion of algal sugars to furans (mg scale to kg scale)

Integral sustainability of MacroFuels chain
A multi-criteria assessment of MacroFuels biofuels
Economic and environmental lifecycle impacts and outlook

Achievements

Cultivation

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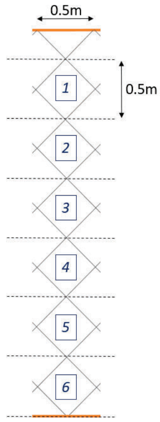
- Kelps and green seaweeds on advanced textiles at unprecedented scale (200+m^2, # sites).
- Novel year-round cultivation successfully proven: 19 kg/l-m.
- Design and test of automated harvesting using textile cultivation sheets.
- New knowledge: Site (eco)types vs. crop requirements, approaches on seeding, timing, coppicing, monitoring, etc.



For more information, visit [Cultivation]

Storage and preservation

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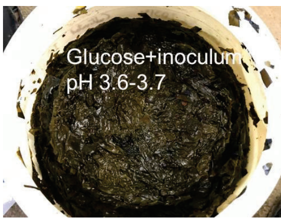
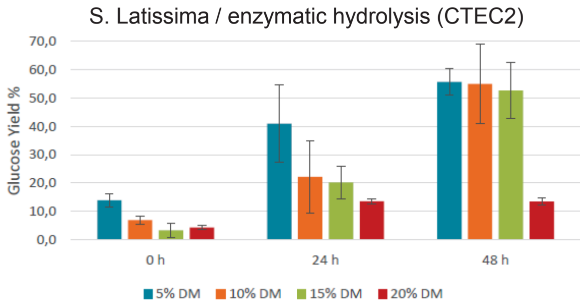
- Biological vs chemical ensiling: Achievable with inherent differences in consumption of sugars and costs.
- Ensiling on land and at sea was demonstrated as means of stabilisation and storage (+6 months).
- Variability in ensilability of seaweeds and contamination.

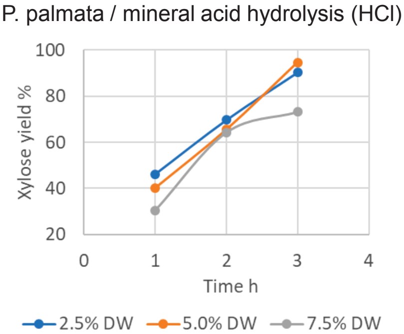


For more information, visit [Ensiling]

Fractionation and conditioning

- Various approaches developed via enzymatic and chemical treatments.
- Process insights: Enzyme deactivation at high loadings, large mineral acid consumption.
- Conditioning via ion exclusion in SMB and nanofiltration: Removal of +90% minerals and recovery of +90% sugars.





For more information, visit [Hydrolysis]

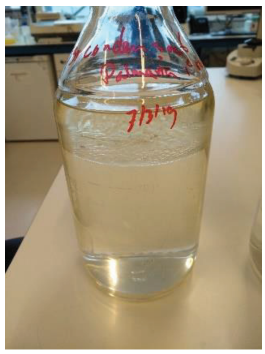
Fermentative biofuel production

Seaweed-based ethanol

- Various fermentation strategies (SHF, SSF) integrated to algal polysaccharide extraction.
- *S. latissima* at pilot scale: Ethanol titre 4.9% v/v, 78% yield.

Seaweed-based Acetone-Butanol-Ethanol

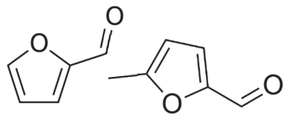
- Via 2 Clostridium strains: 8-15 g/L from *P. Palmaria* and *S. latissima*, +90% sugar conversion.



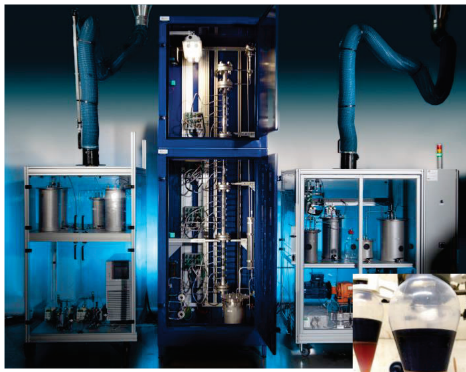
For more information, visit [Biorefinery and biofuel production]

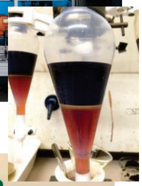
Catalytic biofuel production

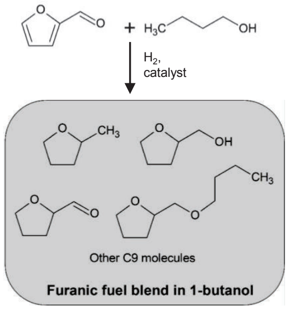
Seaweed-based furanics



- Multiple new (catalytic) thermal conversion: Pyrolysis, dehydration.
- Valuable platform chemicals from *P. palmata* and *U. lactuca*: furfural (+85%) and 5-methylfurfural (+45%).
- Catalytic upgrading to fuel boosters with 1-butanol.
- *P. palmata* at kg-scale: Catalyst activity poses further challenges.



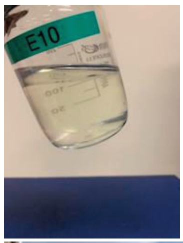


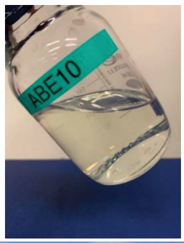


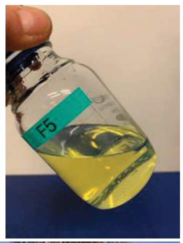
For more information, visit [Biorefinery and biofuel production]

MacroFuels in engine tests

- Tests: 10L of ethanol and butanol in petrol engine and 2.5L butanol+booster in diesel engine.
- Lab and real-driving conditions.
- Excellent engine performance (cold/hot start and operation), equivalent to commercial petrol/diesel.
- No significant differences in terms of emissions under lab and real drive conditions (CO, CO_2, NOx, PN).







[Video: Could seaweed be the fuel of the future?]

For more information, visit [Fuel production & road performance], [D5.1 report] and [D5.2 report]

Sustainability outlook

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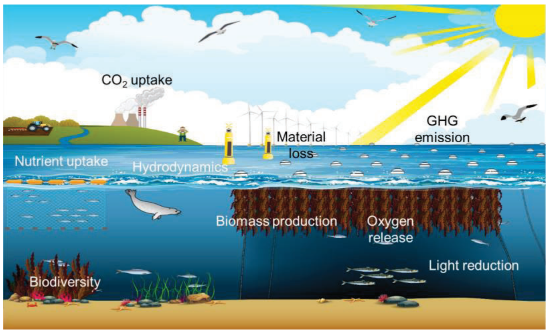
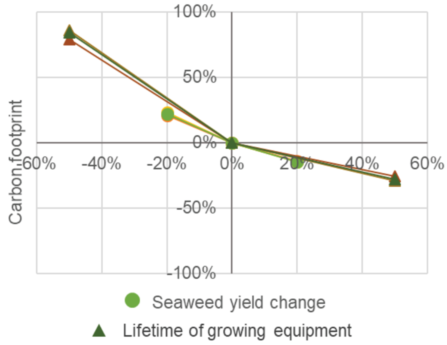
- A multi-criteria assessment comparing MacroFuels and fossil and terrestrial bio-fuels.
- **Remaining challenge:** High costs/impacts from cultivation.
- **Key developments:** Improved cultivation design and co-production of value-added products.
- **Environment:** Depending on site selection and monitoring (Authority setting tolerable impact thresholds).





For more information, visit Environmental and Social/Regional factsheets, and reports on LCA and sustainability assessment

Conclusions and outlook

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MACROFUELS in numbers:

- 3 concepts of biofuel production from seaweeds
- +10 tonnes of 4 seaweed species were harvested in Scotland/Denmark
- 20 litres of seaweed based biofuels were produced
- A test car drove 80 km on seaweed based fuel mix
- The biofuel production from cultivated seaweed was brought from Technology Readiness Level 3 to 5

Challenges yet remain:

- Cultivation: Aligning sustainability aspects of technology.
- Processing: Cascading concepts with high value products.

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