Fuel From The Sea?

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Seaweed

- Collected for human consumption and hydrocolloid production
- Europe - manual and mechanical harvested
- Asia - cultivated
- Traditional market likely higher price than biofuels
- Obtain biomass - cultivation near or offshore

Scoubidou System Used in France (CEVA)
**Where does it come from**

**Seaweed Aquaculture Estimates Main Producers (FAO 2006)**

<table>
<thead>
<tr>
<th>Country</th>
<th>000 tonnes Seaweed Aquaculture (Estimates 2006)</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>10,800</td>
</tr>
<tr>
<td>Philippines</td>
<td>1,300</td>
</tr>
<tr>
<td>Indonesia</td>
<td>900</td>
</tr>
<tr>
<td>Others</td>
<td>2,000</td>
</tr>
</tbody>
</table>

**Seaweed Wild Harvest Estimates for Selected Countries (FAO 2006)**

<table>
<thead>
<tr>
<th>Country</th>
<th>000 tonnes wet seaweed capture (Estimates 2006)</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>323</td>
</tr>
<tr>
<td>Chile</td>
<td>305</td>
</tr>
<tr>
<td>Norway</td>
<td>145</td>
</tr>
<tr>
<td>Japan</td>
<td>113</td>
</tr>
<tr>
<td>France</td>
<td>75*</td>
</tr>
<tr>
<td>Ireland</td>
<td>29</td>
</tr>
</tbody>
</table>

* CEVA estimates
## Current Markets

**Polymers from macro-algae: stable markets (from McHugh 2003).**

<table>
<thead>
<tr>
<th>Product</th>
<th>Production (t y&lt;sup&gt;-1&lt;/sup&gt;)</th>
<th>Algae Harvested (t y&lt;sup&gt;-1&lt;/sup&gt;)</th>
<th>Value (Mio US$)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carrageenan</td>
<td>33,000</td>
<td>168,400</td>
<td>240</td>
<td>mainly <em>Eucheuma and Kappaphycus</em></td>
</tr>
<tr>
<td>Alginate</td>
<td>30,000</td>
<td>126,000</td>
<td>213</td>
<td><em>Laminaria</em>, <em>Macrocystis</em>, <em>Lessonia</em>, <em>Ascophyllum</em>, and others</td>
</tr>
<tr>
<td>Agar</td>
<td>7,630</td>
<td>55,650</td>
<td>137</td>
<td>Mainly <em>Gelidium and Gracilaria</em></td>
</tr>
<tr>
<td>“Extracts”</td>
<td></td>
<td></td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Nori</td>
<td>40,000</td>
<td>400,000 (wet, only Japan)</td>
<td>1500</td>
<td><em>Porphyra</em></td>
</tr>
</tbody>
</table>
Seaweed as Fuel

• Methane via anaerobic digestion
  – Biogas can be used to generate heat and electricity.
  – Also transport fuel (CNG)
• Fermentation
  – Highly enriched in sugars- fermented to produce bioethanol or butanol
Seaweed to methane: not a new idea, but time to revisit the technology……

• 1974, Americans looked for a renewable source of methane from the seas
• Showed that high levels of biogas could be readily produced from seaweed
• However then, off-shore seaweed farms were a failure
• Since then seaweed aquaculture has developed on a massive scale
Sangou Bay, China: the cultivation area stretches for more than 10km out to sea, its visible from space (Google Earth).

China grows 9 million tons L. japonica grown annually making it the largest single species aquaculture crop in the world.
Japanese are considering seaweed for CO₂ mitigation
9 farms X 41.2km²
Methane from the biomass
Annual energy 1.02X10⁹ KWh/yr
CO₂ mitigation 1.04X10⁶ tonnes per annum
0.9% of the 6% reduction agreed under Kyoto Protocol Framework
Offshore Renewables

http://www.awi.de/en/research/new_technologies/marine_aquaculture_maritime_technologies_and(iczm)
Anaerobic Digestion

- Biological process - where there is little or no oxygen.
- Microorganisms degrade organic matter producing biogas - methane and carbon dioxide.
- Can be harnessed and contained in a digester.
- Biogas can be stored, used to run Combined heat and power (CHP) engines.
- Or compressed and used as a transport fuel (just like CNG).
- Some European cities already run public transport on biogas.
Methanisation of Macroalgae

- It is feasible to produce methane from seaweed using Anaerobic Digestion or AD
- Research into varying several factors that affect the process
  - e.g. separation of the juice and non-juice fractions, temperature, inoculum, nutrients, freshwater versus seawater dilution and non-dilution.
- Also advanced digester designs, process optimisation and kinetics have now been investigated.
- In general, brown algae are more easily degraded than the green algae, and the green are more easily degraded than the red.
Bioethanol

• Seaweed contains two main sugars, mannitol and laminaran
• Both are easy to extract and are by-products of the alginate industry
• Initial successful attempts convert sugars to bioethanol
• Microbes were terrestrial also occur in the marine environment
• Technological hurdles conversion of lignocellulosic (terrestrial plant) materials into bioethanol
• Doesn’t exist with seaweed biomass
In the UK and Ireland?

- Largest coast line in Europe
- To meet the complete UK transport needs how much seaweed?
- Farm 1.2 times size of UK
- Employing quarter of work force- Ok in a recession?
- Part of solution for rural coastal communities and also potentially on a larger scale
Biorefinery solutions

- Biogas and ethanol fermentation both technically feasible from seaweed
- Commercially viable Integrated Biorefinery—extraction of energy from waste streams
- Also co-production of energy with other high value products

A Biorefinery Concept for Brown Seaweed (After Horn, 2000)
To produce biofuel from macroalgae it will be necessary to:

- improve performance of AD and bioethanol
- screen for marine bacteria for methanisation and bioethanol production
- latest AD technology from terrestrial systems and design digestors for seaweeds
- Effects of kelp harvesting ecosystems and biofuel production on the terrestrial environment
- Key objective improvements in crop yield.
  
  - Selective breeding
  - Serious need to expand and enlarge existing culture banks
  - Strain selection and maintenance facilities need to be establish similar to those that exist for terrestrial plants and animals
Some of these questions will hopefully be answered by the Interreg IVA funded project - BioMara
Started in January ‘09 and includes the following partners

Partners

• Scottish Association for Marine Science
• QUESTOR, a cross-border centre coordinated by The Queen’s University Belfast
• University of Strathclyde Fraser of Allander Institute.
• Centre for Sustainable Technologies, University of Ulster
• Centre for Renewable Energy, Dundalk Institute of Technology (CREDIT)
• Institute of Technology, Sligo.