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The Developing Biofuels Industry in New Mexico

José A. Olivares

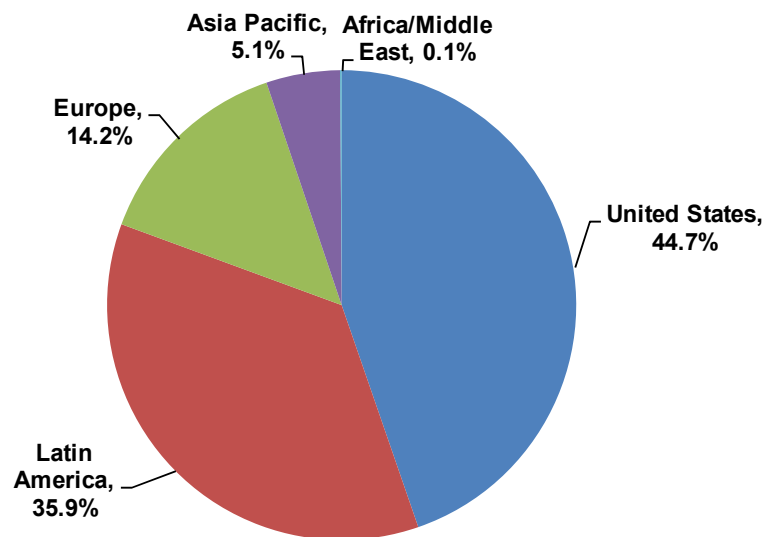
Bioscience Division Leader

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Biofuels Markets

Biofuels Market Share by Region, World Markets: 2010



(Source: Pike Research)

**Top 15 Biofuels Producers by Country, World Markets: 2010
(Thousand Barrels per Day)**

Rank	Country	Production	Primary Fuel
1	United States	656.0	Ethanol
2	Brazil	486.3	Ethanol
3	China	72.5	Ethanol
4	Germany	64.9	Biodiesel
5	France	49.8	Biodiesel
6	Canada	17.2	Biodiesel
7	Argentina	15.5	Biodiesel
8	Italy	14.0	Biodiesel
9	Thailand	13.2	Biodiesel
10	Spain	12.1	Biodiesel
11	Sweden	10.1	Biodiesel
12	United Kingdom	10.4	Biodiesel
13	Austria	8.5	Biodiesel
14	Poland	8.4	Biodiesel
15	Malaysia	8.2	Biodiesel

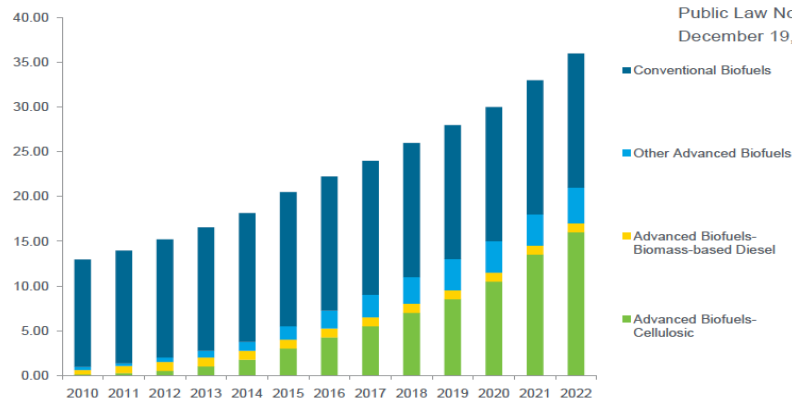
(Source: EIA)

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US Renewable Fuel Standard

**EISA RFS2 Renewable Biofuels Production Targets
In Billions of Gallons per Year (BGY)**



Biofuels Policy Mandate:

EISA (2007). "Energy Independence and Security Act of 2007", H.R.6
110th Congress
Public Law No: 110-140
December 19, 2007.

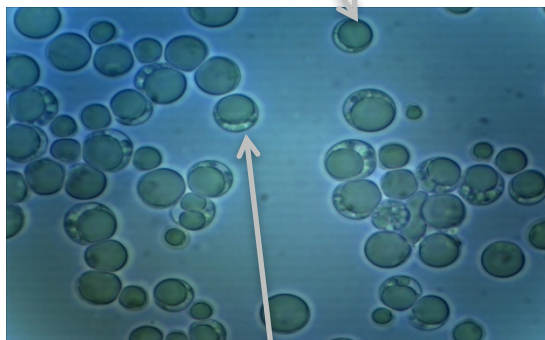
EISA Renewable Fuel Standard 2 Summary

	Cellulosic Biofuels	Biomass-based Diesel	Other Advanced Biofuels	Conventional Biofuel	Total Renewable Fuel
GHG Emission Reduction	≥ 60%	≥ 50%	≥ 50%	≥ 20%	≥ 20%
Feedstock	Cellulosic Biomass	Oilseeds, Algae	MSW, Sugarcane, Cellulosic, Oilseeds, Algae	Corn starch	Any
Volume by 2022	16.0 BGY	1.0 BGY	4.0 BGY	15.0 BGY	36.0 BGY

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**4-50%
Lipid biomass**



**50-90%
Other biomass**

Rapid growth rate

Double in 6-12 hours

High oil content

4-50% non-polar lipids

All biomass harvested

100%

Continuous harvesting

24/7, not seasonally

Sustainable

Capture up to 90% of injected CO₂

Utilize waste water

Non-food

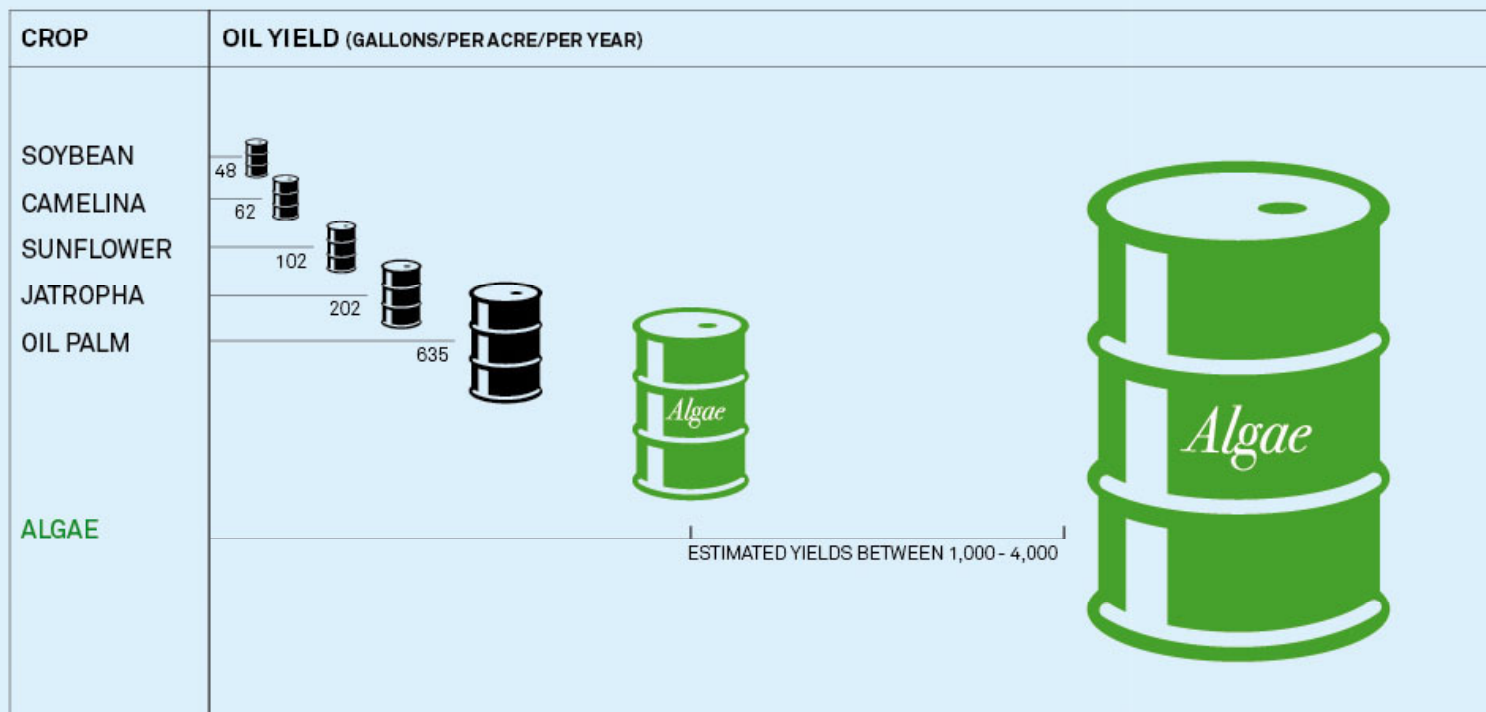
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The Promise of Algae-Based Biofuels

SUPERIOR OIL YIELD COMPARED TO OTHER BIOMASS FEEDSTOCKS

COMPARISON OF OIL YIELDS FROM BIOMASS FEEDSTOCKS



Source: US Department of Energy – Algal Biofuels Roadmap 2009

(Source: U.S. DOE, “National Algal Biofuels Technology Roadmap,” 2009)

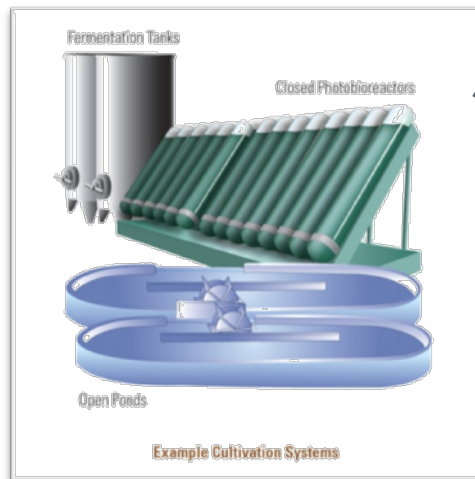
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Technical Challenges for Algae Biofuels

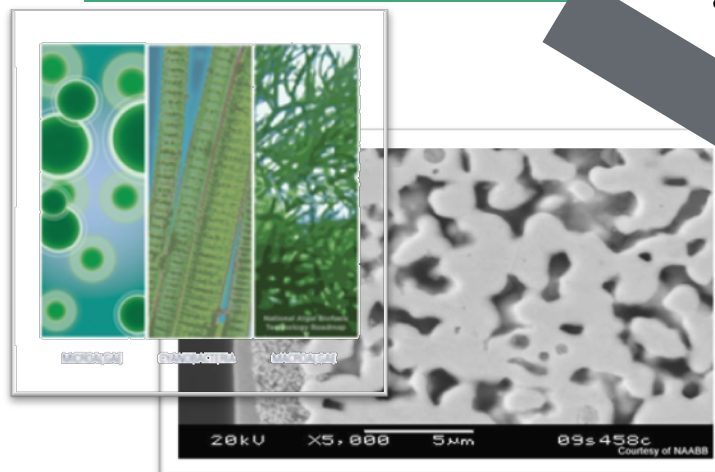
Biology and Cultivation



- Cultivation system design
 - Temperature control
 - Invasion and fouling
- Cultures
 - Growth, stability, and resilience
- Input requirements
 - CO₂, H₂O sources, energy
 - Nitrogen and phosphorous
- Siting and resources

- Energy efficient harvesting and dewatering systems
- Biomass extraction and fractionation
- Product purification

Biomass Harvesting and Recovery



A nano-membrane filter being developed by a NAABB partner.

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A gasifier being used by a NAABB partner to convert algal biomass to fuels



- Process optimization
 - Thermochemical
 - Biochemical
- Fuels characteristics
- Co-Products

Conversion and End-use

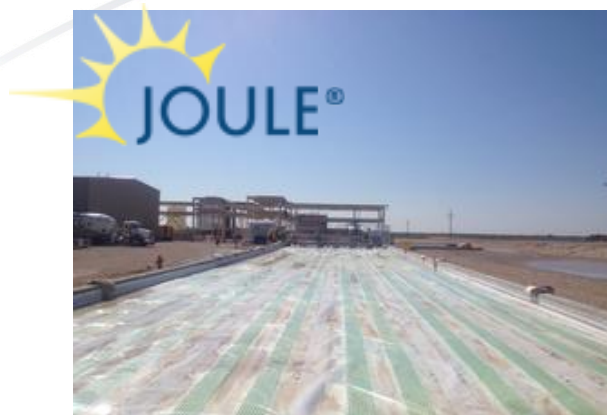
Algal Research in New Mexico



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Algal Industry in New Mexico

Los Alamos National Laboratory



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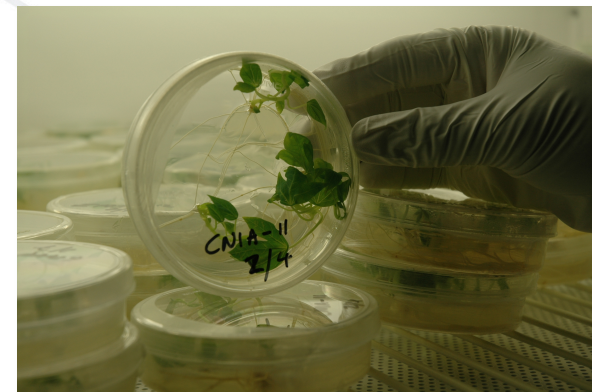




Biofuels at LANL

■ Biofuels Research Areas

- Algae: Systems Biology, Biotechnology, Harvesting and Lipid Extraction
- Cellulosics: Biomass Conversion, Cellulose Structure and Pre-treatment, Cellulase optimization
- Fuel Conversion
- Water and Nutrient Management
- Crop Science and Technology



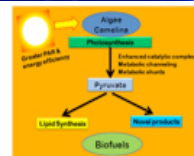
■ Partnerships for Success

DOE-EERE Consortia

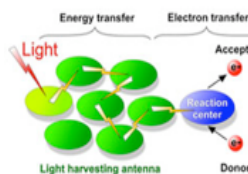


DOE-SC Consortia

Energy Frontier Research Centers



Center for Advanced
Biofuel Systems



Photosynthetic Antenna
Research Center



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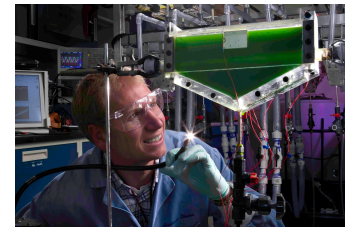


LANL Competencies in Bioenergy Technologies

- **Algae: Systems Biology, Biotechnology, Harvesting and Lipid Extraction**
 - ‘Omics data collection, analysis and ‘Omics integration through bioinformatic
 - Tools and platforms to manipulate gene expression through adaptation or genetic modification.
 - Acoustic harvesting and extraction technologies; bio-flocculation and magnetic algae.
- **Cellulosics: Biomass Conversion, Cellulose Structure and Pre-treatment, Cellulase optimization**
 - Using multiple modeling and simulation strategies to biochemical and thermochemical conversion of biomass
 - Quantified—for the first time—the stacking interactions in cellulose fibril
 - Creating thermostable cellulases that are optimized for industrial environments.
 - Optimizing ammonia-based pretreatment strategies for efficient degradation of cellulose
- **Conversion to Fuel and Chemical Feedstocks**
 - Developing a high-yield chemical process to convert algal lipids into hydrocarbons
 - Cellulose and lignin as pre-cursors for commodity and high value chemicals
- **Water and Nutrient Management**
 - Studying the suitability of non-fresh-water resources for growing algae species suitable for biofuels.
- **Crop Science and Technology**
 - Detecting and mitigating stress conditions and natural threats to plants



Photobioreactor systems for controlled algae growth, transcriptomics experiments



One module of the 9-module scaled-up acoustic harvester

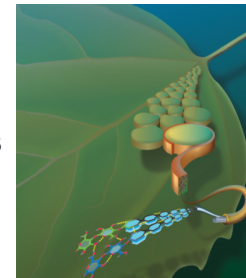


Diagram of cellulose structure



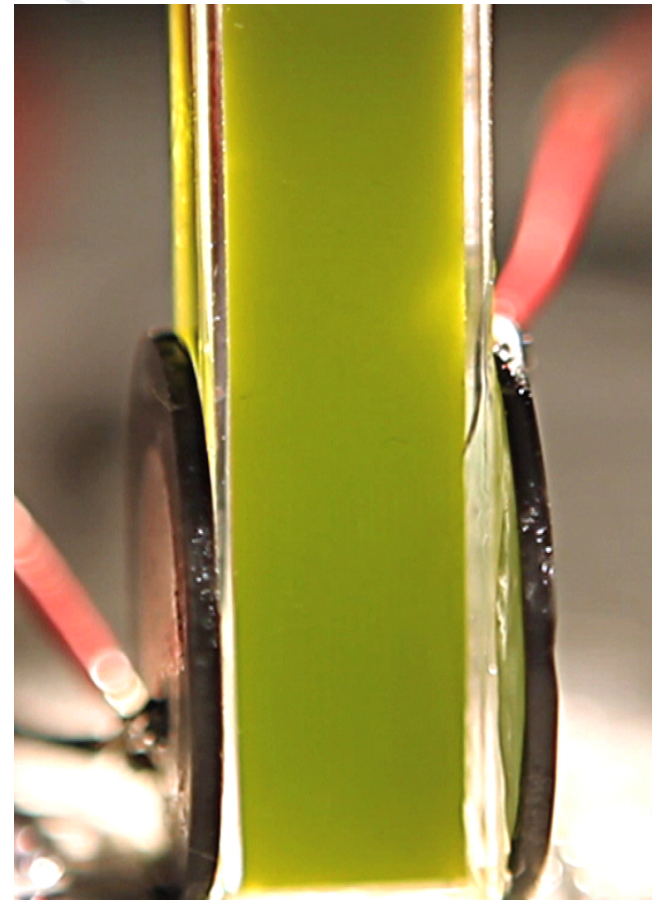
“Produced water” used to grow algae for biofuels

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Ultrasonic Harvesting

- Ultrasonic harvesters have no moving parts that wear and require no chemical additives
- Viability tests (via growth rate and esterase activity) showed no measurable effect on *N. salina*
- 10X-scaled harvester module delivered energy to the liquid layer 100-fold more effectively than laboratory-scale unit
- Multi-module operation delivered energy to the liquid layer 40-fold more effectively than laboratory-scale unit



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National Alliance for Advanced Biofuels and Bioproducts

- Develop advanced biofuels made from algae
- Demonstrate the science and technology needed to:
 - Increase lipid production and biomass value
 - Reduce production costs and energy requirements of harvesting and extraction
 - Establish valuable conversion routes to fuels and co-products





The Donald Danforth Plant Center*†

* NAABB Team Management

† NAABB Board of Directors

Universities

- Brooklyn College
- Clarkson University
- Colorado State University*†
- Iowa State University
- Michigan State University†
- New Mexico State University*†
- North Carolina State University
- Texas AgriLife Research / Texas A&M University System*†
- University of Arizona*†
- University of California Los Angeles
- University of California Riverside
- University of California San Diego
- University of Pennsylvania
- University of Texas (sub)
- University of Washington
- Washington State University
- Washington University St. Louis

National Laboratories

- Los Alamos National Laboratory / New Mexico Consortium*†
- Pacific Northwest National Laboratory*†
- Idaho National Laboratory
- National Renewable Energy Laboratory
- USDA - ARS

Industry

- Albermarle Catilint†
- Diversified Energy
- Eldorado Biofuels
- Genifuel
- Cellana†
- Inventure
- Kai BioEnergy
- Palmer Labs
- Phycal
- Reliance Industries Limited
- Pan Pacific, Ltd.
- Solix Biofuels*†
- Targeted Growth†
- Terrabon
- UOP a Honeywell Company†
- Valicor

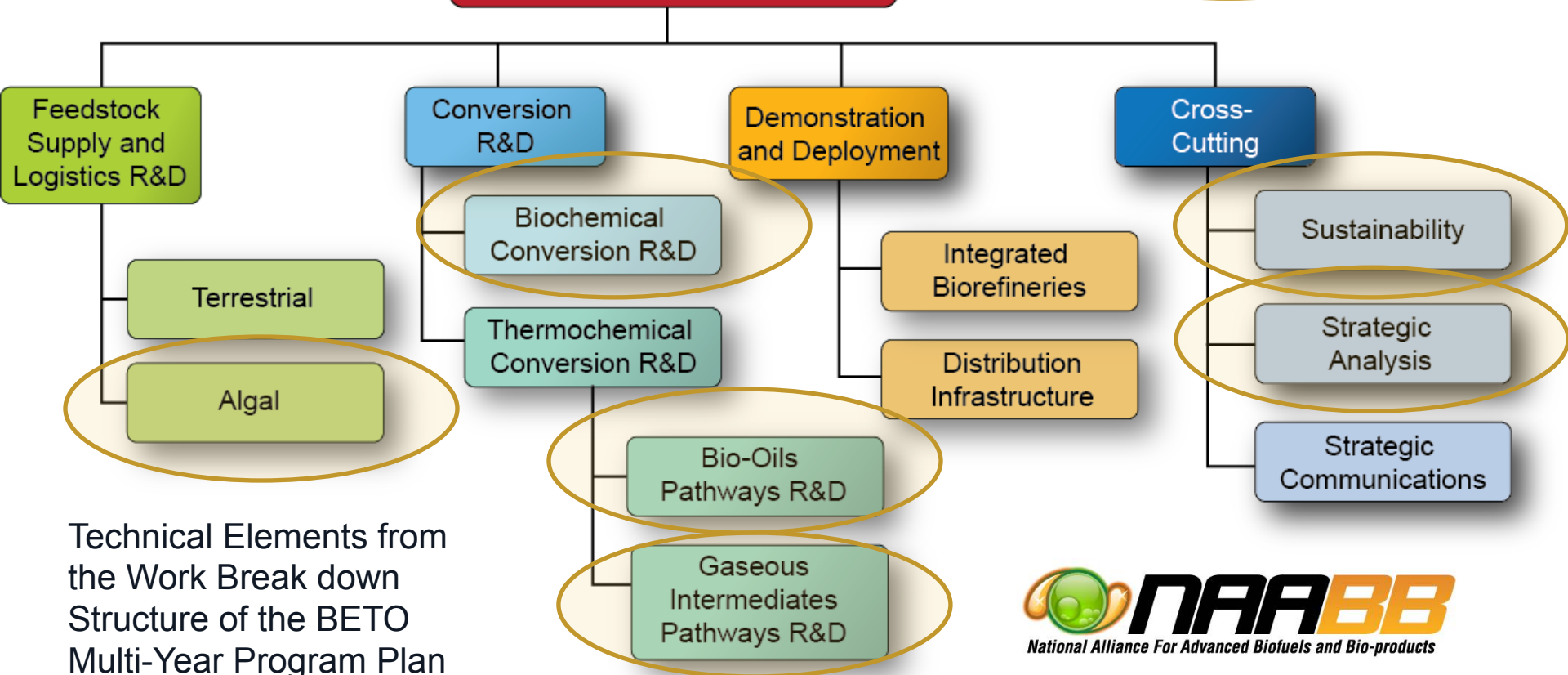
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NAABB has a central role in EERE's Bioenergy portfolio

Bioenergy Technologies Office Work Breakdown Structure

NAABB Areas of Research



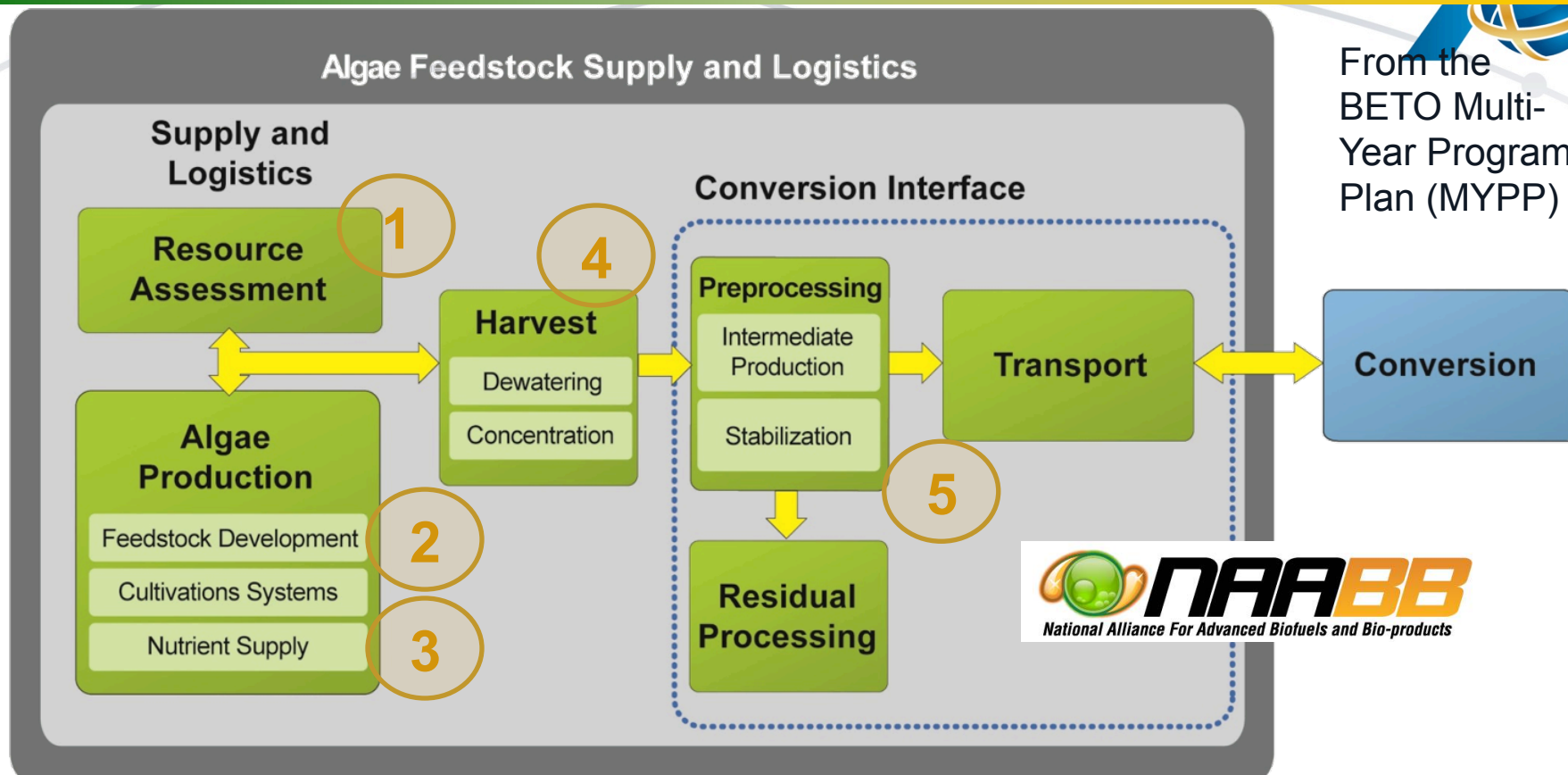
Technical Elements from the Work Break down Structure of the BETO Multi-Year Program Plan (MYPP)

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From the
BETO Multi-
Year Program
Plan (MYPP)



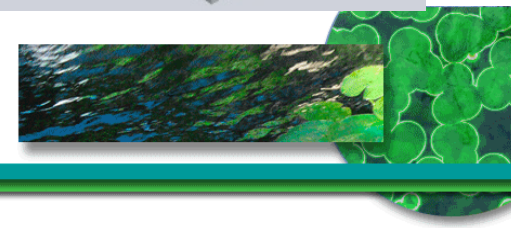
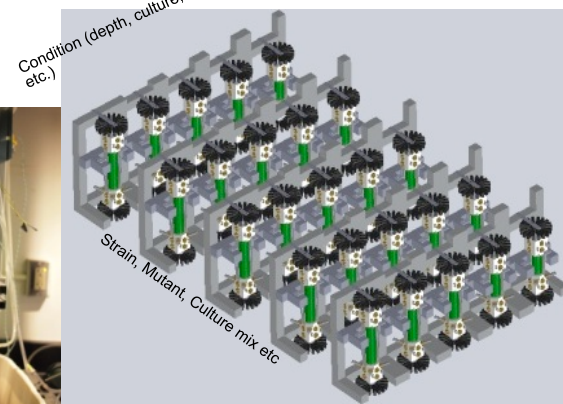
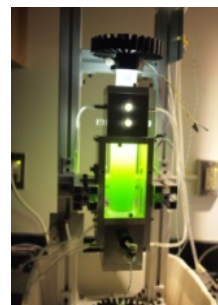
NAABB has...

1. Provided a detailed resource assessment through the AISIMS BAT Module
2. Brought five new strains through the value chain (including outdoor cultivation)
3. Demonstrated the ARID cultivation (heat management) and low nutrient cost
4. Evaluated three new harvesting systems at larger scale
5. Combined extraction with conversion technology (HTL) to reduce cost and demonstrated with NAABB produced algae (with high and low lipid content)

NAABB Accomplishments (as of May 5, 2013)



- Over 150 presentations at national and international conferences
- >65 scientific publications
- Five theses
- New Journal: ALGAL RESEARCH (by Elsevier)
- New Conference Series: *International Conference on Algal Biomass, Biofuels and Bioproducts*
- 33 Intellectual Property Disclosures
 - Molecular biology tools – 10
 - Cultivation – 5
 - Harvesting and Extraction – 7
 - Fuel conversion – 8
 - Co-products and other – 3
- New company: *Phenometrics*



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New Mexico Consortium (NMC) BioLab

- Construction of the New Mexico Consortium BioLab at Entrada Park in Los Alamos
- Collaborative effort between NMC, LANL, Los Alamos County, and Los Alamos National Bank
- 27,000 square foot laboratory and office facility including a 4,000 square foot research greenhouse
- Key facility for algae and plant research at NMC and LANL



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LANL-NMC Strategy

A joint collaboration center to expand the research efforts between LANL, NMC staff and the NM Universities in untraditional mission and customer space.



- Overall advantage
 - Close coordination/collaboration with NM Universities
 - Enabled new programs with USDA, NSF, Foundations, etc.
- Research focus:
 - Bioenergy
 - Plant and food science
 - Biotechnology
- Logistics
 - Dual appointments for LANL staff
 - Co-location at Entrada Park
 - Utilization of facilities at LANL



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