Pre-FEED Industrial FOA0002187 (FY20)

CO_2 Capture from SMR Flue Gas

- Linde

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- 2021

- Capture technology tested from 2009-2017
- Basic engineering completed for a ~1.4 million tonnes CO_2/yr capture system
- Selected one of Linde's largest SMR plants with proximity to CO_2 & H_2 storage sites

Project Benefits

- Recovers up to 95% 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 & LCFS

Linde

BASF
We create chemistry

CO_2 Capture from Cement Plant

- Electricore, Inc.

Sorbent-based Post-Combustion CO_2 Capture

LafargeHolcim Portland Cement Plant in Florence, Colorado

CHALLENGE:

- CO_2 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 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.. single piece of compact equipment (rotary adsorption system) to capture & release CO_2 and regenerate the sorbent

- First commercial-scale Svante capture plant

TOTAL Kiewit LafargeHolcim ELECTRICORE POWERING THE FUTURE OXY Svante

CO_2 Capture from Steel Plant

- Dastur International, Inc.

Solvent-based Blast Furnace Gas CO_2 Capture

Cleveland Cliffs Integrated Steel Plant, in Burns Harbor, Indiana

CHALLENGE:

- CO_2 capture from a blast furnace producing 5 million tons per year of steel at commercial scale

SOLUTION:

- ION Clean Energy's solvent-based CO_2 capture technology

Project Development and Goals- 2021

- Design a 50-70% CO2 capture system to remove 2 million tons per year of CO_2 from blast furnace gas

Project Benefits

- Conversion of CO_2-stripped process gases to H_2-rich fuels with higher energy value
- Production of low carbon emissions steel through the BF-Basic Oxygen Furnace route

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 CO_2 capture from 50% to 70%

DASTUR

ION CLEAN ENERGY

CLIFFS CLEVELAND-CLIFFS INC.

TEXAS The University of Texas at Austin

CO_2 Capture from Ethanol Facility

- ***Post-Combustion CO_2 Capture via Liquefaction and Amine Solvent-Based Absorption***

Red Trail Energy Plant, Richardton, ND

CHALLENGE:

- CO_2 capture and compression from an ethanol facility at commercial scale

SOLUTION:

- Monoethanolamine (MEA) solvent-based chemical absorption & CO_2 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 CO_2 from both bioprocessing and heat production

Project Benefits

- Site provides a well-suited location to establish commercial-scale net negative CO_2 emissions
- Design produces a stream of CO_2 with low oxygen levels suitable for EOR or storage

EERC

TRIMERIC CORPORATION

RED TRAIL ENERGY L L C RICHARDTON, ND

CO_2 Capture from Cement Plant

- Membrane Technology & Research, Inc.

Membrane-based Post-Combustion CO_2 Capture

Balcones Cement Plant, New Braunfels, TX

CHALLENGE:

- CO_2 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 CO_2 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 CO_2 for EOR applications

Project Development and Goals- 2021

- Design a capture system to treat ~2,700 tons per day of flue gas with 16% CO_2
- Builds upon prior pre-FEED & FEED studies on MTR process at coal plants

Project Benefits

- Higher flue gas CO_2 concentration lowers CAPEX through smaller membrane areas and OPEX through higher permeate purity
- Container-sized membrane module skids are pre-fabricated and easily scalable

MTR MEMBRANE TECHNOLOGY & RESEARCH

CEMEX

Sargent & Lundy LLC

Pre-FEED… H_2 Generation SMR & ATR – FOA2400 (FY21)

Engineering Study of Svante's Solid Sorbent Post-Combustion CO_2 Capture Technology at a Linde Steam Methane Reforming H_2 Plant

Linde Inc.

Will complete an initial engineering design of a commercial scale CO_2 capture plant for a steam methane reformer (SMR), using the Svante VeloxoTherm™ solid adsorbent CO_2 capture technology to make blue hydrogen.

Objectives

The engineering design study will cover the core technology for CO_2 separation and purification, other process units inside the battery limits (ISBL) of the CO_2 capture unit to produce high pressure CO_2 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 CO_2 capture
- 90% Capture Efficiency
- Production of "blue" H_2 with 99.97% purity

Partners:

Svante

Linde

Initial Engineering Design Study for Advanced CO_2 Capture from Hydrogen Production Unit

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

Relevance and Outcomes/Impact

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

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

Partners:

Worley
energy | chemicals | resources

PHILLIPS 66

Initial Engineering of a CO_2 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

Relevance and Outcomes/Impact

- 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

Objectives

- Combine carbon capture, pure H_2 production (220 MMSCFD at 99.97% purity), and H_2 combustion in auxiliary burners to become the largest H_2 plant with the lowest CO_2 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.

Partners:

Process for Producing Clean Hydrogen with Autothermal Reforming and Carbon Capture

8 Rivers Capital, LLC

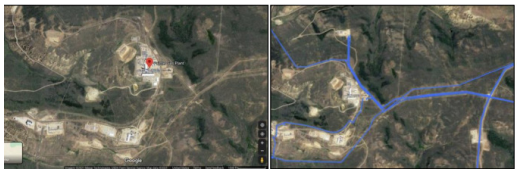
Conduct a Pre-FEED study for an ATR facility with CCS (99% efficiency) to produce H_2 (50 MMSCFD) at the Painter Gas Complex, WY. H_2 product (99.97%) will be converted to ammonia for rail export to CA. CO_2 will be sequestered in a nearby geological storage (300,000 Mty CO_2).

Relevance and Outcomes/Impact

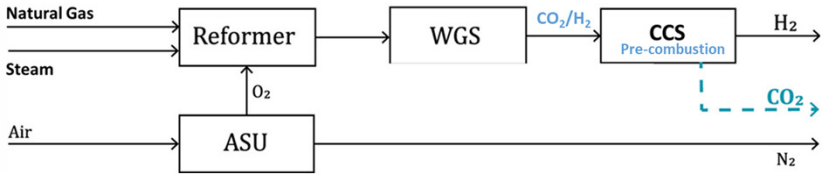
- Produce clean hydrogen for less than \$1/kg H_2 with the 45Q tax credit with up to 99% Capture efficiency
- Advance the proposed flowsheet for immediate development, FEED, and financing for start of construction in 2023, commissioning in 2025, and full operations in 2026.

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 CO_2 separation system



Painter Gas Complex, WY



Autothermal Reforming (ATR): $CH_4 + ½ H_2O + ¼ O_2 \Leftrightarrow CO + 5/2\ H2$

Water Gas Shift: $CO + H_2O \Leftrightarrow CO_2 + H_2$

FEED… Industrial – FOA2515 (FY21)

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

Relevance and Outcomes/Impact

- High capture rates (~95%) with high purity (99.9%).
- Preliminary TEA estimated the breakeven CO_2 sales price as $46-53/tonne.
- Can be used to retrofit existing plants and be deployed at new plants.

Objectives

- Complete FEED study for retrofitting Holcim facility with a carbon capture system that removes >95% of the ~2.9 million TPY CO_2 emitted from two proximate main kiln and coal stacks.[a]
- Employ Air Liquide's two-step Cryocap™ process that uses PSA to preconcentrate the CO_2 in the feed stream, then a cryogenic step to purify & compress the high purity CO_2 product.
- Produce pipeline grade CO_2 for geological storage at a facility approximately 80 miles from the host site.

Emission locations

Kiewit

LafargeHolcim

Air Liquide

Chemical Facility Carbon Capture Using CANSOLV

Wood Environment & Infrastructure Solutions, Inc.

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:

TECHNIP ENERGIES

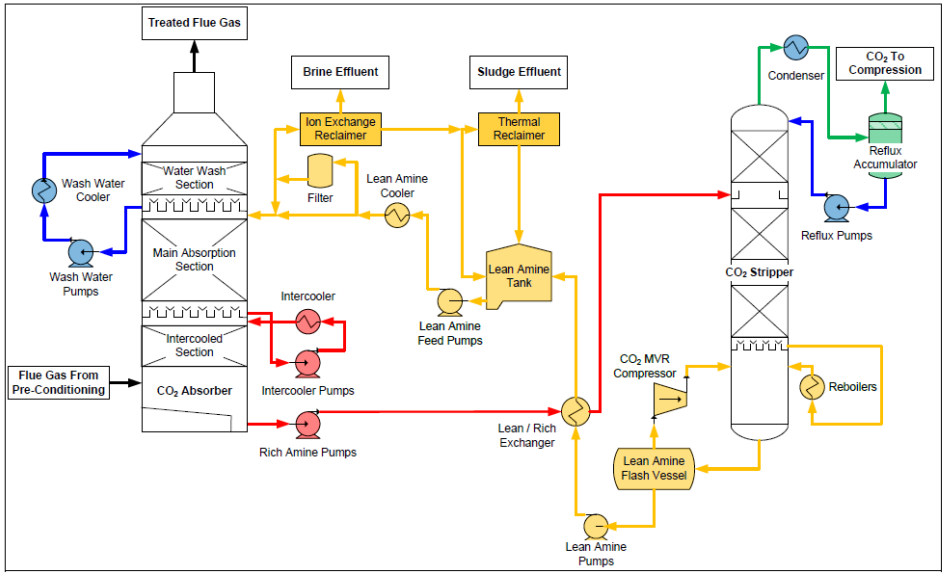
Shell

SOUTHERN STATES ENERGY BOARD

wood.

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