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Sustainable Algal Biofuels Consortium

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SABC Project: Biochemical Conversion of Algal Biomass and Fuel Testing

Lead Institution:	Arizona State University
Leader:	Gary Dirks (ASU)
Funds:	Federal - $6M
	Industry Cost Share - $1.5M
Project duration:	Two years

U.S. DEPARTMENT OF ENERGY · ASU · NREL · Sandia National Laboratories · GT · School of Mines Colorado 1874 · SRS Energy · novozymes Rethink Tomorrow

Biochemical Conversion of Algal Biomass and Fuel Testing

Objective:

The primary objective is to evaluate biochemical (enzymatic) conversion as a potentially viable strategy for converting algal biomass into lipid-based and carbohydrate-based biofuels. Secondary objective is to test the acceptability of algal biofuels as replacements for petroleum-based fuels.

Approach:

- Develop a feedstock matrix of algal biomass based on species and growth/process conditions
- Determine and characterize biochemical composition of selected strains
- Explore multiple enzymatic routes to hydrolyze and convert untreated or pretreated whole algal biomass, oil extracts, and algal residuals
- Determine *fit-for-use* properties of algal derived fuels, fuel intermediates

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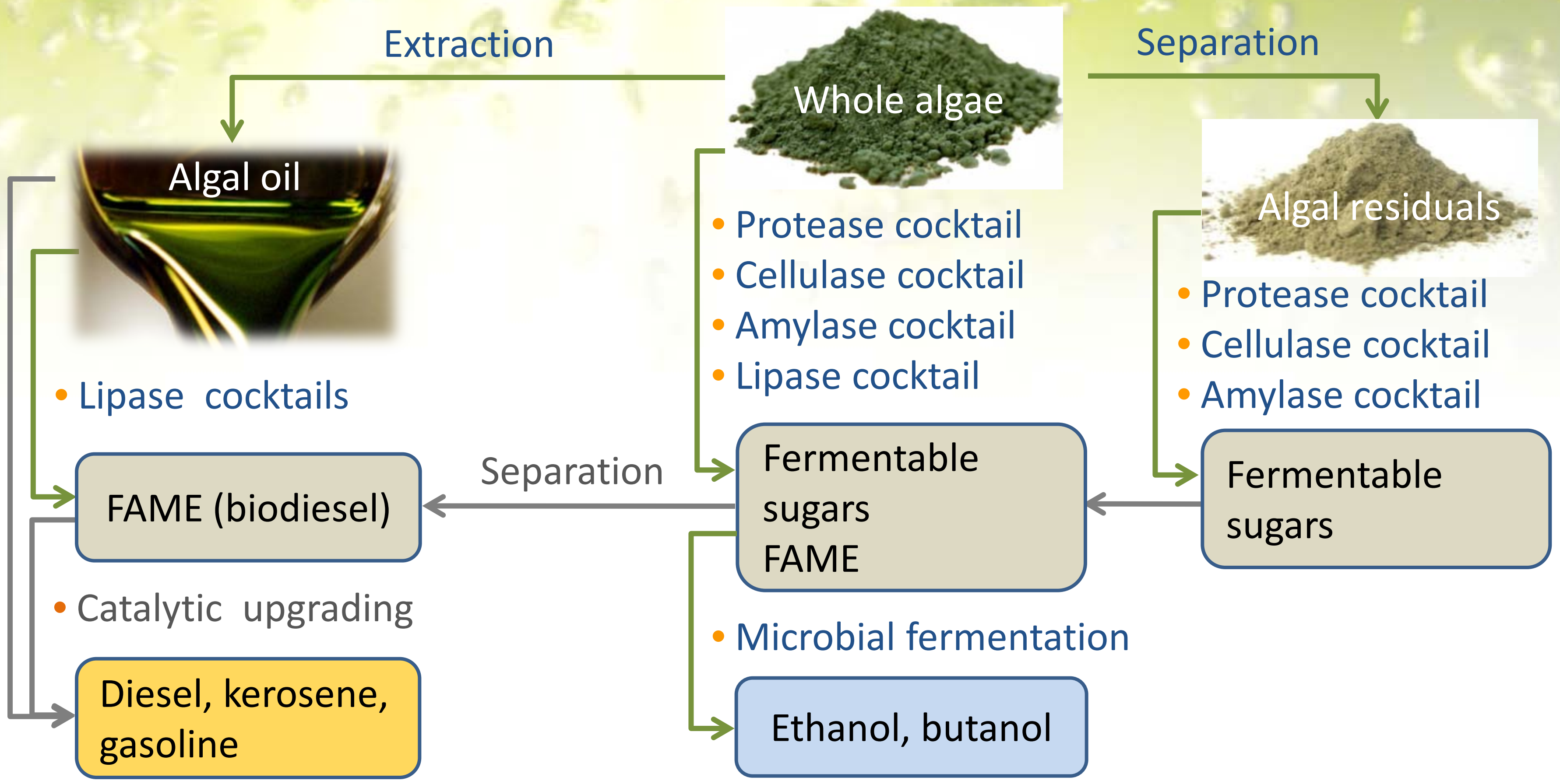
Multiple Biochemical Conversion Strategies and Routes of Algal Feedstocks into Biofuels



Potential Process Improvements from Biochemical Conversion

- Biochemical processing of whole algae has the potential to eliminate costly drying and extraction steps
- Application of multiple enzyme cocktails to whole algae enables simultaneous or sequential production of lipid-based and fermentable sugar-based fuel intermediates
- Simultaneous enzymatic hydrolysis, esterification and transesterification of whole algae or algal oil extracts to produce FAMEs reduce process steps and yield potentially cleaner fuel intermediates for final processing to biodiesel or further upgrading to other fuels
- Biochemical processing under mild reaction conditions may minimize the formation of side products and preserves other potentially valuable co-products (e.g., proteins, carotenoids, vitamins)
- Biochemical processing of algal biomass may be easier than that of lignocellulosic feedstocks due to simpler biochemical composition and structure

SABC Team and Organization

- The project led by Dr. Gary Dirks and administered by **ASU**
- The R&D will be carried out primarily by **ASU**, **NREL** and **SNL**
- Additional contributions from Georgia Institute of Technology, Colorado Renewable Energy Collaboratory, Colorado School of Mines, SRS Energy, Lyondell Chemical Company, and Novozymes.
- 24 month scope of work primarily focused on biochemical conversion of algal residuals and whole algal cells

Two Main Technical Tasks:

Task 1 Investigate several promising biochemical options for converting both whole algae and algal residues into transportation fuels

Task 2 Produce samples of those fuels (both lipid and carbohydrate based) and perform fuel testing to determine if those fuels are *fit-for-purpose*

Task 1: Biochemical Conversion of Whole Algae/Algal Residuals into Fuels

Subtask 1.1. Produce selected algae for biochemical conversion

Subtask 1.2. Develop a fundamental understanding of algal chemical composition and structure

Subtask 1.3. Identify and test a variety of pretreatment options and hydrolytic enzyme preparations to facilitate release of fermentable sugars and conversion of algae residues/whole algae into fuel intermediates/products

Task 2: Product Performance of Algal-Derived Hydrocarbon Fuels and Blend Components

Subtask 2.1: Chemical analysis and basic characterization – FAME, diesel

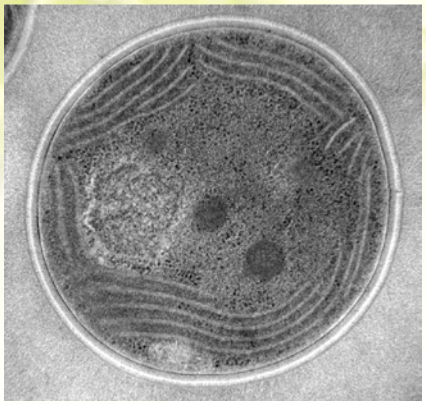
Subtask 2.2: Chemical analysis and basic characterization – alcohols from biochemical conversion.

Subtask 2.3: ASTM specification performance and property assessment

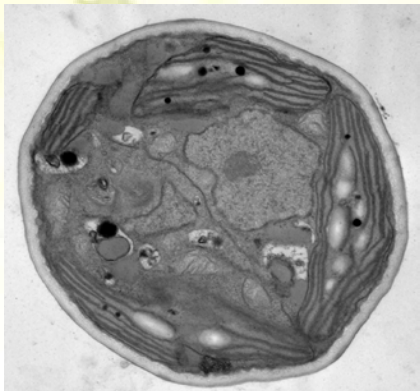
Subtask 2.4: Fuel stability assessment (i.e., storage and thermal stability)

Biochemical Composition of Algae is Species-Specific

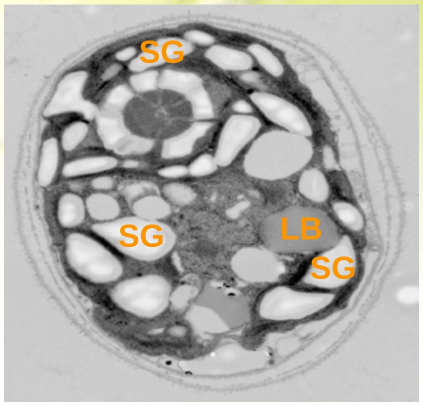
SG = starch granule LB = lipid body



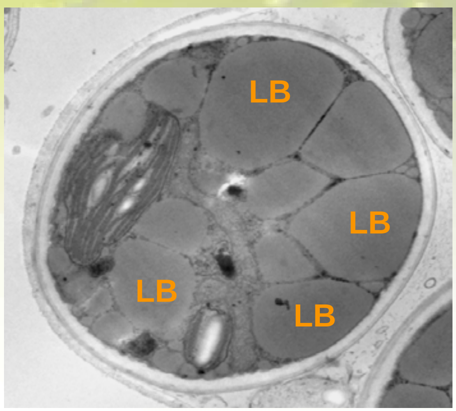
Synechosystis



Palmellococcus



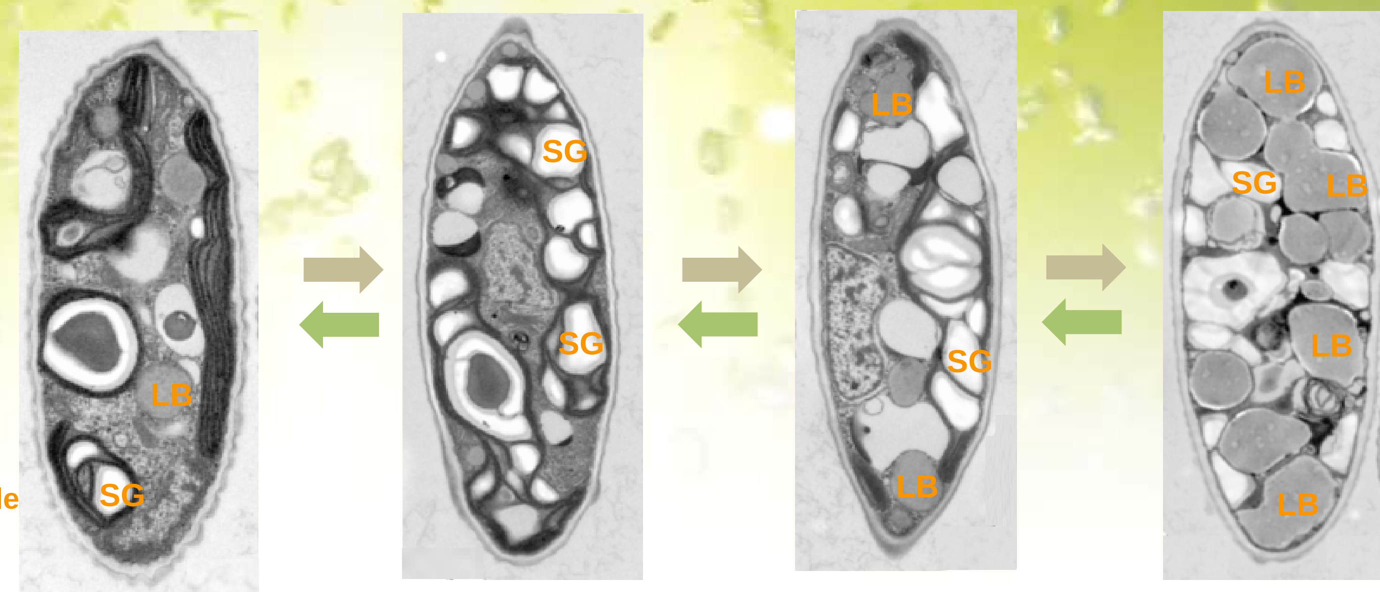
Chlamydomonas



Pesudochlorococcum

Lipid (% dwt)	8	8	15	60
Starch (% dwt)	0	5	45	6
Protein (% dwt)	60	50	20	15

Biochemical Composition of Algae is Condition-Dependent



LB = lipid bodies
SG = starch granule

Reversible transformation of a *Scenedesmus* cell under various culture conditions

Lipid (% dwt)	10	15	20	45
Starch (% dwt)	8	35	25	15
Protein (% dwt)	55	30	20	10
Cell wall (% dwt)	10	12	14	16

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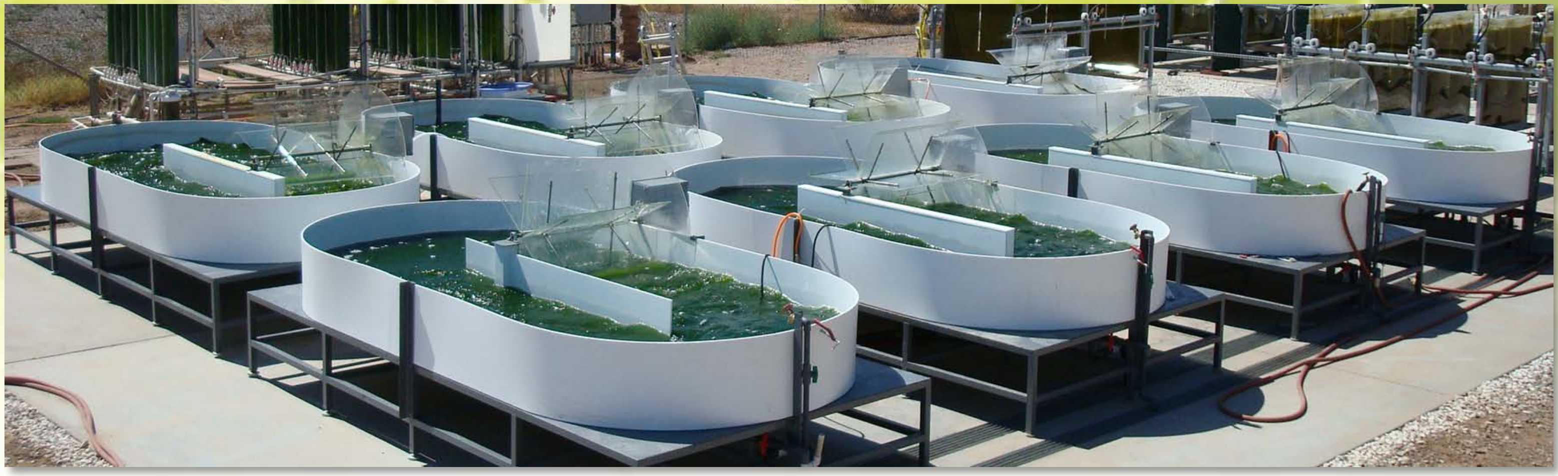
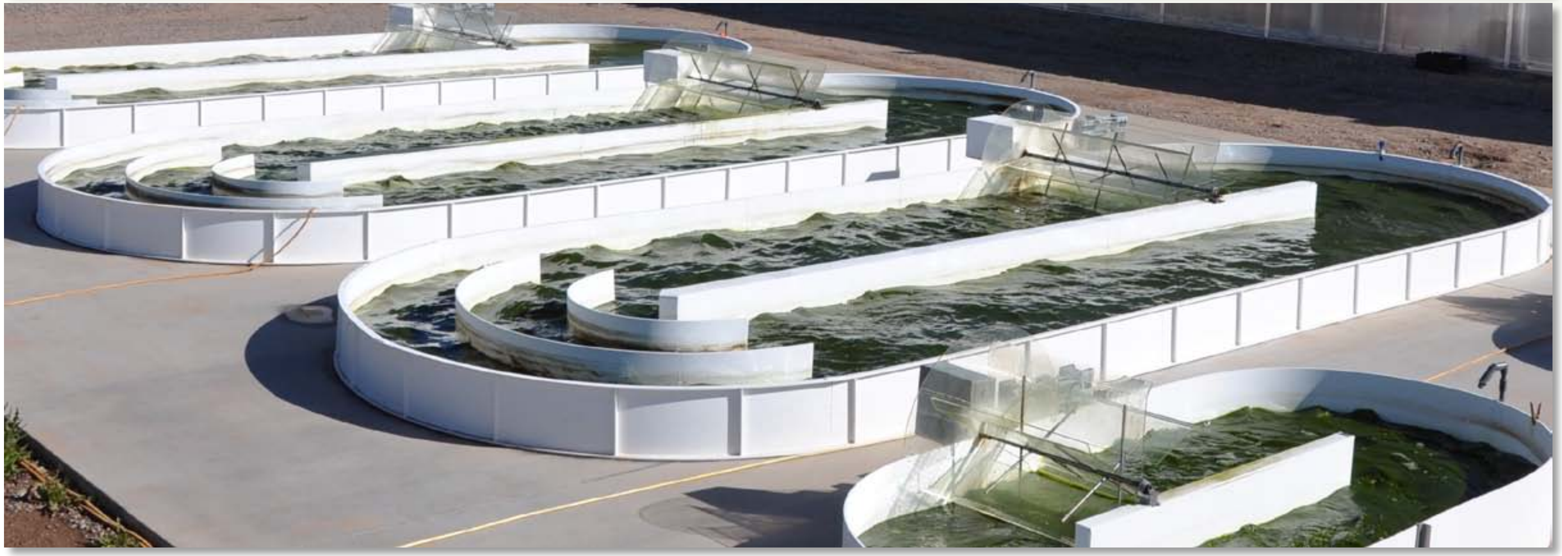
Open Raceways Available for Algal Feedstock Production





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Photobioreactors Available for Algal Feedstock Production

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Major Milestones and Timetable

Phase I:

Small-scale screening for fuel feedstock production and biochemical processing features

Phase II:

Integration of process operations down-selected in Phase I

Phase III:

Scale-up of integrated process for production and testing of fuels

Milestones:

Down-select strains and culture optimization
(Target date: Month 9)

Produce sufficient lipid-rich and carbohydrate-rich algal biomass
(The entire project)

Multiple routes for pretreatment/enzymatic hydrolysis evaluated
(Month 10)

Milestones:

Down-select best strains and processes for maximum lipid and ethanol yields
(Month 15)

Milestones:

Report on chemical analysis and ASTM standards testing for algal biofuels (Month 23)

Final report on fuel production using a biochemical or a combined chemical-biochemical approach and identification of critical elements for future work/cost reduction (Month 24)

Summary of Expected Outcomes

Subtask 1.1 and Subtask 1.2 (NREL, Sandia, CSU, ASU)

- Support biomass growth of g to kg quantities (per selected species/growth condition)
- Complete compositional analysis of algal biomass with the generation of a compositional library as a function of species, growth conditions

Subtask 1.3 (NREL, Sandia, ASU, Novozymes)

- Identify a number of pretreatment options and test existing commercial enzymes to develop baseline
- Explore the development and testing of new pretreatment steps and algae specific enzyme formulations
- While initial focus on algal residuals, also test biochemical conversions on whole cell algae and test whether conversion of whole cell algae will facilitate lipid extraction while at the same time producing fermentable sugars in order to produce a new paradigm in algal biomass processing

Subtask 2 (NREL, ASU, SRS, Lyondell)

- Detailed chemical analysis and basic characterization of the impurities present in the fuels produced from algal biomass generated in Task 1
- Assessment of compliance with ASTM specifications for chemical composition, performance, and stability requirements algal derived biofuels

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Thank for your time and attention!