ECN Seaweed Biorefinery R&D

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Trondheim
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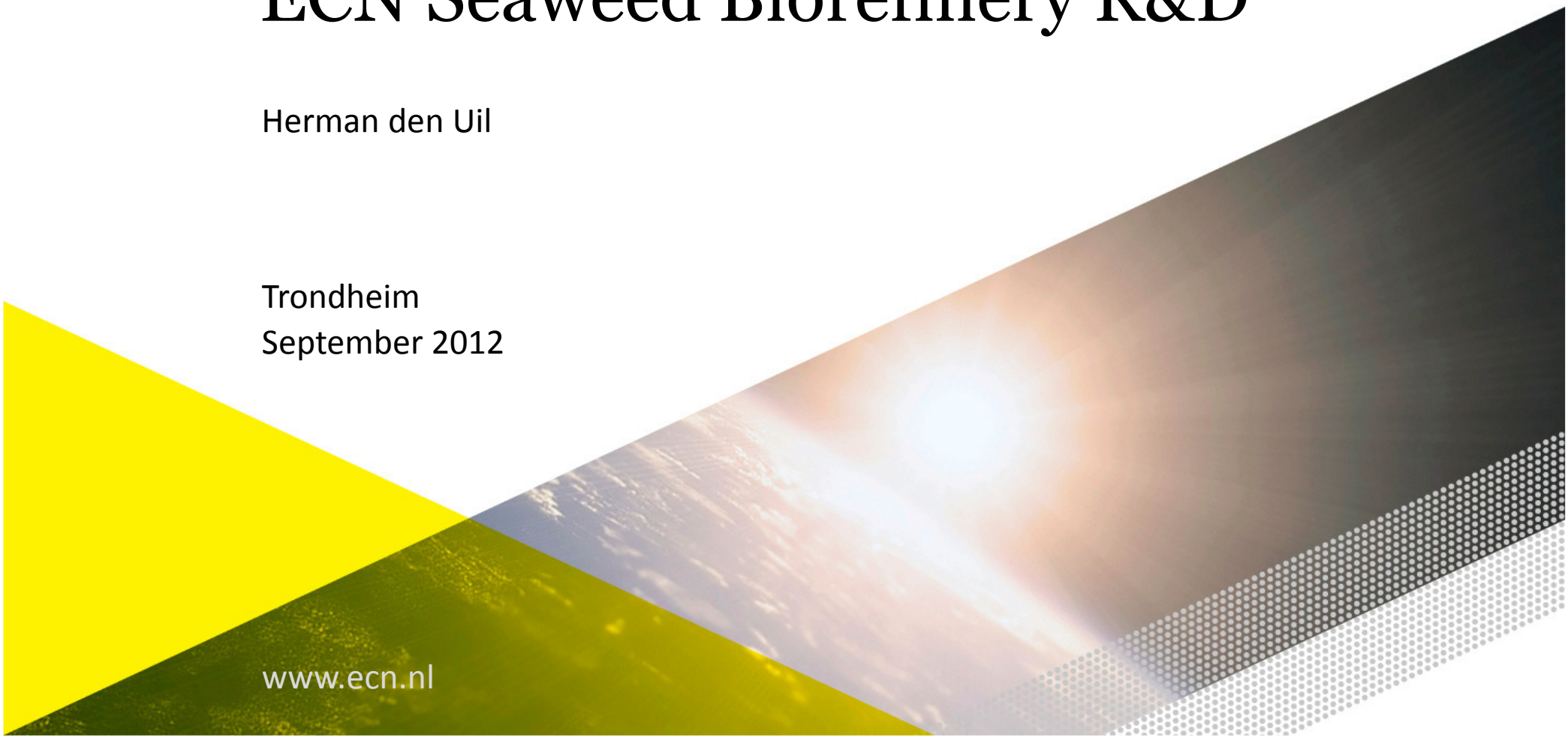


Mission:

ECN develops market driven technology and know-how to enable a transition to sustainable energy

Locations

ECN Petten
(head office)

ECN Wieringerwerf

ECN Amsterdam

ECN Eindhoven

ECN Brussels

ECN Beijing

R&D fields

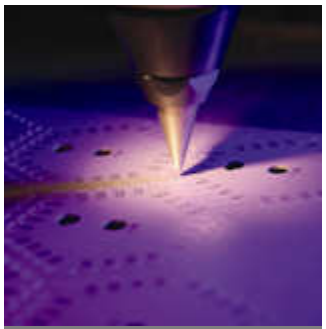
Wind Energy

Solar Energy

Biomass

Energy Efficiency & CCS

Policy Studies



Energy Engineering

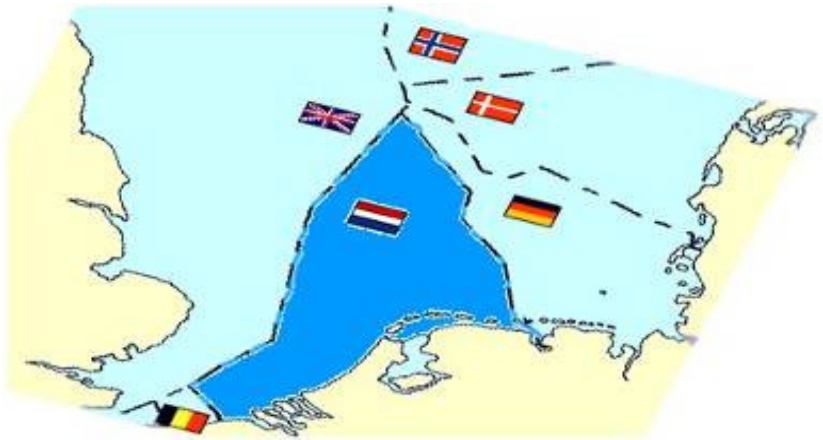
Environment

Biomass R&D

- Pre-treatment for heat and power
  - Torrefaction and Torwash
- Combustion
  - Fuel characterisation and consultancy
- Gasification
  - Gasification and gas-cleanup development
- Biorefinery
  - Fractionation of lignocellulose and seaweed
  - Use of fractions lignin and sugar(polymers)

Seaweed R&D background

- Bio-offshore study on seaweed cultivation on the North sea (ECN-C—05-008)
  - 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)



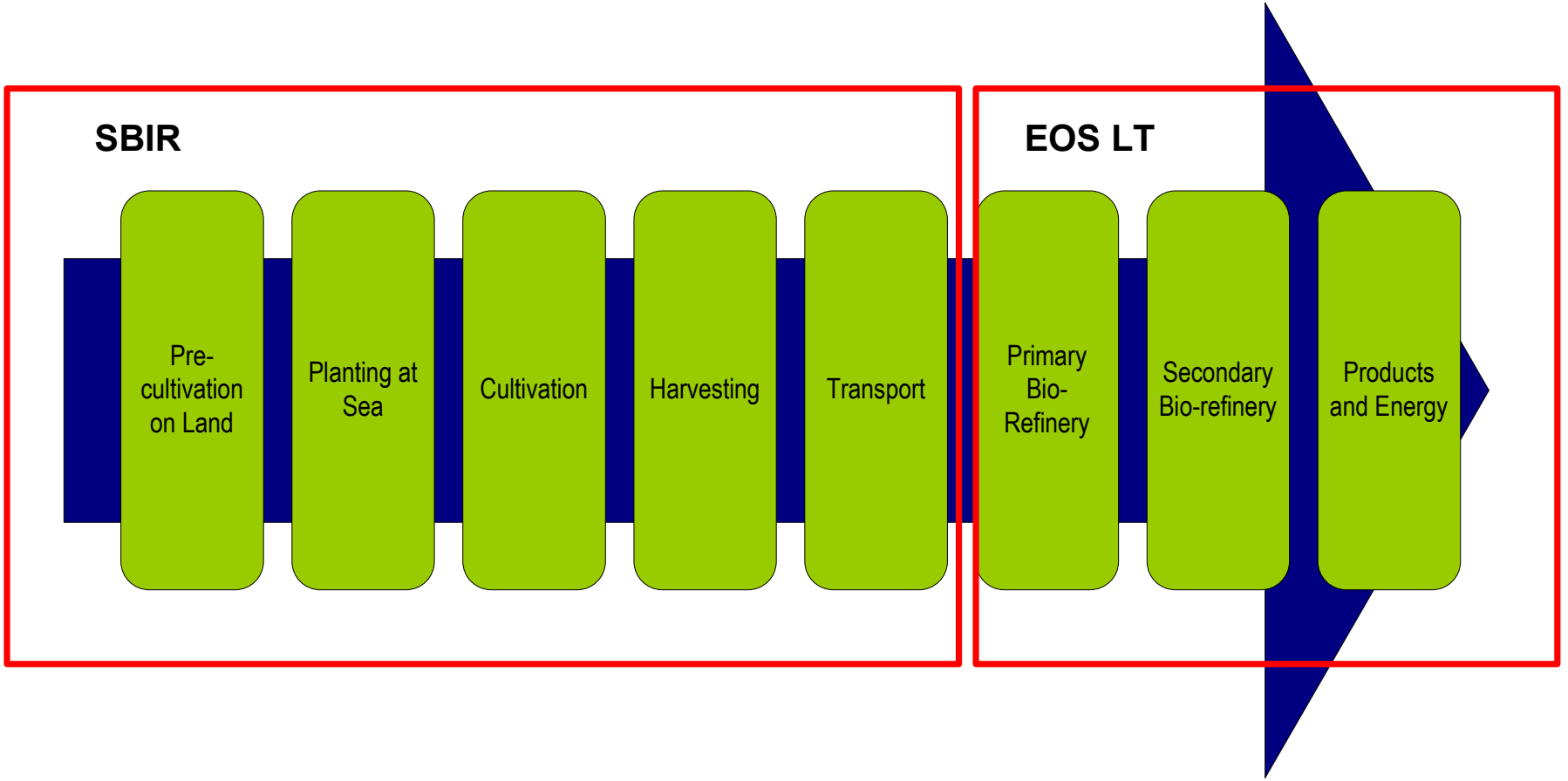
Seaweed R&D background

- Aquatic biomass energy potential

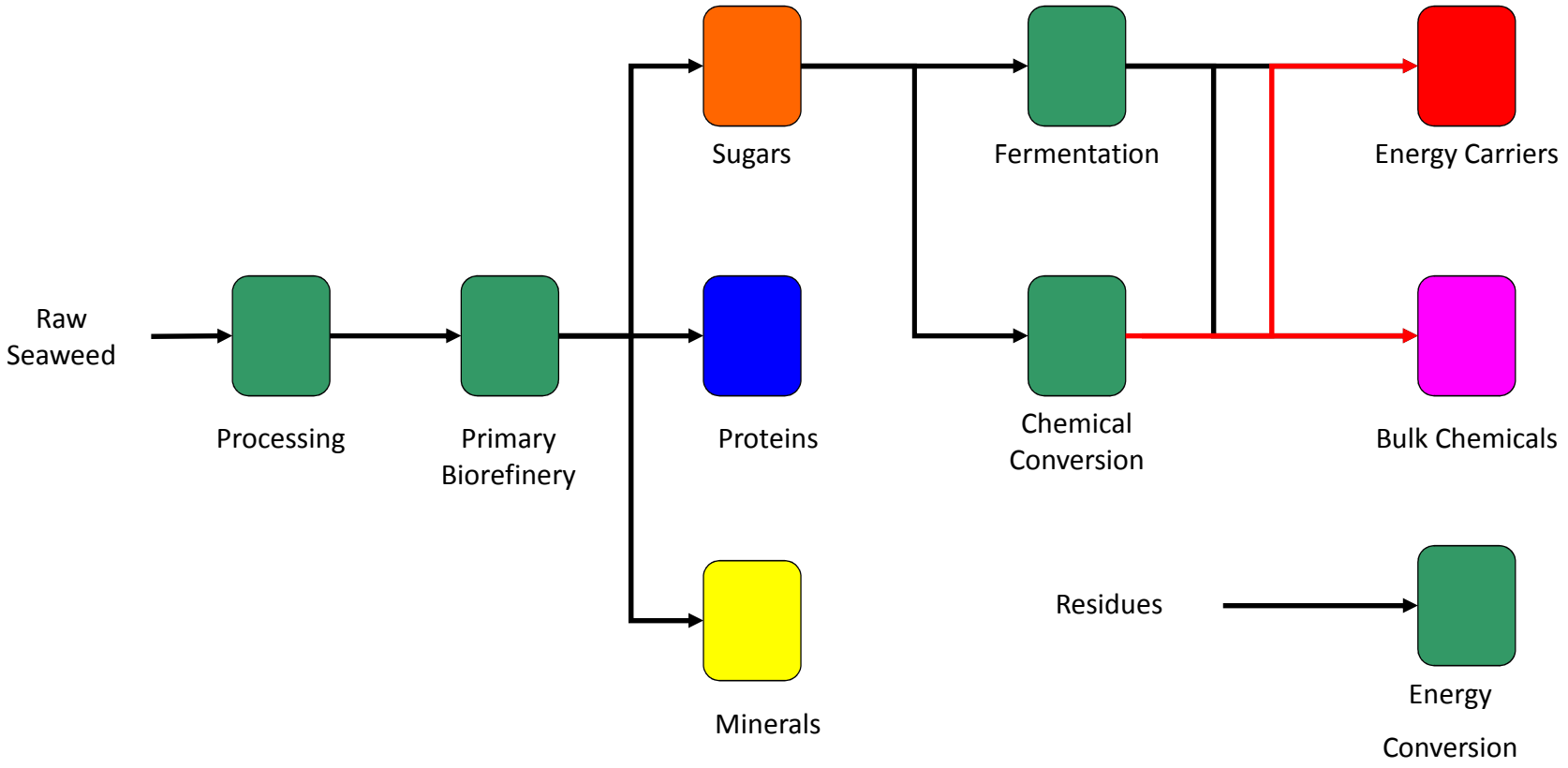
Most feasible technical concepts	Area	Potential
Set 1: Land based open ponds for microalgae	Arid land in (sub) tropical zones (deserts) and close to coast (max 100 km)	90 EJ
Set 3: Horizontal lines for macroalgae	At existing infrastructure – f.e. offshore wind farms (up to 100 km offshore)	110 EJ
Set 5: Vertical lines for macroalgae	Near coast (max 25 km) in nutrient rich water	35 EJ
Set 6: Macroalgae colony	At open sea (biological deserts), up to 2000 km offshore	~6000 EJ
TOTAL		**~ 6235 EJ**

Source: Ecofys

Seaweed R&D background



ECN Seaweed fractionation R&D



Seaweed species

Saccharina latissima

Laminaria digitata

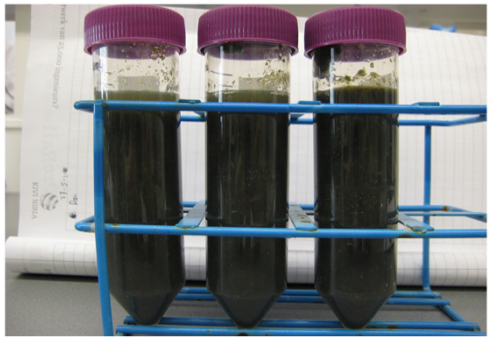
Laminaria hyperborea

Ulva sp.

Alaria esculenta

Palmaria palmata

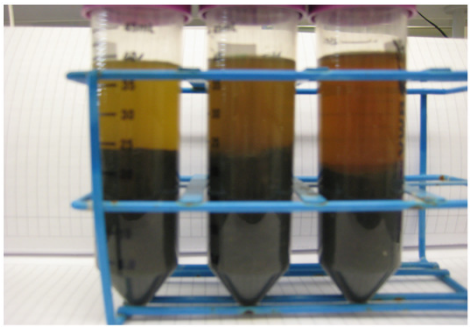
Fractionation experimental



Water +
Seaweed

Optional
Catalyst

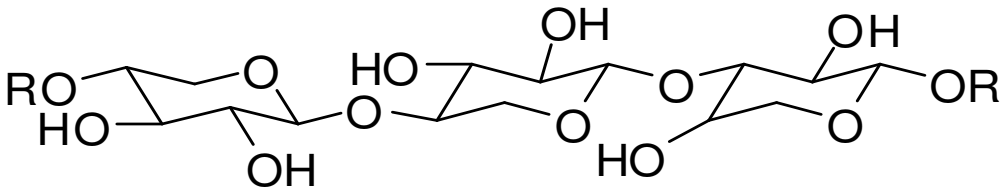
T: 120-160 °C
t: 1-4 h
Liquid:Solid=1:10
Cat: 0-1 M H_2SO_4



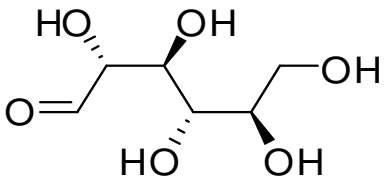
Liquid

Solid

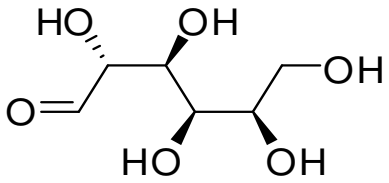
Palmaria palmata composition



Xylan (1,3 and 1,4 linkage)

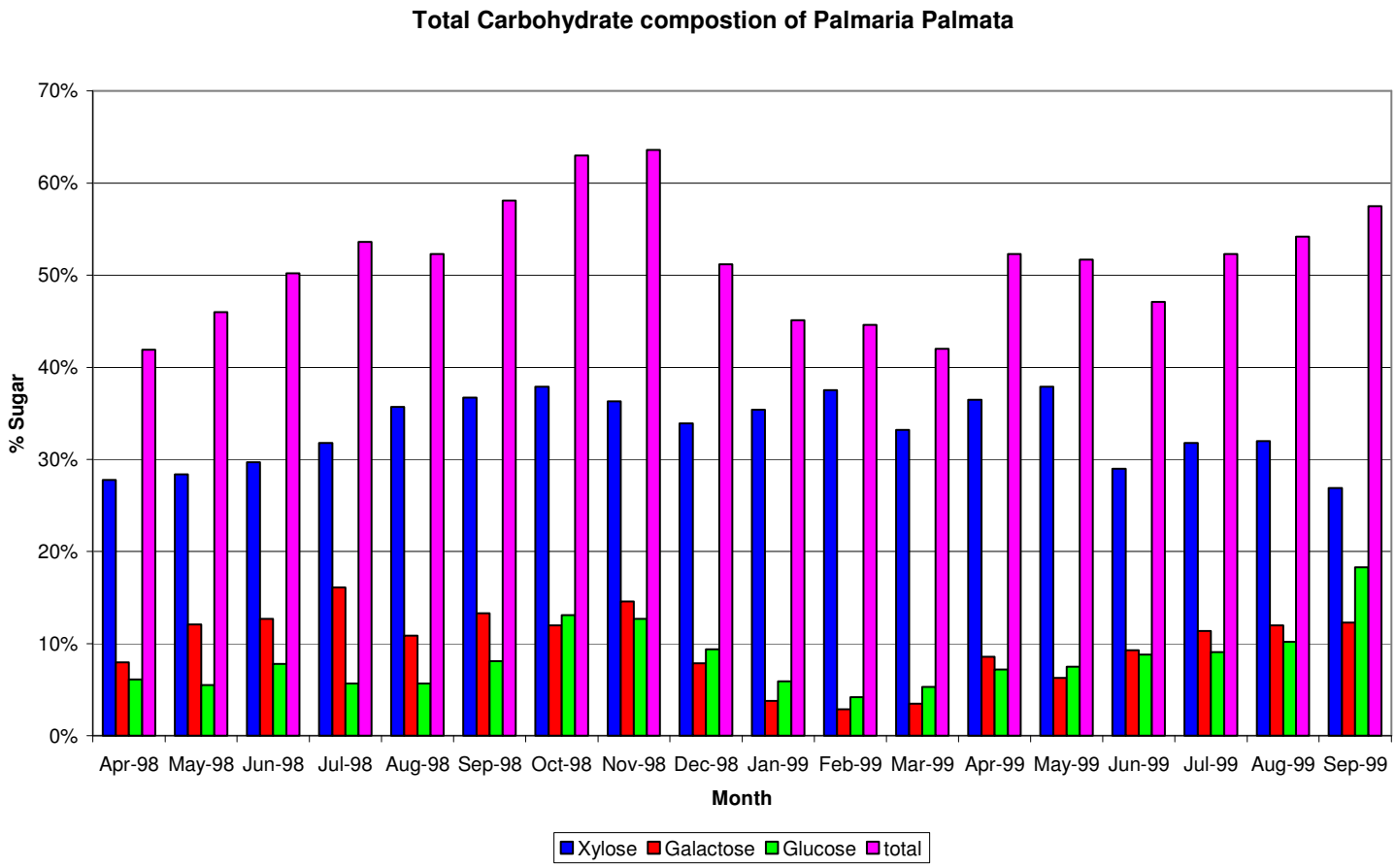


galactose



glucose

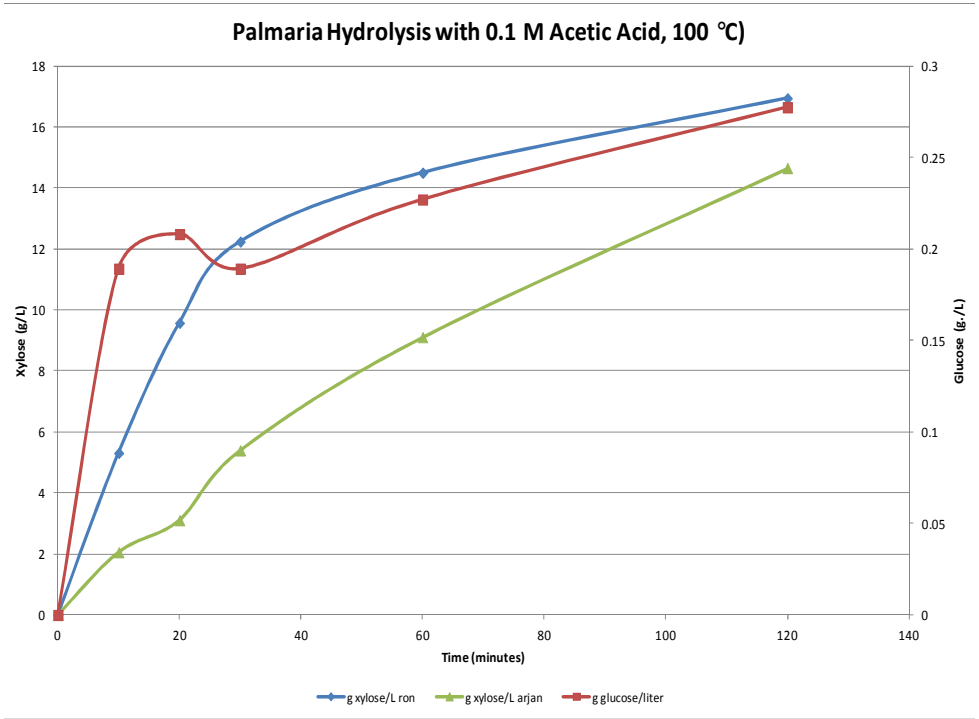
Palmaria palmata composition



Palmaria palmata hydrolysis

- Tests with freeze-dried Palmaria at 2.5 and 25 g d.w. scale.
- Hydrolysis of Palmaria to xylose proven.
- Optimum conditions: 0.1M acetic acid, 100 ^{0}C, 2 hr.
- Xylose concentration is dependent on the $[H]^{+}$ concentration not on acid

→ Scale up and with fresh seaweeds.

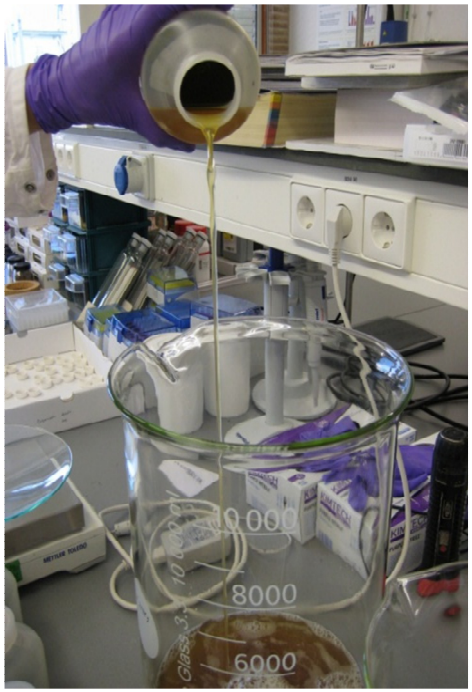


Fresh palmaria palmata tests

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

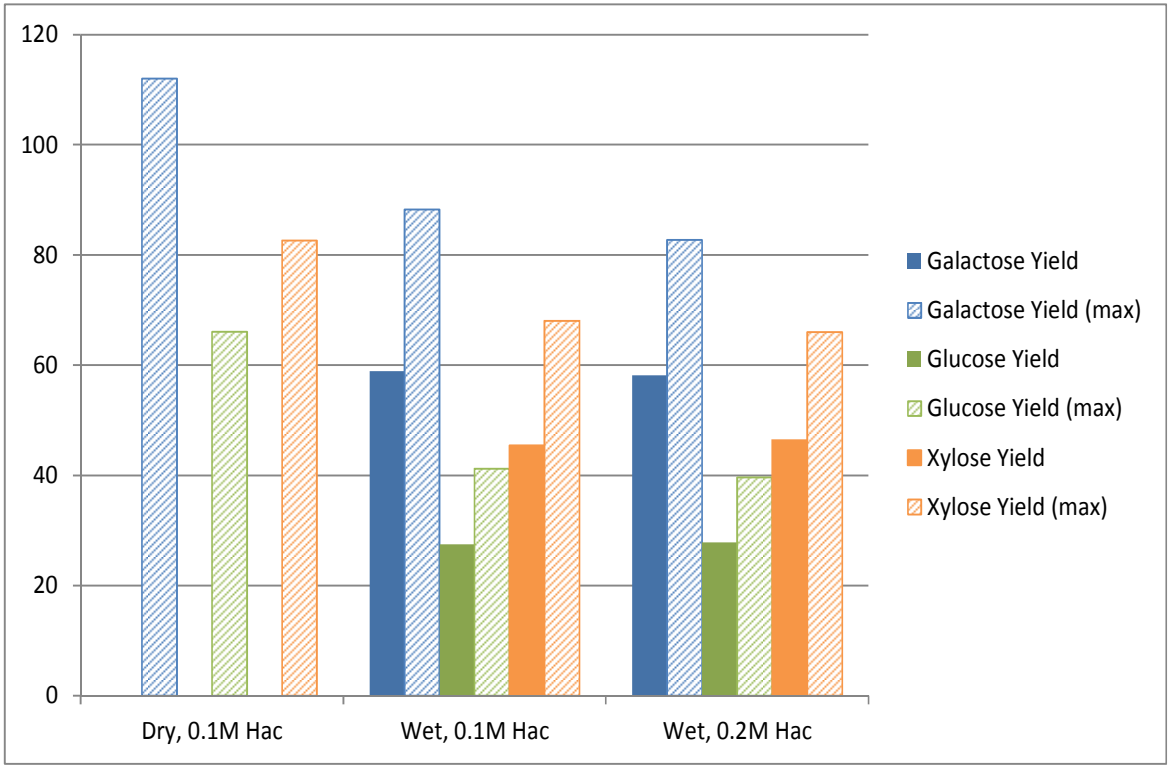
Fresh palmaria palmata tests

- Fresh Palmaria tests (July 2012)
  - 0.1M acetic acid, 100C, 2h, 9 L/kg d.w. seaweed.
  - Red seaweed turned into green ‘soup’.
  - After centrifugation, ~6L viscous liquid, ~ 4kg solid product.
  - pH ND, solids recovery 51.6% d.w.



Fresh palmaria palmata tests

- Sugar yields
  - 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.



Further work and outlook

- Development of fractionation schemes for other seaweeds
- Development of application for seaweed(fractions) with industry and other knowledge institutes
- Conceptual process design and economic evaluation of seaweed fractionation
- Bench-scale experiments on critical process steps in fractionation process

Thank you for your attention

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