Outlook on microalgae production chains

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AlgaePARC Innovation Center

Product costs
Scale
Production chain analysis
Market development
Market pull
Economic feasibility
Market value > production costs

Production costs
• Biomass production costs
• Biorefinery costs
Biomass Production costs: Model

**Input**
- Location: Netherlands, Saudi Arabia, Canary Islands, Turkish Riviera, South Spain, Curacao
- Cultivation System
- Empirical data
- Specific parameters: Culture temperature, Daily Dilution, Mixing day/night, Operation days per year...

**Output**
- Light Intensity
- Electricity costs
- Taxes
- Labor
- € / Kg biomass
- CAPEX & OPEX
- NER
- Sensitivity Analysis
- Areas to focus
Projections with AlgaePARC pilot facility data:

- Photosynthetic Efficiency
- Operational strategy: Chemostat & Turbidostat
- Biomass concentration
- Dilution rate
- Gas flow rates (flat panels and degasser in tubulars)
### Projections: 100 ha, Flat panel

<table>
<thead>
<tr>
<th>Input</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>South of Spain</td>
</tr>
<tr>
<td>Cultivation system</td>
<td>Flat Panel</td>
</tr>
<tr>
<td>Area of culture</td>
<td>100 Ha</td>
</tr>
<tr>
<td>Land</td>
<td>Rented land</td>
</tr>
<tr>
<td>Photosynthetic efficiency</td>
<td>3.3 %</td>
</tr>
<tr>
<td>% of facility to inocul.</td>
<td>10 %</td>
</tr>
<tr>
<td>Operation days per year</td>
<td>300 days</td>
</tr>
<tr>
<td>Mode of operation</td>
<td>Chemostat</td>
</tr>
<tr>
<td>Daily dilution</td>
<td>27 %</td>
</tr>
<tr>
<td>Daily dilution in summer</td>
<td>27 %</td>
</tr>
<tr>
<td>Temperature control</td>
<td>Yes: Cooling tower</td>
</tr>
<tr>
<td>Maximum culture temperature</td>
<td>30 °C</td>
</tr>
<tr>
<td>Nitrogen source</td>
<td>Urea</td>
</tr>
<tr>
<td>Phosphorus recycling rate</td>
<td>0 %</td>
</tr>
<tr>
<td>Nitrogen recycling rate</td>
<td>0 %</td>
</tr>
<tr>
<td>Source of CO₂</td>
<td>Commercial</td>
</tr>
<tr>
<td>Air flow</td>
<td>0.32 vvm</td>
</tr>
<tr>
<td>Air flow (night)</td>
<td>0.32 vvm</td>
</tr>
<tr>
<td>Photovoltaic energy</td>
<td>No</td>
</tr>
</tbody>
</table>

| BIOMASS COST (no CO₂ incentive) | 4.17 €·kg⁻¹ |
| BIOMASS CAPACITY | 7448 Ton·Yr⁻¹ |
| NER | 0.72 |
| CAPEX | 10.55 M€·Yr⁻¹ |
| OPEX | 20.48 M€·Yr⁻¹ |
| Initial investment | 153.8 M€ |

### Cost Breakdown

- **Major Equipment**: 7%
- **Construction and other fixed costs**: 27%
- **Consumable**: 17%
- **Raw materials**: 17%
- **Utilities**: 1.2%
- **Others**: 11%
- **Labor**: 5%
- **Energy**: 26%
- **Wastewater treatment**: 4%
### Input
- Temperature control: Yes, Cooling tower

### Output
<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>BIOMASS COST (no CO₂ incentive)</td>
<td>4.17 €·kg⁻¹</td>
</tr>
<tr>
<td>BIOMASS CAPACITY</td>
<td>7448 Ton·Yr⁻¹</td>
</tr>
<tr>
<td>NER</td>
<td>0.72</td>
</tr>
<tr>
<td>CAPEX</td>
<td>10.55 M€·Yr⁻¹</td>
</tr>
<tr>
<td>OPEX</td>
<td>20.48 M€·Yr⁻¹</td>
</tr>
<tr>
<td>Initial investment</td>
<td>153.8 M€</td>
</tr>
</tbody>
</table>

- **Raw materials**: 17%
- **Energy**: 26%
- **Major equipment**: 7%
- **Consumable**: 2%
- **Utilities**: 1.2%
- **Labor**: 5%
- **Wastewater treatment**: 4%
- **Others**: 11%
- **Construction and other fixed costs**: 27%

**4.17 € /Kg**
### Temperature control

<table>
<thead>
<tr>
<th>Input</th>
<th>Yes: External Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>25°C</td>
<td></td>
</tr>
</tbody>
</table>

### Output

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>BIOMASS COST (no CO₂ incentive)</td>
<td>3.21 €·kg⁻¹</td>
</tr>
<tr>
<td>BIOMASS CAPACITY</td>
<td>7448 Ton·Yr⁻¹</td>
</tr>
<tr>
<td>NER</td>
<td>1.55</td>
</tr>
<tr>
<td>CAPEX</td>
<td>8.47 M€·Yr⁻¹</td>
</tr>
<tr>
<td>OPEX</td>
<td>15.45 M€·Yr⁻¹</td>
</tr>
<tr>
<td>Initial investment</td>
<td>123.1 M€</td>
</tr>
</tbody>
</table>

### Cost Breakdown

<table>
<thead>
<tr>
<th>Category</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Major Equipment</td>
<td>7%</td>
</tr>
<tr>
<td>Construction and other fixed costs</td>
<td>29%</td>
</tr>
<tr>
<td>Raw materials</td>
<td>22%</td>
</tr>
<tr>
<td>Consumable</td>
<td>3%</td>
</tr>
<tr>
<td>Utilities</td>
<td>0.0%</td>
</tr>
<tr>
<td>Energy</td>
<td>15%</td>
</tr>
<tr>
<td>Wastewater treatment</td>
<td>5%</td>
</tr>
<tr>
<td>Labor</td>
<td>6%</td>
</tr>
</tbody>
</table>

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4.17 € /Kg

3.21 € /Kg

23%
Temperature control

Yes: External Source

10°C

Input

Output

BIOMASS COST (no CO$_2$ incentive) 2.71 €·kg$^{-1}$
BIOMASS CAPACITY 7448 Ton·Yr$^{-1}$
NER 1.61
CAPEX 5.42 M€·Yr$^{-1}$
OPEX 14.79 M€·Yr$^{-1}$
Initial investment 78.1 M€
**Temperature control**
- Yes: External Source 25°C

**Maximum culture temperature**
- 30->45°C

**Output**
- BIOMASS COST (no CO₂ incentive) 2.60 €·kg⁻¹
- BIOMASS CAPACITY 7448 Ton·Yr⁻¹
- NER 1.63
- CAPEX 4.75 M€·Yr⁻¹
- OPEX 14.63 M€·Yr⁻¹
- Initial investment 68.2 M€

**Cost breakdown**
- Energy 18%
- Raw materials 26%
- Consumables 4%
- Utilities 6%
- Major equipment 5%
- Major equipment and other fixed costs 22%
- Labor 7%
- Others 12%
- Wastewater treatment 6%

**Prices per kg**
- 4.17 € /Kg (23%)
- 3.21 € /Kg (35%)
- 2.71 € /Kg (23%)
- 2.60 € /Kg (38%)

**Percentages**
- Energy 18%
- Raw materials 26%
- Consumables 4%
- Utilities 6%
- Major equipment 5%
- Major equipment and other fixed costs 22%
- Labor 7%
- Others 12%
- Wastewater treatment 6%
Photosynthetic efficiency: 3.3 - 6.0%

Output:
- BIOMASS COST (no CO₂ incentive): 1.65 €·kg⁻¹
- BIOMASS CAPACITY: 13542 Ton·Yr⁻¹
- NER: 2.96
- CAPEX: 4.75 M€·Yr⁻¹
- OPEX: 17.57 M€·Yr⁻¹
- Initial investment: 68.2 M€

Initial investment breakdown:
- Raw materials: 35%
- Energy: 16%
- Wastewater treatment: 6%
- Utilities: 3%
- Consumable: 3%
- Labor: 6%
- Energy: 16%
- Other fixed costs: 17%
- Major Equipment: 4%
- Others: 13%

Input:
- Cost of different inputs:
  - 4.17 € /Kg (23%)
  - 3.21 € /Kg (35%)
  - 2.71 € /Kg (38%)
  - 2.60 € /Kg (60%)
  - 1.65 € /Kg (60%)

For quality of life
### Input

<table>
<thead>
<tr>
<th>Role</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant manager</td>
<td>1</td>
</tr>
<tr>
<td>Supervisor</td>
<td>3</td>
</tr>
<tr>
<td>Operator</td>
<td>28 -&gt; 10</td>
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</table>

### Output

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>BIOMASS COST (no CO₂ incentive)</td>
<td>1.57 €·kg⁻¹</td>
</tr>
<tr>
<td>BIOMASS CAPACITY</td>
<td>13542 Ton·Yr⁻¹</td>
</tr>
<tr>
<td>NER</td>
<td>2.96</td>
</tr>
<tr>
<td>CAPEX</td>
<td>4.75 M€·Yr⁻¹</td>
</tr>
<tr>
<td>OPEX</td>
<td>16.44 M€·Yr⁻¹</td>
</tr>
<tr>
<td>Initial investment</td>
<td>68.2 M€</td>
</tr>
</tbody>
</table>

### Costs

<table>
<thead>
<tr>
<th>Role</th>
<th>Cost/Kg</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant manager</td>
<td>4.17 €</td>
<td>23%</td>
</tr>
<tr>
<td>Supervisor</td>
<td>3.21 €</td>
<td>35%</td>
</tr>
<tr>
<td>Operator</td>
<td>2.71 €</td>
<td>38%</td>
</tr>
<tr>
<td>Plant manager</td>
<td>2.60 €</td>
<td>60%</td>
</tr>
<tr>
<td>Operator</td>
<td>1.65 €</td>
<td>62%</td>
</tr>
<tr>
<td>Plant manager</td>
<td>1.57 €</td>
<td>62%</td>
</tr>
</tbody>
</table>
BIOMASS COST (no CO₂ incentive): 1.23 €·kg⁻¹
BIOMASS CAPACITY: 13,542 Ton·Yr⁻¹
NER: 2.96
CAPEX: 4.75 M€·Yr⁻¹
OPEX: 11.92 M€·Yr⁻¹
Initial investment: 68.2 M€

Source of CO₂: Commercial -> Flue gas

Costs:
- 4.17 € /Kg (23%)
- 3.21 € /Kg (35%)
- 2.71 € /Kg (38%)
- 2.60 € /Kg (60%)
- 1.65 € /Kg (62%)
- 1.57 €/Kg (62%)

70% of the costs are indicated.
Sensitivity Analysis

- Example for flat panels
- Done for raceway ponds & tubular at 6 locations
- Can be extended to other systems and locations
Biorefinery

Design of scenarios: SUPERPRO DESIGNER®

1 - 3 € /Kg dw
Production costs

- Biomass production costs
- Biorefinery costs

Market value > production costs

Economic Feasibility
Market combinations vs costs

€/kg biomass

Actual costs for production and biorefinery

Future costs for production and biorefinery

Biofuels
Chemicals
Biofuels
Food and Feed
Chemicals, Food and Feed
Specialties
Conclusions

- Techno-Economic models are a powerful tool to support business decisions and determine research objectives.

- Business cases within reach on basis of projected costs of biomass production and biorefinery:
  - Increase product range and volume
  - Reliability: quality and quantity

- Scale up still needs to be realized.

- Further reduction in cost is required for commodities.
## Industrial partners

## Academic partners
Ben Gurion University of the Negev, Cambridge University, Centre for Research and Technology Hellas, Cranfield University, CSIC, ECN, Ege University, Fraunhofer, INRA, Joanneum Research, Qingdao Institute of BioEnergy and Bioprocess Technology, Rijksuniversiteit Groningen, Technical University Delft, Thomas Moore Kempen, Uni Research, Universität Bielefeld, Universidad de Antofagasta, University of Bergen, University of Huelva, University of Las Palmas de Gran Canaria, University of Utrecht, VITO, VU Amsterdam, Westfälische Wilhelms-Universität Münster, University of Nordland
Everyone can grow algae...