



# The National Alliance for Advanced Biofuels and Bioproducts

## *An Algal Biofuels Consortium*

*José A. Olivares  
Executive Director*

*Los Alamos National Laboratory and  
The Donald Danforth Plant Science Center*

Slide 1

# New DOE-EERE Award for an Algal Biofuels Consortium

- **National Alliance for Advanced Biofuels and Bioproducts (NAABB)**
  - **Institutional Lead:** The Danforth Plant Science Center (St. Louis, Mo)
  - **Leader:** Jose A. Olivares (LANL/DAPSC)
  - **Funds:** Federal - \$48,844,840 ; Industry Cost Share - \$20M
  - ***Develop the science and technology necessary to significantly increase production of algal biomass and lipids, efficiently harvest and extract algae and algal products, and establish valuable conversion routes to fuels and co products.***



## Algal Biology

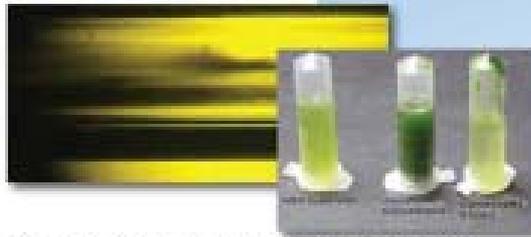


Greater space-time  
lipid/algae yields

## Cultivation



## Harvesting and Extraction



Novel techniques to reduce  
cost and environmental impact

## Valuable Coproducts



Livestock feed



Direct energy  
production



Chemicals for  
industry use

## Fuel Conversion



High energy-density fungible fuels



CO<sub>2</sub>



Water



Land



Nutrients

SUSTAINABILITY

# The NAABB Targets for a Viable Algal Biofuels Industry

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- **Increased Algal Production**
  - >50% lipid/hydrocarbon dry weight
  - >20 gdw/m<sup>2</sup>/day from pond cultivation
  - 1-2 gdw/L from bioreactors
- **Efficient Harvesting and Extraction**
  - 5000 gal/day processing
  - 15 gal/day lipid extraction
  - \$0.51 /std barrel/day
- **Marketable Co-products**
  - Animal feed development and testing
  - Glycerol = \$80/ton
  - Lipid extracted algae = \$250-1000 / ton
- **Affordable Fuel**
  - <\$0.40 / algal processing
  - <\$2.10 / gal lipid

# NAABB Algal Biofuels Consortium Partnership

The Donald Danforth Plant Center, lead institution

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## *National Laboratories*

- Los Alamos National Laboratory
- Pacific Northwest National Laboratory

## *Universities*

- Brooklyn College
- Colorado State University
- New Mexico State University
- Texas AgriLife Research (TAMU)
- Texas A&M University System
- University of Arizona
- University of California Los Angeles
- University of California San Diego
- University of California Davis
- University of Washington
- Washington University, St. Louis
- Washington State University

## *Industries*

- AXI
- Allied Minds
- Catilin
- Diversified Energy
- Eldorado Biofuels
- Genifuel
- HR Biopetroleum
- Inventure
- Kai BioEnergy
- Palmer Labs
- Pratt & Whitney
- Solix Biofuels
- Targeted Growth
- Terrabon
- UOP

**Subcontractors:** Iowa State University, North Carolina State University, University of Pennsylvania, University of Texas, Clarkson University

# Development and Commercialization Value Chain



**DISCOVERY**  
Feedstock Logistics

WHAT STARTS HERE CHANGES THE WORLD  
THE UNIVERSITY OF TEXAS AT AUSTIN

Logiged Growth, Inc.

UCLA

SOLIX  
ALGAE TO ENERGY

DIERSIFIED ENERGY

W UNIVERSITY OF WASHINGTON

HR BioPETROLEUM

Los Alamos NATIONAL LABORATORY

UC DAVIS ENERGY INSTITUTE

USDA

AgriLIFE RESEARCH  
Texas A&M System

Pacific Northwest NATIONAL LABORATORY  
Proudly Operated by Solix Since 1913

AXI  
An Allied Minds Company

DONALD DANFORTH PLANT SCIENCE CENTER  
DISCOVER • ENLIGHTEN • SHARE • NOURISH

Pacific Northwest NATIONAL LABORATORY  
Proudly Operated by Solix Since 1913

**DEVELOPMENT**  
Harvesting

INVENTURE

KAI BIOENERGY  
Tennessee's Energy Today

SOLIX  
ALGAE TO ENERGY

Clarkson UNIVERSITY

Penn

Los Alamos NATIONAL LABORATORY

AgriLIFE RESEARCH  
Texas A&M System

UCLA

HR BioPETROLEUM

DIERSIFIED ENERGY

W UNIVERSITY OF WASHINGTON

HR BioPETROLEUM

Los Alamos NATIONAL LABORATORY

AgriLIFE RESEARCH  
Texas A&M System

Pacific Northwest NATIONAL LABORATORY  
Proudly Operated by Solix Since 1913

Clarkson UNIVERSITY

THE UNIVERSITY OF ARIZONA

KAI BIOENERGY  
Tennessee's Energy Today

SOLIX  
ALGAE TO ENERGY

INVENTURE

**DEPLOYMENT**  
Fuel Conversion & Coproducts

UCLA

NC STATE UNIVERSITY

UC DAVIS ENERGY INSTITUTE

Uop  
A Honeywell Company

Genifuel CORPORATION

Colorado State University

U.S. DEPARTMENT OF ENERGY

AgriLIFE RESEARCH  
Texas A&M System

TERRABON

UC San Diego

KAI BIOENERGY  
Tennessee's Energy Today

Palmer Labs  
where new ideas come to life

IOWA STATE UNIVERSITY

Penn

Los Alamos NATIONAL LABORATORY

Eldorado Biofuels

DIERSIFIED ENERGY

HR BioPETROLEUM

Pacific Northwest NATIONAL LABORATORY  
Proudly Operated by Solix Since 1913

Uop  
A Honeywell Company

Genifuel CORPORATION

Colorado State University

U.S. DEPARTMENT OF ENERGY

Other NAABB Partners: Pratt & Whitney, LiveFuels



# NAABB Executive Team



**José Olivares**  
(LANL/Danforth)  
Executive Director



**Richard Sayre**  
(Danforth)  
Scientific Director



**Kimberly Ogden**  
(UA)  
Engineering



**Meghan Starbuck**  
(NMSU)  
Economics



**John Holladay**  
(PNNL)  
Operations



**David Hadley**  
(LANL)  
Industry Relations



**Hal Davies**  
(Danforth)  
Finances

## Algal Biology



**Jon Magnuson**  
(PNNL)



**Cliff Unkefer**  
(LANL)

## Algal Cultivation



**Pete Lammers**  
(Solix)



**Mike Heusemann**  
(PNNL)

## Harvesting and Extraction



**Ron Lacey**  
(TAMU)



**Greg Goddard**  
(LANL)

## Fuel Conversion and Coproducts



**Doug Elliot**  
(PNNL)



**Anthony Marchese**  
(LANL)

## Sustainable Practices



**Jim Richardson**  
(TAMU)



**Meghan Starbuck**  
(NMSU)

## Animal Feed



**Tyron Wickersham**  
(TAMU)



**Shauna Ivey**  
(NMSU)

# NAABB Intellectual Property

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- 1. All inventions belong to the originating/inventing organization(s)**
- 2. Invention Disclosure to 'parent organization' and NAABB leadership**
  - Inventorship is verified
  - NAABB disseminates info to members under the non-disclosure agreement (NDA)
  - 30 Day Disclosure Information Period
- 3. Commercial License**
  - 60 Day faith effort to negotiate licenses
  - If one NAABB member is interested, exclusive OR non-exclusive rights will be granted
  - If multiple NAABB members are interested, non-exclusive rights will be negotiated for each
- 4. Copyrights**
  - Parent organization can seek copyright OR NAABB members may seek to elect title

# NAABB Specific Objectives

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- **Developing technologies for cost-effective production of algal biomass and lipids**

**Algal Biology** - Increase overall productivity of algal biomass accumulation and lipid/hydrocarbon content

**Cultivation** - Increase overall productivity by optimizing sustainable cultivation and production systems

**Harvesting/Extraction** - Develop cost-effective and energy efficient harvesting and lipid extraction technologies

- **Developing economically viable fuels and co-products**

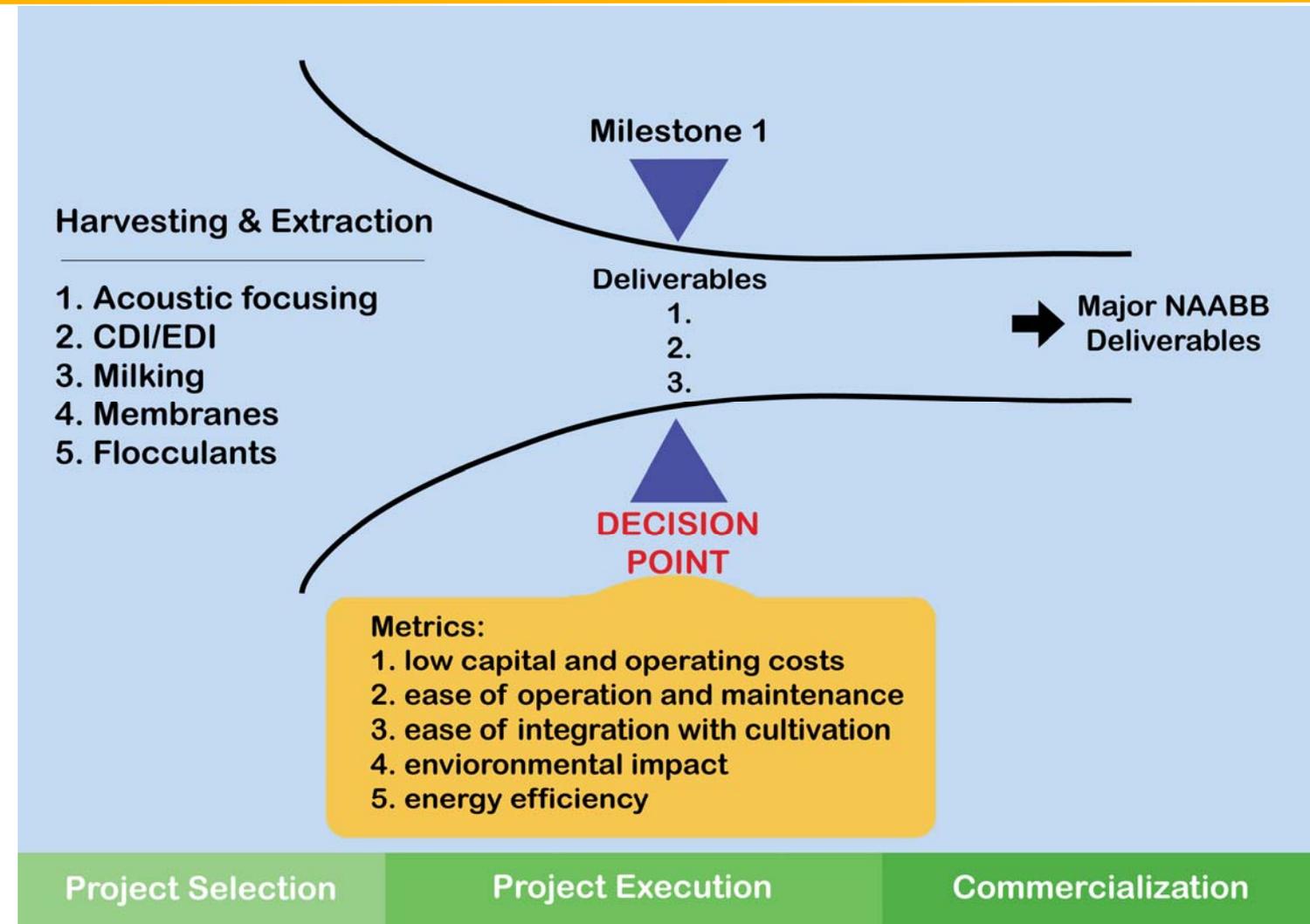
**Fuel Conversion** - Develop technologies to convert lipids/hydrocarbons and biomass residues into useful fuels

**Valuable Coproducts** – Develop a set of valuable coproducts to add profitability and provide flexibility to allow responsiveness to changing demands/opportunities in the market.

- **Providing a framework for a sustainable algal biofuels industry**

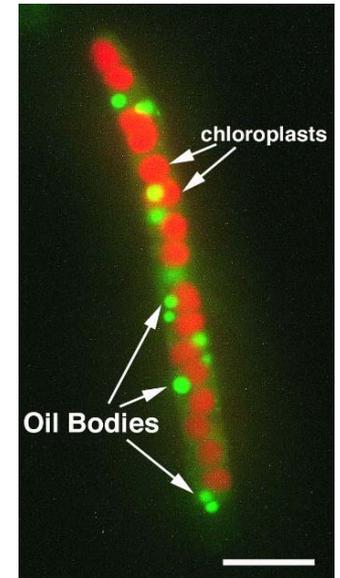
**Sustainability Analysis** – Quantitatively assess the energy, environment, economic viability and sustainability of the NAABB approaches to guide our strategy

# NAABB Gate Decision Process



# NAABB Algal Biology Objectives

- **Increase overall productivity of algal biomass accumulation and lipid/hydrocarbon content**
  - **Mining natural diversity** (Brooklyn, UW)
  - **Mutagenesis for increased lipid production** (WUSL)
  - **Systems biology for lipid production**
    - Genomics, proteomics, transcriptomics (LANL/PNNL, UCLA)
  - **Crop protection**
    - Adaptive evolution (U of Az)
    - Genetic modification for environmental traits (Danforth)
  - **Maximizing yield**
    - Screening tools (WSU), Metabolic regulation (LANL), Nutrient and ionomics (ARS/Danforth)
  - **Maximizing lipid production**
    - Gene ID (WUSL, Danforth), Transcriptomics (UCLA, TG), Lipid secretory system and lipid packaging (Danforth, UW, AXI)
  - **Maximizing production of hydrocarbons**
    - Isoprenoids (LANL, TAMU, UAz)



# NAABB Algal Cultivation Strategies



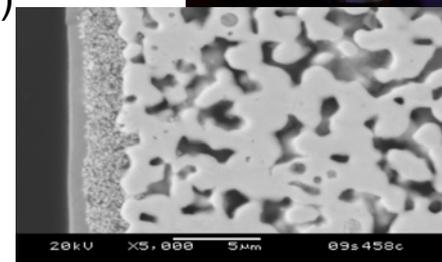
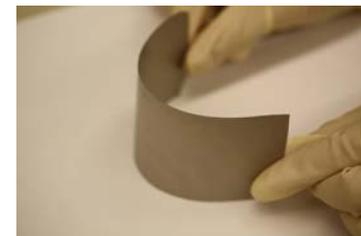
- **Increase overall productivity by optimizing sustainable cultivation and production systems**
  - Optimization of photobioreactors (Solix, U Az, NMSU, CSU)
  - Optimization of ponds (NMSU, PNNL, HRBP, Eldorado B., TAMU)
  - Demonstration test beds (HRBP, NMSU, Solix, U Az, TAMU, PNNL, PalmerLabs)



# NAABB Algal Harvesting and Extraction Strategies

## ■ Develop cost-effective and energy efficient harvesting and lipid extraction technologies

- Harvesting technologies
  - Acoustic focusing (LANL)
  - Hybrid capacitive deionization/electro deionization (CDI/EDI) (TAMU)
  - Membranes and flocculants (PNNL)
- Extraction Technologies
  - Acoustic technologies (LANL)
  - Mesoporous nanomaterials (MNM) (Catilin)
  - Amphiphilic solvents (TAMU)



# NAABB Conversion Strategies

- **Develop technologies to convert lipids/hydrocarbons and biomass residues into useful fuels**
  - **Fuel characterization** • *Physical and chemical properties of algal esters and biofuels* • *Thermophysical and transport properties of biofuels* (CSU, UOP, NMSU, UA )
  - **Lipid conversion to fuels** • *Catalytic decarboxylation and deoxygenation* • *Catalytic and supercritical transesterification* (UOP, DE, LANL,CAT, PNNL, NMSU)
  - **Biomass conversion to fuels** • *Catalytic gasification* • *Thermochemical gasification and power* • *Fast pyrolysis and hydroprocessing* • *Anaerobic fermentation to EtOH and gasoline* (CSU, UCSD, TER, GEN)



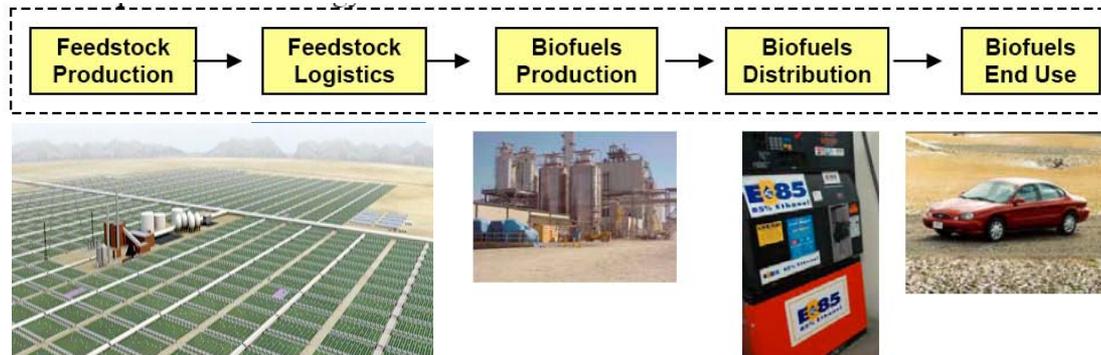
# NAABB Valuable Coproducts

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- **Develop a set of valuable coproducts to add profitability and provide flexibility to allow responsiveness to changing demands/opportunities in the market**
  - **Livestock and mariculture feed** • *Production of lipid-extracted micro and macro-algae* • *Testing nutritional content of LEA* • *Animal and Mariculture studies (NMSU, CSU, TAMU, PAL)*
  - **Industrial Coproducts** • *Synthetic natural gas production and thermal energy from LEA* • *Bioplastics from proteins and lipids* • *Feedstock for nitrogen chemical industry and amino acids from LEA (DE, INV PAL, GEN, PNNL)*

# NAABB Sustainability

- Quantitatively assess the energy, environment, economic viability and sustainability of the NAABB approaches to guide our strategy
  - **Economic analysis** • Economic models • Global analysis • LCA and Process Analysis (TAMU, PNNL NMSU, UOP, UA)
  - **Resource Management** • CO2 management • Hydrology/water management (LANL, NMSU, PNNL, HRBP)



# Challenges and Summary

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## ■ A Virtual Consortium

- Communication
- Openness
- Complexity

## ■ Opportunities

- Strong alliance based on scientific principles and service to the National Energy need
- Development of an agronomic industry
- Multiple innovative approaches for technology development
- Strong commitment to commercialization of technologies