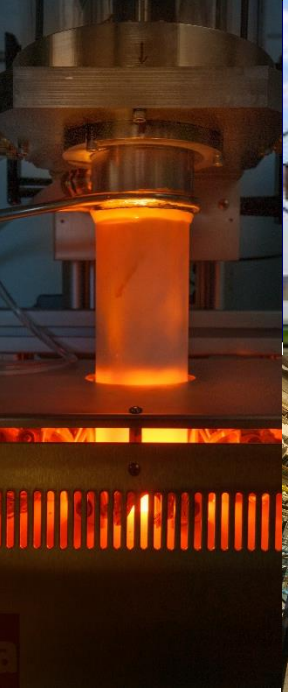

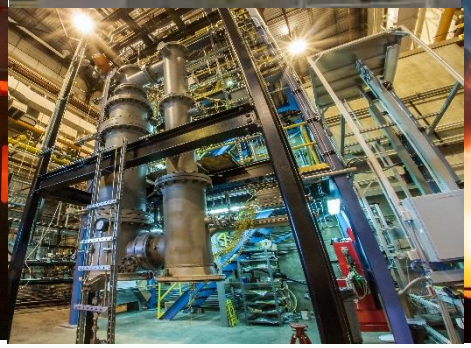


U.S. DEPARTMENT OF ENERGY | Office of Fossil Energy

Overview of Carbon Capture and Opportunities for Hydrogen

Fuel for Thought:H2 &Carbon Capture Opportunities

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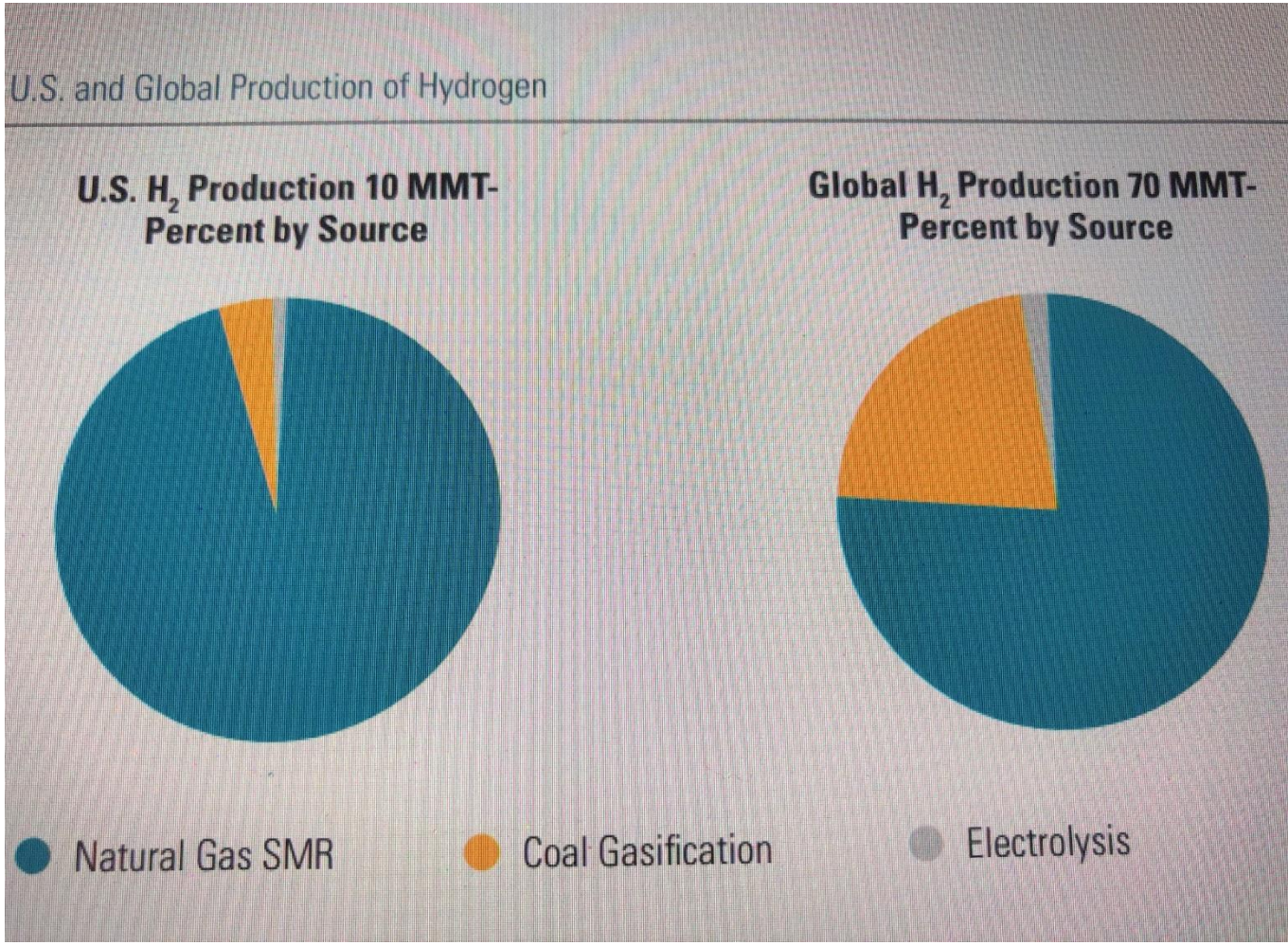
Office of Clean Coal and Carbon Management, Office of Fossil Energy

June 2021

Hydrogen Production (US & Global)

EIA – Energy Technology Perspectives, 2017

By 2050, fossil fuels will remain the primary source of hydrogen for the US (75%), Europe (65%) and Japan (85%).

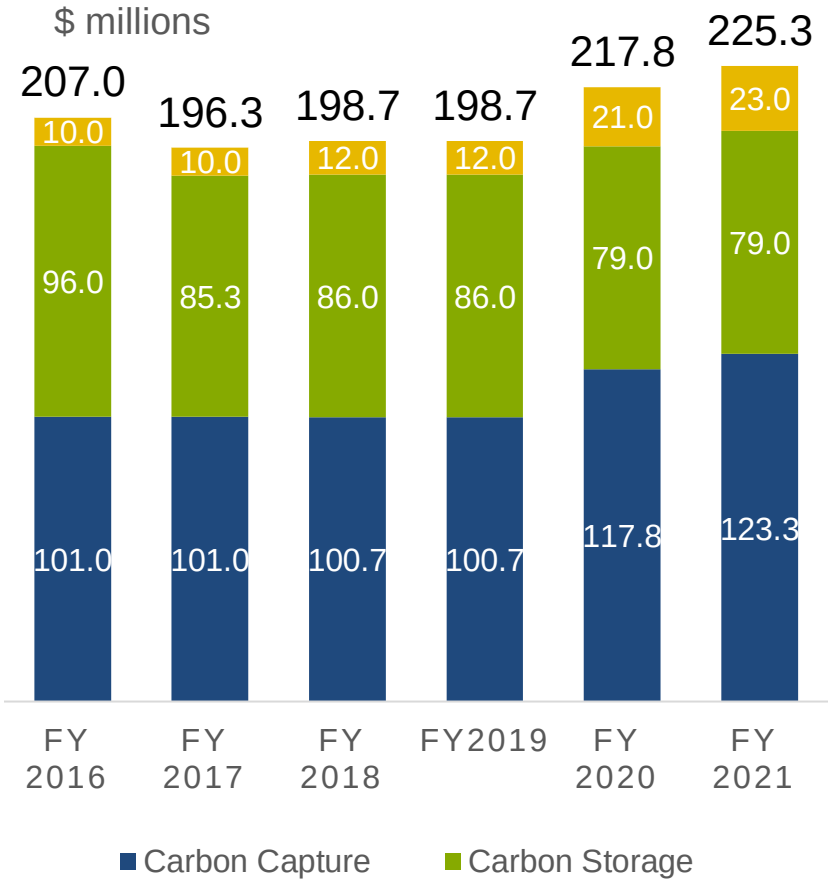


DOEs-FECM CCUS BUDGET (2016-2021)

Carbon capture
R&D and scale-up technologies for capturing CO_2 from new and existing industrial and power plants, and direct air capture

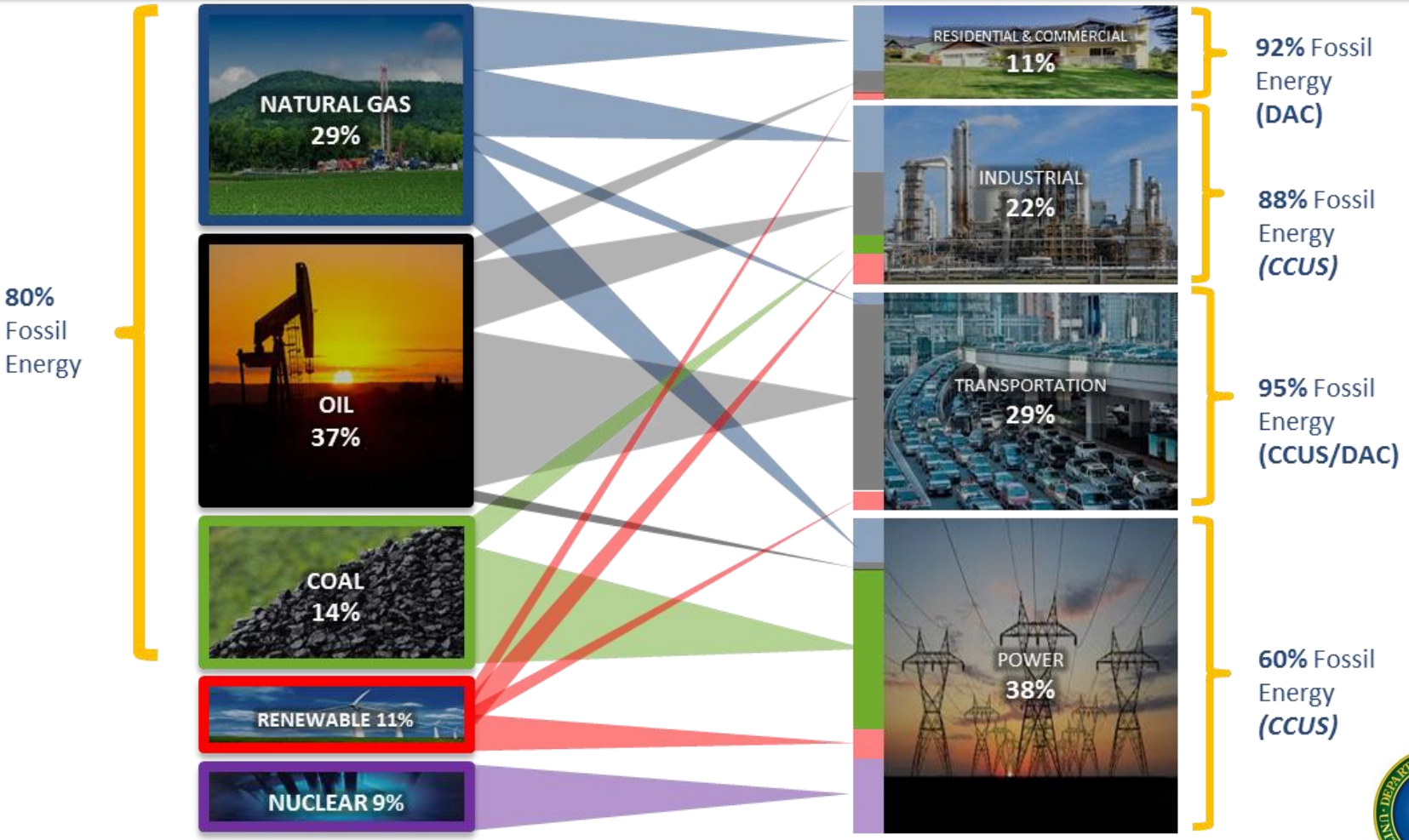
CO_2 utilization
R&D and technologies to convert CO_2 to value-added products

Carbon storage
Safe, cost- effective, and permanent geologic storage of CO_2



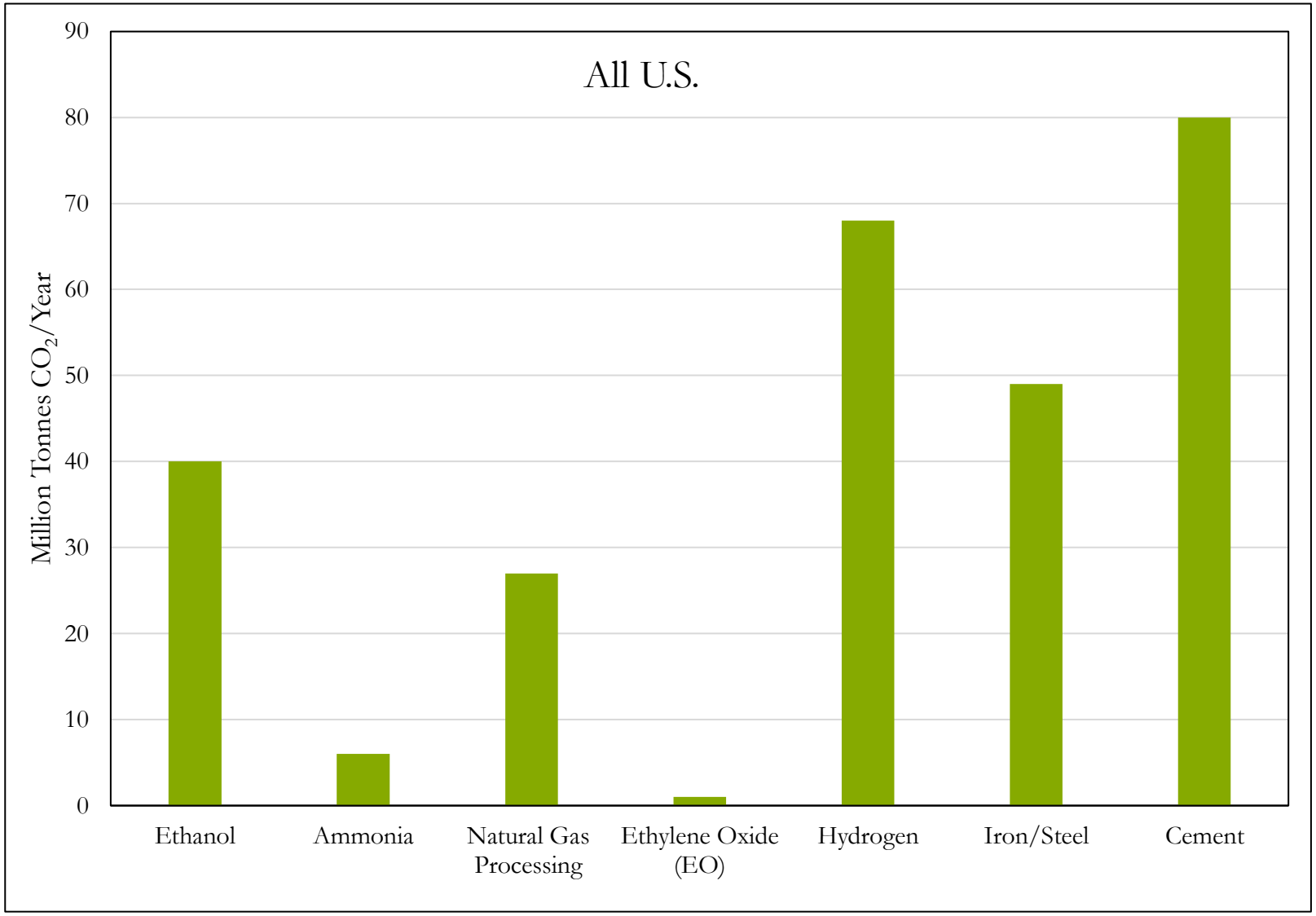
EXCITING TIME FOR CCUS

CCUS is increasingly becoming widely accepted as a viable option for various point sources to lower their carbon dioxide (CO_2) emissions.



EIA, *Annual Energy Outlook 2017*, Reference Case, https://www.eia.gov/totalenergy/data/monthly/pdf/flow/css_2017_energy.pdf

INDUSTRIAL PROCESSES: CO_2 AVAILABLE FOR CAPTURE IN THE US



Cost of Capturing CO_2 from Industrial Sources, January 10, 2014, DOE/NETL-2013/1602; https://www.netl.doe.gov/energy-analysis/details?id=1836

Policy Incentives for CCUS - 45Q tax credits

"Technology push" through R&D is matched with "market pull" through financial incentives

	Threshold by Facility Type ($ktCO_2/y$)			Credit in 2026 ($/t)
	Power Plant	Industrial Facility	Direct Air Capture	
Dedicated Storage	500	100	100	50
EOR	500	100	100	35
Utilization	25	25	25	35

Source: McCoy, 2018

- **Credit available to qualified facilities for 12 year period**
- **Defines qualified Carbon Oxides (CO or CO_2)**
- **Measured at point of capture and verified at the point of disposal/injection/use**
- **Qualified facilities:**
  - 1) Construction must begin by the end of 2025;
  - 2) Original planning and design includes carbon capture equipment
- **Credit can be claimed by owner of capture equipment or transferred to disposal/use entity**

MAJOR CCUS DEMONSTRATION PROJECTS

Air Products Facility (Port Arthur, TX) – operations began in 2013

- Built and operated by Air Products and Chemicals Inc. at Valero Oil Refinery
- State-of-the-art system to capture CO_2 from two large **steam methane reformers**
- **Over 5.0 million metric tons of CO_2** captured and transported via pipeline to oil fields in eastern Texas for **enhanced oil recovery (EOR)** since March 2013

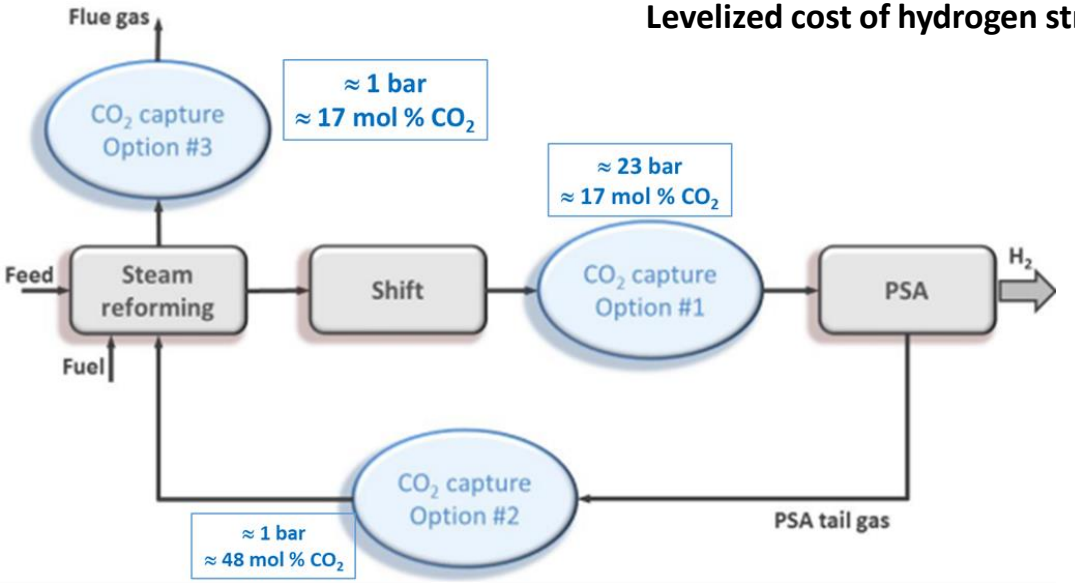
Petra Nova CCS (Thompsons, TX) – operations began in 2017

- Joint venture by NRG Energy, Inc. (USA) and JX Nippon Oil and Gas Exploration (Japan)
- Demonstrating Mitsubishi Heavy Industries' solvent technology to **capture 90% of CO_2 from 240-MW flue gas stream** (designed to capture/store 1.4 million metric tons of CO_2 per year)
- **Nearly 3.3 million metric tons of CO_2** used for **EOR** in West Ranch Oil Field in Jackson County, Texas since January 2017

ADM Ethanol Facility (Decatur, IL) – operations began in 2017

- Built and operated by Archer Daniels Midland (ADM) at its existing biofuel plant
- CO_2 from **ethanol biofuels production** captured and stored in **deep saline reservoir**
- **First-ever CCS project** to use new U.S. Environmental Protection Agency (EPA) Underground Injection **Class VI well permit,** specifically for CO_2 storage
- **1.3 million metric tons of CO_2 stored**, since April 2017

SMR PROCESS.. CARBON CAPTURE OPTIONS



Levelized cost of hydrogen strongly depends on the CCS Option / Capture Efficiency

Location	CO_2 Source	Technology	% CO_2 Captured	Increased LCOH (c€/Nm^3 H_2)
1	Shifted Syngas	MDEA	56	2.1
2	PSA Tailgas	MDEA	54	2.8
3	Flue Gas	MEA, Post Combustion	90	5.2

**IEAGHG, "Techno-Economic Evaluation of SMR Based Standalone (Merchant) Plant with CCS", 2017/02*

Initial Engineering Studies for Carbon Capture Systems at Hydrogen Plants- SMR & ATR

CCS System for SMR and ATR Plants

100,000+ tonne/yr. net CO_2 from new or existing Hydrogen Plants (SMR and ATR) and 90% Carbon Capture Efficiency

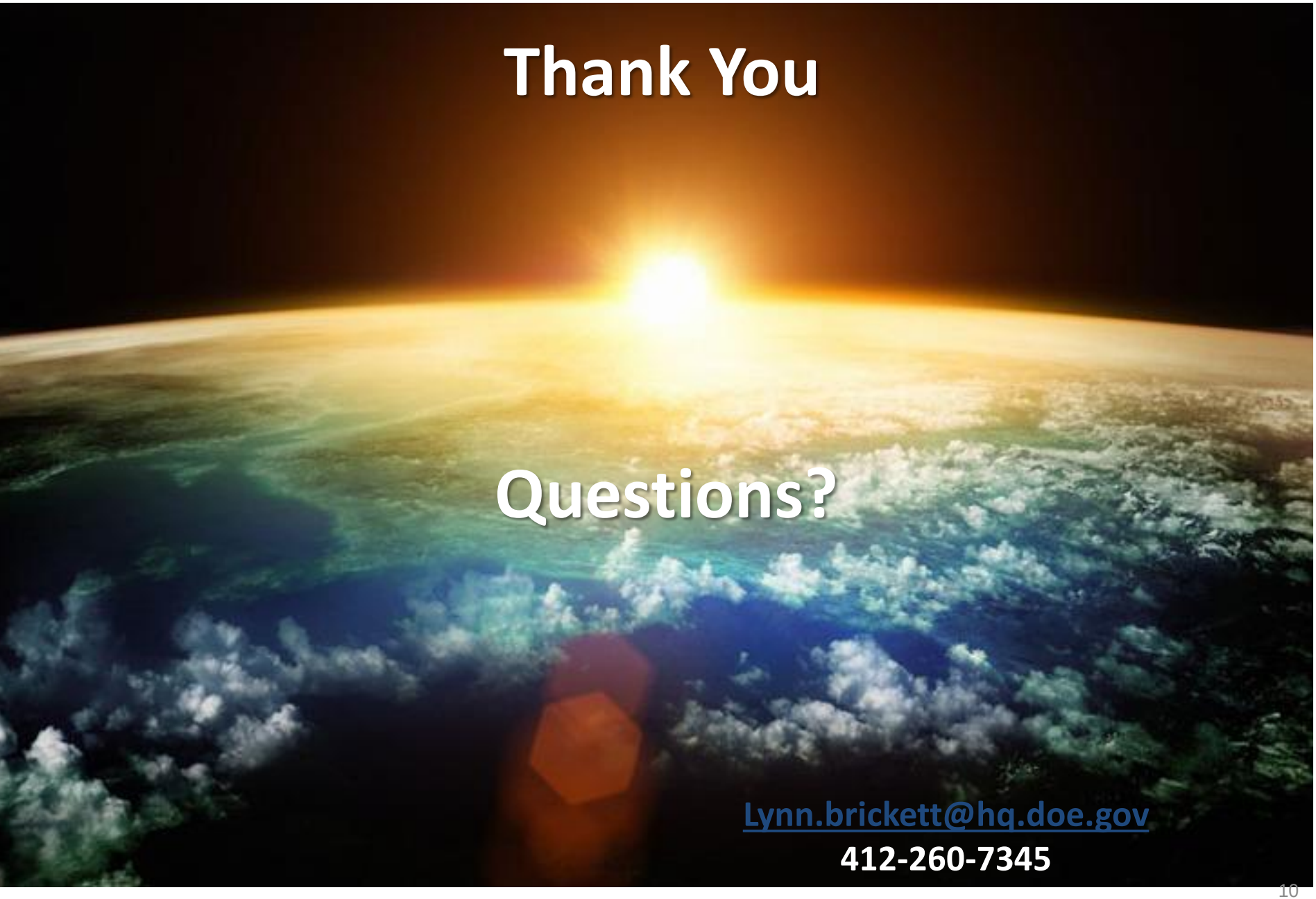
Problem Statement

Complete an initial engineering design for an advanced CO_2 capture system for commercial application at new or existing Hydrogen Plants (SMR or ATR) with the following specifications:

- 90%+ Carbon Capture Efficiency, 95+% CO_2 Purity,
- 100,000+ t/year CO_2 captured
- 99.97+% H_2 Purity
- Advanced Pre- and Post- Carbon Capture Technology at TRL 6+
- Identification of possible CO_2 storage or utilization options.

Success Criteria: By 2023, projects will develop an initial engineering study for an advanced CCS at a new or existing Hydrogen Plant facility. These designs should provide the basis for the subsequent deployment of CCUS projects that are targeting the 45Q tax credits and will be early adopters of the technology.

Leveraging Advanced CCS for H_2 Generation


Thank You
Questions?
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