MELISSA
MICRO-ECOLOGICAL LIFE SUPPORT SYSTEM ALTERNATIVE

WAGENINGEN UNIVERSITY & RESEARCH

CREATING A CIRCULAR FUTURE

A novel multiproduct pathway towards algal food ingredients

Deep eutectic solvents for the processing of seaweed

Kazbar Antoinette
Antoinette.kazbar@wur.nl

Seaweed as a source of food ingredients

Eucaryotic	Multicellular	Macroscopic	Marine

Red Macroalgae

Eucheuma and Kappaphycus

Gracilaria

Agars and Carrageenans
Color due to phycobiliproteins:
Phycocyanin and Phycoerythrin

Green Macroalgae

Ulva sp.

Cladophora

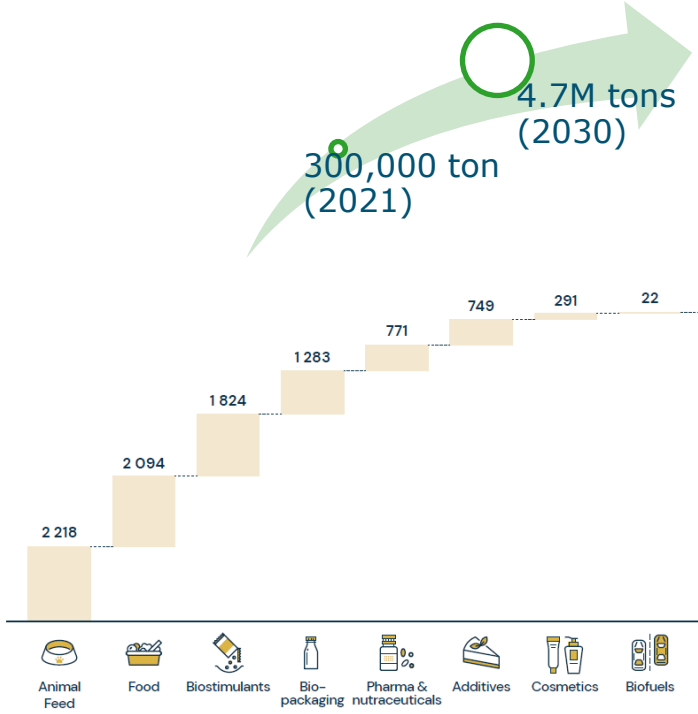
Ulvans
Color due to
Chlorophyll a and b

Brown Macroalgae

Saragassum

Laminaria

Alginates and Fucoidan
Color due to
Fucoxanthin



European demand for seaweed products in 2030 in million euros (Seaweed of Europe, 2020)

Seaweed as a source of food ingredients

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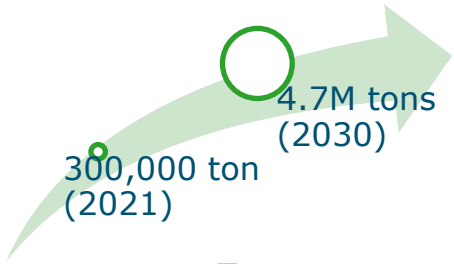


Seaweed	Class	Carbohydrate composition	Total carbohydrates (%)	Lipid (%)	Protein (%)	Ash (%)	Sugars released by hydrolysis	Sugar composition
Gelidium amansii	Red	Agar, Carrageenan, Cellulose	75.2–83.6	0.6–1.1	12.2–18.5	3.3–5.7	34.6–67.5	Glucose. Galactose
Laminaria japonica	Brown	Laminarin, Mannitol, Alginate, Fucoidan, Cellulose	51.9–59.5	1.5–1.8	8.1–14.8	30.9–31.5	9.6–37.6	Glucose, Mannitol
Sargassum fulvellum	Brown	Laminarin, Mannitol, Alginate, Fucoidan, Cellulose	39.6	1.4	13	46	9.6	Glucose, Mannitol
Ulva lactuca	Green	Starch, Cellulose	54.3	6.2	20.6	18.9	19.4	Glucose
Ulva pertusa	Green	Starch, Cellulose	65.2	2.6	7.0	25.2	59.6	Glucose

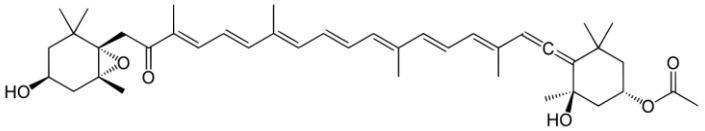
Current seaweed processes (Alginate)

Seaweed

Formaldehyde

Pigments
Phenolic compounds

Fucoxanthin



Pre-treated Seaweed

Sodium carbonate solution

Alkaline extract

Separation

Seaweed residue

Sodium alginate solution

Calcium chloride

Acid

Calcium Alginate fibers

Alginic acid gels

Multi-Stage Process

Acid

Alginic acid fibers

Dewatering alginic acid

Sodium carbonate

Sodium carbonate

Sodium alginate

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Need to innovate...

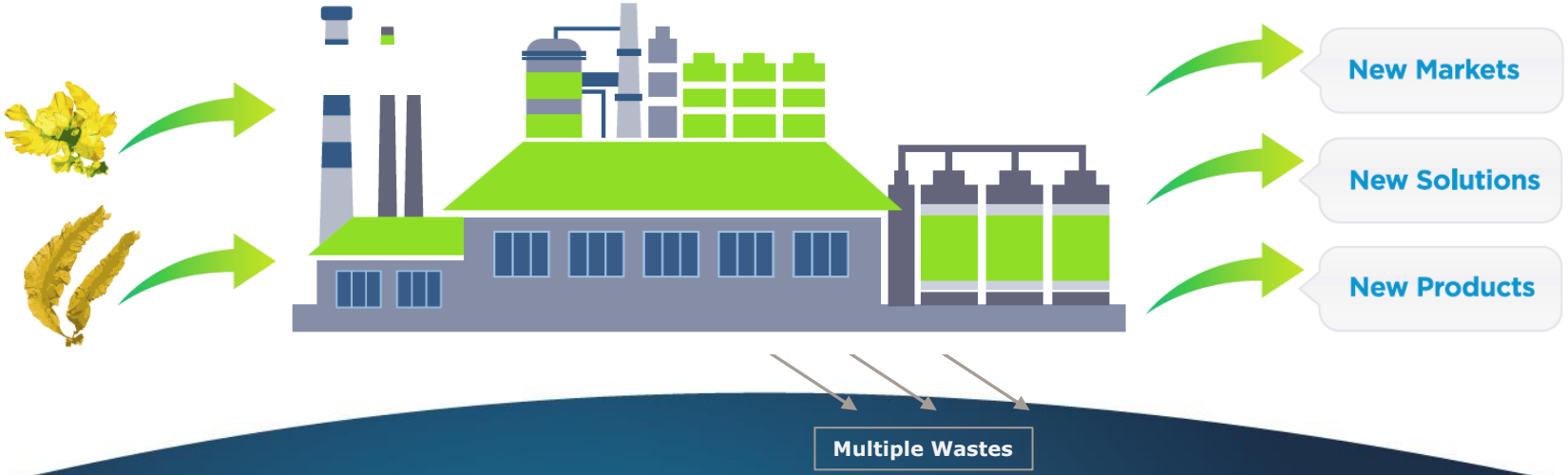
Chemical or Mechanical treatments

Solvent Extraction

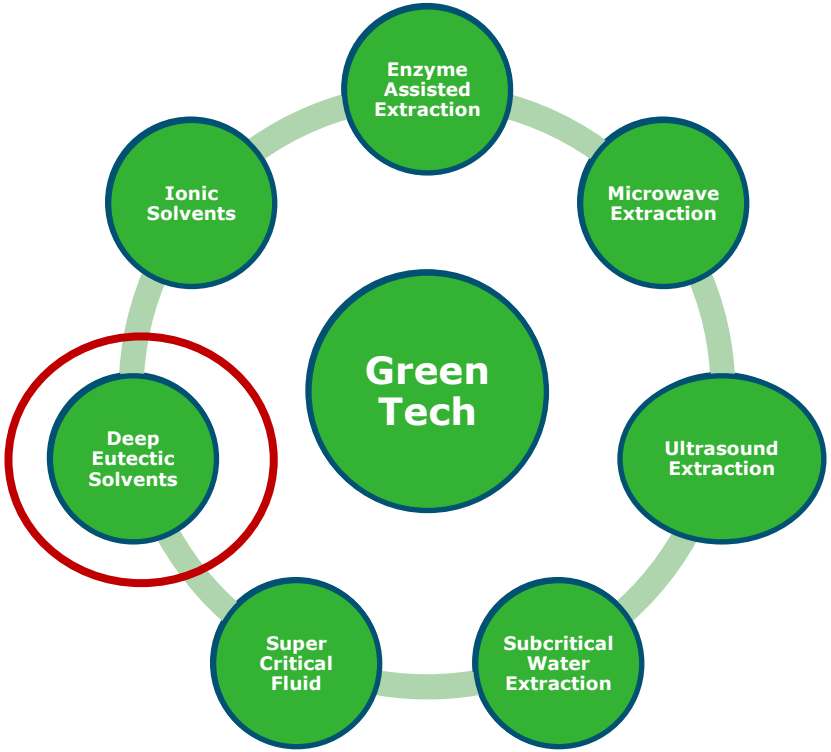
Focus on one single product

"Green Technologies"

Multi-product

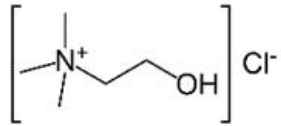


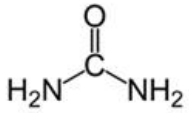
Novel technologies



What is Deep Eutectic Solvents

- 1 Choline chloride + 2 Urea = ChCl-Ur (1:2)





Mp = 302 °C

Mp = 575 °F

Mp = 133 °C

Mp = 271 °F

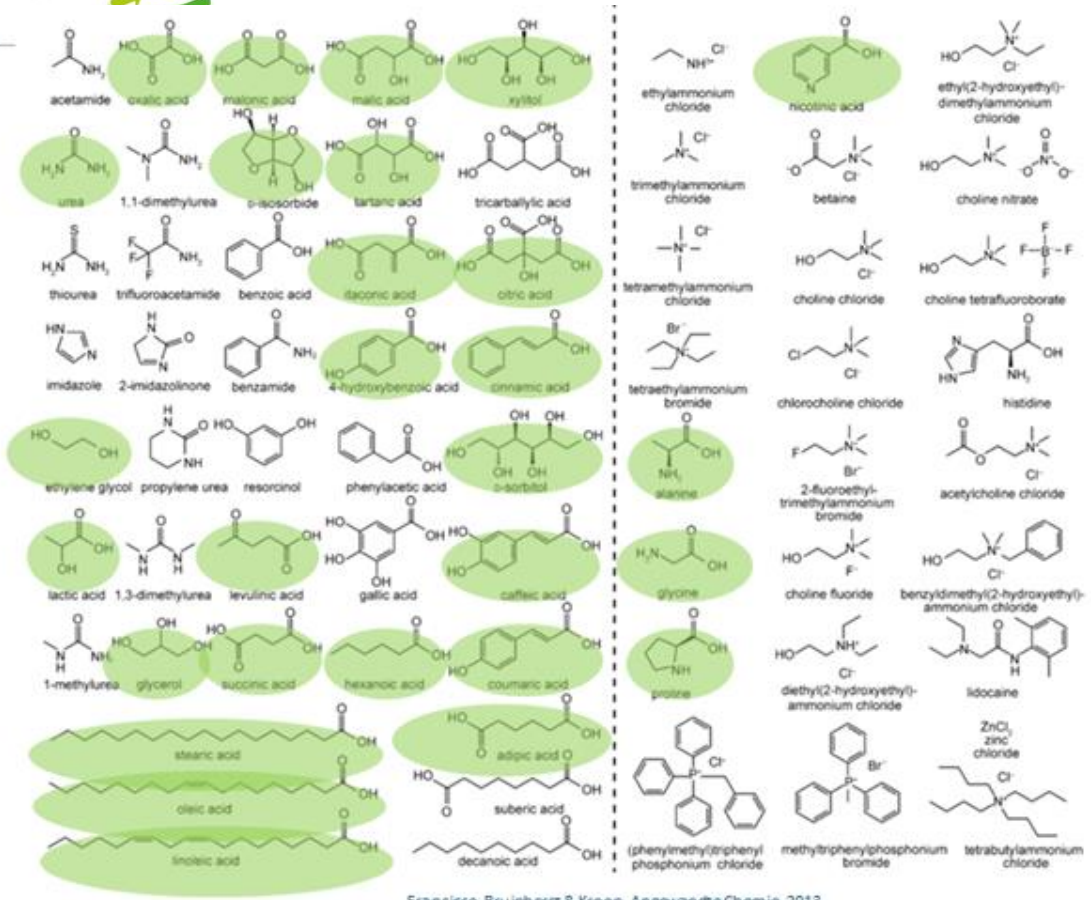
Mp = 12 °C

Mp = 56 °F

Other compounds:

Polyols (glycerols, sugars), carboxylic acids (lactic acid, fatty acid), amino acids, terpenoids (mentol, thymol, etc...

Some possible combination



Francisco, Bruinhorst & Kroon, Angewandte Chemie, 2013

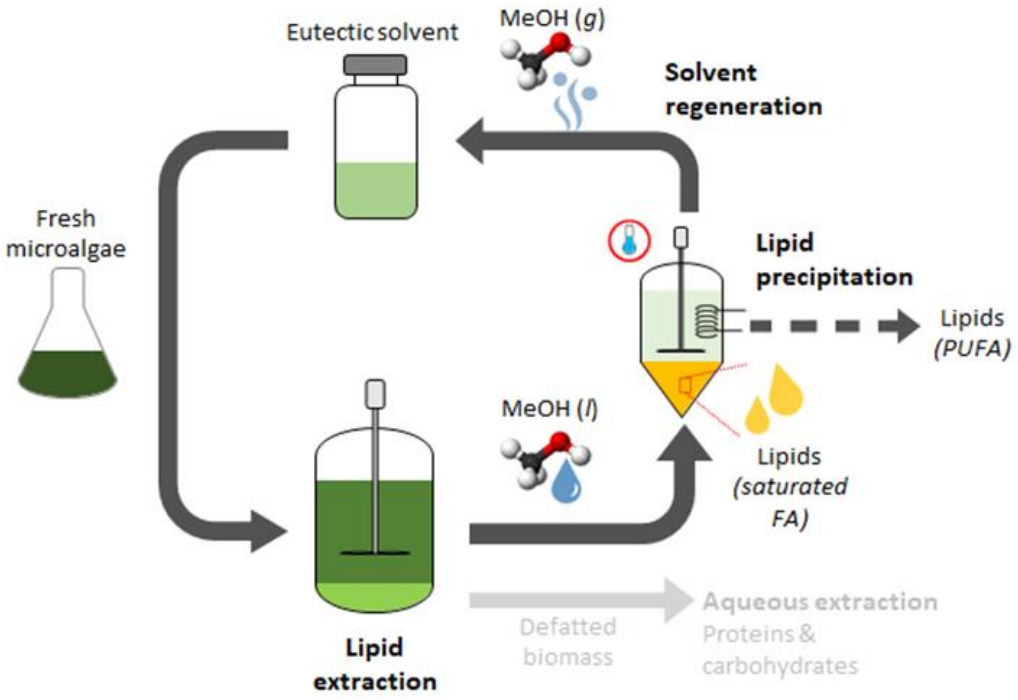
Other compounds:

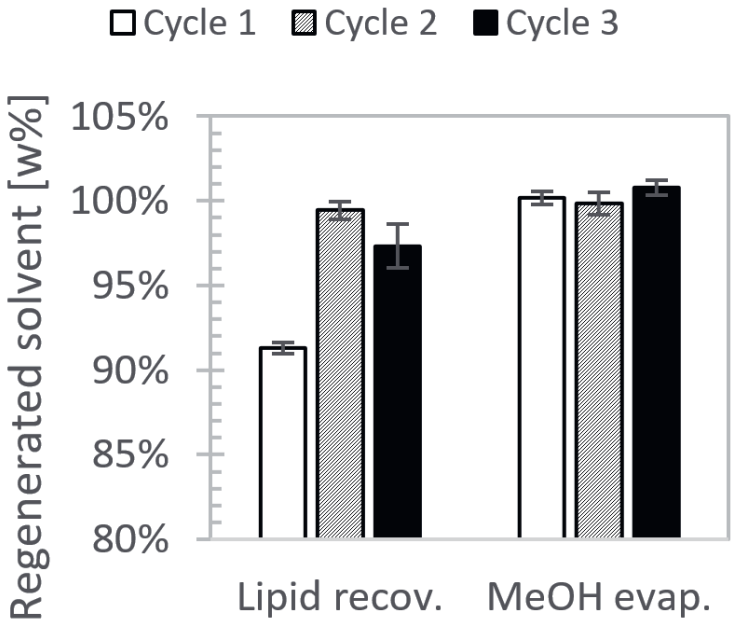
Polyols (glycerols, sugars), carboxylic acids (lactic acid, fatty acid), amino acids, terpenoids (mentol, thymol, etc...

Novel technologies

- Is it efficient?
- Is it feasible?
- Scalable? Any bottlnecks?
- Any impact on the product quality?

DES-based microalgae extraction





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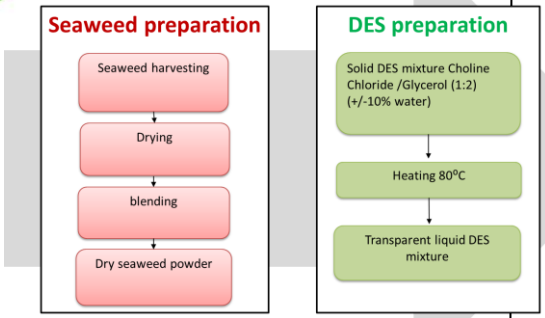
DES-based seaweed extraction

Seaweed preparation

- Seaweed harvesting
- Drying
- blending
- Dry seaweed powder

DES preparation

- Solid DES mixture Choline Chloride /Glycerol (1:2) (+/-10% water)
- Heating 80^{o}C
- Transparent liquid DES mixture



Suspension of 500g dry seaweed in 10 gram DES

Incubation: 1H at 50 - 80˚C

Centrifugation

Liquid: DES + residue

Solid: κ-Carrageenan

Recycle DES

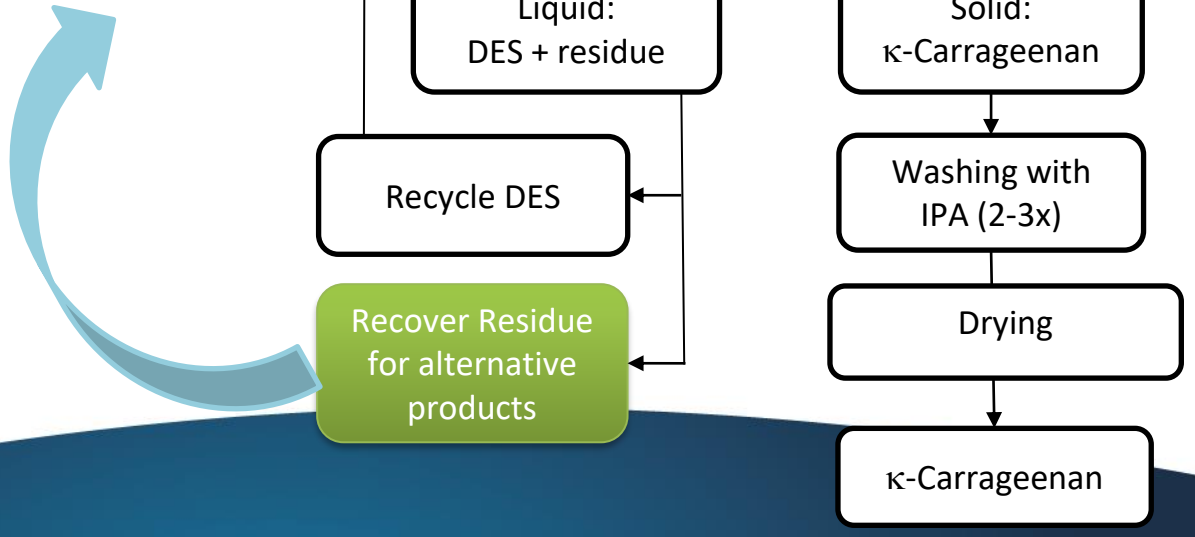
Recover residue for alternative products

Washing with IPA (2-3x)

Drying

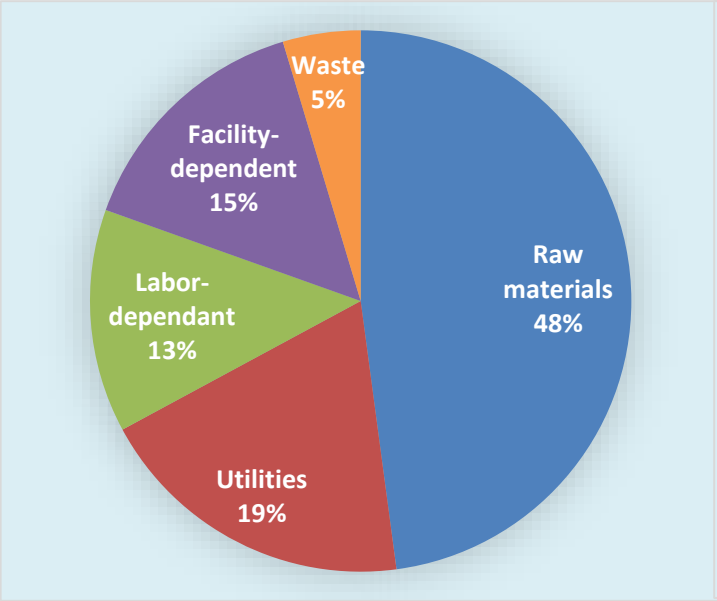
κ-Carrageenan

E. cottonii		
Carrageenan market ton/year	60 000	Proteins in seaweed
biomass need Dry (ton/year)	**300 000**	**4-20%**
Proteins (ton/year)	**30 000**	



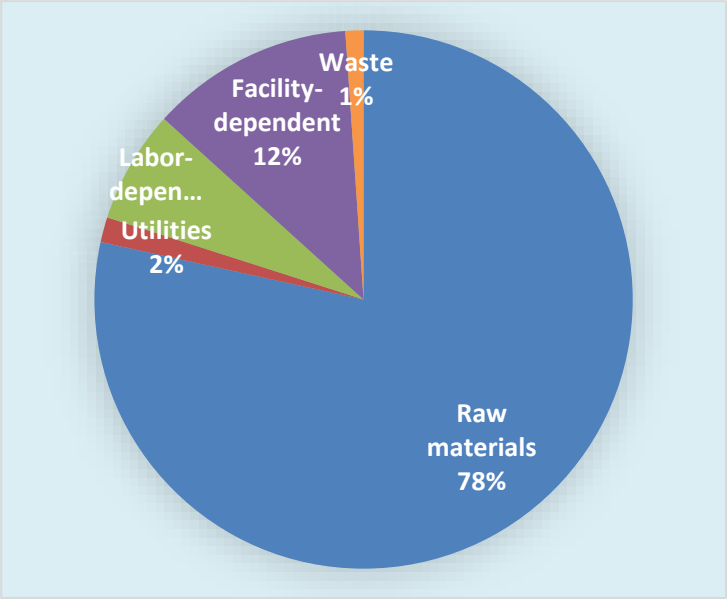
Techno-economics

7€/kg carrageenan



Conventional Method (Cargill)

5.5€/kg carrageenan



DES (our study)

Novel technologies

- Is it efficient?
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  - Scalable? Any bottlnecks?
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Novel technologies

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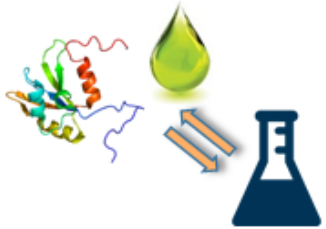
DES research

1. Extraction & back-extraction

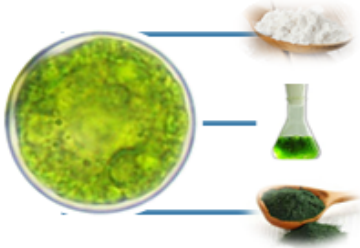


- Screening for DES
- Solubility of model compounds
- Back-extraction

3. Understanding physicochemical properties

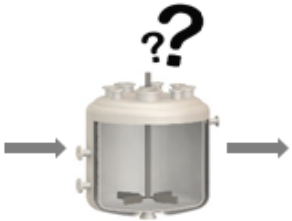
- Molecular interaction – physicochemical prop.
- Optimization: viscosity, water stability, etc.

2. DES-based Seaweed extraction



- Increasing complexity
- Effect on cell wall
- Selectivity and yield

4. Extraction system design

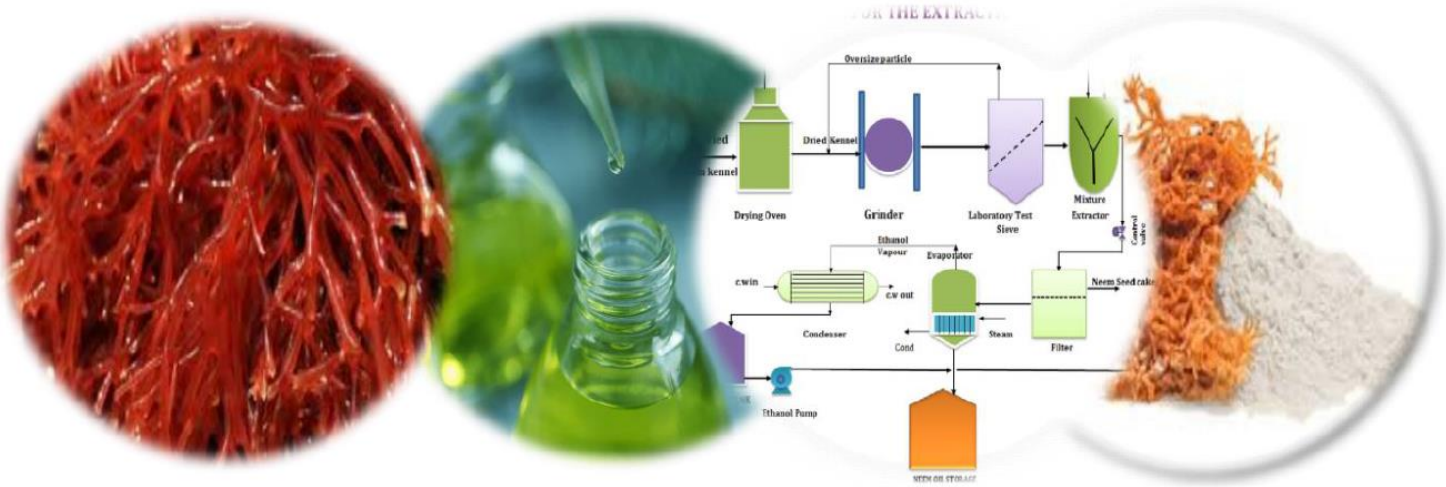


- Diffusivities of biomolecules
- Non-ideal system
- Design to improve mass transfer
- Scale up
- Techno-economic analysis

SeaSolv

Multi-product biorefinery of seaweed using green solvents

Dutch Research Council (NWO), NWO Domain, Applied and Engineering Sciences (TTW)



SeaSolv concept

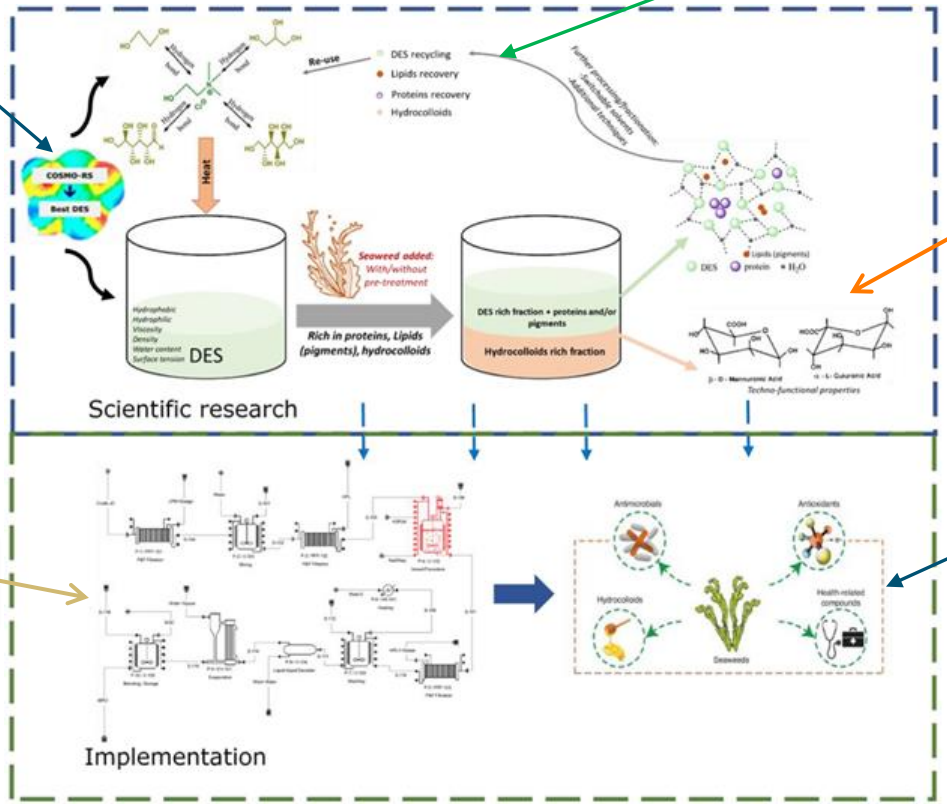
DES recovery

DES screening

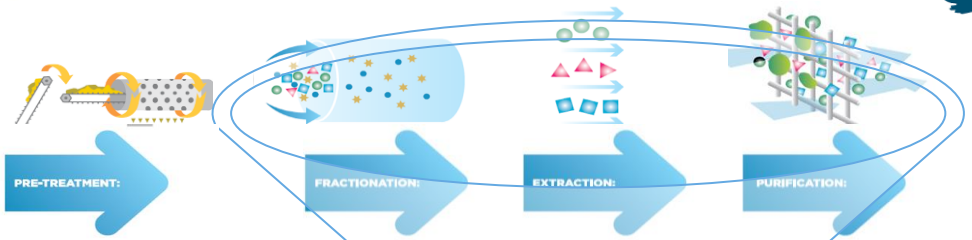
Seaweed-metabolite extraction

Techno-economics

Product formulation



SeaSolv

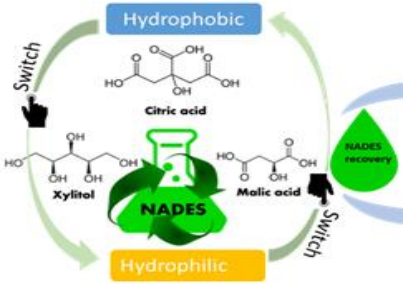


Novel Multi-steps biorefinery

Current innovations

SeaSolv innovation

One-step biorefinery



Natural Deep eutectic solvents (NADES)

How?

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MICRO-ECOLOGICAL
LIFE SUPPORT SYSTEM
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THANK YOU.

Kazbar Antoinette
Antoinette.kazbar@wur.nl

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