A biological solar energy generator

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Calorific Value of Sludge

Graph showing the relationship between dry mass rest in % and calorific value in GJ/t. The calorific value increases linearly with the dry mass rest.
Requirement of Space to Deliver Primary Energy in FRG

Contribution of the total surface of FRG in %

- Algal Biogas
- Algues
- Energy Forests
- C4-Plants
## Process Simulation

<table>
<thead>
<tr>
<th>Loss of Carbon</th>
<th>Compensation:</th>
<th>Slurry from cows</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO₂-loss via exhaust:</td>
<td>2.416,574 m³/a = 1.208,29 t/a</td>
<td>Content of Carbon: 33,6 %</td>
</tr>
<tr>
<td>CH₄-delivery:</td>
<td>3.844,750 m³/a = 1.922,38 t/a</td>
<td>Moisture: 70 %</td>
</tr>
<tr>
<td>Sum:</td>
<td>3.130,66 m³/a</td>
<td>Mass: 31,058,2 t/a</td>
</tr>
<tr>
<td></td>
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<td>after adjusting process moisture: 39,931,9 t/a</td>
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<tr>
<td></td>
<td></td>
<td>Calorific value: 6,99E+13 J/a</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Process data</th>
<th>Moisture: 90 %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass flow at process moisture:</td>
<td>134,486,3 t/a</td>
</tr>
<tr>
<td>Mass flow at 70 % moisture:</td>
<td>104,600,5 t/a</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Energy harvest</th>
<th>Power</th>
</tr>
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<tbody>
<tr>
<td>Electrical:</td>
<td>5,60E+13 J/a</td>
</tr>
<tr>
<td>Thermal:</td>
<td>1,29E+13 J/a</td>
</tr>
<tr>
<td>Methane:</td>
<td>1,38E+14 J/a</td>
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<tr>
<td>Sum:</td>
<td>2,07E+14 J/a</td>
</tr>
<tr>
<td>Net yield:</td>
<td>1,37E+14 J/a</td>
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<table>
<thead>
<tr>
<th>Requirement of floorspace</th>
<th>Investment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Algal reactors (ponds):</td>
<td>590,965 m²</td>
</tr>
<tr>
<td>Anaerobic reactor:</td>
<td>20,000 m²</td>
</tr>
<tr>
<td>Local power plant / Gas separation:</td>
<td>2,212 m²</td>
</tr>
<tr>
<td>Sum:</td>
<td>613,177 m²</td>
</tr>
<tr>
<td>Specific floorspace:</td>
<td>2,96 m²/(GJ/a)</td>
</tr>
<tr>
<td>Specific energy harvest:</td>
<td>3,374,3 GJ/ha a</td>
</tr>
<tr>
<td>Net specific energy harvest:</td>
<td>2,234,7 GJ/ha a</td>
</tr>
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<table>
<thead>
<tr>
<th>End energy supply (1998)</th>
<th>Base: consumption only households total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Citizens</td>
<td>6,041</td>
</tr>
<tr>
<td>Households</td>
<td>2,762</td>
</tr>
</tbody>
</table>
Increase of Expenses (Relative to Actual Energy Prices)

<table>
<thead>
<tr>
<th>Method</th>
<th>Increase of Expenses in %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Photovoltaic</td>
<td>1570</td>
</tr>
<tr>
<td>Photovoltaic (looking in the future)</td>
<td>680</td>
</tr>
<tr>
<td>Algal Biomass</td>
<td>690</td>
</tr>
<tr>
<td>Algal Biomass (looking in the future)</td>
<td>170</td>
</tr>
</tbody>
</table>
Micro-algal reactor
Win Algal Biomass
Difficulties
Harvesting Micro-Algal Biomass
Harvesting Micro-Algal Biomass

Filtrat 1 bar mit alten Algen 4.2.02

Counts

Teilchengröße in μm
Harvesting Micro-Algal Biomass

Counts

Teilchengröße in µm
Treatment of Micro-Algal Biomass
Anaerobic reactor
Anaerobic Process

Fixed bed | fluidized bed

mesophilic/mesophilic | thermophilic/mesophilic
Gasproduction and pH Value

Days of Operation

Gasproduction in l/d

pH Value

- Gasproduktion
- pH-Wert 1. Stufe
- pH-Wert 2. Stufe
Anaerobic Process using Micro-Algal Biomass

COD Concentrationen and Degree of Decomposition

Days of Operation

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

1. Stufe 2. Stufe Substrat Abbaugrad

COD in mg/L

0 500 1000 1500 2000 2500 3000 3500 4000 4500 5000 5500 6000 6500 7000 7500 8000 8500 9000 9500 10000 10500 11000 11500 12000 12500 13000 13500 14000 14500 15000 15500 16000 16500 17000 17500 18000 18500 19000 19500 20000

Degree of Decomposition
Anaerobic Process using Micro-Algal Biomass

Gas Composition and Gasproduction

Gasproduction in l/d

Days of Operation

Methane in %Vol

Carbon dioxide in %Vol

Gasproduktion
Methan
Kohlendioxid
Anaerobic Process using Micro-Algal Biomass

Säure und Kalkreserve

Acidogenesereaktor

HAc [mg/l] vs. Betriebstage

Puffer [mg/l] vs. Betriebstage

pH-Wert vs. Betriebstage

Betriebstage

Puffer, HAc, pH-Wert
Anaerobprozess mit Algenbiomasse

Säure und Kalkreserve

Methanogenesereaktor

Betriebstage

- Puffer
- HAc
- pH-Wert

HAc [mg/l] Säuren [mg/l] pH-Wert
Anaerobic Process using Micro-Algal Biomass

NH₄-Concentration

Days of Operation

NH₄ in mg/L

- Substrat
- 1. Stufe
- 2. Stufe
ATR-Measurement
Probe 12.9. bei pH = 4.4

Extinktions PD 1150 cm⁻¹

- Essigsäure
- Propionsäure
- Buttersäure

Wellenzahl (cm⁻¹)
Sample from September 12th
1st stage of anaerobic bioreactor, pH = 4.4

Carbonic acids, all at pH = 5.0

Butyrate
Propionate
Acetate

Absorbance

Wavenumber (cm\(^{-1}\))
Samples from 1st stage of anaerobic bioreactor

Sampling dates: 7.10.
Concentration (HPLC) in mmol/L

Concentration (IR) in mmol/L

IR2(1550 und 1740 cm⁻¹)

pH

Polynomic (pH)

Polynomic (IR2{1550 and 1740 cm⁻¹})
Concentration by IR-spectrometry (mmol/L) vs. concentration determined by HPLC (mmol/L). The data is fitted with a stage 1 sigmoid and a stage 2 linear model.
Reforming

Synthesegasgewinnung
(z. B. zur Ammoniak- und Methanolsynthese)

\[ \text{Ni} \]

\[ \text{CH}_4 \; + \; \text{H}_2\text{O} \rightarrow \text{CO} \; + \; 3\text{H}_2 \]

800 °C

CO-Konvertierung

\[ \text{Fe/Cr-Oxid} \]

\[ \text{CO} \; + \; \text{H}_2\text{O} \rightarrow \text{CO}_2 \; + \; \text{H}_2 \]

500 °C

Summenreaktion

\[ \text{CH}_4 \; + \; 2\text{H}_2\text{O} \rightarrow \text{CO}_2 \; + \; 4\text{H}_2 \]

35,9 MJ/m³

4 (10,8) MJ/m³
Summary and Conclusion

• An algal biomass based solar energy generator is possible
• There is a high efficient anaerobic process
• Higher organisms are problematic in the algal reactor; nitric species in the anaerobic process
• Currently the process is not economic
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Acknowledgements

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