ECN

Energy research Centre of the Netherlands

Ocean Seaweed Biomass

For large scale biofuel production

W.J. Lenstra, J.W. van Hal & J.H. Reith

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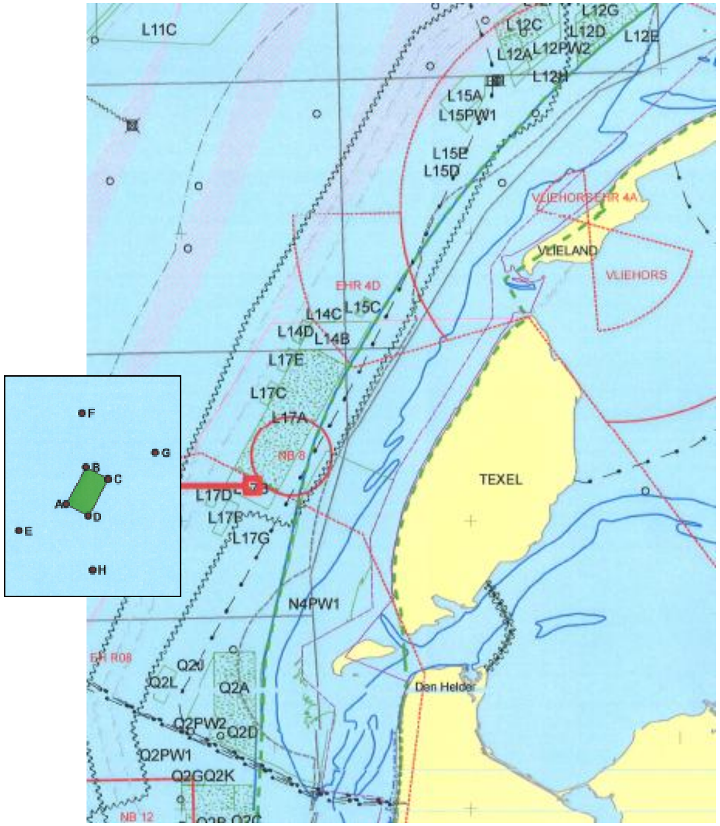
Aquatic biomass energy potential

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

ECN activities on seaweed

- Bio Offshore 2005
- EOS-LT seaweed biorefinery
- SBIR-1 feasibility study
- SBIR-2 pilot cultivation
- At~Sea Advanced textiles (FP7)
- Mermaid (Multi-use offshore platforms, FP7)
- Main interest of ECN is conversion to energy!



Scale similarity agriculture/aquaculture

greenhouse horticulture

open field horticulture

farming

large scale farming

photo bioreactor

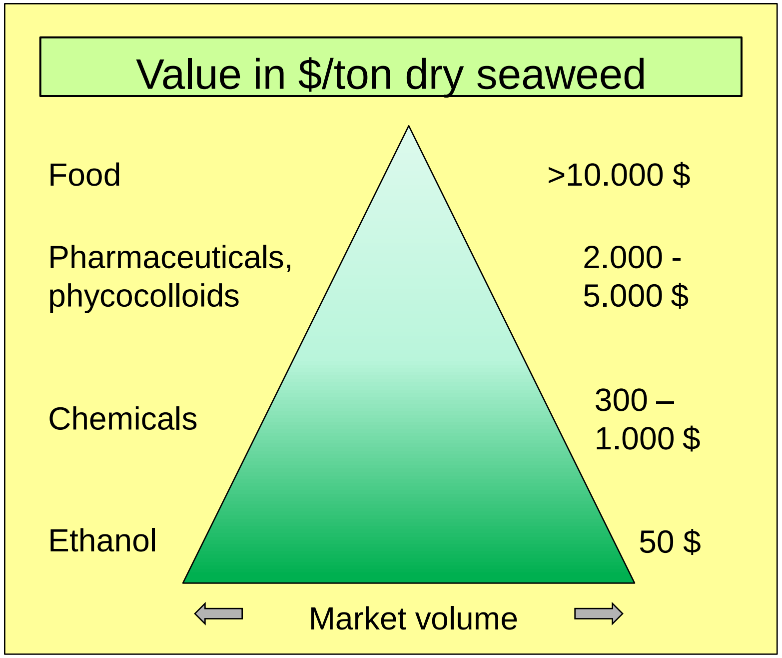
open pond aquaculture

seaweed farming

ocean farming

The role of aquatic biomass for energy production

- Micro algae are probably too valuable
- Seaweed in wind farms (North Sea) could be feasible combined with extraction of alginates
- Seaweed from ocean farms seems most promising for large scale biofuel production



Many ocean farm concepts proposed

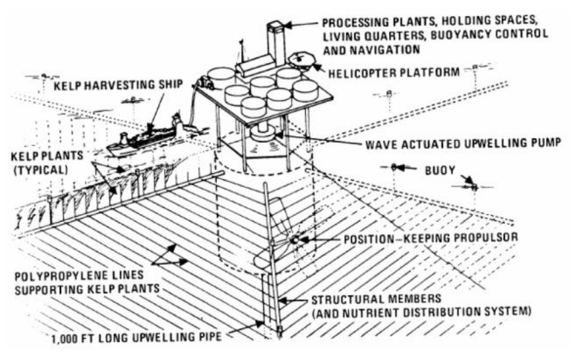
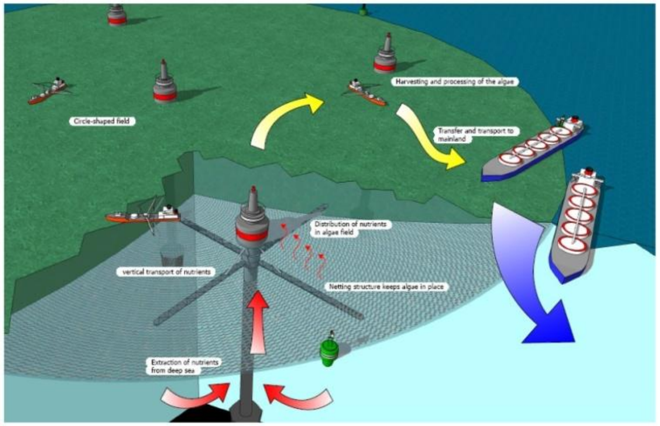
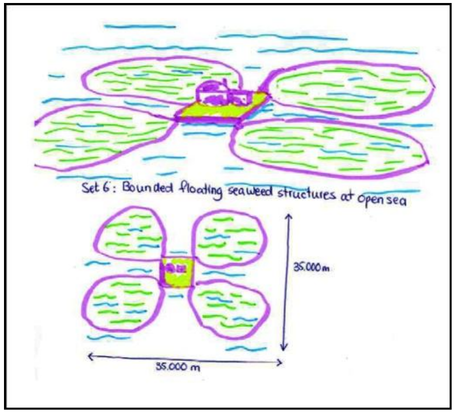


Figure 3: Conceptual design of a 405 ha (1,000 acre) ocean food and energy farm unit. (Leese, 1976)

Leese, 1976

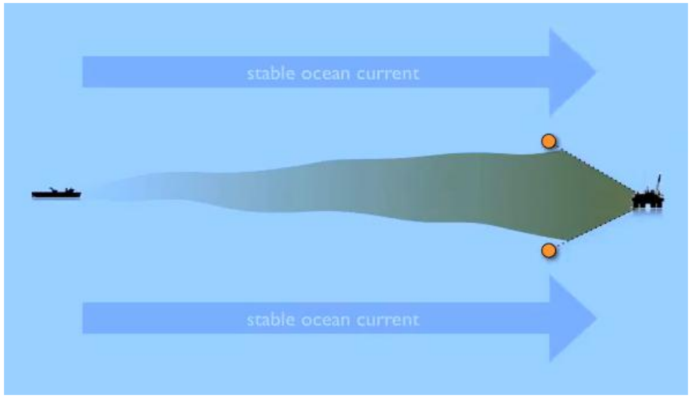


TU Delft, 2008



Ecofys, 2008

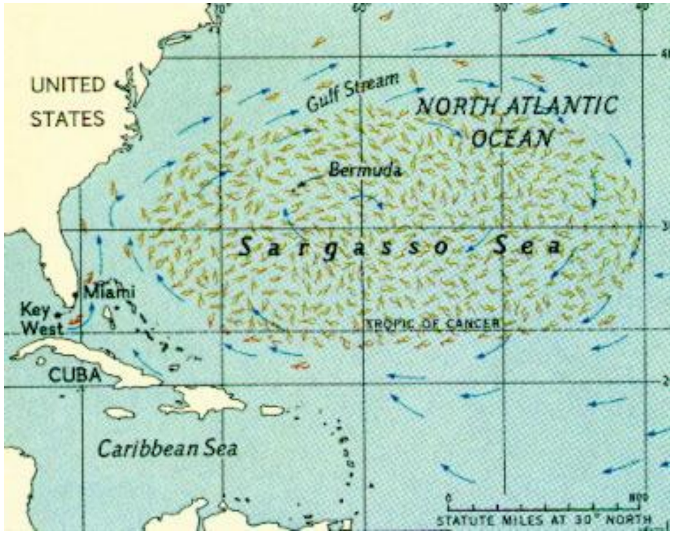
ECN, 2009



Kaare Baekgaard, kb@idesign.li

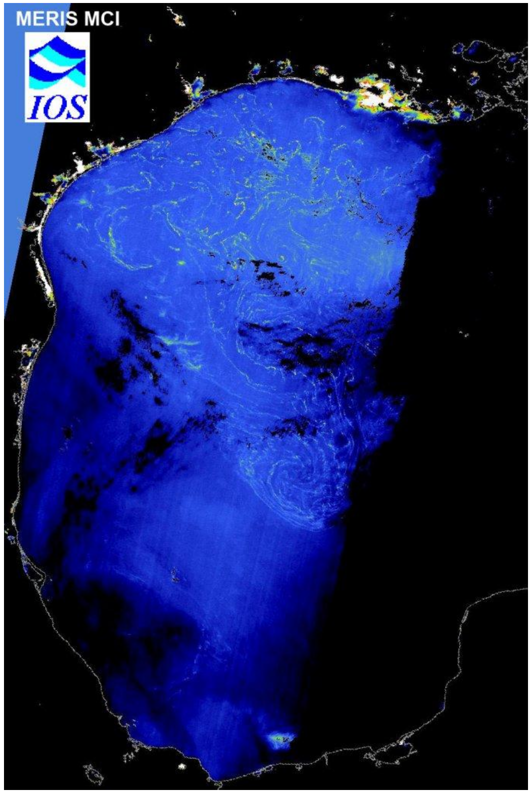
ECN proposal

- The Sargasso Sea as location
- Not much current, waves and storms
- Sargasso seaweed has attractive properties (fast growing, floating, global occurrence)
- *Sargassum Natans* uses nitrogen fixation by an associated epiphyte or cyanobacteria (Philips et al, 1986)



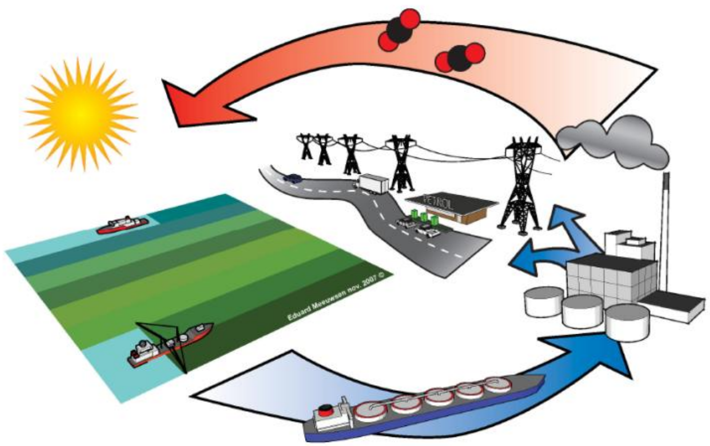
Sargassum Natans

- Sargassum seaweed is now a pest (on shores)
- It forms also a good habitat for fish and many other species
- It can be monitored by satellite (MERIS)



Ocean farm concept ECN

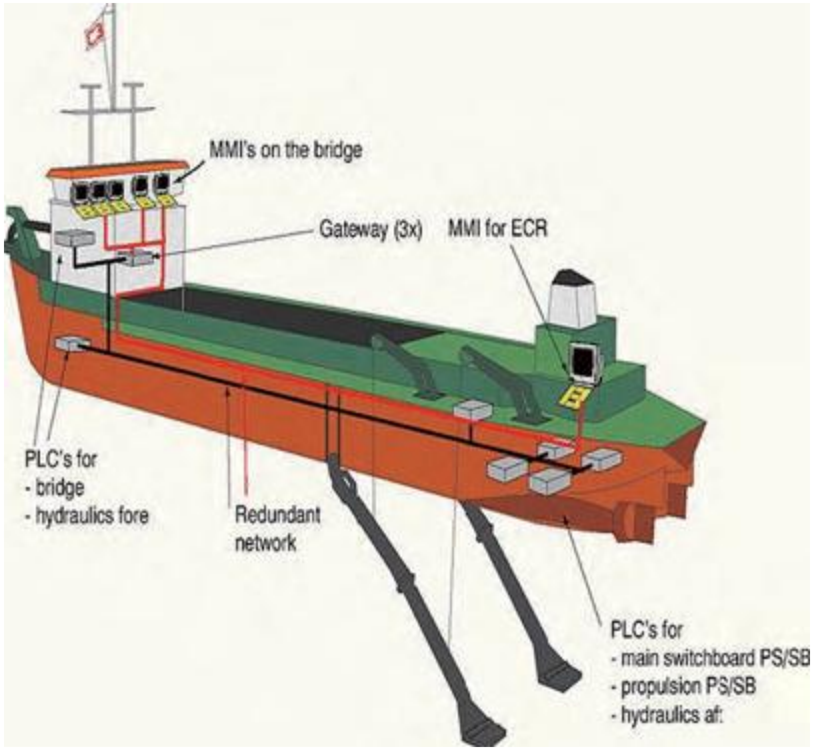
- Open farm seems most promising
- Farm location in gyre areas marked with buoys (ownership)
- Sowing with small pieces *Sargassum Natans*
- Selective fertilizer (no nitrogen) for *Sargassum Natans,* slow release
- Selective harvesting (no fish or turtles)



Concept for offshore open ocean farming (Herfst, TU-Delft, 2008)

Harvesting and logistics

- Mass flows comparable to dredging ships
- Dewatering at sea (pressing)
- Further processing on shore
- Ecological uncertainties
- Much more research is needed



Economics

Advantages

- No road transport involved until after refinery
- Large scale shipping and harvesting possible
- No costs for surface use
- No water use
- No land owners
- Fast growing species
- Abundant CO_2 available

Disadvantages

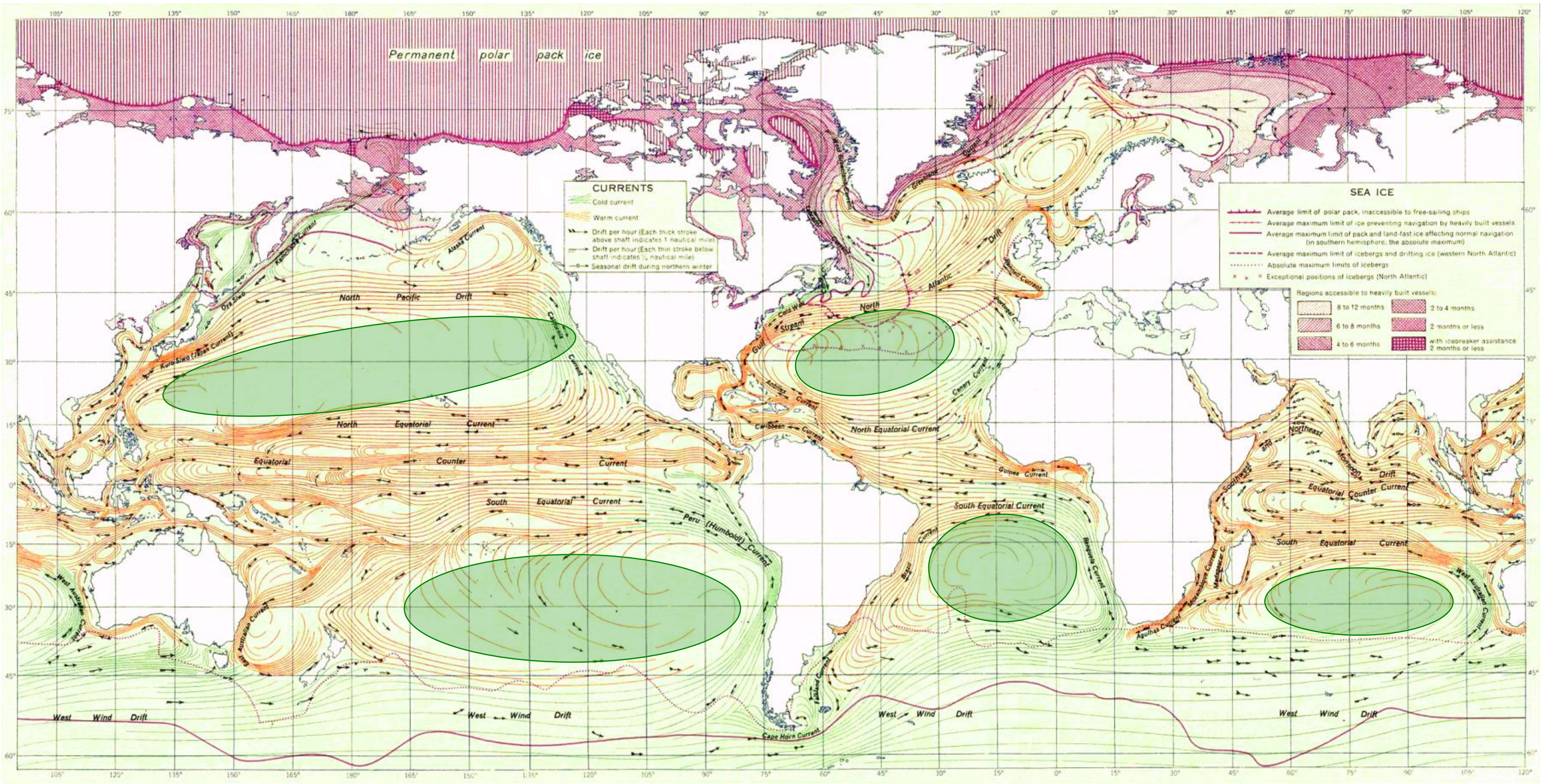
- Ecological constraints
- International conventions
- No protected ownership
- Harsh conditions
- Long distances
- Very wet biomass

Cost estimate (preliminary)

- Scale: 1 harvester\transporter Aframax size (80.000 ton)
- Harvesting capacity 3000 ton/hr (wet)

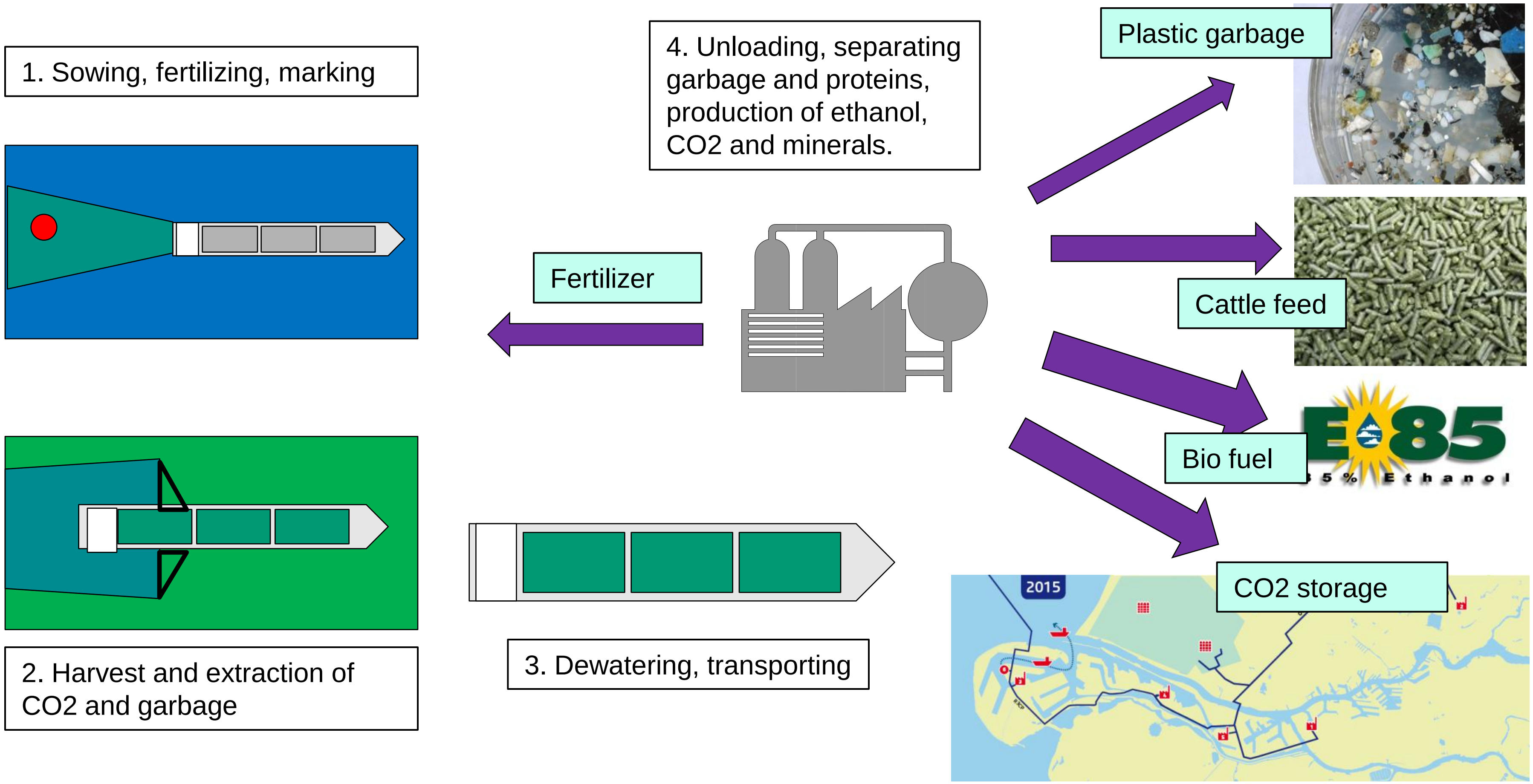
	US-harbor (500 km)	Rotterdam (6000 km)
Biomass in harbor (dw)	12 €/ton	35 €/ton
Ethanol plant (on shore)	0,15 €/ltr	0,15 €/ltr
Total	0,20 €/ltr	0,27 €/ltr
Market value	0,68 €/ltr	0,68 €/lr
Total per liter petrol eq	0,29 €/ltr	0,40 €/ltr
Market value petrol	0,50 €/ltr	0,50 €ltr

Ocean potential: >25.000.000 km^2



Current agricultural crop area: 15. 000.000 km^2 (FAO, 2006)

Ocean seaweed to fuel chain



Composition of *Saragssum Natans*

Composition of Sargassum Natans as reported by some studies.

Sargassum Fluitans and *Natans*

Sargassum	Natans + fluitans, Arabian Gulf (Kamel, 1980)	Natans, Guangdong, China (Wang et al, 2008)
Protein (% dry matter)	6.59	9.6
Fat (%)	0.54 (lipid)	1.39 (lipid)
Carbohydrate (%)	76.43	63.97
Phosphorus (%)	0.0818	
Potassium (%)	19.56	
Energy (kJ/100g dry matter)	1410	868

S Natans proteins compared with soy beans

Sargassum Natans

- 6,6% (dw) proteins o.w.:
  - Methionine 2,3%
  - Lysine 4,5%
  - Threonine 3,8%

Source: Basil S. Kamel (1980)

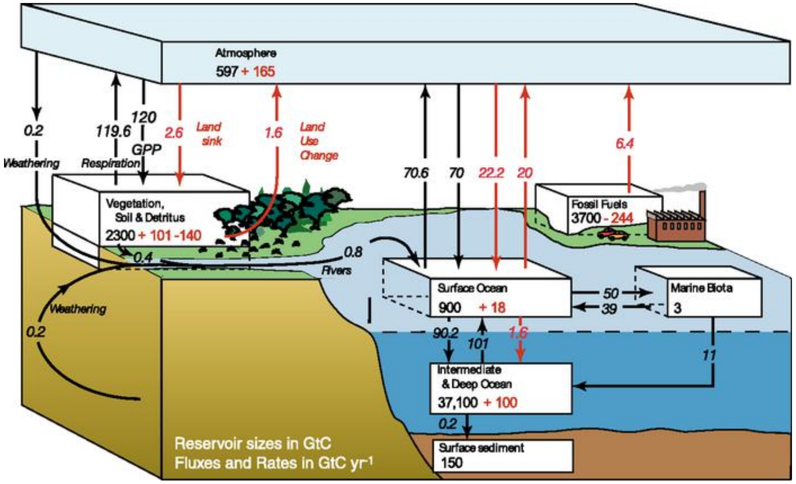
Soy beans

- 36,5% proteins o.w.:
  - Methionine 1,4%
  - Lysine 7,4%
  - Threonine 4,9%

App. 5 ton dry *S Natans* could replace 1 ton soy beans

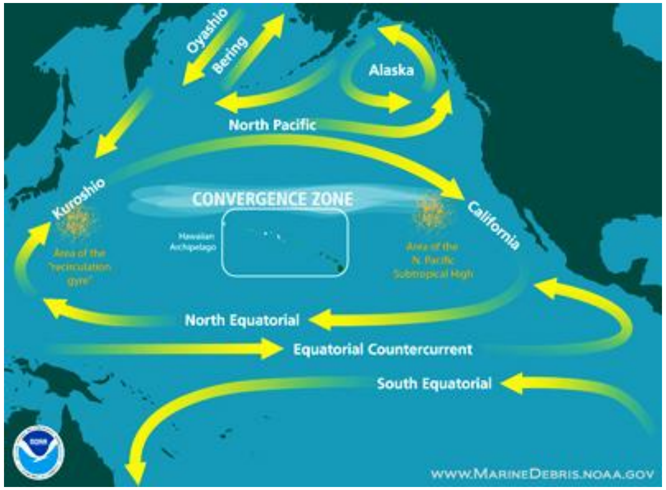
Seaweed to reduce ocean acidification?

- Ocean CO2 uptake 2.4 GtC (8.8 GtCO2) per year
- Production of 15% of world energy consumption with ocean biomass would be needed to compensate
- High yields (ton/ha) and large area will be needed
- Ocean biomass will help but not enough to solve the problem



Seaweed to reduce the garbage patches

- Low density and small particles (density 5 ton/km2)
- Methods to collect the garbage are expensive
- Collection together with seaweed could be possible with little extra costs
- 0,25% of dry mass would be garbage



Conclusions

- Seaweed from ocean farming is a promising source for bio fuel production with low costs and a large potential
- Ocean farming for large scale energy production deserves more attention of researchers and investors
- Ecological benefits and risks need to be balanced