

› ZEEWIER POTENTIE NOORDZEE

platform duurzame biomassa | Jaap W. van Hal



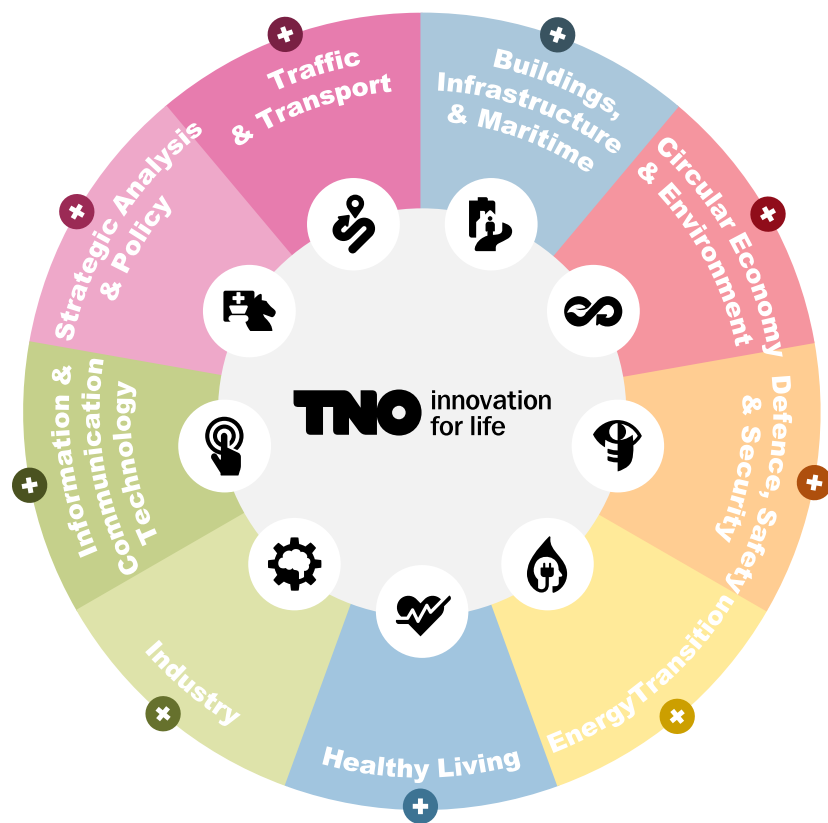
ECN ›

TNO

innovation
for life

TNO

WHO WE ARE?



TNO ENERGY TRANSITION



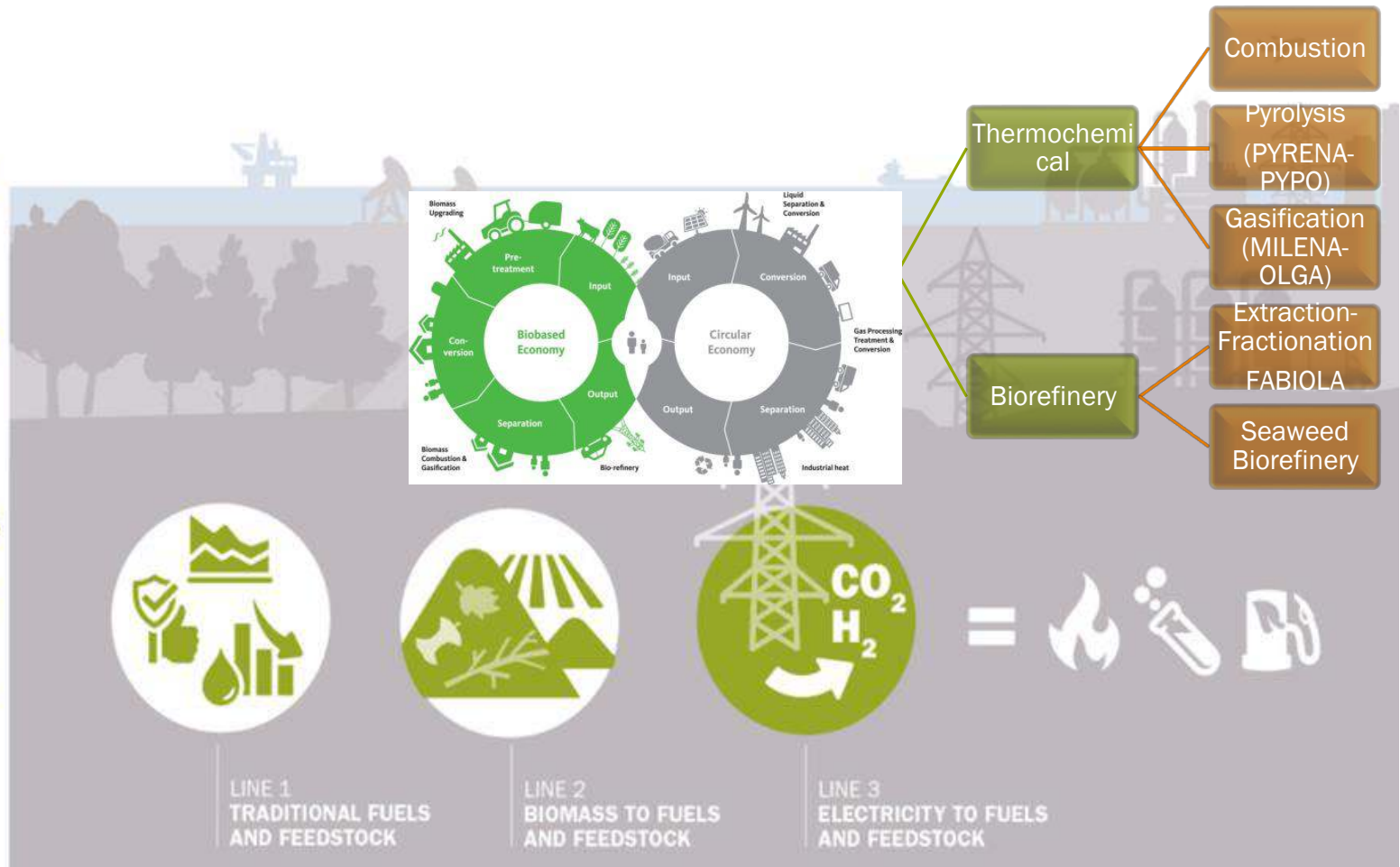
Towards
CO₂-neutral
**FUELS AND
FEEDSTOCK**

GOALS 2050

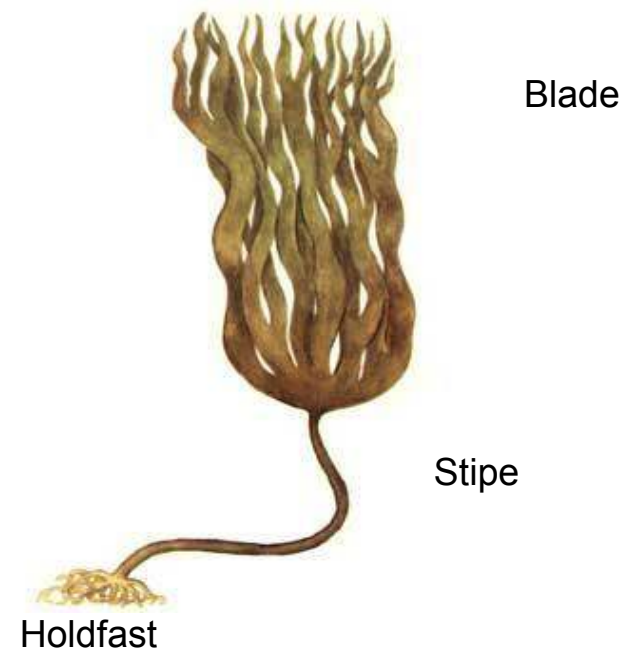
ENABLING THE
**SMOOTH, SAFE
AND EFFICIENT
TRANSITION**
FROM TRADITIONAL
ENERGY SOURCES

TOWARDS
**RENEWABLE
CO₂- NEUTRAL
ENERGY CARRIERS**
FOR MOBILITY/TRANSPORT
AND OTHER ENERGY
FUNCTIONS

**CHEMICAL
BUILDING BLOCKS**



PARTS OF SEAWEED



SEAWEED SPECIES NATIVE TO THE NORTH SEA



Saccharina latissima



Laminaria digitata



Laminaria hyperborea



Ulva sp.



Alaria esculante



Palmaria palmata

DIFFERENCES BETWEEN LIGNOCELLULOSIC AND SEAWEED 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

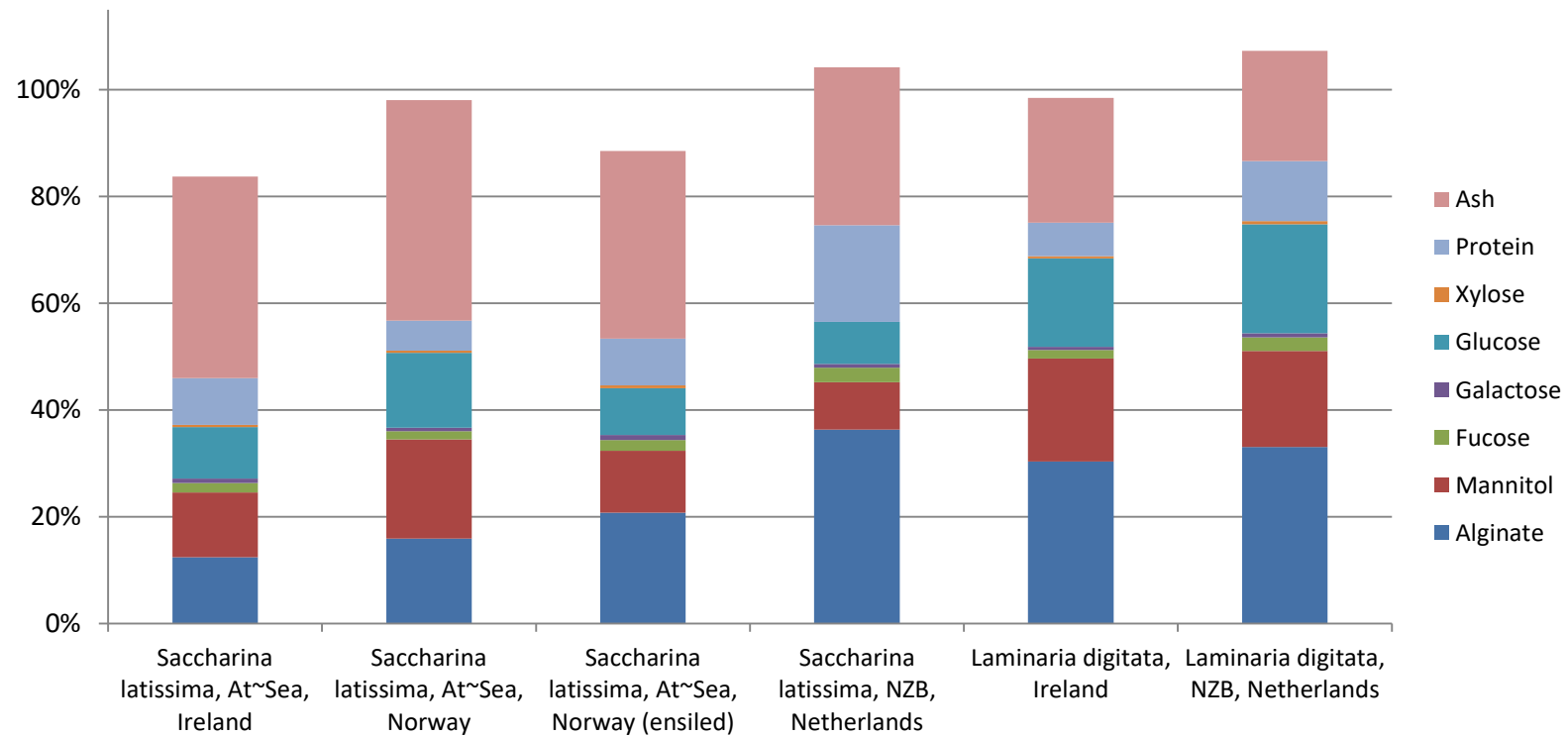
- › Aminoacid composition dependent on species
- › Amount dependent on season and location

Ash

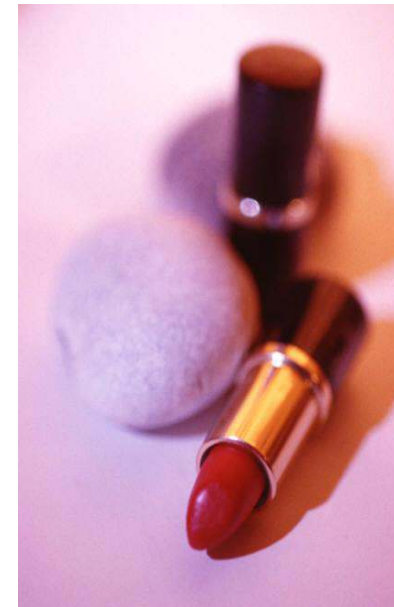
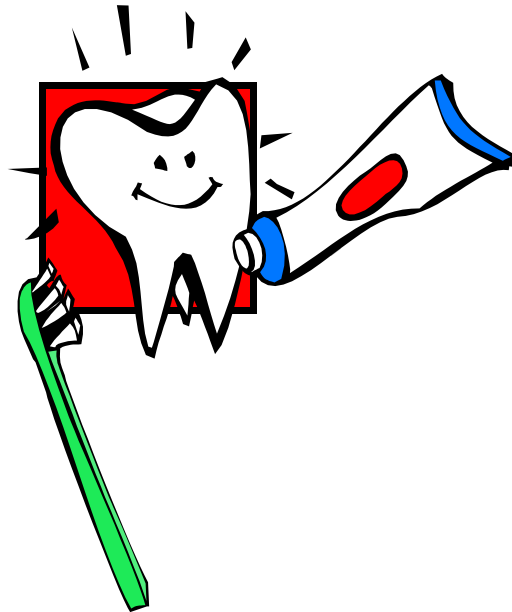
- › Species dependent
- › Amount dependent on season and location

Extreme differences between seasons

LOCATION LOCATION LOCATION



SEAWEED IN EVERYDAY PRODUCTS



SEAWEED IN FOOD

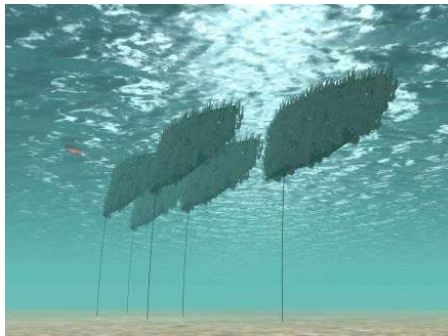


SEAWEED IN YOUR MOBILE



› SEAWEED CULTIVATION

SEAWEED CULTIVATION SYSTEMS UNDER DEVELOPMENT



SES



Inrada



Ocean Rainforest



Stichting NZB

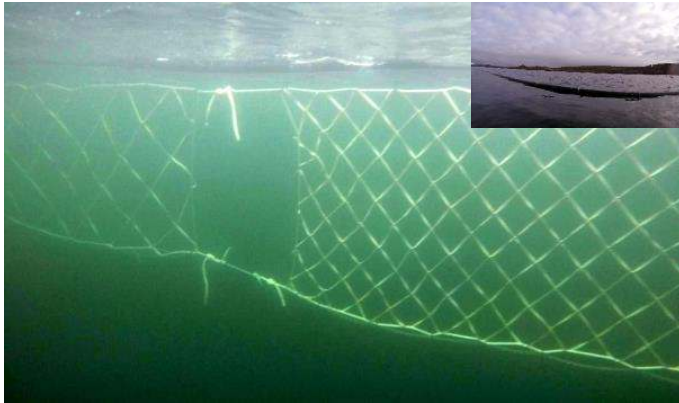


At~Sea technologies

SEAWEED MECHANISED WILD HARVEST



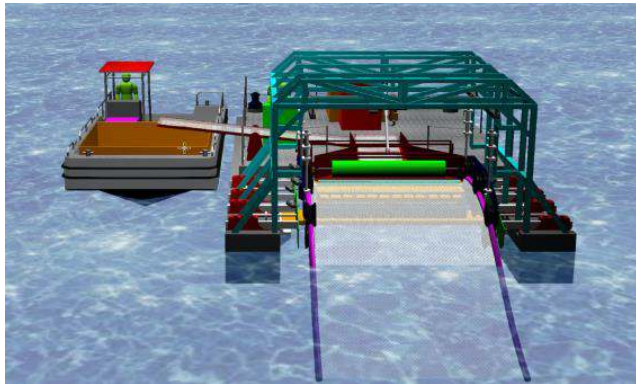
ADVANCED CULTIVATION IN SCOTLAND



DRYING THE HARVEST IN SCOTLAND (2017)



MECHANISED HARVESTING



ENSILING ON LAND



THE DUTCH SEAWEED PROGRAMME

- › Seaweed cultivation area 14,000 km² (cf. NL area of the North Sea @ 57,000 km²)
- › Integration with off-shore wind parks & (other) aquaculture operations
- › Theoretical energy potential up to 350 PJ_{th} (25 Mton dry biomass per year, 5,000 km²)
- › Report: ECN-C—05-008
- › Carrying capacity: ????



THE DUTCH SEAWEED PROGRAMME IS:



- Combines the 5 (now 4) applied research centres in the Netherlands with sea research centres
- Aims at developing a comprehensive integrated research agenda
- Starts with seaweed as food programme
- Covers diverse subjects such as spatial planning, multi-use of the sea, etc.
- Implemented in the National Programme (MMIP 12 D, English version available upon request)

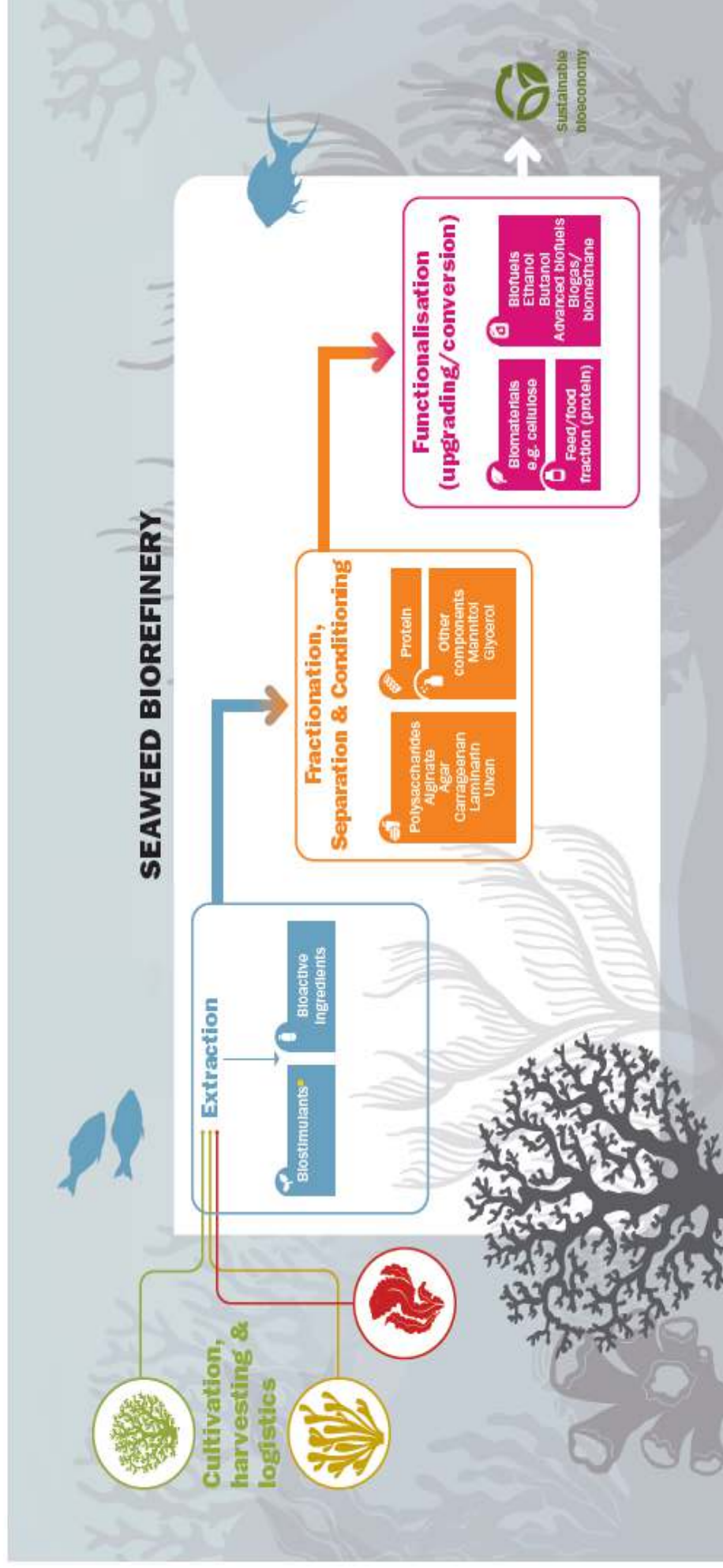
TOWARDS A 100 HA DEMO MULTI USE PRODUCTION UNIT

- › Practical implementation of the multi-use procedure
- › <https://www.noordzeeboerderij.nl/en/projects/multi-use-procedure>
- › Produce sufficient seaweed for large scale product demo
- › AND
- › Accurate determination of the effects on the environment
- › Synergies with the other users
- › Seaweed for materials, chemicals and energy carriers in the later presentation

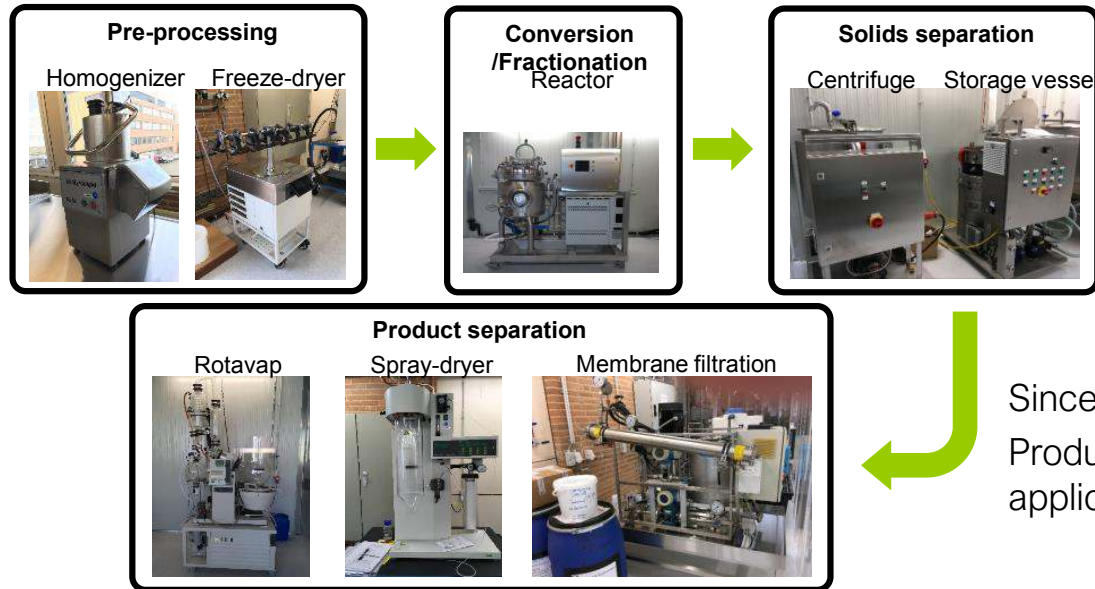


Lacroix, Denis & Pioch, Sylvain, 2011

FROM SEAWEEED TO VALUABLE CHEMICALS, FOOD AND FUELS



SEAWEED BIOREFINERY LAB – PETTEN, NL



Since November 2019

Production facility for fractions (intermediates) from seaweeds for application tests:

- › Seaweed fractionation 100 L autoclave reactor – Mannitol stimulants, enzymatic hydrolysis, sugars
- › Modular / flexible unit.
- › From brown, red and green seaweeds to monomeric sugars (later expansion to co-products).
- › 1-5 kg scale demonstration – Seaweed hydrolysis, sugar conditioning, glucoside esters production, product purification

Brown	Green	Red
Alginate (uronic acids)	Cellulose (glucose)	Carrageenan (S-galactose)
Fucoidan (S-fucose)	Ulvan (rhamnose-uronic acids)	Floridoside (gal-glycerol)
Laminarin (glucose)		Xylan (xylose)

<https://www.youtube.com/watch?v=Yb9JApeb7Bw>

PRODUCING SUGAR SYRUPS

Day 1 Reaction in vessel



Slurry = 100L
Start = 5 kg dry seaweed

Day 2-3 Centrifugation/ filtration (>25 μ m)



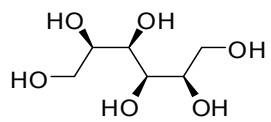
Solid recovery $\approx$ 1.5 kg dry
Liquid recovery $\approx$ 80 L

Day 4 Membrane filtration

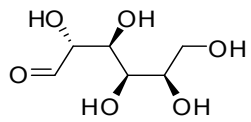


Sugar concentration $\approx$ 200%
No increase of K/Na content

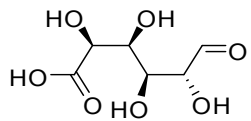
ULVA (GREEN SEAWEED)



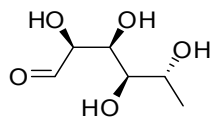
mannitol



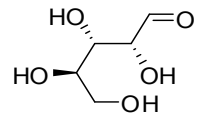
glucose



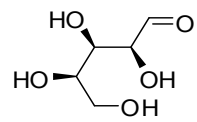
glucuronic acid



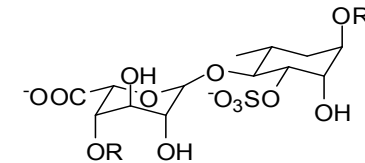
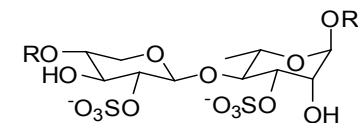
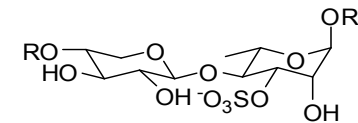
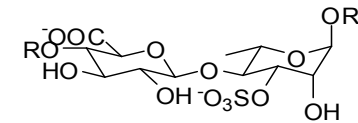
rhamnose



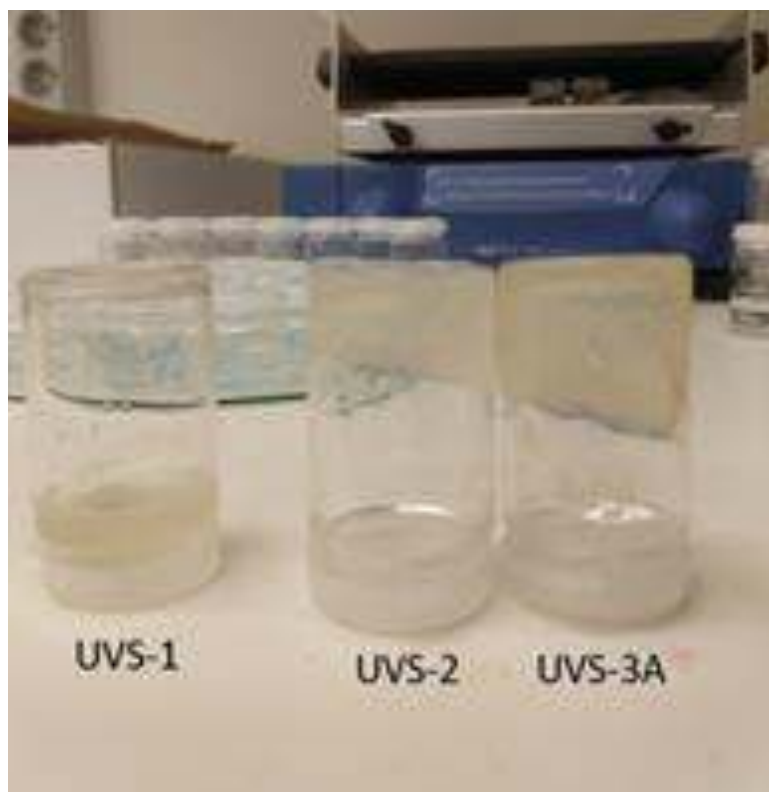
xylose



arabinose



Ulvans



NANO CELLULOSE



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<http://www.herewear.eu/>
<http://www.macrofuels.eu>
<http://www.macrocascade.eu>
<http://www.noordzeeboerderij.nl>
<https://port4innovation1.nl/>

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