OriginOil®

Developments in Algae Harvesting and Processing

European Algae Biomass 27th & 28th April 2011

Pestana Chelsea Bridge Hotel, London, UK

A BREAKTHROUGH TECHNOLOGY TO TRANSFORM ALGAE INTO OIL

Safe Harbor Statement

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Algae Harvesting: A Twofold Challenge

1. Algae Grow Suspended in Large Amounts of Water
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   - Algae in suspension neither sink nor float
   - Wet biomass retains interstitial water, which acts as a lubricant
   - Harvesting oil requires solids separation
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   - Cell wall has a high elasticity modulus
   - Cell rupture through mechanical friction and steam explosion requires dry biomass
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Cost of Conventional Extraction:
US$1.24/kg

The Extraction Landscape

- Chemical/Enzymatic
  - Protease, surfactants, acids, salts, osmotic, etc.
- Physical
  - Freeze/thaw
  - Heat
  - Electromagnetic
  - Pressurization/expansion
  - Supercritical Extraction
- Mechanical
  - Ultrasound - Sonication
  - Impeller - rotating paddles or surfaces
  - Pressurized Liquid Flow
  - Bead Mills
  - Droplets - atomization

Source: Glen Mills presentation at NAA 28 March 2011
www.glenmills.com

OriginOil: A Multilayer, Integrated Approach

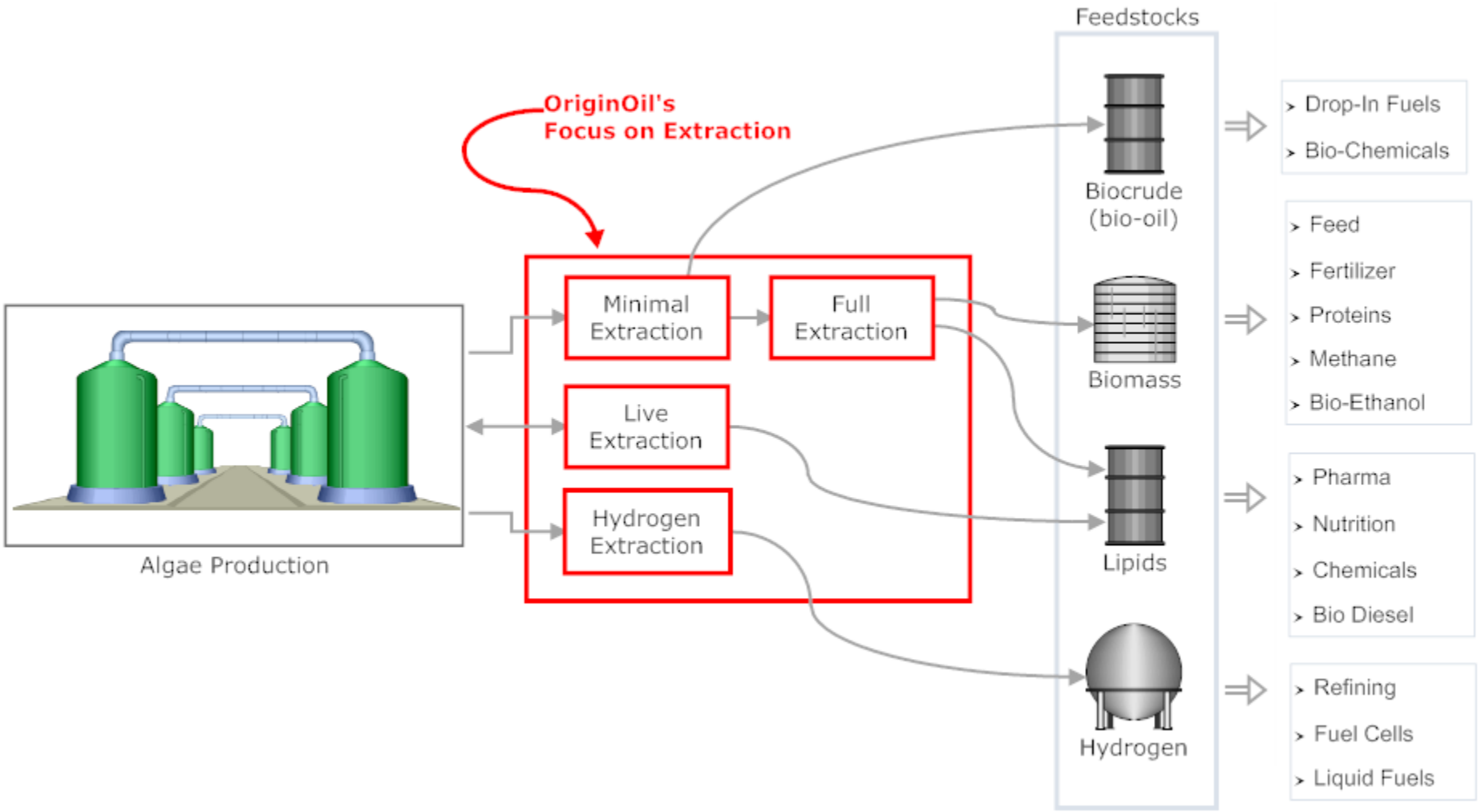
- CO2 Injection
  - Lowers pH to optimize electromagnetic delivery
  - Chemically assists in cell degradation
- Quantum Fracturing™
  - Creates fluid fracturing effect
  - Mechanically distresses algae cells
- Electromagnetic Field
  - Specifically tuned EMP ruptures algae cells
  - Evolved hardware design
  - Causes cells to release internal lipids
- Integrated Externals:
  - Dissolved Air Flotation (DAF) for Concentration - World Water Works
  - 3-Phase Separation post Extraction

OriginOil Field Implementation

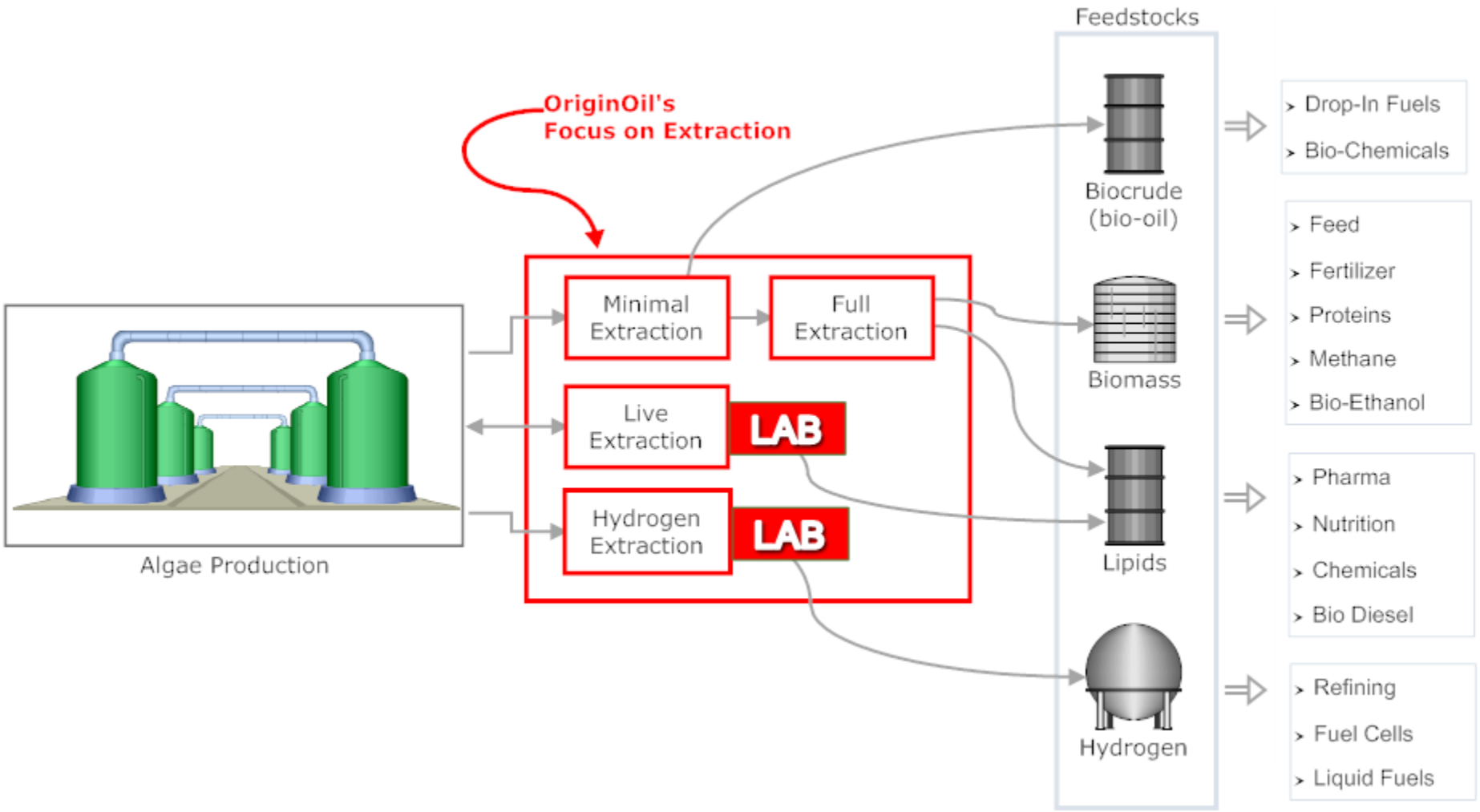
1. Dewatering
   - Reduce water by about one order (from 1000:1 to ~100:1)
   - Biomass integrity must be preserved
   - A chemical-free solution is preferred
2. Extraction
   - Destroy cell viability
   - Release lipids
   - Release cell components (specialized applications)
3. Concentration
   - Targeting 10-20% solids
4. Separation
   - Fully release all lipid from biomass.
   - Three-phase separation: liquid/liquid/solid (oil/water/biomass)

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



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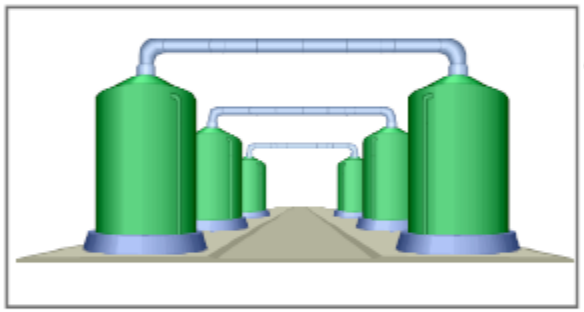
Minimal or full extraction?

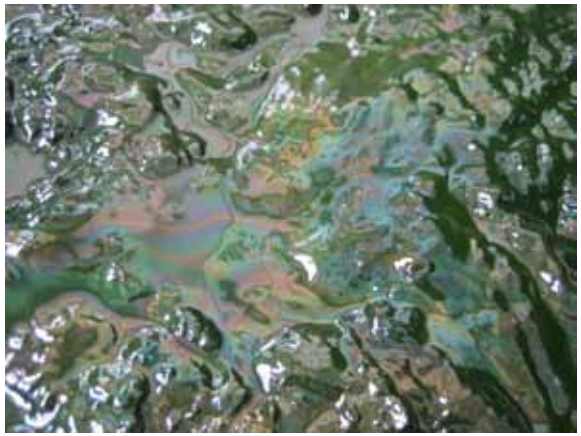
<u>OriginOil's process serves both</u>.



Algae Production

Minimal Extraction

Full Extraction



Feedstocks

Biocrude (bio-oil)

- Drop-In Fuels
- Bio-Chemicals

Biomass

- Feed
- Fertilizer
- Proteins
- Methane
- Bio-Ethanol

Lipids

- Pharma
- Nutrition
- Chemicals
- Bio Diesel

Hydrogen

- Refining
- Fuel Cells
- Liquid Fuels

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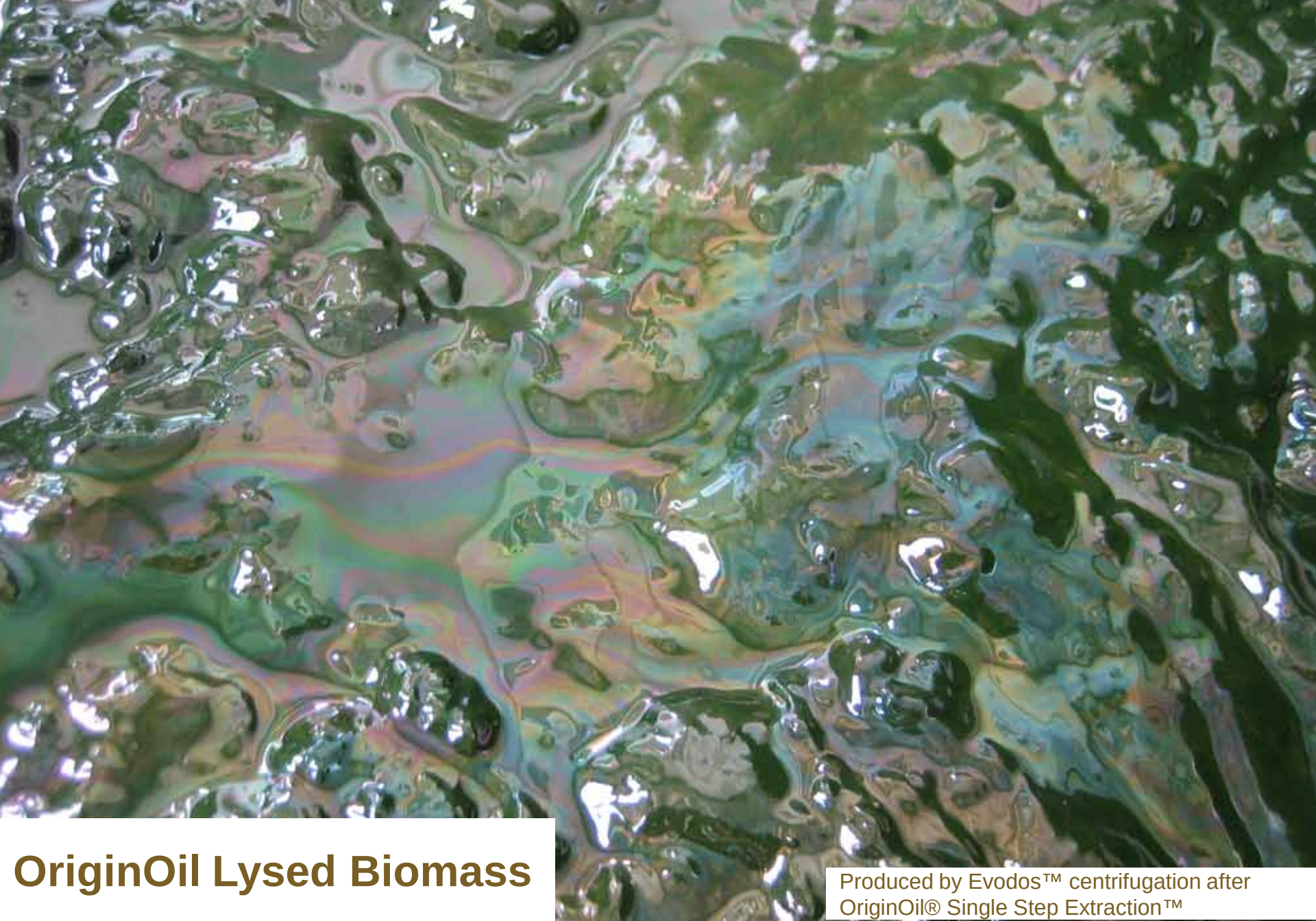


OriginOil Lysed Biomass

Produced by Evodos™ centrifugation after OriginOil® Single Step Extraction™

Lysed Biomass as a Standardized Product

- With OriginOil's single step process, growers can deliver lysed biomass ("oily paste") to processors for any application.
- Growers can focus on growing and leave the processing to processors.

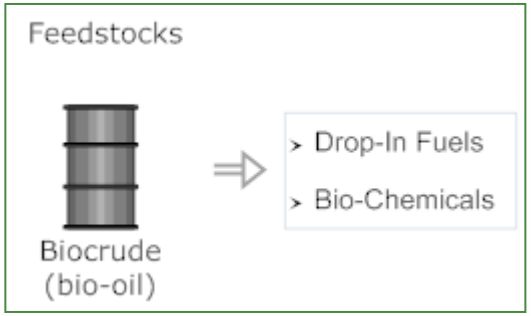
Key decision point: certifying product for food-grade applications.

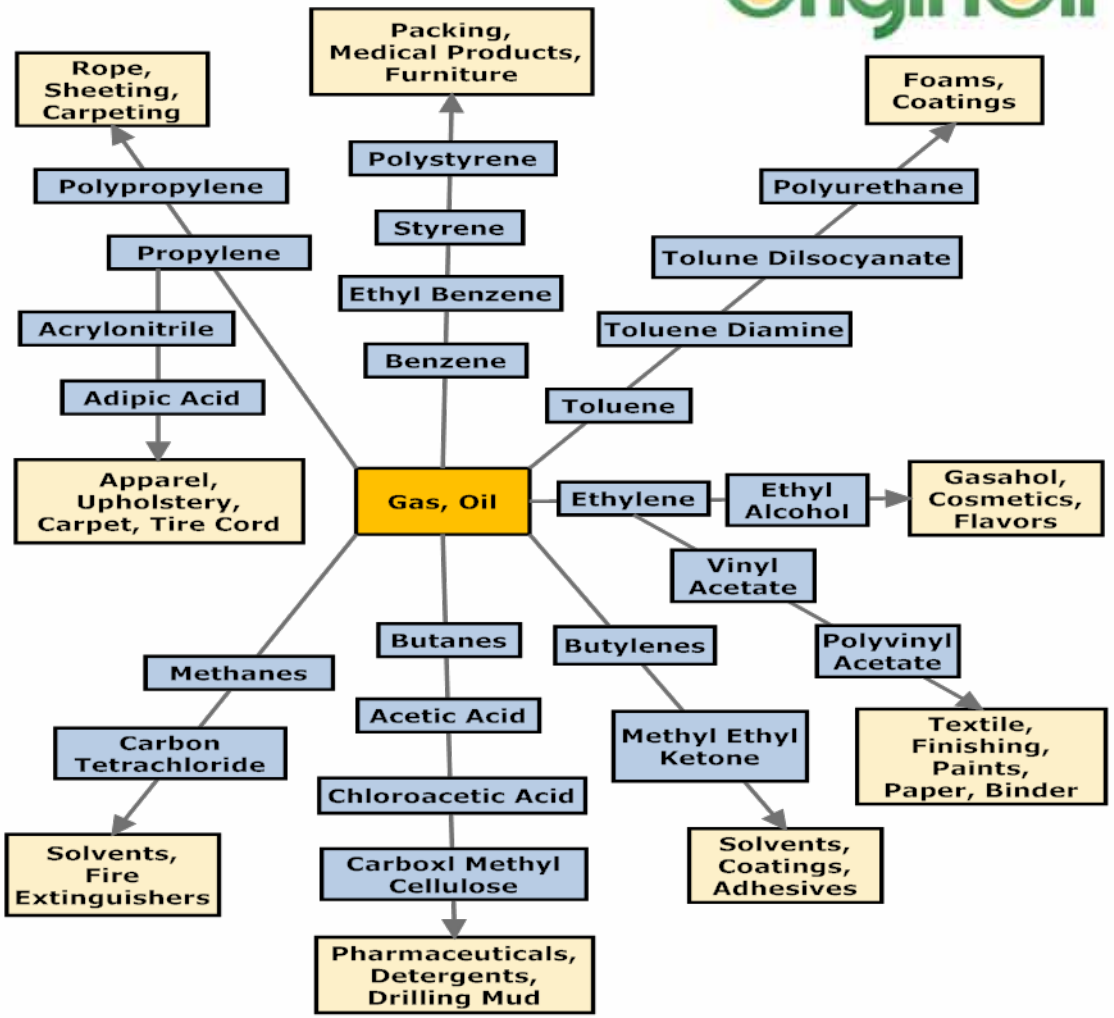
Considerations for Food Grade Applications

- Photosynthetic (autotrophic) growth systems are inherently sustainable:
  - "Free" sunlight for large-scale applications
  - World-class CO2 adsorption
  - Arable land is not required for any phase of operation.
- Key benefits are at odds with food-grade applications:
  - Using waste water for uptake of nitrates
  - Using brackish or salt water
  - Using industrial CO2
  - Using cheap open ponds
- Inputs can be controlled – at a cost – to achieve food-grade purity.
- Planners must consider the costs of food-grade applications in solar growth systems.
- For food grade apps: consider dark cycle growth (heterotrophic).

Fuels and Chemicals

- Biocrude from algae biomass is the most direct route to drop-in fuels and bio-chemicals.
- Every fraction of petroleum is achievable through this route.





Chemicals: price/volume sweet spot

- 90% of crude oil goes into fuel, but 40% of the profits come from petrochemicals.
- The chemicals market can deliver both large volumes and better pricing than fuel.
- Some data points:
  - Renewable chemicals market: US$56.9 billion in sales by 2015.
  - Elevance (Cargill spinoff in biochemicals) grossing $10MM today, forecasts $1 billion in 2016.
  - Elevance raised $100MM in 2010. Looking to transition to algae.
  - Fast-growing renewable chemicals company Cereplast (NASDAQ: CERP) has announced an intention to move from corn feedstocks to algae.

The CO2 Factor

- CO2 is driving major algae rollouts where governments are serious about carbon reduction.
  - Example: MBD Energy (largest stockholder Anglo-American Mining) now rolling out massive algae tracts to absorb CO2 from brown coal power plants.
  - Australia has spent AU$2B to date* on geo-sequestration, now committed to algae as far cheaper, quicker and more sustainable.
  - Algae-based CO2 abatement is an export technology for Australia.
- The CO2 benefit alone justifies algae for major emitters – especially in countries that plan to penalize emissions heavily.
  - 40 euros/ton on the way for CO2 emitters in Europe?

* Source: Austrade briefing at Advanced Biofuels Leadership Conference, Washington DC, 20 April 2011

Conclusions

- A standard for lysed biomass (“oily paste”) will allow growers to focus on growing, processors on processing.
- Solar growers must carefully consider the cost of certified food-grade operation vs. the benefits.
- Biocrude is the simplest path to fuel and chemicals.
- Chemicals are the sweet spot for non-food grade algae processing.
- CO2 regulation will continue to drive the development of large-scale solar algae systems.

THANK YOU!

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QUESTIONS?

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