# The Advanced Research Projects Agency – Energy: A New Paradigm in Transformational Energy Research

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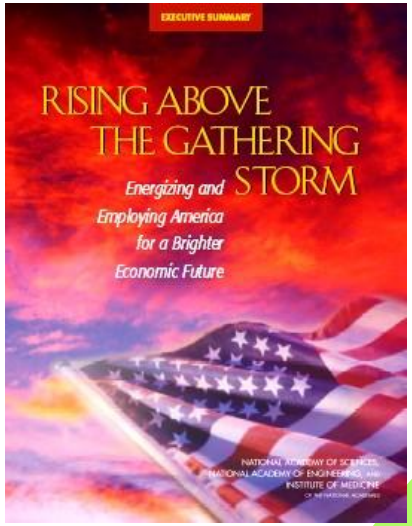
**Deputy Director for Technology**

**July 26, 2011**

# Creation & Launching of ARPA-E




**2006**
***Rising Above the Gathering Storm***
**(National Academies)**

**2007**
**America COMPETES Act**

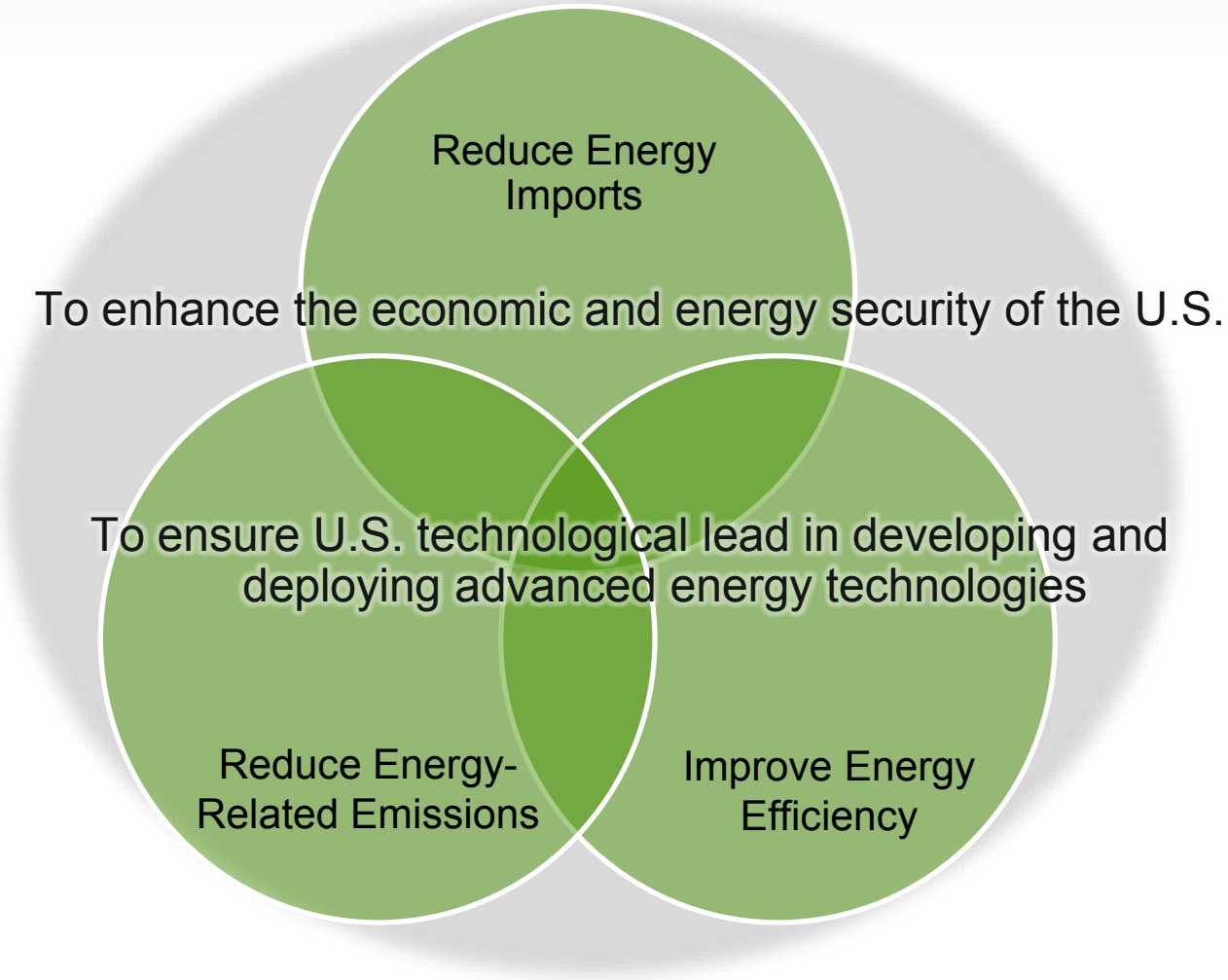
**2009**
**American Recovery and Reinvestment Act**
($400M appropriated)

**2011**
**FY2011 Budget**
($180M appropriated)

President Obama launches ARPA-E at National Academies on April 27, 2009

Innovation based on science and engineering will be primary driver of our future prosperity & security

# ARPA-E's Mission and Means




To overcome the long-term and high-risk technological barriers in the development of energy technologies.

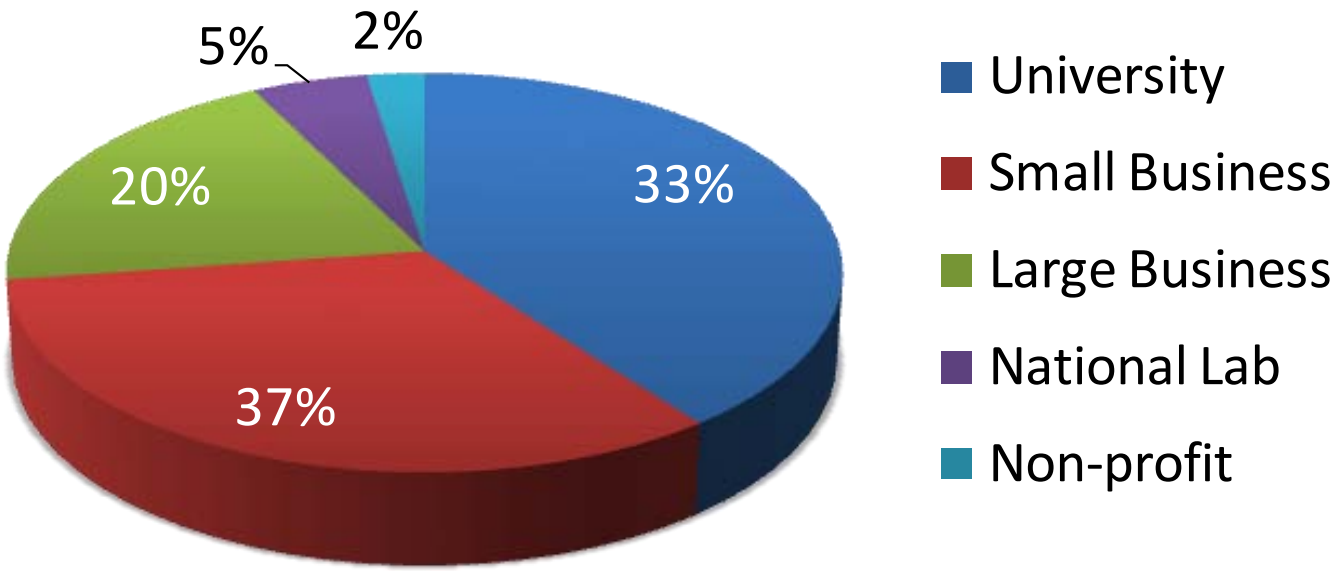
(A) identifying and promoting revolutionary advances in fundamental sciences; **AND**

(B) translating scientific discoveries and cutting-edge inventions into technological innovations; **AND**

(C) accelerating transformational technological advances in areas that industry by itself is not likely to undertake because of technical and financial uncertainty.

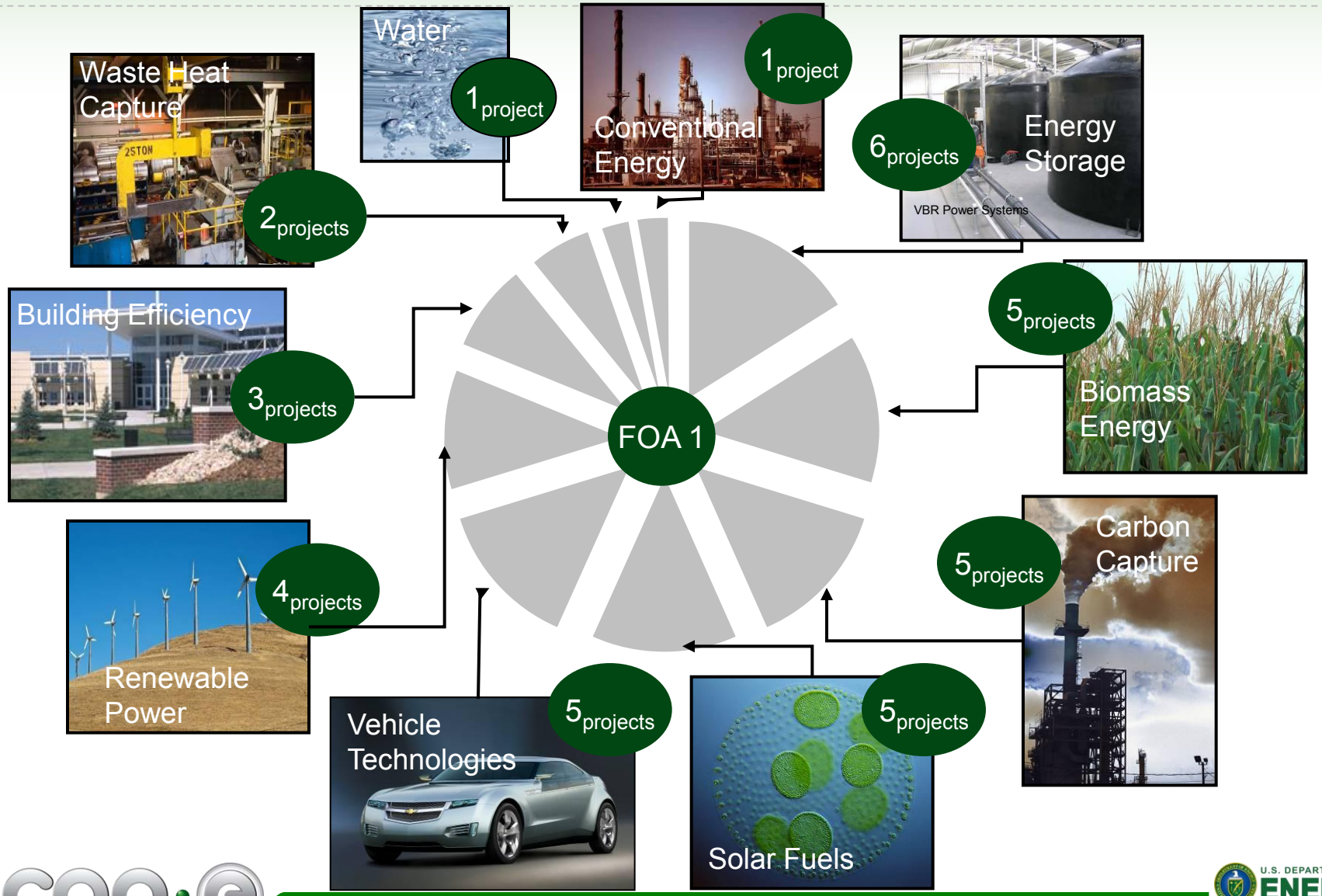
# To date ARPA-E has made 121 awards from seven FOAs to a wide variety of organizations

## Project Breakdown by Lead Organization Type (% based on award value)*




*Total Value of Awards = $366 million

# ARPA-E FOA 1 projects can be categorized into one of ten energy technology areas



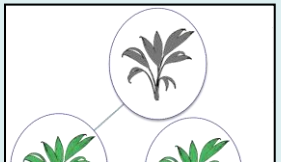
# ARPA-E currently has 11 focused programs plus a broad portfolio of projects from its first solicitation

## Transportation

Electrofuels

BEEST

PETRO



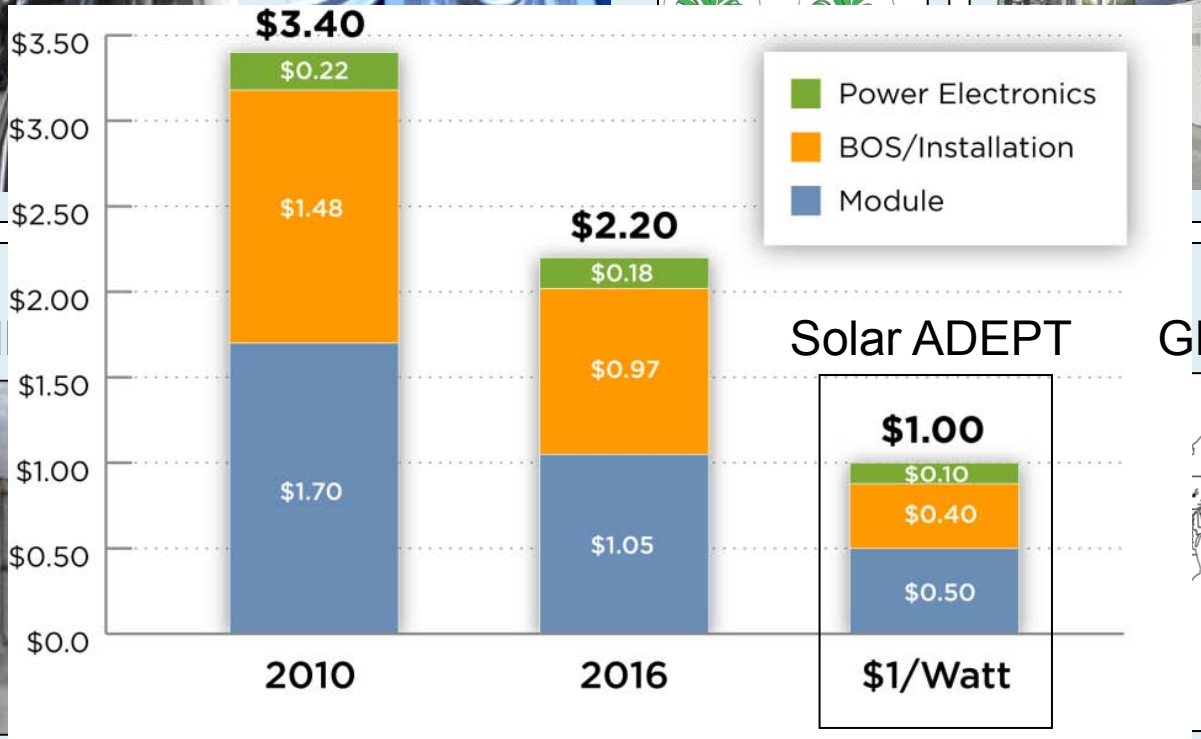
## End-Use Efficiency

HEATS

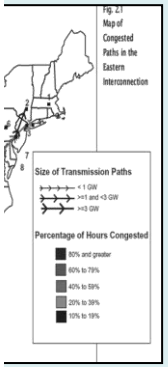
BEETIT

IM

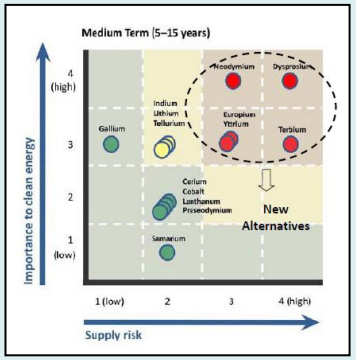
Solar ADEPT




GENI




REACT

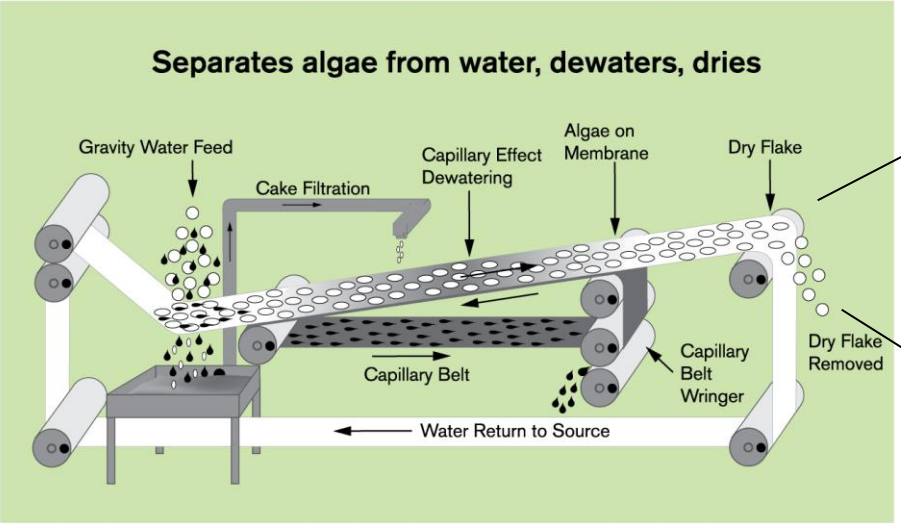



**5-6¢/kWh fully installed at the MW scale by 2020**

# Reducing the energy/economic cost of dewatering & drying microalgae

Deployment | **Demonstration** | Development | Applied Research | Basic Research

- Algaeventure Systems is developing a new and inexpensive method for harvesting algae utilizing low energy surface chemistry properties in a mechanical-electrical device.
- Algaeventure Systems has designed and fabricated an innovative algae harvesting dewatering and drying system that is far more energy-efficient than existing techniques. If successful, this technology could dramatically reduce the energy cost necessary to harvest, dewater, dry algae and potentially transform the economics of algae-based bio-fuel production.



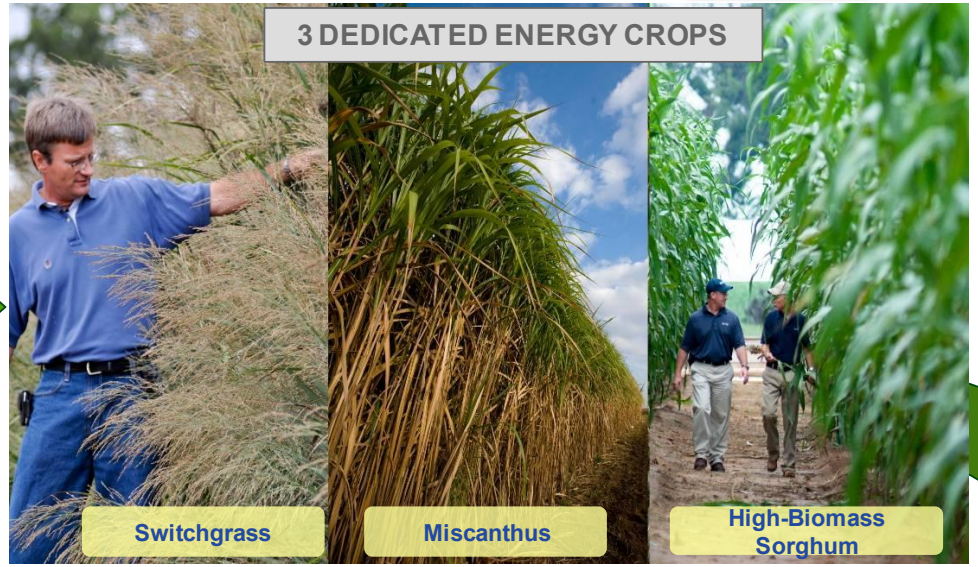
# Developing high biomass dedicated energy crops with increased nitrogen use efficiency

ceres
the energy crop company®

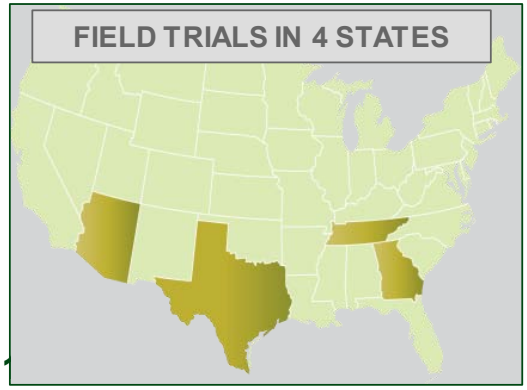
Deployment | Demonstration | **Development** | Applied Research | Basic Research

## 4 HIGH BIOMASS NUE TRAITS

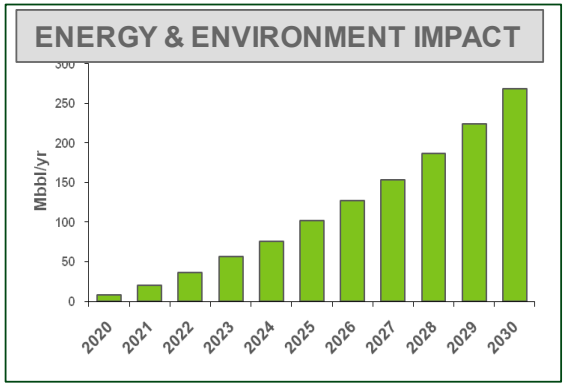
## 3 DEDICATED ENERGY CROPS



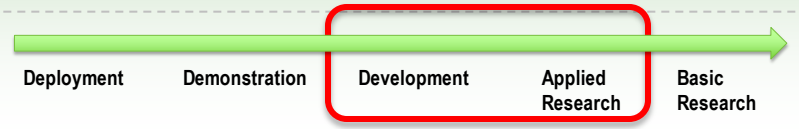

## FIELD TRIALS IN 4 STATES



## ENERGY & ENVIRONMENT IMPACT



# Macroalgae and biobutanol technology combined provide a sustainable biofuel




**Approach**:

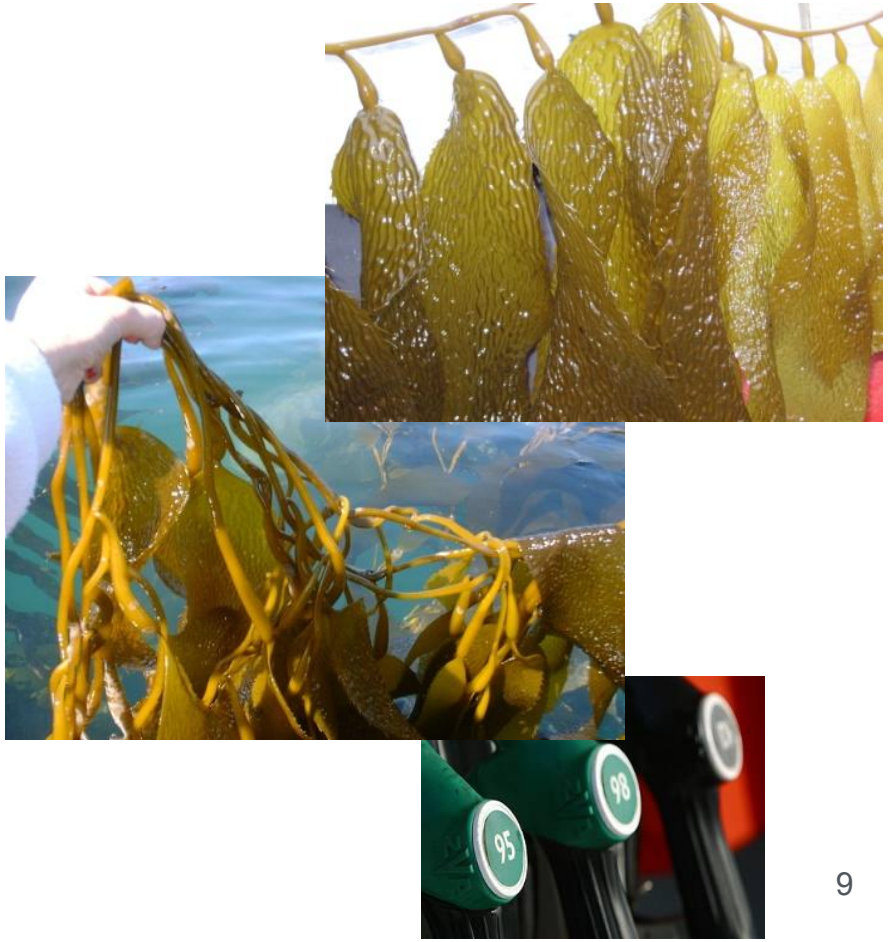
- Technoeconomic Feasibility: Process analysis and pilot-scale demonstration
- Biocatalyst Feasibility: Develop isobutanol producing yeast that converts macroalgal carbohydrate to isobutanol
- Commercialization Strategy: Butamax™ Advanced Biofuels (a DuPont/BP Joint Venture) chartered to develop and commercialize biobutanol from multiple feedstocks

**Seaweed**:

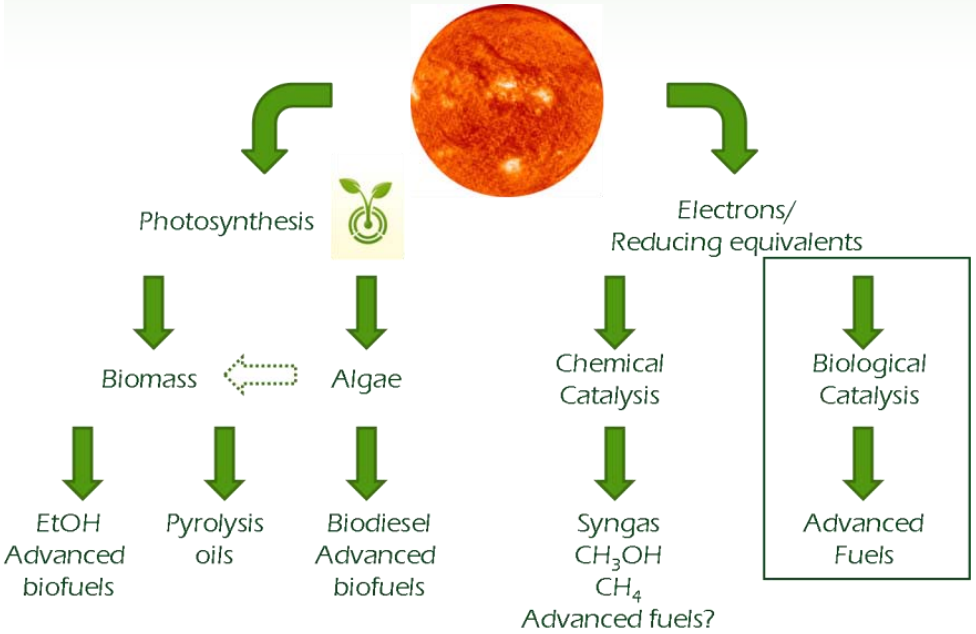
- Scalable production
- Potential to reduce GHG emissions by >90% compared to petroleum based fuels
- Grown at large scale today

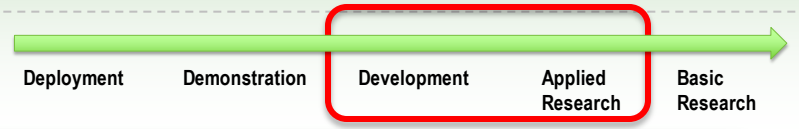
**Biobutanol**:

- Can be produced from a range of feedstocks
- Compatible with current infrastructure
- Physical properties which create value throughout the fuels supply chain (high energy density, high octane, low vapor pressure, water immiscibility)
- Can be blended at 16% in gasoline

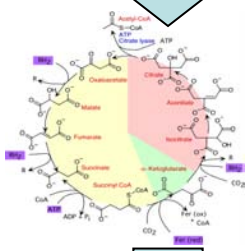


# “Electrofuels”, a program area for mid-to-long term solutions to many current biofuel production inefficiencies

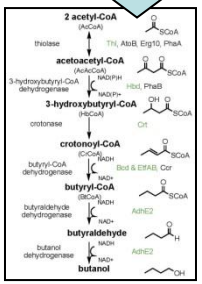


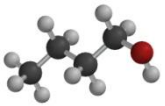
Assimilate Reducing Equivalents: *other than reduced carbon or products from Photosystems I & II (ex. direct current, $H_2$, $H_2S$, etc.)*



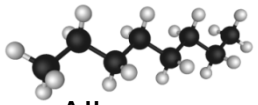
Pathways for Carbon Fixation: *reverse TCA, Calvin- Benson, Wood-Ljungdahl, Hydroxpropionate-hydroxybutyrate, or newly designed biochemical pathways*




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



Butanol



Alkanes

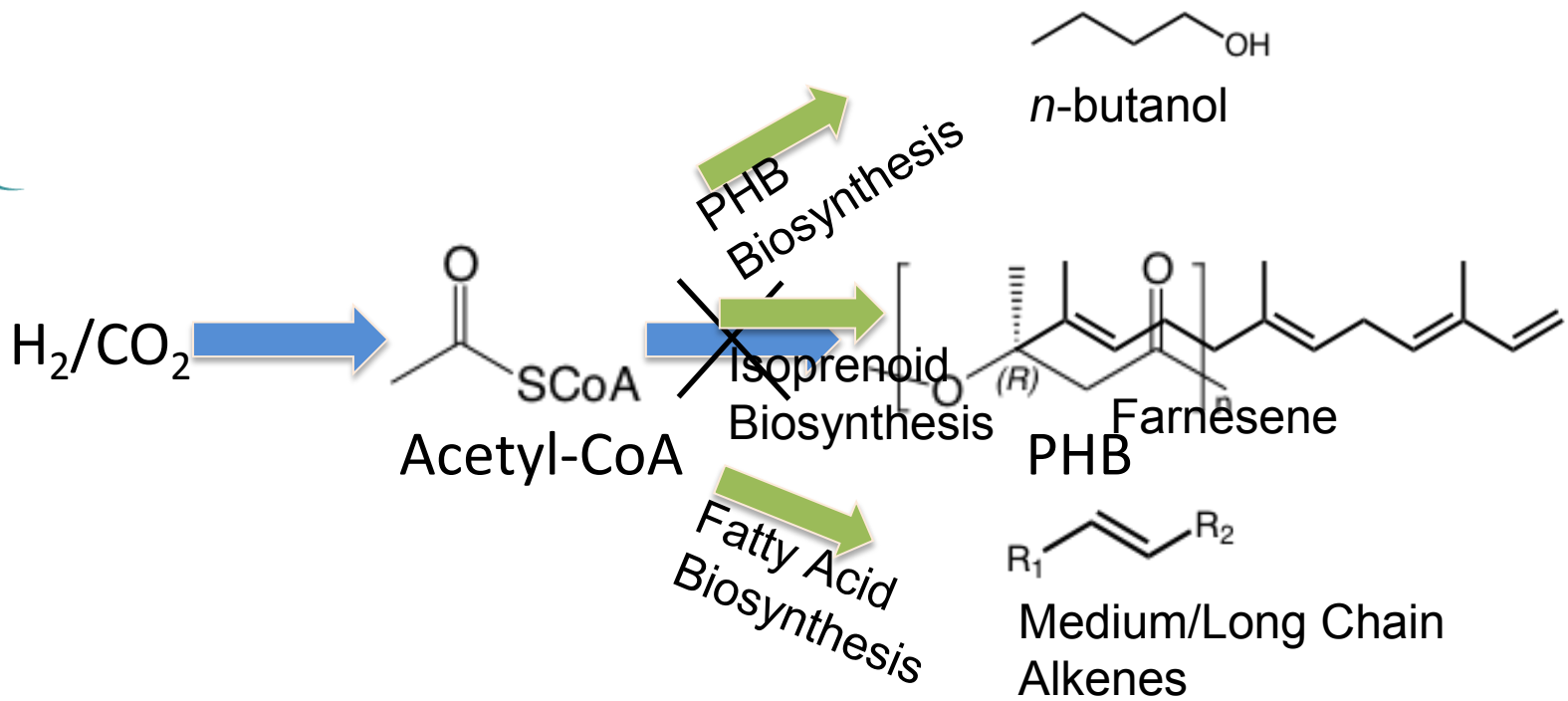
Etc.

“Electrofuels” targets the first application of non-photosynthetic, autotrophic microorganisms for the production of infrastructure compatible biofuels.

13 projects, $45M ARPA-E, $56M Total

# Lawrence Berkeley National Lab is working to engineer *Ralstonia* to produce butanol

| Title | Development of an Integrated Microbial-ElectroCatalytic System for Biofuels | | | | |
|---|---|---|---|---|---|
| **Team Lead** | LBNL; Berkeley, CA | **Project Budget** | $5.0 Million | **POP** | 7/16/2010 - 7/12/2013 (36) |

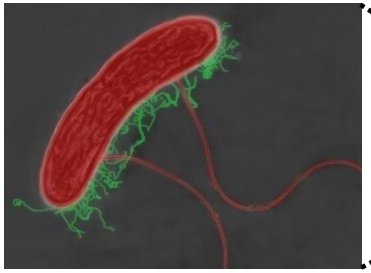


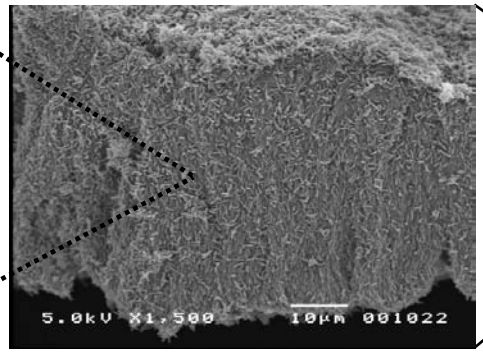

Carbon flux to PHB synthesis will be diverted to produce butanol, fatty-acid derived alkenes and isoprenoids from $H_2/CO_2$

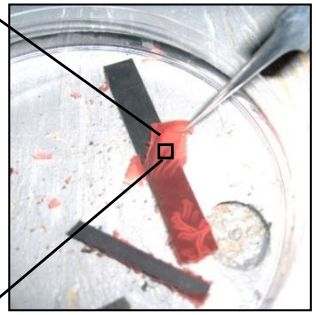
# Direct electron transfer: UMass will leverage the ability of some microbes to make electrical contacts with electrodes

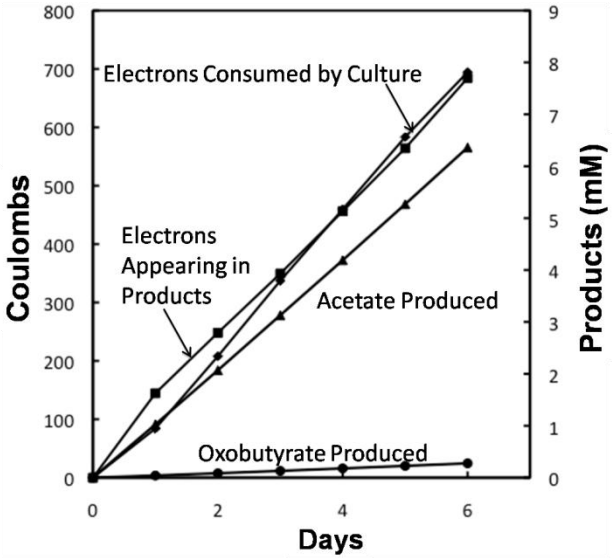
| Title | Electrofuels via Direct Electron Transfer from Electrodes to Microbes | | | | |
|---|---|---|---|---|---|
| **Team Lead** | U. of Massachusetts; Amherst, MA | **Project Budget** | $4.1 Million | **POP** | 7/01/2010 - 7/01/2013 (36) |

*Geobacter metallireducens* can form conductive biofilms on the surface of electrodes



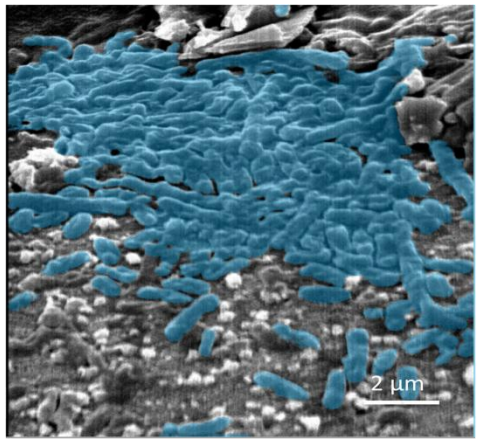




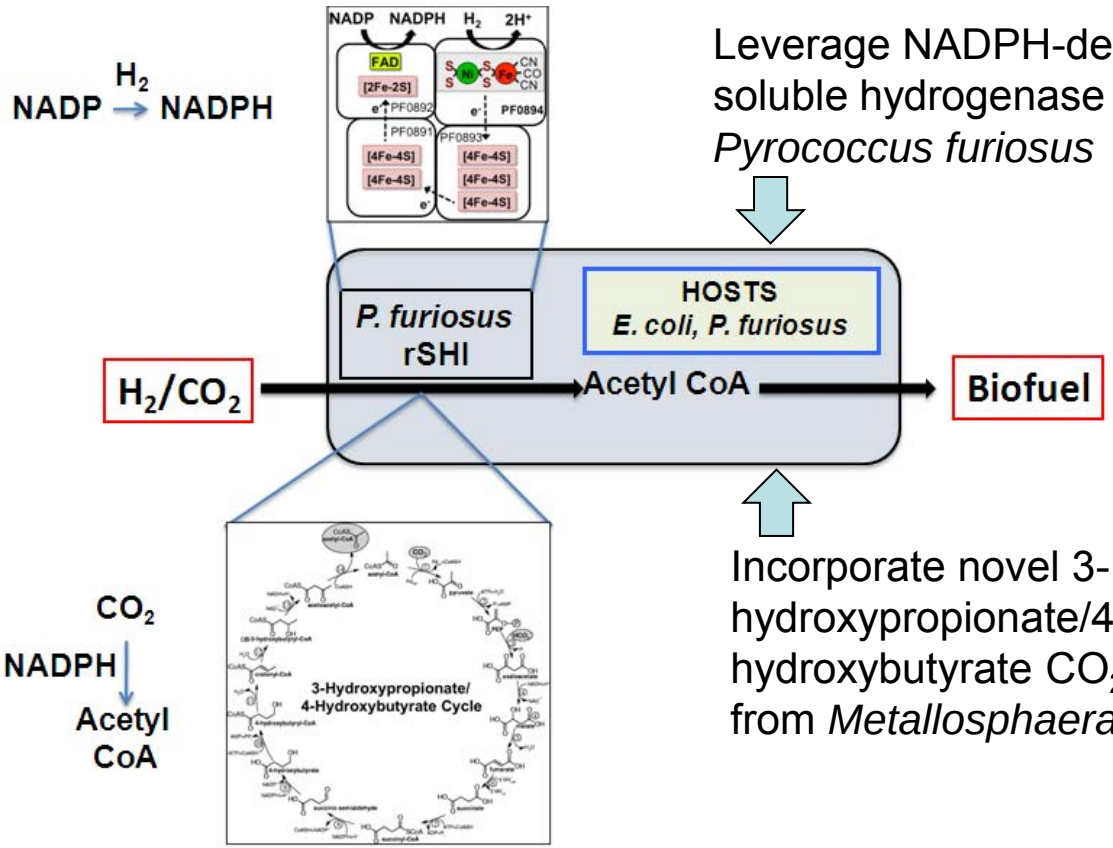

Acetogenes such as *Sporomusa ovata* have demonstrated the ability to produce acetate directly from electrons with high coulombic efficiency

*Clostridium ljungdahlii* will be engineered to produce butanol from electrcity

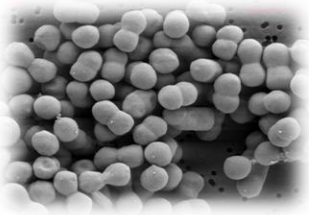


# NCSU & UGA seek to transfer novel $CO_2$ fixation enzymes to convert heterotrophs into autotrophs

| Title | $H_2$-Dependent Conversion of $CO_2$ to Liquid Electrofuels by Thermophilic Archaea | | | | |
|---|---|---|---|---|---|
| **Team Lead** | North Carolina State U.; Raleigh, NC | **Project Budget** | $3.3 Million | **POP** | 7/01/2010 - 6/23/2013 (36) |



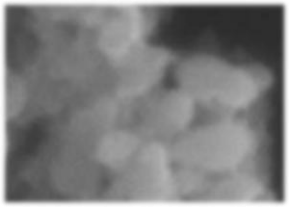

Leverage NADPH-dependent soluble hydrogenase activity from *Pyrococcus furiosus*



The University of Georgia

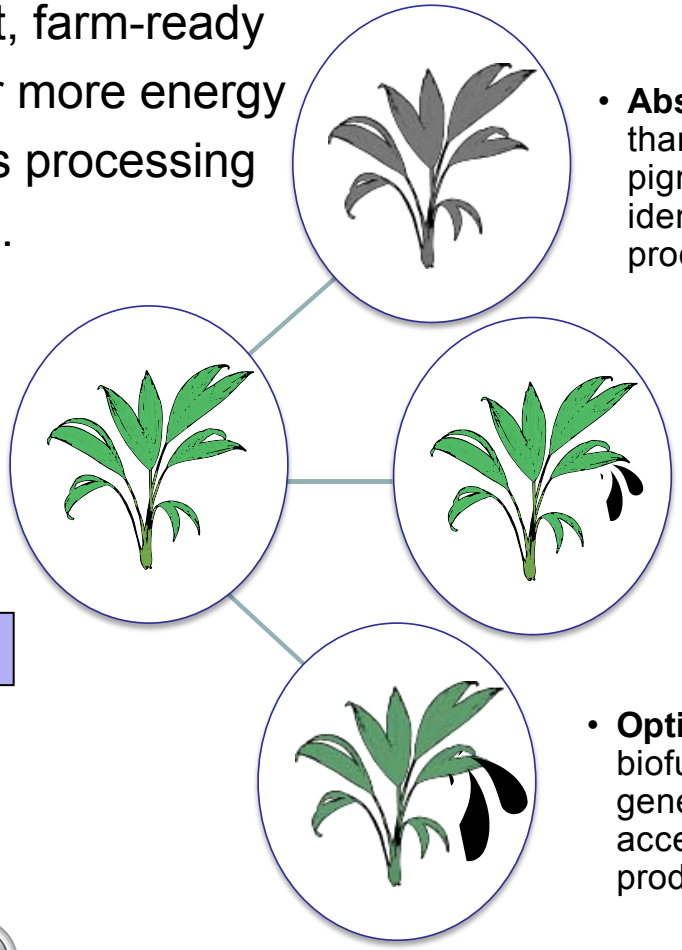
NC STATE UNIVERSITY

Incorporate novel 3-hydroxypropionate/4-hydroxybutyrate $CO_2$ fixation cycle from *Metallosphaera sedula*



# ARPA-E has also recently announced the "PETRO" funding opportunity – Plants Engineered to Replace Oil

PETRO aims to create plants that capture more energy from sunlight and convert that energy directly into fuels. ARPA-E seeks to fund technologies that optimize the biochemical processes of energy capture and conversion to develop robust, farm-ready crops that deliver more energy per acre with less processing prior to the pump.



- **Absorption:** Ordinary photosynthesis uses less than half of the incident light energy. Biological pigments that absorb more energy have been identified, but have not used in biofuel production.
- **Metabolism:** Currently, biofuels are fermented from biologically created materials. The two biological processes are able to be combined into a single process to generate fuel directly.
- **Optimization:** A dedicated source of biofuel is an agricultural crop. Rapid genetic selection can be used to accelerate the development of viable production strains.

Dr. Jonathan Burbaum