The Promise and Challenges of Microalgae as a Source of Transportation Fuel

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The current excitement about algae
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Algae may not become the cheapest form of renewable energy.

But algae may become the most economical source of transportation fuels in a post-fossil-fuel era.
Why use alternatives to fossil fuels?

- Petroleum supplies are limited and are increasing in price
- The current dependency of foreign oil is a strategic risk
- Carbon dioxide emissions from fossil fuels are uncontrolled
Fossil fuels

- energy-dense
- transportable
- storable
- cheap

- non-renewable
- net emitters of carbon dioxide
- net emitters of noxous gases

Carbon-based molecules

[ C_x H_y ]
Processed transported and stored

Atmospheric carbon dioxide

heat buildings
drive industrial processes
decrease manual labor
transportation fuels

carbon-containing molecules pumped and mined
Alternative fuels

- generally renewable
- don’t emit carbon dioxide
- don’t emit noxious gases
- not very transportable
- not very storable

Electricity

- generally renewable
- don’t emit carbon dioxide
- don’t emit noxious gases
- not very transportable
- not very storable

Energy conversion

- not easily stored or transported over long distances

Solar cells

Nuclear energy

Wind

Heat buildings

Drive industrial processes

Decrease manual labor

Transportation

Fuel cells

Storage batteries
Plants or Algae

- energy rich
- transportable
- storable
- renewable
- don’t emit carbon dioxide
- cost

Carbon-based biomass

photosynthetic organisms

light

[ C x H y R y ]
Processed transported and stored

[ C x H y ]

heat buildings drive industrial processes decrease manual labor

carbon-containing molecules extracted

carbon dioxide

transportation fuel

- cost
Algae is the most sustainable known potential source of biofuel.

- They can easily be grown in a CO₂ enriched environment.
- They are diverse in nutrient requirements.
- They can grow in fresh water, salt water or waste water.
- They grow much more rapidly than do plants.
- They are much more genetically diverse than are plants.
- Some kinds are easily modified genetically.
- They thrive in a much greater range of environmental conditions than do plants.
Various transportation fuels can now be produced from algae.

**General Concept of Algal Biofuel Production**

1. **Cultivate algae**
2. **Harvest (concentrate)**
3. **Extract desired product**
4. **Process, refine, etc.**
General Concept of Algal Biofuel Production

cultivate algae

→

harvest (concentrate)

→

extract desired product

→

process, refine, etc.

Biomass

Pyrolysis,

Gasification

Gasoline,

Jet fuel,

etc.
General Concept of Algal Biofuel Production

cultivate algae ➔ harvest (concentrate) ➔ extract desired product ➔ process, refine, etc.

- Biomass ➔ Pyrolysis, Gasification ➔ Gasoline, Jet fuel, etc.

- Drop-in biofuel ➔ Ethanol, Hydrocarbon, etc.
General Concept of Algal Biofuel Production

cultivate algae → harvest (concentrate) → extract desired product → process, refine, etc.

- Biomass
  - Pyrolysis, Gasification
    - Gasoline, Jet fuel, etc.

- Drop-in biofuel
  - Ethanol, Hydrocarbon, etc.

- gasoline, jet fuel, biodiesel, etc.
General Concept of Algal Biofuel Production

- wild strain of algae
- genetically modified algae

1. cultivate algae
2. harvest (concentrate)
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- Biomass
- Pyrolysis, Gasification
- Gasoline, Jet fuel, etc.

- Drop-in biofuel
- Ethanol, Hydrocarbon, etc.
- gasoline, jet fuel, biodiesel, etc.
What is the current status of microalgae as a commodity?

Microalgae are known that grow very fast and microalgae are known that produce lots of oil or other valuable products.

*Chlorella vulgaris* grows very aggressively.

*Botryococcus braunii* produces and secretes large quantities of high-energy hydrocarbons.
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A few companies world-wide are scheduled to scale up algae production to hundreds of acres for the production a commodity within 1 – 2 years.

Sapphire Energy, Inc.
Then why aren’t we right now filling our gas tanks with algae-based gasoline, algae-based alcohol, or algae-based biodiesel?
Here is the central bottleneck

cultivate algae → harvest (concentrate) → extract desired product → process, refine, etc.
No one has ever grown any micro-organism at the massive scale required to produce meaningful quantities of a fuel.
Microalgal culturing for biofuel production will not be like any existing industrial microbial technology.
Microalgal culturing for biofuel production will not be like any existing commercial aquaculture or terrestrial farming.
The Commercial Potential of Microalgae

NON-PHOTOSYNTHETIC BACTERIA
industrial microbiology, molecular biology

MACROALGAE
aquaculture, marine farming

hybrid and novel technologies
mass-cultured microalgae
Scaling-up of microalgal cultures leads to emergent issues that cannot be fully controlled.

Examples:

- competitor algae

- predators such as microscopic animals

- diseases such as bacteria and viruses

- abiotic factors such as temperature