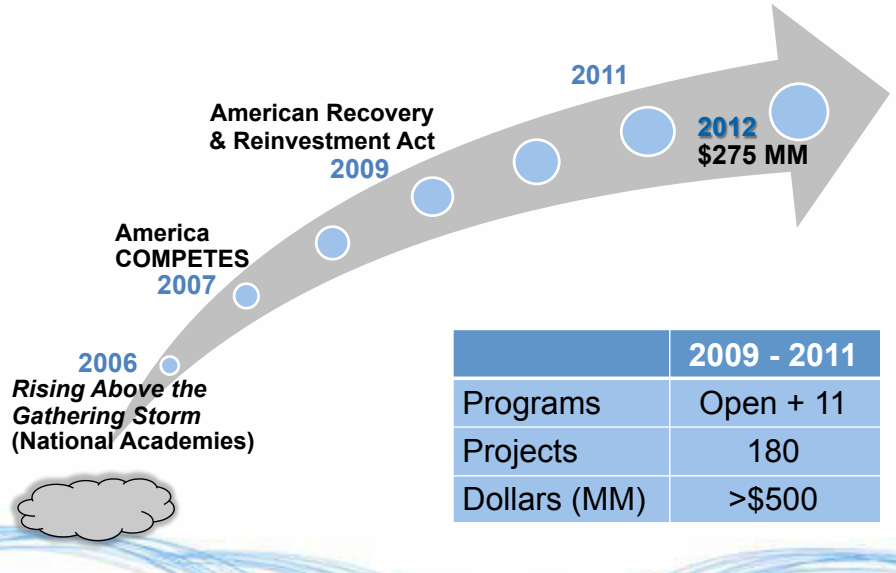
Bioenergy Research & ARPA-E

Purdue University, BioEnergy Day

Dr. Jonathan Burbaum, Program Director

November 7, 2012

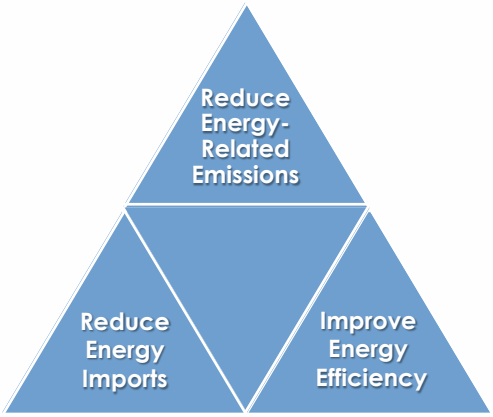
Evolution of ARPA-E



	2009 - 2011
Programs	Open + 11
Projects	180
Dollars (MM)	>$500

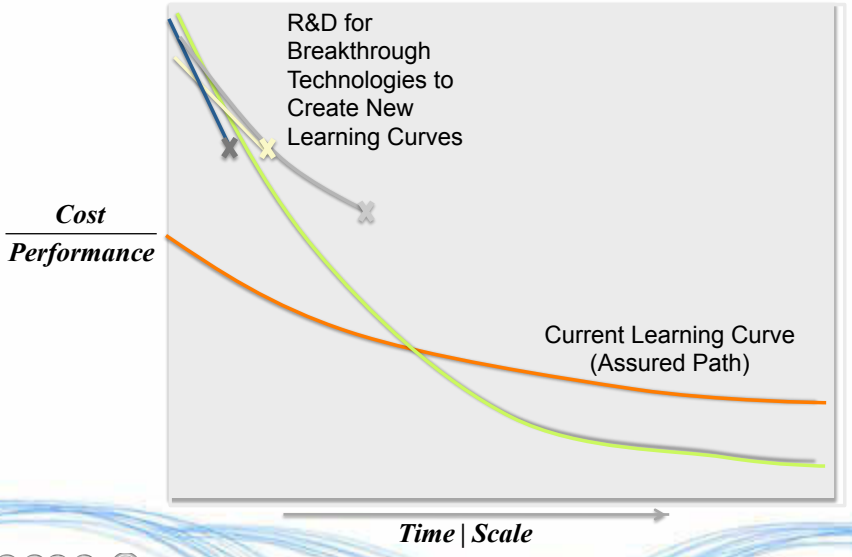
Mission

Enhance the economic and energy security of the U.S.



Ensure U.S. technological lead in developing and deploying advanced energy technologies

Creating New Learning Curves



What makes an ARPA-E project?

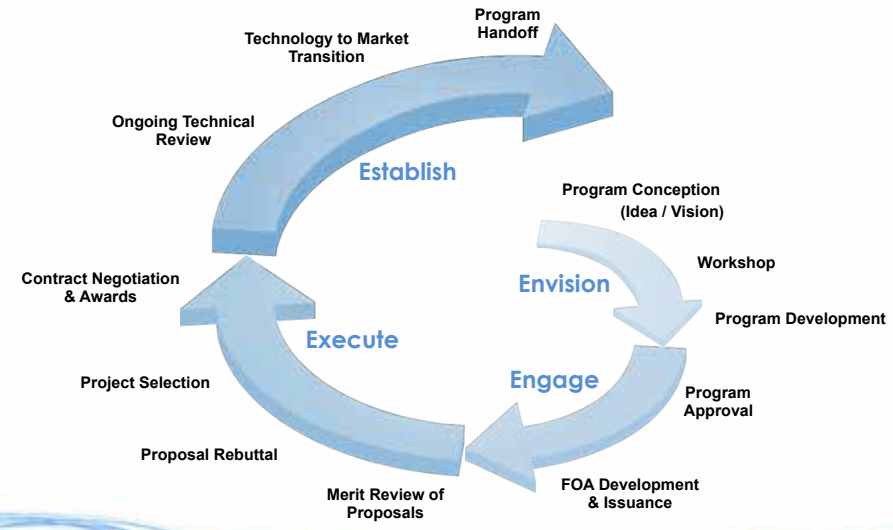
1. Impact
- Aimed at ARPA-E mission areas
- Shows a credible path to market
- Has a large practical application

2. Transform
- Challenges what is possible
- Disrupts existing learning curves
- Can leap beyond today's technologies

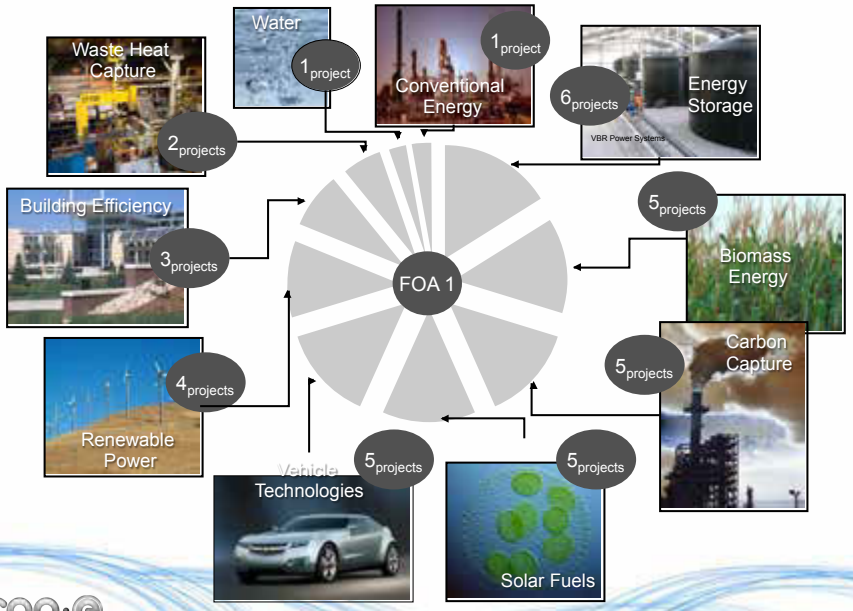
3. Bridge
- Translates science into breakthrough technology
- The path lacks technical or financial resources
- Catalyzes new interest and investment

4. Team
- Comprised of best-in-class people
- Brings skills from different disciplines
- Focuses on translation of technologies to the market

Program Development Cycle



First Open FOA (2009)



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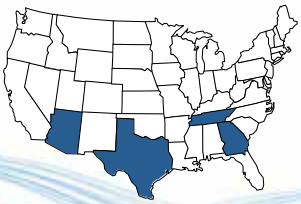
Improved high biomass energy crops

4 HIGH BIOMASS NUE TRAITS

DEDICATED ENERGY CROPS

FIELD TRIALS IN 4 STATES



c e r e s

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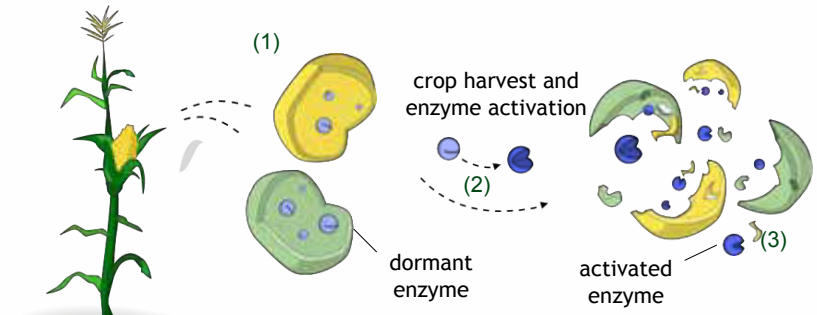
Reduced pre-treatment costs



1. Agrivida™ crops produce dormant enzymes within the plant.
2. The dormant enzymes are activated after harvest.
3. The activated enzymes degrade the cell wall.

Agrivida

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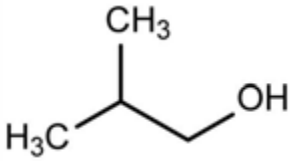
Scalable production of macroalgae as a feedstock for isobutanol



bal
bio architecture lab

DUPONT®

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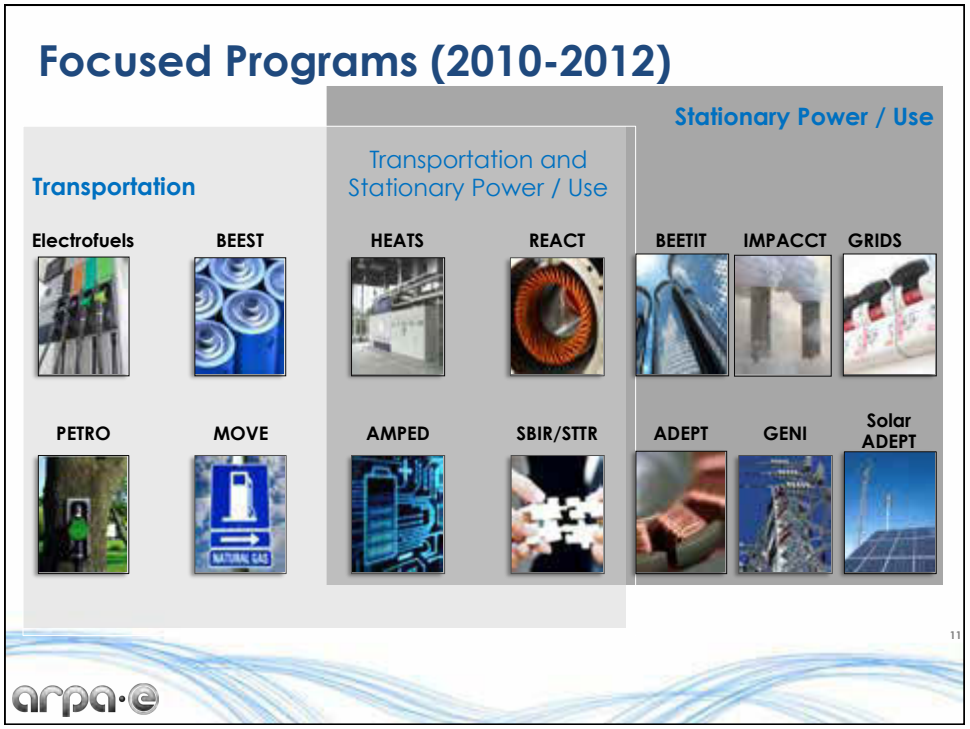
Focused Programs (2010-2012)
Stationary Power / Use
Transportation and Stationary Power / Use
Transportation
Electrofuels
BEEST
HEATS
REACT
BEETIT
IMPACCT
GRIDS
PETRO
MOVE
AMPED
SBIR/STTR
ADEPT
GENI
Solar ADEPT
11
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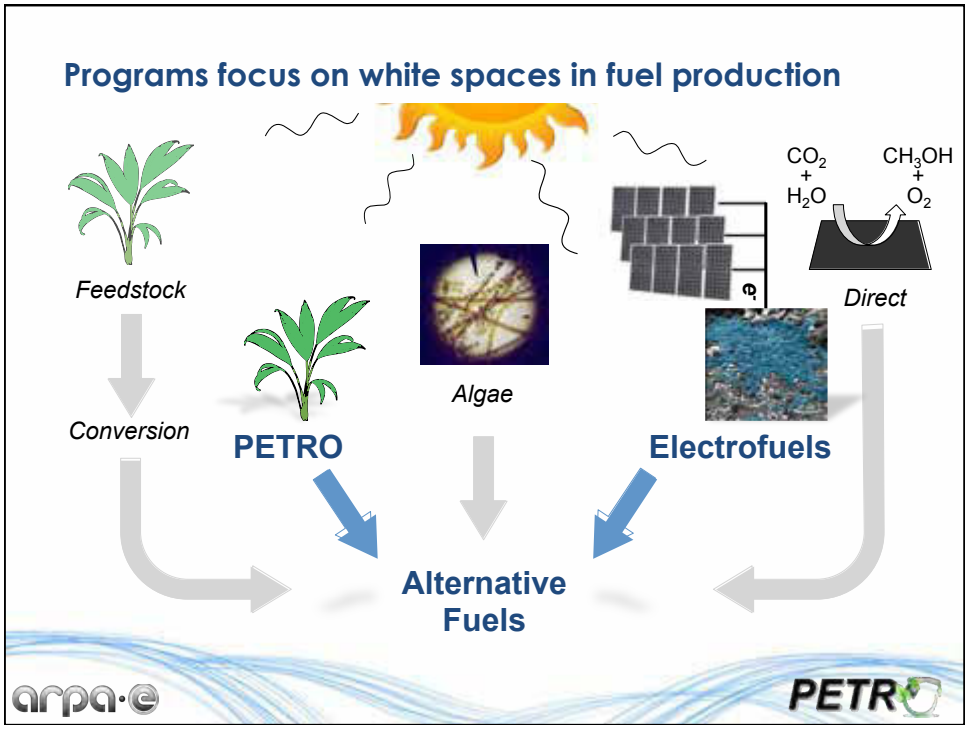
Programs focus on white spaces in fuel production
Feedstock
Conversion
PETRO
Algae
Electrofuels
CO_2 + H_2O
CH_3OH + O_2
Direct
Alternative Fuels
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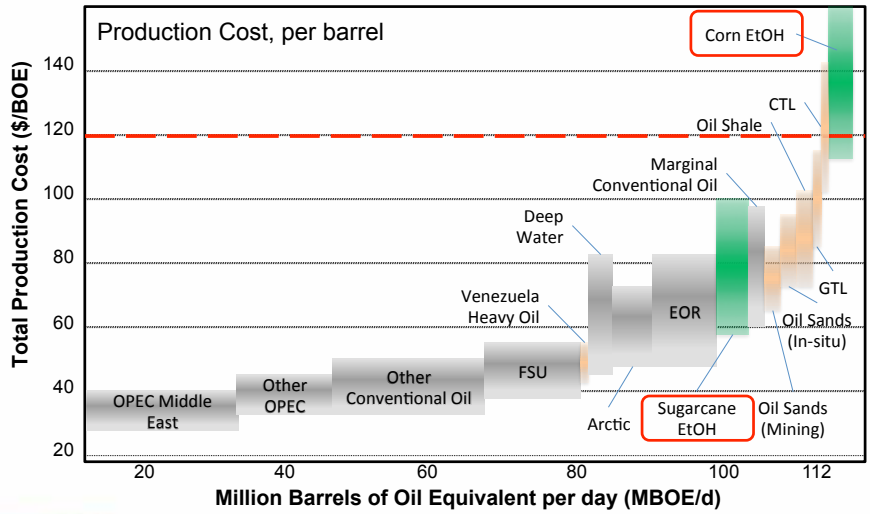
PETRO

Alternative Fuels: A Snapshot



Source: Booz Allen Hamilton analysis based on information from IEA, DOE and interviews with super-majors

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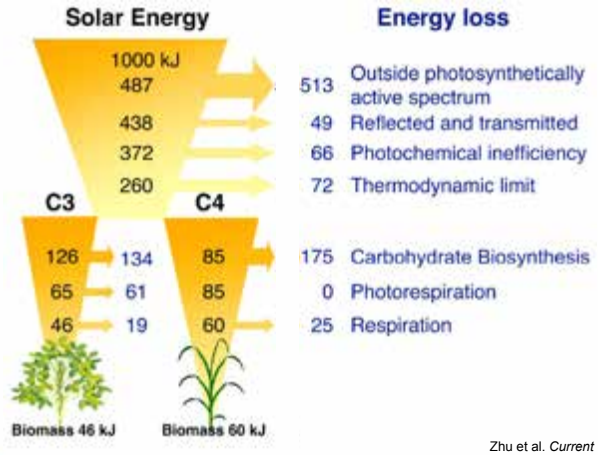
13

Current pathways for liquid fuels from solar energy have low energy efficiency



Zhu et al. *Current Opinion in Biotechnology* (2008) 19:153-159

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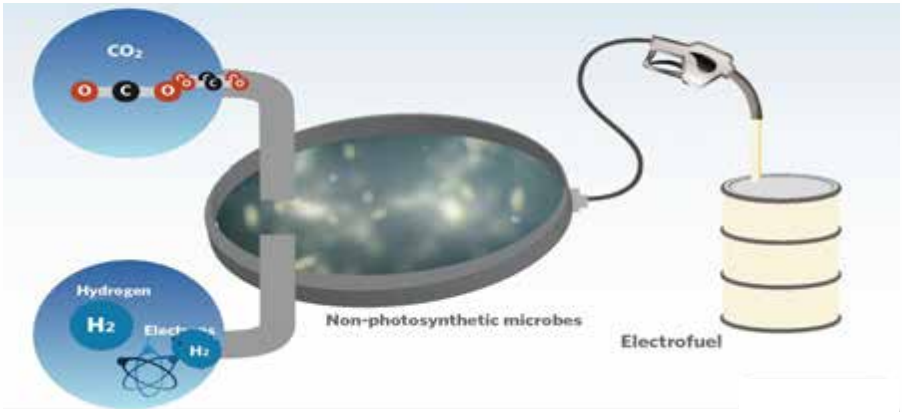
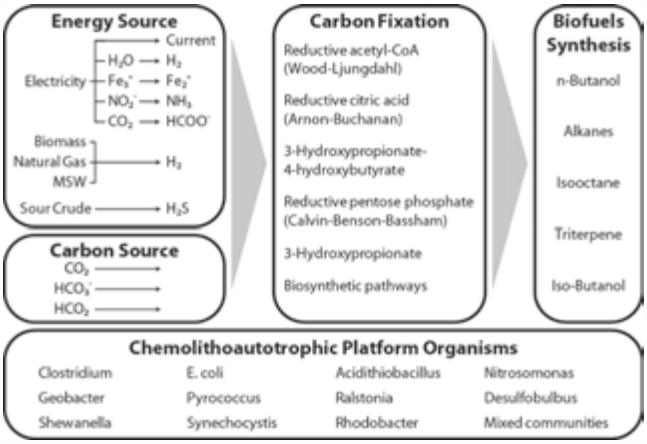


Electrofuels

Chemolithoautotrophs are at the core of a efficient and flexible Electrofuels platform



Source: Conrado, R.J., Haynes, C.A., Haendler, B.E., Toone, E.J.,"Electrofuels: A New Paradigm for Renewable Fuels" 2011, *Advanced Biofuels and Bioproducts (in press)* (Lee, J., ed.): Springer, U.S.

H_2 consuming bacteria

opxbio
good chemistry.



Autotrophic production ▶ Free fatty acid extraction ▶ Final fuel upgrading

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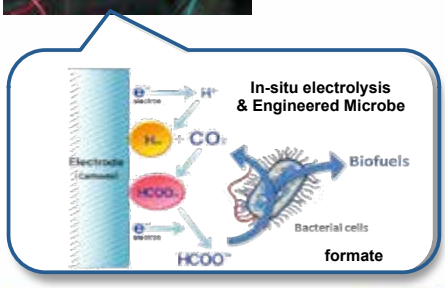
Electrochemically produced formate

Photovoltaic
or
Electricity

CO_2

Gasoline substitutes

UCLA



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PETRO

Plants Engineered To Replace Oil

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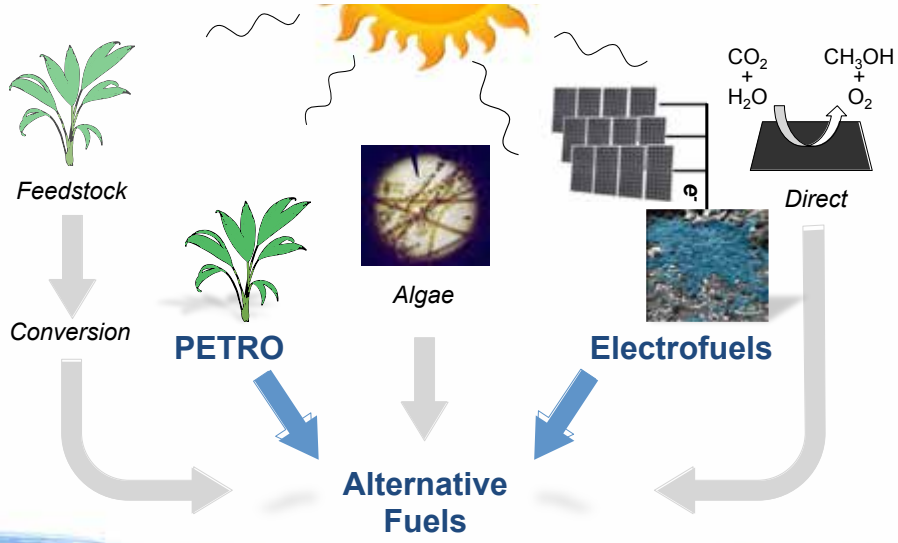
19

Programs focus on white spaces in fuel production



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PETRO's Approach Complements Other Programs

FSA BIOMASS CROP ASSISTANCE PROGRAM

The Billion Ton Study projects that in excess of 200 million dry tons of biomass crops dedicated to energy will be needed by 2030.

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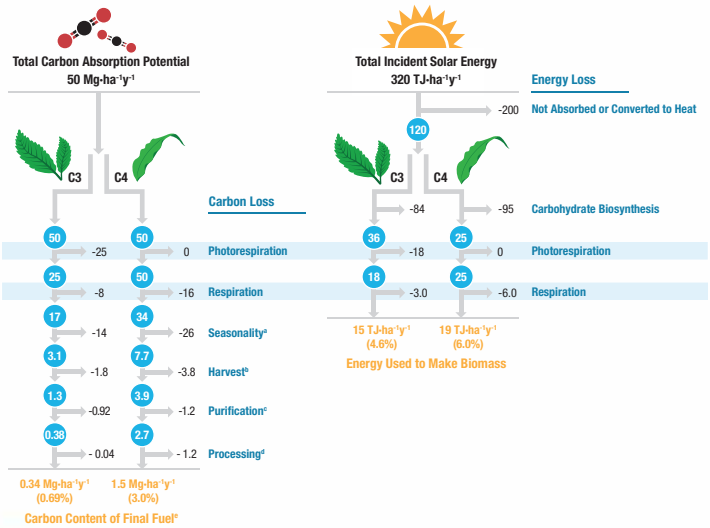
Current pathways in terms of energy & carbon



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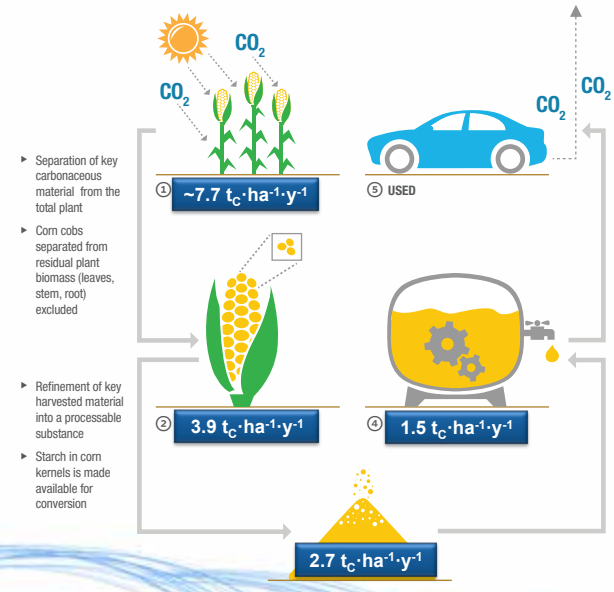
Carbon efficiency in biofuel production



- Separation of key carbonaceous material from the total plant
- Corn cobs separated from residual plant biomass (leaves, stem, root) excluded
- Refinement of key harvested material into a processable substance
- Starch in corn kernels is made available for conversion

Overall Carbon Yield
3.0 %

Overall Fuel Yield
79 $GJ \cdot ha^{-1} \cdot y^{-1}$

- (where applicable) Blending of processed product into a mixture
- Ethanol is blended into a fuel mixture

EtOH Energy Content: 52 $GJ \cdot t_C^{-1}$

- Conversion of bioproducts into a liquid vehicle-compatible fuel
- Fermentation to ethanol

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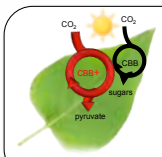
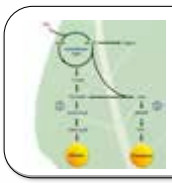
PETRO Targets

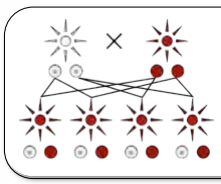
Developing Dedicated Biofuel Crops



Photosynthesis Optimization



Metabolic engineering



Heritable Traits

Yield: 160 GJ/Ha-year (2x corn)
Cost: < $3 GGE

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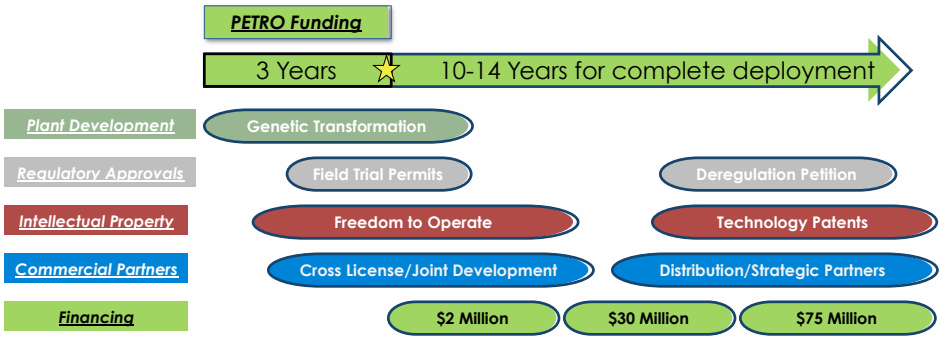
PETRO's impact will be felt in the next decade



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

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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

(*Setaria*→sorghum)

Chromatin, Inc.

(sorghum)

UCLA

(*Arabidopsis*→Switchgrass)

Trees

UF University of Florida

(loblolly pine)

Other

Berkeley Lab

(tobacco)

Chromatin, Inc.

(Guayule)

Texas A&M University

(tobacco→Giant cane)

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

Increase production, fuel quality & storage capacity for pine terpenes

Loblolly pine

Ancient source of turpentine

Processed on an industrial scale

UF UNIVERSITY of FLORIDA ARBORGEN NREL Berkeley

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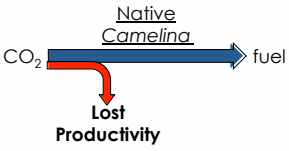
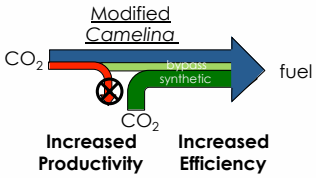
Increasing Camelina Productivity for Drop-In Fuels





- Improved carbon capture by up to 60% over current plants.
- Production of high quantities of modified oils and terpenes.
- Enhanced heat and drought tolerance.

NC STATE UNIVERSITY

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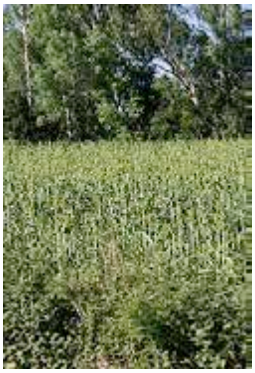
Sorghum engineered to produce fuel



Sweet Sorghum

…engineered…

to make fuel, instead of sugar

Chromatin, Inc. · Ohio State OARDC · K-STATE · Allylix

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Higher yield *Camelina* with improved energy & CO_2 capture

Higher light capturing efficiency

CO_2

Algae traits for improved fixation

Higher yields of seed oils

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

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