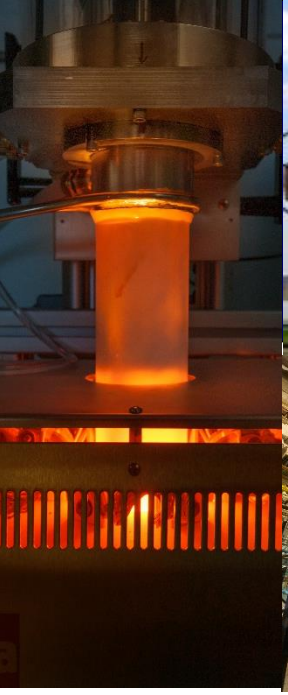
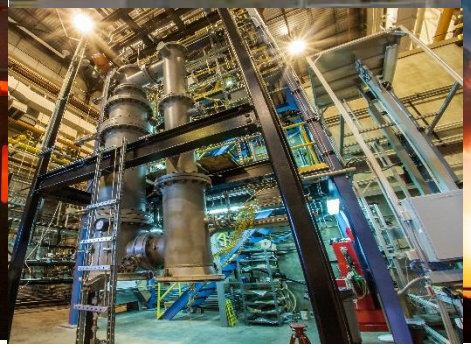





U.S. DEPARTMENT OF ENERGY | Office of Fossil Energy

Office of Clean Coal and Carbon Management

Charter for the Group and Overview of DOE Program Efforts

John Litynski
Deputy Director
Advanced Fossil Technology Systems

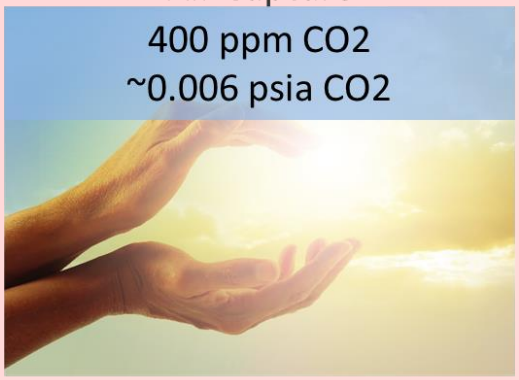
July 24, 2019

CARBON CAPTURE – WHERE CAN WE GET CO_2

Coal Power Plant

Gas Power Plant

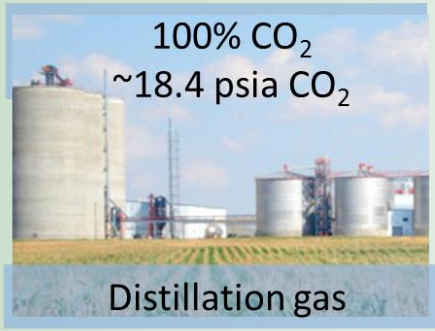
Air Capture



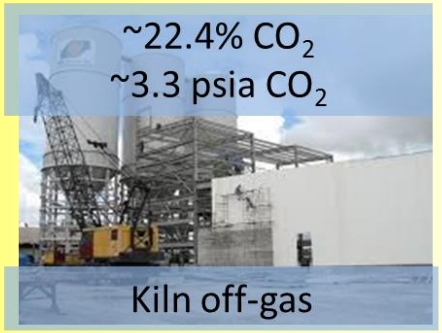
NG Processing Plant

Ammonia Plant

Ethanol Plant



Cement Plant



DIRECT AIR CAPTURE – NAS STUDY

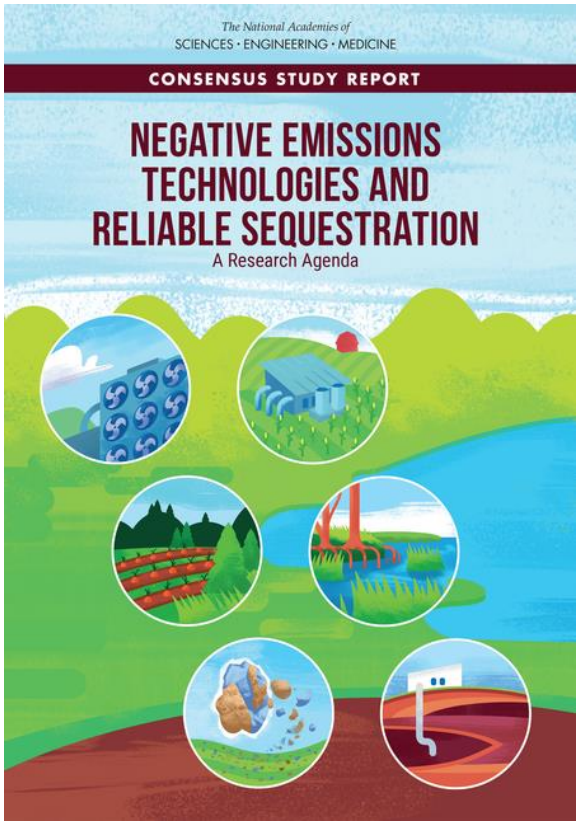
FY16 Congressional Direction – FE $250K – NAS Study

Advantages

- Flexibility of placement/location
- Captures CO_2 from all sources
- Current and legacy emissions

Challenges

- Dilute CO_2 streams costly to separate
- Process optimization / reducing pressure drop
- Water use
- Landuse
- Carbon Lifecycle



Companies Working on Direct Air Capture[1]

Company	System Type	Technology
**Carbon Engineering	Solvent	Potassium hydroxide solution/calcium carbonation
Climeworks	Sorbent	Amine-functionalized filter
Global Thermostat	Sorbent	Amine-modified monolith
Infinitree	Sorbent	Ion-exchange sorbent
Skytree	Sorbent	Porous plastic beads functionalized with benzylamines

[1]Negative Emissions Technologies and Reliable Sequestration: A Research Agenda (2019)

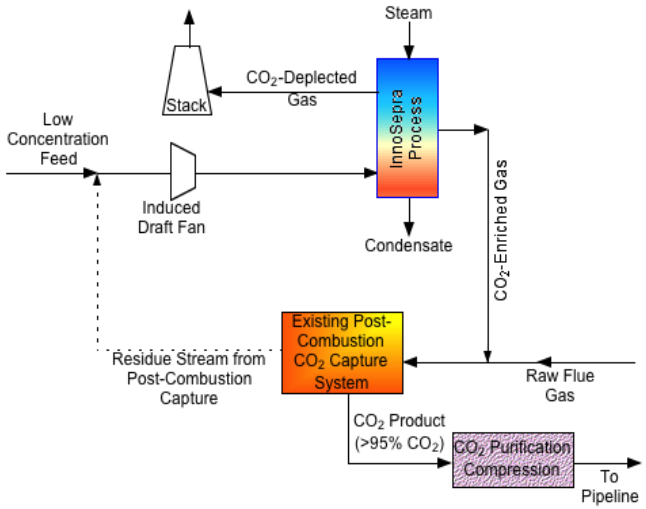
DAC/DILUTE SOURCE CAPTURE: FE/NETL PROJECTS

$200+/tonne

InnoSepra LLC

Physical Sorbent

(1-1.5% CO_2 Concentration)



Fixed-bed laboratory unit for testing structured sorbents

https://www.netl.doe.gov/research/coal/project-information/proj?k=SC0015114

$300+/tonne

The Ohio State University

Membranes

(<1% CO_2 concentration)

Continuous membrane fabrication machine at OSU

https://www.netl.doe.gov/research/coal/project-information/proj?k=FE0026919

$200+/tonne**

Carbon Engineering

Wet scrubbing air contactor

(400 ppm Direct Air Capture)

Carbon Engineering's research pilot facility in Squamish, BC

https://www.netl.doe.gov/research/coal/project-information/proj?k=FE0026861

MicroBio Engineering

Products: Animal feeds

Test at Orlando Utilities Commission – Stanton Energy Center site

Algae Cultivation to capture CO2 from Power Plants and Air

$300+/tonne

Helios-NRG, LLC

Products: Biofuels, food, & nutraceuticals

Test at NCCC

DAC: LEVERAGING EXISTING FE R&D TECHNOLOGIES

Direct Air Capture

Industrial & Power

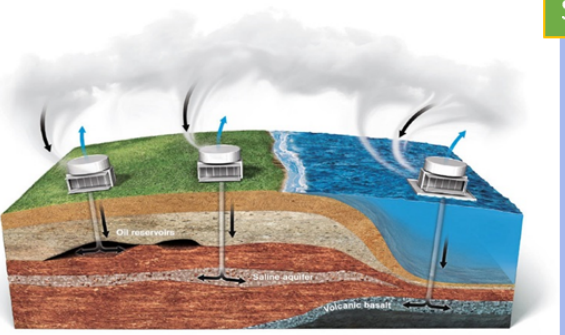
Moisture Swing Adsorption

Pressure/Temperature Swing Adsorption

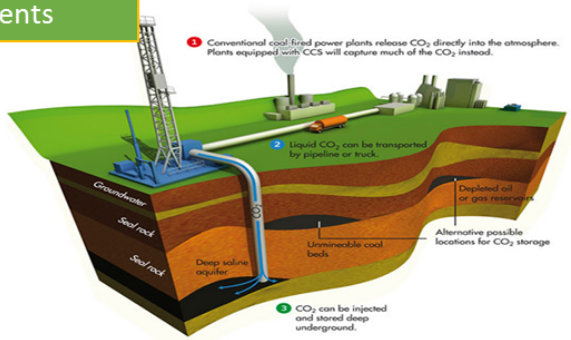
Physical Sorbents

Simple solvents

Simple and Advanced Solvents



Post-combustion results can be leveraged to develop DAC



Cryogenic Technology

Membranes

Solid and Liquid Chemical Sorbents

Metal-Organic Frameworks

Hydrates/Clathrates/Carbonates

Algae

- Low Concentration (400ppm)
- Low efficiency 10-50%
- Large volumes of air flow
- No contaminants
- Requires low pressure drop – larger machines
- Unique Material Properties – Fast kinetics, low oxidation rates

- CO_2 concentrations 100-300X that of air.
- High efficiency (90+%)
- Higher pressure and temperatures
- Contaminants (SO2, NOx, particulates, etc)
- Higher pressure drops
- Unique Material Properties – Low degradation rates, low heat of RX

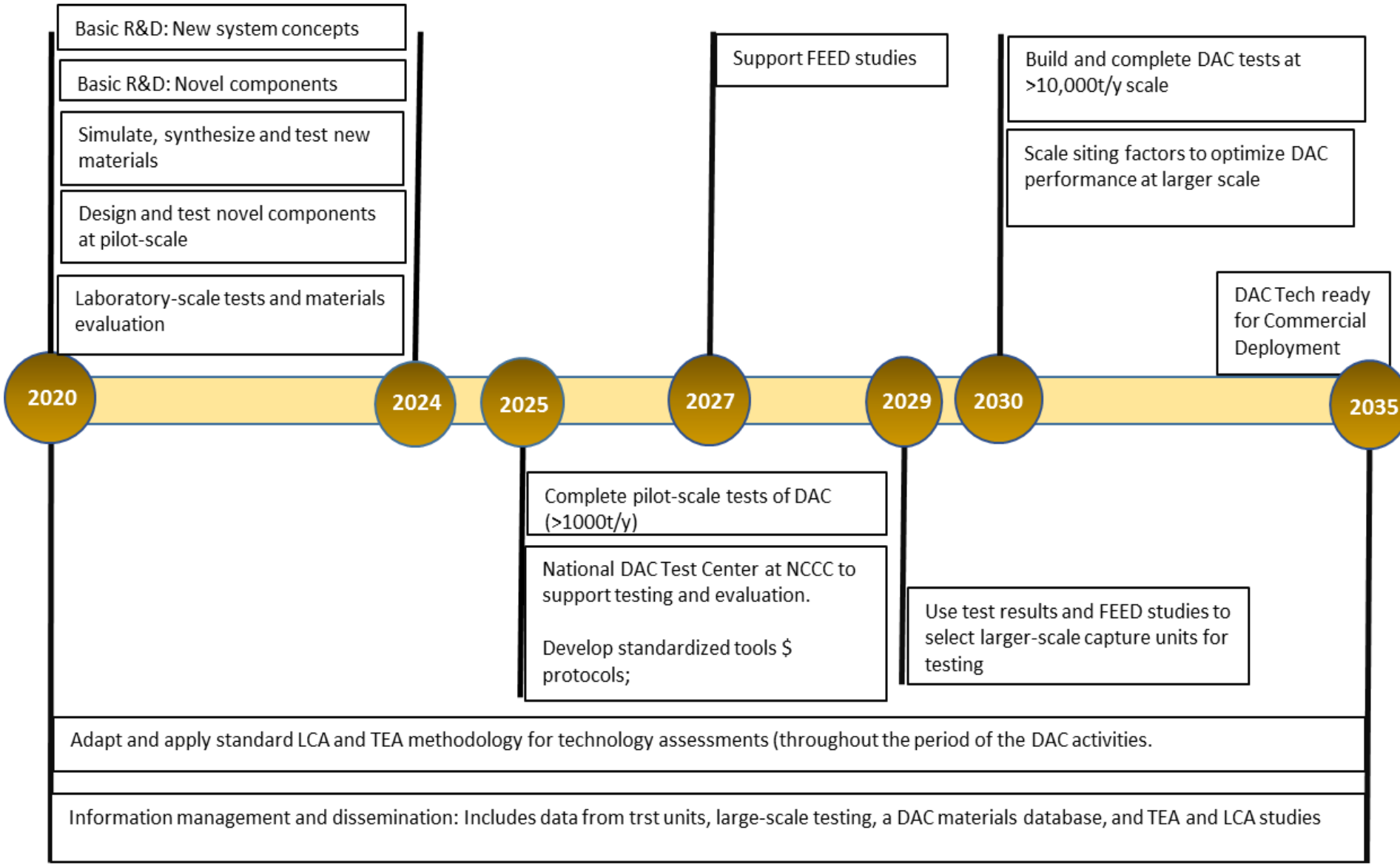
DOE EFFORTS IN FY19 AND FY2020

- **Workshop for DAC R&D Priorities - July 24, 2019**
- **Techno economic assessment (TEA) - Baseline for DAC – FY2019 (In progress)**
- **National Resources Assessment for DAC - FY2020 (In progress)**

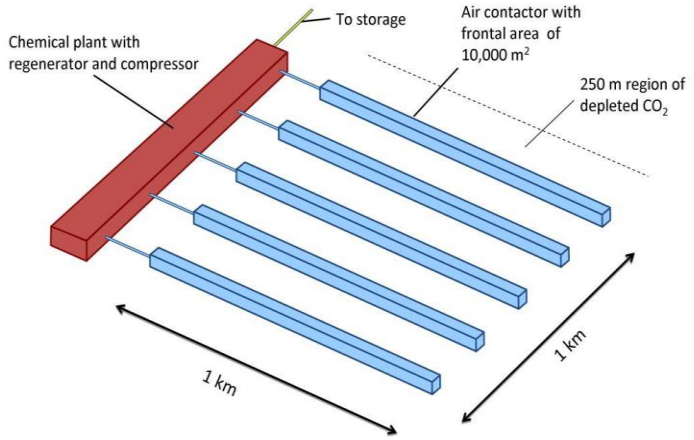
Funding Opportunities

- **University Coal Fossil Energy Research on Materials –** novel DAC materials – (FY2019)
- **Funding Opportunity Announcement / Lab Call** (FY2020)

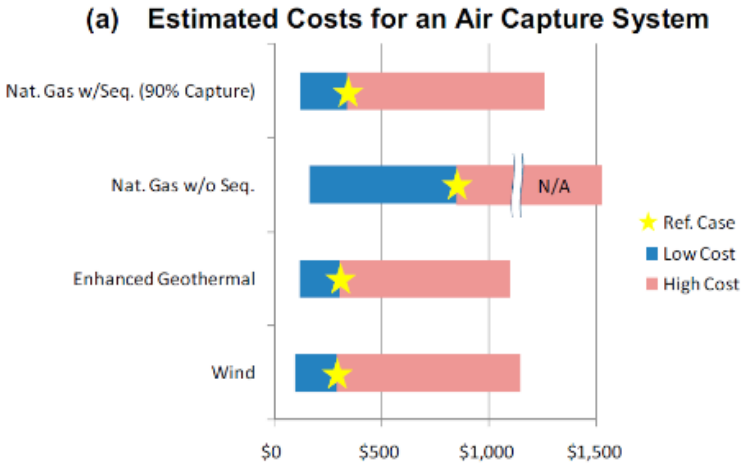
FE R&D PLAN FOR DAC - DRAFT



DAC TODAY: RESOURCE & LOGISTIC CHALLENGES



Sources: SEAB Task Force on RD&D strategy for CO2 Utilization and/or Negative Emissions at the gigatonne scale, Dec 2016



Challenge - Mitigate 1 Gigatonne with Solvent System

DAC Land use: 1000 to 5000 km^2 (50% eff vs 10% eff)

Power Demand:

- 273,000 Windmills (1.5MWe each) at 35% CF
- Enhanced GeoTherm – 150 GW 90% CF
- Natural Gas w/CCS – 200 GW NGCC units 90%CF
- Solar – 234,400 km^2 of solar panels
- Coal CCS - 200 GW with 95% capture 90% CF

Water Demand:

- 3,000,000,000+ tonnes /year

Lifecycle Assessment

- Estimates don't include manufacturing supply chain
- End use of CO_2 – Stored or products

Total System Costs per 1MMT Facility

- ~$2 Billion CAPEX, $100 millon/year per MMT

Capture costs - $200 to $1000/tonne

Sources: Systems Analysis and Cost Estimates for Large Scale Capture of Carbon Dioxide from Air; Simon; Kaahaaina;, Friedmann, Aines; GHGT-10 Proceedings, Energy Procedia 4(2011) 2893-2900

CHARGE TO WORKSHOP CHAIRS, SPEAKERS, AND ATTENDEES

Workshop Sessions

R&D Needs for Novel Materials
(Lynn Brickett)

R&D Needs for Process Configurations
(Mike Matuszewski)

DAC System Optimization
(Roger Aines)

Expectations

Active discussions

No wrong opinions

Be courteous of others opinions

Comment on our DRAFT current efforts, and timeline

Get to know each other and have fun!!!

QUESTIONS