U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

Carbon Utilization Infrastructure, Markets, Research & Development
Bioenergy Technologies Office Perspective on the NASEM Study

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Creating Value from Waste Carbon Resources

Leveraging DOE stakeholder expertise in biomass polymer deconstruction and biological utilization of gaseous carbon to distributed sources of waste carbon to make molecular building blocks for fuels, products, and energy

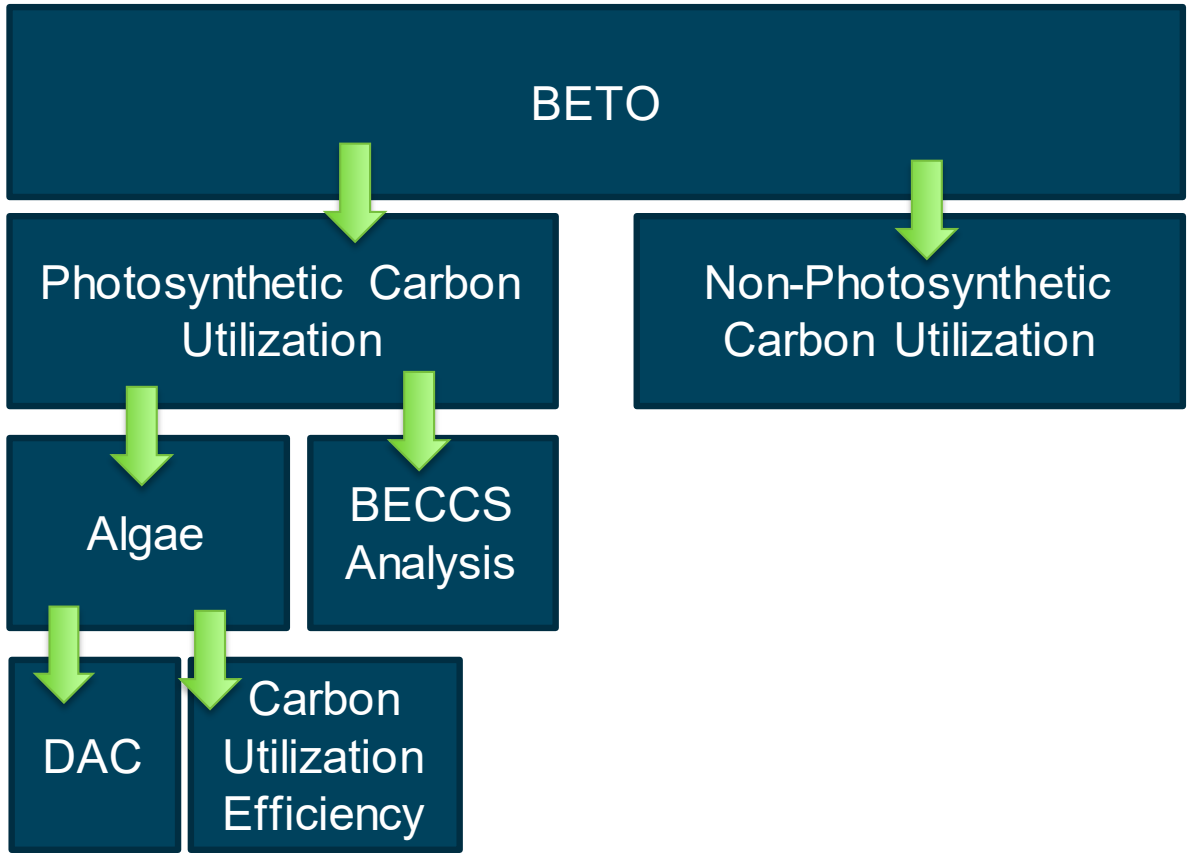
Wet Wastes:
Biosolids, Food Wastes, Manures

Economically Advantageous Feedstocks

Gaseous Wastes:
CO and CO_2

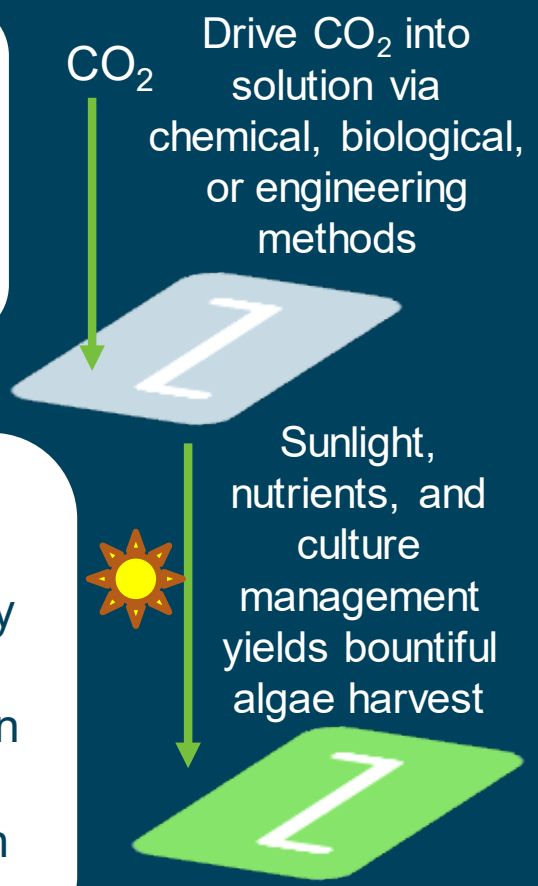
Solid Wastes:
Sorted Municipal Solid Waste including Plastics

BETO's carbon utilization efforts



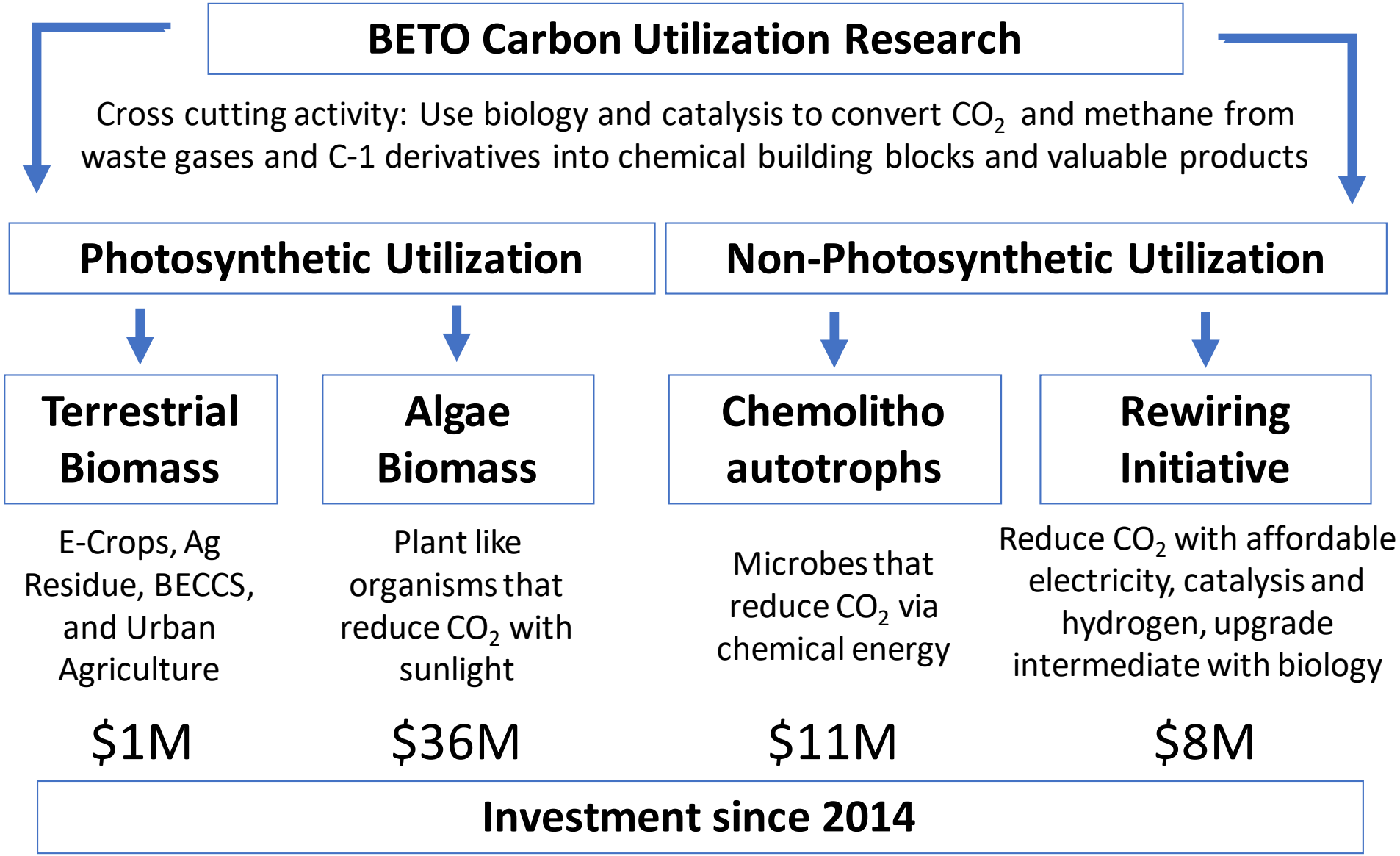
Innovative R&D keeps algae as a forefront technology for the bioeconomy and circular carbon economy.

BETO has a $30-40 million annual R&D program in Advanced Algal Systems.



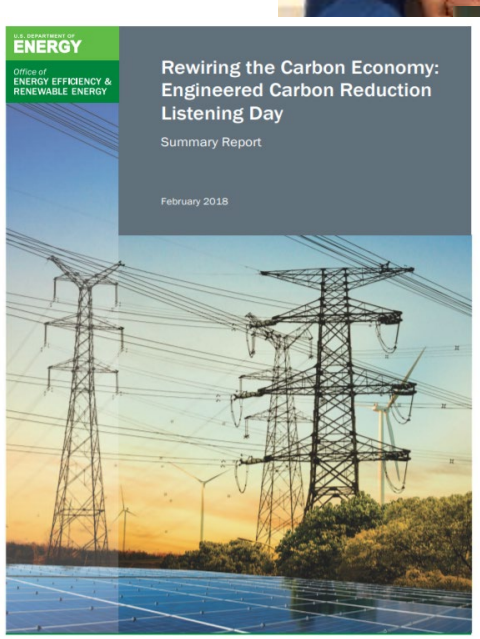
BETO has invested approximately $40 million in R&D directly targeted on photosynthetic carbon utilization of which $28M is on DAC with algae.

Recycling Gaseous Carbon



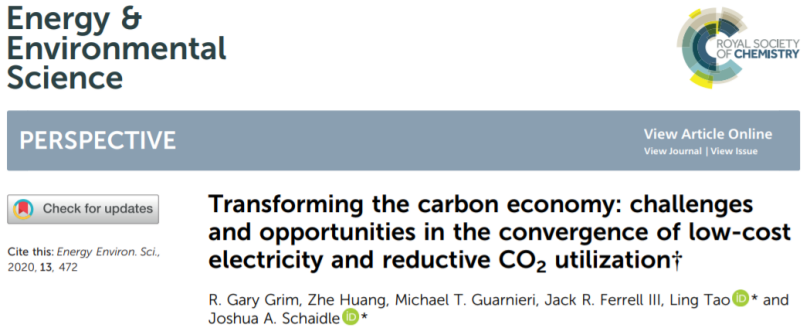
CO2 Utilization at BETO

- Interest in subject intensified in Early 2017
- Solicited for SBIR projects in CO_2U in Spring 2017
- Detail to the Office of Fossil Energy in March 2017 (Ian Rowe)
- Hosted the “Engineered Carbon Reduction Listening Day” in Summer 2017

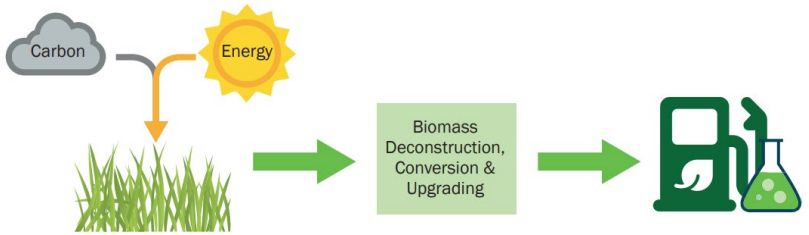


FY18 CO_2 Utilization at BETO

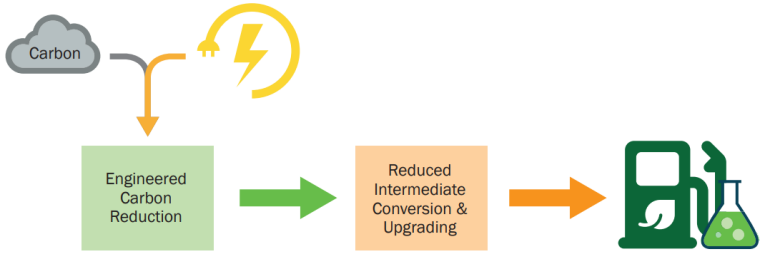
Started the "*Feasibility Study of Utilizing Electricity to Produce Intermediates from CO2*" AOP at NREL ($400k/yr). Also launched a biological CO2 fermentation AOP.



Launched another round of SBIR topics on CO_2 Utilization



FY18: Released the BEEPS FOA, which ended up awarding $4.5M to 3 "rewiring" projects which coupled carbon reduction to biological upgrading



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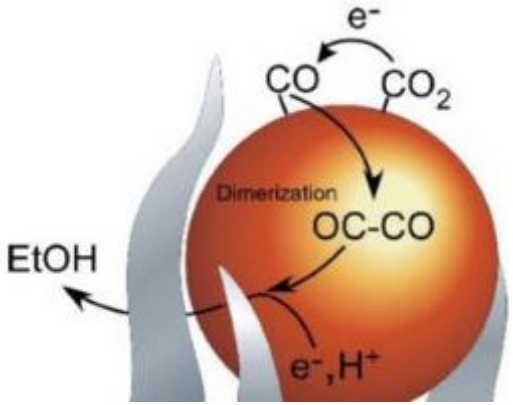
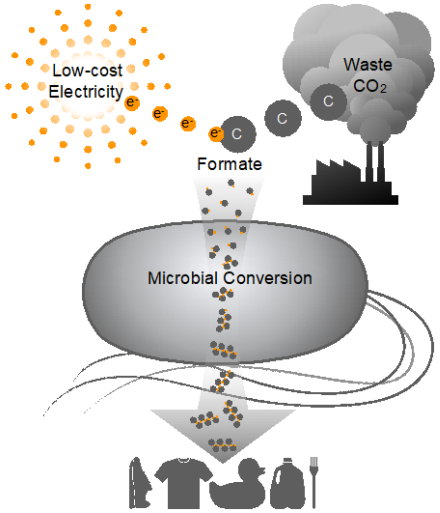
FY19 CO_2 Utilization at BETO

Biopower lab call funded CO_2 utilization efforts in biomethanation at NREL and LLNL as well as flue gas conversion to fuel (NREL/Dioxide Materials/Lanzatech)



Funded new ChemCatBio efforts on CO_2 electrocatalysis at ORNL and NREL



Lab call on C1 intermediate upgrading and awarded 3 projects for formate upgrading

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FY20 CO_2 Utilization at BETO

Topic Area 7: Scalable CO2 Electrocatalysis

Sought efforts in electrocatalytically converting CO_2 to C1 or C2 intermediates and pushed the boundaries of what is possible in terms of scale, Faradaic efficiency, and current density. $8M total, 3 projects

Collaborated with FCTO to fund NREL ESIF to work on directly integrating H2 generation into a biomethanation reactor for increased energy efficiency and reduced capital intensity ($600k BETO, $100k FCTO)

USDRIVE
DRIVING RESEARCH AND INNOVATION FOR VEHICLE EFFICIENCY AND ENERGY SUSTAINABILITY

Set up the Net-Zero Tech Team analyses ($400k)

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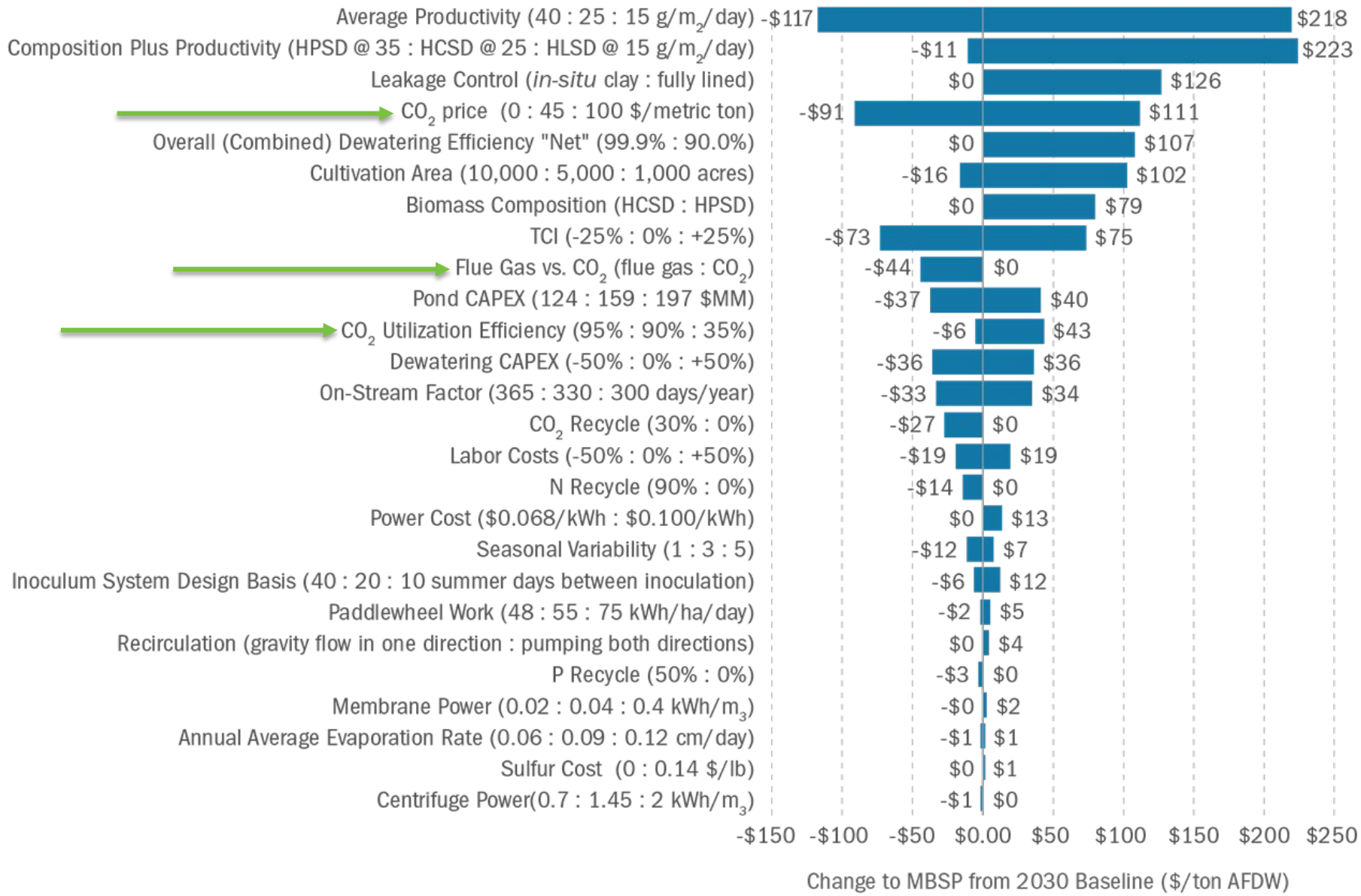
Algae – Perfect Biological, Photosynthetic Capture and Utilization Mechanism!!

- Initial CO_2-focused projects awarded from Targeted Algal Biofuels and Bioproducts FOA in 2015 (one on CO_2 from flue gas, one on direct air capture)
- Algae Cultivation for Carbon Capture and Utilization Workshop, May 23, 2017 (in coordination with Office of Fossil Energy and Stanton Energy Center)
- Efficient Carbon Utilization in Algal Systems FOA, 2018 (two topic areas – CO_2 utilization within cultivation systems and direct air capture)
- Coordination/Information Sharing with the Office of Fossil Energy (most recently coordinated language, metrics, topic areas for both FE's and BETO's FY20 FOAs, including participation on each other's FCBs; sharing project info for synergies and to avoid duplicative efforts)
- FY20 BETO Multi-topic FOA – Topic Area 3, Algal Bioproducts and CO_2 Direct Air Capture Efficiency (all projects include direct air capture technologies and CO_2 utilization metrics/goals)
- FY21 Feedstocks Technologies and Algae FOA – Topic Area 2, Algae Productivity Exceeding Expectations (APEX) (two subtopics, one on increasing productivity utilizing traditional carbon supplies and one on increasing productivity utilizing direct air capture)

CO_2 Capture and Utilization – Impact on Algae Costs



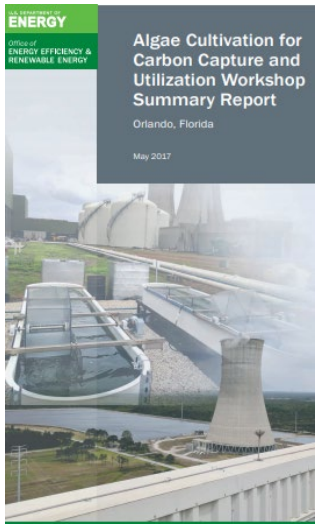
Algae – Early DAC and Flue Gas Capture Adopter

BETO has **partnered with the Office of Fossil Energy and Carbon Management (FECM) on carbon utilization** algae efforts to investigate both flue gas capture and direct air capture (DAC) to reduce delivered CO_2 costs and provide added value.

2015

Selection of FOA awards that include carbon utilization from a point source and direct air capture

2017

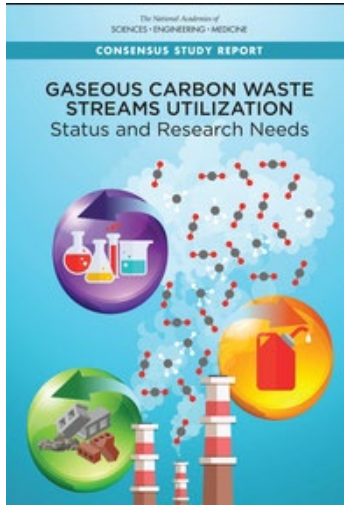


2018

ECUAS Topic language developed with input from FE

45Q includes algae as a CCU technology

2017-2019



2020

ABCDE
Scoping on FOA discussed with FE
FE reviewer
FE Federal Consensus Board

The IRS released a new set of regulations for the Section 45Q tax code that can award a federal investment tax credit of up to $35 per ton for carbon utilization with algae.

2021

Selection of APEX FOA awards that include increased productivity and carbon utilization from a point source or direct air capture

Enabling technology for algae utilization of CO_2 from DAC

2018 BETO FOA

Technology development approaches for enabling DAC used by FOA awardees

CO_2 concentration in air is about 405ppm. Oxygen in air is **about 500 times** higher than CO_2

CO_2 Drive CO_2 into solution via chemical, biological, or engineering methods

Sunlight, nutrients, and culture management yields bountiful algae harvest

Engineering

Direct Air Capture of CO2 and Delivery to Photobioreactors for Algal Biofuel Production, $2M

Team: Georgia Tech, Global Thermostat, Algenol Biotech, NREL

Use DAC machine with amine-based sorbents to capture CO_2 and deliver to algae cultivation systems

This project will reduce algal biofuel costs and carbon intensity by using 20% or more of CO_2 from DAC and lower the cost CO_2 collection from air by developing DAC technology that utilizes improved sorbents and less intense operating conditions.

Chemically

Air Carbon for Algae Production – AirCAP, $2.2M

Team: MicroBio Engineering Inc , PNNL, Qualitas Health, Global Thermostat

Use pH of the algae cultivation system to convert CO_2 into a more soluble species

Direct mass-transfer of air-CO_2 into algal ponds is limited by diffusion of CO_2 at the air-water interface and the subsequent slow hydration of dissolved CO_2 into carbonic acid. This project will focus on accelerating transfer from air CO_2 into ponds at high pH, as well as biological and physical methods.

Biologically

Enhanced Algal Production of CA for Improved Atmospheric Delivery of CO_2 to Ponds, $2M

Team: J. Craig Venter Institute, Global Algae Innovations, Cal Poly San Luis Obispo

Use a biologically produced enzyme to catalyze CO_2 into a more soluble species

This project will utilize carbonic anhydrase (CA) to catalyze hydration of dissolved CO_2 to bicarbonate, thereby enhancing delivery of atmospheric CO_2 to the growth medium. Commercial CA use is cost-prohibitive at scale, therefore algal-derived extracellular CA production will be evaluated through the generation of transgenic lines.

FY20 Algae Awards

TOPIC 3: Algae Bioproducts and CO_2 Direct Air Capture and Efficiency

The objective of Topic 3 was to lower the MFSP of algal biofuels through increased algae product value and/or yields. Utilization of direct air capture for the CO_2 source was a requirement.

Awardee	Title	Summary	Funding
Global Algae Innovations	Production of Algal Biofuel and Bioproducts with CO_2 Direct Air Capture	Cultivate algae solely on CO_2 from direct air capture	$2,000,000
Montana State University	Transforming High pH/High Alkalinity Cultivation Through Beneficial Microbiomes and Improved Pond Design	Cultivate algae in high pH/high alkalinity environment with enhanced direct air capture to produce fuels and high value products	$2,000,000
Arizona State University	ASU's Polymer-enhanced Cyanobacterial Bioproductivity (AUDACity)	Utilize ASU's novel DAC technology that integrates newly developed CO_2 capture polymers to continuously and rapidly deliver inorganic carbon directly into the algae cultivation medium	$1,999,051
University of California, San Diego	Biomolecular Films for Direct Air Capture of CO_2	Establish carbon sequestering molecular films for enhanced atmospheric CO_2 capture and increased productivity in open pond algae systems	$2,000,000

FY20 Algae Awards

Awardee	Title	Summary	Funding
Lumen Bioscience Incorporated	Alkaline Carbon Capture and Expression – Streamlined Spirulina Cultivated in Air for Reliable Bioproducts, Oil, and Nutrition	Lessen Spirulina cultivation dependence on concentrated CO_2, increase its energy dense components, and develop strains with expression of heterologous protein byproducts	$2,000,000
MicroBio Engineering, Incorporated	Microalgae Commodities Production with a Direct Air Capture Process	Utilization of CO_2 from air to cultivate microalgae and produce biomass for higher value nutritional products in the near term and commodities in the longer term; 2 approaches – use of Global Thermostat's direct air capture technology and use of the cultures and systems themselves to provide CO_2 absorption from the air	$1,999,882
Duke University	Development of High Value Bioproducts and Enhancement of Direct-Air-Capture Efficiency with a Marine Algae Biofuel Production System	Increase the market value of post-fuel algae biomass residues by assessing alternative high-value products and demonstrating direct air capture as the source of CO_2	$1,967,473

Thank you, questions?

Useful reports

Federal Activities Report on the Bioeconomy: Algae

2019 BIOENERGY TECHNOLOGIES OFFICE 2019 R&D State of Technology

2017 Algae Harmonization Study: Evaluating the Potential for Future Algal Biofuel Costs, Sustainability, and Resource Assessment from Harmonized Modeling

2016 National Algae Technology Review

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