CHANGING WHAT'S POSSIBLE

Synthetic biology and crop engineering to improve biofuel productivity

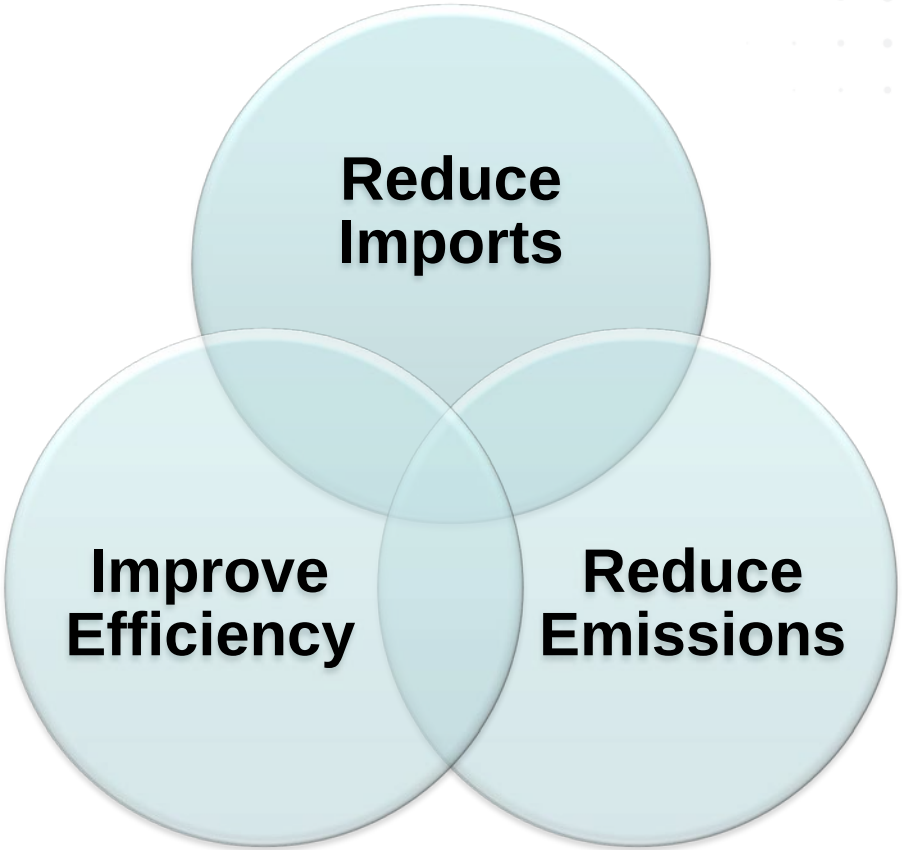
Jonathan Burbaum
Program Director

The ARPA-E Mission

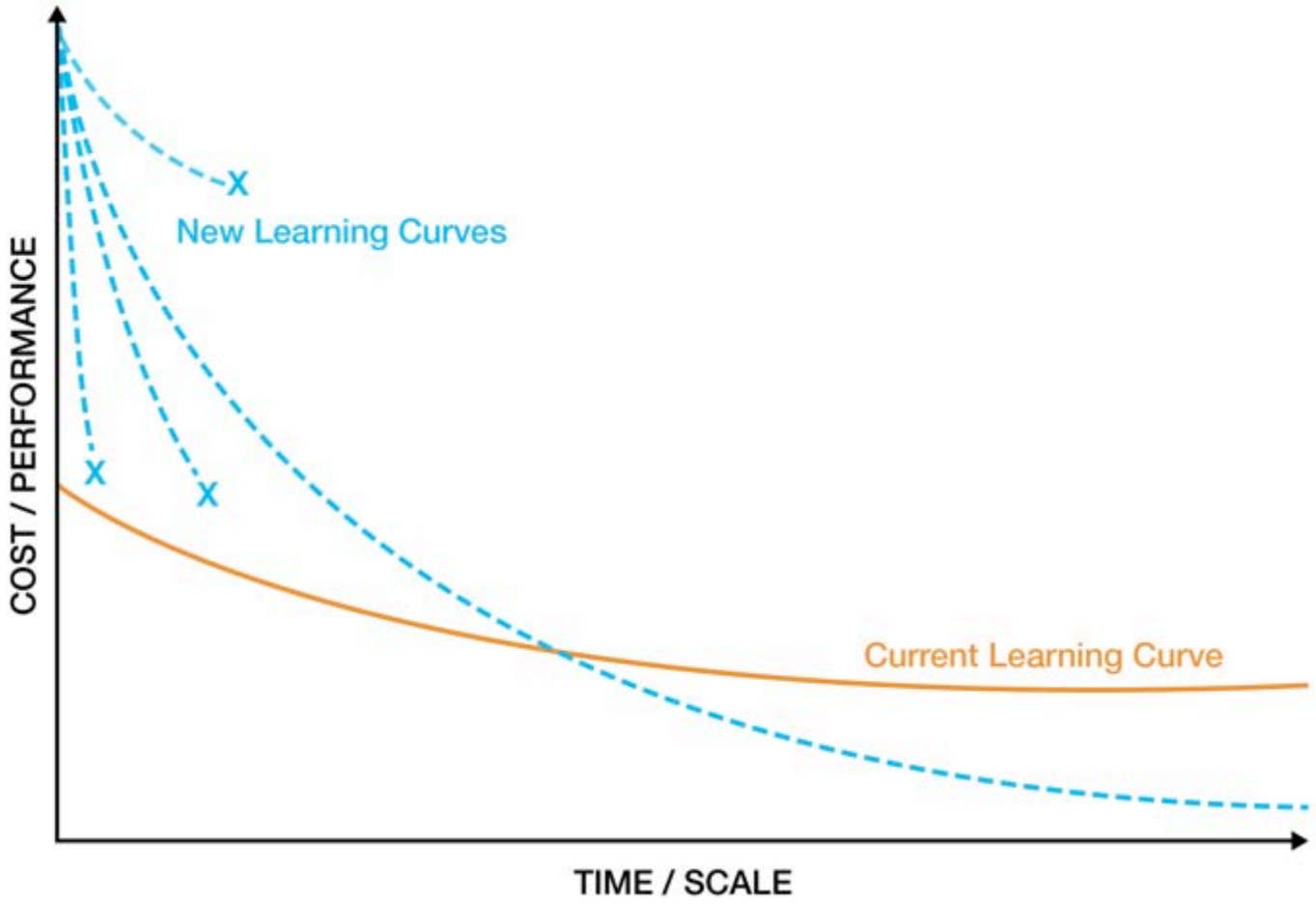
Catalyze and support the development of transformational, high-impact energy technologies

Ensure America's

- National Security
- Economic Security
- Energy Security
- Technological Lead



Creating New Learning Curves



What Makes an ARPA-E Project?

IMPACT

- High impact on ARPA-E mission areas
- Credible path to market
- Large commercial application

TRANSFORM

- Challenges what is possible
- Disrupts existing learning curves
- Leaps beyond today's technologies

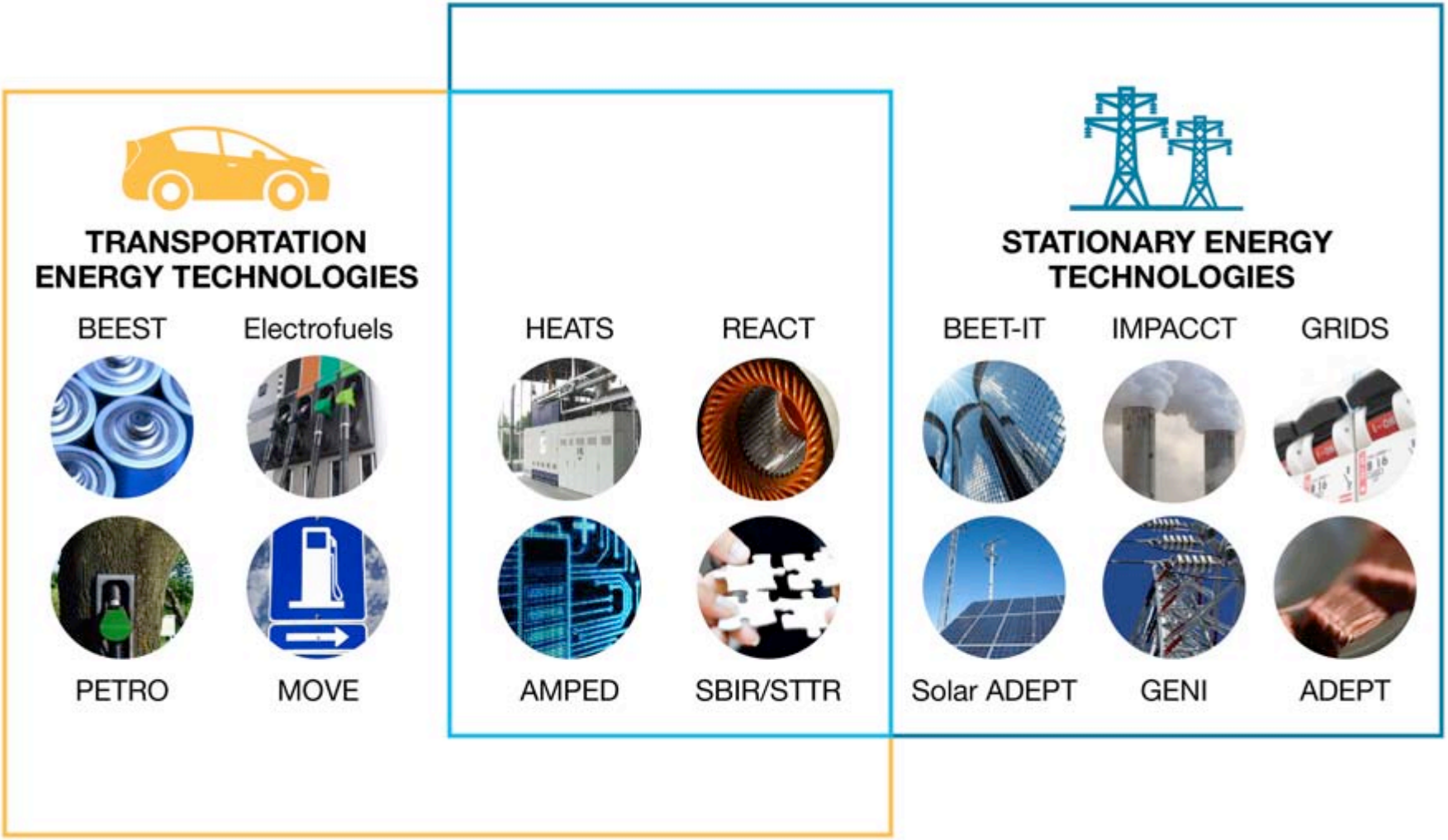
BRIDGE

- Translates science into breakthrough technology
- Not researched or funded elsewhere
- Catalyzes new interest and investment

TEAM

- Comprised of best-in-class people
- Cross-disciplinary skill sets
- Translation oriented

Focused Programs



New Solicitations

RANGE

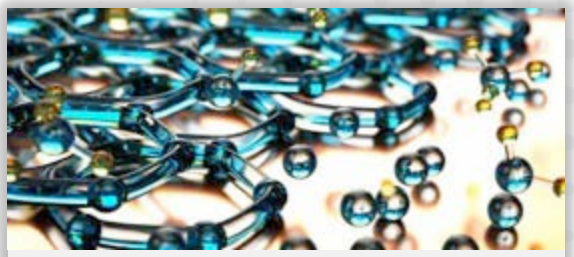
Robust Affordable Next Generation EV-storage

Release Date: 2/19/2013

METALS

Modern Electro/ Thermochemical Advances in Light-metal Systems

Release Date: 3/20/2013



REMOTE

Reducing Emissions Using Methanotrophic Organisms for Transportation Energy

Release Date: 3/20/13

SWITCHES

Strategies for Wide-bandgap, Inexpensive Transistors for Controlling High Efficiency Systems

Release Date: 6/11/2013

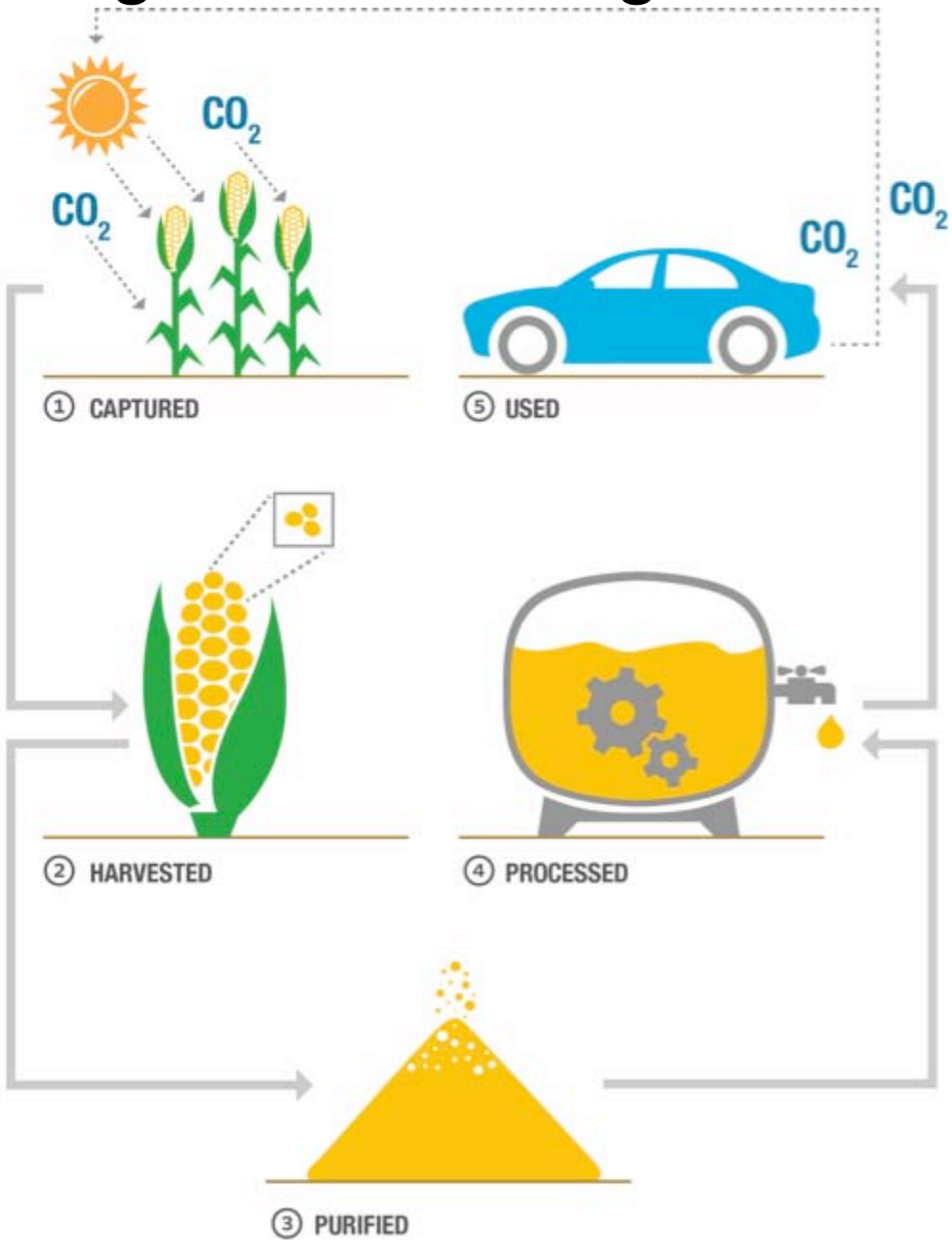
FOCUS

Full-spectrum Optimized Conversion and Utilization of Sunlight

Release Date: 7/16/2013

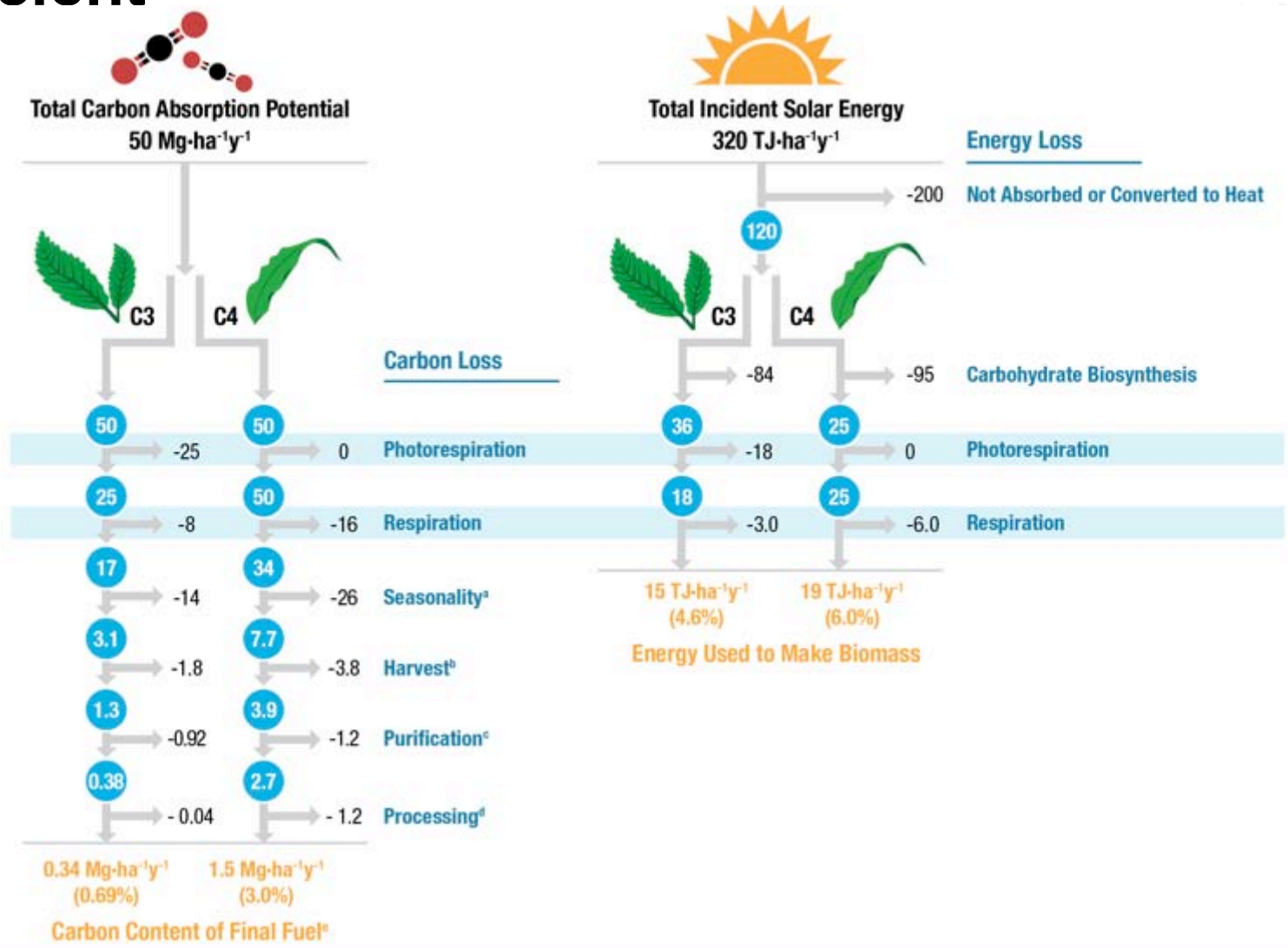
Learn more at
www.arpa-e.energy.gov

Tracking carbon through biofuel production



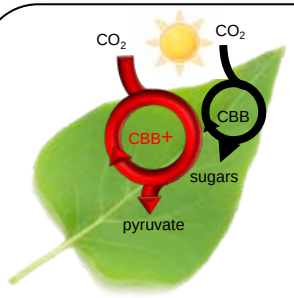
From Borak, JB, Ort, DR & Burbaum, JJ, *Curr Op in Biotech*, 2013

Current pathways for liquid fuels from plants are inefficient

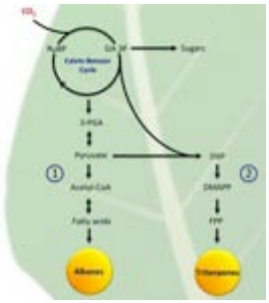


PETRO Targets

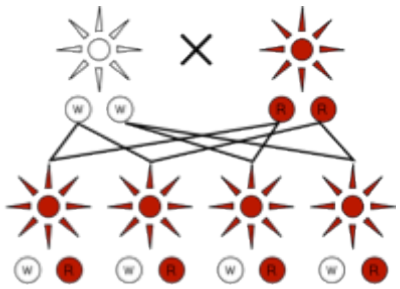
Developing Dedicated Biofuel Crops



Photosynthesis Optimization



Metabolic engineering



Heritable Traits

Yield: 160 GJ/Ha-year (2x corn)

Cost: < $3 GGE

PETRO

HIGHER PRODUCTIVITY CROPS FOR BIOFUELS

Mission

Develop non-food crops that directly produce transportation fuels to be cost-competitive with petroleum and not impactful on U.S. food supply.

Program Director	Dr. Jonathan Burbaum
Year	2011
Projects	10
Total Investment	$37.3 Million

Goals

- To reduce biofuel production costs
- To increase energy yields per acre of land
- To recycle atmospheric CO_2

Highlights

- Develop pine trees that will accumulate 20% of their biomass as high energy terpene molecules
- Develop tobacco that produces oil directly, together with high planting density agriculture
- Introduce multiple metabolic pathways into oilseed crops to significantly improve photosynthesis

Plants being developed under PETRO

Oilseed

DONALD DANFORTH PLANT SCIENCE CENTER

NC STATE UNIVERSITY

UMASS AMHERST

(*Camelina*)

C_4 Grasses

ILLINOIS

(sugarcane, sorghum)

Arcadia BIOSCIENCES

(sorghum)

Chromatin, Inc.

(sorghum, sugarcane)

UCLA

(*Arabidopsis*➔Switchgrass)

Trees

UF UNIVERSITY of FLORIDA

(loblolly pine)

Other

BERKELEY LAB

(tobacco)

TEXAS A&M UNIVERSITY

(tobacco)

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Project Spotlight: University of Florida

UF | UNIVERSITY of FLORIDA

The University of Florida is working to increase the amount of turpentine in harvested pine from 4% to 20% of its dry weight. The team aims to increase the terpene storage potential and production capacity while improving the terpene composition to a point at which the trees could be tapped while alive, like sugar maples.

Program: PETRO

Technology: Tappable Pine Trees

Location: Gainesville, FL

Pine trees engineered to produce fuel molecules in addition to providing pulp for paper

Increase production, fuel quality & storage capacity of pine terpenes

Loblolly pine

Ancient source of turpentine

Processed on an industrial scale

UF UNIVERSITY of FLORIDA

ARBORGEN

NREL NATIONAL RENEWABLE ENERGY LABORATORY

Berkeley University of California

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Direct solar production of oil in sugarcane and sweet sorghum stems (PETROSS)

- Converting sugarcane and sweet sorghum from sugar to oil producing crops, which can be processed using sugarcane mill crushing technology to release the oil.

- Improving photosynthetic capacity and cold tolerance will increase growing ranges in the U.S.

ILLINOIS
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN
Nebraska Lincoln
UF UNIVERSITY of FLORIDA
BROOKHAVEN NATIONAL LABORATORY

Project Spotlight: Danforth Center

DONALD DANFORTH
PLANT SCIENCE CENTER

The Danforth Center is optimizing light utilization in Camelina – a drought-resistant, cold-tolerant oilseed crop – by engineering its topmost leaves to be lighter in color; more uniform distribution of light improve photosynthesis to help yield more oil per plant

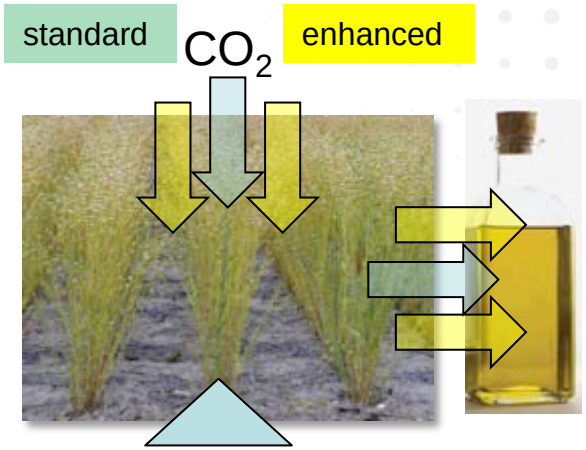
Program: PETRO

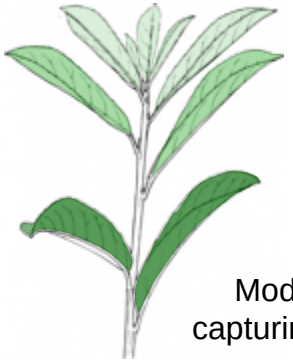
Technology: Improved Light Utilization in Camelina

Location: St. Louis, MO

Engineered *Camelina* with enhanced light capture, carbon capture, and yield of seed oil

- Leaf are lighter in color to spread light more evenly across the plant canopy for improved overall photosynthetic efficiency
- Borrowed traits from algae allow for increased CO_2 uptake and fixation
- Metabolic engineering expected to enhance seed oil productivity
- Improved oil quality and productivity significantly reduces the cost/gal of biodiesel produced.





Modified light capturing efficiency

University of Missouri St. Louis
University of Nebraska Lincoln
Montana State University
Donald Danforth Plant Science Center
USDA ARS
Michigan State University

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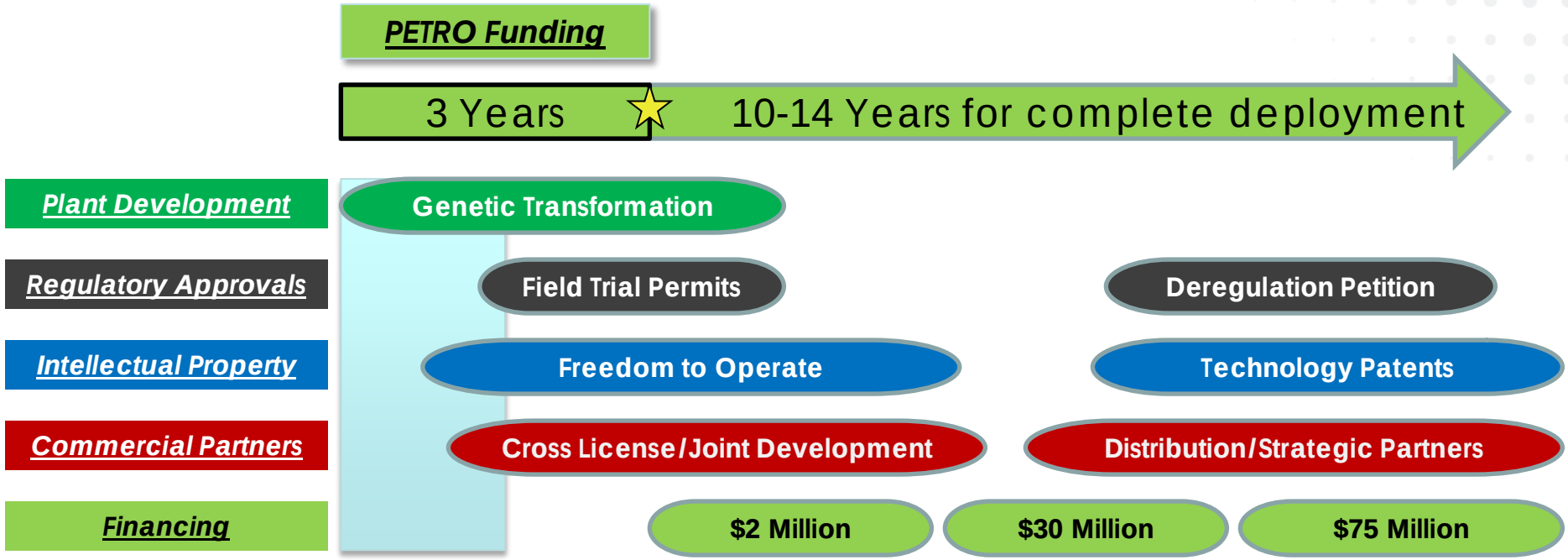
PETRO

Programmatic Environmental Review

- A programmatic Environmental Impact Statement will formally addresses regulatory & societal risks from PETRO
- Covers a variety of plants expressing energy traits
- Initial region: Southeastern U.S.
- Quantitative impact with public input *versus* base case
- Purpose: To guide program and regulators after ARPA-E

PETRO's impact will be felt in the next decade



Plants will be ready for field testing at the end of the project period.

Contacts

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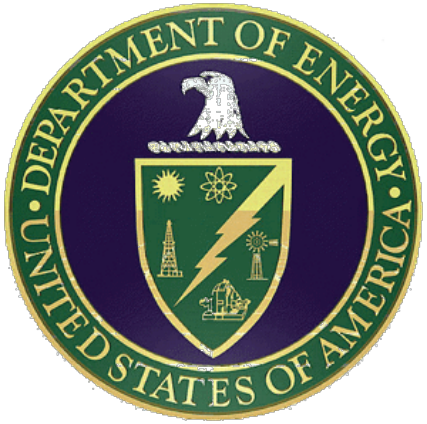


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