

Large scale cultivation, storing and refining of seaweed

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Who is ECN?

Energy research Centre of the Netherlands (ECN)



- What do we do:
 - ECN develops market driven technology and know-how 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

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)
 - All Dutch households
 - All gasoline and jet
- ECN-C—05-008



Current initiatives

- Crown Estate, 15,000 km² for biogas production
- Denmark, MAB3
- France, seaweed for biogas project
- Norway, Statoil initiative (seaweed to ethanol)
- India, national seaweed initiatives (seaweed to ethanol)
- South Korea, seaweed to ethanol initiative
- EU, use seaweed for biofuels
- US: PNNL-Canadian initiative
- Etc.

Cultivating seaweed

Seaweed species native to the North Sea



Saccharina latissima



Laminaria digitata



Laminaria hyperborea



Ulva sp.



Alaria esculenta



Palmaria palmata

Wild seaweed harvest

- Industrial
- Fully mechanised

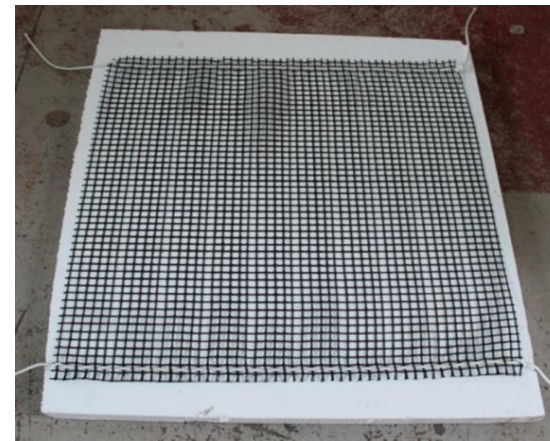


Current cultivation

- Large scale seaweed cultivation
- Manual and 1D



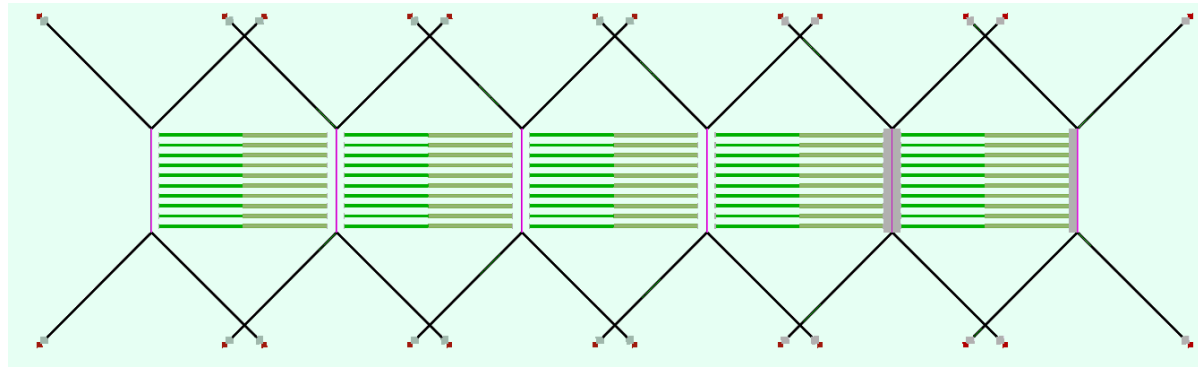
Selection of advanced substrates towards 2-D



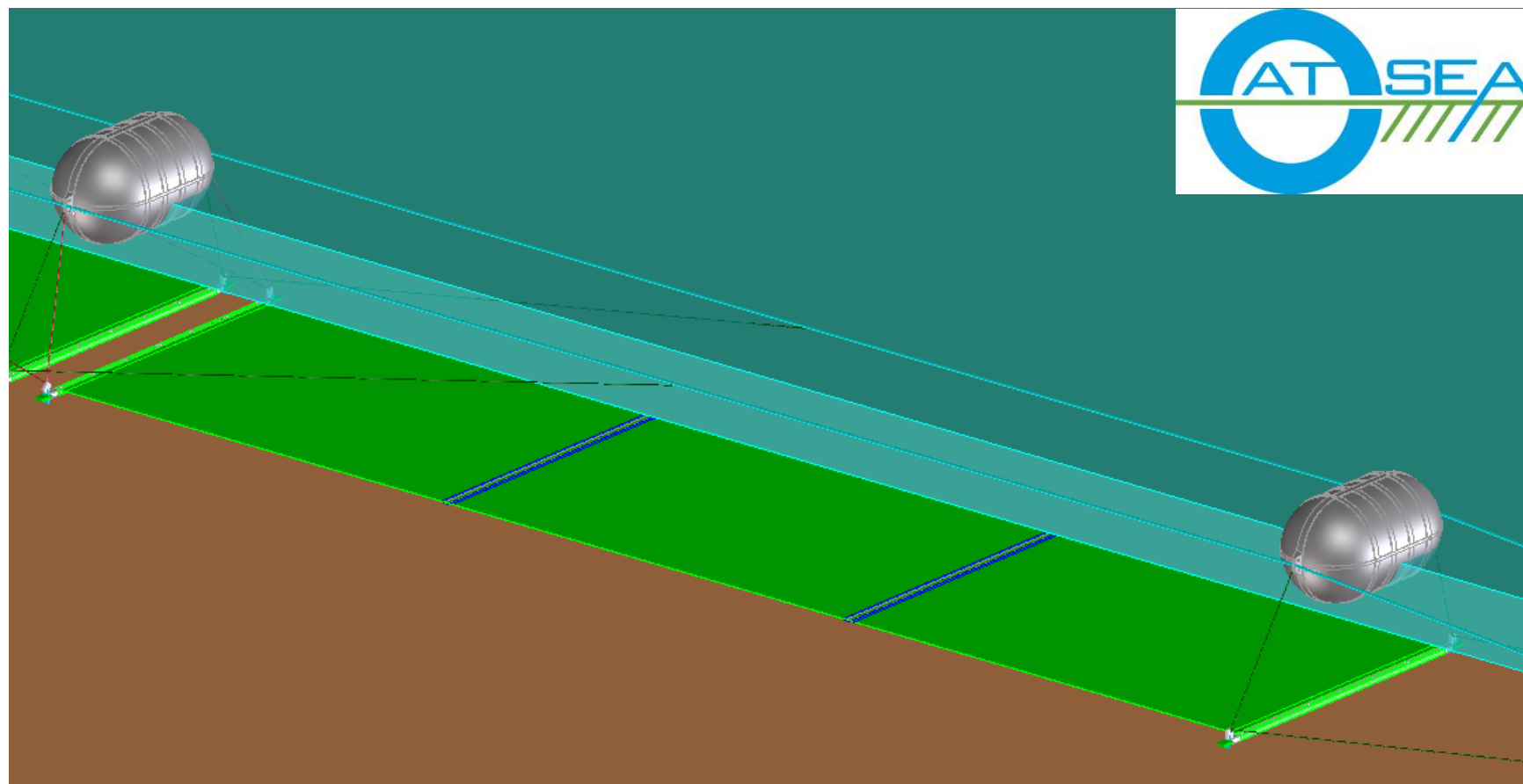
Field tests of substrates



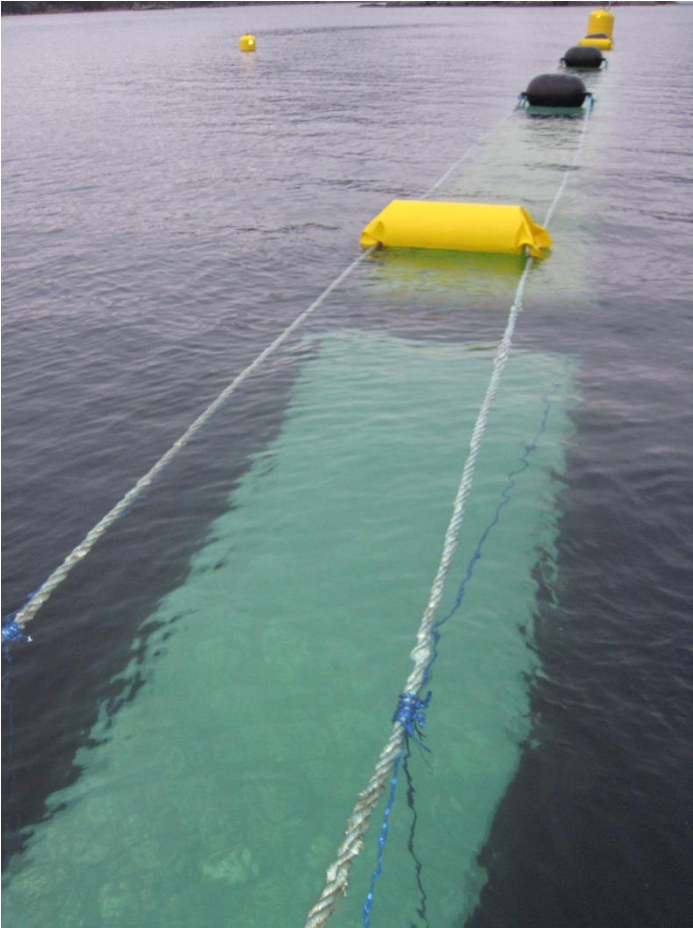
Conceptual demonstrator cultivation system



Detailed artist impression



Deployment and harvesting



15/06/2015



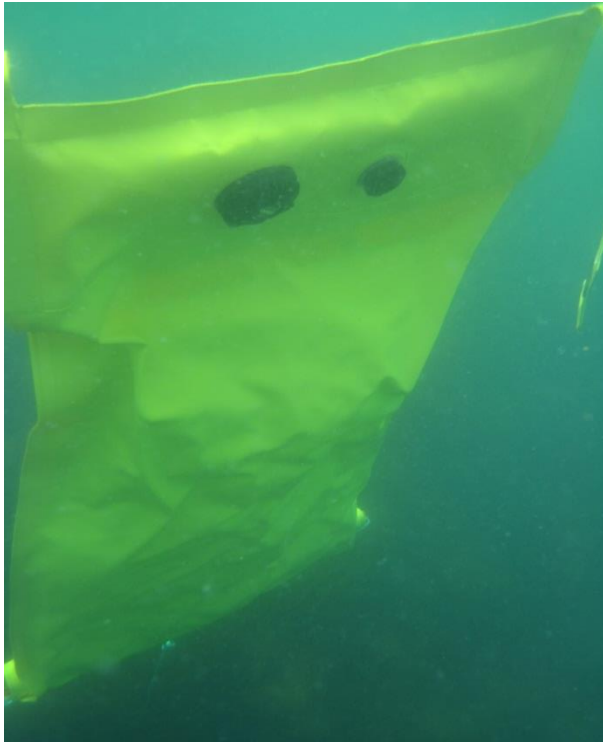
BFFM ECN

Drying the harvest in Ireland



Storing seaweed

Storing seaweed at sea



Initial experiments

- Fresh Seaweed



- Stored Seaweed



Experiments

- Seaweed stored under N_2 at $15 \pm 1^\circ C$
- Samples at Day 1, 2, 3, 7, 14, 21, 28, 25, 49, 63, 77, 88
- Samples freeze dried at analyzed for main sugars (mannitol, glucose, galactose) at 28 days
- Allows to see which concepts works



Results

- Pureed stored seaweed



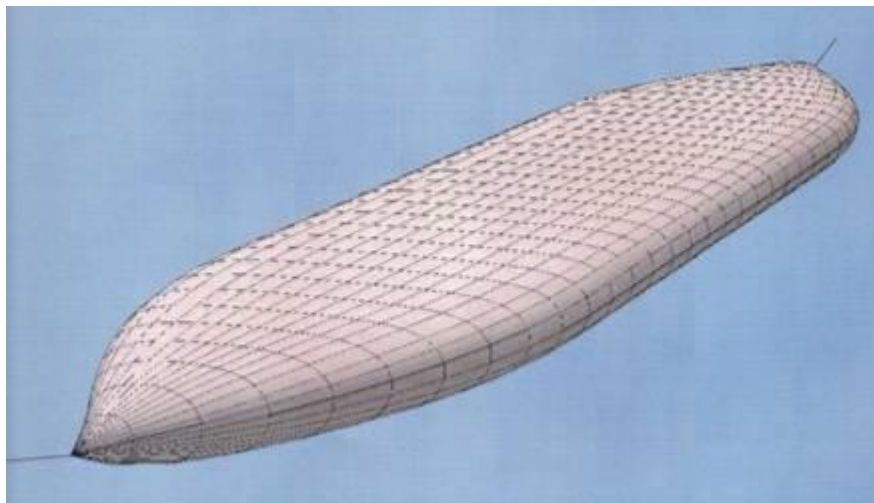
- Cut stored seaweed



Preservation of the valuable sugars

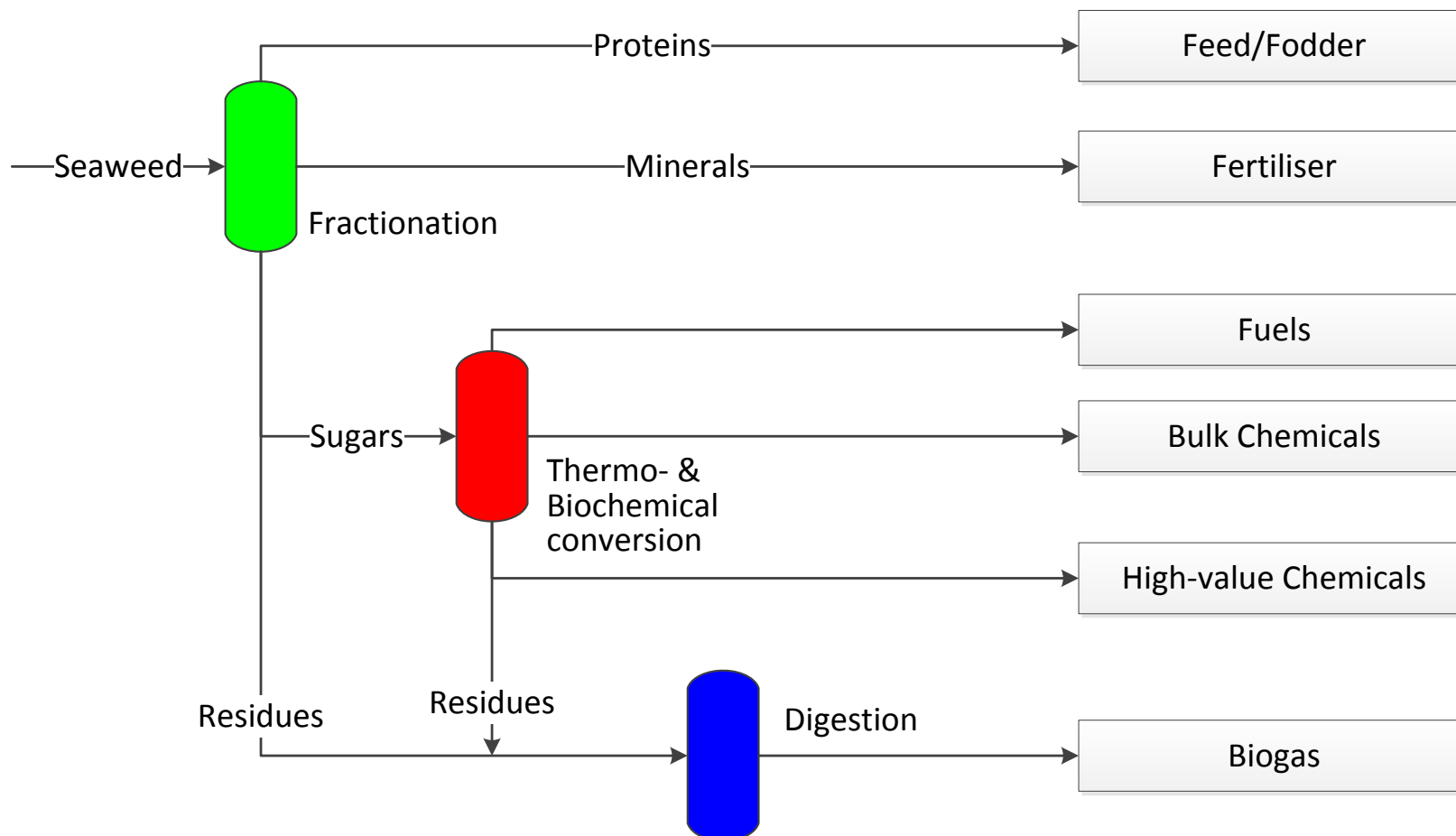


Large storage at sea



Fractionating seaweeds

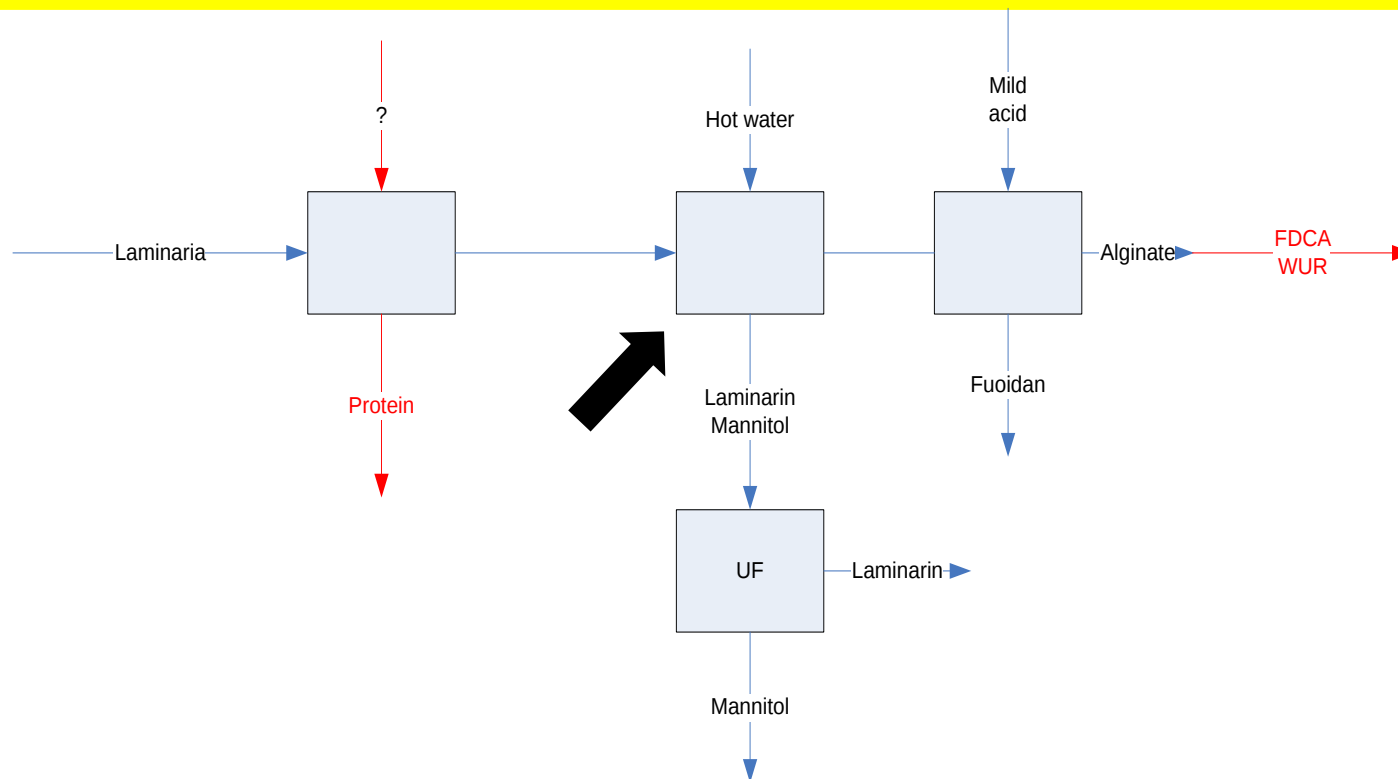
Seaweed biorefinery



Differences between biomass

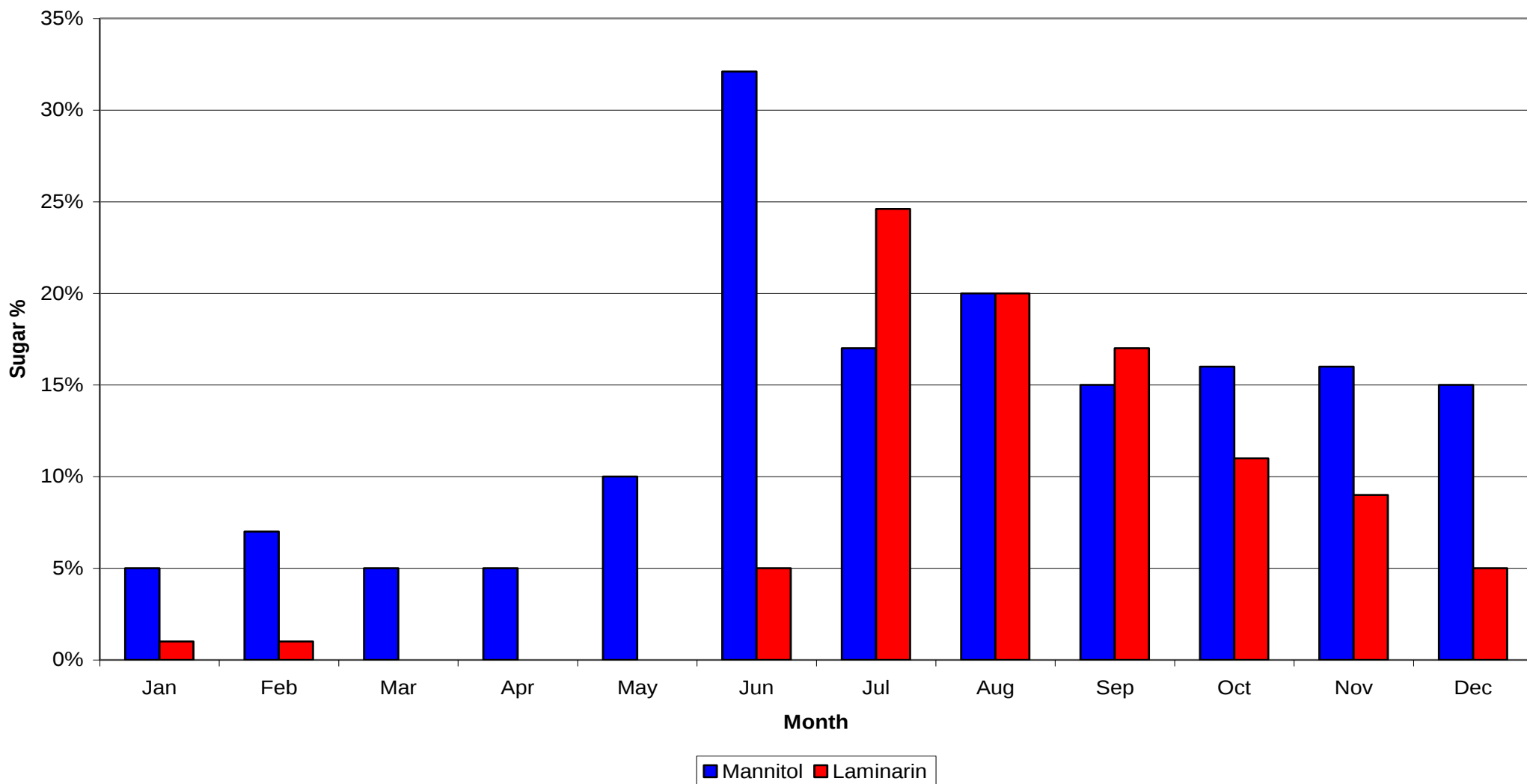
- Lignocellulosic biomass:
 - Cellulose
 - Extremely recalcitrant
 - Lignin
 - Heterogeneous polymer
 - Species, source and time of harvesting dependent
 - Hemicellulose
 - Easy to hydrolyse
 - Ash
 - Low to high
 - Overall composition reasonably stable
- Seaweed biomass
 - Carbohydrates
 - Type dependent on species
 - Amount dependent on season and location
 - Proteins
 - Amino acid composition dependent on species
 - Amount dependent on season and location
 - Ash
 - Species dependent
 - Amount dependent on season and location
 - Extreme differences between seasons

Fractionation *Laminaria* / *Saccharina*

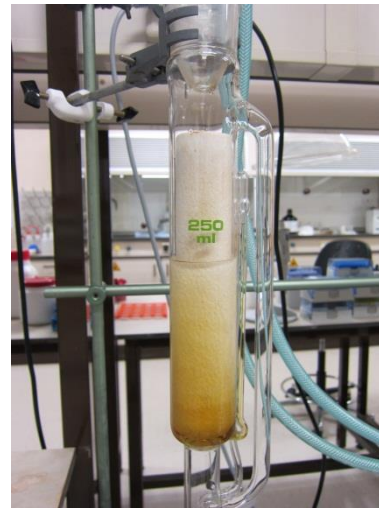


- Potential mannitol uses: e.g., conversion to isomannide, intermediate for plasticizers, fuel additives, PET replacements, epoxy resins & PUR.
- Patent filed on mannitol extraction from brown seaweed (Sept, 2012).

Laminaria Digitata



Crude carbohydrates and isolated mannitol



Synthesis of iso-mannide



Applications of iso-mannide

- Isomer of iso-sorbide
- Interconvertible into other isomers
- Separation based on boiling point possible
- Intermediate for
 - Plasticizers
 - Fuel additives
 - PET replacements
 - Epoxy resins
 - PUR
- Prepared isomannide from fresh seaweed!

Questions?

For more information

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<http://www.atsea-project.eu>

<http://www.mermaidproject.eu>



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