# Storing and refining seaweed

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# Storing and refining seaweed

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Germany, Hamburg
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*Presentation download: www.ecn.nl*

# 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

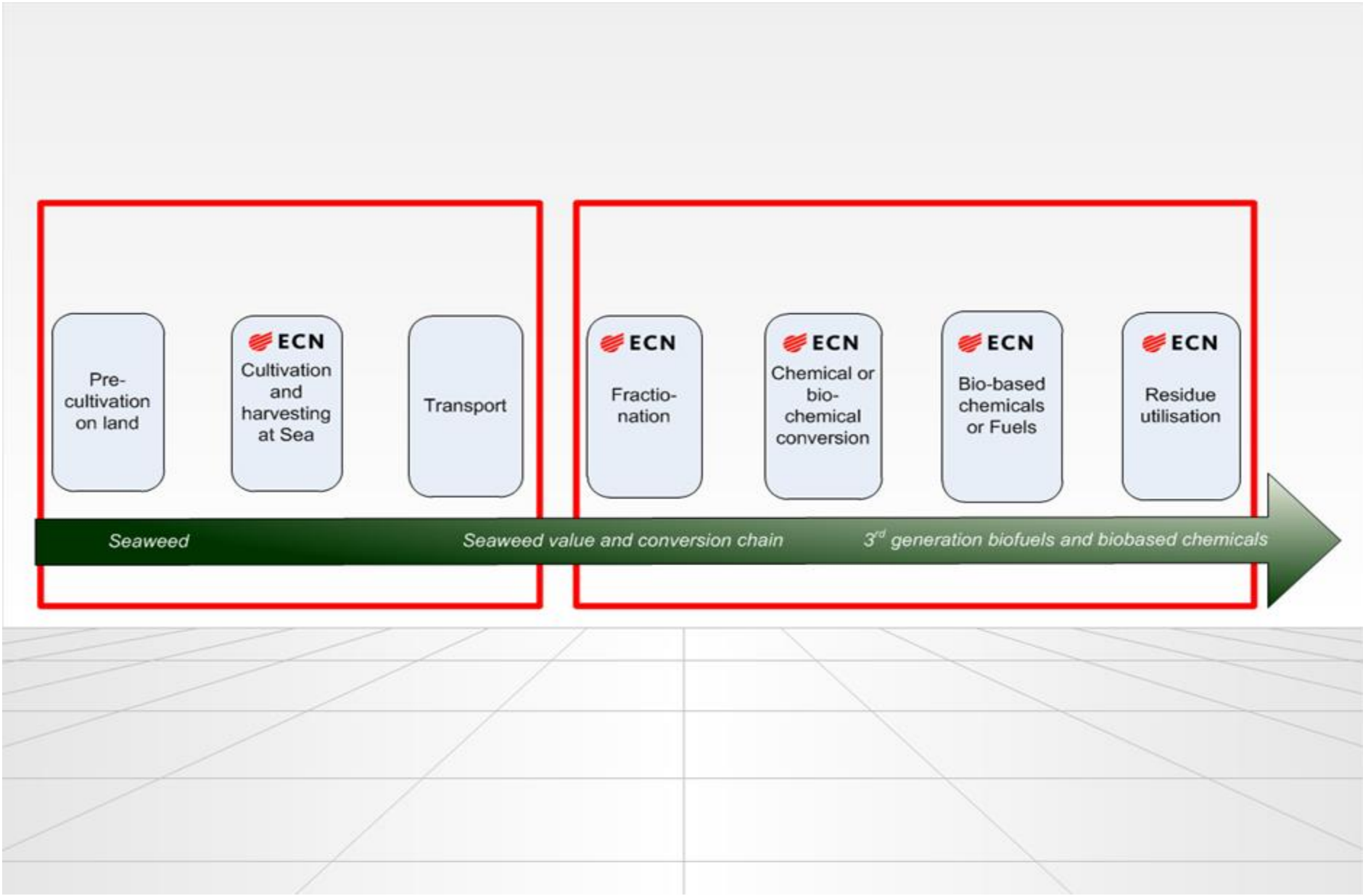
**ECN**

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

# 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


Pre-cultivation on land
ECN
Cultivation and harvesting at Sea
Transport
ECN
Fractio-nation
ECN
Chemical or bio-chemical conversion
ECN
Bio-based chemicals or Fuels
ECN
Residue utilisation
Seaweed
Seaweed value and conversion chain
3rd generation biofuels and biobased chemicals

# Seaweed species native to the North Sea

*Saccharina latissima*

*Laminaria digitata*

*Laminaria hyperborea*

*Ulva sp.*

*Alaria esculenta*

*Palmaria palmata*

# Potential for Seaweed

# Seaweed cultivation potential

- Potential *( Florentinus et al, Ecofys, 2008 )*
  - Near off shore wind infrastructure <100km — 110EJ — 5.000.000km$^2$
  - Near coast <25km and in nutrient rich water — 35EJ — 1.700.000km$^2$
  - Global energy use — 450EJ
- Marine spatial Planning
  - Shipping lanes
  - Military exclusion areas
  - Nature 2000 areas
- Ambitions
  - Scotland 15.000km$^2$
  - Norway 5.000km$^2$
- Example biorefinery
  - 4 Offshore wind turbine parks of 50 km$^2$ = 200 km$^2$

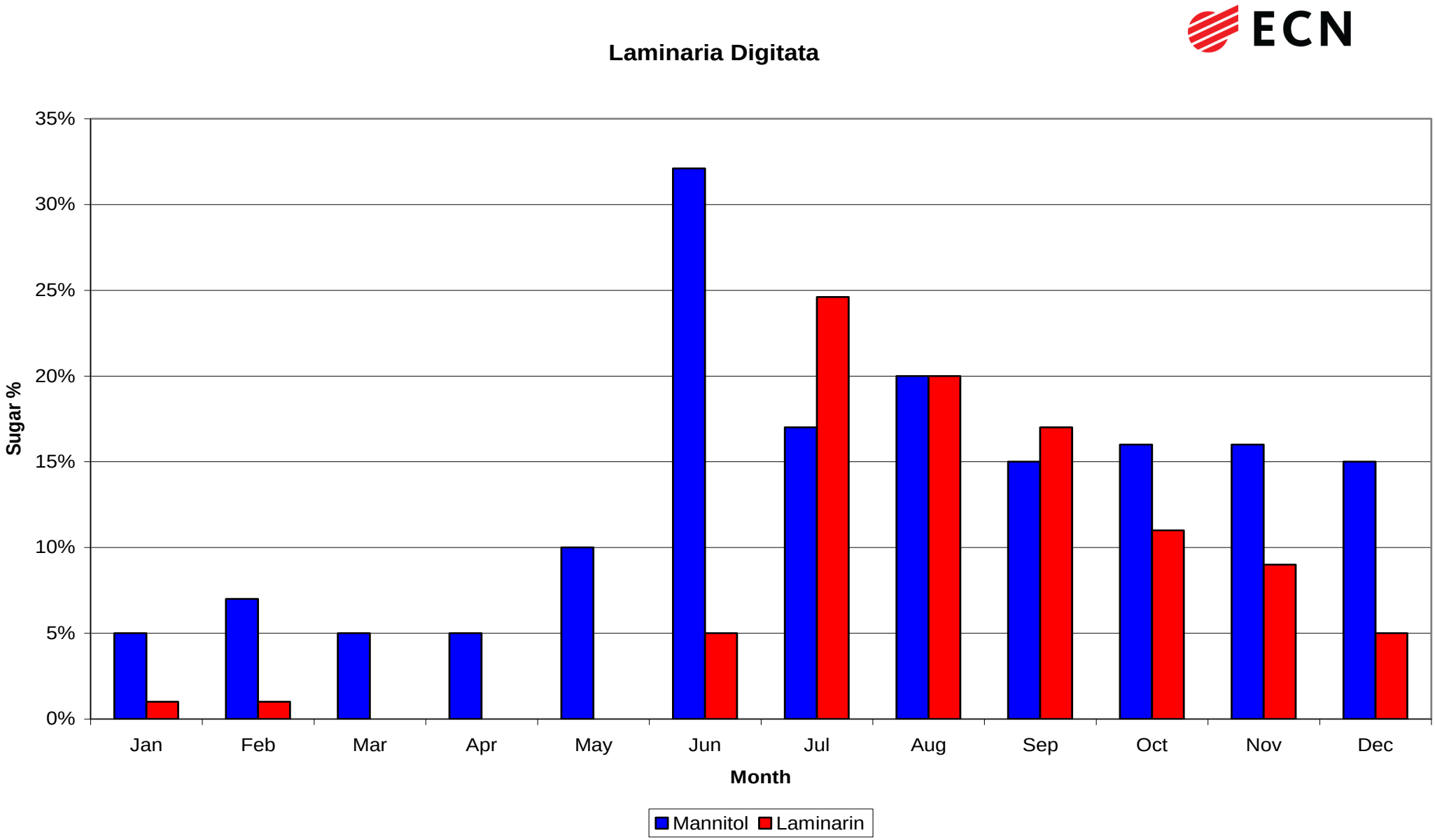
# Lignocellulosic *vs* seaweed biomass

Lignocellulosic biomass

- Cellulose
  - Recalcitrant
- Hemicellulose
  - Easy to hydrolyse
- Lignin
  - Heterogeneous polymer (species etc. dependent)
- Ash
  - Low (wood) to medium (straw)
- Overall composition reasonably stable

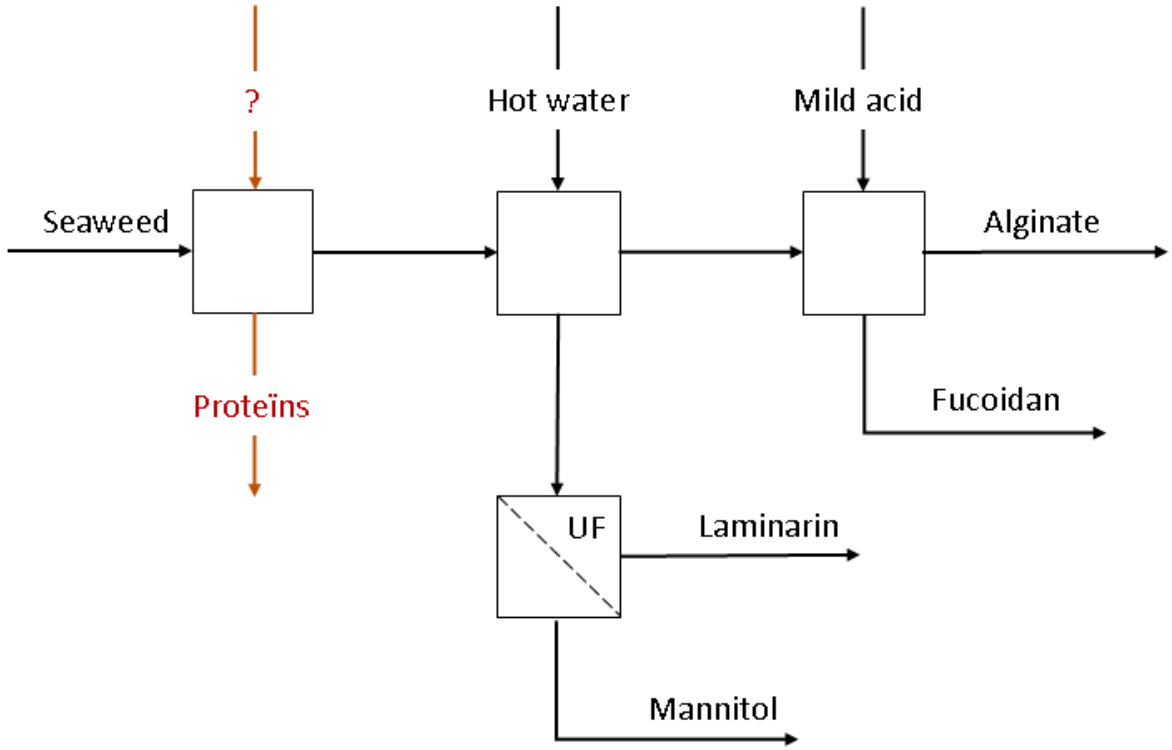
Seaweed biomass

- Carbohydrates
  - Reducing sugars (xylose, rhamnose), sugar alcohols (mannitol), uronic acids (alginate), sulfated sugars (fucoidan).
  - Type dependent on species
- Proteins
  - Amino acid amount and composition dependent on species
- Ash
  - High (Cl!)
- Large differences between seasons and location!


Laminaria Digitata
35%
30%
25%
20%
15%
10%
5%
0%
Sugar %
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month
Mannitol
Laminarin

# Seaweed biorefinery

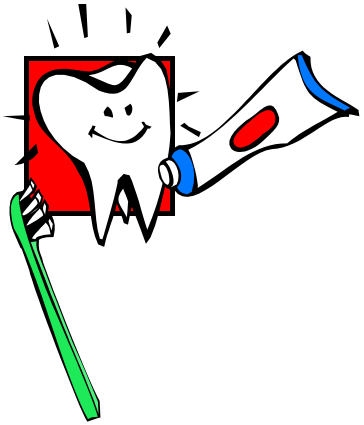
# Seaweed primary biorefinery




- Patent filed on mannitol extraction from brown seaweed (Sept, 2012).

# Key components

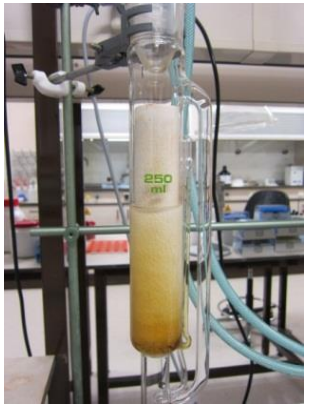
- Alginate
- Established market



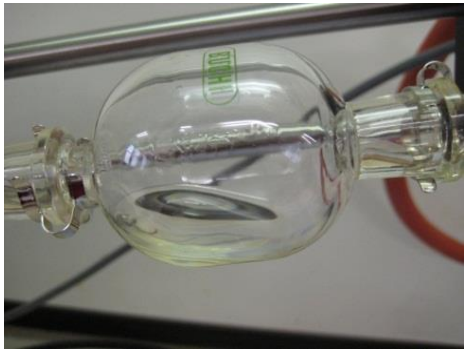
# Key components

- Mannitol
- Conversion to high value Iso-mannide

Extracted mannitol

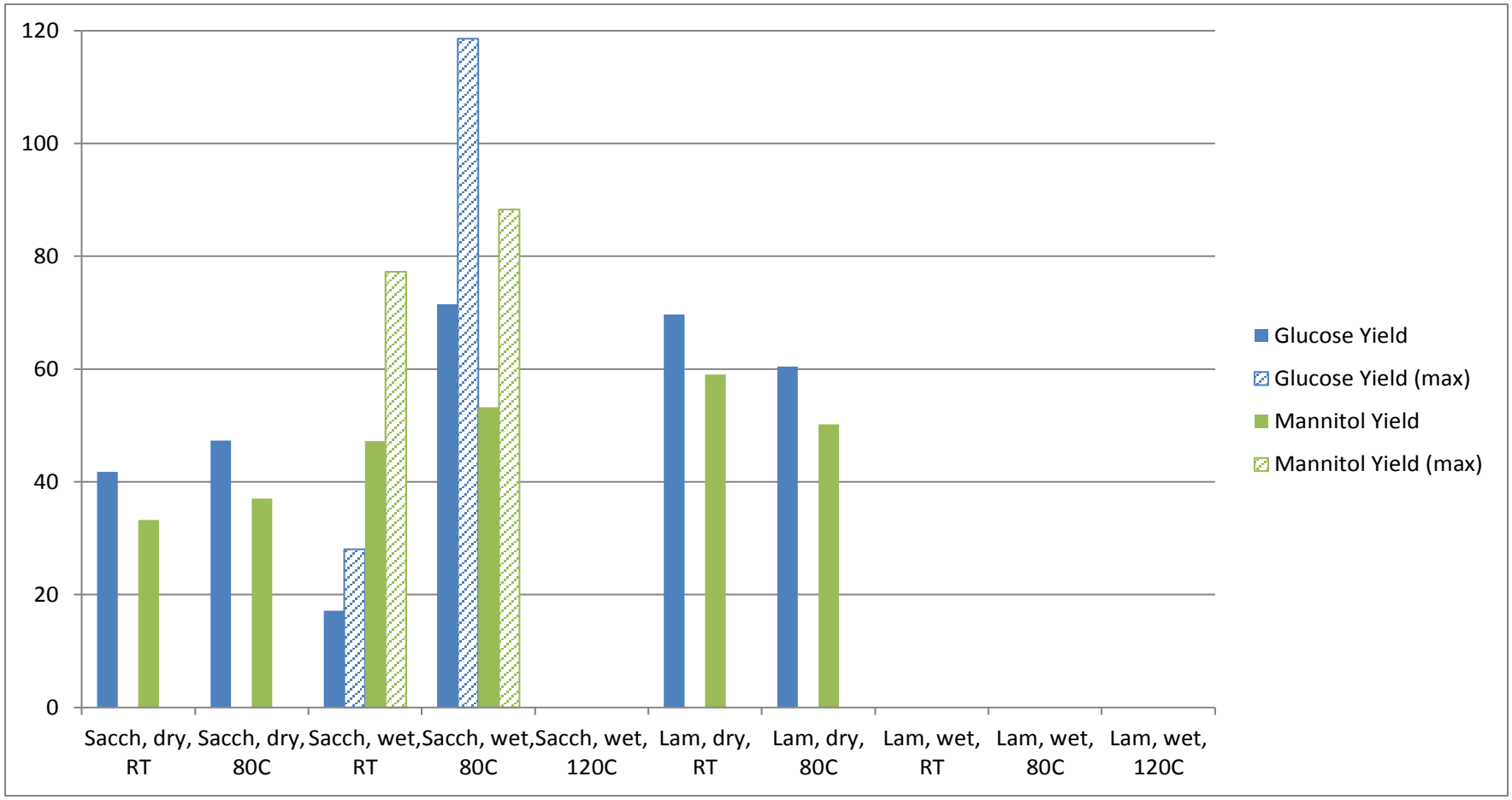



Purified mannitol

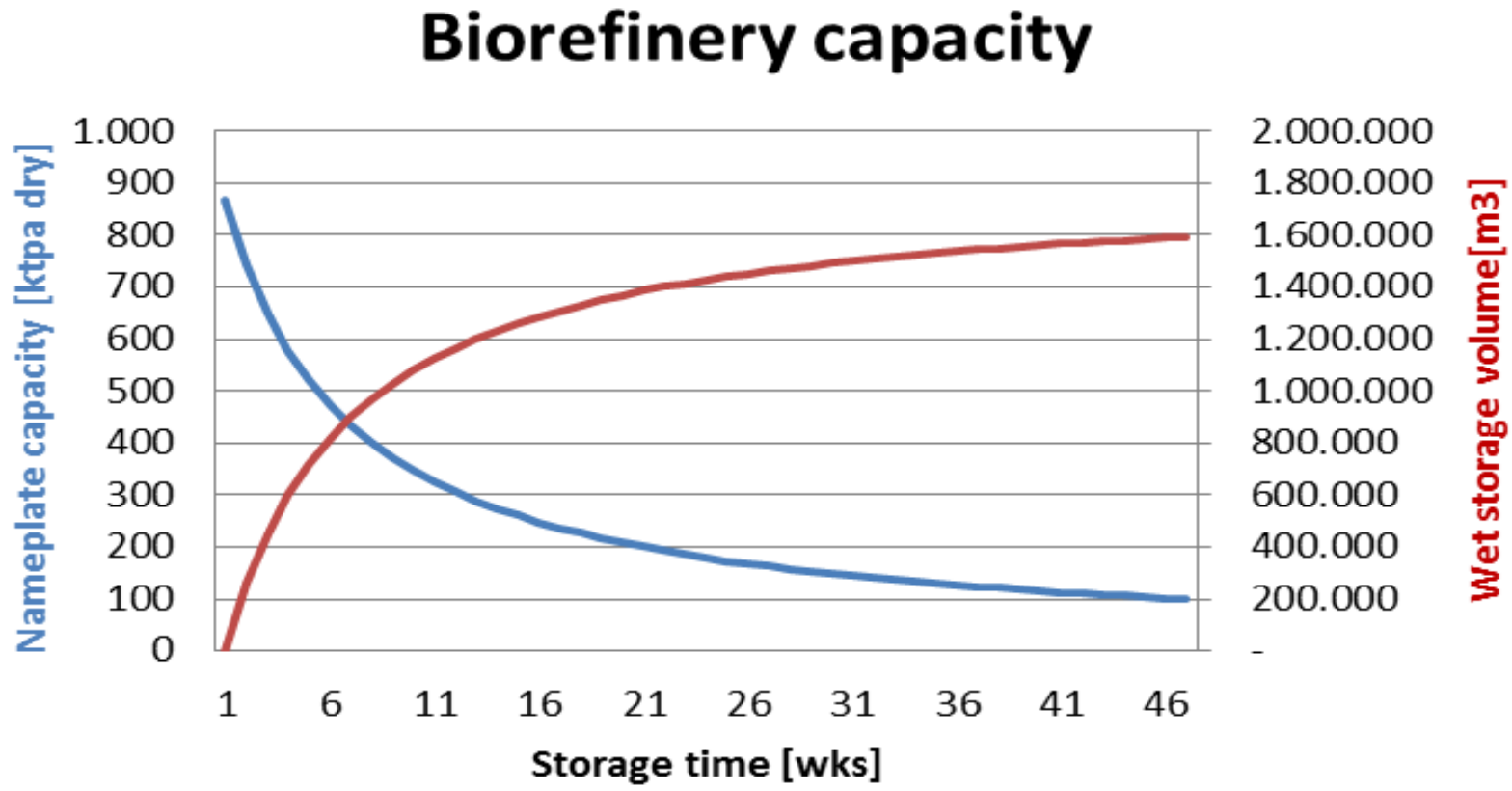


Iso-mannide

# Mannitol / laminarin extraction results



# Biorefinery capacity



# Seaweed storage

# Storage methods

- Wet
  - Wet seaweed contains 16% dry matter
  - 6 tons of wet seaweed per dry ton
  - 3 $m^3$ storage volume per wet ton seaweed
  - 6x3 = 18 $m^3$ Storage volume per dry ton
- Dry
  - Large energy consumption
  - 5 tons of water vapor per dry ton seaweed
- Preserved
  - Silage of minced seaweed
  - 1 $m^3$ storage volume per wet ton seaweed
  - Lactic acid, low pH, anaerobic preservation

# Wet storage experiments

- Parameters
  - Cutting size: whole, 3 cm, minced
  - Wet or drip dry
  - Aerated or anaerobic
  - Storage time: 1-75days

# Wet storage experiments

- Results

- Optimal
  - Uncut/large cuts
  - Drip dry
  - Anaerobic

fresh

25 days

- Key components:
  - 30 days: 80% loss of Mannitol
    15% loss of Alginate

- Safety
  - 75 days: Major release of $H_2S$ gas

# Dry storage experiments

- Parameters
  - Uncut leaves
  - Weight reduction:
    20%, 50%, 80%
  - Storage time 1-75days
- Monitor content key components
- Results
  - Ongoing work

# Seaweed drying

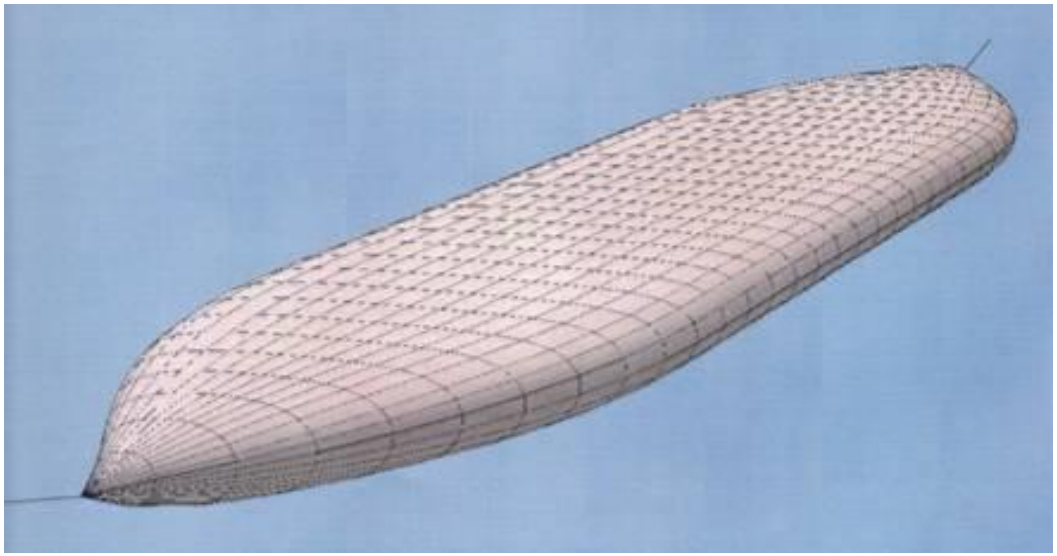
- Harvest time 6 weeks
- 100 kton dry, 650 kton wet seaweed input
- Drying time 6hrs for 80% weight reduction
- Dryer
  - 650 ton per hour
  - 10 v% seaweed in drying sections
  - 120.000 m3 volume in drying sections
  - 350 MW power

# Silage experiments

- Parameters
  - Minced seaweed, <3mm
  - Simulate Lactid Acid Bacteria activity
    - 0.1%, 0.3%, 1%, 3% Lactic acid
  - Storage time 1-75days
- Monitor content key components
- Results
  - Ongoing work

# Seaweed silage

- 100 kton dry, 650.000 m3 minced wet seaweed
- Transport and storage in 50.000 m3 textile bags
- Reduced transport cost

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# ACKNOWLEDGEMENT

Thank you for your attention

Visit ECN at the exhibition booth B11

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