Algae and Other Co-products from Digesters: Opportunities and Challenges

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Benefits of Anaerobic Digestion

- **Renewable energy**
- **BOD/COD reduction**
- **Odor reduction**
- **Pathogen reduction**
- **Nutrient conservation**
- **Greenhouse gas reduction**

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STORAGE *versus* TREATMENT

- **Unbalanced fermentation**
- **Intermediate metabolite accumulation**
- **Malodor**

- **Balanced fermentation**
- **Waste stabilization**
- **Permanent odor reduction**

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BIOGAS and ALGAE

- **Nutrient-rich effluent from biogas production can be used for mass cultivation of algae**
- **CO_2 supplied from biogas combustion promotes algal growth.**

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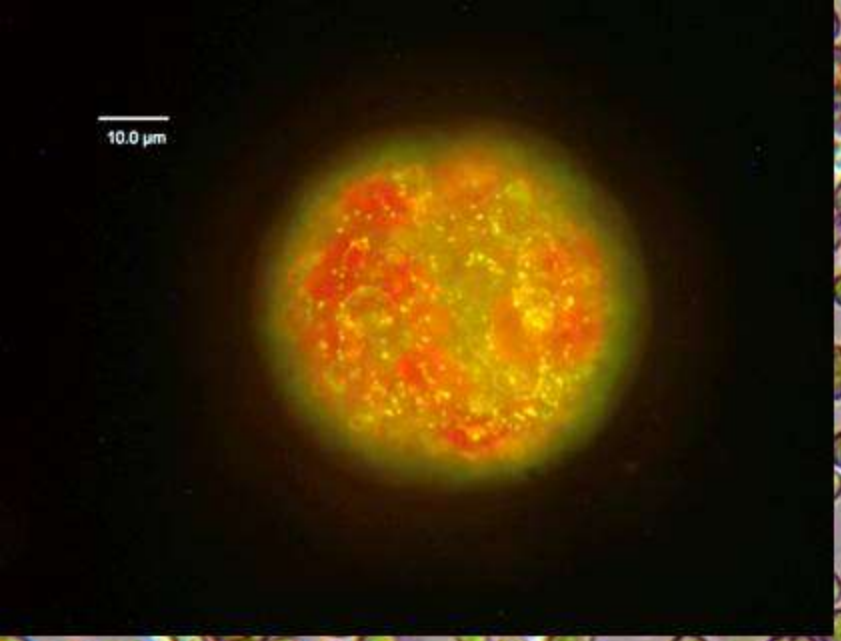
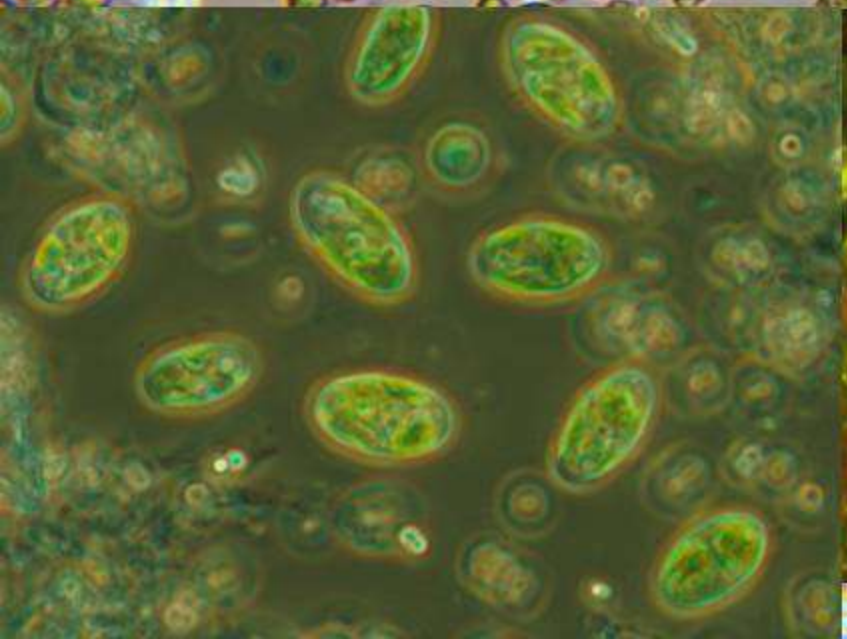
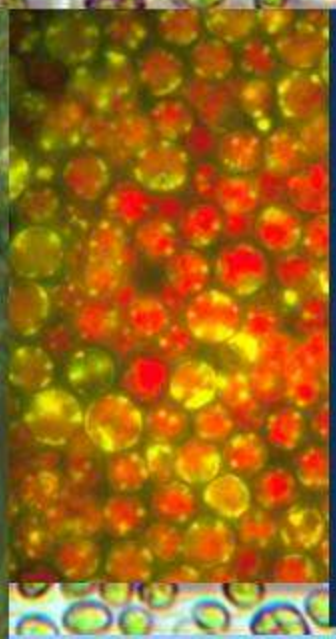
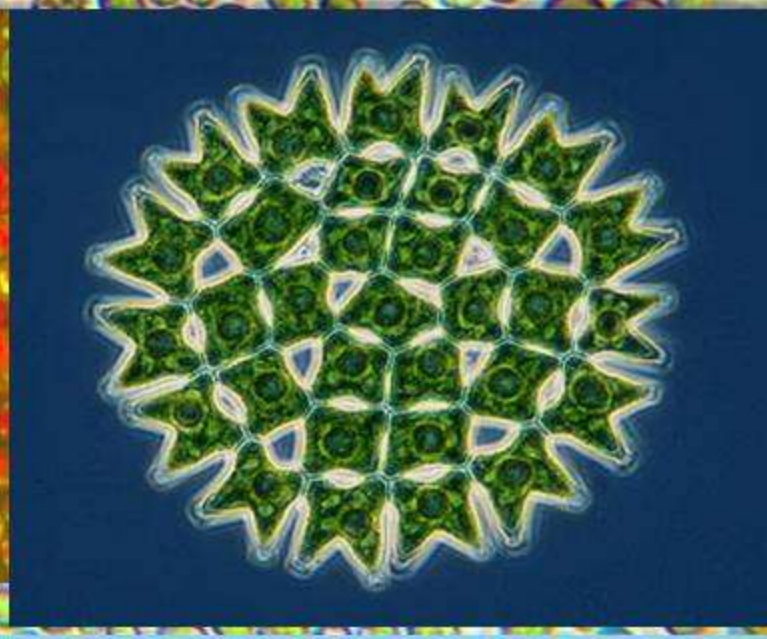


Algae : a catch-all phrase referring to any of the micro and macroscopic plants that lack true leaves, roots, and stems. Ranging in size from single-cells to giant kelps and including both prokaryotic and eukaryotic organisms.





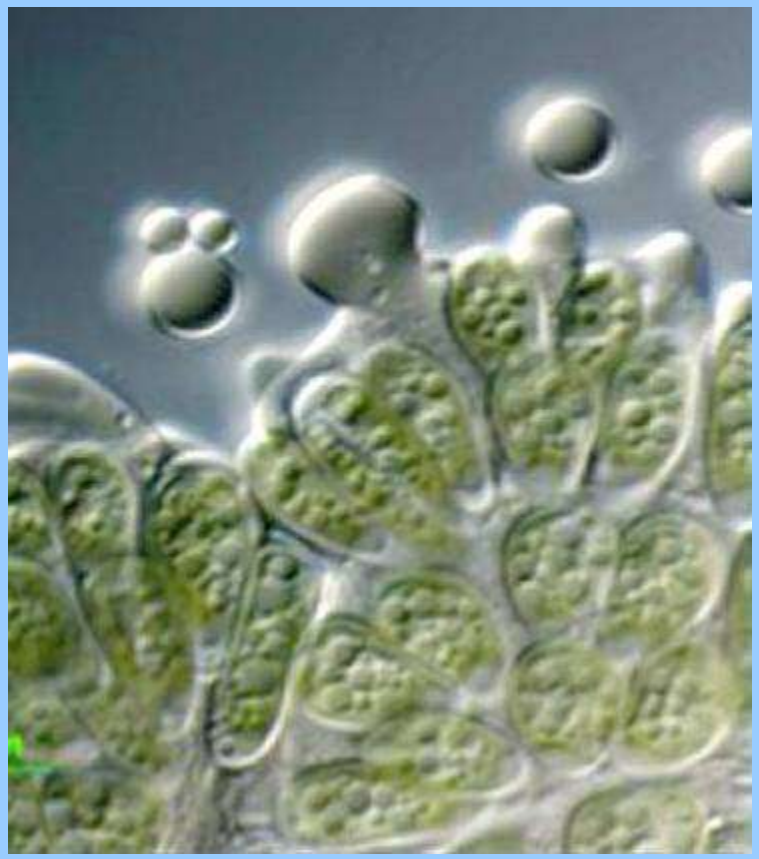


The Botanical Diversity of Algae

- Algae are a diverse polyphyletic group of organisms
  - 40,000 recognized species
  - 10,000,000 yet to be described
- Nine major taxonomic Divisions
- Ubiquitous, found on every continent and in every ocean.

Why Algae?

- **Algae produce lipids that can be used as a fuel**
  - **Some algae can store up to 50% of their dry weight as oils**



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Algae as an Energy Crop

- **Land Use** – Marginal lands, Vertical potential, small footprint

  +

- **Water Use** – Municipal/Agricultural wastewaters, Saline water, Conserves freshwater use

  +

- **Nutrient Resource** – Utilization of abundant, nutrient-rich wastes replaces expensive synthetic nutrient inputs

  +

- **Carbon Capture** – Greenhouse gas mitigation, potential sequestration

  =

- **Sustainable Energy Production**

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Diverse Options

- **Lipids** – Petroleum alternatives
- **Carbohydrates/Fibers** – Biogas or Alcohol production, Animal feed
- **Proteins –** Animal feed or Nitrogenous fertilizers
- **Residual/Total Biomass** – co-fired in existing coal boilers, anaerobically digested, or gasified for use in combined-cycle systems

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Abundant Growth

- **Aquatic Advantage**
  - Efficient exchange
  - No complex support structures
- **Cellular Multiplicity**
  - Daily doublings
- **Biomass Production Potential**
  - Daily Biomass Harvesting

Strain	Genus	Family	Growth Rate (doublings•day^{-1})
OSCIL2	*Oscillatoria*	Cyanophyceae	**4.23**
OSCIL3	*Oscillatoria*	Cyanophyceae	**3.50**
AMPHO46	*Amphora*	Bacillariophyceae	**2.81**
NANNO13	*Nannochloris*	Chlorophyceae	**2.78**
CHLOR23	*Chlorella*	Chlorophyceae	**2.66**
SYNEC3	*Synechococcus*	Cyanophyceae	**2.51**

Adapted from: Sheehan J, Dunahay T, Benemann J, Roessler P (1998). A Look Back at the U.S. Department of Energy's Aquatic Species Program—Biodiesel from Algae. U.S. Department of Energy's Office of Fuels Development. Prepared by: the National Renewable Energy Laboratory.

Algae can utilize wastes

- **Algae have been used successfully to treat N and P excess of sewage/manure wastes generated by animals and human activities.**
- **Algae can significantly reduce farm waste environmental impacts, while creating useful products.**

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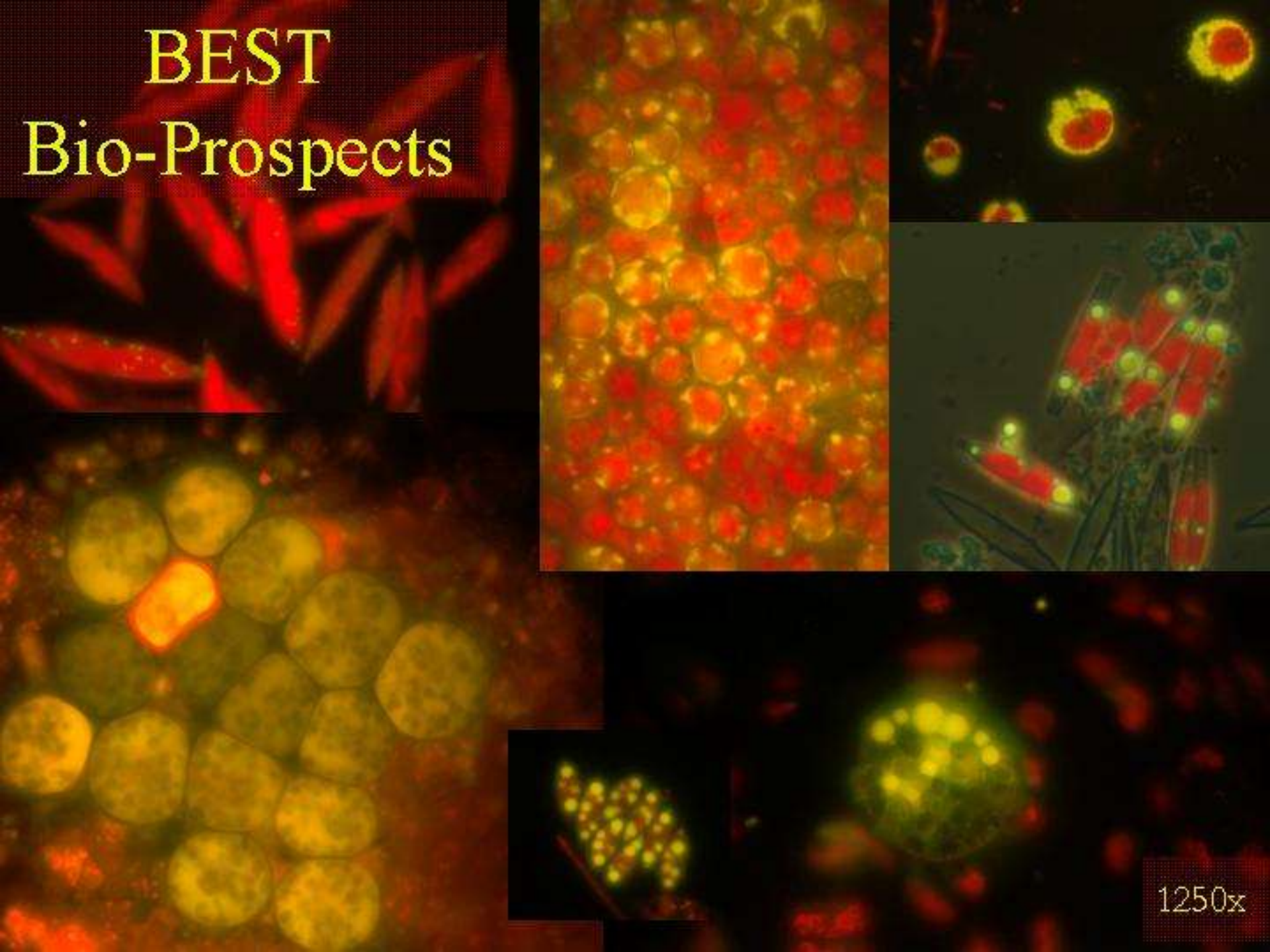
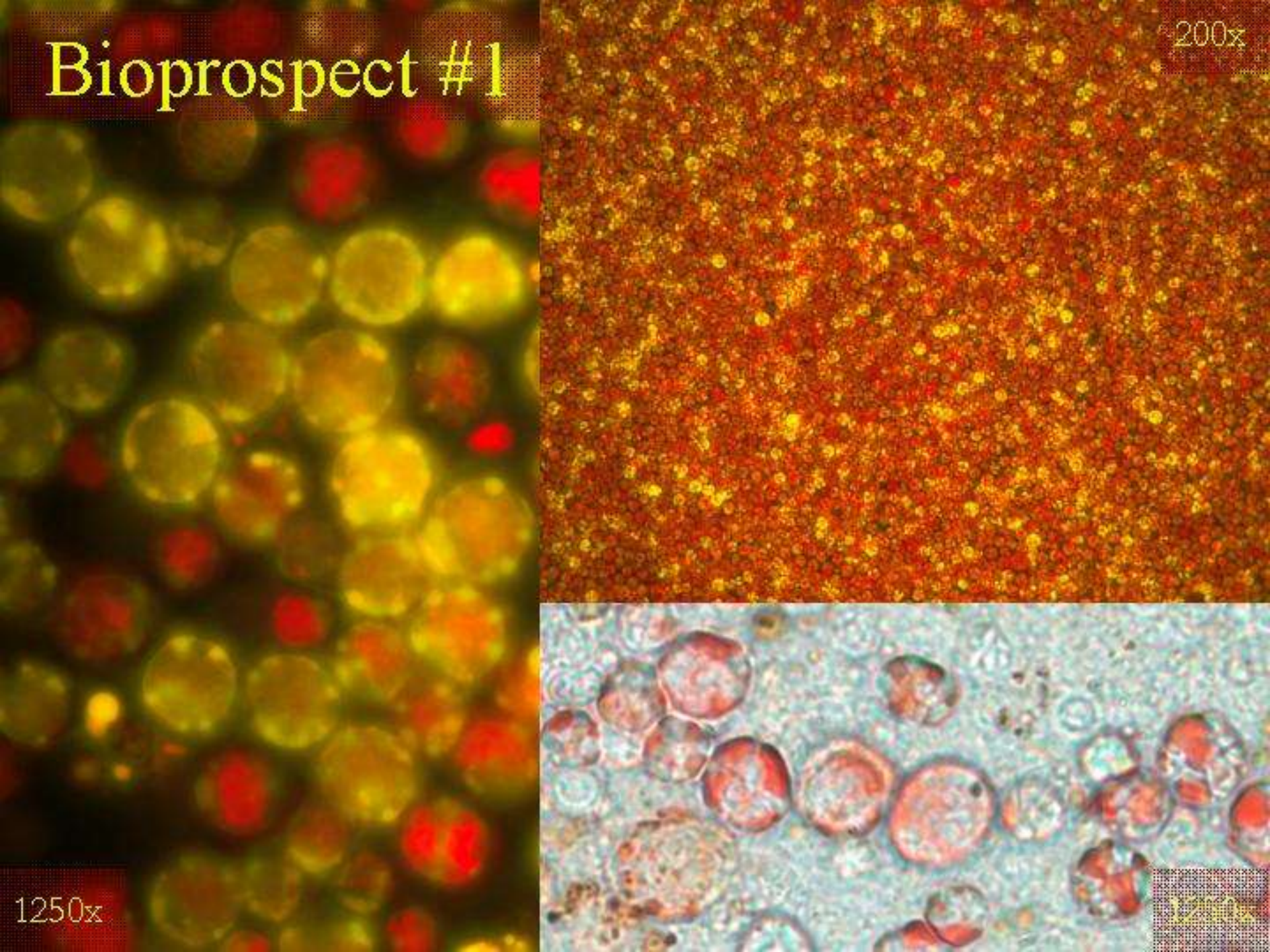
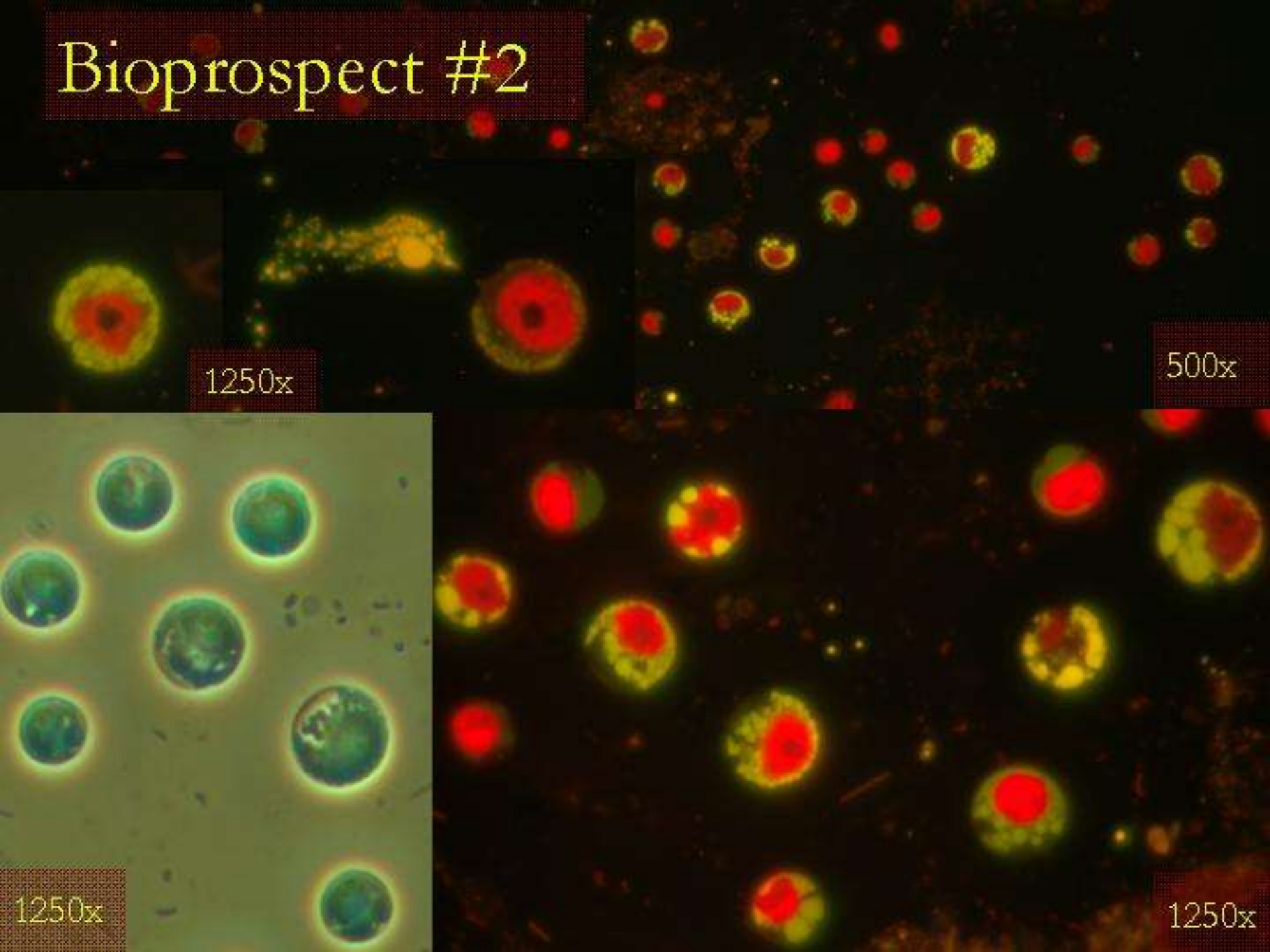
Growing Prospects

Chlorella

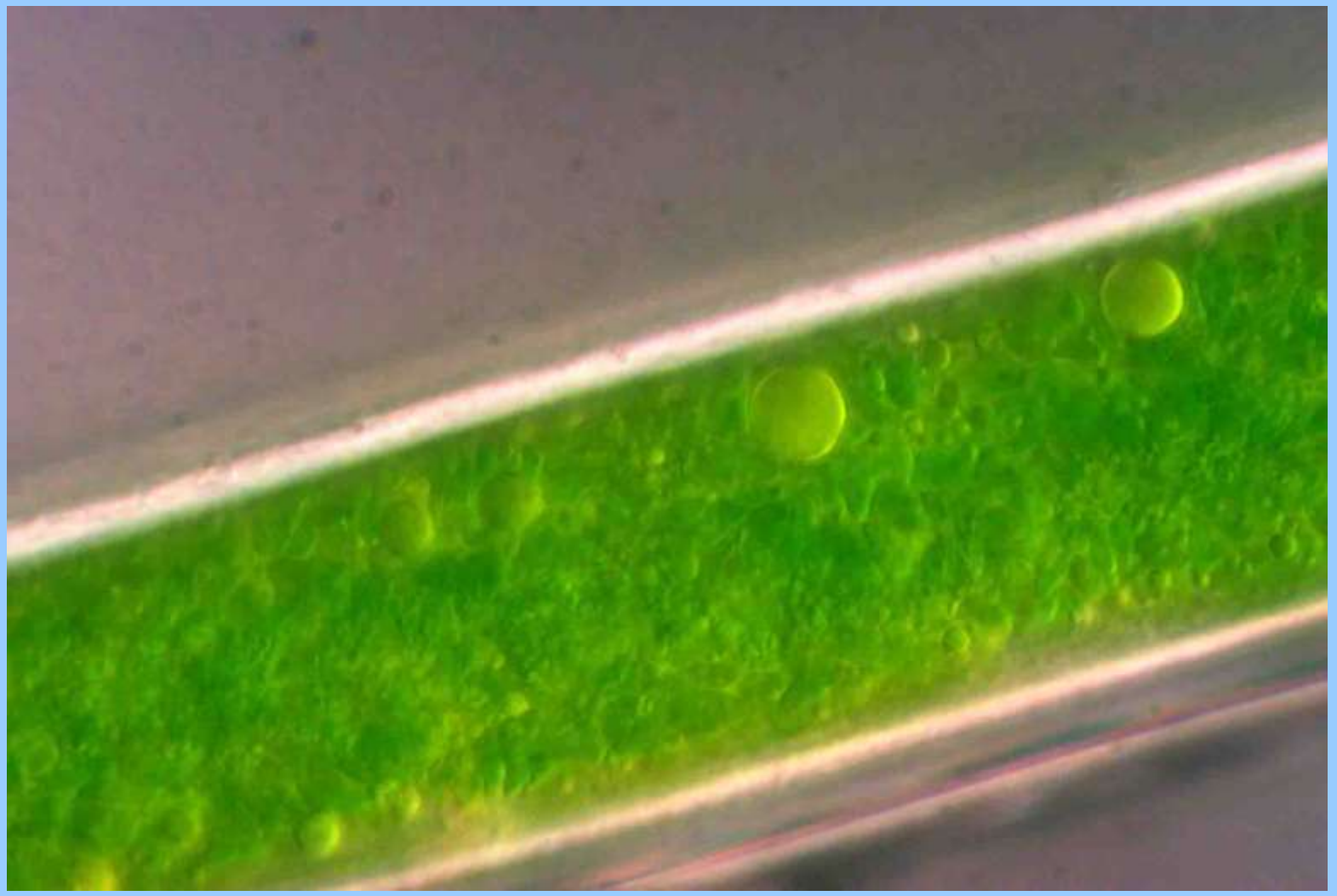

BEST
Bio-Prospects
1250x


Bioprospect #1
200x
1250x

Bioprospect #2



Algal Lipids



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Cladophora

What is *Cladophora*?

Courtesy Protist Information Server

Cladophora is a branching, green filamentous alga found naturally along the coastline of most of the Great Lakes. Research in the 1960's and 70's linked *Cladophora* blooms to high phosphorus levels in the water, mainly as a result of human activities such as fertilizing lawns, poorly maintained septic systems, inadequate sewage treatment, agricultural runoff and detergents containing phosphorus. Due to tighter restrictions, phosphorus levels declined during the 1970's and *Cladophora* blooms were largely absent in the 1980's and 90's.

What is the status of *Cladophora* in Lake Michigan today?

There has been a recent resurgence of macroalgae, predominantly *Cladophora*, along the coast of Lake Michigan and other Great Lakes. These algae blooms lead to unsightly and foul-smelling beaches and have negative economic consequences as a result of the lowered beach use. In addition, *Cladophora* blooms result in reduced quality of drinking water and decreased property values.

Cladophora *washed up on a Wisconsin beach in 2004.*

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- **Fugitive nutrients**
  - **Wild algae**

- **Farmed algae**
  - **Domesticated algae**

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Algae on the Farm – Opportunities

- **Manage excess nutrients**
- **Animal Feed**
- **Fertilizer**
- **Feedstock for anaerobic digesters**
- **Feedstock for biodiesel production**
- **Feedstock for biorefineries**

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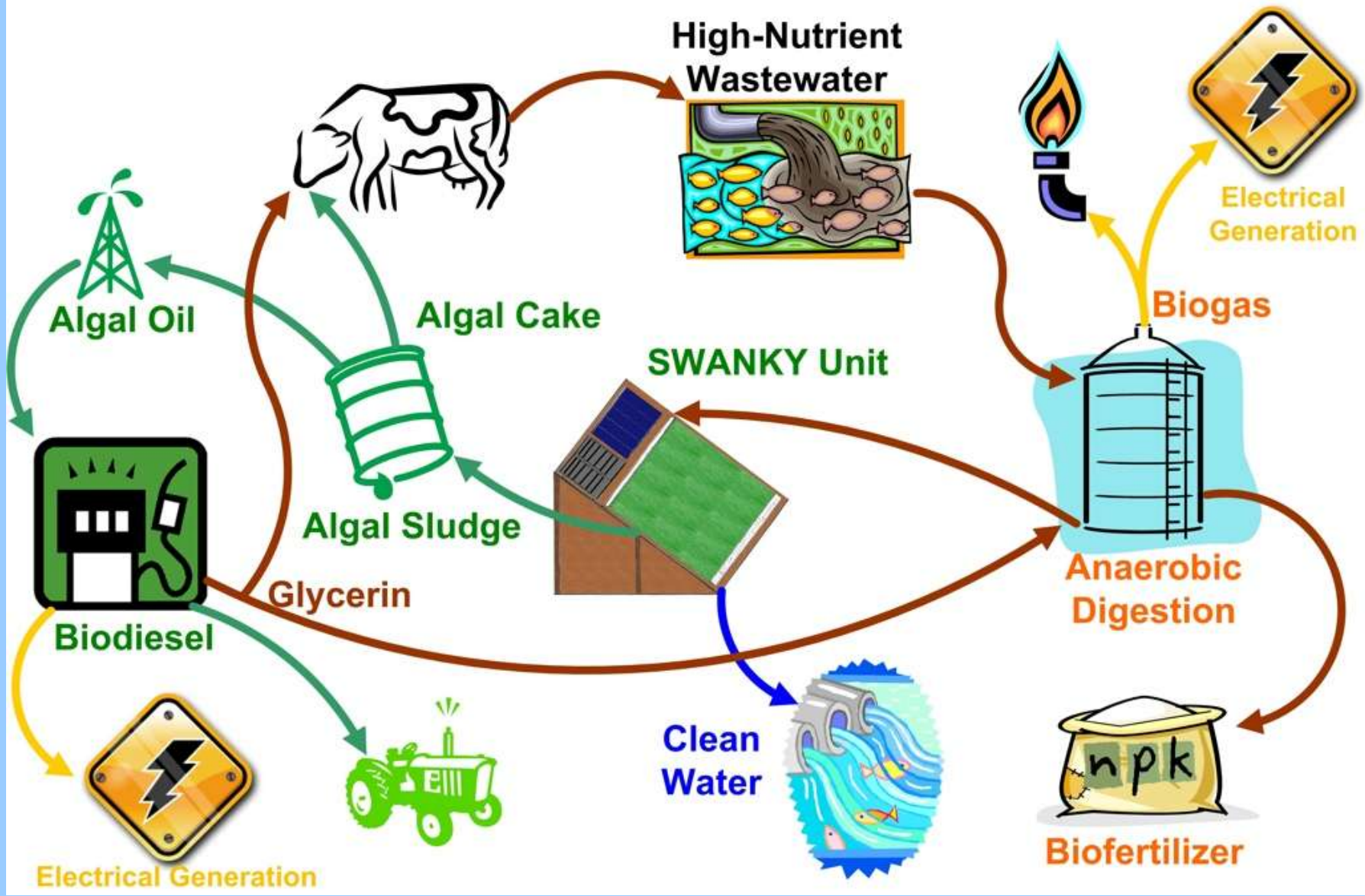
SWANKY Farm Refinery



Algae on the Farm – Opportunities

Nutrient Management

- **Comprehensive nutrient management plans**
- **TMDL – Total Maximum Daily Load**
- **Manage excess nutrients**

Algae on the Farm – Opportunities

Animal Feed

- **On-farm use**
- **Local feed co-op**

Algae on the Farm – Opportunities

Fertilizer

- **On-farm use**
- **Local organic fertilizer co-op**

Algae on the Farm – Opportunities

Feedstock for Anaerobic Digesters

- **Increase gas production**
- **Increase electricity generation**
- **Facilitate co-digestion by capturing imported nutrients**

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Algae on the Farm – Opportunities

Feedstock for Biodiesel Production

- **On-farm – future**
- **Local biodiesel co-op**

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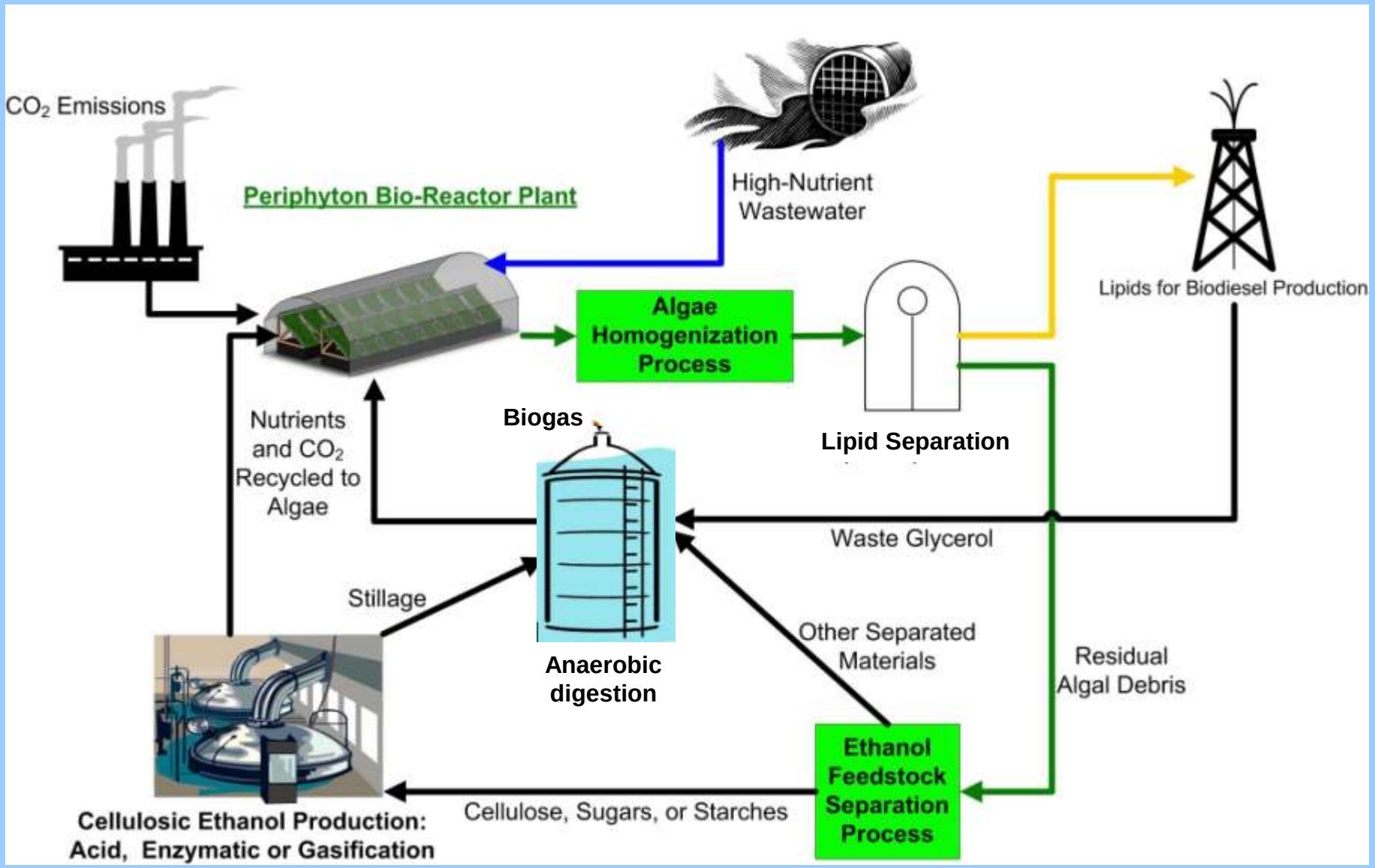
Algae on the Farm – Opportunities

Feedstock for Biorefineries

- **Biofuel refineries**
  - **Ethanol**
  - **Bio-crude**

Biodiesel and Bioethanol from Algal Biomass



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Algae on the Farm - Challenges

- **Which algae to grow ?**
  - **Local strains are best fitted**
  - **Strains indigenous to manure types**
- **When to grow ?**
  - **Warm weather crop**
  - **Greenhouse cultivation**
- **How to harvest algae ?**
  - **Size and density**
  - **Mechanical / Chemical**
  - **Drying**
- **Is there a market for manure algae ?**

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http://biogas.ifas.ufl.edu

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