May 2017

Carbon Use and Reuse Program Overview Briefing

Presenter: Lynn Brickett, Technology Manager

May 23, 2017

NATIONAL ENERGY TECHNOLOGY LABORATORY

U.S. DEPARTMENT OF ENERGY

FE-NETL Carbon Use/Reuse History

- 2000-2010 DOE Office of Fossil Energy CCS R&D Program focused primarily on CO2 capture from coal-fired power plants and geological storage of CO_2 in deep saline aquifers and storage as part of EOR

- However, the Storage R&D Program includes a small effort related to CO2 use/reuse

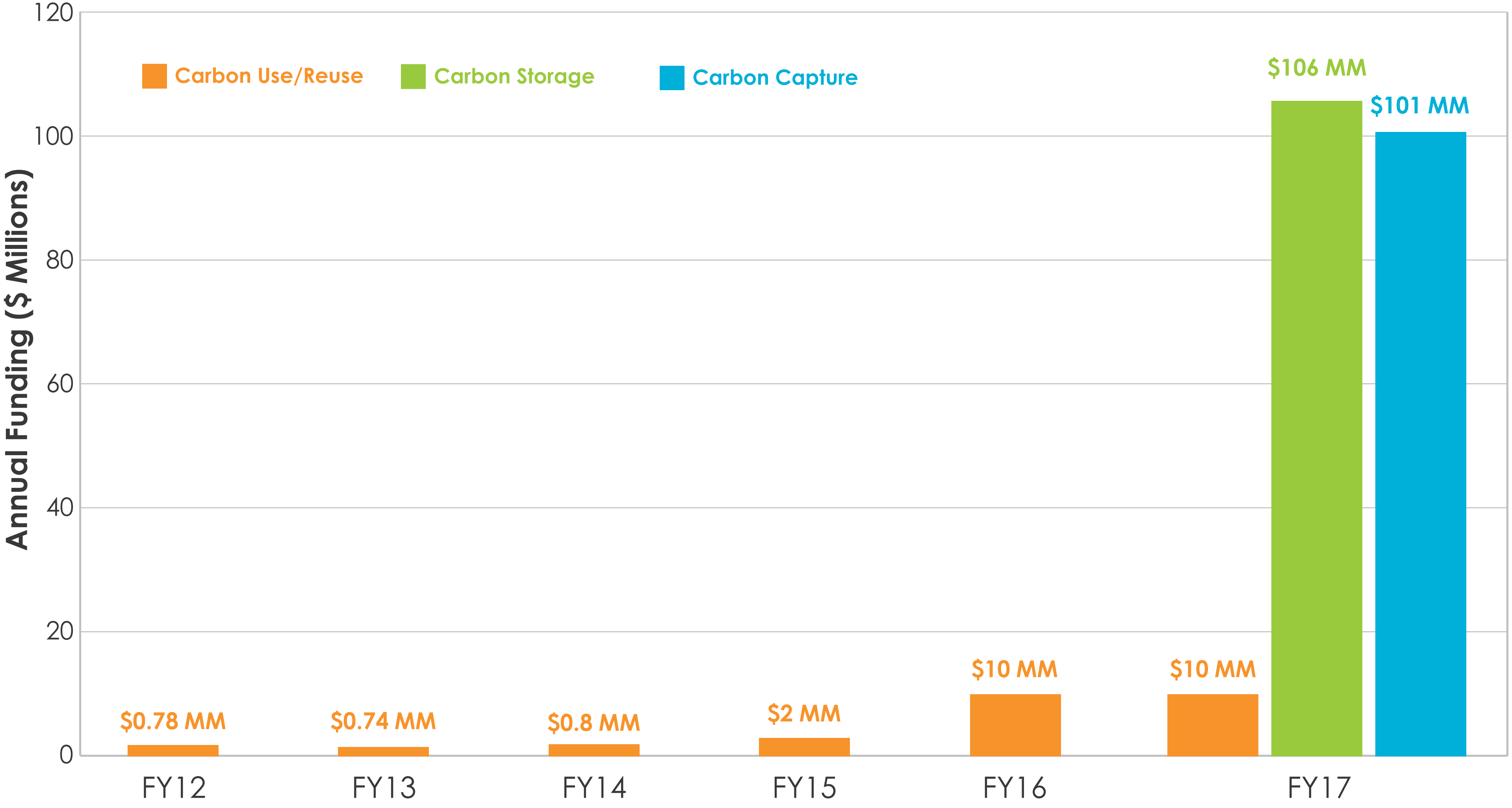
- 2010 ARRA Funding for Utilization:
  Algae Biomass: 5 Phase 1→2 Phase 2 – total award $36 million
  Thermal Catalytic: 2 Phase 1 – total award $23 million – 1 Phase 2- total award $23 M
  Mineralization: 4 Phase 1 → 3 Phase 2 – total award $63 million

- 2014 & 2016 Funding Opportunity Announcement

NETL Carbon Use and Reuse Budget

NATIONAL ENERGY TECHNOLOGY LABORATORY

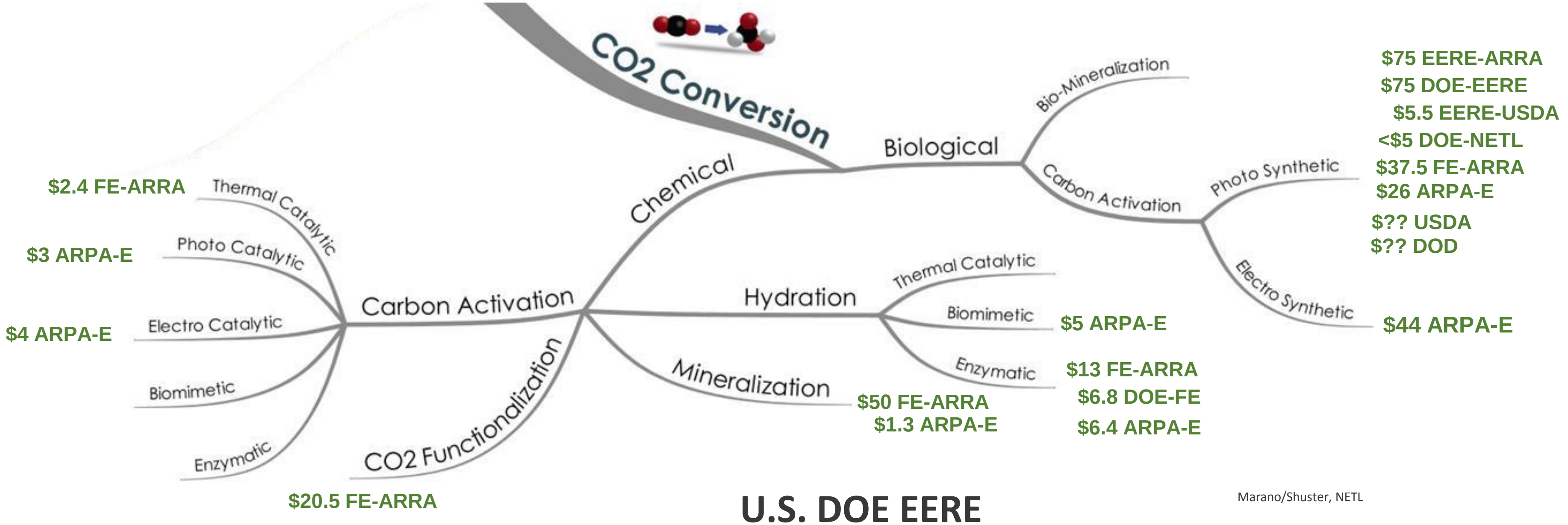
Funded by the NETL Carbon Storage Program, Carbon Use and Reuse is a new but expanding program.



CO_2 Conversion Federal R&D Space

Programmatic Funding Activity

Million $

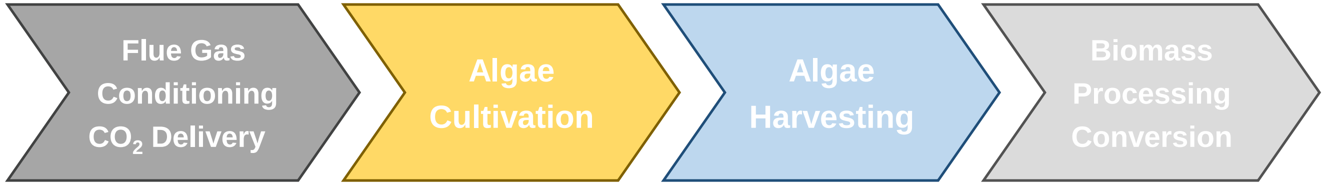


A role for DOE-FE

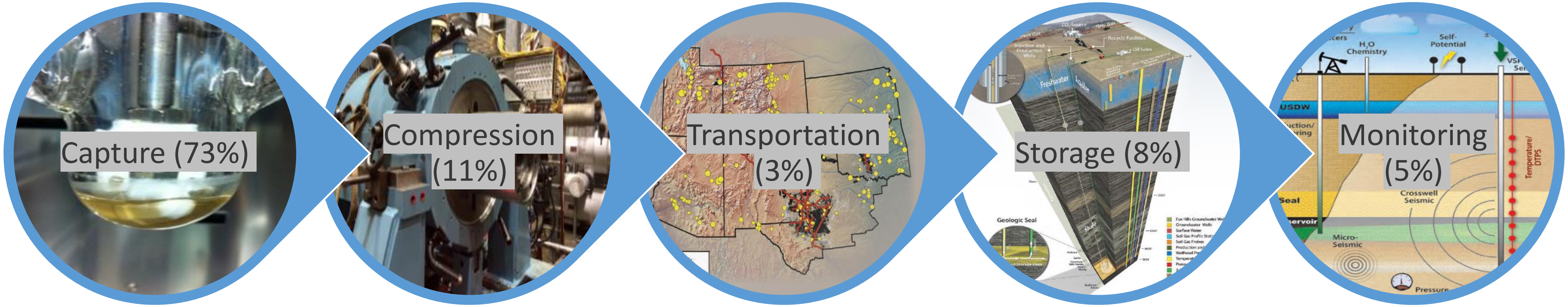
USDA
Aquaculture
Demo Loan Guarantees

U.S. DOE EERE
Production of Algae-based feedstocks for liquid fuels

U.S. DOD
Fuels Development & Testing



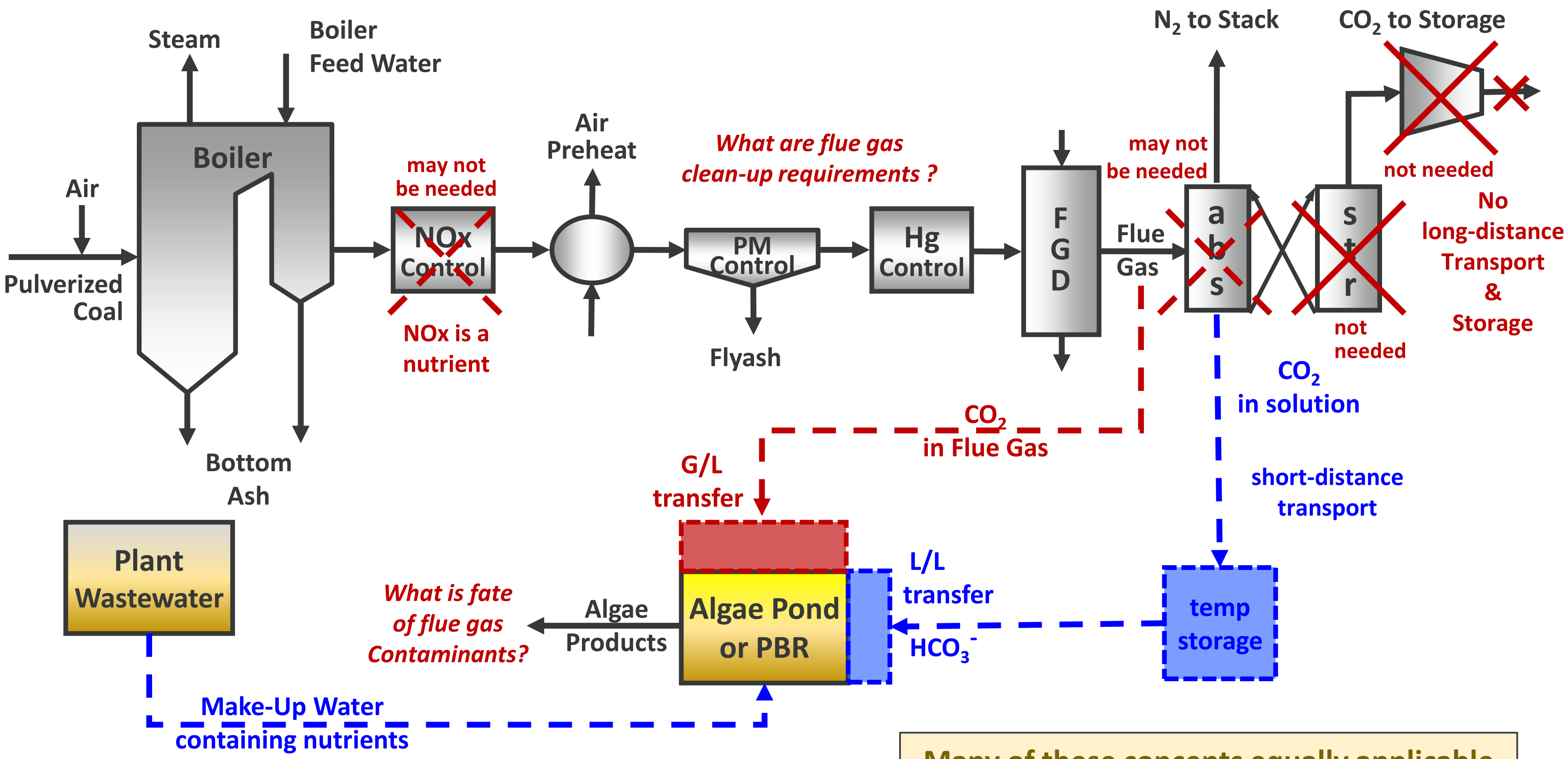
CCS Value Chain



Source: NETL, Cost and Performance Baseline for Fossil Energy Plants, Revision 3, July 2015

Flue Gas Conditioning & CO_2 Delivery

1100 units
273 GW



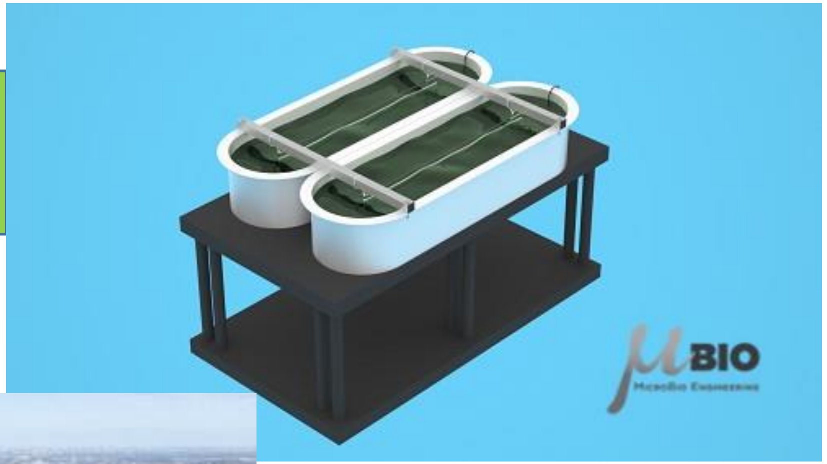
Many of these concepts equally applicable
To chemical conversion systems

Power Plant Integrated Reuse Projects

NATIONAL ENERGY TECHNOLOGY LABORATORY

U of Kentucky – Duke Energy's East Bend Station

MicroBio Engineering



Orlando Utilities Stanton Station

CO_2 to Bioplastics: Beneficial Re-use of Carbon Emissions using Microalgae

University of Kentucky

Approach – Developing dual photobioreactor/pond cultivation system to harvest algal biomass using CO_2 from coal-fired flue gas with mechanism to convert biomass into feedstocks for production of bioplastics, chemicals and fuels, field testing to evaluate algae productivity and culture health

Advantages

- Minimal growth lag time
- High yield of biomass per unit area
- Low risk of culture contamination

Challenges

- Retaining high CO_2 capture efficiency
- Impact of flue gas contaminants on culture health
- Developing feedstock suitable for production of bioplastics and fuels

Benefits

- Minimal growth lag time and high algae productivity reduces cost of algae cultivation and CO_2 capture

Pilot-scale "Cyclic Flow" Photobioreactor
Duke Energy, East Bend Station, KY

NATIONAL ENERGY TECHNOLOGY LABORATORY

Research Highlights

- Goal is to test the influence of NOx and SOx on culture growth
- *Scenedesmusacutus* was grown at lab scale using:-air (ca. 400 ppm CO_2)-9% CO_2/N_2-simulated flue gas consisting of 9% CO_2/N_2 with 50 ppm NO and 25 ppm SO_2 added
- Cultures first acclimated to conditions for 3 weeks
- Despite difficulties with gas flow rates for some of the replicates, the flue gas treatment gave the highest productivity, specific growth rate, and final biomass density at day 6.

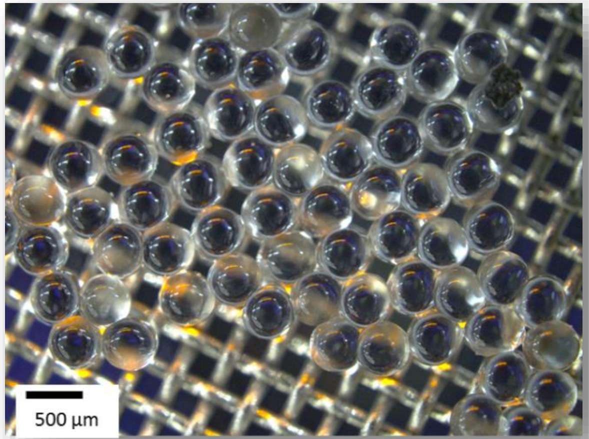
Average and standard deviation productivity and specific growth rate during log phase growth, as well as the final biomass density for each treatment

Effect of flue gas constituents on biomass composition

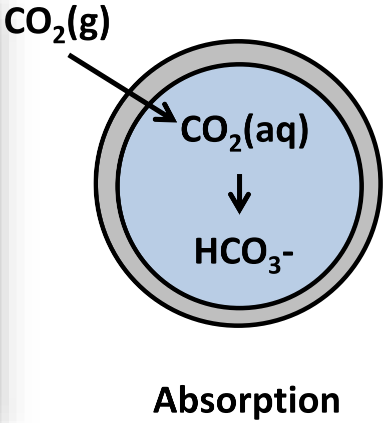
	Productivity	Specific growth rate	Final biomass density
Air	0.003 ±0.01 g $L^{-1}d^{-1}$	0.05 ±0.04	0.21 ±0.01 g L^{-1}
CO_2	0.14 ±0.02 g $L^{-1}d^{-1}$	0.32 ±0.04	1.00 ±0.10 g L^{-1}
Flue Gas	0.17 ±0.02 g $L^{-1}d^{-1}$	0.36 ±0.04	1.15 ±0.12 g L^{-1}

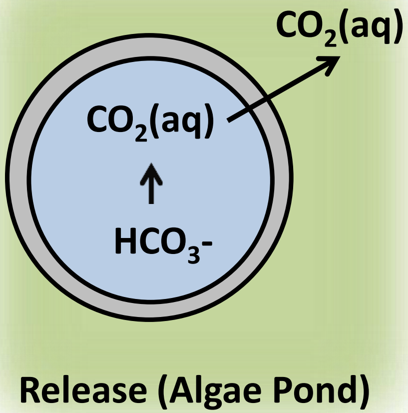
Microencapsulated Carbonate Solutions (MECCS)

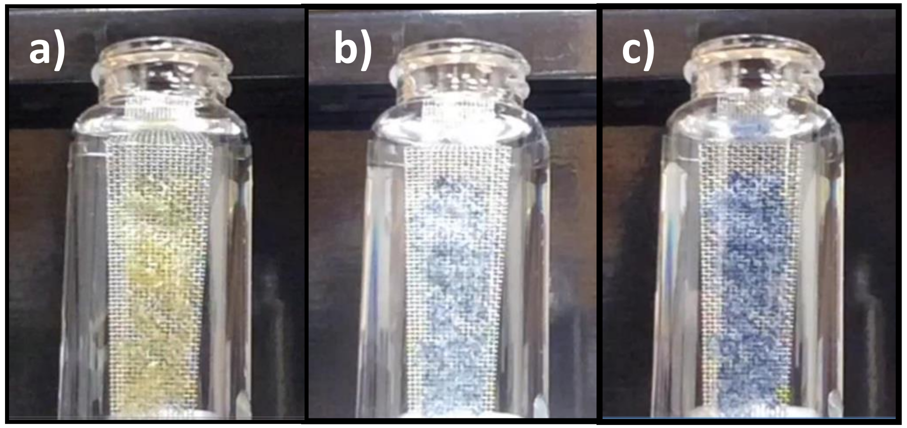
NATIONAL ENERGY TECHNOLOGY LABORATORY



Encapsulated carbonate liquids







Loaded capsules — *5 minutes* → Exchangeable CO_2 delivered

- Loaded capsules: 20 wt% exchangeable $CO_{2;}$ non-toxic biocompatible materials
- Capture and utilization can be geographically separated-no pipelines
- Only dissolved CO_2 permeates the shell (no alkalinity problem)
- CO_2 delivery can be tuned to daily/seasonal demand to optimize growth and minimize loss to atmosphere

Efficient Capture of CO_2 using Algae and Conversion to Value Added Products

NATIONAL ENERGY TECHNOLOGY LABORATORY

Heilos-NRG, LLC

Approach – Developing novel algae-based technology to efficiently capture and use CO_2 captured from coal-fired power plant flue gas to produce biofuels, utilizing a closed photobioreactor (PBR) system for high growth rate microalgae to metabolize the CO_2

Advantages

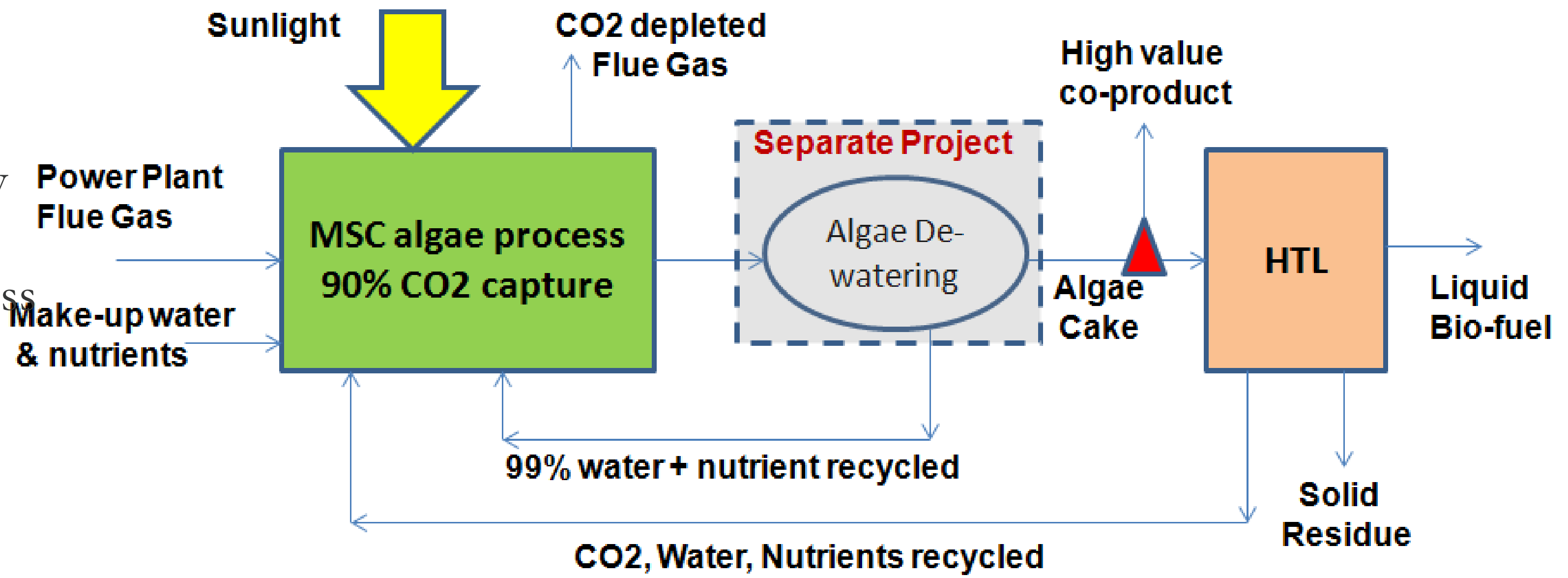
- Enables stable capture efficiency
- High productivity – high growth rate, low down time
- Suitable for upstream/downstream process integration

Challenges

- SO_X and NO_X impact
- Dewatering capital and energy intensive

Benefits

- Minimizes dewatering energy requirements and reduces capital cost



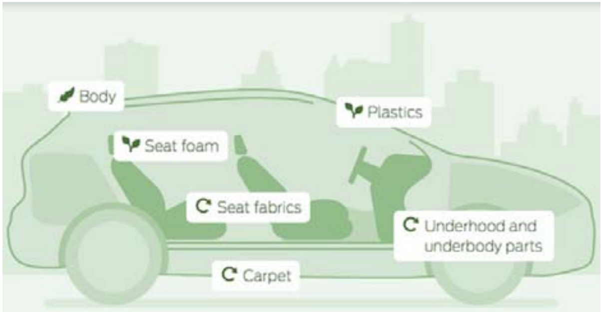
Process Flow with Multi-stage continuous flow (MSC) PBR for CO_2 Capture

Reuse Success Story - Novomer

- **$18.4 M DOE investment – 2009 -2010**
- **Convert CO_2 to develop foam and plastics**

- **FORD – sustainability goals (soy foam and coconut fiber)**
  - Seating & underhood applications
  - Up to 50% CONVERGE CO_2 - based polyols
  - Reduce petroleum use by more than 600 million lbs/yr
  - 2018 -2020

- **The End of the Story…**
  - Saudi Aramco acquires CONVERGE $100M



It’s All About a Clean, Affordable Energy Future

For More Information, Contact NETL

the ENERGY lab

U.S. DEPARTMENT OF ENERGY | National Energy Technology Laboratory