Algae for biogas
– in the Central Denmark Region (2010-2013)

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Algae for biogas - aims

- **Platforms**
  - Cultivation
  - Network – integration of industry and research
  - Dissemination

- **Scientific/industrial focus points**
  - Algae cultivation
  - Optimisation of biochemical composition
  - Bioremediation of waste streams
  - Pre-treatment technologies
  - Biogas production
Algae for Biogas – partners
Algae for biogas - contract

- Cultivation facility
- New technologies for energy production from algae
- Scenario for large-scale cultivation
- Exchange of knowledge – industry-GTS-science
- Network based in Central Denmark Region
  - national and international
  - research and industry
Cultivation facility

- Pilot scale
- Recirculated water flow / open flow
- Minimum of 12 tanks – 2 separate systems
- Opening September 2010
New technologies for energy production

- Bioremediation
- Biomass production
- Pretreatment technology
- Energy production
- Thermal
- Mechanical
- Enzymatic
Cultivation – bioremediation

Hypotheses:

- Waste streams are quality nutrient/carbon supplies
- Increase in protein content
- No negative effect on metal concentration
- Efficient N,P,C removal

Degassed pig manure

Reject water

Flue gas
Cultivation - bioremediation

- Quality nutrient/carbon supplies
- Increase in protein
- Efficient N,P,C removal
- No negative effects on metal concentrations

Biogas – different seaweed species

![Methane potentials graph]

<table>
<thead>
<tr>
<th></th>
<th>Laminaria digitata</th>
<th>Saccharina latissima</th>
<th>Chaetomorpha linum</th>
<th>Ascophyllum nodosum</th>
<th>Ulva lactuca</th>
<th>Pilayella littoralis, &amp; Ectocarpus siliculosus</th>
</tr>
</thead>
<tbody>
<tr>
<td>90 days</td>
<td>7</td>
<td>2</td>
<td>7</td>
<td>8</td>
<td>24</td>
<td>0</td>
</tr>
<tr>
<td>60 days</td>
<td>34</td>
<td>12</td>
<td>18</td>
<td>54</td>
<td>50</td>
<td>1</td>
</tr>
<tr>
<td>30 days</td>
<td>257</td>
<td>206</td>
<td>162</td>
<td>119</td>
<td>100</td>
<td>117</td>
</tr>
</tbody>
</table>

L CH₄/kg VS
Seaweed boosting biogas from manure?

Continuous thermophilic experiments

Ulva lactuca

Laminaria digitata
Negative effect of thermal pre-treatment

![Graph showing the negative effect of thermal pre-treatment on different types of macroalgae.](image-url)
REnescience enzymatic pre-treatment

- **Variation of waste**
  - 9 kg waste (4 replicates)
  - 8 kg waste plus 1 kg *Ulva lactuca* (3 replicates)

- **Enzyme addition**
  - Cellic CTec2

### HPLC measurements

<table>
<thead>
<tr>
<th>Component (g/l)</th>
<th>Raw Waste + Algae</th>
<th>Raw Waste</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glucose</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gluc+Lact</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Xylose</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### House hold waste ± Algae

<table>
<thead>
<tr>
<th>Component</th>
<th>Raw Waste + Algae</th>
<th>Raw Waste</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bioliquid total mass (kg)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DM (%) of bioliquid</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total DM (kg)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Solid Fraction wet (kg)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
REnescience enzymatic pre-treatment

- Quick fermentation
- 355 Nm$^3$ CH$_4$/ton VS
  - Raw waste
- 353 Nm$^3$ CH$_4$/ton VS
  - Raw waste + Algae
- 385 Nm$^3$ CH$_4$/ton VS
  - Industriel waste – higher lipid content
Scientific conclusions

- **Cultivation - bioremediation**
  - Efficient bioremediation of nutrient rich waste streams
  - Fluegas/CO\(_2\) boosts production - bioremediation potential is limited
  - Biomass with high protein content (up to 40%)

- **Pretreatment**
  - Enzymatic: no effect on biogas potential
  - Thermal: negative effect on biogas potential
  - Extrusion: no positive effect on biogas potential

- **Biogas production**
  - *Laminaria* – highest biogas potential of species tested
  - *Laminaria* – positive effect on biogas production from manure (+100%)
  - *Ulva* – more than 10% - negative effect on biogas from manure
  - Rest product – suitable for use as soil improvement
Dissemination - network

- New exhibition at the KattegatCentre: Havet i maven (Eating from the ocean)
- Teaching material – biotechnology (high school level)
  Freely available on the internet
- Algaecentre tour for high schools
Industry-science knowledge exchange

Industrial network
- Based at Havets Hus
- 25 participants from entire production chain

Conference
- 80-100 participants
- National and international algae environments
- Industry
- Research
- Governmental organisations
International Networks

- BioWalk4Biofuel (FP7)
- MAB 3
- Nordic Algae Network

India
Jordan
Overall conclusions

- **Energy → biorefinery**
- **Landbased cultivation → cultivation at sea**
- **Green algae → Laminaria**

- Great industrial interest and drive in Central DK region
- Increasing political interest and focus
- Large potential impact in Central DK region
Thanks for your attention

And thanks to:

- Central Denmark Region
- EU FP7 – BioWalk4Biofuels
- Fredericia Spildevand
- The Harbour master in Nakkebølle
Products and commercial impact

- 3 peer-reviewed papers
- Oral presentations
- Posters
- Dissemination events
  - 3 Macroalgae conferences
  - Forskningens Døgn
Dissemination

› **Popular**
  › Papers
  › Talks
  › Posters

› **Scientific**
  › Peer-reviewed papers
  › Talks
  › Posters
Perspectives
Cultivation – bioremediation capacity

- High N availability – high N content – high protein
- Amino acid composition OK

1 Nielsen et al, 2011.  2 FAO, 2008
Seaweeds for biogas

- Inhibiton – salt, sulphur
- Inoculum – optimisation

\[
\begin{array}{ccccccccccc}
\text{m}^3 \text{CH}_4 \text{kg}^{-1} \text{VS} \\
\text{M. porifera} & \text{A. nodosum} & \text{S. latissima} & \text{S. fluitans} & \text{G. tikvahiae} & \text{Chaetomorpha sp.} & \text{U. lactuca} & \text{Wheat straw} & \text{Turf grass} & \text{Manure} \\
\text{a} & \text{a} & \text{a} & \text{a} & \text{b} & \text{c} & \text{d} & \text{e} & \text{e} & \text{f} \\
\end{array}
\]

Cultivation - bioremediation efficiency

- Aquaculture
- Agriculture
- Municipal

- Output
  - Max clean water
  - Max N/P removal
  - Min energy cost
- Construction of system

\[ \text{Nielsen et al, 2011.} \quad \text{Neori et al, 2003.} \]