Seaweeds on the high sea

Seaweed farming in and seaweed biorefinery around the North-Sea

J.W. van Hal **(ECN)**
A. Florentinus **(Ecofys Netherlands)**
W.J. Lenstra **(ECN)**
J.H. Reith **(ECN)**

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ECN
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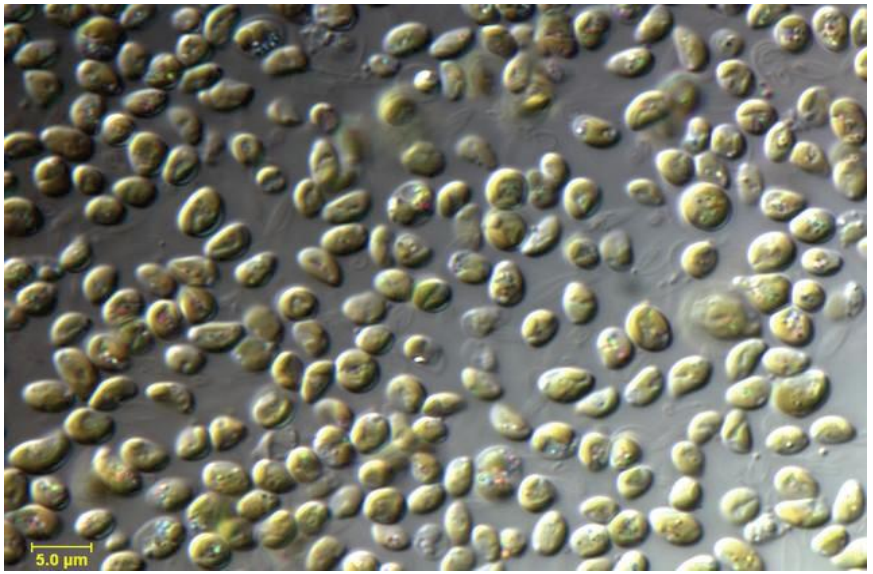
Jaap W. van Hal, Anouk Florentinus, W.J. (Jip) Lenstra, and J.H. (Hans) Reith

Denver
September 26th, 2012

Aquatic Biomass



Parts of seaweed plant

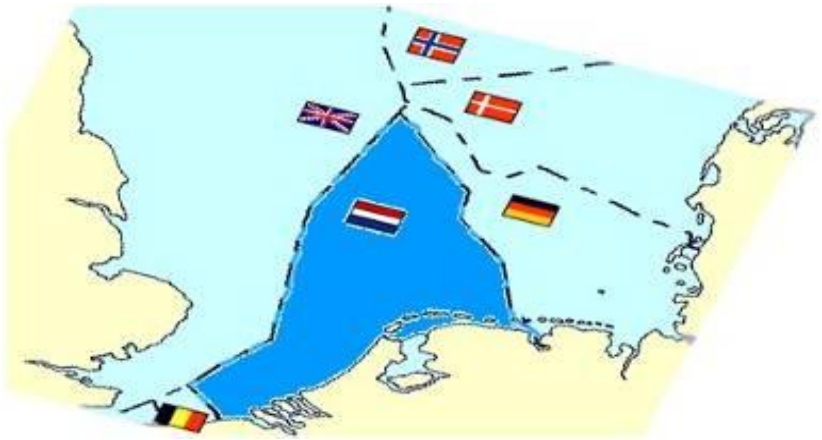
Blade

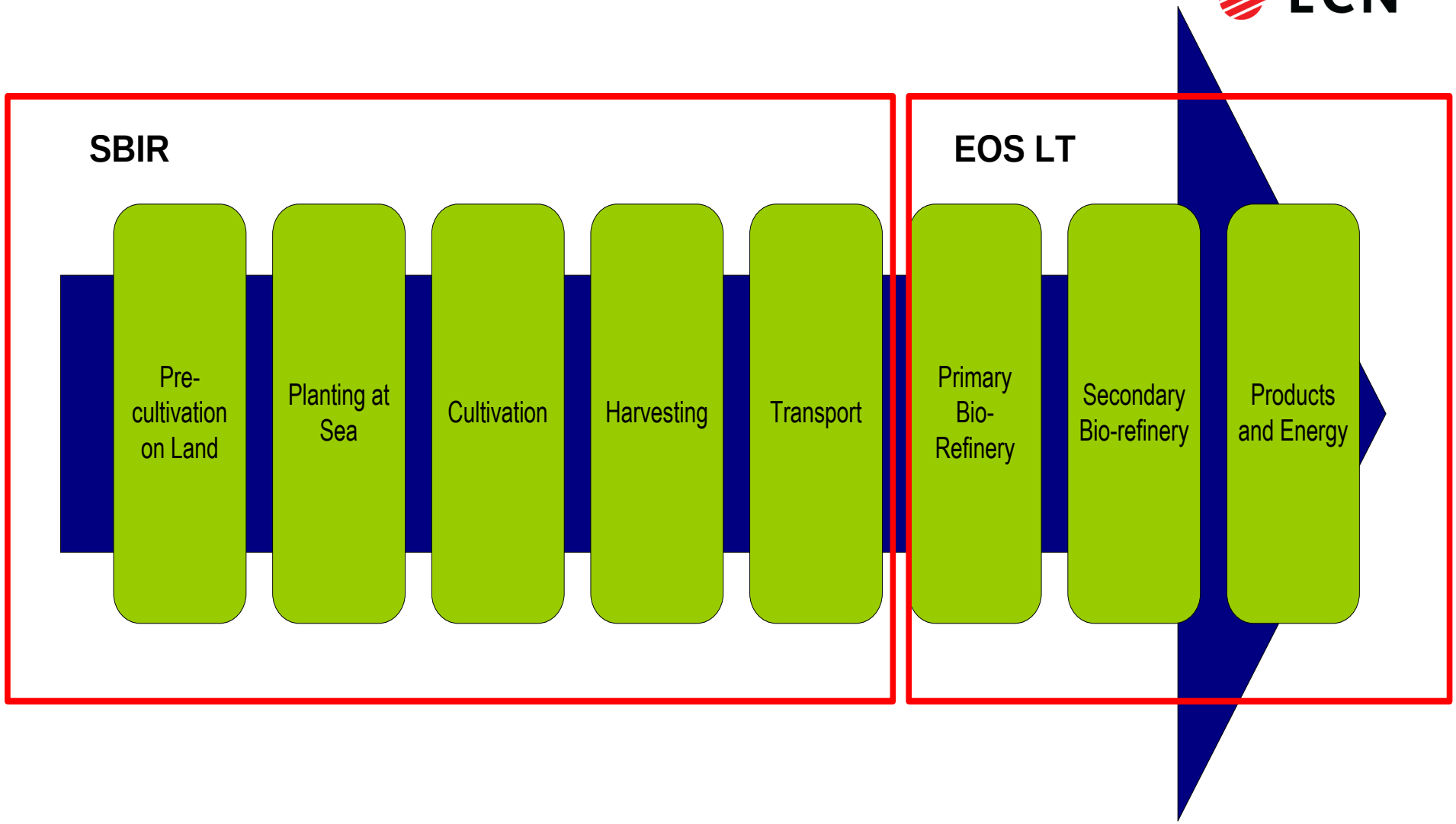
Stipe

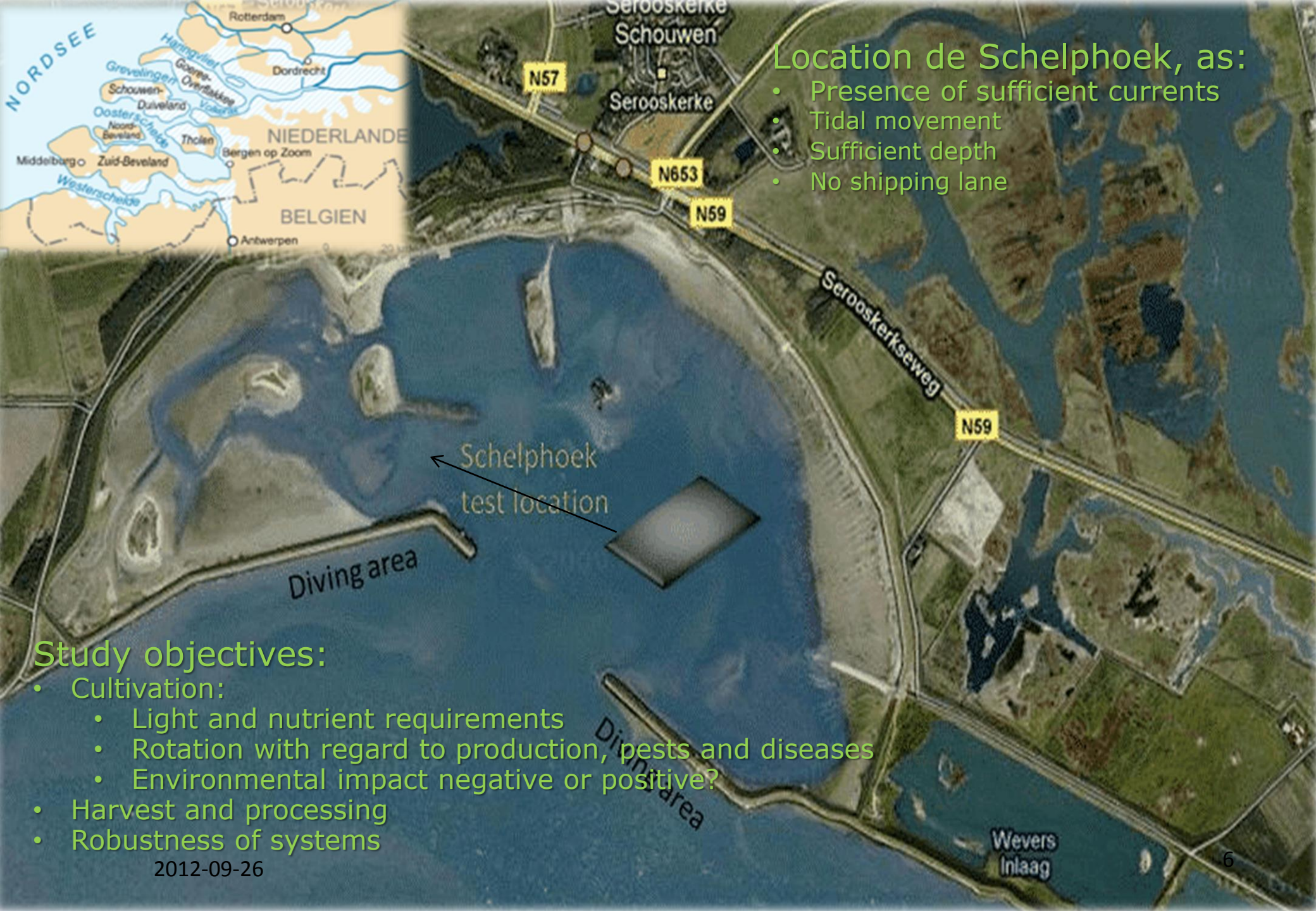
Holdfast

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



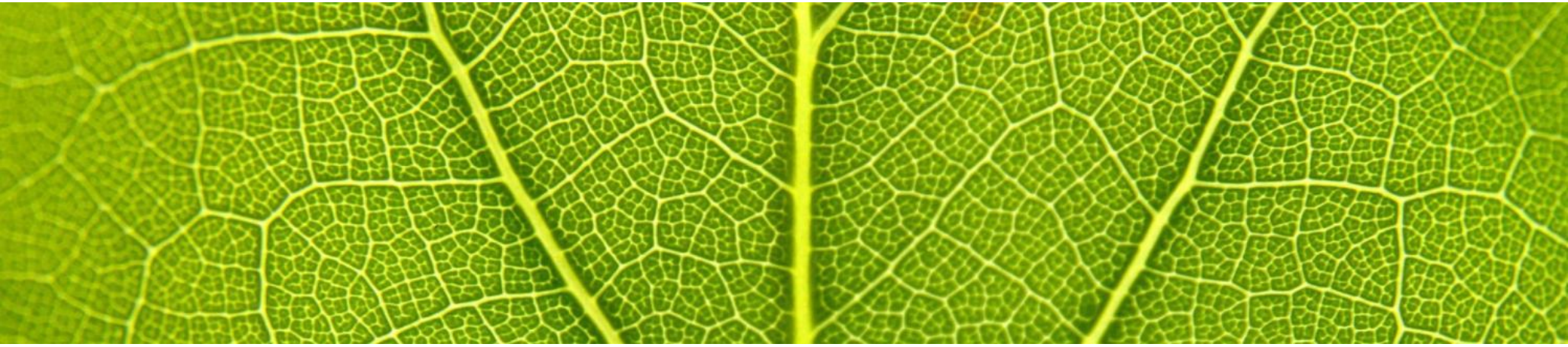

SBIR
EOS LT
Pre-cultivation on Land
Planting at Sea
Cultivation
Harvesting
Transport
Primary Bio-Refinery
Secondary Bio-refinery
Products and Energy


Rotterdam
NORDSEE
Hollandsch Diep
Dordrecht
Grevelingen
Schouwen-Duiveland
Oosterschelde
Noord-Beveland
Tholen
NIEDERLANDE
Bergen op Zoom
Middelburg
Zuid-Beveland
Westerschelde
BELGIEN
Antwerpen
Serooskerke
Schouwen
N57
Serooskerke
N653
N59
Location de Schelphoek, as:
• Presence of sufficient currents
• Tidal movement
• Sufficient depth
• No shipping lane
Serooskerkseweg
N59
Schelphoek
test location
Diving area
Diving area
Wevers Inlaag
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



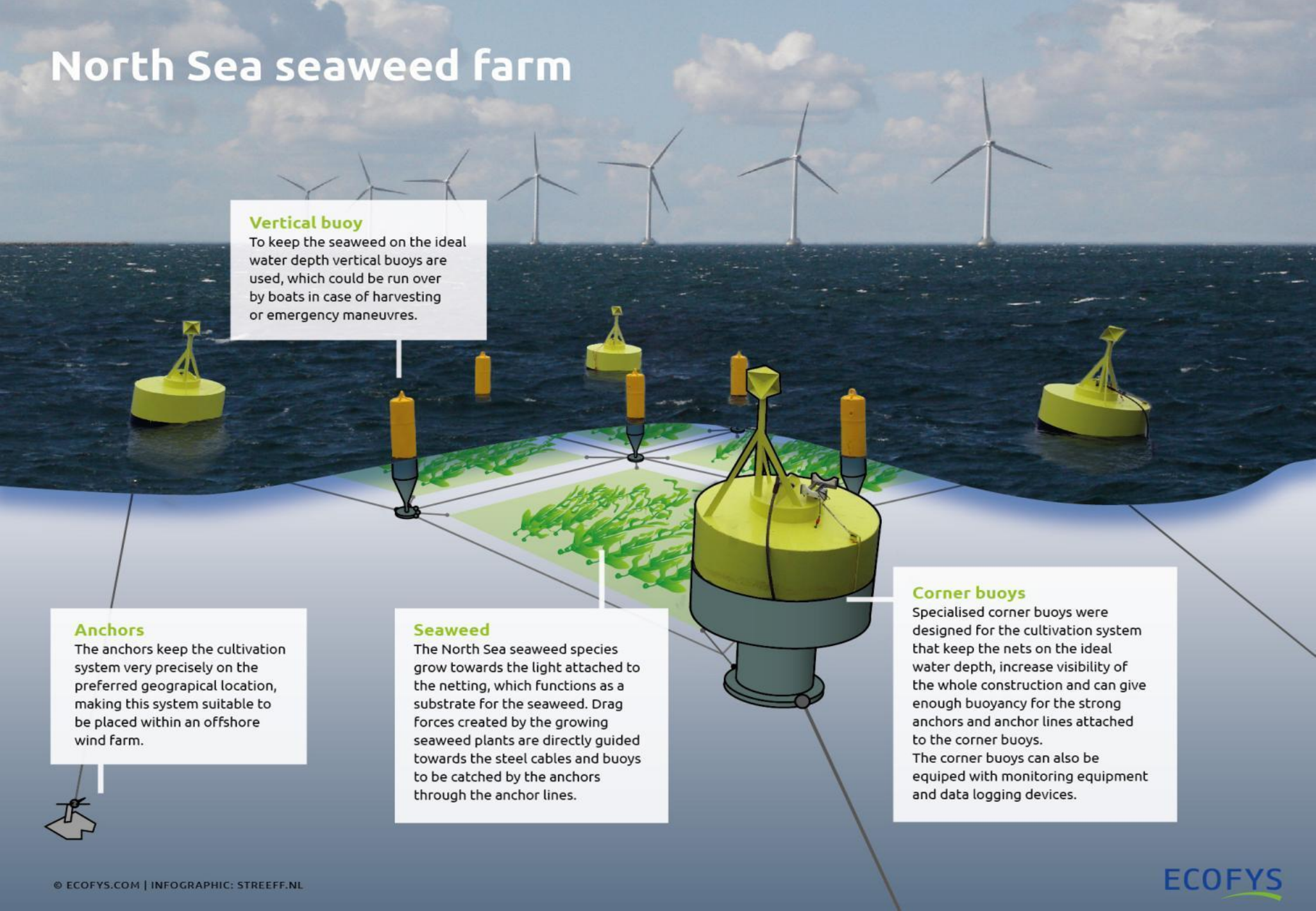
Offshore Seaweed Cultivation Project

The Ecofys Test Module

2012-09-26

Denver ABS 2012 ECN

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.

ECOFYS

Assembly onshore

Outlook & opportunities – short term

ECN

Current test module project

- Complete monitoring phase with successful harvest
- Analyse strength and weakness of design

Opportunity

- Noordzeeboerderij – North Sea Test Farm
  - Ecofys, NIOZ, Hortimare, ECN
  - Extend design life of test module
  - Facilitate 3rd party research initiatives
  - Investigate further sustainability of seaweed farming

Outlook & opportunities – mid term

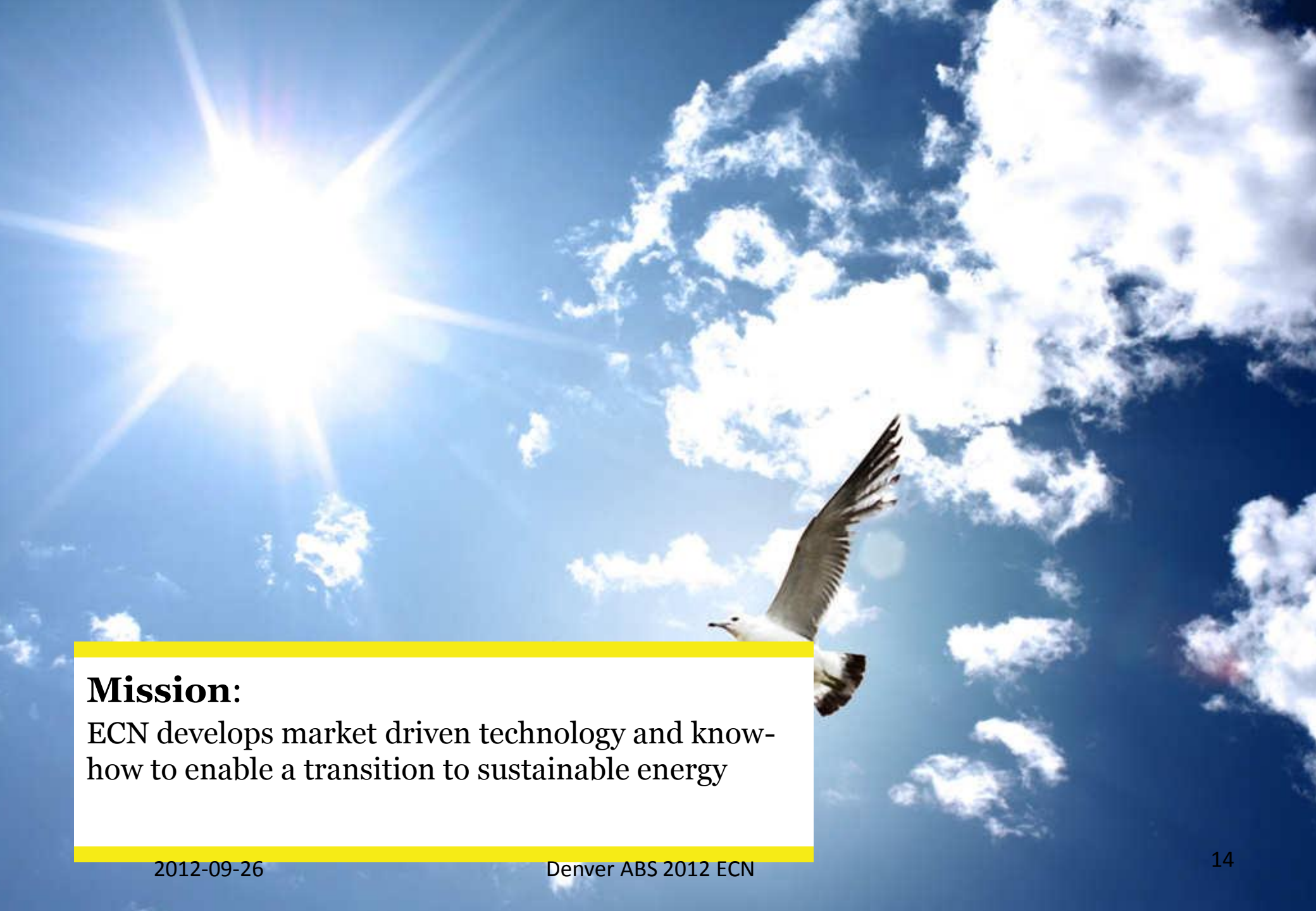
ECN

Opportunities

- Follow-up demonstration project => new investors
- Test module 2.0 in wind farm
- Increase scale and ROI
- Cooperation with bio based clients
- Identify offshore farmers

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



Mission:

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

Locations

ECN Petten
(head office)

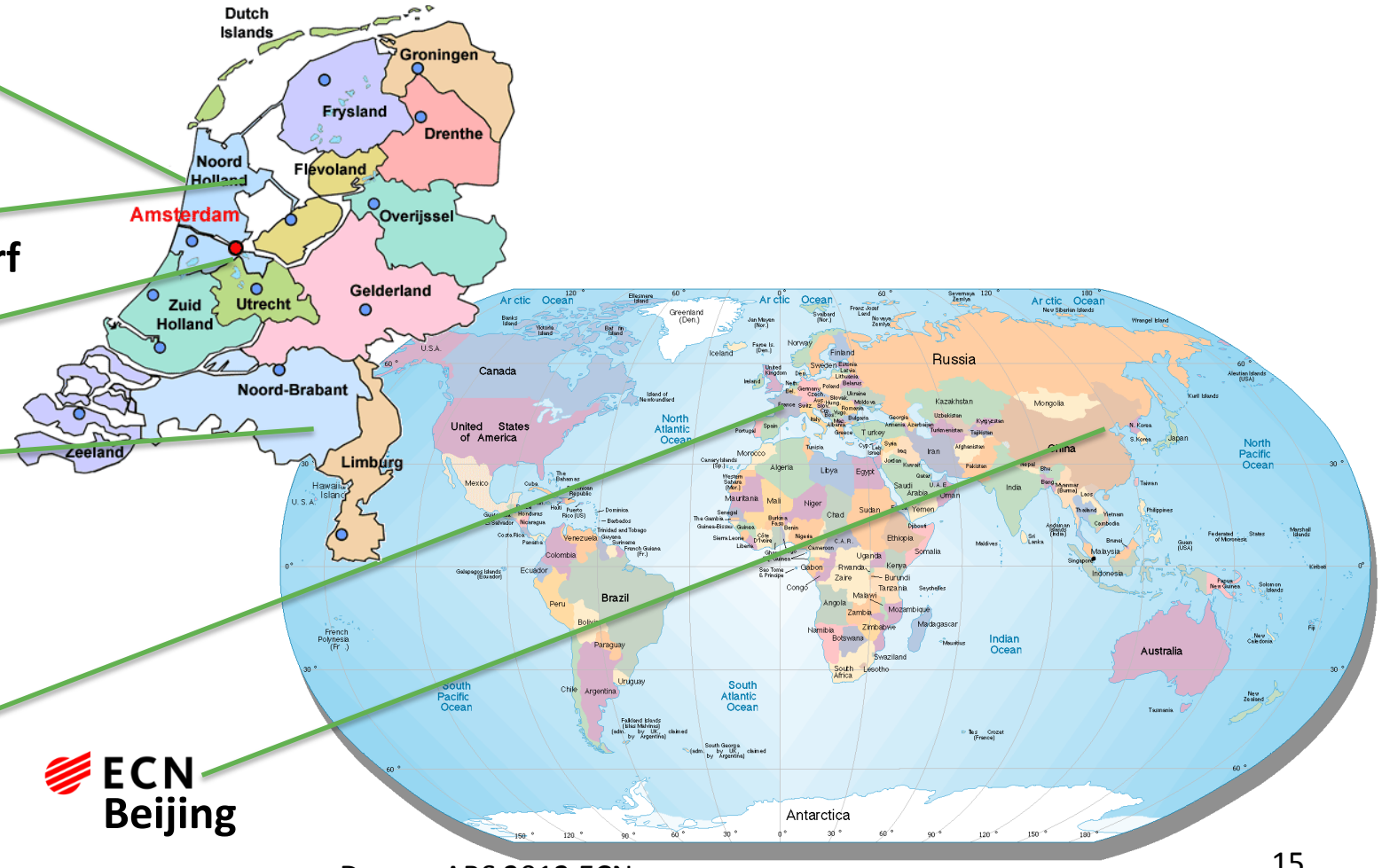
ECN Wieringerwerf

ECN Amsterdam

ECN Eindhoven

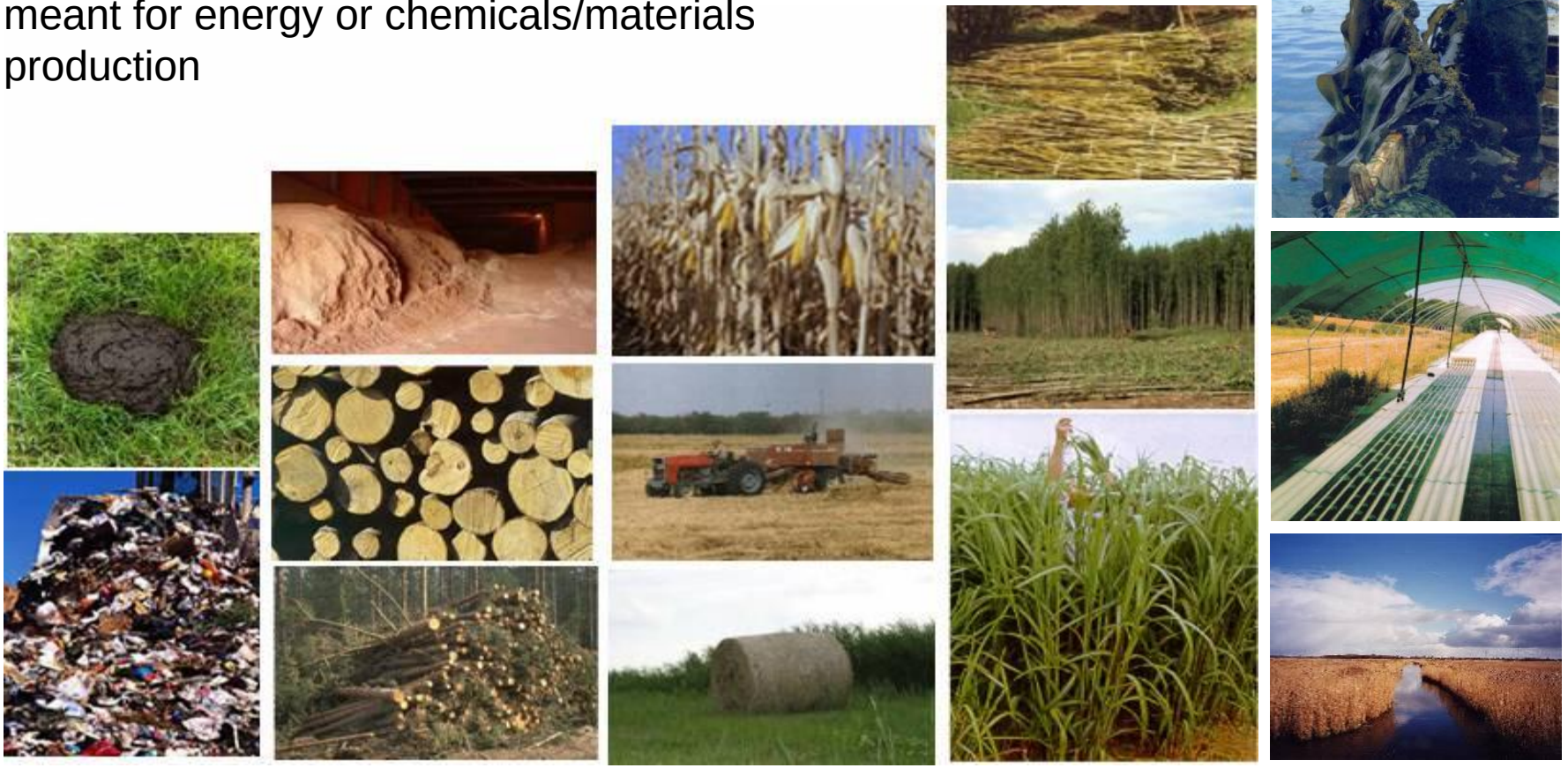
ECN Brussels

ECN Beijing



Biomass – a diverse energy source

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

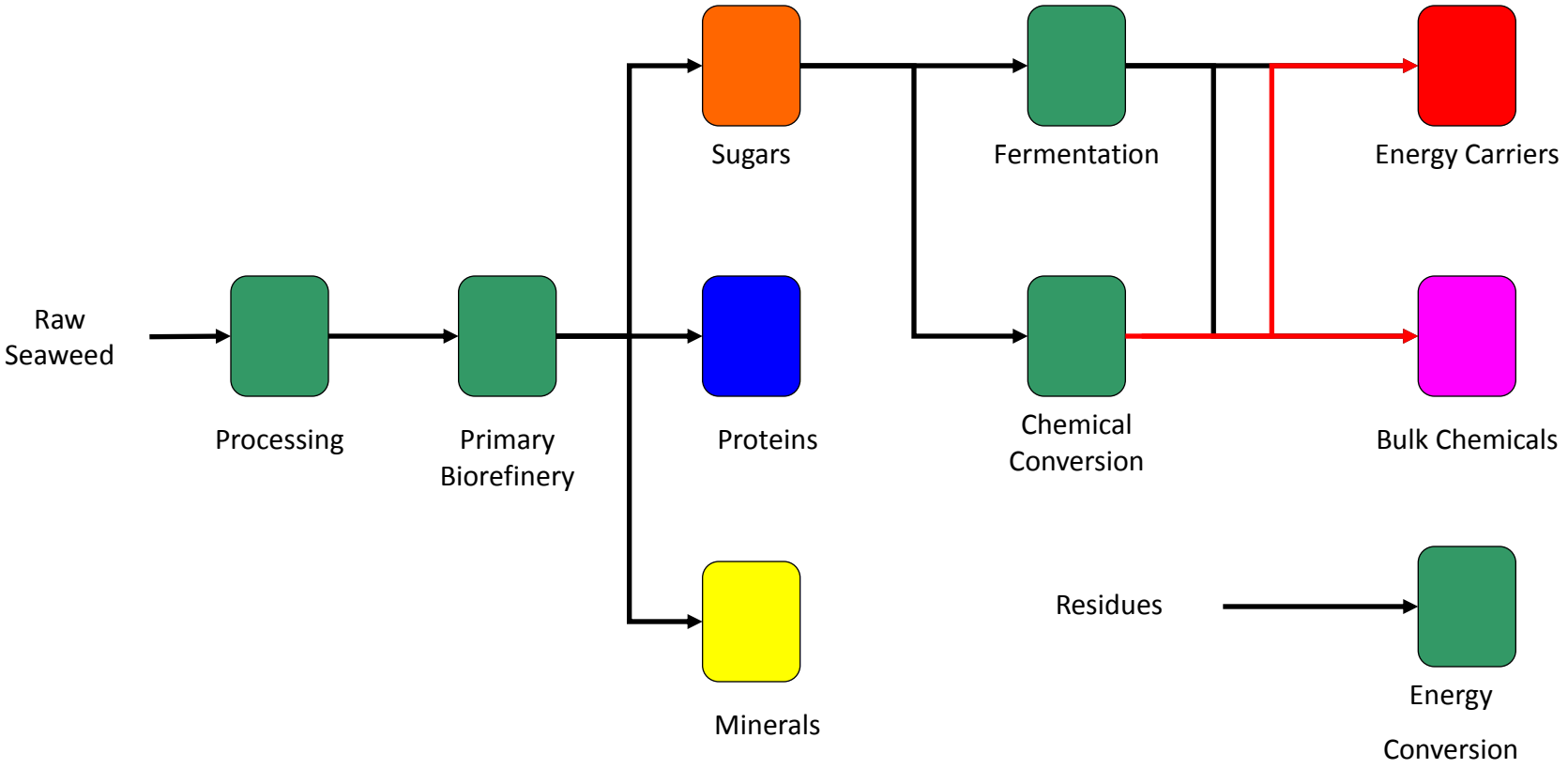


waste | wood | (agricultural) residues | energy corps | aquatic biomass

Biorefinery and processing

- Organosolv: fractionation technology
  - Conversion of lignocellulosic biomass into cellulose and pure lignin
  - 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

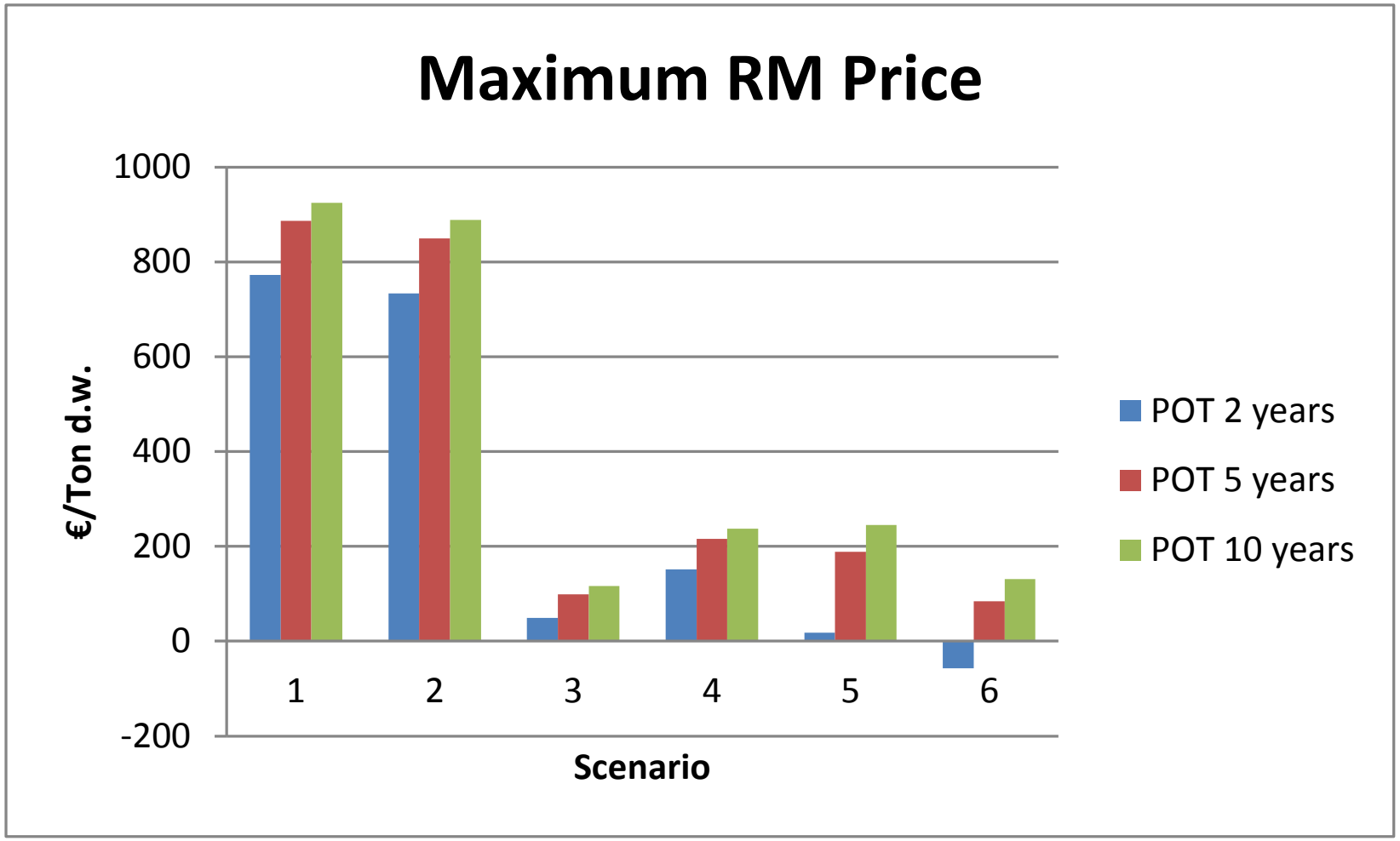
Seaweed biorefinery process concept



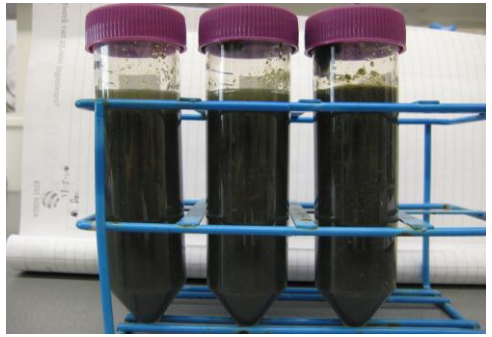
Three Cases Estimated

- Full biorefinery
- Alginate only
- Simplified biorefinery

Economic model



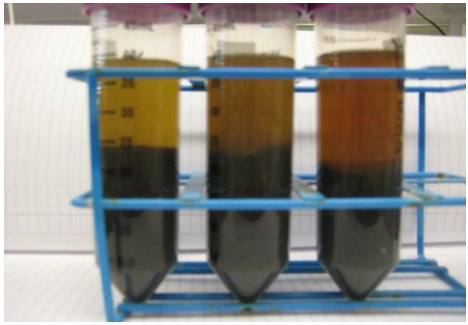
Fractionation



Water +
Seaweed

Optional
Catalyst

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



Liquid

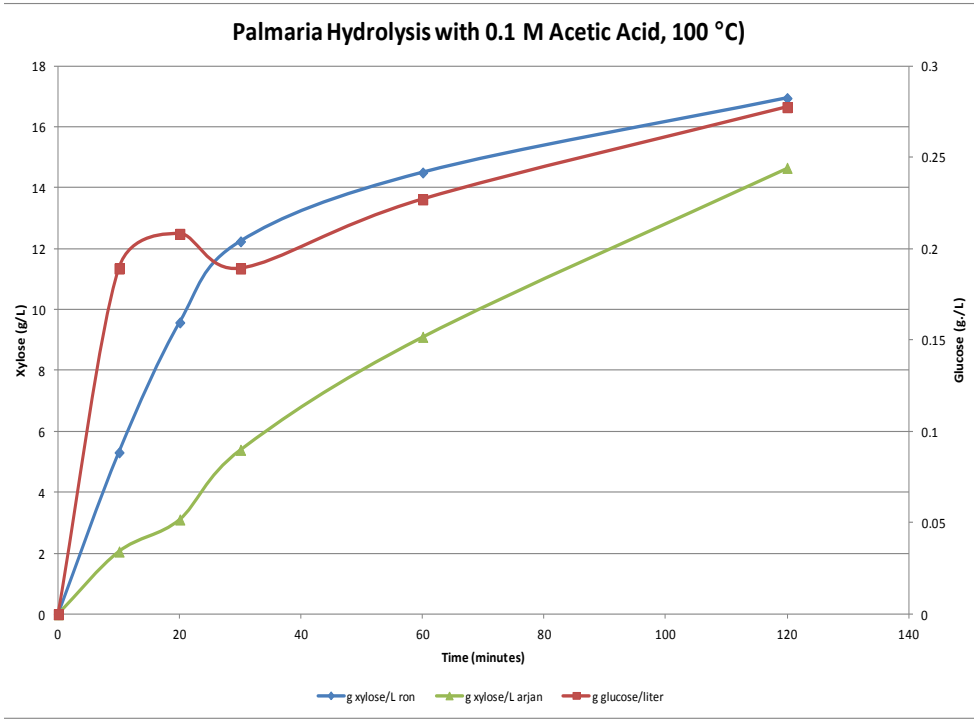
Solid

- 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

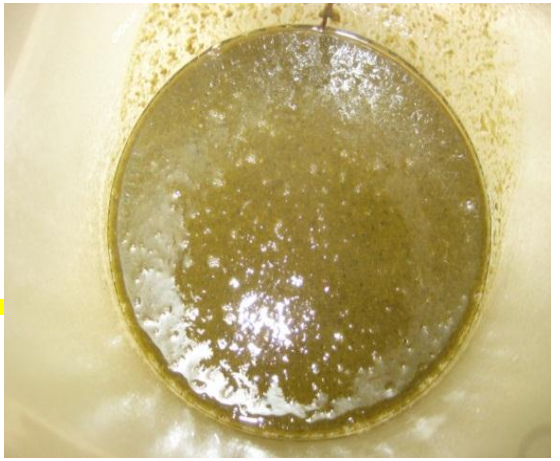
→ Scale up and with fresh seaweeds.



Fresh Palmaria tests (July 2012)

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

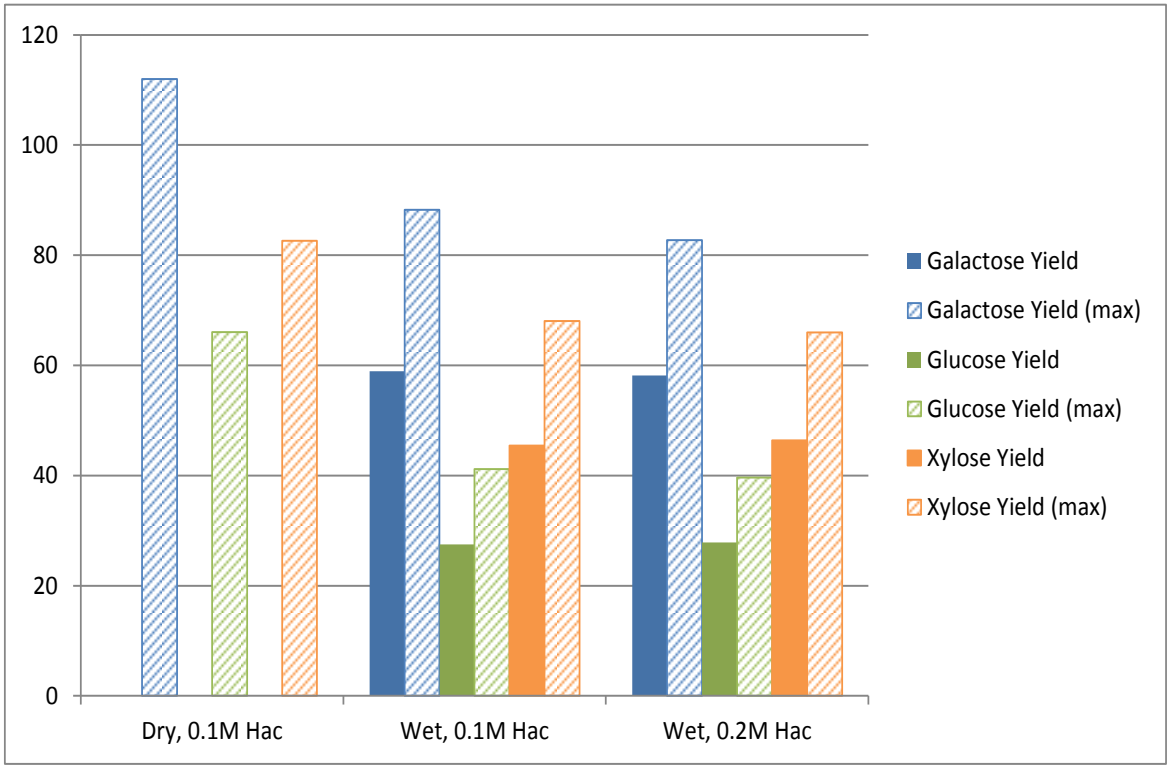
Test 1



- 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.



Question?
Further information

Jaap W. van Hal
The Energy Research Center of the Netherlands (ECN)
Biomass, Bio-Refinery and Processing
P.O. Box 1, 1755 ZG Petten
+31-(0)224-564297
vanhal@ecn.nl
http://seaweed.biorefinery.nl
http://www.noordzeeboerderij.nl
http://www.mermaidproject.eu
http://www.atsea-project.eu