



Energy research Centre of the Netherlands

Economic perspectives of seaweed

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Economic perspectives of seaweed

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Why aquatic biomass?

- Land based biomass has limited potential
- Competition with food, feed, forestry and nature
- 50% of global biomass is aquatic
- Biomass is heavy so transport over land is expensive
- Aquatic biomass seems to be suitable to produce liquid and gaseous fuels



Scale similarity agriculture/aquaculture



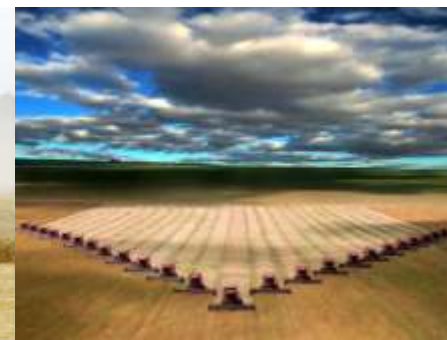
greenhouse horticulture



open field horticulture



farming



large scale farming

photo bioreactor



open pond aquaculture



seaweed farming

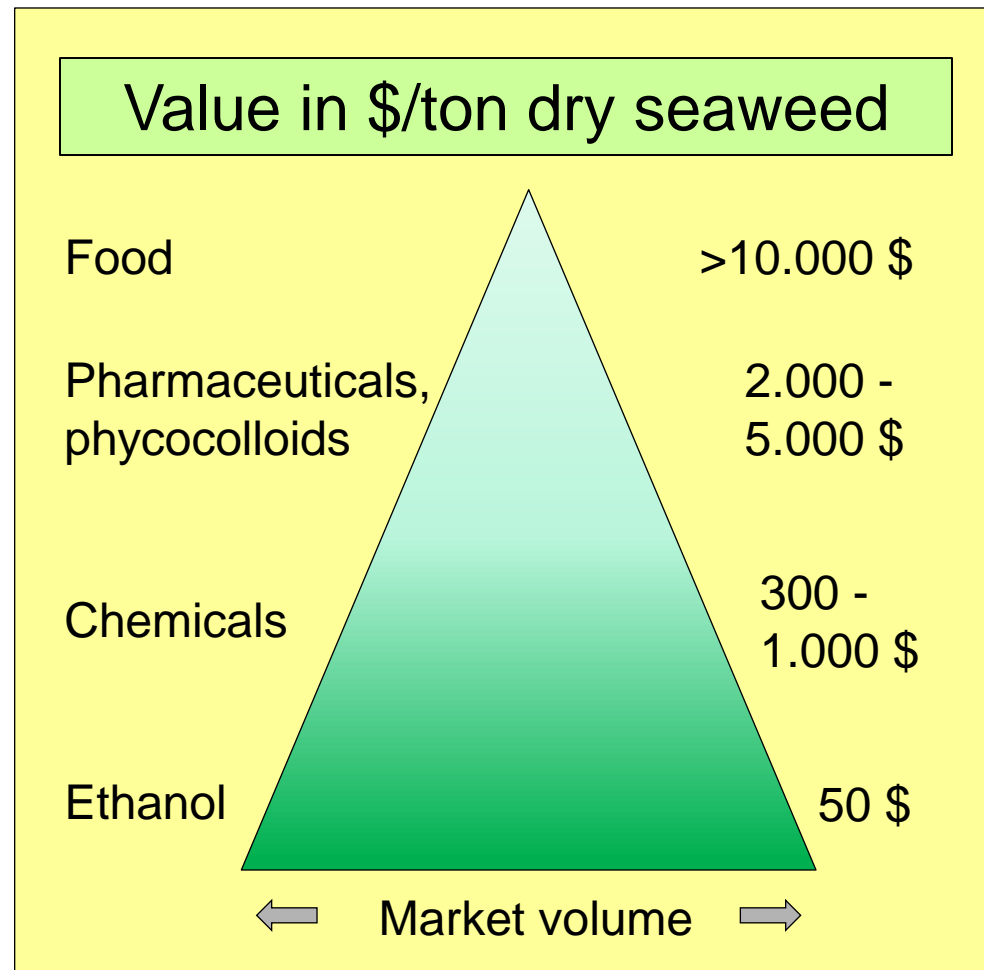


ocean farming



Production pyramid

- Low volume and high value or high volume and low value
- Commercial operations are now focusing on top and middle of the pyramid
- Energy production seems only possible in combination with other products
- Or on very large scale...



Aquatic biomass energy potential

Most feasible technical concepts	Area	Potential
Set 1: Land based open ponds for microalgae	Arid land in (sub) tropical zones (deserts) and close to coast (max 100 km)	90 EJ
Set 3: Horizontal lines for macroalgae	At existing infrastructure – f.e. offshore wind farms (up to 100 km offshore)	110 EJ
Set 5: Vertical lines for macroalgae	Near coast (max 25 km) in nutrient rich water	35 EJ
Set 6: Macroalgae colony	At open sea (biological deserts), up to 2000 km offshore	~6000 EJ
TOTAL		~ 6235 EJ

Source: Ecofys. World energy consumption: 480 EJ/yr

Macro algae (seaweed)

- Commercial activities in several countries
- First based on harvesting of wild seaweeds
- Now 90% cultivation (China, Japan)
- Labor intensive cultivation systems
- Extraction as conversion technology



Macro algae (seaweed)

- Current production aimed at food, food ingredients, fertilizer, etc.
- E.g. alginate, carrageenan and agar
- Total global market volume is 6 bln \$ and 10 mln ton fresh seaweed per year (2005).



Agar production (source: FAO)

Seaweed species North sea



*Laminaria
Saccharina*



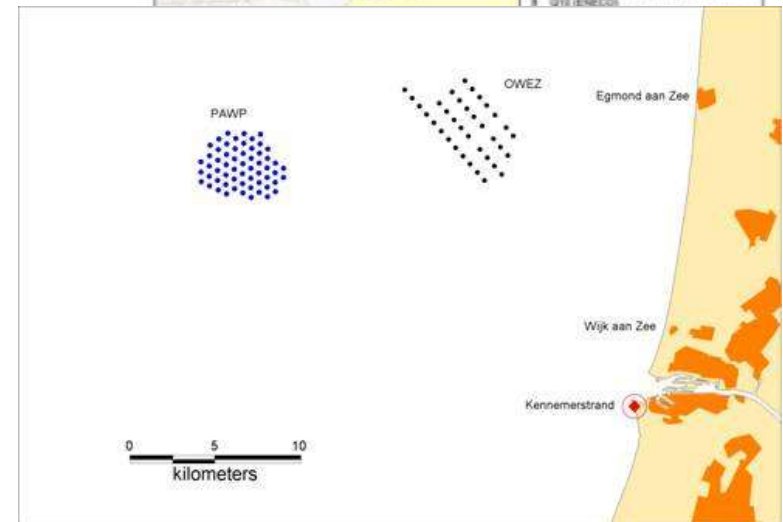
*Laminaria
Digitata*



Ulva

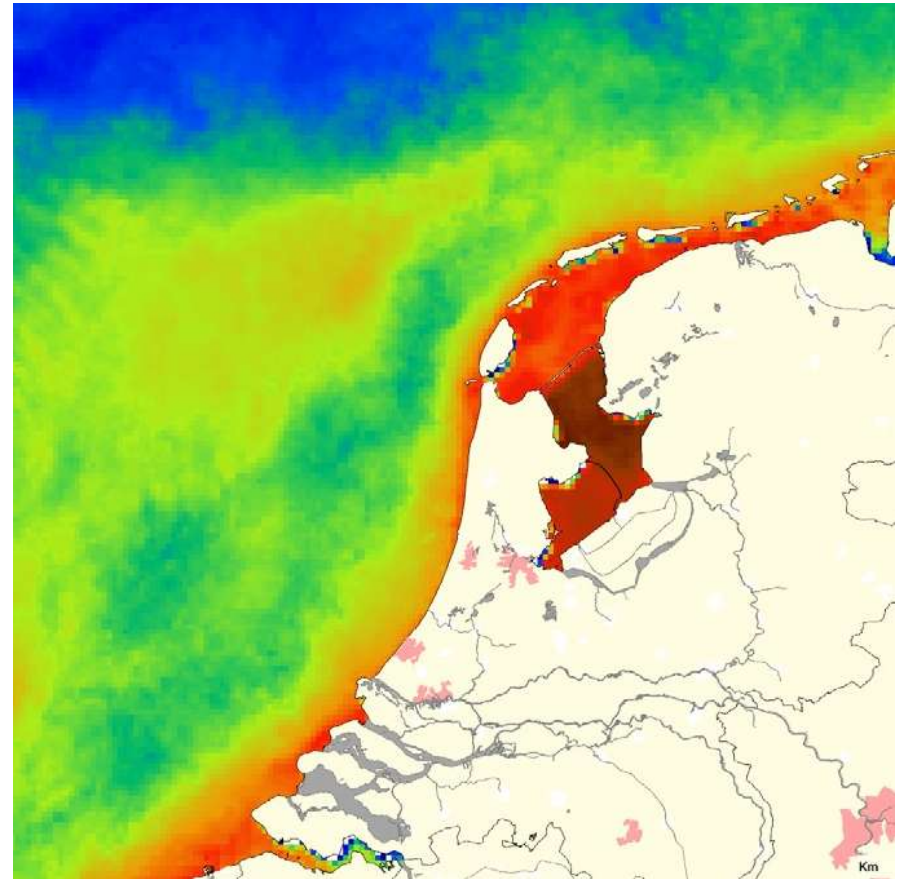
Seaweed at the North Sea

- Plans for combination with wind parks (Ecofys/Eneco/ECN)
- High yield per hectare necessary
- Construction must be stable in storms and high waves
- Bio refinery on shore
- No extra nutrition to avoid eutrophication
- Area is closed for all navigation



Seaweed at the North Sea

- Seaweed production without extra nutrients
- Dependant on present phosphates and nitrogen
- Map shows eutrophication, chlorophyll as indicator



Current projects

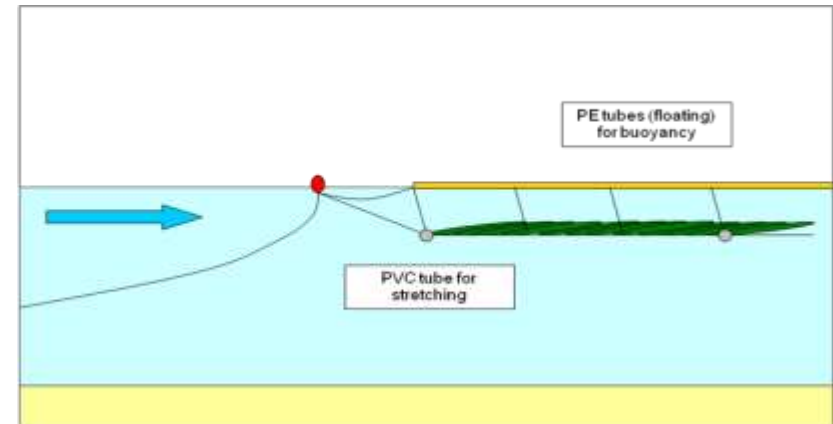
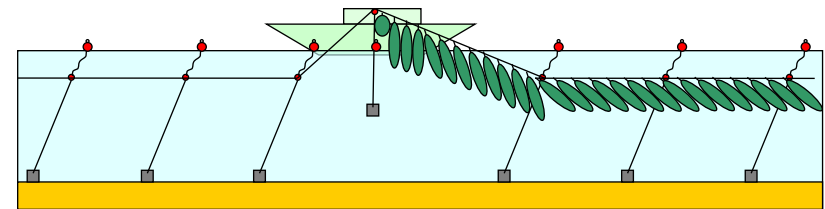
- EOS Seaweed Biorefinery, ECN (with WUR and others)
- SBIR proposals (Ecofys, ATO, Hortimare, Oonkay),
- EU-projects in Scotland, Ireland, France, etc.
- Large project with BA-Labs (Statoil, Dupont, Butamax, US-DOE, Chili)



Source: BA-lab.com

Cultivation systems

- Criteria:
 - Stable under sea conditions
 - Low investment costs
 - Full mechanization, high yield
 - High density
- Line systems
- Net systems

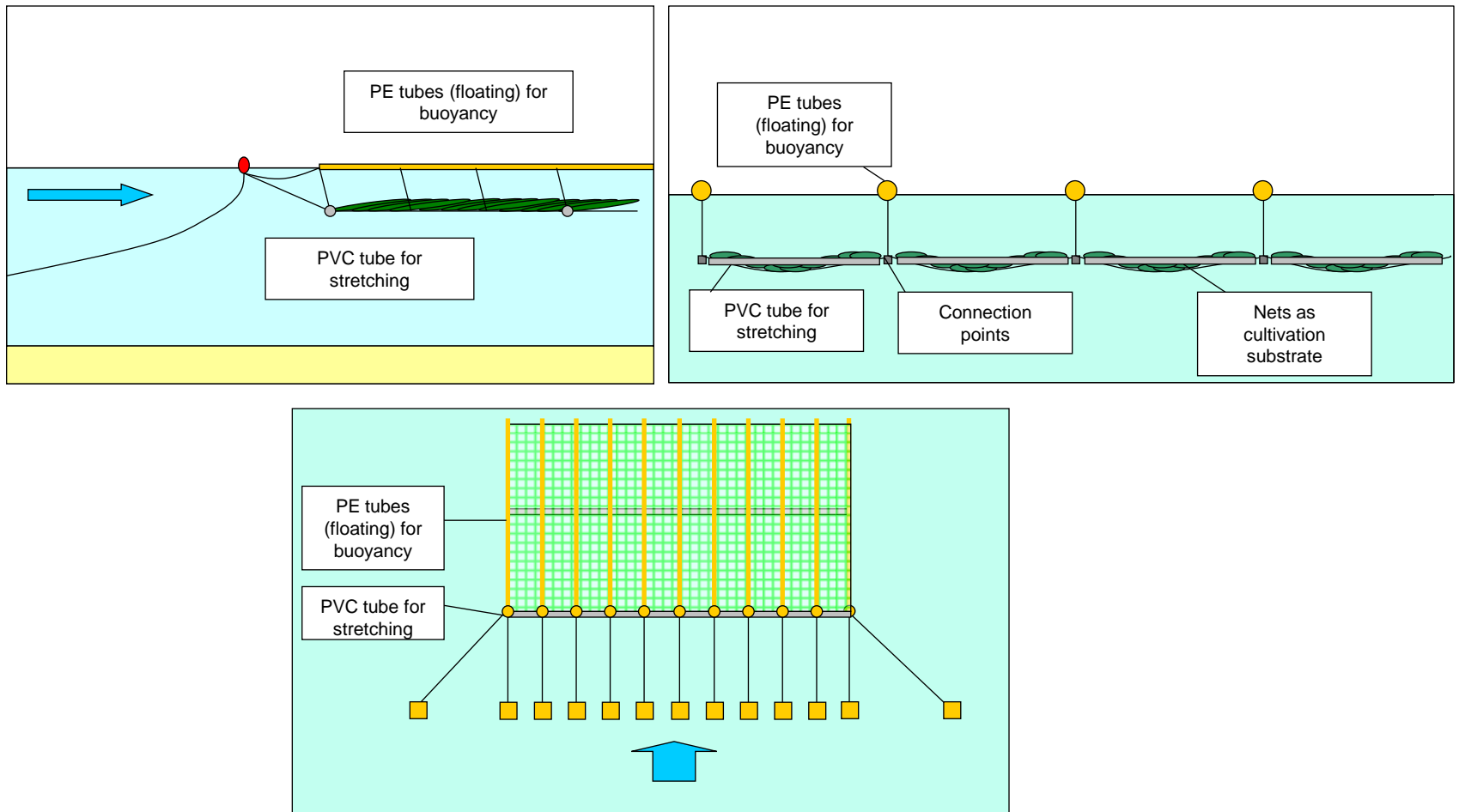


Proposed cultivation system

- Based on mussel catching facility
- Horizontal nets (10 x 50 m)
- On floating PE-pipes
- In tidal current

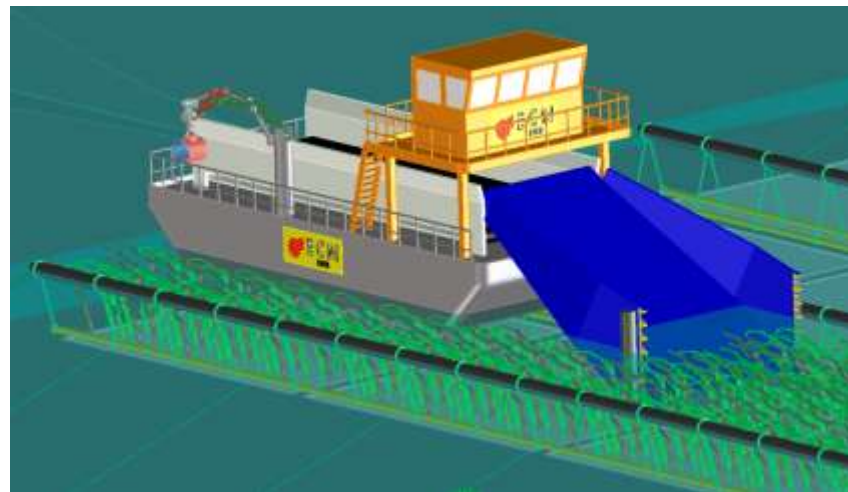


Proposed cultivation system

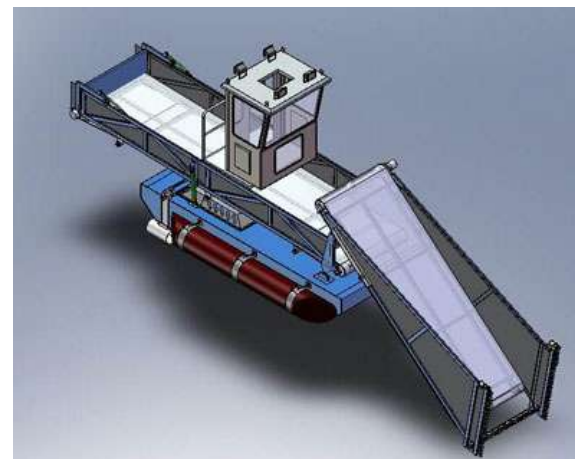


Harvesting

- Criteria:
 - High capacity
 - Low draft (< 2 meter)
 - Continuous operation
- Existing harvesters



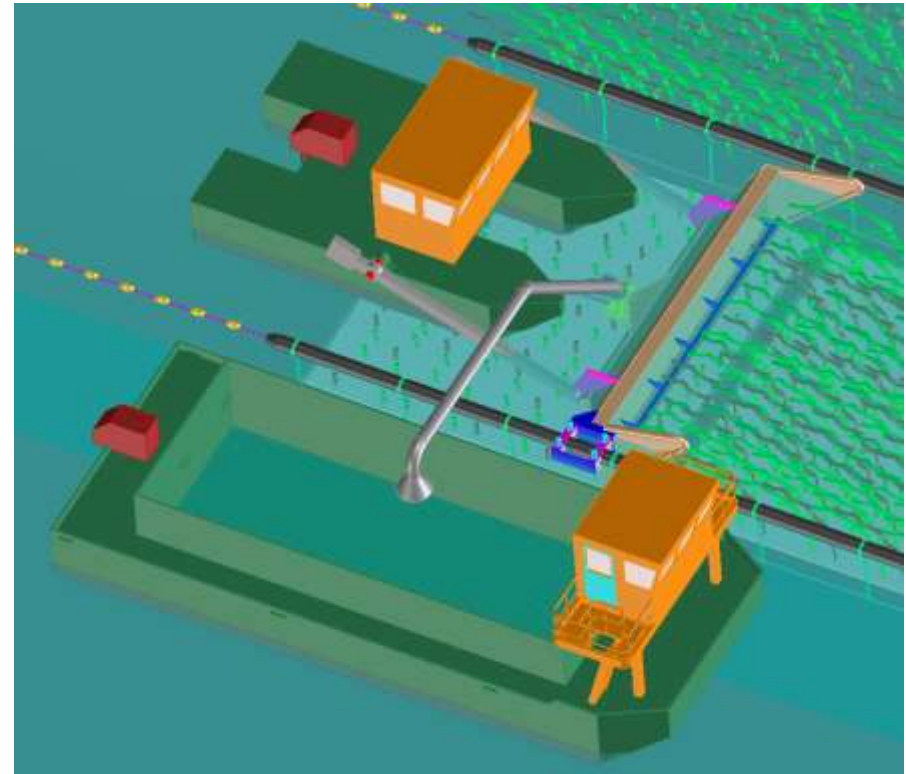
Source: WeedHarvesters.com



Source: RS Planering

Large scale harvester (proposed)

- System can work continuously
- Separate barge for transport to storage barge
- Seaweed is pumped with water to barge
- Excess water is flowing off from barge

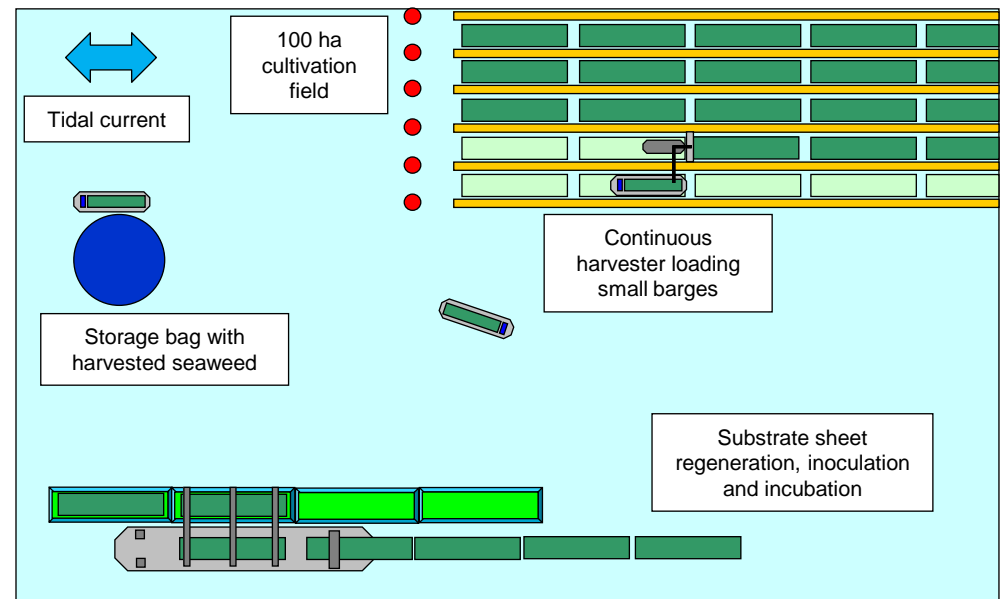


Cost development

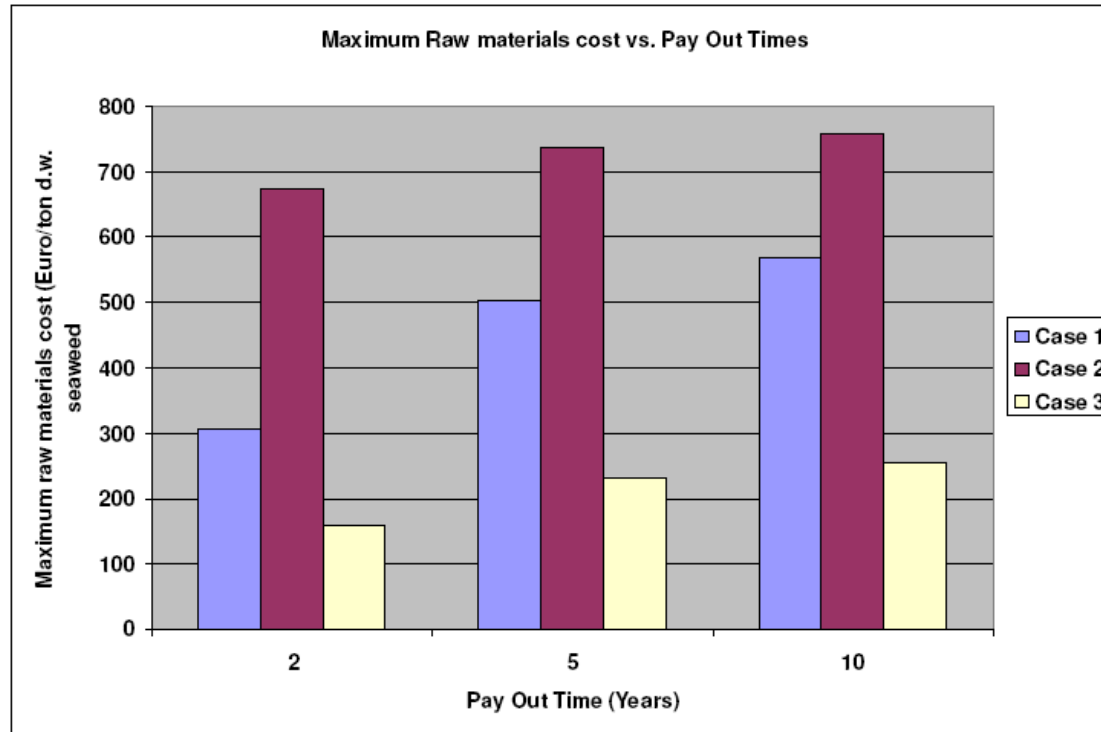
	100 ha	1.000 ha	10.000 ha	
Estimated yield	50	50	50	ton dm/ha/year
Production capacity	5,000	50,000	500,000	ton dm/year
Material	150	100	75	k€/ha
Installation	100	80	60	k€/ha
Total investment	25,000	180,000	1,350,000	k€
Pay Out Time (POT)	10	10	10	Years
Return on investment	10	10	10	%
Yearly CAPEX (rough)	2,750	19,800	148,500	k€/year
Operation and Maintenance	75	75	75	k€/year
Harvesting costs	104	39	39	€/ton dm
Cost price indication	669	437	336	€/ton dm

Innovative concepts

- Longer pipes = less anchors
- Inflatable tubes
- Closed substrate could allow for extra nutrients
- On sea storage
- On sea substrate preparation
- Etc...



Biorefinery concepts

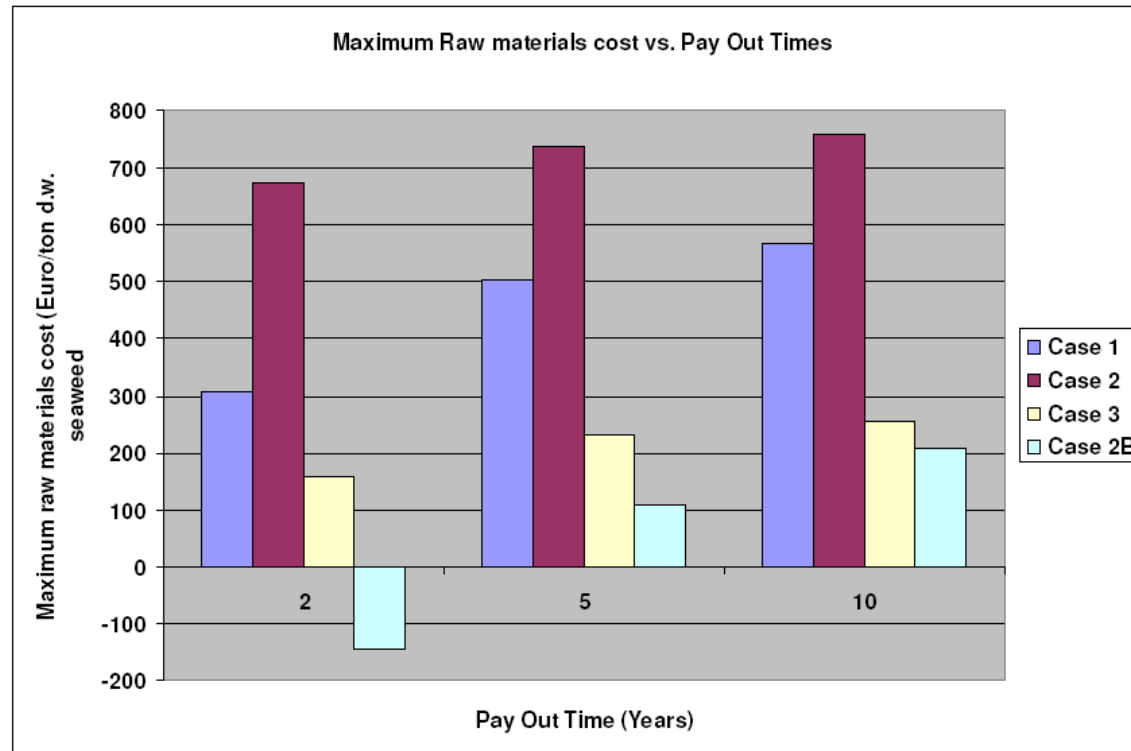


Case 1: Full Biorefinery

Case 2: Extraction of (too much) alginate and fertilizer en energy

Case 3: Simplified Biorefinery producing butanol and fertilizer

The value of seaweed biomass



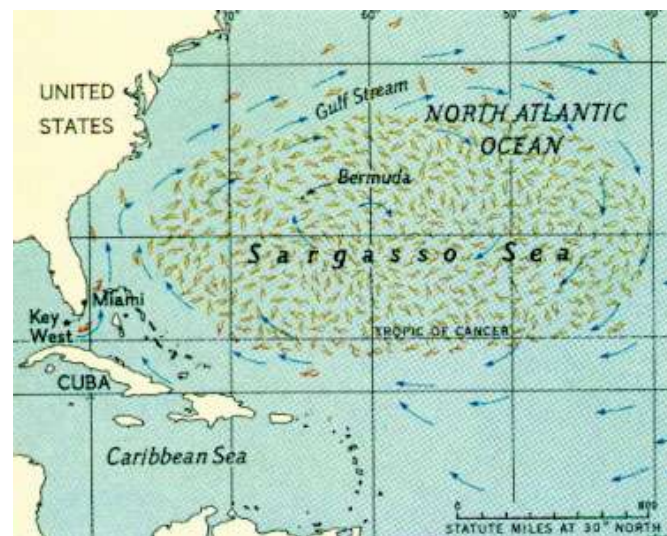
- Alginate case is too large for market
- Case 2b (down sized) less attractive
- Case 1 (full Biorefinery) allows for 500 €/ton dm seaweed

Economic perspectives

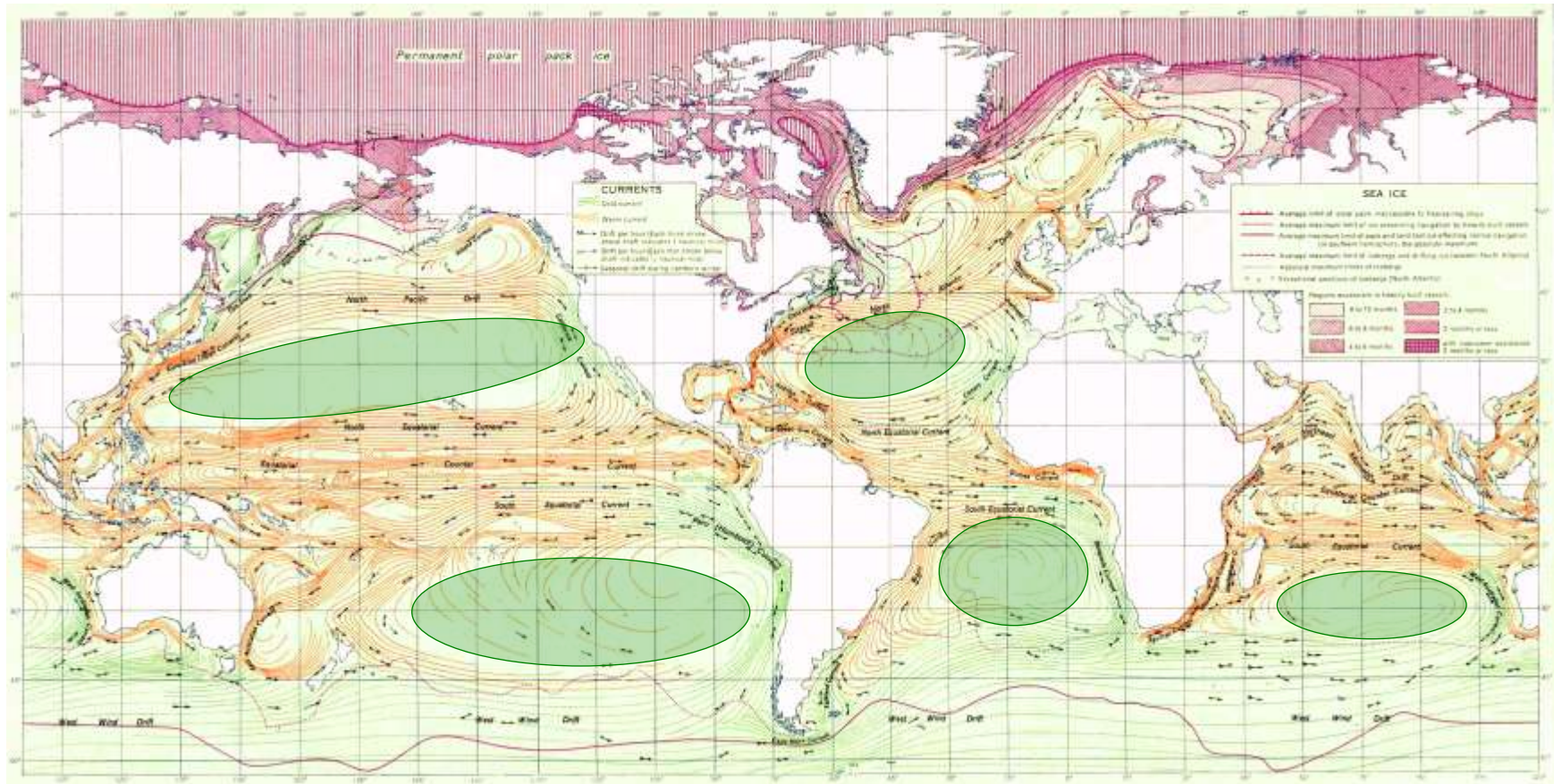
- Seaweed production on the North Sea could be profitable if:
 - Proposed concepts survive pilot and demonstration phase
 - The scale is at least 1.000 ha (1 wind park) per farm
 - The Biorefinery could serve several of these farms
 - Products and energy are produced
- Innovative concepts could reduce costs and increase productivity
- For large scale energy production Ocean Farming should be developed

Seaweed on ocean scale

- The Sargasso Sea seems a good location
- Sargasso seaweed has attractive properties (fast growing, floating)
- *Sargassum* uses micro algae to produce nitrogen
- Cost estimate floating cultivation ca. \$50/ton d.w. (Chynoweth)



Ocean potential: ~25.000.000 km²



Economics

Advantages

- No road transport involved until after refinery
- Large scale shipping and harvesting possible
- No costs for surface use
- No land owners
- Fast growing species
- Abundant CO₂ available

Disadvantages

- Ecological constraints
- International conventions
- No protected ownership
- Harsh conditions
- Long distances

Concluding remarks

- Seaweed research is growing
- Perspectives are promising
- Pilots and demonstrations are expected soon
- There are plenty opportunities for innovative investors



Laminaria Saccharina