Fuel From Seaweed

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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

<table>
<thead>
<tr>
<th>Product</th>
<th>Production (t y⁻¹)</th>
<th>Algae Harvested (t y⁻¹)</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 Eucheuma and Kappaphycus</td>
</tr>
<tr>
<td>Alginate</td>
<td>30,000</td>
<td>126,000</td>
<td>213</td>
<td>Laminaria, Macrocystis, Lessonia, Ascophyllum, and others</td>
</tr>
<tr>
<td>Agar</td>
<td>7,630</td>
<td>55,650</td>
<td>137</td>
<td>Mainly Gelidium and Gracilaria</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>Porphyra</td>
</tr>
</tbody>
</table>

Seaweed as Fuel

- **Methane via anaerobic digestion**
  - Methane (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……

- As long ago as 1974, Americans looked for a renewable source of methane (natural gas) from the seas.
- Their data showed that high levels of methane 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 CO$_2$ mitigation
9 farms $\times$ 41,000km$^2$
Methane from the biomass
Annual energy $1.02 \times 10^9$ KWh/yr
CO$_2$ mitigation $1.04 \times 10^6$ tonnes per annum
0.9% of the 6% reduction agreed under Kyoto Protocol Framework
Offshore Renewables

Why kelp species?

- *Alaria esculenta*
- *Saccharina latissima*
- *Saccorhiza polyschides*

- Proven trials of seeding and on-growth
  - Previous SAMS studies, also BIM and other British/Irish studies
- Fast growth rates
  - Seeding and out-planting to harvesting in 6-7 months
- Lower polyphenol content than fucoid sp.
  - Plus greater potential biomass per unit area
- Ready availability of seed stock
  - Many sites available for collection within a 20 mile radius
Seaweed culture now established in Scotland

Tiny plants 2mm seeded to string

Each plant at harvest, 6 – 8 months later, 1- 2m

3 months
Anaerobic Digestion

- Biological process - occurs naturally where there is little or no oxygen.
- Microorganisms degrade organic matter producing biogas
- Primarily 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 factor 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.
• Results have shown in general the 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 attempts using microbes to convert these sugars to bioethanol have been made
- Although the microbes used were terrestrial in origin they also occur in the marine environment
- Many technological hurdles have to be overcome conversion of lignocellulosic (terrestrial plant) materials into bioethanol
- Doesn’t exist with seaweed biomass
Large Scale Methane & Bioethanol Production

• To produce biofuel from macroalgae it will be necessary to:
  − improve performance of the AD and bioethanol processes
  − screen for marine bacteria efficient at methanisation and bioethanol production from seaweed
  − incorporate latest AD technology from terrestrial biomass digestion and design digestors specifically for seaweeds
• Effects of kelp harvesting on surrounding ecosystems and biofuel production on the terrestrial environment will need to be investigated.

• Another key objective must be 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
In the UK?

• 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
BioMara Partners

- 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.

Funders