Perspectieven van zeewierteelt en gebruik als grondstof voor de industrie

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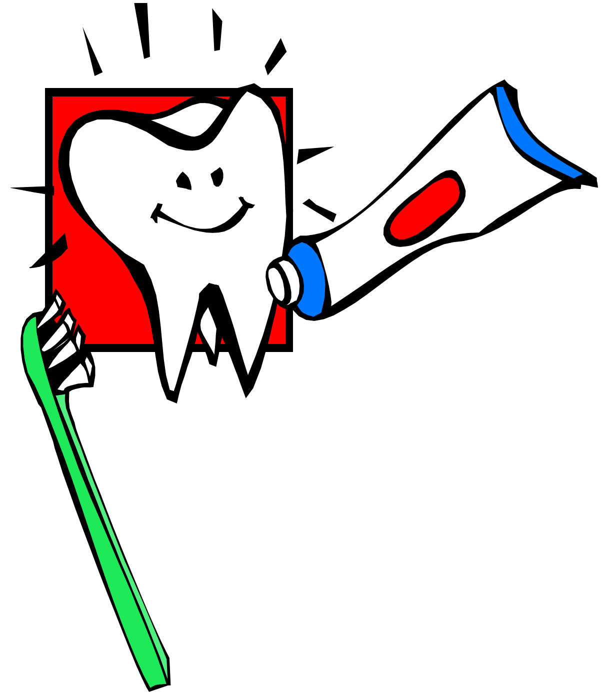
IIR BioBased Business Cases
WTC, Rotterdam
2012-12-18

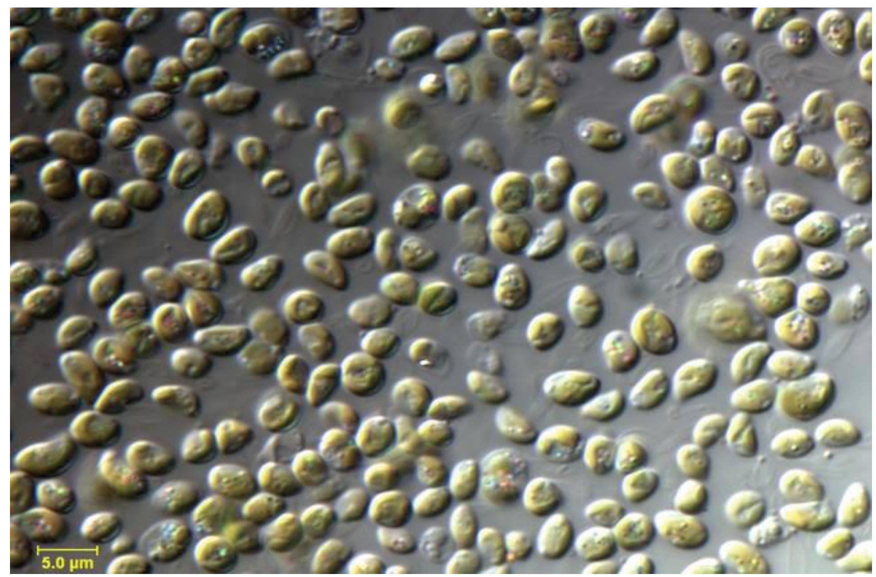
Have you had your seaweed today?

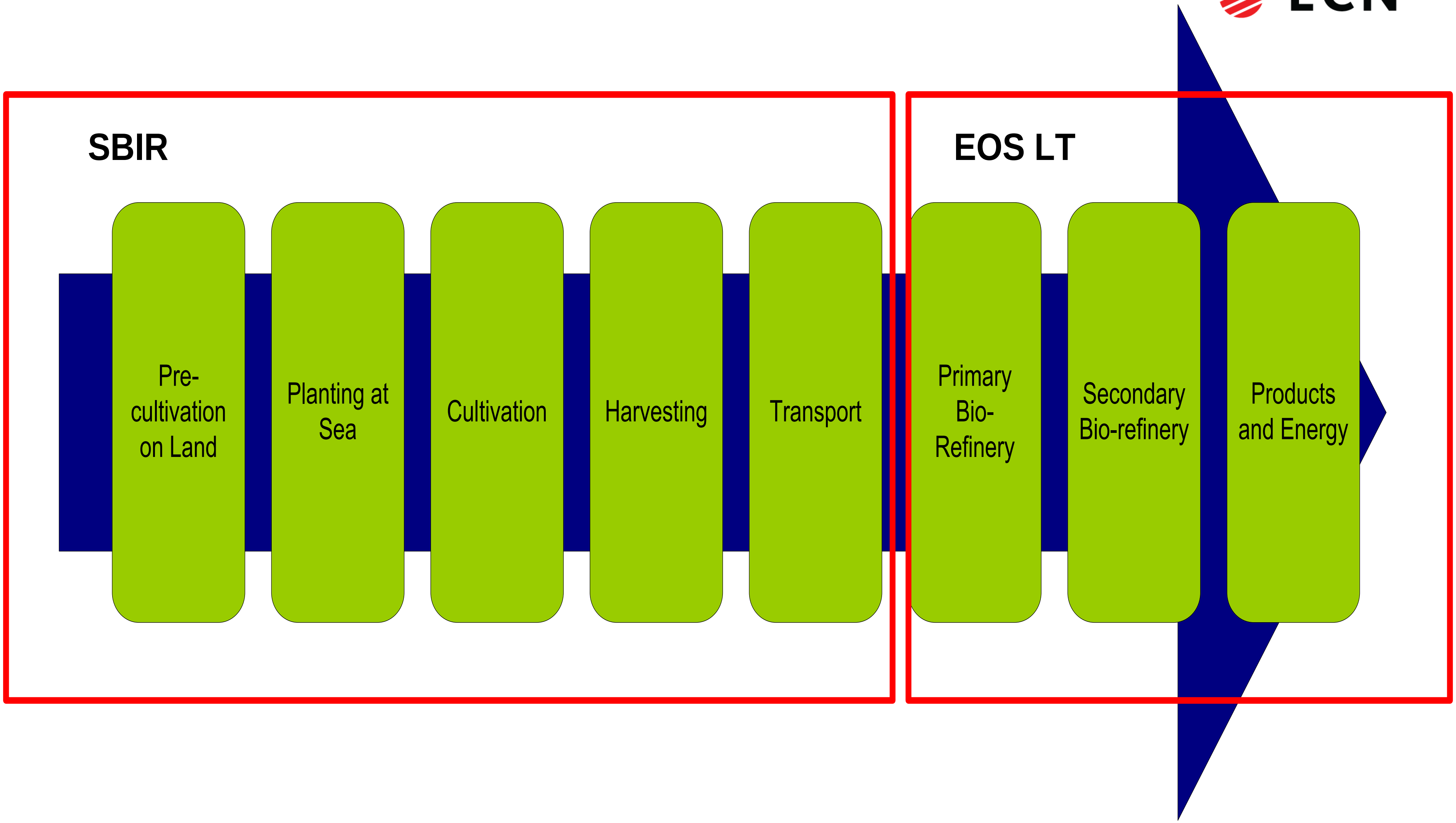
Sushi

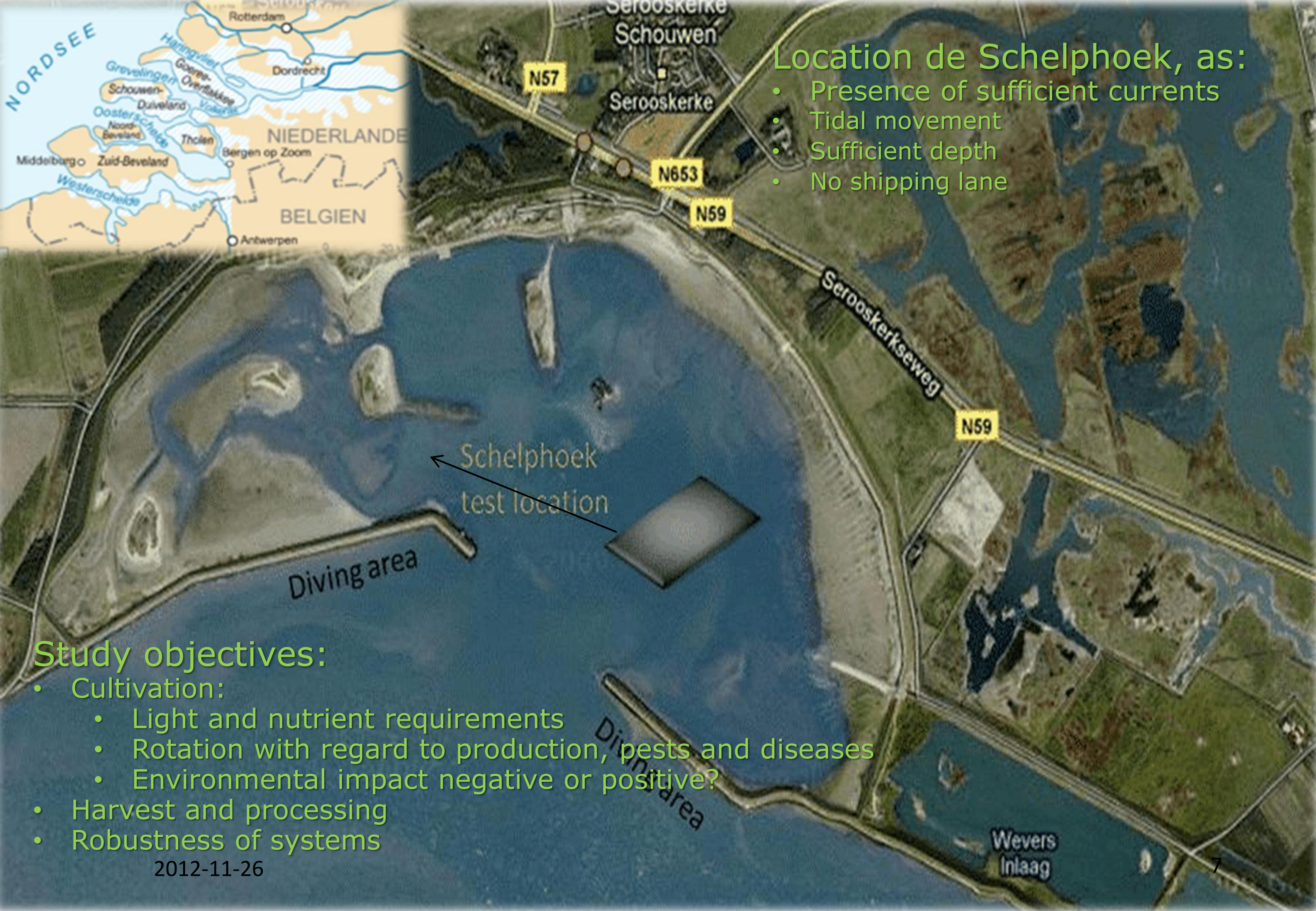


Agar

Aquatic Biomass




SBIR
EOS LT
Pre-cultivation on Land
Planting at Sea
Cultivation
Harvesting
Transport
Primary Bio-Refinery
Secondary Bio-refinery
Products and Energy



Location de Schelphoek, as:

- Presence of sufficient currents
- Tidal movement
- Sufficient depth
- No shipping lane

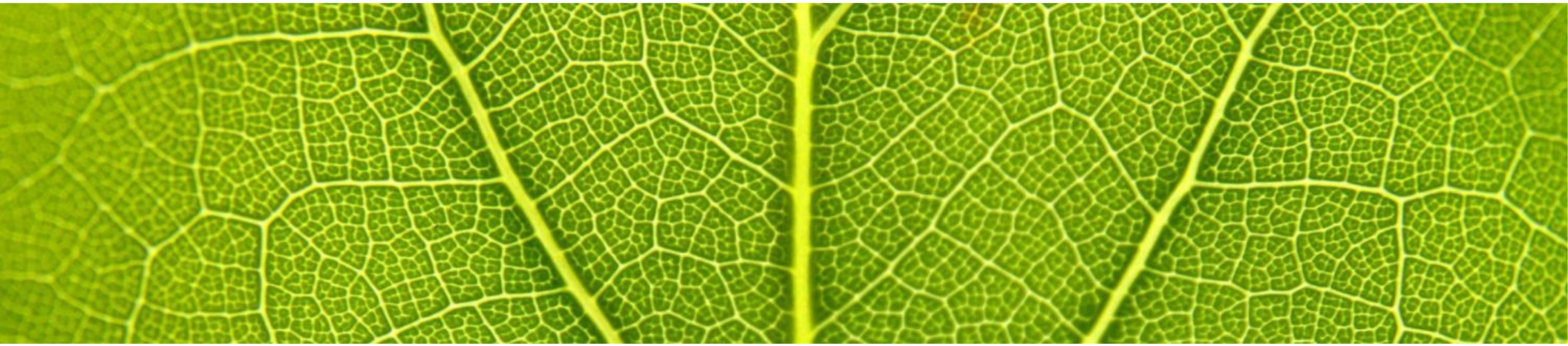
Study objectives:

- Cultivation:
    - Light and nutrient requirements
    - Rotation with regard to production, pests and diseases
    - Environmental impact negative or positive?
- Harvest and processing
- Robustness of systems

The team:
Willem de Visser
Julia Wald
Willem Brandenburg

ECOFYS

sustainable energy for everyone

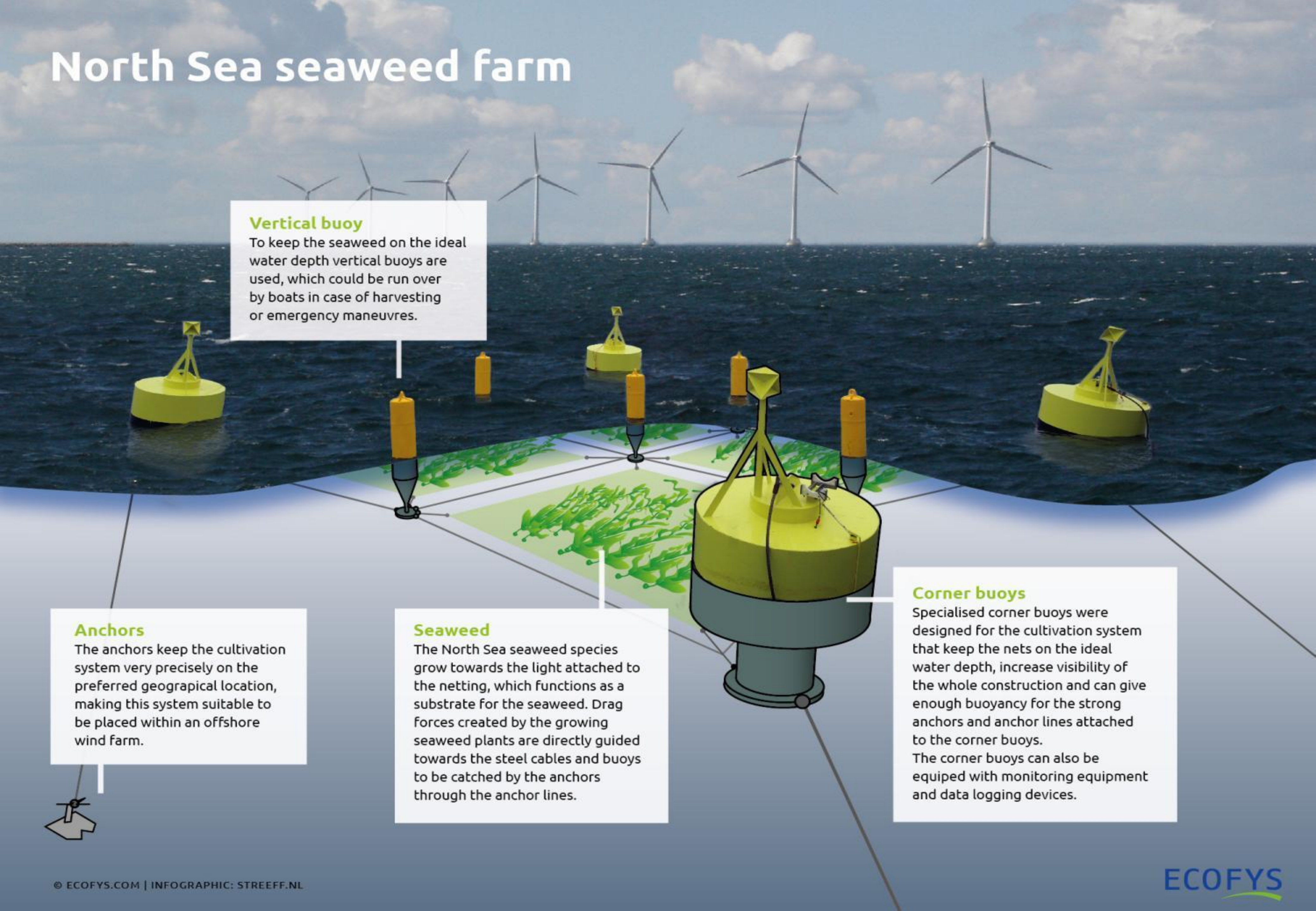


Offshore Seaweed Cultivation Project

The Ecofys Test Module

2012-11-26

ECN seaweed


North Sea seaweed farm
Vertical buoy
To keep the seaweed on the ideal water depth vertical buoys are used, which could be run over by boats in case of harvesting or emergency maneuvres.
Anchors
The anchors keep the cultivation system very precisely on the preferred geograpical location, making this system suitable to be placed within an offshore wind farm.
Seaweed
The North Sea seaweed species grow towards the light attached to the netting, which functions as a substrate for the seaweed. Drag forces created by the growing seaweed plants are directly guided towards the steel cables and buoys to be catched by the anchors through the anchor lines.
Corner buoys
Specialised corner buoys were designed for the cultivation system that keep the nets on the ideal water depth, increase visibility of the whole construction and can give enough buoyancy for the strong anchors and anchor lines attached to the corner buoys.
The corner buoys can also be equiped with monitoring equipment and data logging devices.
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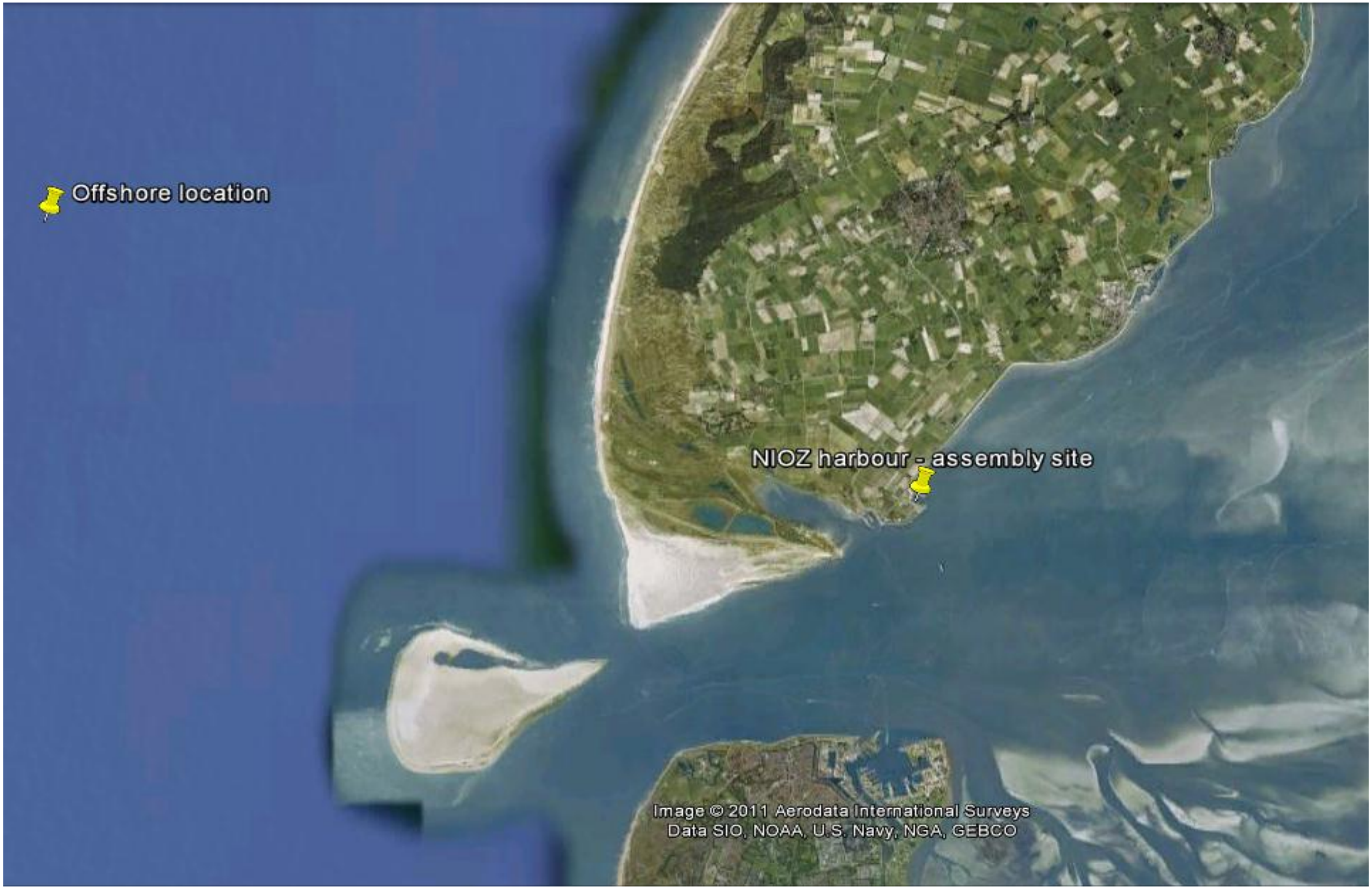
ECOFYS

Location of the test module



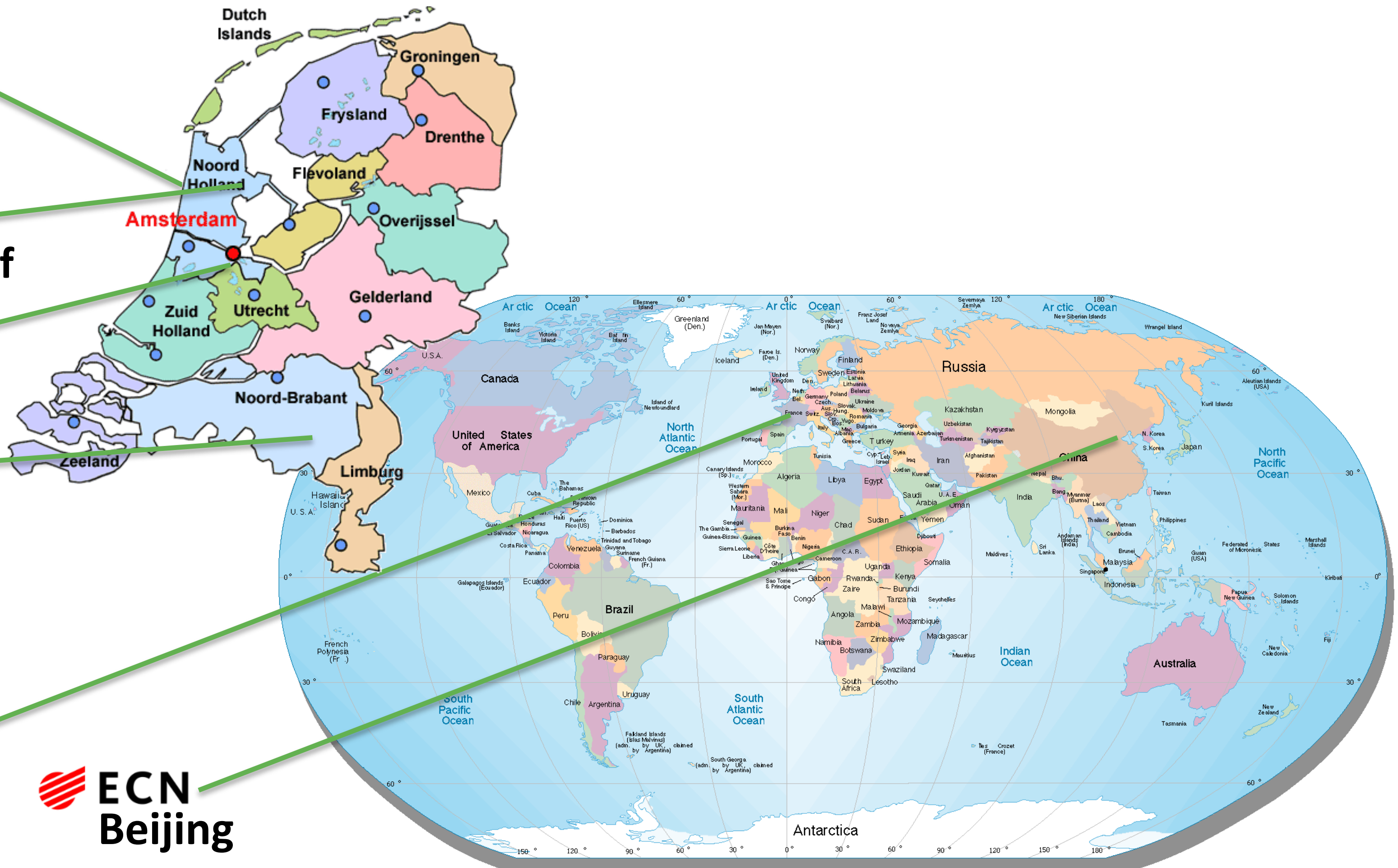
Locations

ECN Petten (head office)

ECN Wieringerwerf

ECN Amsterdam

ECN Eindhoven

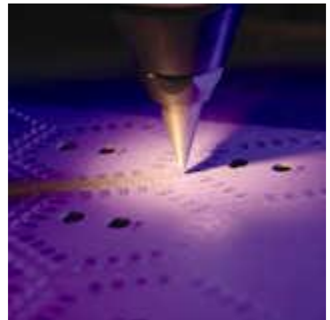


ECN Brussels

ECN Beijing

R&D fields

Policy Studies



Energy Engineering

Environment

Wind Energy

Solar Energy

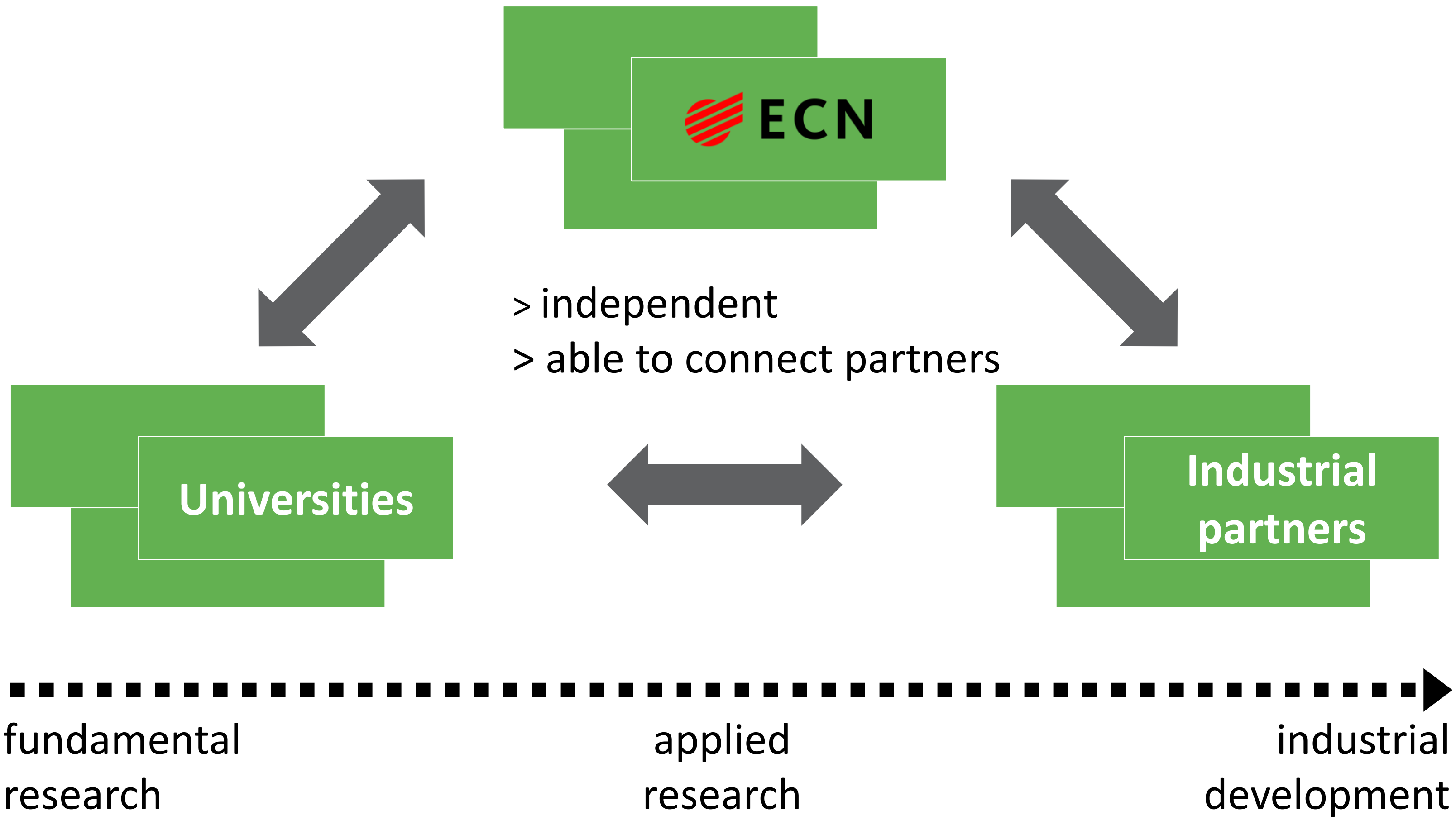
Biomass

Energy Efficiency & CCS

What we do

- Problem solving
  Using our knowledge, technology, and facilities to solve our clients' challenges
- Technology development
  Developing technology into prototypes and industrial application
- Studies & Policy support
  Creating insights in energy technology and policy

Position


ECN
> independent
> able to connect partners
Universities
Industrial partners
fundamental research
applied research
industrial development

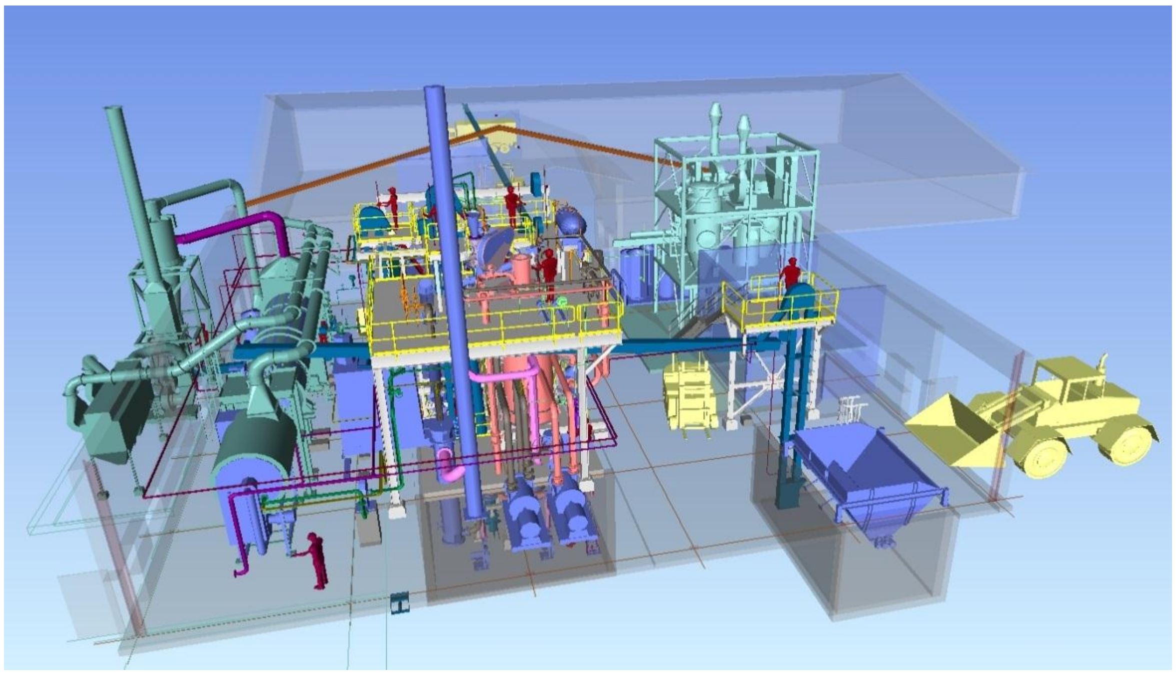
Biomass – a diverse energy source

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

waste wood (agricultural) residues energy corps aquatic biomass

Biomass Pre-Treatment Licensees, clients

- Torrefaction technology
  - Demo plant operational



DAHLMAN

Biorefinery and processing

- Organosolv: fractionation technology
  - Conversion of lignocellulosic biomass into cellulose and pure lign
  - Cellulose conversion to bio-ethanol
  - Lignin: base materials for bio-chemicals

- Seaweed (macroalgae) as a bio-feedstock
  - Conversions to chemical intermediates
  - Source of protein: alleviates land-use issues

- Synthesis processes
  - Catalytic conversion
  - Separation processes

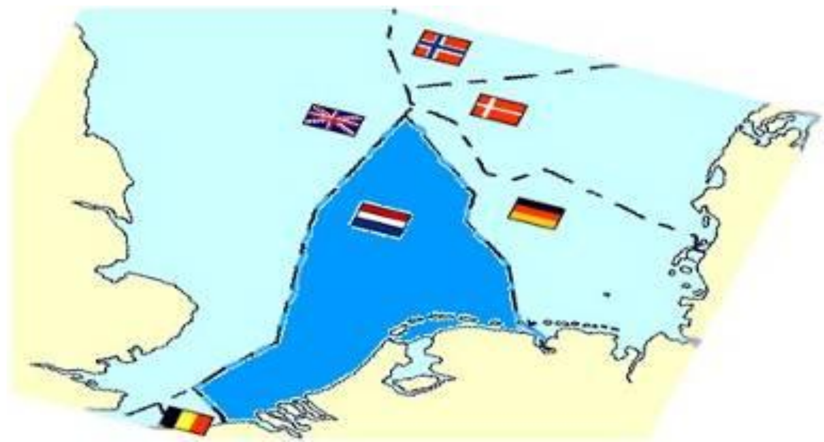
Parts of seaweed plant

Does not compete with food

No land use issues

Bio-Offshore

- Seaweed cultivation area 5.000 km^2 (<10 % of the NL area of the North Sea @ 57.000 km^2)
- 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 km^2 for biogas productions



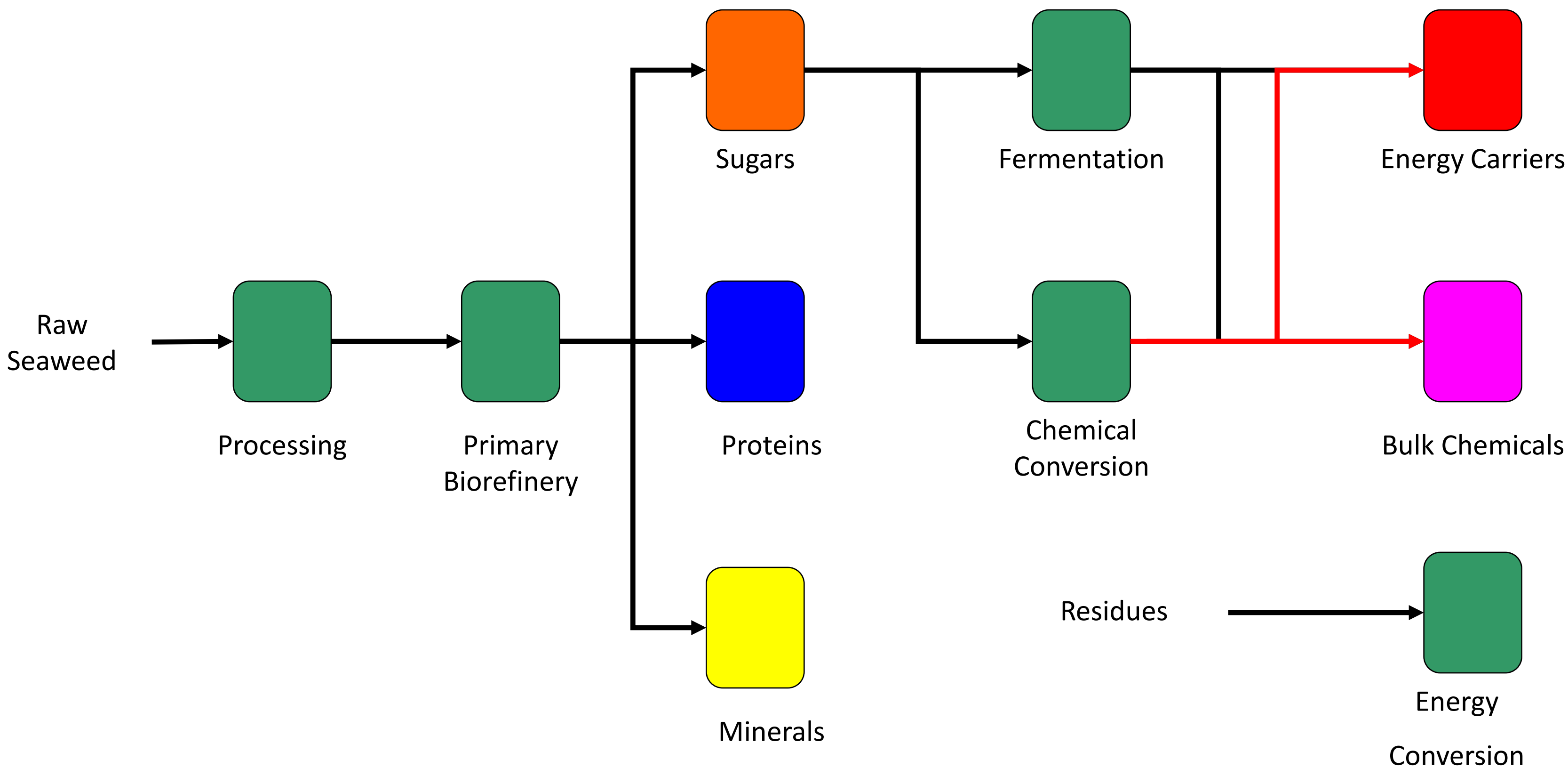
Why seaweeds

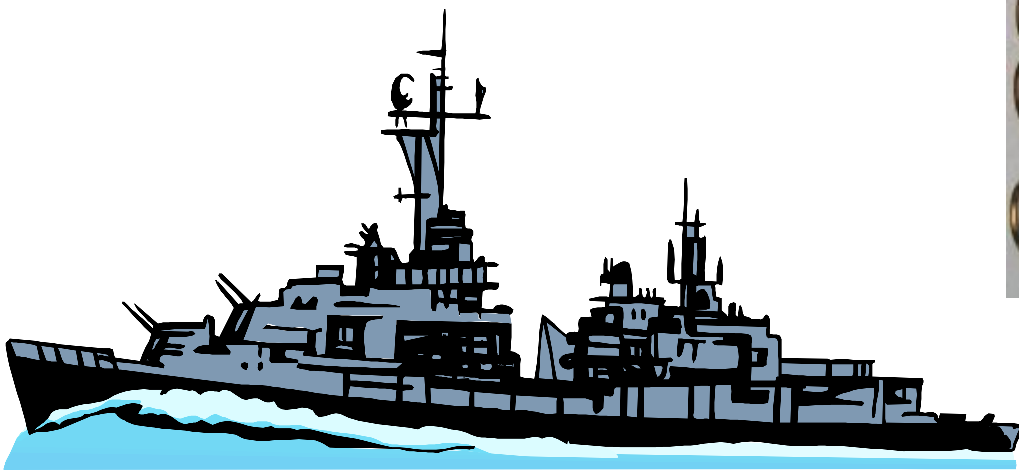
- Does not compete with food
- Does not compete with any other land use
- Grows in cold seawater
- The fastest growing biomass at our latitude
  - The Netherlands is as far north as New Foundland
- Biochemical composition: complementary (for fuel/chemicals production) to micro-algae
  - Comprised of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





Cordite

Seaweed species native to the North Sea

Saccharina latissima

L

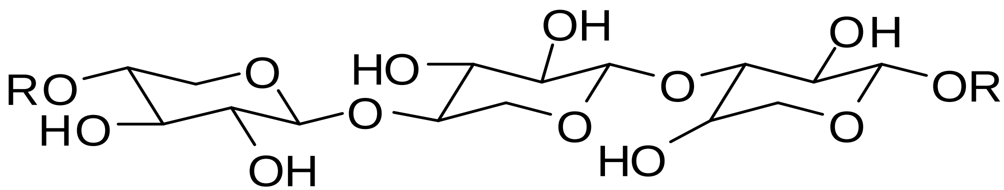
aminaria hyperborea

Ulva sp.

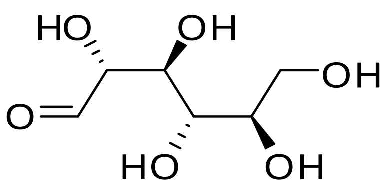
Alaria esculenta

Palmaria palmata

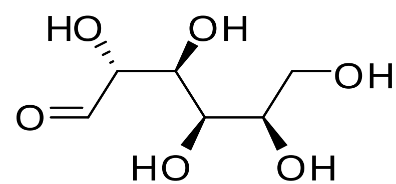
Palmaria (red seaweed)



Xylan (1,3 and 1,4 linkage)

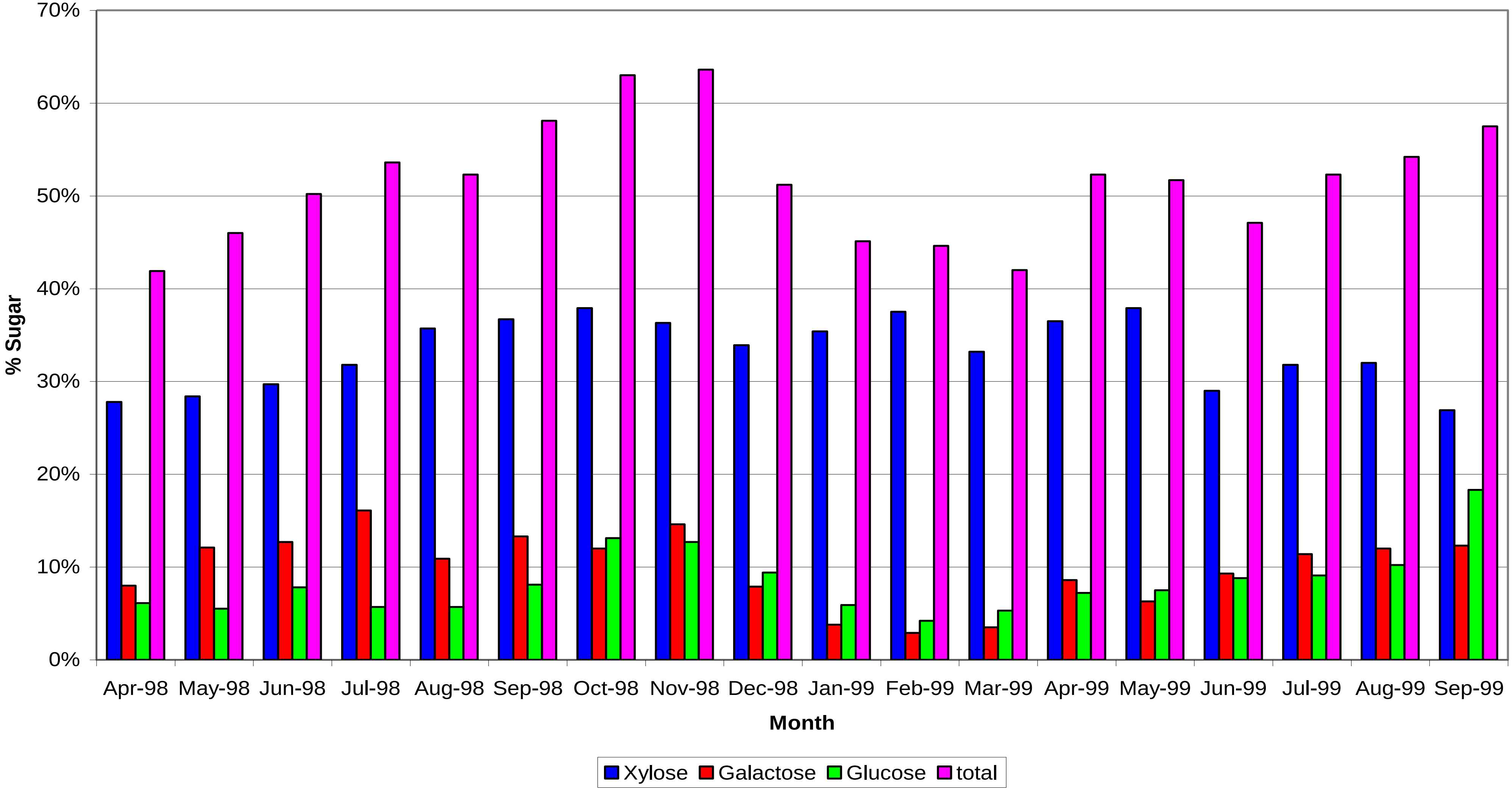


galactose



glucose

Total Carbohydrate compostion of Palmaria Palmata

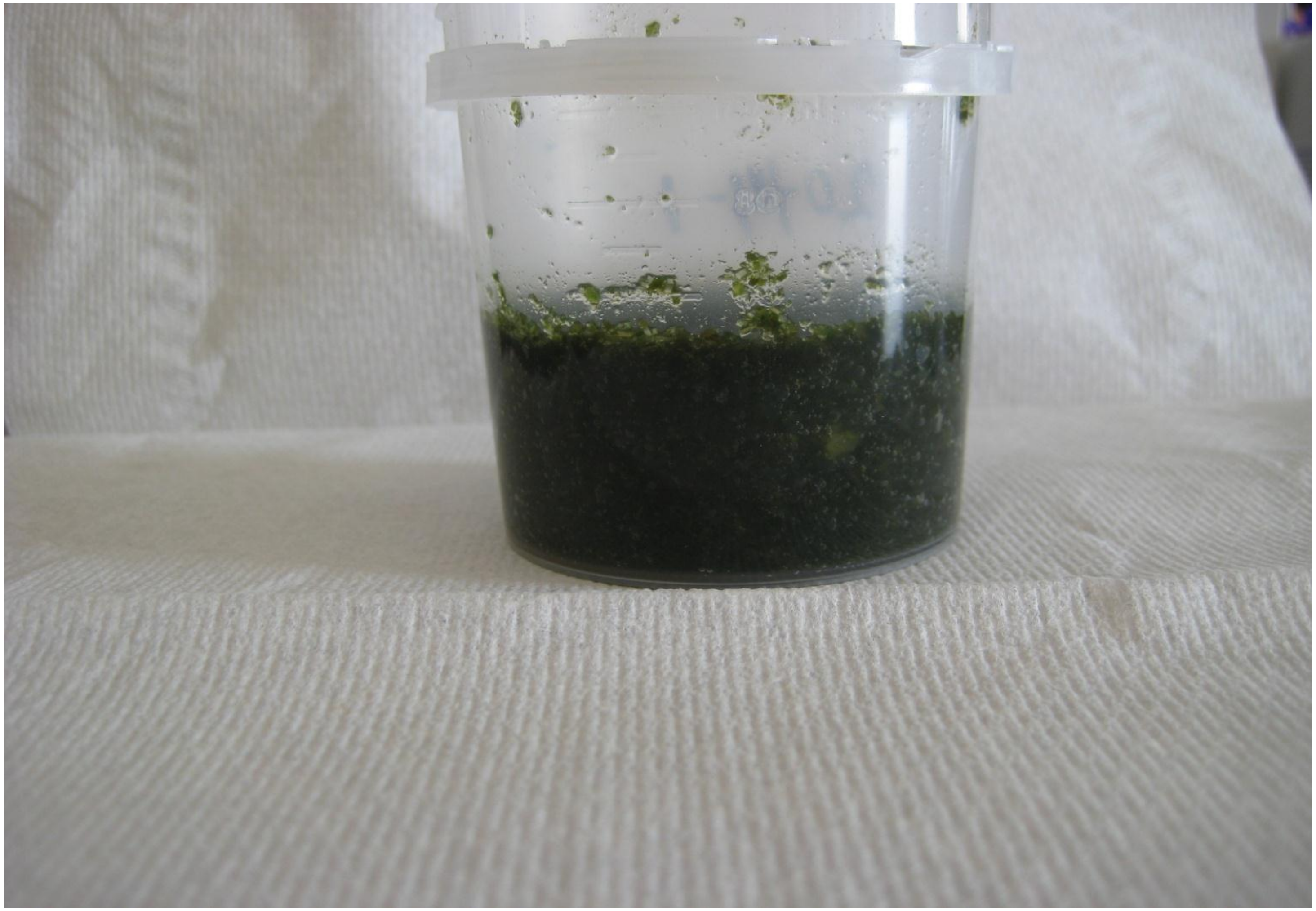


Differences between biomass

- 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

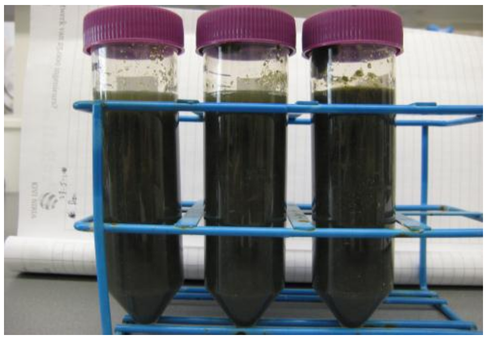
- Seaweed biomass
- Carbohydrates
    - Type dependent on species
    - Amount dependent on season and location
- Proteins
  - Aminoacid composition dependent on species
  - Amount dependent on season and location
- Ash
  - Species dependent
  - Amount dependent on season an location
- Extreme differences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

Rehydrated seaweed



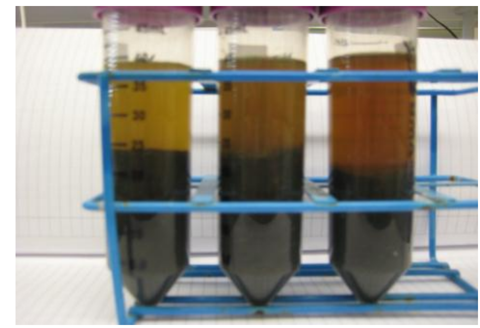
Fractionation

Optional
Catalyst



Water +
Seaweed

T: 120-160 °C
t: 1-4 h
Liquid:Solid=1:10
Cat: 0-1 M H_2SO_4



Liquid

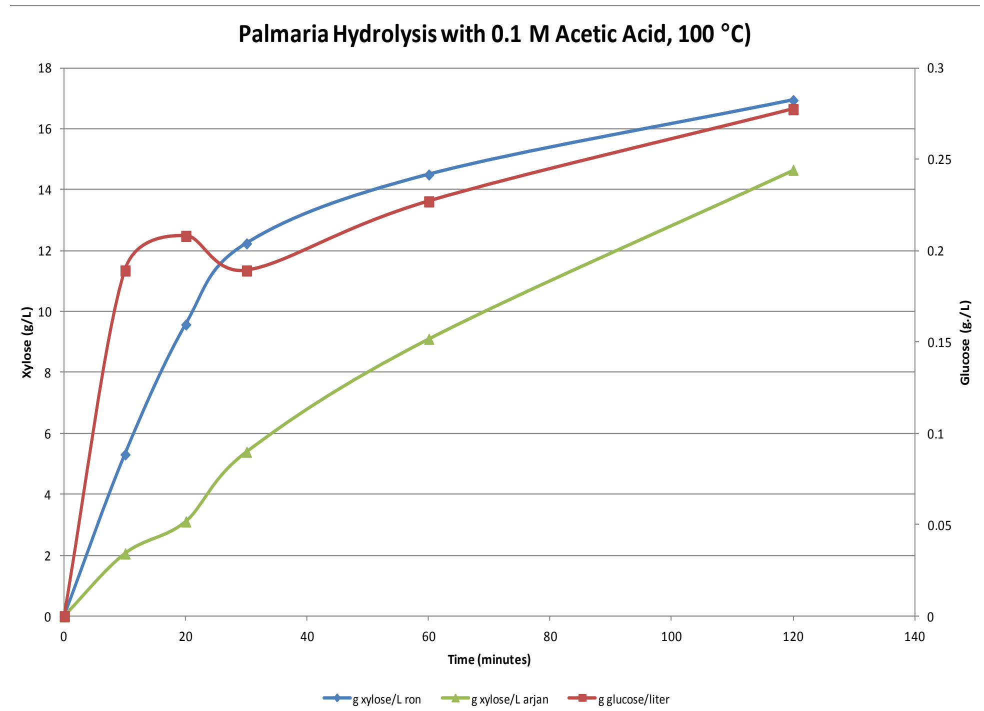
Solid

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

Simultaneous extraction and hydrolysis of *Palmaria*

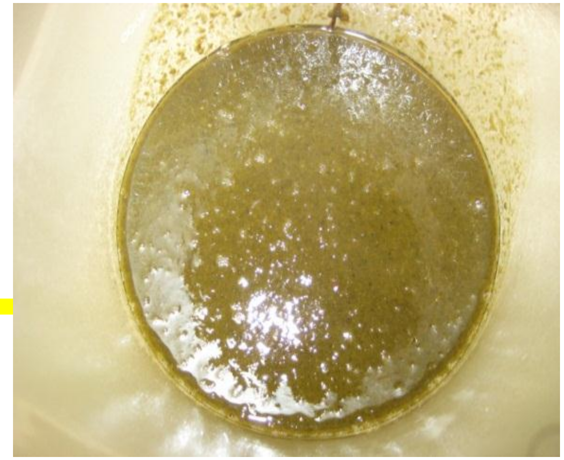
- Tests with freeze-dried Palmaria at 2.5 and 25 gr dw scale.
- Hydrolysis of Palmaria to xylose proven.
- Optimum conditions: 0.1M acetic acid, 100C, 2hrs.
- Xylose concentration is dependent on the $[H]^+$ concentration not on acid

→ Scale up and with fresh seaweeds.



Fresh Palmaria tests (July 2012)

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

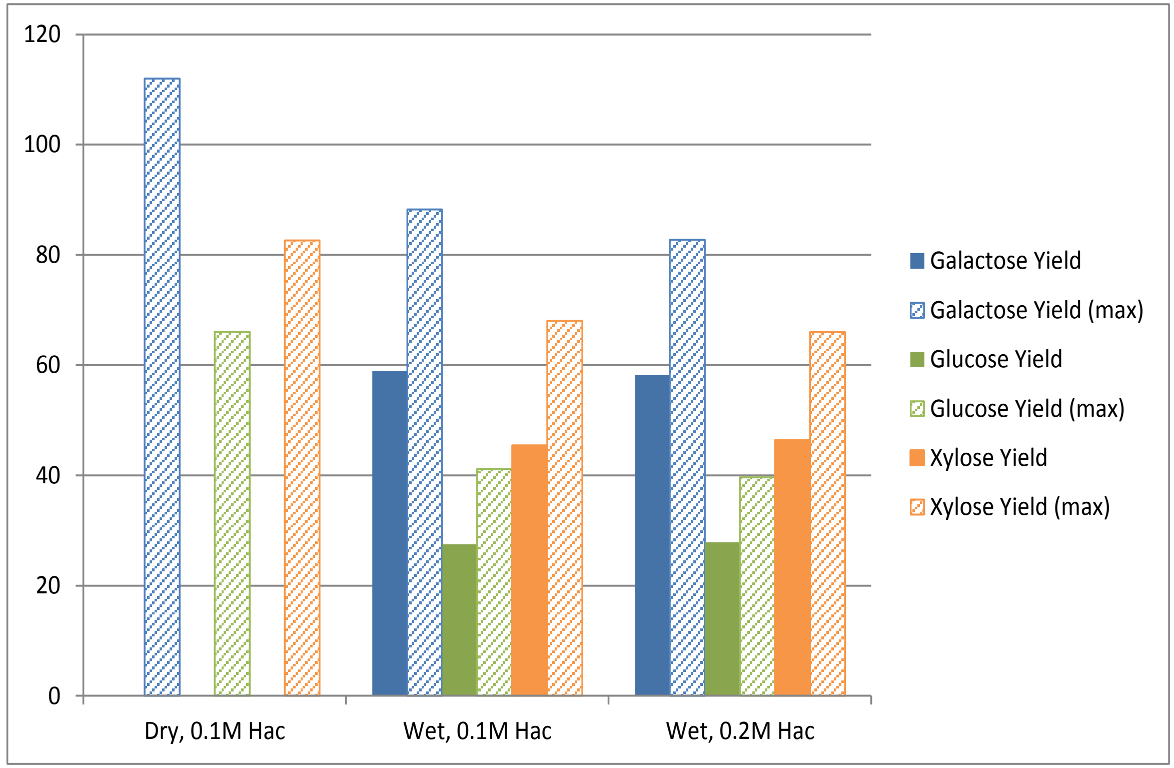


Mild acid pretreatment

- 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.

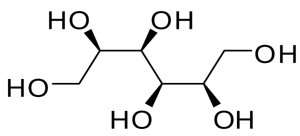
Yields sugars

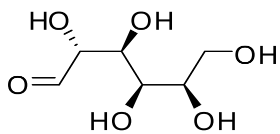
- Yields based on amount of extract.
- Max. achievable yield based on liquor starting amount.
- Yield xylose: ~45%.
- Optimization of separation extracted *Palmaria* / extract might increase yield to max ~65%.
- Future work: optimisation of process conditions.

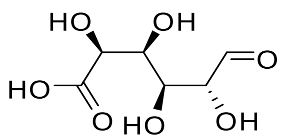


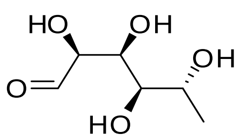
Applicable to all seaweeds?

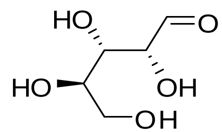
Ulva (green seaweed)

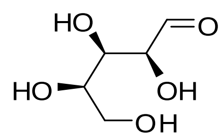

mannitol


glucose

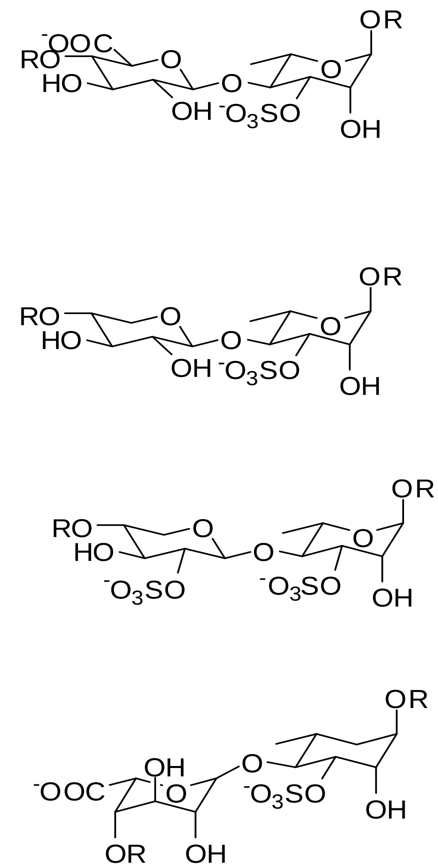

glucuronic acid

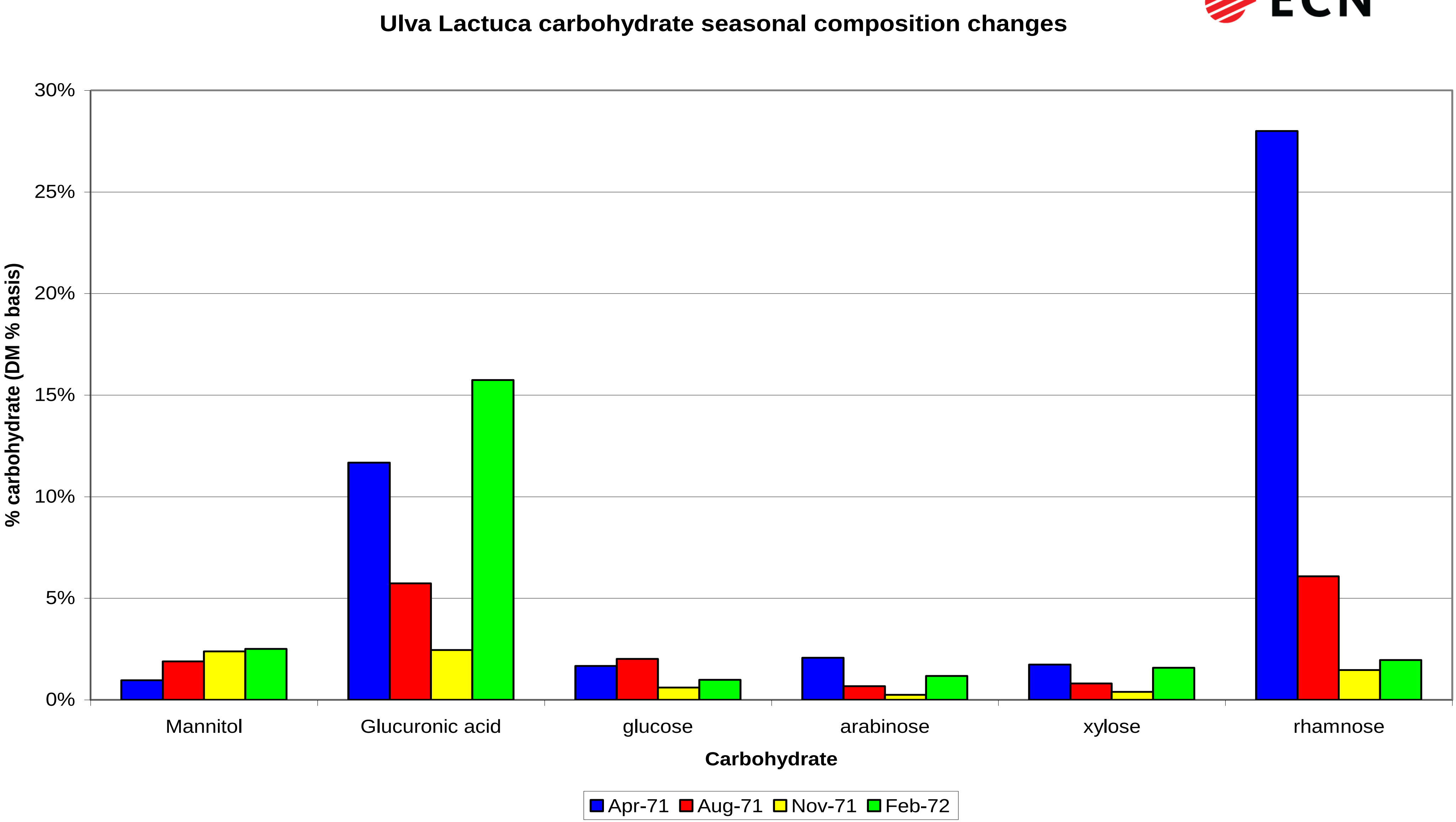

rhamnose


xylose

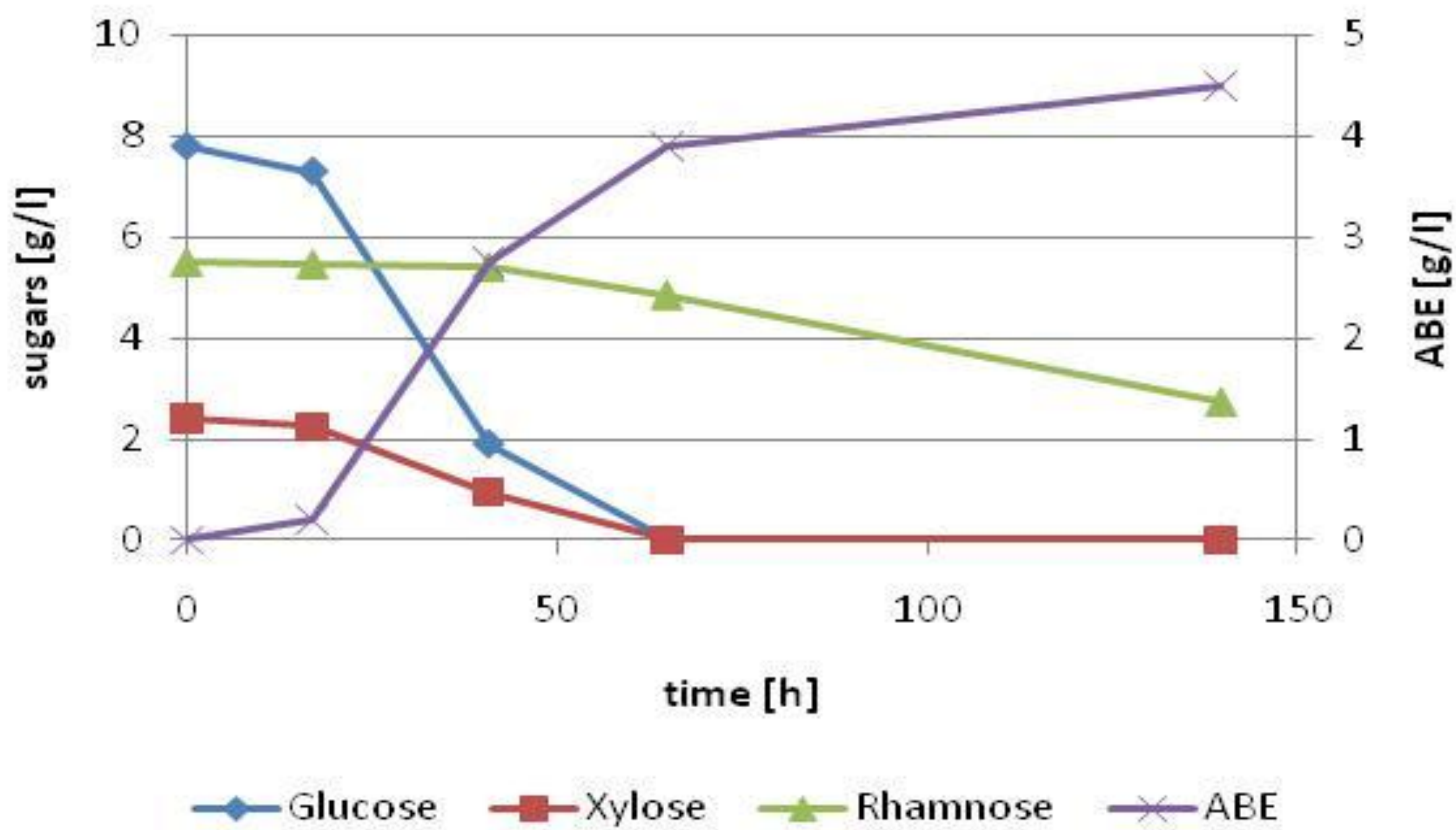

arabinose

Ulvans



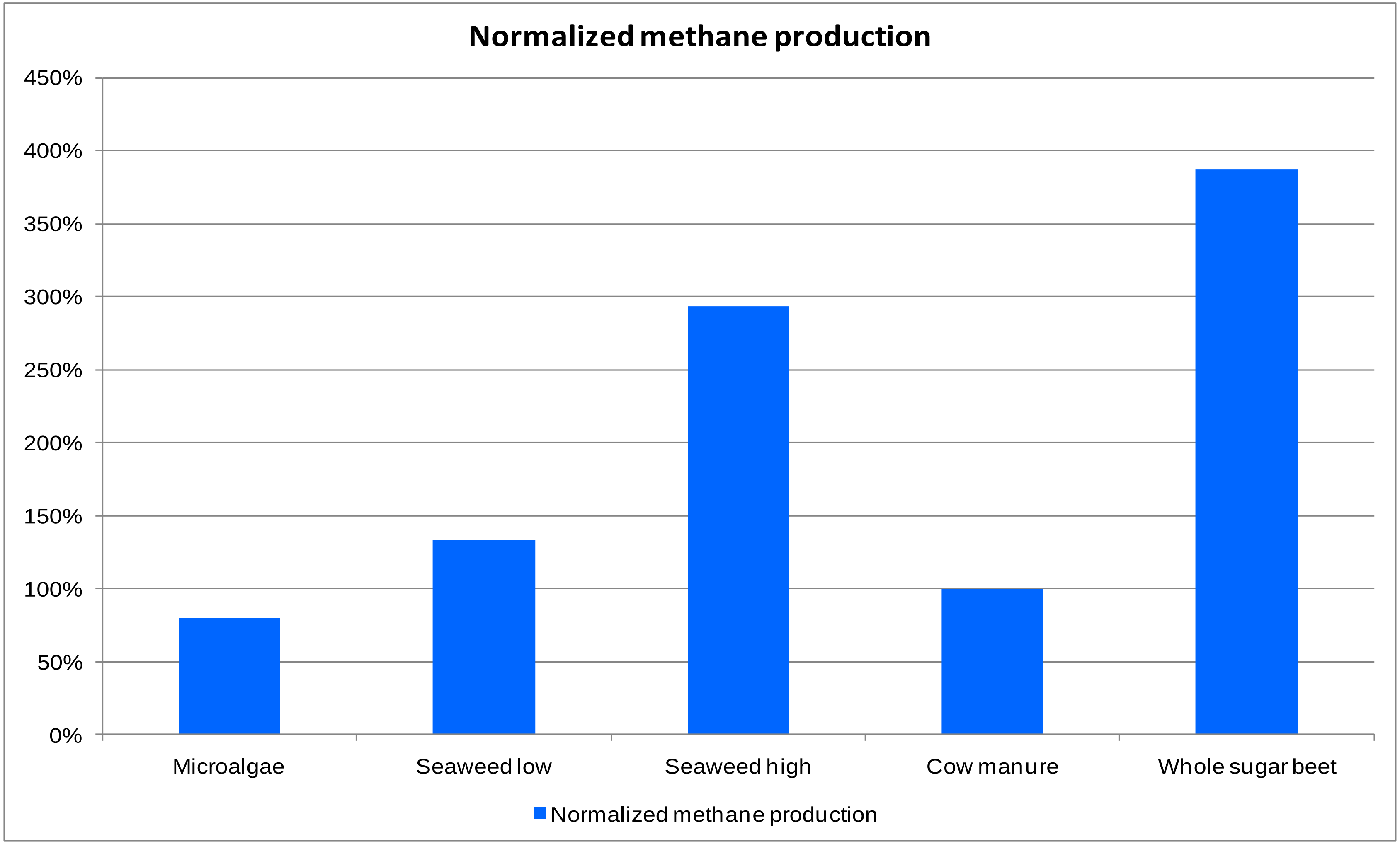

Ulva Lactuca carbohydrate seasonal composition changes
% carbohydrate (DM % basis)
30%
25%
20%
15%
10%
5%
0%
Mannitol
Glucuronic acid
glucose
arabinose
xylose
rhamnose
Carbohydrate
Apr-71
Aug-71
Nov-71
Feb-72

ABE fermentation (2)



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

Digestion results



Question?
Further information

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http://www.mermaidproject.eu

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