Pre-FEED Industrial FOA0002187 (FY20)
**CHALLENGE:**

- CO₂ capture from steam methane reformer flue gas at 90+% efficiency with minimum impact on cost of H₂

**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

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**Project Development and Goals- 2021**

- Capture technology tested from 2009-2017
- Basic engineering completed for a ~1.4 million tonnes CO₂/yr capture system
- Selected one of Linde’s largest SMR plants with proximity to CO₂ & H₂ storage sites

**Project Benefits**

- Recovers up to 95% of the CO₂ from the flue gas stream produced by a reformer
- Higher CO₂ content in SMR flue gas (~22% by vol. dry basis)
- Eligibility for 45Q tax credits & LCFS

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**Advanced Aqueous Amine Post-Combustion CO₂ Capture**

Steam Methane Reformer (SMR)
**CO₂ Capture from Cement Plant**

- Electricore, Inc.

**Sorbent-based Post-Combustion CO₂ Capture**

**CHALLENGE:**
- CO₂ capture from industrial 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 and plant capacity
  - Phase 2: CAPEX and OPEX estimates
- Identify plausible CO₂ storage options

**Project Development and Goals- 2021**
- Design a 1.5 mtpa capture system to remove CO₂ from cement kiln flue gas (14% conc.) & CO₂ from natural gas-fired steam generator (8.5% conc.)
- Pre-feasibility report completed

**Project Benefits**
- Reduced CAPEX.. single piece of compact equipment (rotary adsorption system) to capture & release CO₂ and regenerate the sorbent
- First commercial-scale Svante capture plant
CO₂ Capture from Steel Plant

**CHALLENGE:**
- CO₂ capture from a blast furnace producing 5 million tons per year of steel at commercial scale

**SOLUTION:**
- ION Clean Energy’s solvent-based CO₂ capture technology

**Key Process Features and Objectives**
- Complete pre-FEED analysis for ION Clean Energy capture system at Cleveland Cliffs Integrated Steel Plant
- State-of-the-art carbon capture technology with proven capture efficiencies of 90-98%
- Water-gas shift integration to increase CO₂ capture from 50% to 70%

**Project Development and Goals- 2021**
- Design a 50-70% CO₂ capture system to remove 2 million tons per year of CO₂ from blast furnace gas

**Project Benefits**
- Conversion of CO₂-striped process gases to H₂-rich fuels with higher energy value
- Production of low carbon emissions steel through the BF-Basic Oxygen Furnace route
**CO₂ Capture from Ethanol Facility**

**Challenge:**
- CO₂ capture and compression from an ethanol facility at commercial scale

**Solution:**
- Monoethanolamine (MEA) solvent-based chemical absorption & CO₂ liquefaction systems

**Key Process Features and Objectives**
- Initial engineering design & cost estimate includes installation of a hybrid capture/liquefaction system at an ethanol facility in ND
- Uses commercially-available technologies and expands on existing process design for an onsite stand-alone liquefaction system
- Utilizes existing natural gas boilers to supply steam

**Project Development and Goals - 2021**
- Completed design basis for hybrid capture at the site, with TEA and pre-FEED level cost estimates for implementation to follow
- Design for 200,000 tonnes/yr of CO₂ from both bioprocessing and heat production

**Project Benefits**
- Site provides a well-suited location to establish commercial-scale net negative CO₂ emissions
- Design produces a stream of CO₂ with low oxygen levels suitable for EOR or storage

**U.S. Department of Energy**
Fossil Energy and Carbon Management

**Trimeric Corporation**

**EERC**

**Red Trail Energy Plant, Richardton, ND**
**CHALLENGE:**
- CO₂ capture from industrial plant flue gas at commercial scale

**SOLUTION:**
- MTR’s Polaris membrane separation technology with 10X higher permeance than conventional membranes

**Key Process Features and Objectives**
- Higher CO₂ content of cement plant flue gas streams reduces capture energy costs compared to coal flue gas
- Polaris™ membranes’ permeance reduces membrane area
- Cement plant location in TX is ideal for injecting CO₂ for EOR applications

**Project Development and Goals - 2021**
- Design a capture system to treat ~2,700 tons per day of flue gas with 16% CO₂
- Builds upon prior pre-FEED & FEED studies on MTR process at coal plants

**Project Benefits**
- Higher flue gas CO₂ concentration lowers CAPEX through smaller membrane areas and OPEX through higher permeate purity
- Container-sized membrane module skids are pre-fabricated and easily scalable
Linde Inc. will complete an initial engineering design of a commercial scale CO₂ capture plant for a steam methane reformer (SMR), using the Svante VeloxoTherm™ solid adsorbent CO₂ capture technology to make blue hydrogen.

**Objectives**

The engineering design study will cover the core technology for CO₂ separation and purification, other process units inside the battery limits (ISBL) of the CO₂ capture unit to produce high pressure CO₂ ready for transport by pipeline, and balance of plant components outside the battery limits (OSBL) of the capture plant.

**Relevance and Outcomes/Impact**

Svante’s VeloxoTherm™ capture technology will target:
- \(~1,100,000\) tonnes/year net CO₂ capture
- 90% Capture Efficiency
- Production of “blue” H₂ with 99.97% purity

**Partners:**

Svante

Linde Inc.
Phillips 66

Will complete an initial engineering design of a commercial scale, advanced CO$_2$ Capture and Sequestration (CCS) plant that separates and stores CO$_2$ from an existing steam reforming plant at Phillips 66 Rodeo Refinery, California.

Location: Houston, Texas

Objectives

- Select commercially available carbon capture technologies that best suit the existing steam reforming plant.
- Evaluate the most technological and economical CCS system design.
- Further advance the engineering effort for completing the initial design for this selected CCS system such that it will have enough scope definition for proceeding into the next phase of engineering.
- The completed initial design at the conclusion of this project will provide adequate information on the engineering design, environmental considerations, and basis for the subsequent deployment of Carbon Capture, Utilization and Sequestration (CCUS) projects that are targeting the federal 45Q tax credits.

Relevance and Outcomes/Impact

- Separate & store ~190,000 tons/year net CO$_2$ from hydrogen production unit with >90% carbon capture efficiency

Partners:

Worley

Phillips 66

U.S. Department of Energy

Fossil Energy and Carbon Management
**Initial Engineering of a CO₂ Capture Unit from an ATR Producing Pure Hydrogen**

**Tallgrass MLP Operations LLC - 13316883**

Will design a commercial scale carbon capture unit installed on the Greenfield Blue Bison autothermal reforming (ATR) plant.

**Location:** Leawood, Kansas

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**Objectives**

- Combine carbon capture, pure H₂ production (220 MMSCFD at 99.97% purity), and H₂ combustion in auxiliary burners to become the largest H₂ plant with the lowest CO₂ footprint in the world.

- A successful project will facilitate the engineering of the ATR carbon capture plant which will increase the accuracy of estimating the capital costs for the project and will reduce the contingency levels in the preliminary Techno-Economic Assessment.

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**Relevance and Outcomes/Impact**

- Separate and store 1.66 million tonnes/year of 95% pure CO₂ with >97% carbon capture efficiency

- System combining carbon capture, H₂ production (220 MMSCFD at 99.97% purity), and H₂ combustion in auxiliary burners

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**Partners:**

- Tallgrass Energy
- Ten Energies
- BASF

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**U.S. Department of Energy**

**Fossil Energy and Carbon Management**
Conduct a Pre-FEED study for an ATR facility with CCS (99% efficiency) to produce $\text{H}_2$ (50 MMSCFD) at the Painter Gas Complex, WY. $\text{H}_2$ product (99.97%) will be converted to ammonia for rail export to CA. $\text{CO}_2$ will be sequestered in a nearby geological storage (300,000 Mty $\text{CO}_2$).

**8 Rivers Capital, LLC**

**Objectives**
- Evaluate process schemes ATR/CCS
- Execute Pre-FEED on a fully integrated ATR-CCS:
  - Heat exchanger reformer (HEXR)
  - Oxygen-blown autothermal reformer
  - Low-energy cryogenic $\text{CO}_2$ separation system

**Relevance and Outcomes/Impact**
- Produce clean hydrogen for less than $1/\text{kg H}_2$ with the 45Q tax credit with up to 99% Capture efficiency
- Advance the proposed flowsheet for immediate development, FEED, and financing for start of construction in 2023, commissioning in 2025, and full operations in 2026.

![Diagram of hydrogen production process](image)

**Autothermal Reforming (ATR):**
- Water Gas Shift: $\text{CH}_4 + \frac{1}{2} \text{H}_2\text{O} + \frac{4}{3} \text{O}_2 \leftrightarrow \text{CO} + 5/2 \text{H}_2$
- $\text{CO} + \text{H}_2\text{O} \leftrightarrow \text{CO}_2 + \text{H}_2$
Cement Facility Carbon Capture Using the Cryocap™ FG Process

University of Illinois at Urbana-Champaign

Complete a FEED study employing Air Liquide's Cryocap™ FG system to retrofit Holcim's Ste. Genevieve cement plant in Bloomsdale, Missouri.

Location: Champaign, IL

Cost-Share:
DOE: $3,999,585
Non-DOE: $1,000,000
Total: $4,999,585

Objectives
- Complete FEED study for retrofitting Holcim facility with a carbon capture system that removes >95% of the ~2.9 million TPY CO₂ emitted from two proximate main kiln and coal stacks.
- Employ Air Liquide’s two-step Cryocap™ process that uses PSA to preconcentrate the CO₂ in the feed stream, then a cryogenic step to purify & compress the high purity CO₂ product.
- Produce pipeline grade CO₂ for geological storage at a facility approximately 80 miles from the host site.

Relevance and Outcomes/Impact
- High capture rates (~95%) with high purity (99.9%).
- Preliminary TEA estimated the breakeven CO₂ sales price as $46-53/tonne.
- Can be used to retrofit existing plants and be deployed at new plants.

Emission locations

Kiewit

Air Liquide
Complete a FEED study to separate and capture over 950,000 tpy CO$_2$ emissions from the Shell Chemicals Complex in Deer Park, Texas, reducing overall CO$_2$ emissions by 95%.

**Location:** Blue Bell, PA

**Sub-Recipients:**

**Objectives**

- Complete a FEED study for applying CANSOLV capture technology to a chemical plant.
- Design for separating and capturing over 950,000 tonnes per year CO$_2$ at 95% capture rate.

![Process Flow Diagram of Shell's CO2 Capture Process](image-url)