U.S. DEPARTMENT OF ENERGY
Fossil Energy and Carbon Management

Carbon Capture Program at DOE

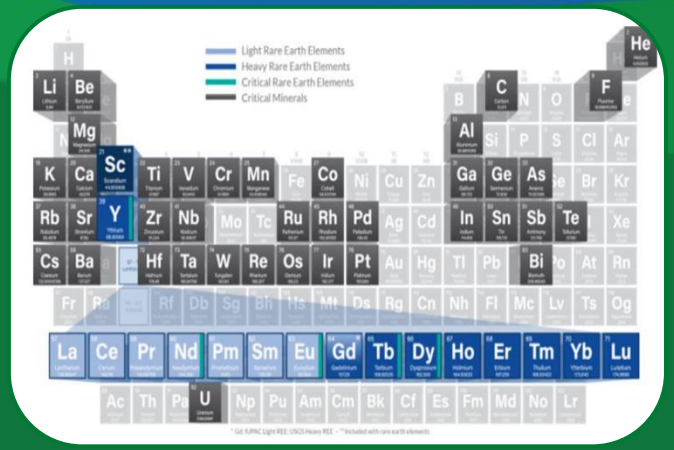
Progress toward decarbonization of Industrial and Power Sectors

Dr. Dan Hancu

Senior Program Manager, Point Source Carbon Capture
FOSSIL ENERGY AND CARBON MANAGEMENT

April 6, 2022



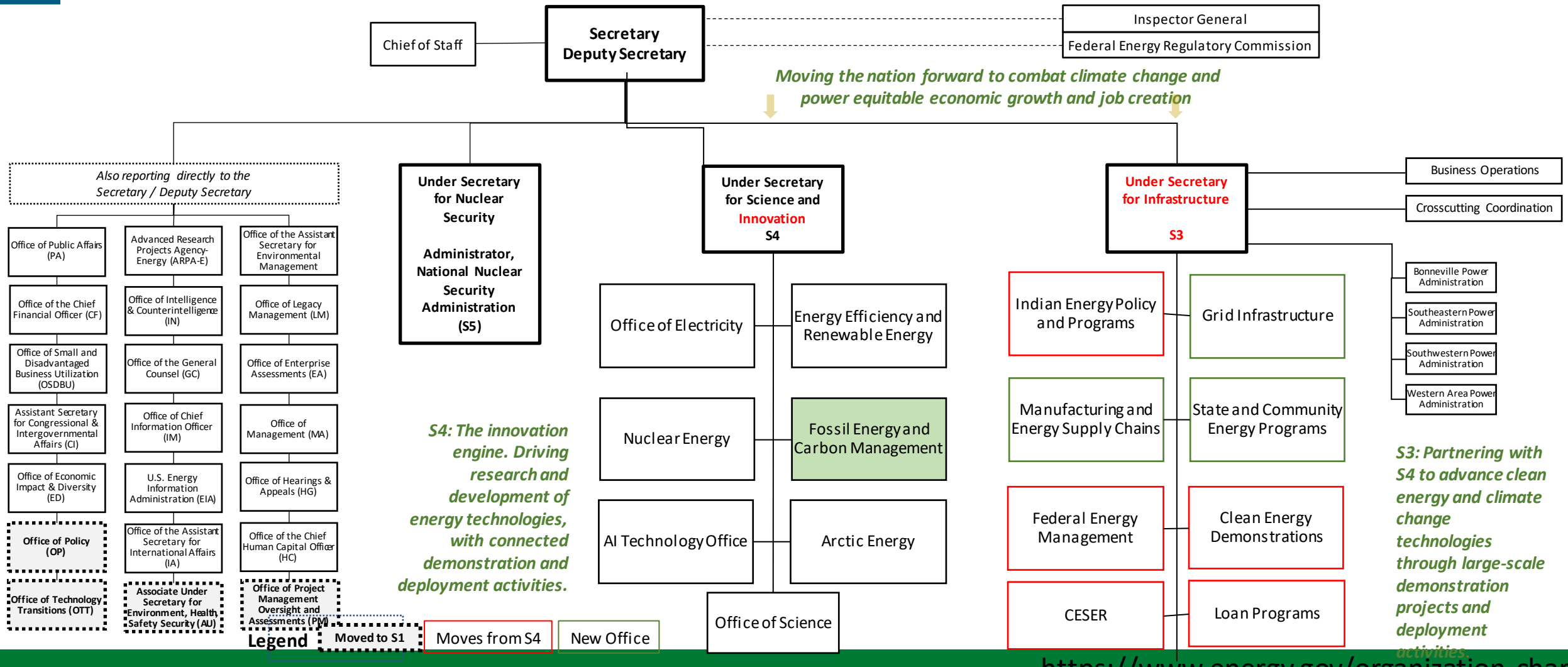


Agenda

- DOE Realignment
  - ❑ Fossil Energy and Carbon Management (FECM), Office for Clean Energy Demonstrations (OCED)
- Infrastructure Bill
  - ❑ Carbon managements provisions.. CCS Demos, DAC Hubs, Carbon Capture Large Pilots
- FECM Carbon Capture Program
  - ❑ Program structure; technical approach; industrial, power, DAC projects (highlights); current FOAs
- Program Outreach

Administration's goals:
- ✓ *50% emissions reduction by 2030*
- ✓ *Carbon emissions-free power sector by 2035*
- ✓ *Net zero emissions economy by no later than 2050*

Realigned DOE



https://www.energy.gov/organization-chart

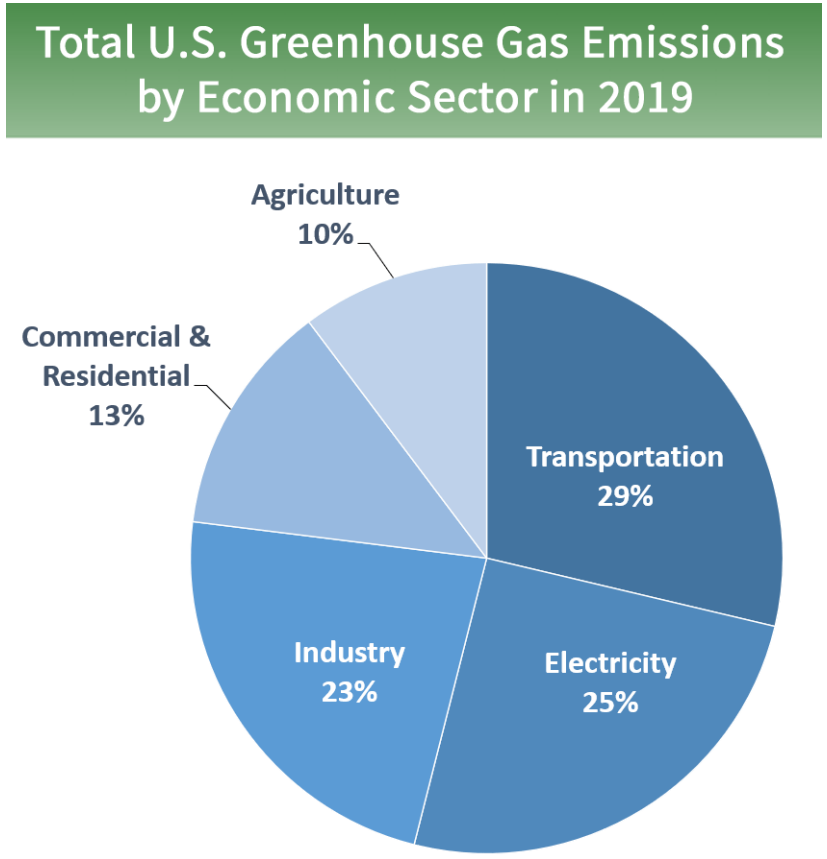
Fossil Energy and Carbon Management (FECM)

Office of Fossil Energy and Carbon Management

DOE-FE is now DOE-FECM

New name for our office reflects our **new vision**

- President Biden's goals:
  - 50% emissions reduction by 2030
  - CO_2 emissions-free power sector by 2035
  - Net zero emissions economy by no later than 2050



U.S. Environmental Protection Agency (2021). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2019

FECM Mission: Deep Decarbonization

Minimize environmental and climate impacts of fossil fuels from extraction to use

Priority Technology Areas

1. Point source carbon capture
2. Carbon dioxide (CO_2) removal
3. CO_2 conversion into products
4. Reliable CO_2 storage
5. Hydrogen production

Office of Carbon Management
(FECM-20)

6. Critical mineral production from industrial and mining waste
7. Methane mitigation

Office of Resource Sustainability
(FECM-30)

Address hardest-to-decarbonize applications in the electricity and industrial sectors

Office of Clean Energy Demonstrations (OCED)

OCED established December 2021

- Builds on existing DOE investments in clean energy research and development
- Increases DOE's partnership with industry leaders

OCED Projects Areas:

- Clean hydrogen
- Carbon capture
- Grid-scale energy storage
- Small modular reactors and more

DOE Will Oversee $20 Billion Federal Investment to Stand Up Clean Energy Projects Across the U.S. to Reach President Biden's Net-Zero Goals

DOE Establishes New Office of Clean Energy Demonstrations Under the Bipartisan Infrastructure Law | Department of Energy

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Bipartisan Infrastructure Law

$10+ billion in new carbon management funding over 5 years through the Infrastructure Investment and Jobs Act (Bipartisan Infrastructure Law).

Carbon Dioxide Removal - Direct Air Capture
Regional Direct Air Capture Hubs: $3.5 billion
DAC Technology Prize Competition: $115 million

Front-End Engineering Design Studies
Carbon Capture Technology Program: $100 million

Carbon Dioxide Utilization and Storage
Carbon Storage Validation and Testing: $2.5 billion
Carbon Utilization Program: $310 million

Hydrogen Hubs

- $8 billion (for at least four projects, including at least one using fossil fuels with carbon management)

Carbon Capture Demonstrations and Large Pilots

- $3.5 billion

Carbon Capture Demonstrations – Key Provisions

Demonstration projects (16 962(b)(2)(C) of the Energy Policy Act of 2005 (42 U.S.C. 17 16292(b)(2)(C))

$2.5B

- Establish a demonstration program through a competitive, merit-reviewed process,
- Enter into cooperative agreements for demonstration projects to demonstrate the construction and operation of 6 facilities to capture carbon dioxide from coal electric generation facilities (2 projects), natural gas electric generation facilities (2 projects), and industrial facilities (2 projects).

Each demonstration project shall be designed to further the development, deployment, and commercialization of technologies to capture and sequester carbon dioxide emissions from new and existing coal electric generation facilities, natural gas electric generation facilities, and industrial facilities;

https://uscode.house.gov/view.xhtml?hl=false&edition=prelim&req=granuleid%3AUSC-prelim-title42-section16292&num=0&saved=%7CKHRpdGxlOjQyIHNlY3Rpb246MTYyOTMgZWRpdGlvbjpwcmVsaW0p%7C%7C%7C0%7Cfalse%7Cprelim

Carbon Capture Large Pilots.. Key Provisions

Key BIL Sec. 41004(a)

PROJECTS.—There are authorized to be appropriated to the Secretary to carry out activities under section 7 962(b)(2)(B) of the Energy Policy Act of 2005 (42 U.S.C. 8 16292(b)(2)(B))—

(1) $387,000,000 for fiscal year 2022;
(2) $200,000,000 for fiscal year 2023;
(3) $200,000,000 for fiscal year 2024; and
(4) $150,000,000 for fiscal year 2025.*

The term "large-scale pilot project" means a pilot project that—

(A) represents the scale of technology development beyond laboratory development and bench scale testing, but not yet advanced to the point of **being tested under real operational conditions at commercial scale**;

(B) represents the scale of technology necessary to gain the operational data needed to understand the technical and performance risks of the technology before the application of that technology at commercial scale or in commercial-scale demonstration; and

(C) **is large enough**—

(i) to **validate scaling factors**; and

(ii) to demonstrate the interaction between major components so that control philosophies for a new process can be developed and enable the technology **to advance from large-scale pilot project application to commercial-scale demonstration** or application.

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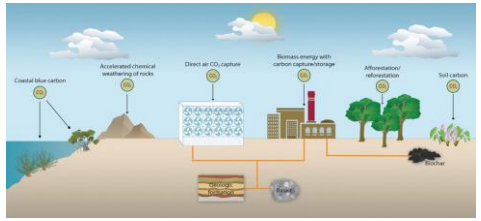
DAC Hubs– Key Provisions

Direct Air Capture Hubs

SEC. 40308. CARBON REMOVAL; *Amended Section 969D of the Energy Policy Act of 2005 (42 U.S.C. 16298d)*



Regional DAC Hubs
$3.5 B

FY 22 – FY 26: $700M / yr.

HUB DEFINITION:
a network of direct air capture projects, potential carbon dioxide utilization offtakers, connective carbon dioxide transport infrastructure, subsurface resources, and sequestration infrastructure located within a region.

Each of the 4 regional direct air capture hubs developed shall be a regional direct air capture hub that has the capacity to capture and sequester, utilize, or sequester and utilize at least 1,000,000 metric tons of carbon dioxide from the atmosphere annually from a single unit or multiple interconnected units.

REGIONAL CARBON MANAGEMENT APPLICANT EDUCATION WORKSHOPS

U.S. DEPARTMENT OF ENERGY | Fossil Energy and Carbon Management

USEA United States Energy Association

Join USEA on April 7th, as we partner with the U.S. Department of Energy's Office of Fossil Energy and Carbon Management (DOE-FECM) for a Virtual Kickoff of its Regional Carbon Management Applicant Education Workshops. These workshops support implementation of the Bipartisan Infrastructure Law (BIL) and will target potential applicants interested in developing commercial-scale storage facilities, point-source CO2 capture demonstration projects, direct air capture hubs, hydrogen production hubs with carbon capture and storage (CCS), carbon utilization, and CO2 transport that will be required by these BIL provisions and support decarbonization.

Selected Agenda Items:

- Components of large-scale projects (DAC Hubs, CCS Demos, H_2 Production Hubs with CCS, Carbon Utilization and CO_2 transport)
- Lessons learned from past demo projects
- DOE procurement requirements and processes
- NEPA requirements
- Environmental Justice and Community engagements
- Energy Jobs;
- Partnering with Tribal Nations

Virtual Event: April 7th (1:00 PM, EST)

In-person Regional Events

- April 13th: Columbus, OH
- April 19th: New Orleans, LA
- April 26th: Salt Lake City, UT

https://us02web.zoom.us/webinar/register/WN_FsT1PNd6RCOPp6oRn3-Tcg

Agenda

- DOE Realignment
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  - ❑ Carbon managements provisions.. CCS Demos, DAC Hubs, Carbon Capture Large Pilots
- **FECM Carbon Capture Program**
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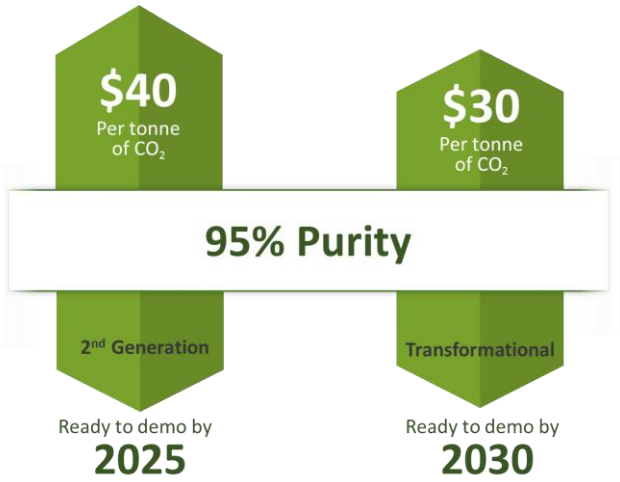
- **Outreach**

Carbon Capture Program…Mission

- Mission
  - Develop cost-effective point source capture and CDR technologies throughout the power-generation and industrial sectors
  - Ensure the U.S. will continue to have access to safe, reliable, & affordable low-carbon energy generation
- Drivers/Challenges
  - Reduce carbon capture CAPEX/OPEX under a wide range of feed conditions and high capture efficiencies
  - Demonstrate first-of-a-kind carbon capture coupled to dedicated and reliable carbon storage, that will lead to commercially viable nth-of-a-kind opportunities for widescale deployment
- Goal & Metrics
  - Support U.S goal to achieve carbon pollution-free power sector by 2035 and zero-carbon economy by 2050

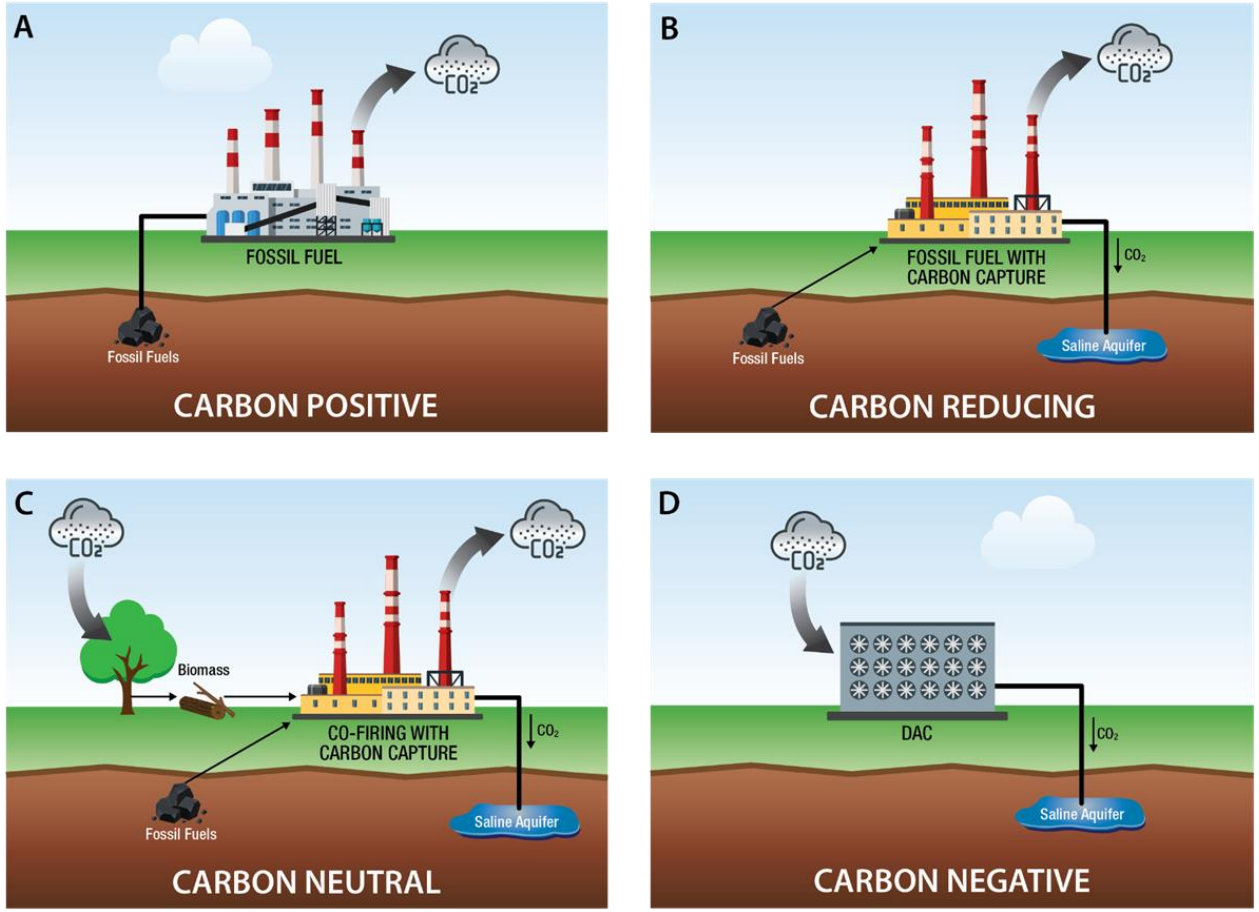


DOE's Carbon Capture performance goals for coal-fired power plants

National Carbon Capture Center

Photo Source: Southern Company Services

Carbon Dioxide Removal vs Carbon Reducing

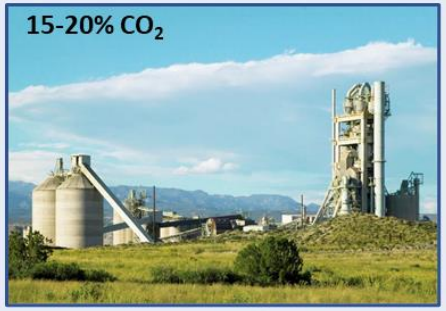


Carbon Negative vs. Carbon Reducing

CARBON REDUCING

Point-Source Capture (PSC) for Power Generation and Industrial Sectors

Power Plants



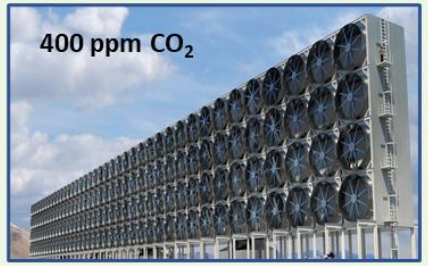
Cement Plants

Steel Plants

Hydrogen Plants

CARBON NEGATIVE

Carbon Dioxide Removal (CDR) from Air



Direct Air Capture (1)

Enhanced Weathering

Bioenergy Carbon Removal and Storage (BiCRS)

(1) Assume C storage as CO_2 off-take

Develop PSC / CDR technologies for a wide range of feed conditions

Carbon Capture Program…Evolution

1st and 2nd Generation Technologies

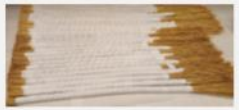
2025: $40/tonne CO_2

2008 -

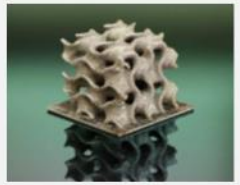
- ✓ Lower CAPEX/OPEX
- ✓ Reduced regeneration energy
- ✓ Increased working capacity

Transformational Technologies

2030: $30/tonne CO_2



Hollow Fibers



3D Print

Biphasic Solvent

2015 -

- ✓ Water Lean Solvents
- ✓ Adv. Membranes
- ✓ Hybrid Systems
- ✓ Process Intensification

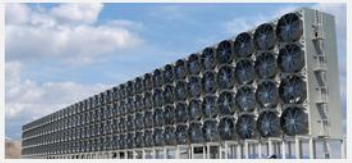
Scale-up

TCM

2018 -

- ✓ Engineering Scale testing
- ✓ FEED studies

Negative Emissions Technologies & Industrial



Carbon Engineering, DAC

Ethanol Plant

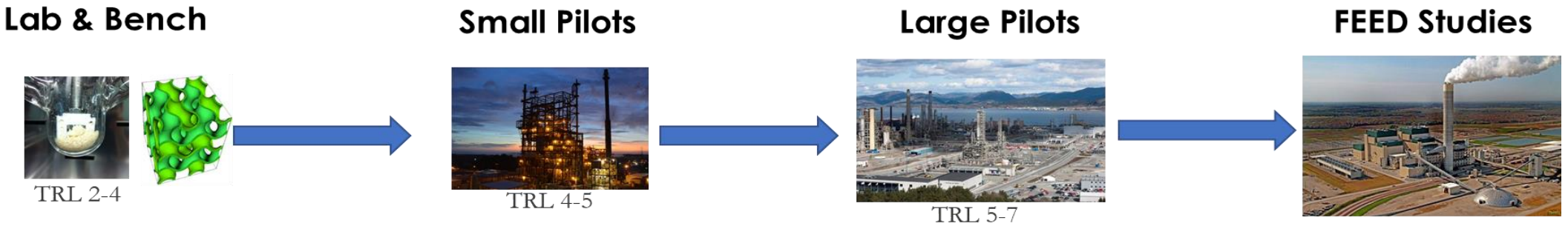
2020 -

- ✓ DAC & BiCRS
- ✓ Industrial
- ✓ NG

Reduce cost and risk to enable wider, strategic commercial deployment

Point Source Capture Program

Integrated Approach to Accelerate Technology Development



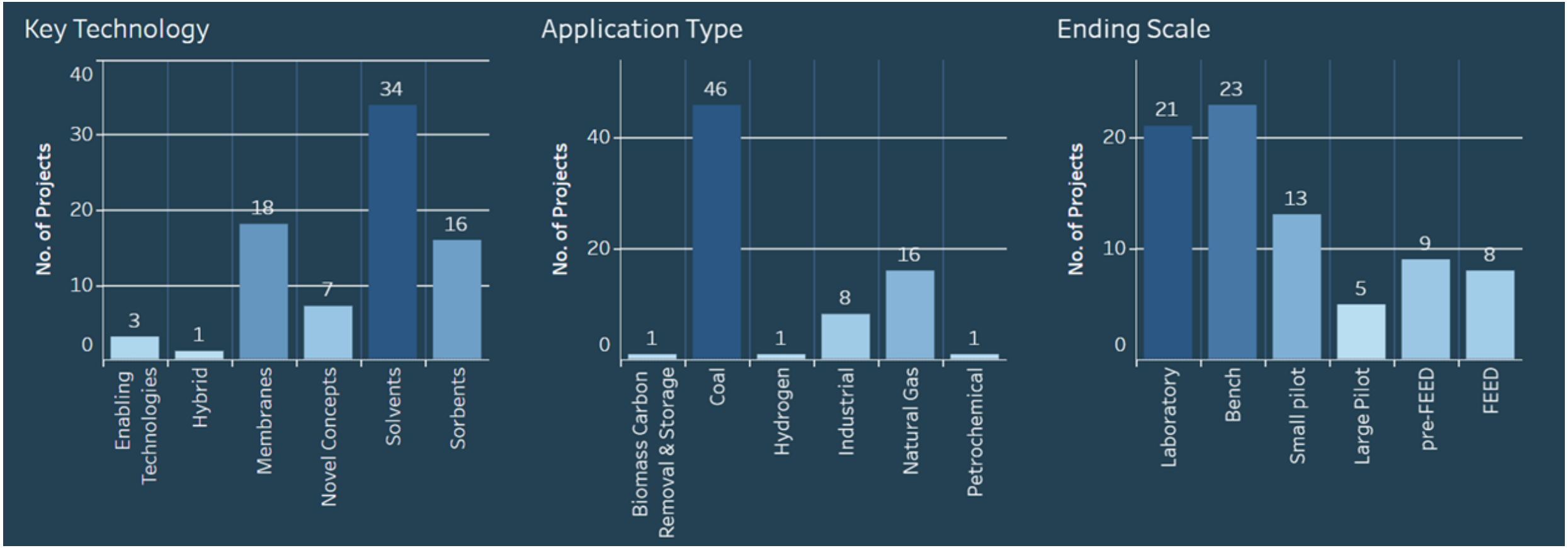
Point Source Capture Focus

- Develop capture technologies for the power and industrial sectors
- Reduce CAPEX/OPEX under a wide range of feed conditions
- Achieve high capture efficiencies (>95%)
- Maximize co-benefit pollutant removal
- Engineering-based Simulation ($CCSI^2$)
- Create low-carbon supply chains (i.e., cement, steel, hydrogen, etc.)

Carbon Capture Interactive Project Map

Point Source Capture Program

Project Distribution



Pre-Commercial.. Industrial (TRL 6+)

Ethanol

Hybrid absorption & liquefaction system

Cement

MTR's membrane technology

ELECTRICORE POWERING THE FUTURE

Svante

VeloxoTherm™ adsorption-based process

Steel

DASTUR ION CLEAN ENERGY

ION Clean Energy's water-lean solvent-based technology

Steam Methane Reforming

Linde BASF We create chemistry

Linde-BASF technology using OASE® blue solvent

Industrial Capture: Cement (pre-FEED)

Electricore, Inc.

Sorbent-based Post-Combustion CO_2 Capture

LafargeHolcim Portland Cement Plant in Florence, CO

CHALLENGE:

- CO_2 capture from cement plant flue gas at commercial scale

SOLUTION:

- Svante's low CAPEX solid sorbent technology

Key Process Features and Objectives

- Complete a pre-FEED analysis for VeloxoTherm™ capture system installed at a LafargeHolcim-owned cement plant
  - Phase 1: select preferred design & plant capacity
  - Phase 2: CAPEX & OPEX estimates
- Identify plausible CO_2 storage options

Project Development and Goals - 2021

- Design a 1.5 mtpa capture system to remove CO_2 from cement kiln flue gas (14% conc.) & CO_2 from natural gas-fired steam generator (8.5% conc.)
- Pre-feasibility report completed

Project Benefits

- Reduced CAPEX as compact equipment (rotary adsorption system) to capture & release CO_2 & regenerate the sorbent
- First commercial scale Svante capture plant

LafargeHolcim · Kiewit · ELECTRICORE POWERING THE FUTURE · TOTAL · OXY · Svante

FOA 2515: 2nd Closing

Carbon Capture R&D For Natural Gas and Industrial Point Sources and FEED Studies for Carbon Capture Systems at Industrial Facilities and Natural Gas Plants

Closing Date: 04/11/2022

This FOA has a dual focus for natural gas & industrial applications:

1. FEED studies using Generation 2 system capable of ≥95% CO_2 capture
2. Develop lower-cost, highly efficient, transformational carbon capture technologies

Area of Interest
AOI 4: Carbon Capture R&D: Laboratory-Scale Testing of Highly-Efficient Materials or Novel Concepts for Natural Gas Combined Cycle (NGCC) Power Plants
AOI 5: Engineering-Scale Testing of Transformational Post-Combustion Carbon Capture Technologies for NGCC power plants
AOI 6: Engineering-Scale Testing of Transformational Carbon Capture Technologies for Industrial Plants and Waste-to-Energy Plants
AOI 7: Front-End Engineering Design Studies for Carbon Capture Systems at Existing (Retrofit) Domestic Industrial Facilities and NGCC Power Plants

Pre-Commercial.. H_2 Generation (TRL 6+)

Advanced CCS Systems for SMR

Svante VeloxoTherm™ solid adsorbent at Linde SMR H_2 plant

- ~1,100,000 tonnes/year net CO_2 capture
- 90% Capture Efficiency
- Production of "blue" H_2 with 99.97% purity

Gen 1 CCS technology at Phillips 66 refinery in Rodeo, California

- Separate & store ~190,000 tons/year net CO_2 from hydrogen production unit with >90% carbon capture efficiency

Advanced CCUS +for ATR

CO_2 Capture Unit at Tallgrass MLP Operations LLC's Planned Blue Bison ATR Plant

- Separate and store 1.66 million tonnes/year of 95% pure CO_2 with >97% carbon capture efficiency
- System combining carbon capture, H_2 production (220 MMSCFD at 99.97% purity), and H_2 combustion in auxiliary burners

Industrial Capture: H_2 SMR (pre-FEED)

Linde Inc.

Advanced Aqueous Amine Post-Combustion CO_2 Capture

Steam Methane Reformer (SMR)

CHALLENGE:

- CO_2 capture from steam methane reformer flue gas at 90% efficiency with minimum impact on cost of H_2

SOLUTION:

- Advanced aqueous amine solvent (BASF's OASE® blue) combined with high-capacity structured packing

Key Process Features and Objectives

- Design a hybrid system and complete pre-FEED analysis for green field SMR plant for a refinery in LA.
- Utilize commercially available chemical absorption technology
- Utilize existing natural gas boilers to supply steam

Project Development and Goals- 2020

- Capture technology tested from 2009-2017
- Design a ~3,500 tonnes CO_2/day capture system

Project Benefits

- Recovers >90% of the CO_2 from the flue gas stream produced by a reformer
- Higher CO_2 content in SMR flue gas (~22% by vol. dry basis)
- Eligibility for 45Q tax credits

Linde

BASF
We create chemistry

FOA 2400: 2nd Closing

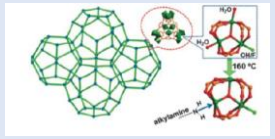
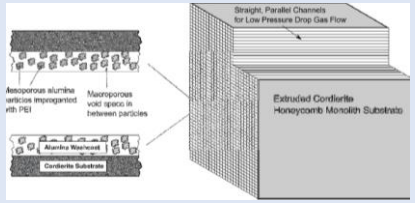
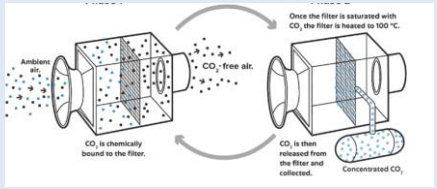
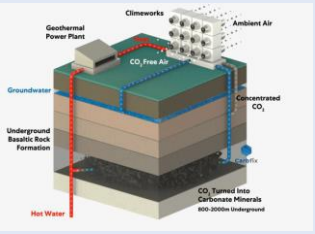
CLEAN HYDROGEN PRODUCTION, STORAGE, TRANSPORT AND UTILIZATION TO ENABLE A NET ZERO CARBON ECONOMY

Closing Date: 03/30/2022

Area of Interest
AOI-8a: Front-End Engineering Design Studies for Carbon Capture Systems at Domestic Steam Methane Reforming (SMR) Facilities Producing H2 from Natural Gas **AOI-8b:** Front-End Engineering Design Studies for Carbon Capture Systems at Domestic Autothermal Reforming (ATR) Facilities Producing H2 from Natural Gas

FundOpp_DE-FOA-0002400_Amd_000007.pdf

FECM DAC Technology Development

	Materials (TRL 2-3)	Structured Material Systems / Components (TRL 3)	Bench Scale / Integrated system (TRL 4)	Field Demo Integrated System (TRL 4-5)	Pre- FEED / FEED (TRL 6+)
Gen 1					
			FOA 2402 $8M FY 21		**FOA 2402** $7.5M FY 20 **FOA 2560** FY 22?
Gen 2	**FOA 2188** $11M FY 20-21	**FOA 2402** $10.2M FY 21 **NOI 2684** FY 22?	**NOI 2684** FY 22?		

DAC Funding 2020-22	Funding
FY 20	$14,250,000
FY 21	$26,439,000
FY 22	~ $10,500,000

FEEDs for DAC Coupled to Low Carbon Energy Sources

Closing Date: 12/22/2021

AOI 1: FEED Studies for DAC Systems at Existing (retrofit) Domestic Nuclear Power Plants

AOI 2: FEED Studies for DAC Systems at Existing (retrofit) Domestic Geothermal Resources

AOI 3: FEED Studies for DAC Systems Using Waste Heat at Existing (retrofit) Domestic Industrial Plants Coupled with CO_2 Conversion Producing Low Carbon Intensity Products

Department of Energy

DOE Announces $14.5 Million Supporting Direct Air Capture and Storage Coupled to Low Carbon Energy Sources

OCTOBER 26, 2021

Energy.gov » DOE Announces $14.5 Million Supporting Direct Air Capture and Storage Coupled to Low Carbon Energy Sources

Funding Addresses Urgent Need for Global Leadership and Collaboration on Deployment of Durable Carbon Dioxide Removal

Washington, D.C. - The U.S. Department of Energy (DOE) today announced $14.5 million in available funding to leverage existing low-carbon energy to scale-up direct air capture (DAC) technology combined with reliable carbon storage. DAC, a carbon dioxide removal approach, is a process that separates carbon dioxide (CO2) from ambient air. The separated CO2 can then be safely and permanently stored deep underground or converted into products. DAC is considered a growing and necessary field that still requires significant investments to create a cost-effective and economically viable technology that can be deployed at scale in the commercial CO2 market. Advancing the deployment of DAC approaches is critical to combatting the current climate crisis and achieving net-zero emissions by 2050—a key priority for the Biden-Harris Administration.

Carbon Capture Program.. Outreach

Carbon Capture Newsletter

Carbon Capture Program R&D Compendium

Carbon Capture Program Website

U.S. DEPARTMENT OF ENERGY
Fossil Energy and Carbon Management

Questions?

dan.hancu@hq.doe.gov