Algae CC
Rural Rejuve

Coal competitiveness
• Algae industry can pay for CO₂ and cost of capture/delivery
• CO₂ becomes co-product

Algae, High tech farming
• Economic boon
• Full spectrum of jobs
• Large markets: protein, fuel, polymers

USA needs to invest so we are the world leader

40-50x revenue per acre will transform to rural economy & standard of living
Algae Industry: Solution to the Protein Crisis

FAO projections
- Need 3x aquaculture protein
- Need 2x other protein
- Crop yield increase ~1-1.5%/year

2% of crop land in algae solves problem

Food Prices Trigger Unrest
ONR/AFOSR Study
Algae Industry: Large Part of Environmental Solutions

- Leading cause of deforestation and habitat loss is food production
- Leading cause of global water impairment is agricultural run-off
- Agriculture accounts for 25% of global greenhouse gas emissions


1,000 acres of algae saves 40,000 acres

Algae has no run-off, prevents dead zones
# Energy Scale CCU Products Required

<table>
<thead>
<tr>
<th>Product</th>
<th>Value ($/mt)</th>
<th>CO₂ Utilization (550 MW Coal Plants)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pigments, Nutraceuticals, Cosmetics, Specialty chemicals</td>
<td>4,000 - 10,000</td>
<td>0.3</td>
</tr>
<tr>
<td>Consumer polymers, Food protein</td>
<td>1,000 - 3,000</td>
<td>25</td>
</tr>
<tr>
<td>Bulk polymers, Aquaculture feed, Specialty feeds</td>
<td>600 – 1,000</td>
<td>200</td>
</tr>
<tr>
<td>Animal feed &amp; Transportation fuel</td>
<td>350 – 550</td>
<td>500</td>
</tr>
<tr>
<td>Transportation fuel</td>
<td>250 – 350</td>
<td>8000</td>
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</tbody>
</table>
Demonstrated innovations that achieve cost targets

- PBR growth rates in Open Raceways
- Effective contamination control

- Zobi harvester
  - 100% separation efficiency
  - 1/100th energy
  - 15-20% solids

- CO₂ supplied from power plant flue gas
  - 0.1 psi pressure drop
  - 24 hr/day capture
Scalable Technologies
(550 MW supports 20-30,000 algae acres)

We seem to have a few problems going from lab-scale to full-scale production

20,000-acre facility control points
Conventional CC or direct: 40,000
Global Algae Absorber: 1
20,000-acre facility
Conventional Raceways: 10,000
Global Algae Raceways: 100

Zobi Membrane Technology
6 billion gpd installed
228 million gpd plant
Algae Flue Gas Utilization Obstacles

1. Achieve low cost CO₂ supply
   - Capture & Storage
   - Distribution & control
   - Energy use

2. Capture CO₂ when algae not growing

3. Prevent ground level flue gas release
<table>
<thead>
<tr>
<th>System Attribute</th>
<th>Bubble Flue Gas</th>
<th>Carbon Capture</th>
<th>Global Algae Innovations</th>
<th>Direct Air Capture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost of CO₂ supply</td>
<td>$$$</td>
<td>$$$</td>
<td>$</td>
<td>$</td>
</tr>
<tr>
<td>CO₂ storage</td>
<td>N/A</td>
<td>$$</td>
<td>$</td>
<td>N/A</td>
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<tr>
<td>Gas distribution</td>
<td>Miles</td>
<td>Miles</td>
<td>None</td>
<td>None</td>
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<tr>
<td>Control points</td>
<td>40,000</td>
<td>40,000</td>
<td>1</td>
<td>None</td>
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<tr>
<td>Gas pressure</td>
<td>2-10 psi</td>
<td>0.1 / 900 psi</td>
<td>0.1 psi</td>
<td>N/A</td>
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<tr>
<td>Prevent ground level flue gas release</td>
<td>$$</td>
<td>0</td>
<td>0</td>
<td>N/A</td>
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<tr>
<td>Capture when algae is not growing</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>
Global Algae Innovations
CO₂ Supply System

Flue Gas Supply

Flue Gas
Exhaust

CO₂ Absorber
Na₂CO₃ (aq) + CO₂ (g) → 2 NaHCO₃ (aq)

Recycled Media
Pond
Na₂CO₃ (aq)

Harvest

Algae Biomass

Algae Raceways
CO₂ (aq) + H₂O + light → (CH₂O)ₙ
2 NaHCO₃ (aq) → Na₂CO₃ (aq) + CO₂ (aq)

Carbonated Media
Pond
NaHCO₃ (aq)

Global Algae
Innovations
All algae cultivated on CO$_2$ supplied from power plant flue gas.
Power Plant Flue Gas CO$_2$ Supply

- 50’ tall, 5’ diameter absorber
- Power plant off-gas returned to stack after CO$_2$ recovery
- For past three years, all CO$_2$ for growth from power plant flue gas
All CO₂ Supplied From Power Plant Flue Gas

- 24 hour per day CO₂ capture
- Store in media: 80-90% capture limit instead of 5%
- Very low energy: 2.5” water pressure drop on flue gas
- Eliminates need for gas distribution or controls

GLOBAL ALGAE INNOVATIONS
Conclusions

- Algae CCU can lower electric rates
- Addresses some of world's largest markets
- Re-establish US as bread basket of the world
- Full-scale implementation would create economic boon that transforms rural standards of living and job quality
- Scalable and economic approaches have been demonstrated at reasonable scale
- USA investment needed to maintain world leadership
Thank you