

# Culture Systems

*ABLC: The New Normal: Innovations in Crops and Products*

June 7, 2016

# Agenda

## **Algae Industry Overview**

Novel Cultivation Methods

# Global Industry

## Legend:

Green = Private company  
Red = Academic Institution



Source: Algal Biomass Organization

## State of Major Players – Successful Commercialization To-Date Has Been Away From Industrial Products

Name	Description	Status
<b>Sapphire Energy</b>	<ul style="list-style-type: none"> <li>• Phototosynthetic cultivation of bred algae in open ponds</li> </ul>	<ul style="list-style-type: none"> <li>• Total raise \$320M (\$100M from USG)</li> <li>• 300 acre project field partly operational in New Mexico</li> <li>• In discussion to move away from energy products</li> </ul>
<b>TerraVia (formerly Solazyme)</b>	<ul style="list-style-type: none"> <li>• Heterotrophic cultivation of algae by providing glucose</li> <li>• Focused primarily on high-value components</li> </ul>	<ul style="list-style-type: none"> <li>• Raised \$120M then IPO in 2011</li> <li>• Partnered with Bunge</li> <li>• Sold 20,000 gallons to USN</li> <li>• Selling Algenist face cream at JCPenny's</li> <li>• Restructured in early 2016; non-industrial products placed in TerraVia</li> </ul>
<b>Algenol</b>	<ul style="list-style-type: none"> <li>• Photosynthetic cultivation of ethanol secreting algae</li> </ul>	<ul style="list-style-type: none"> <li>• Total raise of \$150M</li> <li>• Reliance Industries major strategic investor and partner</li> <li>• Changed senior management in 2015</li> </ul>



## Key Inter-Related Challenges

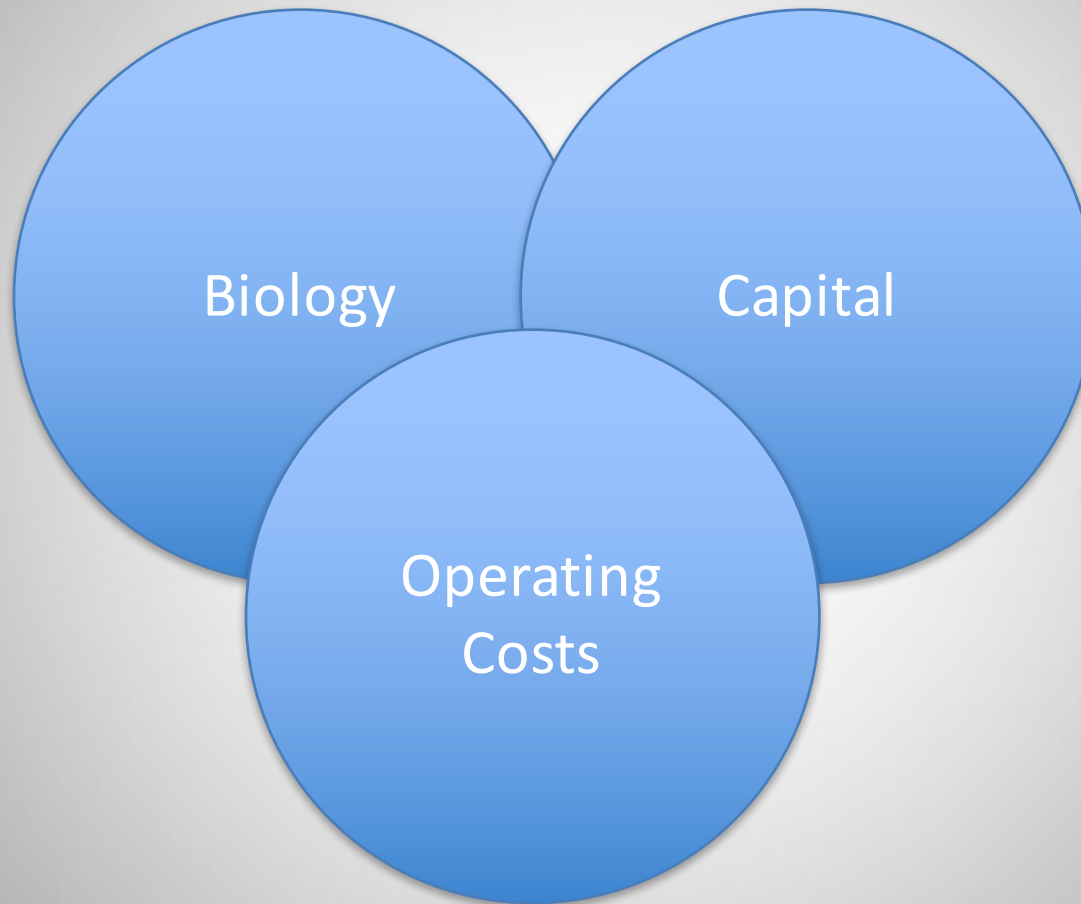
- 1 Availability of feedstock! To make products
- 2 Loss of investor appetite at early stage and pre-commercial
- 3 Inefficient cultivation systems

# Agenda

Algae Industry Overview

**Novel Cultivation Methods**

# Components of Cultivation Economics



# Algae Cultivation Technologies

## Open Pond



- Low investment
- Low biomass density
- High contamination risk
- Low yield



**Water intensive**  
**Low productivity**

## Closed Photobioreactor (PBR)

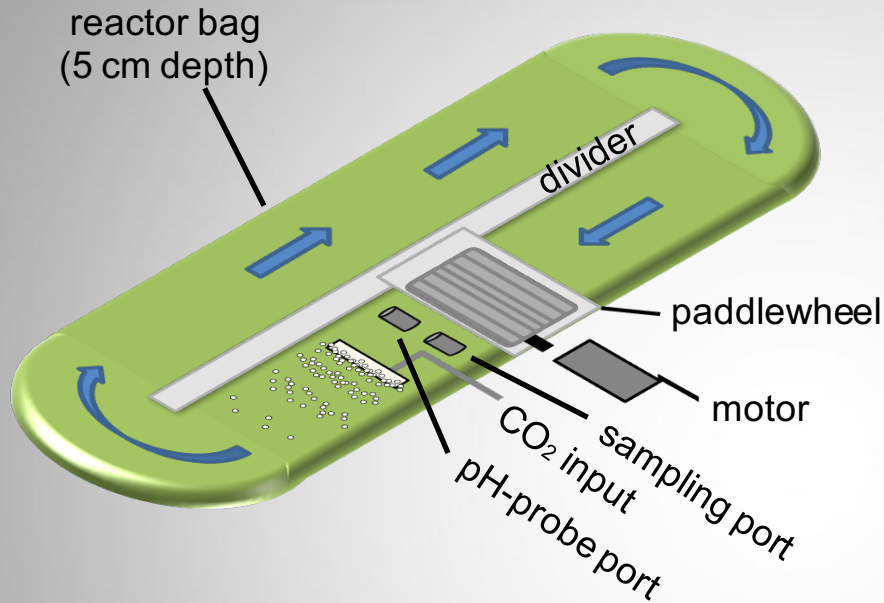


- High investment
- High biomass density
- Low contamination risk
- High yield

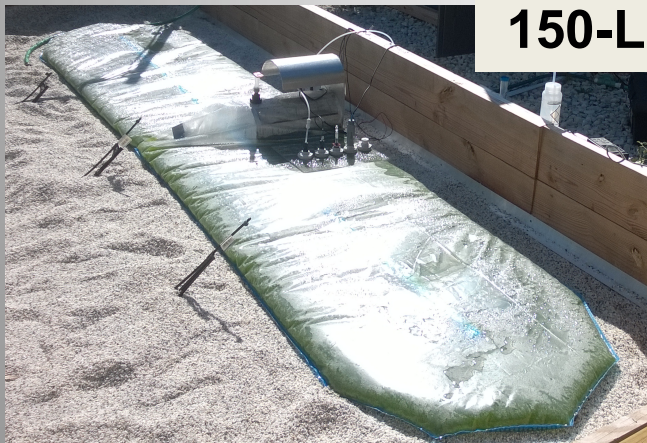


**High productivity**  
**High cost**

# Innovative Approach: Horizontal Bioreactor (HBR)\*



- Low capital cost
- High cell density & productivity
- Fraction of water use (75-80% less)
- Lower cost of downstream processing
- Contamination barrier
- Floating or on-ground
- Readily scalable (modular)



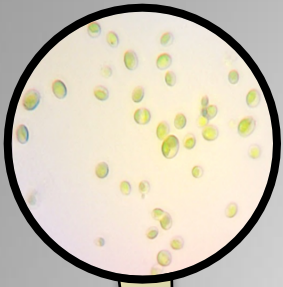
(\*) Patent pending

# Lab Testing

Micro-algae strain *Nannochloris oculata* LB 1998 (UTEX)

- Marine green algae
- Intracellular lipids for biofuel production

## *Algae culturing scheme*



Flask  
1 L

10%



Vertical Bioreactor  
(VBR) 7.5 L

10%



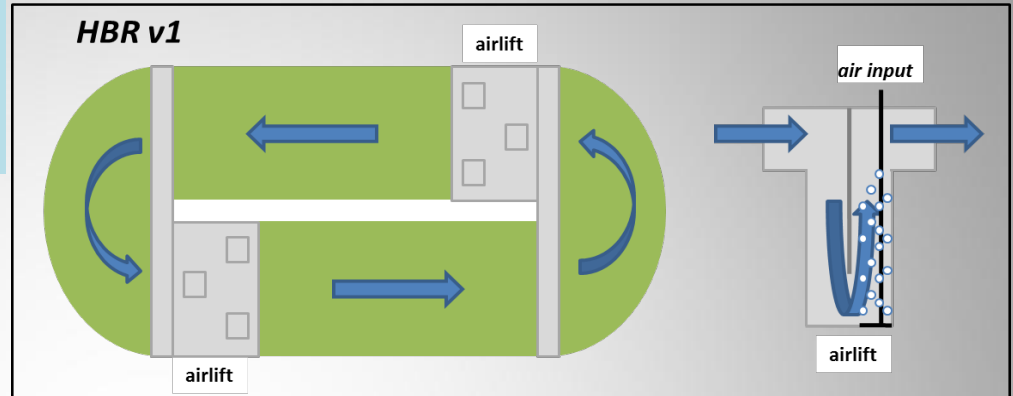
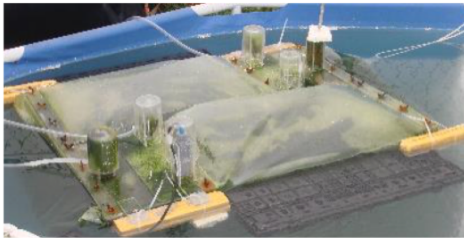
Horizontal Bioreactor (HBR)  
150 L



# Phase 2: HBR Design and Testing

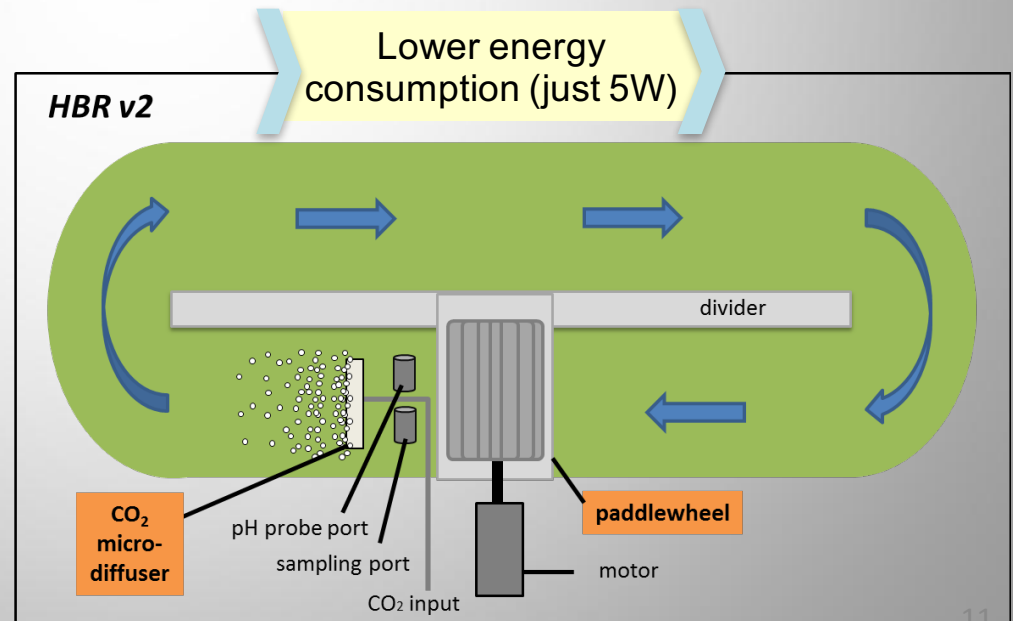
## HBR version 1 (65-L prototype)

Mixing and CO<sub>2</sub> diffusion by two acrylic airlifts



## HBR version 2 (150-L prototype)

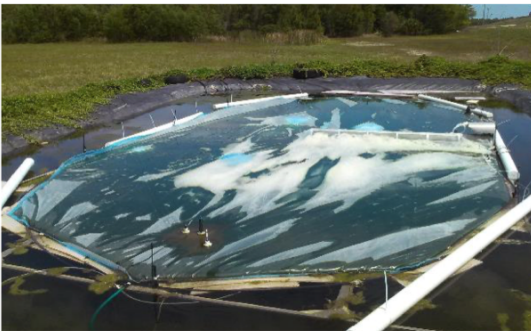
- Mixing by 8-blade paddlewheel.
- High-efficiency CO<sub>2</sub> micro-diffusers



# Phase 3: HBR Scale-up

Semi-continuous operation in progress

**2000-L**



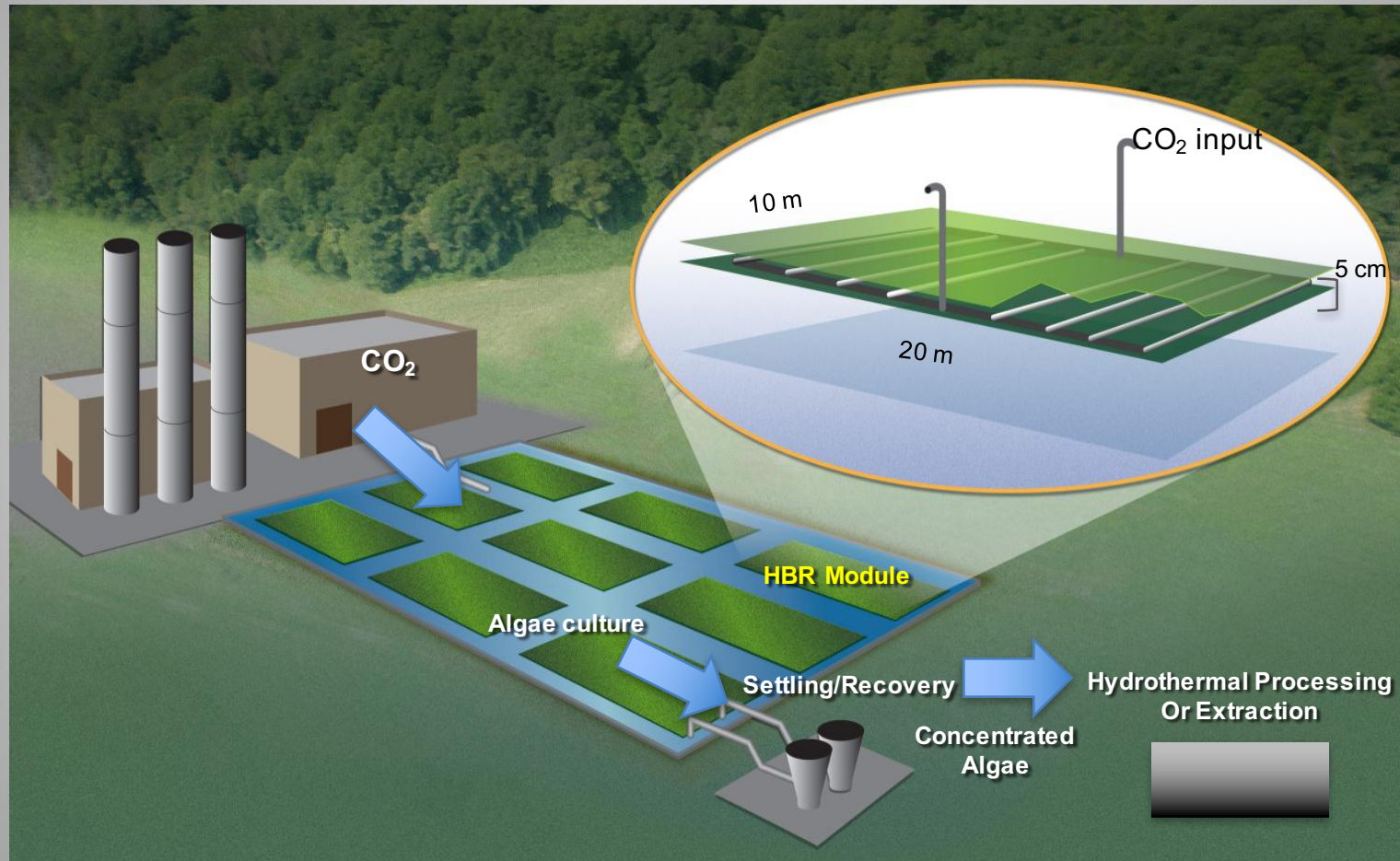
## 2000-L HBR Testing

- ✓ Average culture flow speed: **10.4 cm/s**
  - ✓ Leak test: **Pass**
  - ✓ Wind and rain test: **Pass**
  - ✓ Integrity test: **Pass**
  - ✓ Operation: **In Progress**
- Monitoring systems:**

- 1.
- 2.
- 3.
- 4.
- 5.



# Semi-Commercial Deployment In Process



# HBR Projected Cost

Cultivation system	Reactor (per ha) and algal mass (per DW) Capital Cost		
	Capital costs included:	\$/ha	\$/kg DW
1,000 m <sup>2</sup> HBR	PE film, paddlewheel, labor, overhead costs	25,000	0.50 (at 15 g/m <sup>2</sup> /d yearly average)



- Significantly lower than PBRs
- comparable to open ponds

# Appendix

# Culture Systems Management and Advisory Team (1/2)

## Lawrence A. Walmsley – CEO & Co-Founder

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- McKinsey biofuel and biomass-to-energy practice
- Goldman Sachs investment banking

• MBA from MIT, MPA from Harvard University, BSE from Princeton University

## George Philippidis, PhD – Strategic Partnerships Manager

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- Associate Professor of Sustainable Energy, University of South Florida

• PhD in Chemical Engineering from the University of Minnesota, MBA from University of Denver

## Andreas Meiser, PhD – CTO & Co-Founder

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- Founder of algae companies
- Operated algae pilot plant at a Fraunhofer Institute
- McKinsey biofuel and biotechnology

• PhD in Natural Sciences from the University of Hohenheim, Germany

## Ioannis Dogaris – Laboratory Manager

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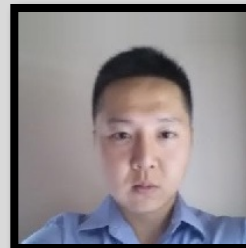
- Postdoctoral researcher in sustainable energy at the Patel College of Global Sustainability, USF

• Ph.D. in Biotechnology from the National Technical University of Athens, Greece



## Mike Welch - R&D

- BA in Biochemistry and a Minor in Business Administration from the University of South Florida



## Eric Yi – Business Dev.

- BD TrekkSoft and Spa Belles
- Co-founder of DPS Care,
- Master of Science from NYU BBA from Baruch

## Culture Systems Management and Advisory Team (2/2)



### **Jeremy Oppenheim - Advisor**

- Director at McKinsey & Co.
- Global Director of the Sustainability and Resource Productivity



### **Doug Kirkpatrick - Advisor**

- General Partner Inner Product
- Senior Advisor, VantagePoint Capital Partners
- Prior, led DARPA algae work