ARPA-E Advanced Fuels Projects Overview

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ARPA-E Programs

Broad Solicitation

"FOA1"

Transportation

Electrofuels

BEEST

End-Use Efficiency

BEETIT

Stationary Power

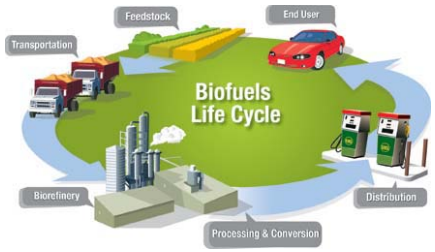
ADEPT

IMPACCT

GRIDS

FOA 1 Biomass programs target critical supply chain aspects

Sustainability Challenges

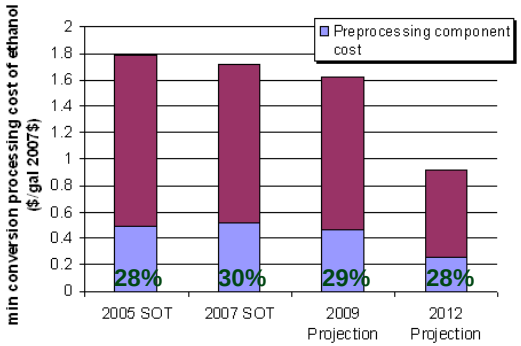


Credit Office of the Biomass Program

- Land & resource competition
- Market impacts (food & feed)
- Environmental impacts (nitrogen, etc.)
- Economic viability/parity with traditional fuels

$6.2M	Ceres, Inc. High Yielding, Low Input Energy Crops *Trait development to increase biomass yields while decreasing use of nitrogen fertilizers*
$18M	EI du Pont de Nemours & Company MacroAlgae Butanol *Produce isobutanol from macroalgae, an advantaged, environmentally sustainable feedstock*
$7.5M	Algaeventure Systems Scaling and Commercialization of Algae Harvesting Technology *Transform economics of algae-based fuels by dramatic energy cost reductions*

Pretreatment Challenges



Office of the Biomass Program, MYPP

- Despite cost reductions, pretreatment cost component is expected to remain at 30%
- Preprocessing is deleterious to downstream biochemical processing

$5.7M	Agrivida Conditionally Activated Enzymes Expressed in Cellulosic Energy Crops *Produce inactive enzymes within plant biomass for conditional activation, and pretreatment cost/impact reduction*
$3.9M	RTI International Catalytic Biocrude Production in a Novel Short-Contact Time Reactor *Novel single step catalytic biomass pyrolysis process to maximize carbon conversion efficiency and yield a low oxygen-content biocrude*

Another FOA1 focus area is photosynthetic direct solar fuels

Innovative Approaches for Photosynthetic Solar Fuel Production

Benefits –

- Photosynthetic CO_2 reduction
- Direct fuel/fuel precursor production bypasses biomass feedstock production, logistics & conversion
- Genetically tractable organisms for tailor-made fuel production

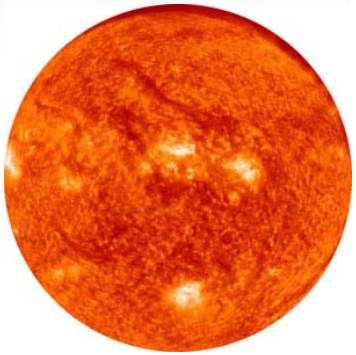
Challenges –

- Culture refinement, maintenance, & viability
- Production rate & yield
- Photobioreactor design & cost
- Downstream processing of fuel precursors
- Overall economic feasibility

$6.5M	**Arizona State University** Cyanobacteria Designed for Solar-Powered Highly Efficient Production of Biofuels *Engineer photosynthetic Synechocystis cyanobacteria to enable highly efficient production and secretion of fatty acids in a continuous culture maintained in stationary phase*
$5.5M	**Iowa State University** A Genetically Tractable Microalgae Platform for Advanced Biofuel Production *Empower the economic viability, versatility, and sustainability of the algae-based fuels industry via development of a genetically tractable Chlamydomonas microalgal platform*
$2.8M	**University of Minnesota** Shewanella as an Ideal Platform for Producing Hydrocarbon Biofuels *Develop a co-culture with photosynthetic cyanobacteria and Shewanella bacteria to produce and continuously harvest hydrocarbons for fuel production*

ARPA-E's Electrofuels program seeks to address U.S. oil dependence with significantly more efficient biofuels

The Electrofuels program is anticipated to open up a new area of research and path to biofuels



Photosynthesis

Electrons/
Reducing equivalents

Biomass

Algae

Chemical
Catalysis

Biological
Catalysis

EtOH
Advanced
biofuels

Pyrolysis
oils

Biodiesel
Advanced
biofuels

Syngas
CH_3OH
CH_4
Advanced fuels?

Advanced
Fuels

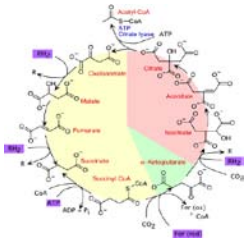
Electrofuels approach is non-photosynthetic, modular, with mix-and-matchable solutions

Assimilate Reducing Equivalents

Reducing equivalents: *other than reduced carbon or products from Photosystems I & II*

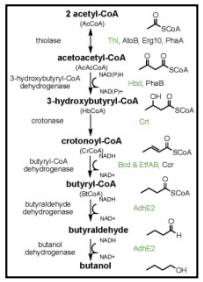
H_2S H_2 Direct Current NH_3 Fe^{2+}

Fix CO_2 for Biosynthesis



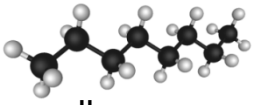
Pathway for carbon fixation: *reverse TCA, Calvin- Benson, Wood-Ljungdahl, hydroxpropionate/hydroxybutyrate, or newly designed biochemical pathways*

Generate Energy Dense Liquid Fuel



Fuel synthesis *metabolic engineering to direct carbon flux to fuel products*

butanol



alkanes

+ numerous possibilities

The projects selected create a diverse portfolio of approaches

	Reducing Equivalents				CO_2 Fixation Pathways				Organism Platforms						
	H_2	E-	NH_3	NADH	CB	WL	4HB	rTCA	Ral-stonia	E-coli	Clost-ridium	Geo-bacter	Rhodo-bacter	Shew-anella	Pyro-cocus
UMass		●				●	●				●	●			
PSU	●				●								●		
OSU	●				●				●				●		
MIT	●				●				●						
Gingko				●				●		●					
Harvard		●			●									●	
MIT	●	●				●					●				
NCSU	●						●			●					●
OPX	●				●				●						
UCLA		●			●			●		●	Synechocystis		Rhodopseudomonas		
MUSC		●				●					●	Acetobacterium			
Colum			●		●				Nitrosomonas europaea						
LBNL	●				●				●						

Advanced fuels program breakout

Spotlighters

1. **Cyanobacteria for Solar-Driven Biofuel Production**
   - Arizona State University (FOA1)
   - Lead PI: Willem Vermaas
2. **Microbial ElectroCatalytic (MEC) Biofuel Production**
   - Lawrence Berkeley National Laboratory (Electrofuels)
   - Lead PI: Steven Singer
3. **Microbial Electrosynthesis**
   - University of Massachusetts, Amherst (Electrofuels)
   - Lead PI: Derek Lovely
4. **Ammonia Oxidizing Reverse Microbial Fuel Cell**
   - Columbia University (Electrofuels)
   - Lead PI: Scott Banta

Industrial Panel

Focused Networking