

Algal-Derived Oil Feedstock Research at NREL: Beyond the DOE's Aquatic Species Program

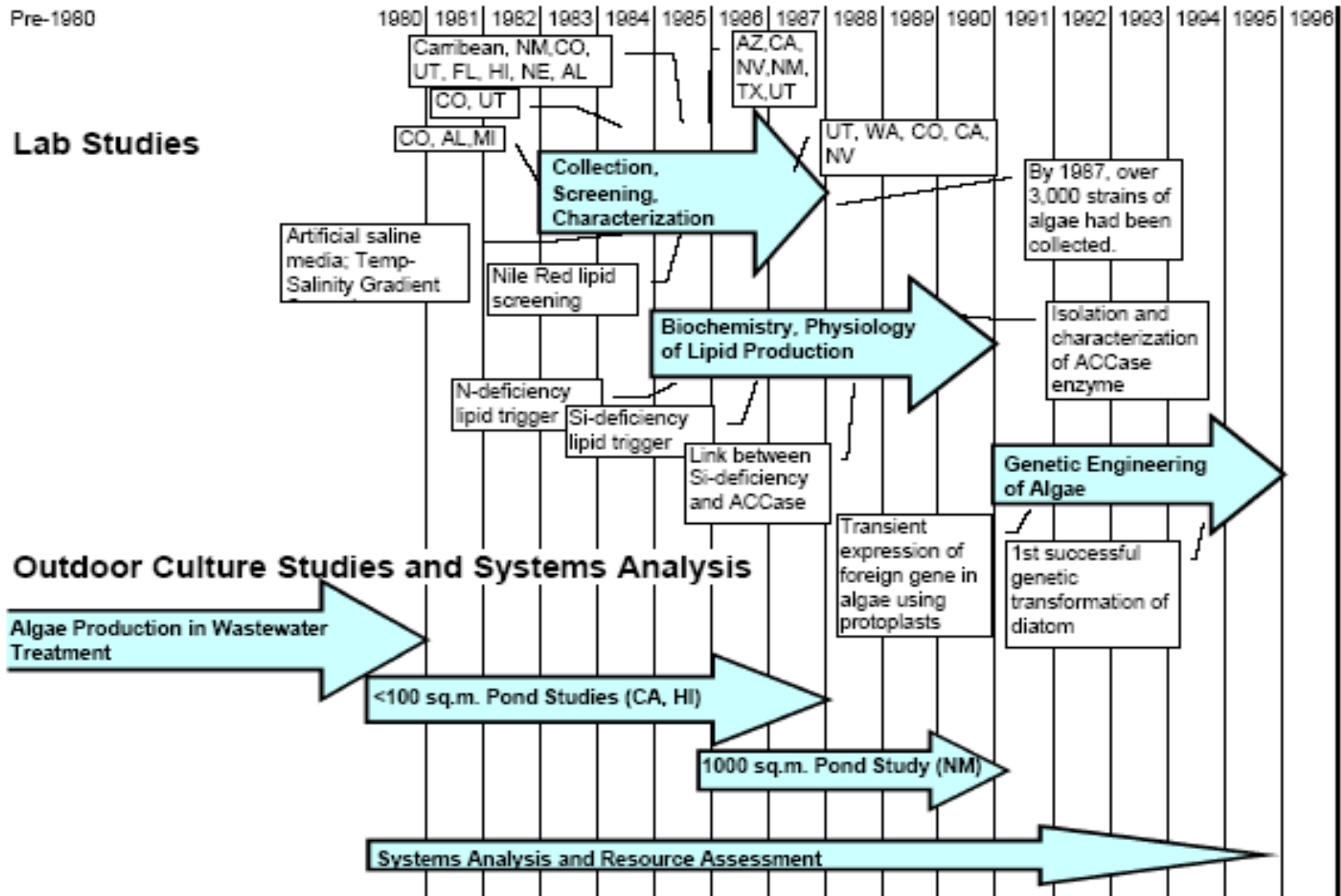


Why Fuels from Algae?



Crop	Oil Yield Gallons/acre
Corn	18
Cotton	35
Soybean	48
Mustard seed	61
Sunflower	102
Rapeseed	127
Jatropha	202
Oil palm	635
Algae	"10,000"

- Algae can produce more lipids per acre than other plants -- *potentially 10x - 50x*
 - Lipids (oils) are the preferred starting point to make diesel or jet fuel from biomass
- Can use marginal, non-arable land
- Can use saline/brackish water
- No competition with food, feed, or fiber
- Can utilize large waste CO₂ vent resources
- Potential to replace significant percentage of U.S. diesel and jet fuel needs



Major Accomplishments:

- 3,000 strains of algae collected and screened
- Advances in applied biology and design of algae production systems achieved
- 1000m² open pond facility operated in Roswell, New Mexico for one year
- Final cost estimates for algal lipids \$40 - \$70 per bbl oil (Benemann and Oswald, 1996)
- Final report is still referenced
- Important resource for algae researchers worldwide

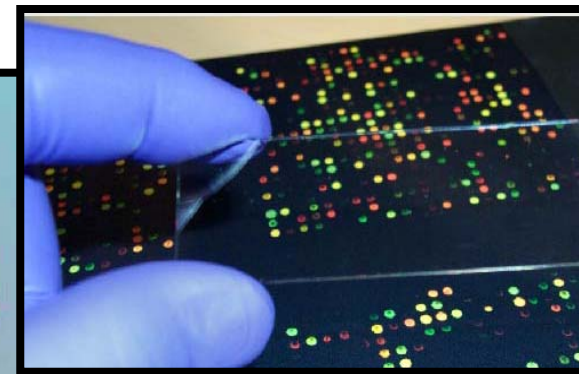
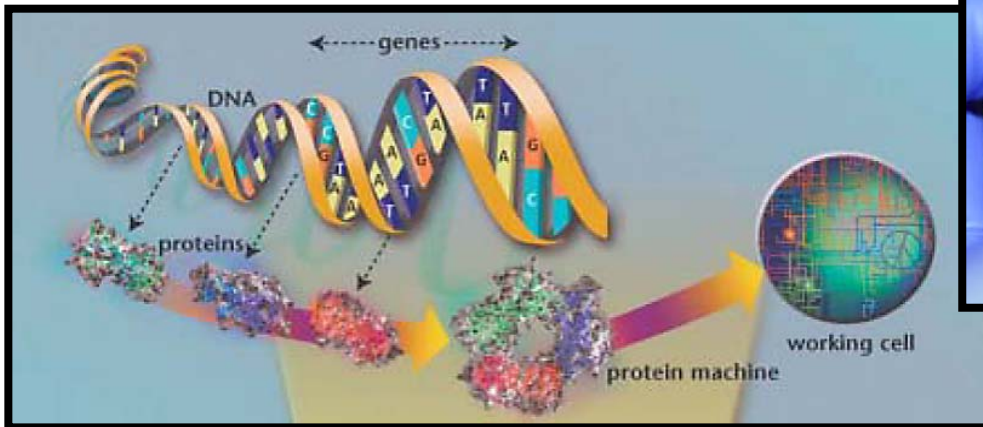


See the close-out report at:

<http://govdocs.aquake.org/cgi/eprint/2004/915/9150010.pdf>

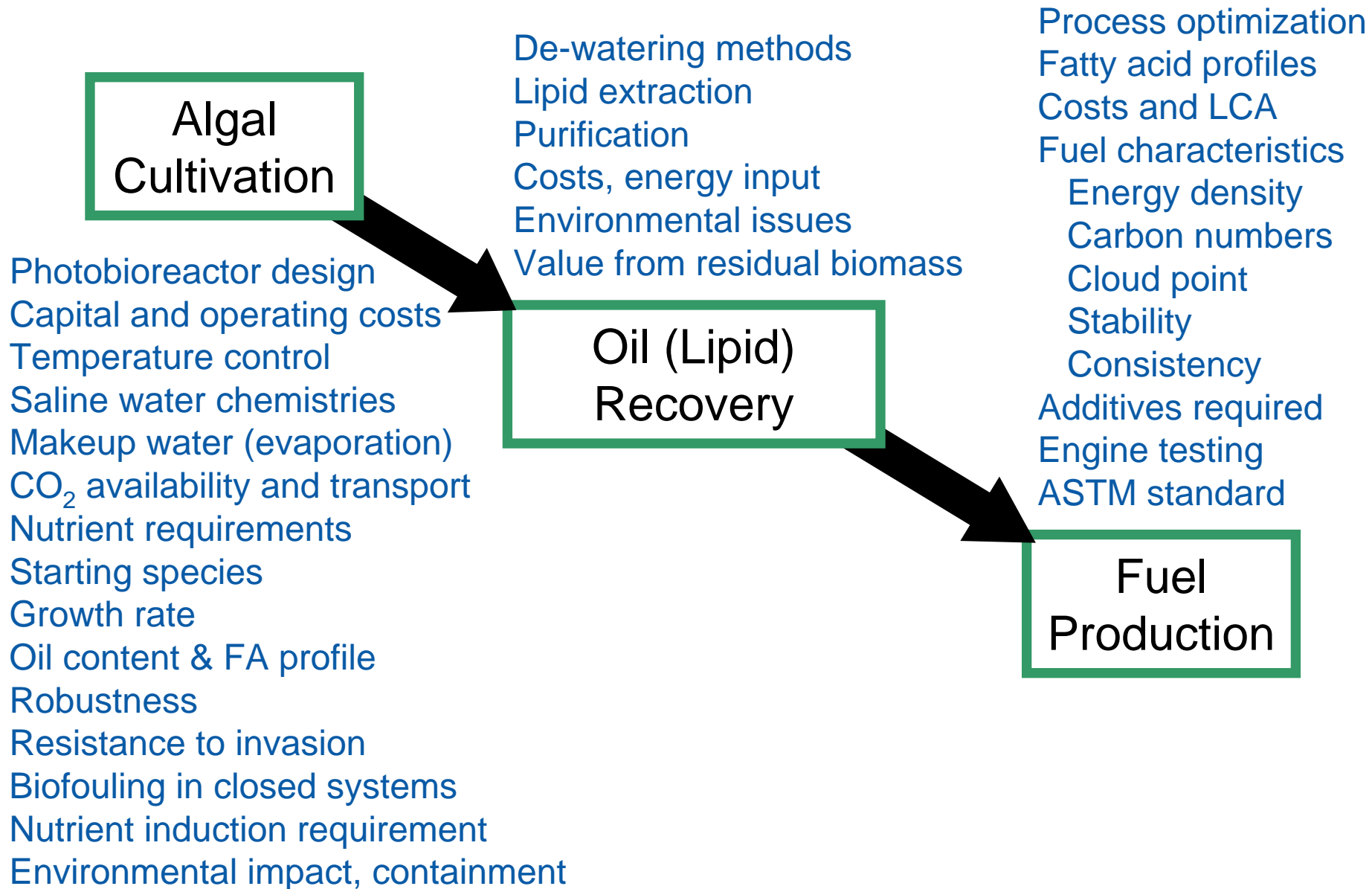
Beyond the Aquatic Species Program

- Crude oil prices have seen record highs (\$135/barrel)
- Diesel is no longer 60 cents/gal; current cost \$3.80
- Greater emphasis on energy security
- Increased interest in CO₂ capture, carbon trading
- Advances in material science allow new photobioreactor designs
- Advances in metabolic engineering and systems biology



A2BE Carbon Capture, LLC
Algae Biofuels
Algae Link
Algenol (ethanol)
Aquaflow Bionomic
Aurora BioFuels Inc.
Blue Biofuels
Bodega Algae
Community Fuels
Diversified Energy
Energy Farms
Enhanced Biofuels & Technologies
General Atomics
Global Green Solutions
Green Star
Greenfuel Technologies Corp
GreenShift (ethanol)
GS Cleantech
HR Biopetroleum/Shell (Cellana)
IGV
Imperium Renewables

Infinuel Biodiesel
Inventure Chemical
KAS
Kent SeaTech Corp.
Kwikpower
Los Alamos Natl. Lab.*
LiveFuels, Inc.
National Renewable Energy Lab.*
OriginOil
Pacific Northwest Natl. Lab.*
PetroAlgae (XL Tech Group)
PetroSun
Sandia Natl. Lab.*
Sapphire Energy
SeaAg, Inc
Solazyme, Inc.
Solix Biofuels, Inc.
Texas Clean Fuels
Trident Exploration/Menova
Valcent Products
XL Renewables



Cryopreservation System

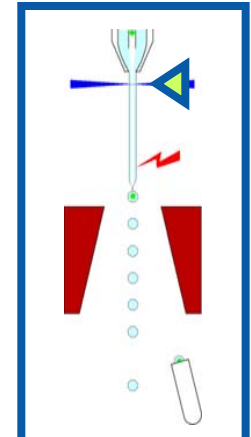


Minimize damage to algae during low temperature storage and maintain long-term cell viability

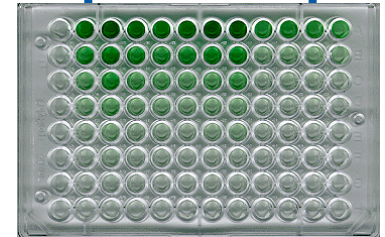
NREL ASP Greenhouse Renovation



Fluorescence Activated Cell Sorter (FACS)



High-speed algal cell sorting of populations and individual cells



Expanded lab space dedicated to algal research

Collaborative Research and Development Agreement (CRADA) under Chevron/NREL Alliance

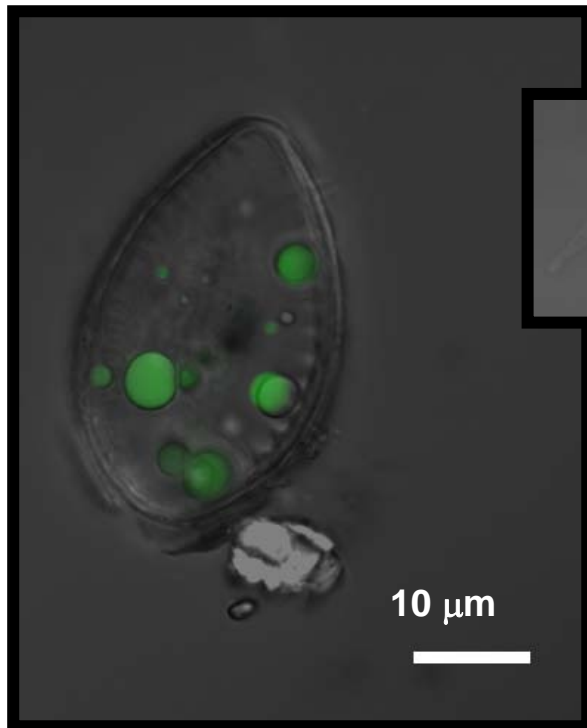
Goal: Identify and develop algae strains that can be economically harvested and processed into finished transportation fuels



Colorado Center for Biorefining and Biofuels seed grant award; collaboration between NREL and Colorado School of Mines

“Establishment of a Bioenergy-Focused Microalgae Strain Collection Using Rapid, High-Throughput Methodologies”

P.I., Al Darzins; co-P.I., Matt Posewitz; Lee Elliott; Ryan Sestric



C2B2 { University of Colorado
Colorado State University
Colorado School of Mines
National Renewable Energy Laboratory

Profit From Our Synergy
Colorado Center for
Biorefining and Biofuels

- **Laboratory Directed Research & Development (LDRD) Awards:**

- Develop a High-Throughput Technique for Assessing Lipid Production in Algae
- Use of Digital Gene Expression: Tag Profiling for High Throughput Transcriptomics in Microbial Strains Involved in Advanced Biofuel Production
- Biodiesel from Cyanobacteria

- All of the elements for the production of lipid-based fuels from algae have been demonstrated.
- Algae can be grown in large outdoor cultures and harvested. The lipids can be extracted and converted to biodiesel or other transportation fuels.
- The question is not whether biofuels from algae are possible, but rather whether they can be made economically and at a scale sufficient to help contribute to U.S. fuel demand.
- The potential of algal biofuels is significant, but a greater understanding of the underlying principles is necessary before commercial scale-up is feasible.
- Many years of basic/applied R&D will be needed before algal-based fuels can be produced economically enough to be cost-competitive with petroleum based fuels.
- This will require long-term coordinated support from relevant government agencies, private sector, academia, and all interested stakeholders in land and water use for biofuels production.



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