

More than sushi and agar Developing a seaweed biorefinery





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www.ecn.nl



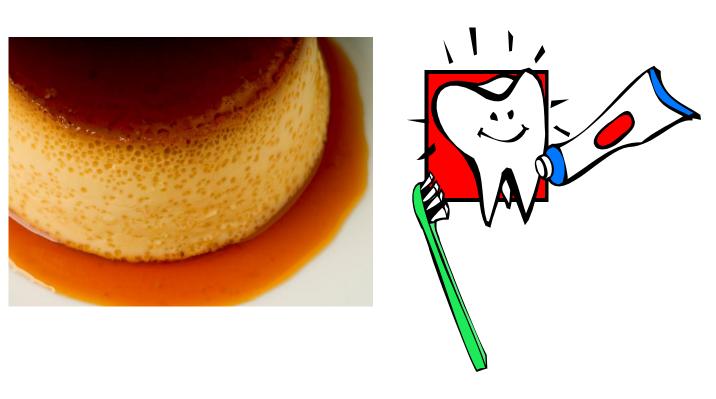
Have you had your seaweed today?







Sushi





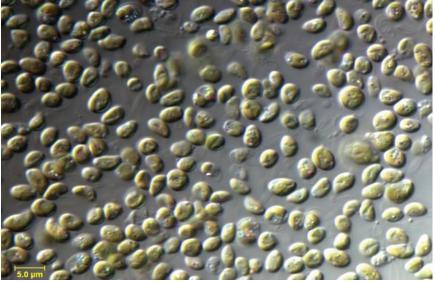
Agar

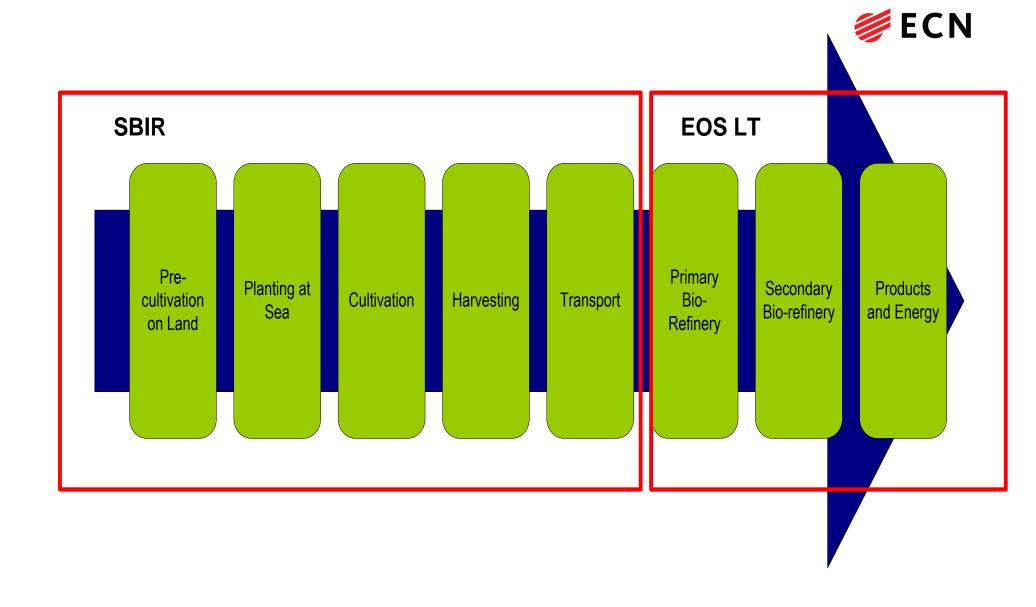


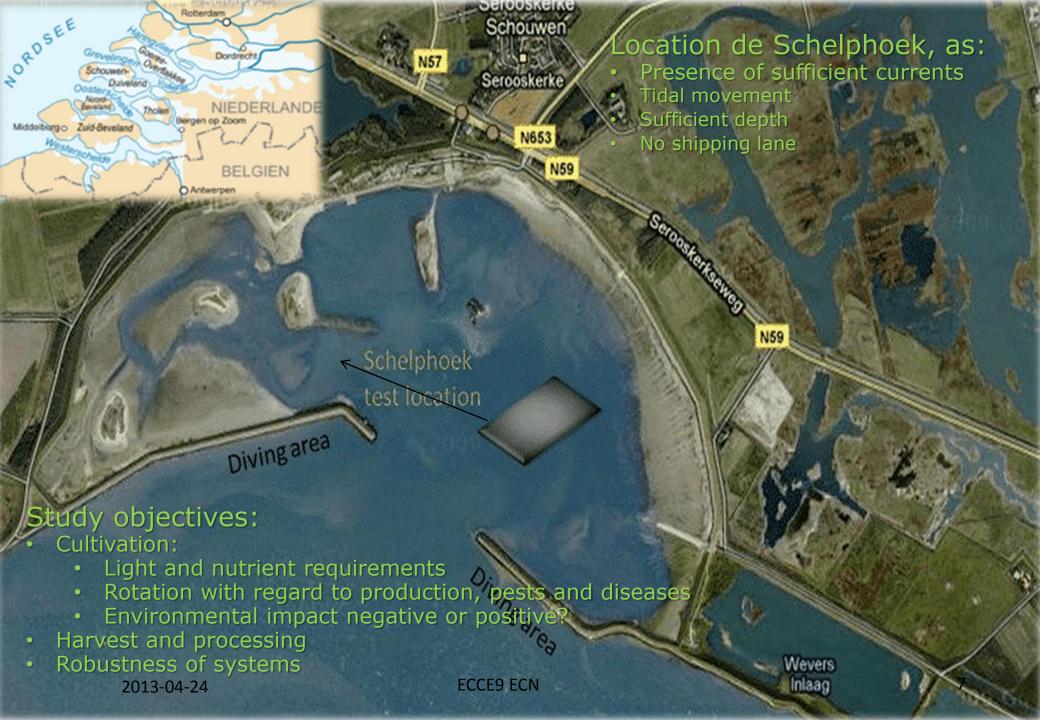
Aquatic Biomass





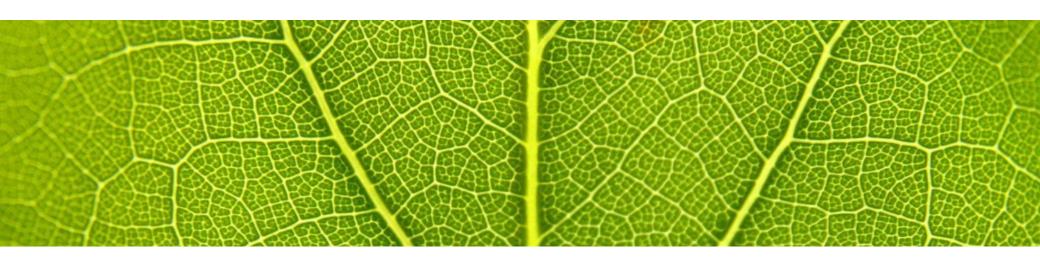










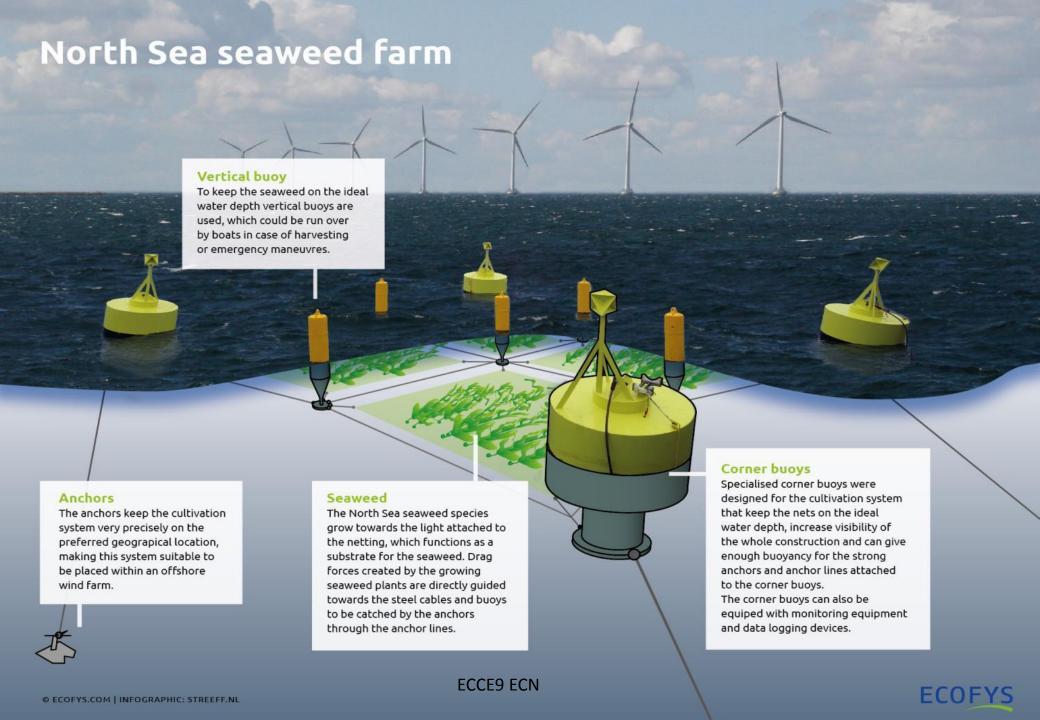


Offshore Seaweed Cultivation Project

The Ecofys Test Module

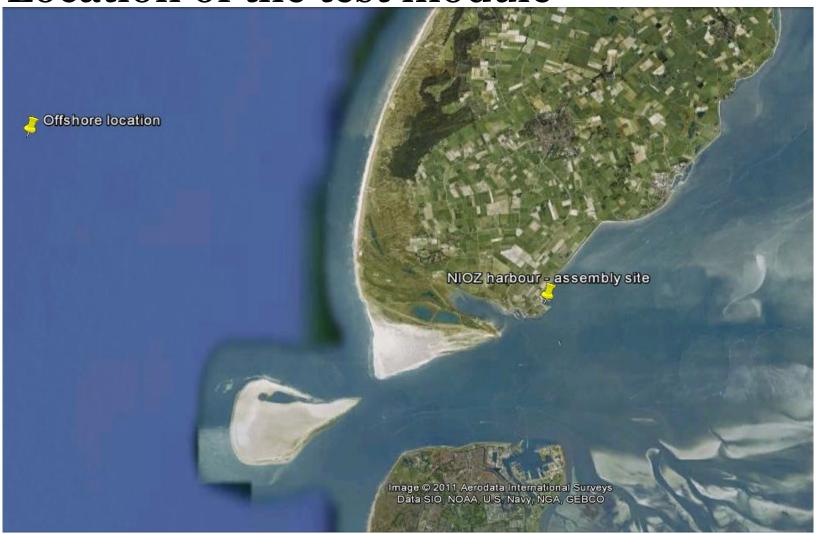
2013-04-24

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Location of the test module





Who is ECN?

Energy research Centre of the Netherlands (ECN)



• What do we do:

 ECN develops market driven technology and knowhow to enable a transition to sustainable energy society

• Business units:

- Biomass & energy efficiency
- Solar energy
- Wind energy
- Policy studies
- Environment & energy engineering



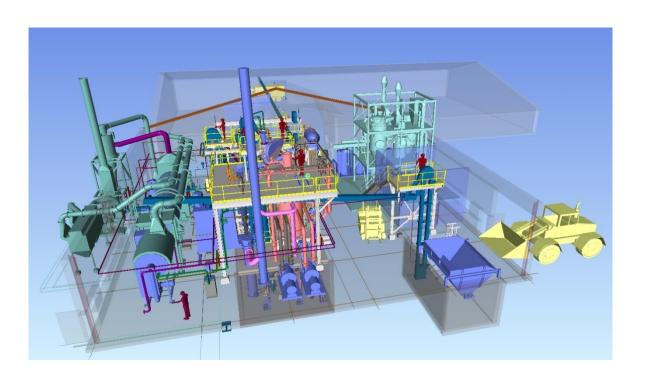
ECN

- Independent research institute
- ~600 employees
- Locations:
 - Petten (HQ)
 - Amsterdam
 - Eindhoven
 - Brussels
 - Beijing

Biomass Pre-Treatment Licensees, clients



- Torrefaction technology
 - Demo plant operational













Biomass – a diverse energy source

ECN

 Biomass = all organic material of non-fossil origin meant for energy or chemicals/materials

production

waste



wood







(agricultural) residues energy corps aquatic biomass

Differences between lignocellulosic and seaweed biomass



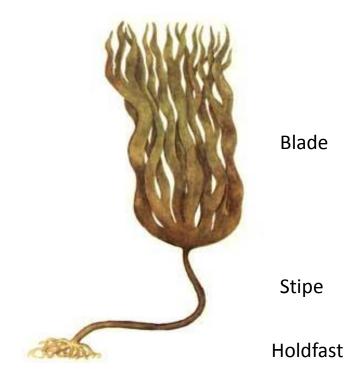
- Lignocellulosic biomass:
- Cellulose
 - Extremely recalcitrant
- Lignine
 - Heterogeneous polymer
 - Species, source and time of harvesting dependent
- Hemicellulose
 - Easy to hydrolyse
- Ash
 - Low to high
- Overall composition reasonably stable

- Seaweed biomass
- Carbohydrates
 - Type dependent on species
 - Amount dependent on season and location
- Proteins
 - Aminoacid composition dependent on species
 - Amount dependent on season and location
- Ash
 - Species dependent
 - Amount dependent on season an location
- Extreme differences between seasons



Parts of seaweed plant







Does not compete with food







No land use issues





Bio-Offshore

- Seaweed cultivation area 5.000 km² (<10 % of the NL area of the North Sea @ 57.000 km²)
- Integration with off-shore wind parks & (other) aquaculture operations
- Energy potential up to 350 PJth (25 Mton dry biomass per year)
- ECN-C-05-008
- The Crown Estate envisions 15,000 km² for biogas productions





Why seaweeds

- Does not compete with food
- Does not compete with any other land use
- Grows in cold seawater
- The fastest growing biomass at our latitude
 - The Netherlands is as far north as New Foundland
- Biochemical composition: complementary (for fuel/chemicals production) to micro-algae
 - Comprised of carbohydrates, protein and ash

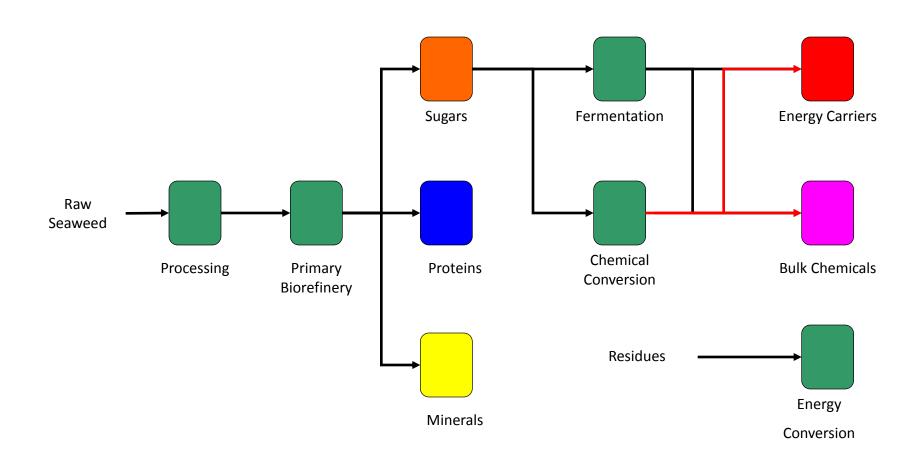


Potential Applications

- Furanics (carbohydrate conversion)
- Polyols for poly-urethanes (direct application)
- Butanol (fermentation)
- Bleach activators (derivatization)
- Phosphate recycling/fertilizers (Ash utilization)
- Fodder (protein fraction)
-



Seaweed biorefinery process concept













Seaweed species native to the North Sea



Saccharina latissima



Ulva sp.



Alaria esculenta



aminaria hyperborea



Palmaria palmata

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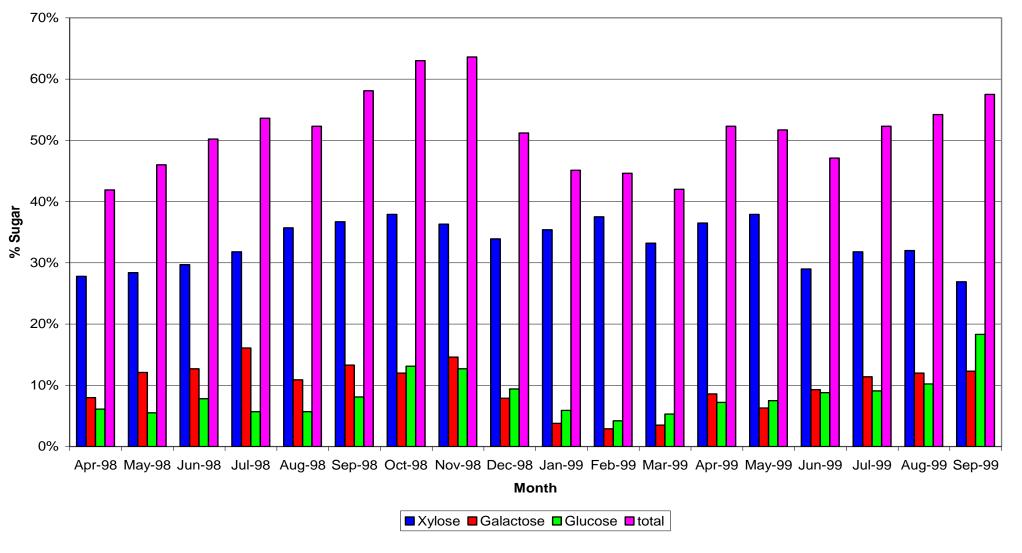


Palmaria (red seaweed)

Xylan (1,3 and 1,4 linkage)



Total Carbohydrate compostion of Palmaria Palmata



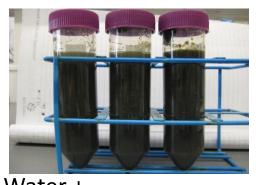


Rehydrated seaweed





Fractionation



Water + Seaweed



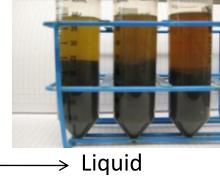
Optional Catalyst

T: 120-160 °C

t: 1-4 h

Liquid:Solid=1:10

Cat: 0-1 M H₂SO₄



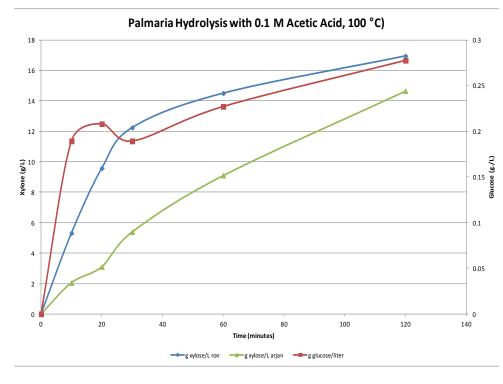
→ Solid

 After reaction, separation by centrifugation (10 min, 4000 rpm) and separation of the phases.

Simultaneous extraction and hydrolysis of *Palmaria*



- Tests with freeze-dried Palmaria at 2.5 and 25 gr dw scale.
- Hydrolysis of Palmaria to xylose proven.
- Optimum conditions: 0.1M acetic acid, 100C, 2hrs.
- Xylose concentration is dependent on the [H]⁺ concentration not on acid
- → Scale up and with fresh seaweeds.





Fresh Palmaria

- Two tests in 20L autoclave (1 kg dw seaweed).
- >10 kg received, 5 kg wet per test.





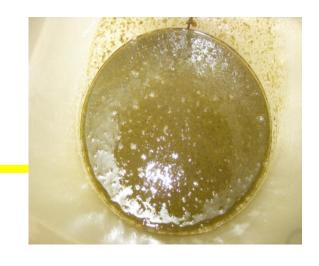
Mild acid pretreatment

- 0.1M acetic acid, 100C, 2h, 9 L/kg dw seaweed.
- Red seaweed turned into green 'soup'.
- After centrifugation, ~6L viscous liquid, ~ 4kg solid product.
- pH ND, solids recovery 51.6% dw.





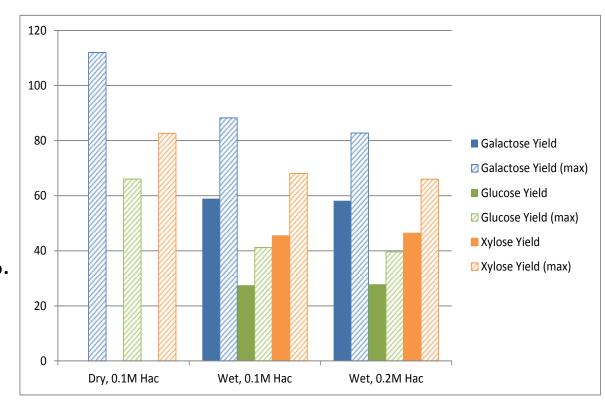






Yields sugars

- Yields based on amount of extract.
- Max. achievable yield based on liquor starting amount.
- Yield xylose: ~45%.
- Optimization of separation extracted *Palmaria* / extract might increase yield to max ~65%.
- Future work: optimisation of process conditions.

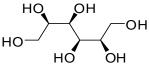




Applicable to all seaweeds?

Ulva (green seaweed)





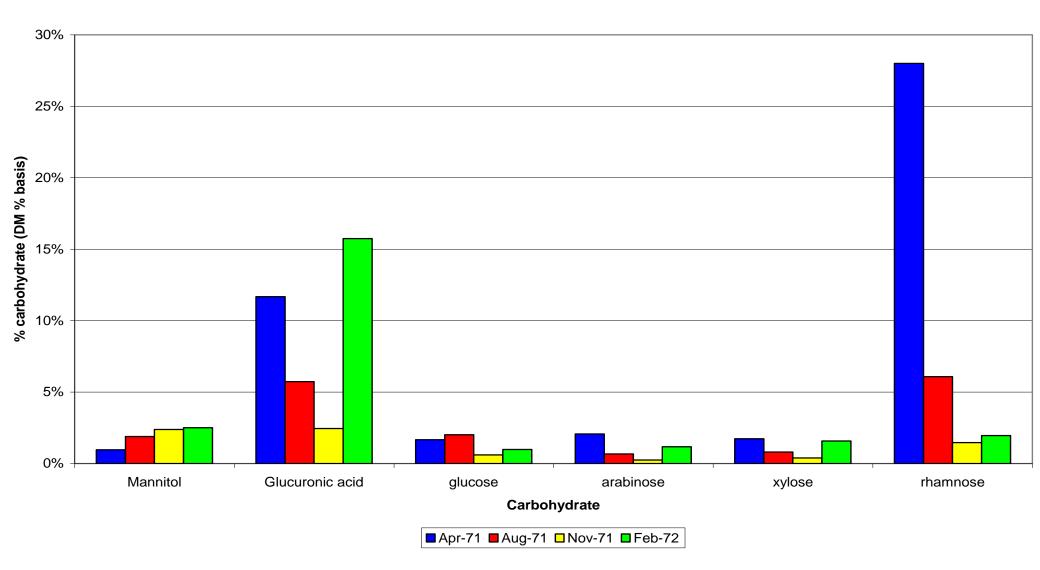
mannitol

arabinose

Ulvans



Ulva Lactuca carbohydrate seasonal composition changes

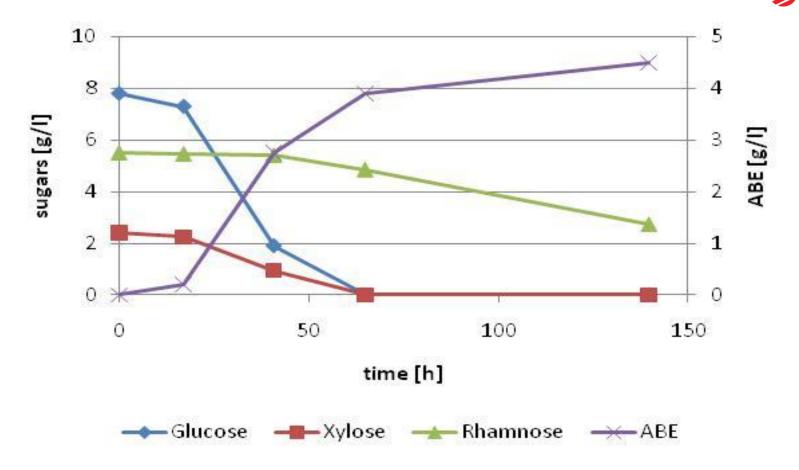


ABE fermentation (2)







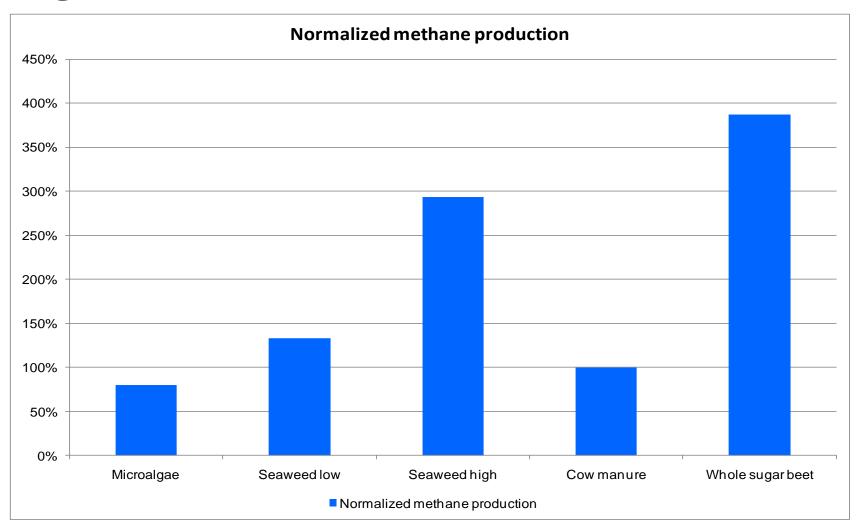


Fermentation of *Ulva lactuca* hydrolysate by *C. Beijerinckii* to acetone, butanol and ethanol (ABE): Higher ABE productivity, rhamnose utilised as well.

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Digestion results



Question? Further information



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http://seaweed.biorefinery.nl

http://www.noordzeeboerderij.nl

http://www.atsea-project.eu

http://www.mermaidproject.eu

And yes, we are hiring

