Safe Harbor Statement

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Recovering Oil: A Twofold Challenge

- Algae Grow Suspended in Large Amounts of Water
  - Cells have similar specific gravity to water
  - Algae in suspension neither sink nor float
  - Wet biomass retains interstitial water, which acts as a lubricant
  - Harvesting oil requires solids separation
  - Dewatering is energy and capital intensive

- Cell Walls are Difficult to “Crack”
  - Algae have a tough exterior to protect internal lipids
  - Cell wall has a high elasticity modulus
  - Cell rupture through mechanical friction and steam explosion requires dry biomass
  - Mechanical extraction is energy and capital intensive
  - Chemical extraction requires caustic solvents
Conventional Approach

Current State of the Art is a 3-Stage Process:

1. **Solids Separation**
   - Options Include:
     - Polymer Flocculation
     - Decanters/Centrifuges
     - Hydrocyclones

2. **Dewatering**
   - Options Include:
     - Steam Drying
     - Fluid Bed
     - Microwave

3. **Extraction**
   - Options Include:
     - Expellers/Presses
     - Solvent Extraction
     - Supercritical CO₂

Conventional Systems Feature a Combination of Technologies
Solids Separation: Polymer Flocculation

- Solute particles form biomass aggregate called “floc”
- Two main types of flocculants
  - Inorganic Flocculants
  - Organic Polymer/Polyelectrolyte Flocculants
- Microalgae can form stable suspensions
- Advantages:
  - Capable of treating large quantities of culture
  - Applicable to wide range of algae strains
  - Less energy intensive than mechanical separation
- Limitations:
  - Flocculants can be expensive and caustic
  - Flocculation alone is not sufficient
  - Typically combined with other processes
Solids Separation: Decanters/Centrifuges

- Mechanical approach to solids separation
  - Decanters are typically used in the ethanol industry
  - Centrifuges are widely used in the algae industry
- Operates using the sedimentation principle
- Requires specific gravity differential
- Advantages
  - Seen as the most efficient recovery technique
  - Capable of processing large algae cultures
  - Appropriate for cultures that are more liquid and less solid
- Limitations
  - Capital and energy intensive
  - Requires additional drying for mechanical and chemical extraction
Solids Separation: Hydrocyclones

- Uses gravity to separate solids from liquids
- Requires specific gravity differential
- Hydrocyclone dimensions must be precision engineered

**Advantages**
- Low capital costs

**Limitations**
- Only appropriate for select algae strains (e.g. Coelastrum)
- Efficiency is highly dependent on solids concentration
- Process is energy intensive
- Requires additional drying for mechanical and chemical extraction
- Reliability is questionable
Dewatering: Indirect/Direct Heat

- Heat is used to evaporate water
- Indirect heating uses rotating disks to accelerate heat exchange
- Direct heat uses open flame to create steam

**Advantages**
- Very effective as reducing moisture content
- Appropriate for applications with significant “waste heat”

**Limitations**
- Capital and energy intensive
- Direct heat has combustion risks
- Regular maintenance required
Dewatering: Fluid Bed

- Designed to dry biomass as it floats on a cushion of air
- Uses rotating screen that allows air to percolate through wet biomass

Advantages
- Effective at reducing moisture content of biomass
- Does not require steam or heat
- Relatively low maintenance costs

Limitations
- Typically used when moisture content is relatively low
- Capital and energy intensive
Dewatering: Microwave

- Process uses volumetric heating to achieve even distribution
- Energy is delivered electromagnetically, rather than as heat

Advantages
- Drying time can be reduced significantly
- Reduced risk of combustion
- Lower energy cost compared to steam drying
- Low maintenance costs

Limitations
- Potential of uneven drying
- Capital and energy intensive
Extraction: Expellers/Presses

- Uses mechanical force to rupture algae cells
- Widely used in oil extraction from various feedstock
- Design must be tailored to algae strain

Advantages
- No chemical input required
- Appropriate for high oil content algae
- Capable of extracting up to 80% oil

Limitations
- Residual biomass remains with pressed oil
- Typically requires additional solvent extraction
- Capital and energy intensive
- High maintenance costs
Extraction: Solvents

- Chemicals including benzene, ether and hexane are used to degrade cell walls
- Oil dissolves into solvent and is recovered through distillation
- Can be used in conjunction with mechanical extraction

Advantages
- Relatively inexpensive
- Effective at releasing up to 95% oil

Limitations
- Requires the use of caustic chemicals
- Hexane requires two year permitting process (U.S.)
Extraction: Supercritical CO$_2$

- Process uses liquid CO$_2$ at high temperature and high pressure to extract algae oil
- CO$_2$ penetrates algae cells and causes them to rupture
- Widely used in various industries, including coffee

Advantages
- Low environmental impact
- High quality oil and biomass product

Limitations
- Works best when algae cells are partially ruptured
- Process is highly tuned and sensitive
- High pressure systems involve risk
- Capital and energy intensive
Other Approaches: Enzyme Extraction

- Uses enzymes to degrade cell walls
- Water acts as the solvent material
- Process makes fractionation of oil much easier

Advantages:
- Does not require dry cake for oil extraction
- Low environmental impact
- No caustic chemicals

Limitations:
- Costs are much higher than hexane extraction
Other Approaches: Ultrasonication

- Uses ultrasonic waves to create cavitation bubbles in a solvent material
- Bubbles collapse, resulting in shock waves that break down cell walls
- Can be used in conjunction with enzymatic extraction

Advantages:
- Does not require dry cake for oil extraction
- Low environmental impact
- No caustic chemicals

Limitations:
- Energy intensive
- Technology unproven at industrial scale
The OriginOil Difference

**Conventional Approach**

Solids Separation → Dewatering → Extraction

**OriginOil Approach**

Extraction → Solids Separation → Dewatering

Radical Shift vs. Incremental Gains
OriginOil Single-Step Extraction™

- In one step, Quantum Fracturing™ combines with electromagnetism and pH modification to break down cell walls.
- Algae oil rises to the top for skimming and refining, while the remaining biomass settles to the bottom for further processing as fuel and other valuable products.
Single-Step Extraction Process Details

**CO₂ Injection**
- Lowers pH to optimize electromagnetic delivery
- Chemically assists in cell degradation

**Quantum Fracturing**
- Creates fluid fracturing effect
- Mechanically distresses algae cells

**Electromagnetic Field**
- Highly tuned EMP ruptures algae cells
- Causes cells to release internal lipids

**Additional Key Process Innovations**
- Subject to imminent patent filings
Gravity Settling

- Single Step Extraction separates oil from biomass
- Processed culture is transferred to a gravity clarifier
  - Oil rises to the top
  - Biomass sinks to the bottom
- Oil is skimmed for downstream polishing
- Biomass is drained for further drying (if necessary)
- Water is recycled to the bioreactor or pond
Single Step Extraction Benefits

- No initial dewatering required
- Significant energy savings
- No caustic chemicals
- Tunable to a wide range of feedstock
- Small footprint
- Easy installation
- Applicable to all growth platforms
- Fast throughput – highly scalable
- Greatly-reduced Capital Expenditure

A BREAKTHROUGH TECHNOLOGY TO TRANSFORM ALGAE INTO OIL
Conventional vs. Single-Step Extraction™

<table>
<thead>
<tr>
<th>Extraction Method</th>
<th>Energy Cost of Oil Extraction ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional Process</td>
<td>1.24</td>
</tr>
<tr>
<td>Single-Step Extraction™ (Dry Cake)</td>
<td>0.79</td>
</tr>
<tr>
<td>Single-Step Extraction™ (Biomass Slurry)</td>
<td>0.20</td>
</tr>
</tbody>
</table>

Harvest Concentration: 1 gram/L dry weight

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Live Extraction™

- Continuous ‘milking’ process works by stimulating the algae cells electrically.
- Algae oil is extracted continuously, algae remains alive.
- Combines with daily harvest for improved productivity, refreshed cell cultures.
- Does not use expensive consumables, not limited to one strain.
- Now being scaled up to OriginOil’s intermediate 200-gallon tank size.
OPTIMIZED ALGAE PRODUCTION SYSTEM

Nutrients

CO₂

O₂ exhaust

Livestock Feed Co-Products

Methane + CO₂

Stripping Column

Methane

Power generation (pictured), or conversion to gas & liquid fuels

Fuel Chemicals Health Products

CO₂ Recovery

CO₂

Make-up Water

Recovered Water

Quantum Fracturing™

Helix Bio Reactor™

Live Extraction™

Dynamic Control System

Water Recovery

Algae Slurry

Fertilizer or Feed

Lipids

Straight Vegetable Oil (SVO)

Gravity Clarifier

Algae Biomass

Extraction Tank

Quantum Fracturing

Single-Step Extraction™

Electromagnetic Pulsing

Daily Harvest

TITLE Optimized Algae Production System

AUTHOR OriginOil, Inc.
Next Steps

Single-Step Extraction:
- 28 January 2010, launched pilot scale lab system (3-5gpm)
- By mid-2010, will launch mobile algae extraction system (ALGAEMAX) – on-site demos to interested algae companies.
- Pursuing commercial pilot projects in 2H2010.
- Ongoing discussions with OEMs.

Live Extraction:
- Displayed bench scale system at 28 January event.
- Currently scaling up to 200-gallon tank system.
- Testing productivity singly and in tandem with daily harvest and Single-Step Extraction.
Path to an Algae Market

Development of an integrated network of global partners, including:

- Original Equipment Manufacturers (OEMs)
- Country and Regional Partners
- Device and Component Manufacturers
- Service and Maintenance Providers
- Customized Application Developers
THANK YOU!

QUESTIONS?

COMMENTS?

partners@originoil.com

(SEE FOLLOWING SLIDES FOR PROCESS COMPARISON DETAILS )
Conventional Energy Requirements

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Centrifuge for 1 MGD sludge processing</td>
<td>1,059 kWh</td>
</tr>
<tr>
<td>Centrifuge for processing 10,000,000 L (2.64 MG)</td>
<td>2,798 kWh</td>
</tr>
<tr>
<td>Sludge solid content</td>
<td>27%</td>
</tr>
<tr>
<td>Sludge moisture content</td>
<td>73%</td>
</tr>
<tr>
<td>Total biomass in 10,000,000 L</td>
<td>10,000 kg</td>
</tr>
<tr>
<td>Total moisture (water) content</td>
<td>27,037 kg</td>
</tr>
<tr>
<td>Energy requirement for water evaporation</td>
<td>16,770 kWh</td>
</tr>
<tr>
<td>Total energy requirement for dewatering</td>
<td>19,568 kWh</td>
</tr>
<tr>
<td>Cost for dewatering 10,000,000 L of algae culture</td>
<td>1,370 $</td>
</tr>
<tr>
<td>Energy cost for oil extraction</td>
<td>1,113 $</td>
</tr>
<tr>
<td>Total energy cost of crude oil</td>
<td>2,483 $</td>
</tr>
<tr>
<td>Energy cost per kg of crude oil</td>
<td>1.24 $/kg</td>
</tr>
</tbody>
</table>

Harvest Concentration: 1 gram/L dry weight
### OriginOil Energy Requirements (Sludge)

**Case A - biomass product is bio-digestible sludge**

<table>
<thead>
<tr>
<th>Description</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extraction energy for 10,000,000 L</td>
<td>5,625 kWh</td>
</tr>
<tr>
<td>Post-extraction dewatering of 10,000,000 L</td>
<td>179 kWh</td>
</tr>
<tr>
<td>Unit power cost</td>
<td>0.07 $/kWh</td>
</tr>
</tbody>
</table>

**Cost for processing 10,000,000 L**

<table>
<thead>
<tr>
<th>Description</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total oil content (assuming 20% yield)</td>
<td>2,000 kg</td>
</tr>
<tr>
<td>Energy cost per kg of crude oil</td>
<td>0.20 $/kg</td>
</tr>
</tbody>
</table>

16.4% percent of conventional process energy cost
**Single-Step Extraction™ (Cake)**

*Case B - biomass product is dry (10%)*

- Extraction energy for 10,000,000 L: 5,625 kWh
- Post-extraction dewatering of 10,000,000 L: 179 kWh
- Energy requirement for water evaporation: 16,770 kWh
- Unit power cost: 0.07 $/kWh

**Cost for processing 10,000,000 L**

- 1,580 $

**Total oil content (assuming 20% yield)**

- 2,000 kg

**Energy cost per kg of crude oil**

- 0.79 $/kg

**63.6 percent of conventional process energy cost**