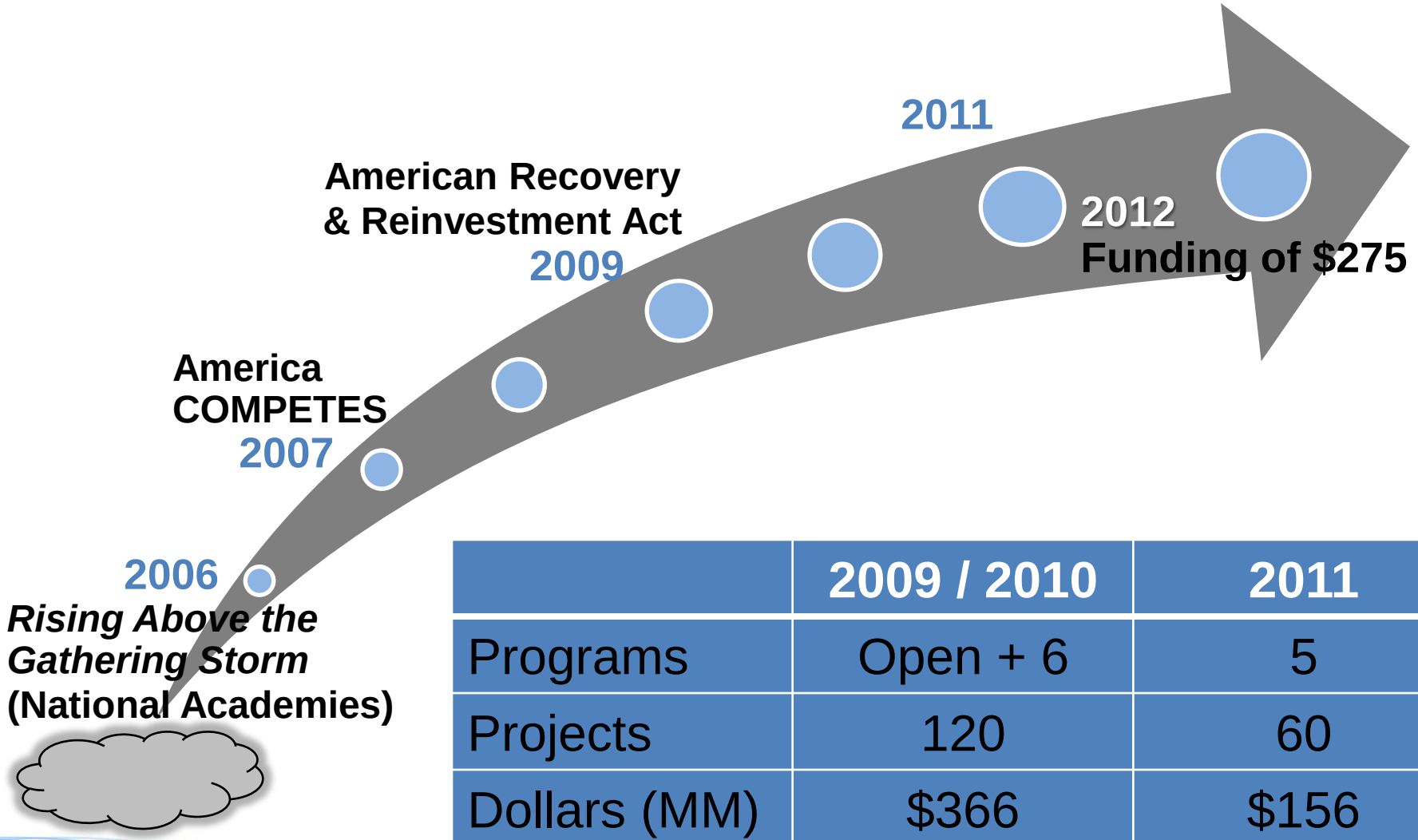
The Advanced Research Projects Agency – Energy:
A New Paradigm in Transformational Energy Research

Chad Haynes

April 10, 2012

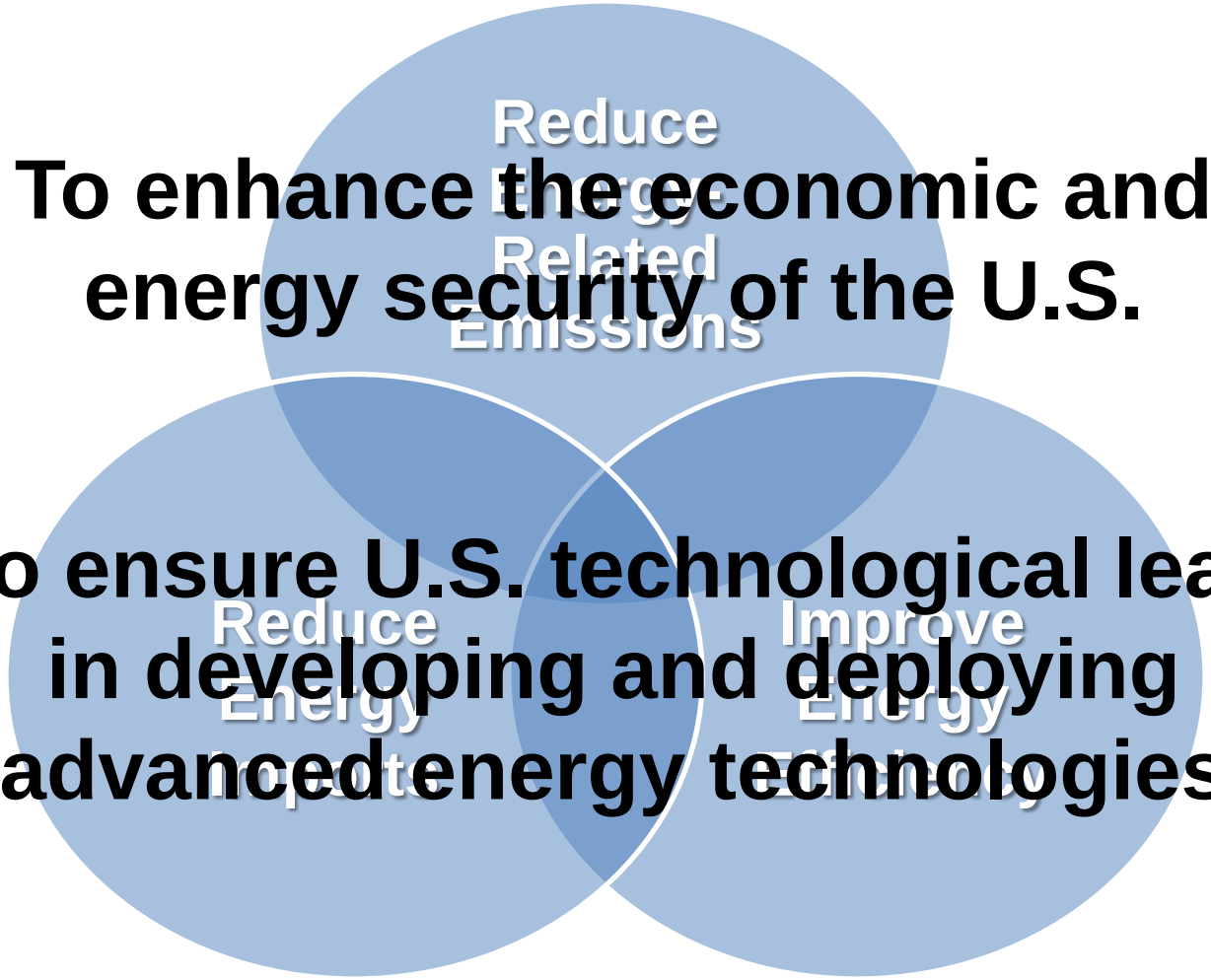
arpa·e

Evolution of ARPA-E



	2009 / 2010	2011
Programs	Open + 6	5
Projects	120	60
Dollars (MM)	$366	$156

Mission

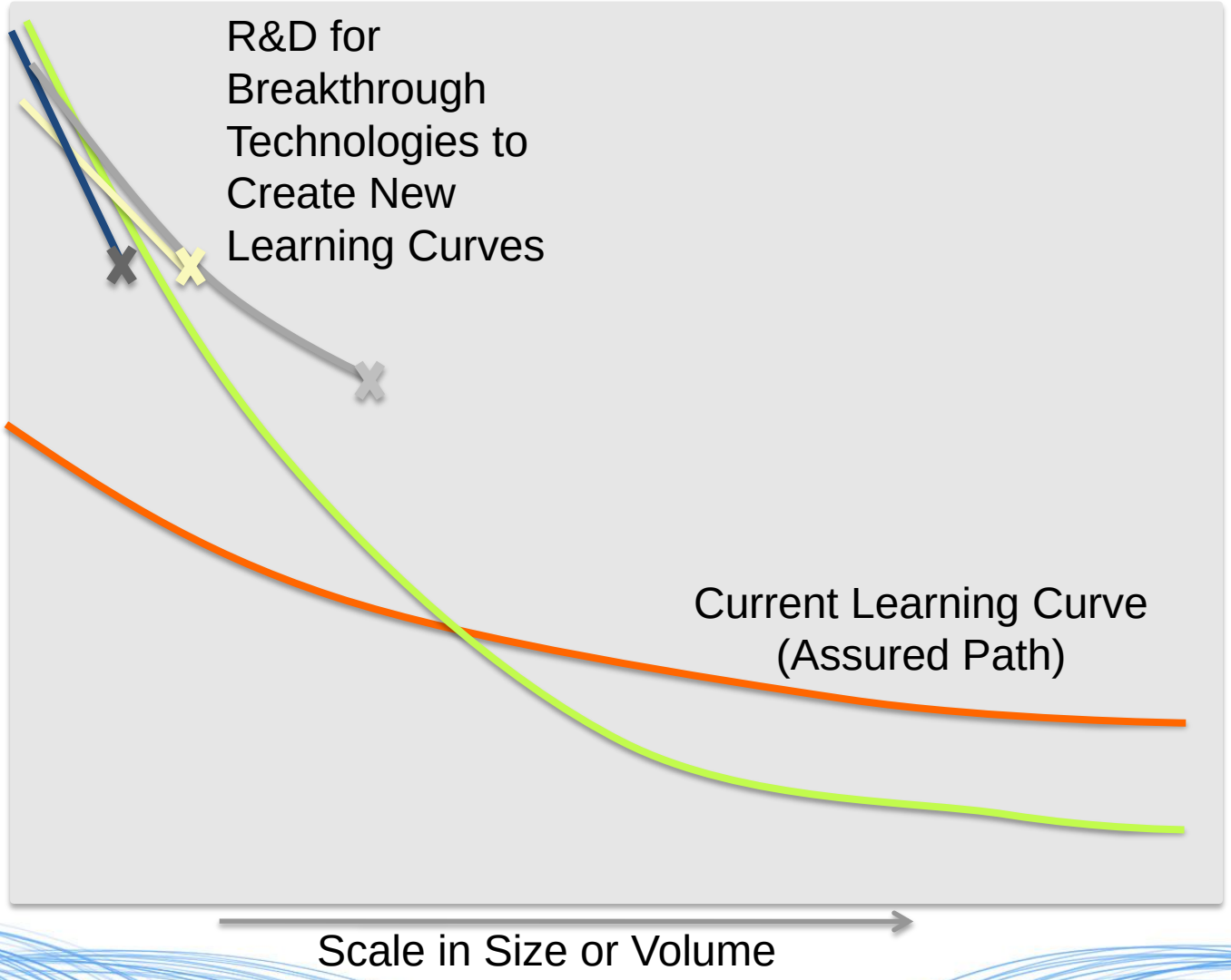


To enhance the economic and energy security of the U.S.

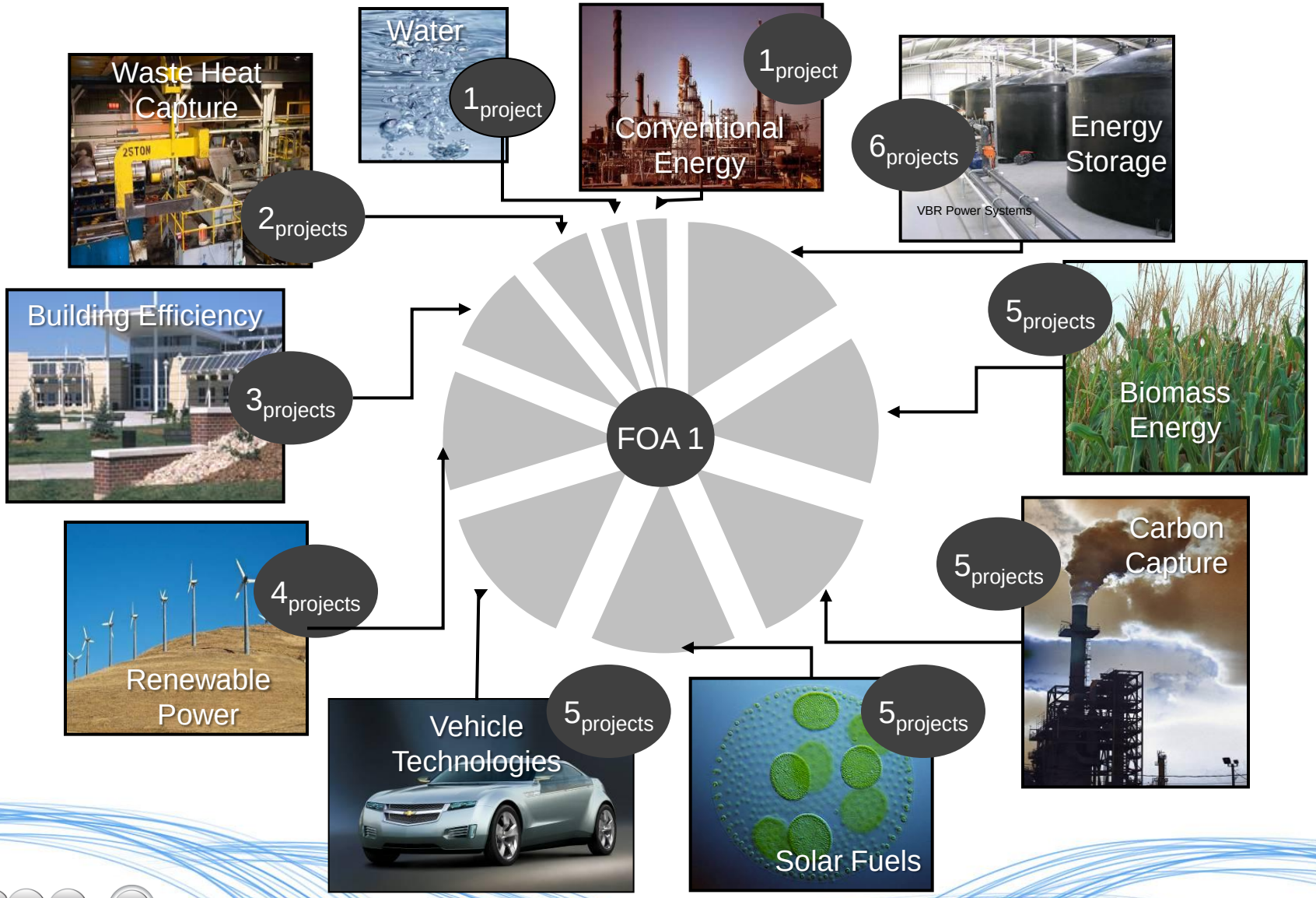
To ensure U.S. technological lead in developing and deploying advanced energy technologies

Advanced Transformative Technologies

Creating New Learning Curves



10 Technology Areas within First Open FOA



11 Focused Programs

Transportation

Electrofuels

BEEST

PETRO

End-Use Efficiency

HEATS

BEETIT

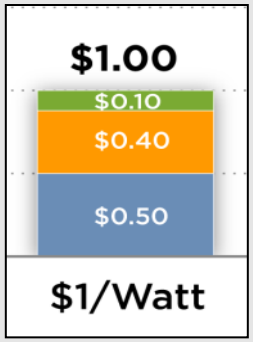
Stationary Power

IMPACCT

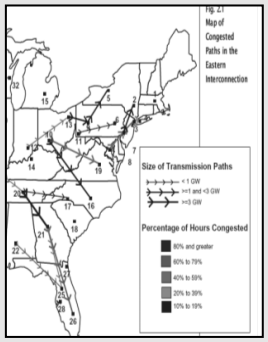
ADEPT

GRIDS

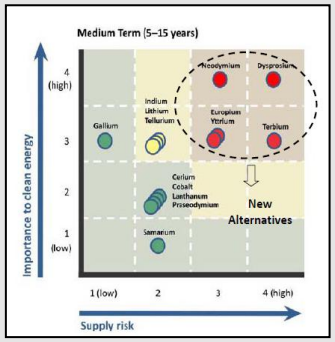
Solar ADEPT



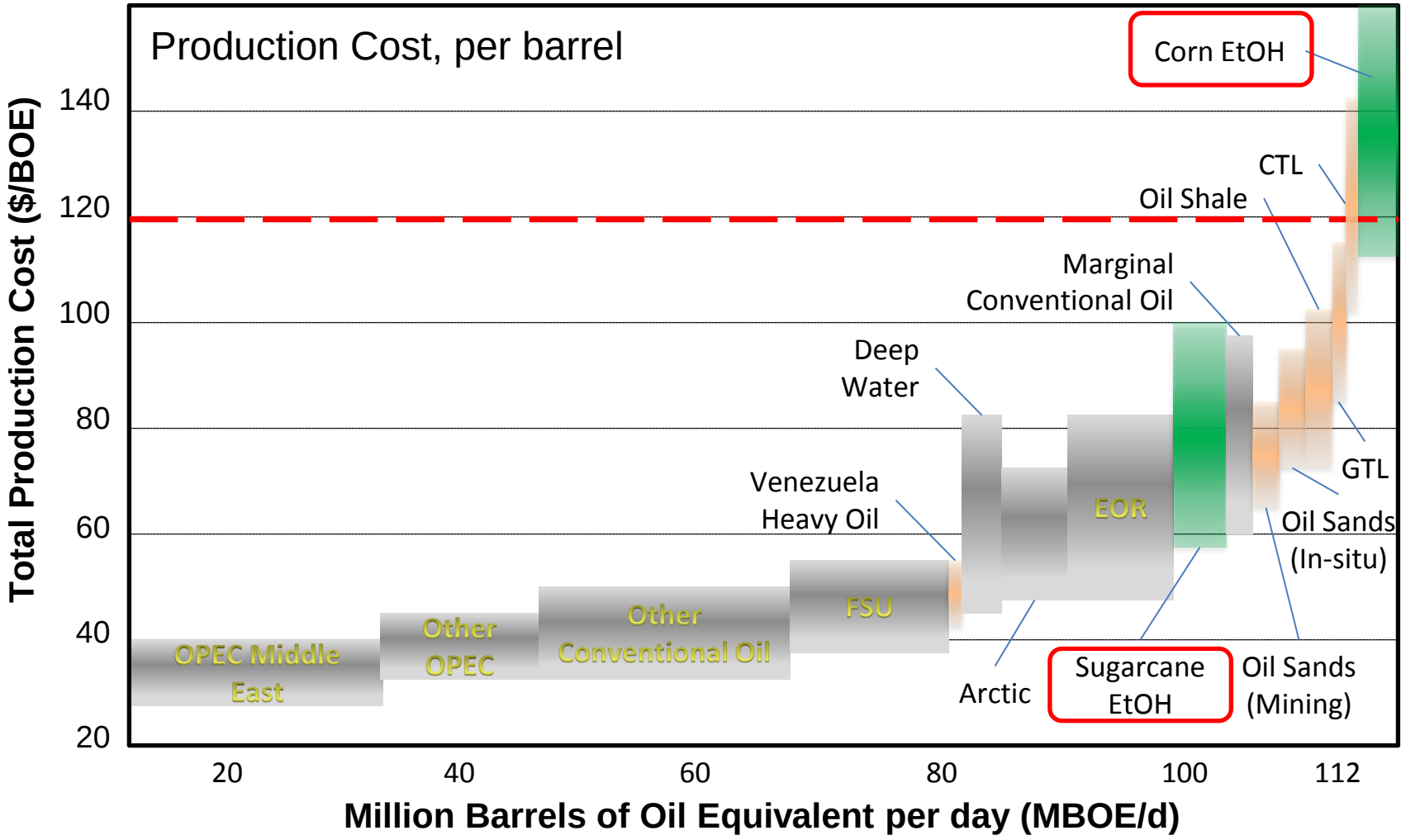
GENI



REACT

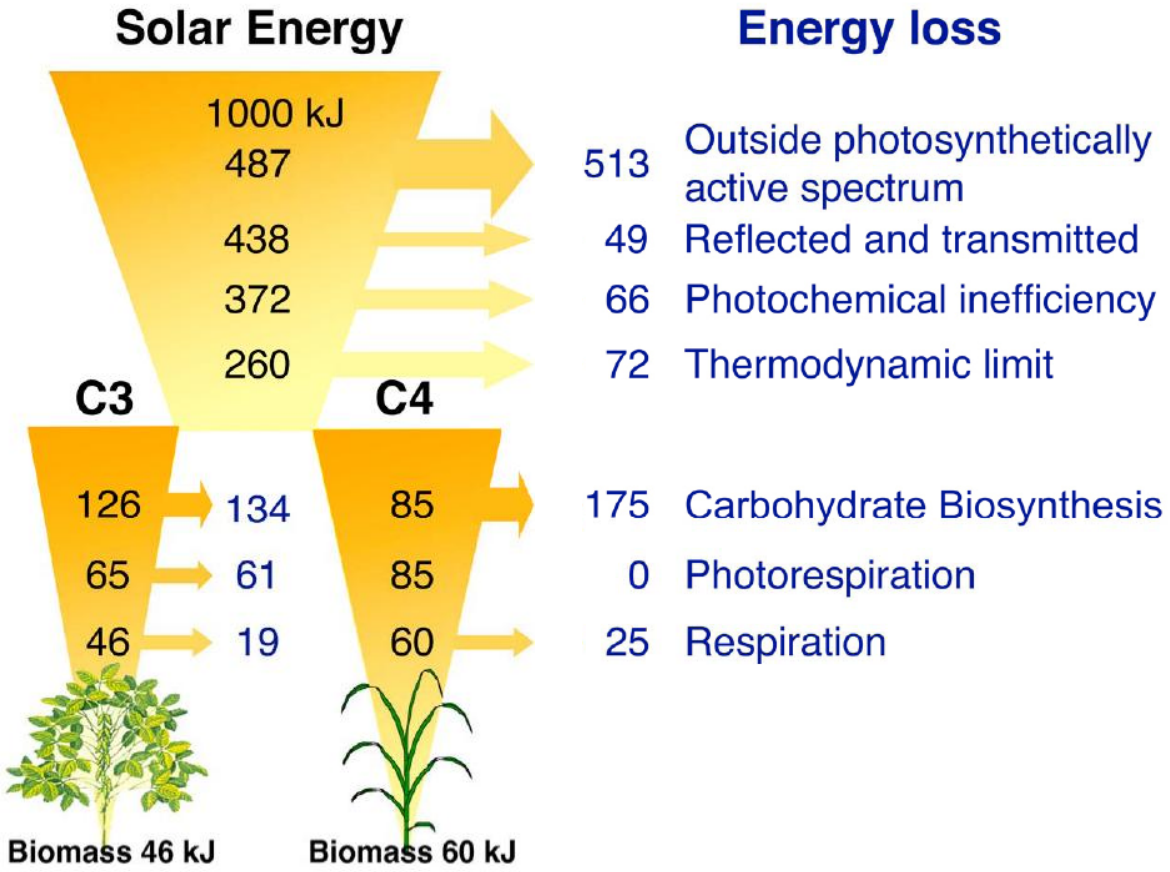


Biofuels: A tough nut to crack



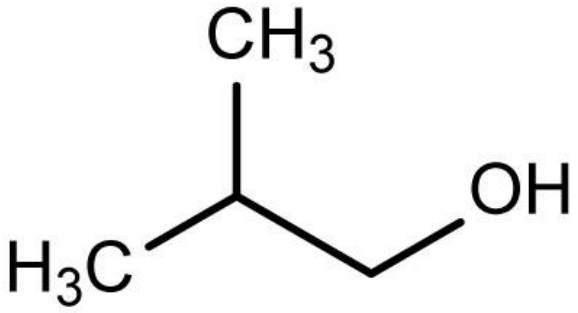
Source: Booz Allen Hamilton analysis based on information from IEA, DOE and interviews with super-majors

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



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

Scalable production of macroalgae as a feedstock for isobutanol

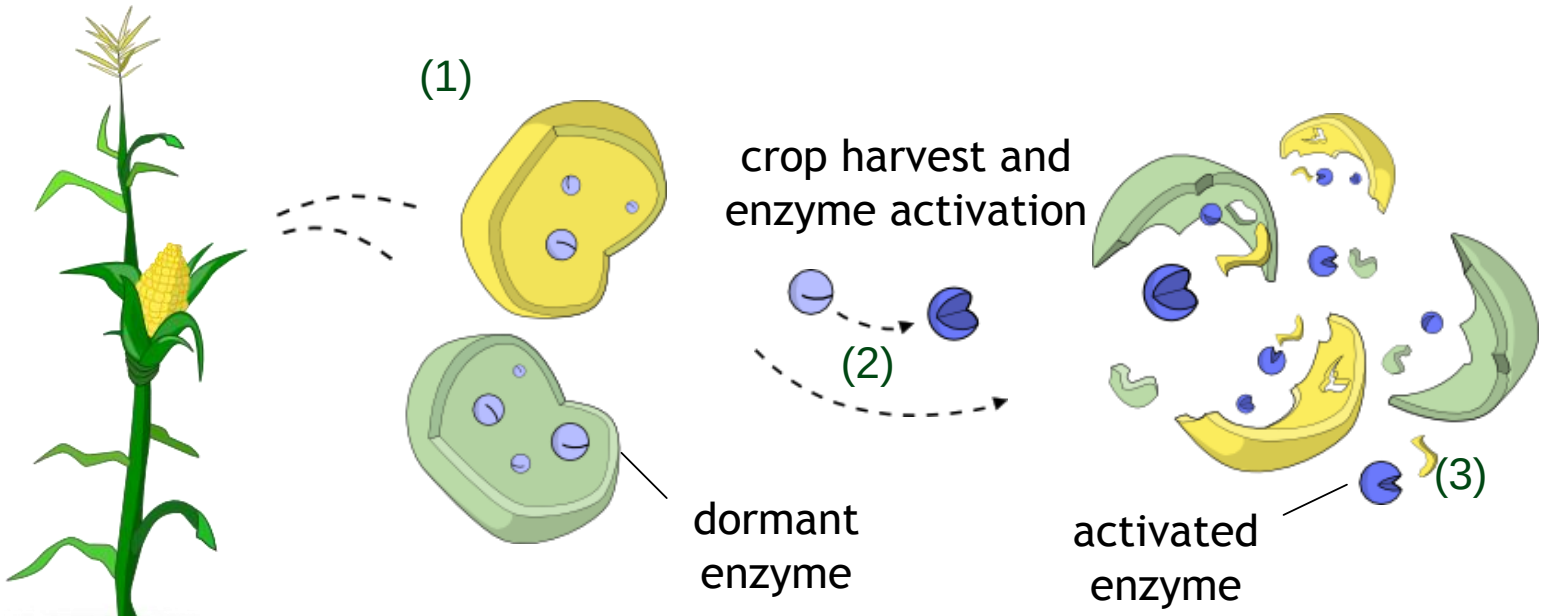


bio architecture lab

DUPONT

arpa·e

Diminishing biomass pre-treatment costs through plant biotechnology



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

arpa·e

Developing high biomass dedicated energy crops with increased nitrogen use efficiency

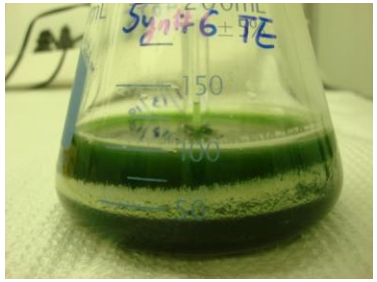
4 HIGH BIOMASS NUE TRAITS

DEDICATED ENERGY CROPS

FIELD TRIALS IN 4 STATES

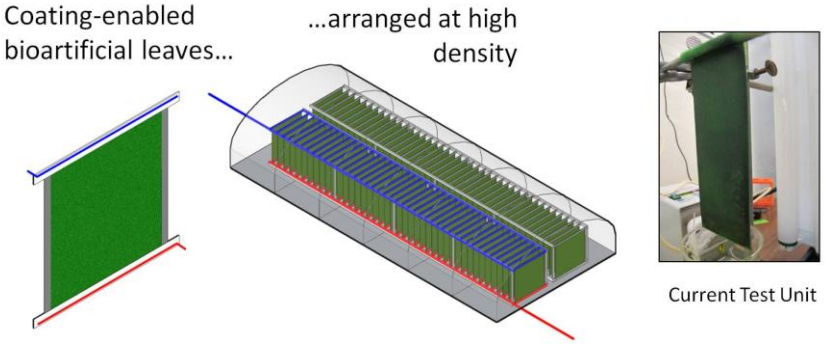
arpa·e

Economically-viable algae systems technologies suitable for deployment



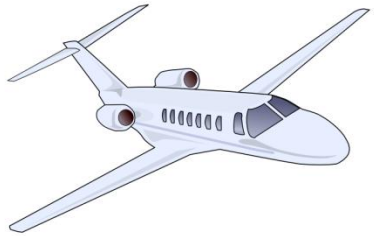
Biocatalyst development

ASU



Smart Flow Photobioreactor

BIOCEE



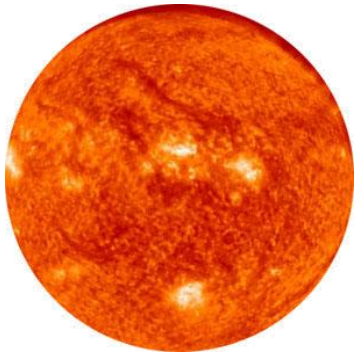
Upgrading to jet fuel

NC STATE UNIVERSITY

DIVERSIFIED ENERGY

arpa·e

ARPA-E seeks new biofuels programs to address current biofuel production inefficiencies



Photosynthesis

Electrons/
Reducing Equivalents

Biomass ⇦ Algae

EtOH,
Advanced
Biofuels

Pyrolysis
oils

Biodiesel,
Advanced
Biofuels

Chemical
Catalysis

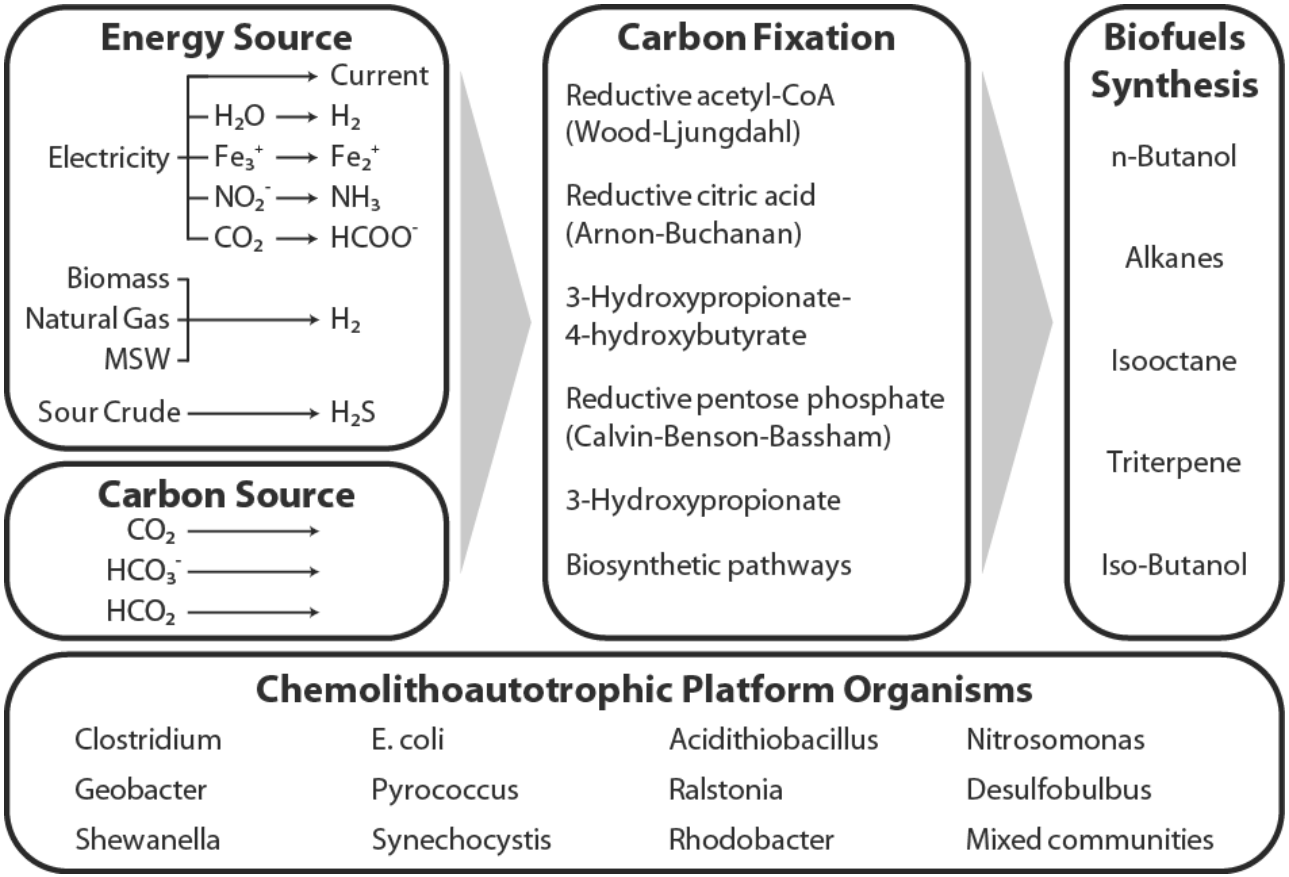
Syngas,
CH_3OH, CH_4,
Advanced Fuels?

Electrofuels

Biological
Catalysis

Advanced
Fuels

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.

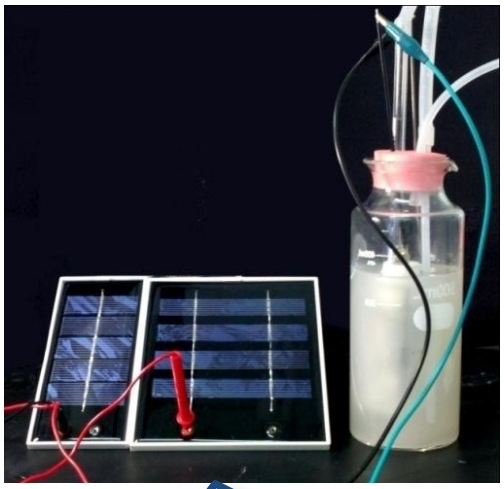
Autotrophic production → Free fatty acid extraction → Final fuel upgrading

arpa·e

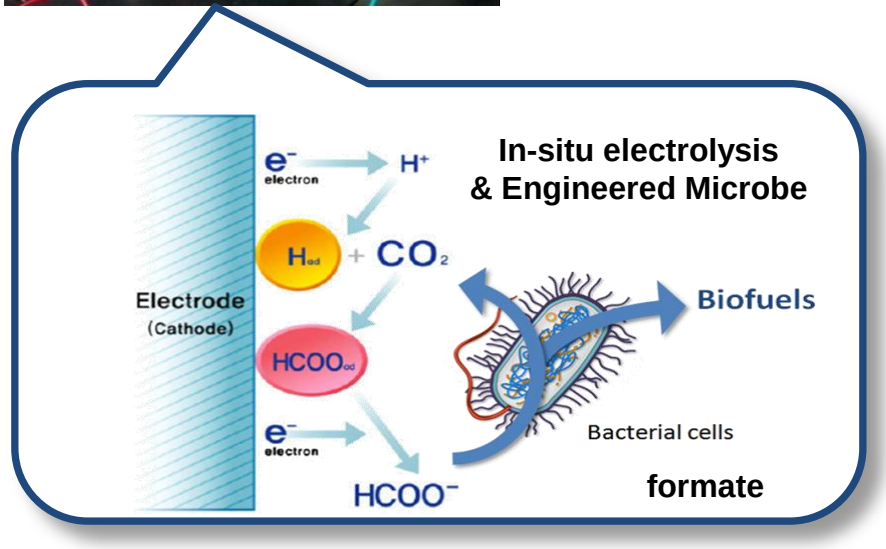
Electrochemically produced formate

Photovoltaic
or
Electricity

CO_2



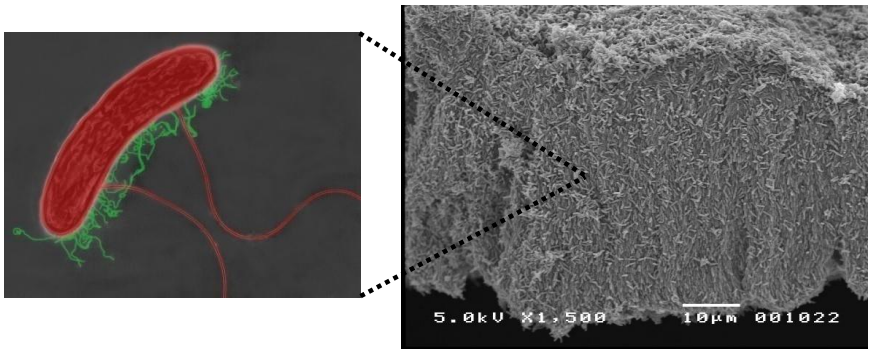
Gasoline substitutes



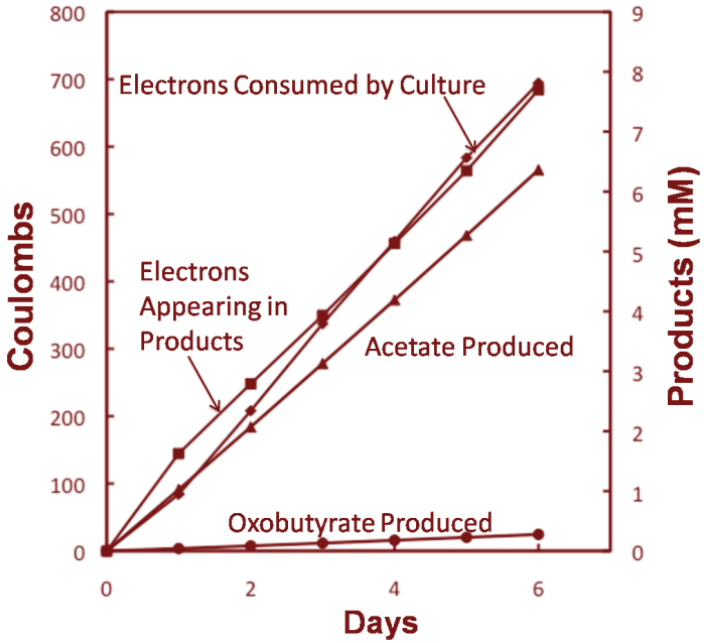
UCLA

arpa·e

Direct current/biocathodes



Geobacter metallireducens
can form conductive biofilms on the surface of electrodes

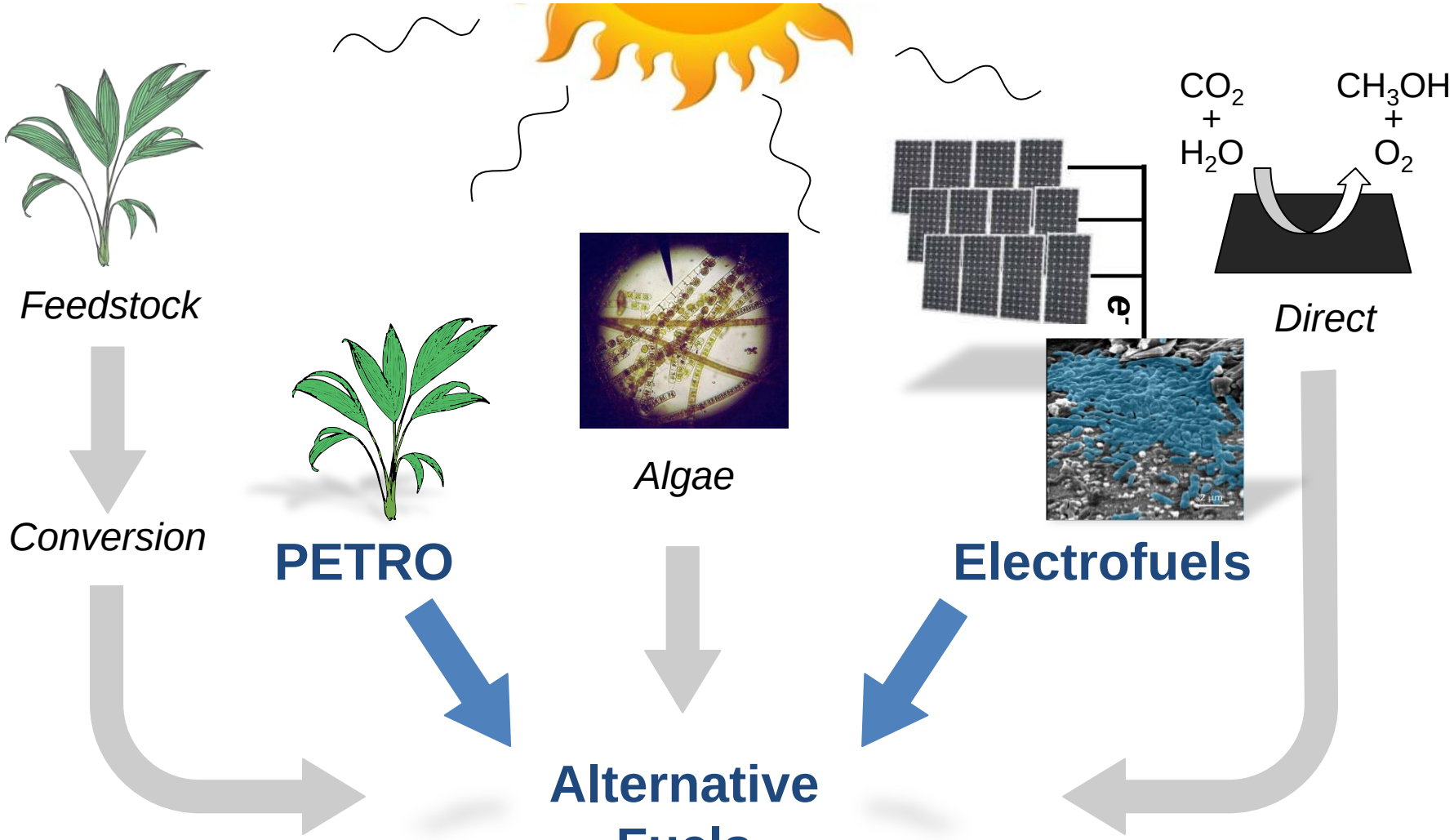


Acetogenes have demonstrated the ability to produce acetate directly from electrons with high coulombic efficiency

UMASS AMHERST

arpa·e

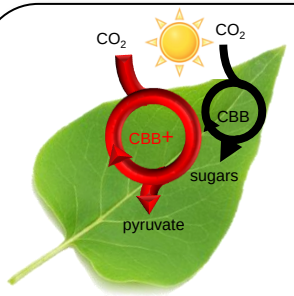
Programs focus on white spaces in biofuel production



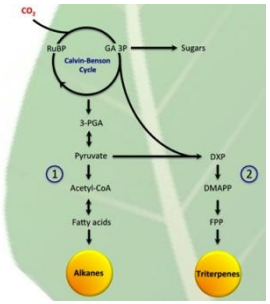
PETRO

Plants Engineered To Replace Oil

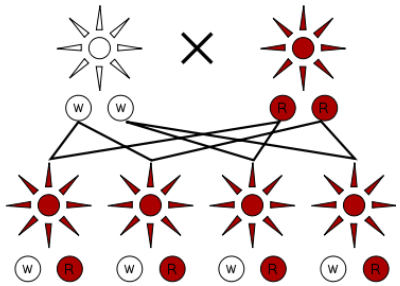
Developing Dedicated Biofuel Crops



Photosynthesis Optimization



Metabolic engineering



Heritable Traits

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

Cost: < $3 GGE

arpa·e

PETRO

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)

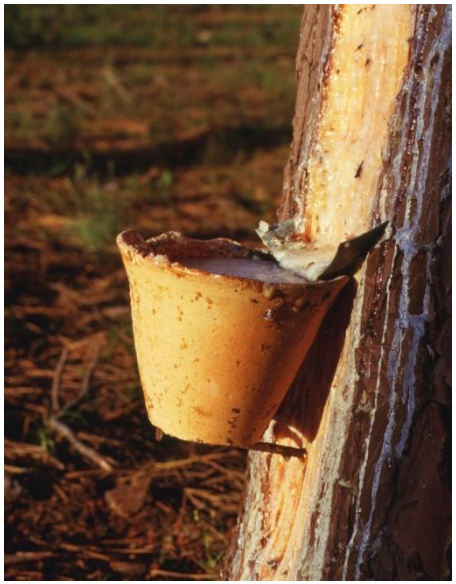
arpa·e

PETRO

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 NATIONAL RENEWABLE ENERGY LABORATORY

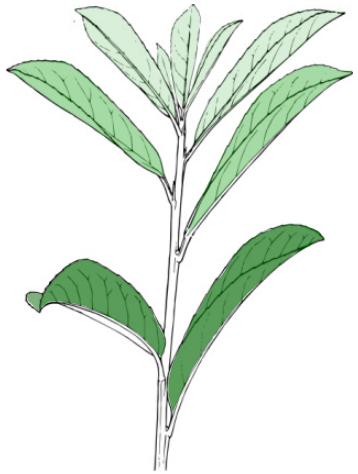
Berkeley University of California

arpa·e

PETRO

Higher yield *Camelina* with improved energy & CO_2 capture

CO_2



Higher light capturing efficiency

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

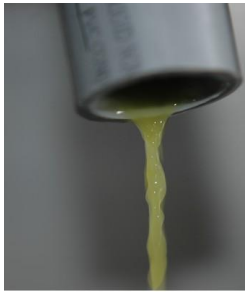
arpa·e

PETRO

Sorghum engineered to produce fuel

Sweet Sorghum

…engineered…



to make fuel,
instead of sugar

Chromatin, Inc.

THE OHIO STATE UNIVERSITY OARDC

K-STATE

Allylix

arpa·e

PETRO

Future FOAs

- How else can biology be used to transform the energy landscape?
- Just closed a round of "intent" for an open solicitation
- RFI open for scaling electro/chemolithoautotrophic biofuels