Large-Scale Commercial Carbon Capture Retrofit of the San Juan Generating Station

primary project goal

The overall goal of this project is to perform a front-end engineering design (FEED) study for the retrofit of the San Juan Generating Station (SJGS) with post-combustion carbon capture. The FEED study will document the initial engineering and cost estimates for the retrofit project, including the levelized cost of carbon capture on an existing plant, and provide estimates of the technical and economic viability of extending the life of the existing SJGS coal-fired power plant through the installation of Mitsubishi Heavy Industries' (MHI) Kansai Mitsubishi Carbon Dioxide Recovery (KM CDR) Process™ carbon dioxide (CO_2) capture technology. The FEED study will enable SJGS to move forward into detailed engineering, procurement, installation, and operation in future work.

technical goals

- The purpose of the FEED study is to complete preliminary engineering and design work to support developing a detailed cost estimate for the cost of retrofitting CO_2 capture at SJGS.
- The team will perform multiple feasibility and design studies based on project-specific details in preparation for developing engineering deliverables. These studies will help define the scope of the retrofit project, based on project-specific decisions, technology-specific performance, site-specific requirements, and client-specific needs.
- Once the scope has been defined, detailed design will commence for the CO_2 capture system and its integration with the existing facility. Various design and engineering deliverables will be developed that will help define commodity quantities, equipment specifications, and labor effort required to execute the project.

technical content

Enchant and its partners will perform a FEED study for retrofitting the host site with an advanced amine-based carbon capture technology. The FEED study will be performed for 847 megawatts electric (MWe; Units 1 and 4 at SJGS in Waterflow, New Mexico). The coal is supplied by the adjacent mine, San Juan Coal Company, owned by Westmoreland Holdings. The current contract expires on June 30, 2022; however, San Juan Coal has offered SJGS a new contract in support of the plant's continued operation under decarbonization. Both operating units are equipped with state-of-the-art environmental controls that meet or exceed government-permitted levels of emissions for nitrogen oxide (NO_X), sulfur dioxide (SO_2), particulate matter (PM), and mercury (Hg), making the unit carbon capture-ready from an emissions perspective.

SJGS is currently owned by a group of public utilities and municipal power entities and is operated by Public Service of New Mexico (PNM), pursuant to the Amended San Juan Participation Agreement (ASJPA). The City of Farmington (Farmington), currently a part-owner and also sub-recipient under this award, has the right under the ASJPA to acquire the 95% interest in SJGS held by all the other owners

program area:
Point Source Carbon Capture

ending scale:
FEED

application:
Post-Combustion Power Generation PSC

key technology:
Solvents

project focus:
Amine-Based KM CDR Process Retrofit to Coal-Fired Power Plant

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City of Farmington; Mitsubishi Heavy Industries America Inc.; Mitsubishi Heavy Industries Engineering Ltd.; Sargent and Lundy LLC; Navigant Consulting; EJM Associates LLC; Baker Tilly Virchow Krause LLP

start date:
10.15.2019

percent complete:
78%

effective at the termination of the existing coal contract on June 30, 2022. Prior to taking over ownership from the exiting owners on June 30, 2022, Enchant, who acquired Farmington's acquisition rights in August 2019, will manage the CO_2 capture retrofit process by virtue of the Agency Agreement with the City of Farmington. The ASJPA also provides Farmington and its agent, Enchant, the right to access the site immediately for purposes of completing this FEED study.

Work on this FEED study will produce detailed engineering designs, costing, and timelines for the construction. It will also designate permitting agencies and timelines in order to execute the follow-on build and operate project. Lessons learned during the FEED study will be documented to assist in future large-scale capture retrofit projects at coal-fired power plants.

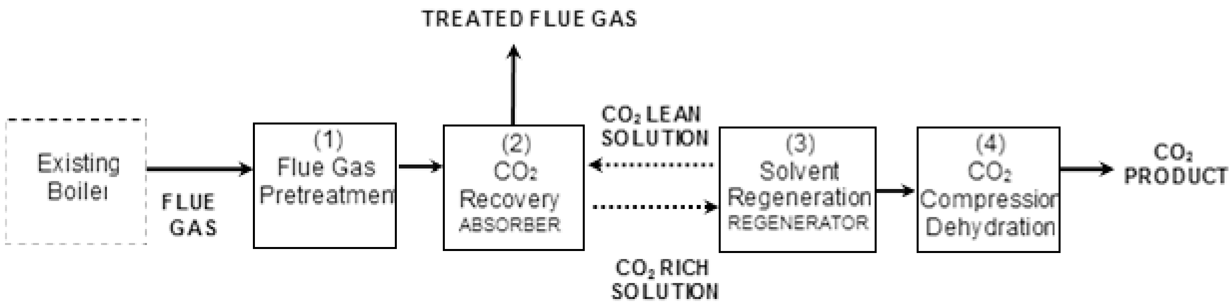

Figure 1: Block flow diagram of the CO_2 recovery plant.

The KM CDR Process has the following key features: (1) demonstrated performance on a large-scale (240 MWe); (2) high-performing amine solvent KS-1™ (high absorption capacity, low steam consumption, high resistance to oxidation and thermal degradation); and (3) key process technologies, such as an amine emission reduction system, solvent degradation reduction, automatic load adjustment control system, and amine purification system.

The CO_2 recovery facility consists of four main sections, as shown in Figure 1: (1) flue gas pretreatment, (2) CO_2 recovery, (3) solvent regeneration, and (4) CO_2 compression and dehydration. In flue gas pretreatment, the flue gas temperature is cooled in the flue gas quencher by direct contact with circulation water. The circulation water is injected with caustic soda to reduce the amount of SO_2 in the flue gas entering the amine system. A flue gas blower is installed downstream of the flue gas quencher to overcome the pressure drop across the flue gas quencher and the CO_2 absorber.

Figure 2 shows the process flow diagram for the CO_2 recovery and solvent regeneration steps. In CO_2 recovery, the cooled flue gas from the flue gas quencher is introduced at the bottom of the CO_2 absorber. The flue gas moves upward through the packing while the CO_2-lean solvent is supplied at the top of the absorption section where it flows down onto the packing. The flue gas contacts with the solvent on the surface of the packing, where 95% of the CO_2 in the flue gas is absorbed by the solvent. The CO_2-rich solvent from the bottom of the CO_2 absorber is sent to the regenerator. The CO_2-lean flue gas exits the absorption section of the CO_2 absorber and enters the flue gas washing section of the CO_2 absorber. The flue gas contacts with circulating water to reduce the carryover amine that is emitted from the top of the CO_2 absorber.

In solvent regeneration, cool-rich solvent is heated by the hot-lean solvent extracted from the bottom of the regenerator in a heat exchanger. The pre-heated rich solvent is then introduced at the top of the regenerator column and flows down over the packing, where it contacts with stripping steam. As it flows down the column, the rich solvent releases captured CO_2 and is regenerated back into lean solvent. The steam in the regenerator is produced by the reboiler, where low-pressure steam is used to heat the lean solvent. The lean solvent is then cooled to the optimum absorption temperature before being recycled back to the CO_2 absorber.

The overhead vapor leaving the regenerator is cooled, and the condensed liquid from this unit is then returned to the system. In CO_2 compression and dehydration, CO_2 is compressed through a multi-stage gas compressor. Treatment such as oxygen (O_2) removal or dehydration may be necessary to meet pipeline and storage guidelines.

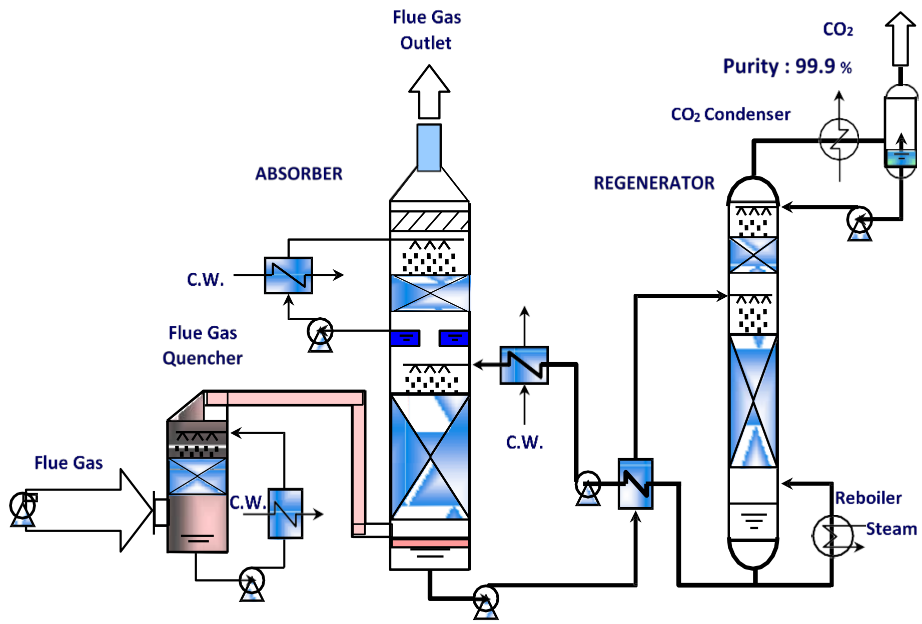

Figure 2: Carbon capture basic process flow diagram.

TABLE 1: SOLVENT PROCESS PARAMETERS

Pure Solvent	Units	Design Value
Molecular Weight	mol^{-1}	proprietary data
Normal Boiling Point	°C	proprietary data
Normal Freezing Point	°C	proprietary data
Vapor Pressure @ 15°C	bar	proprietary data
Manufacturing Cost for Solvent	$/kg	proprietary data
Working Solution		
Concentration	kg/kg	proprietary data
Specific Gravity (15°C/15°C)	-	proprietary data
Specific Heat Capacity @ STP	kJ/kg-K	proprietary data
Viscosity @ STP	cP	proprietary data
Absorption		
Pressure	bar	proprietary data
Temperature	°C	proprietary data
Equilibrium CO_2 Loading	mol/mol	proprietary data
Heat of Absorption	kJ/mol CO_2	proprietary data
Solution Viscosity	cP	proprietary data
Desorption		
Pressure	bar	proprietary data
Temperature	°C	proprietary data
Equilibrium CO_2 Loading	mol/mol	proprietary data
Heat of Desorption	kJ/mol CO_2	proprietary data
Module Design		
Flue Gas Flowrate	kg/hr	5,650,894
CO_2 Recovery, Purity, and Pressure	%/ %/ barg	95% / >95 mol% dry* / 193†
Absorber Pressure Drop	bar	proprietary data

Estimated Absorber/Stripper Cost of Manufacturing and Installation	$ / kg/hr	proprietary data

* Pipeline requirement.
† Facility fence-line pressure requirement, downstream of CO_2 pumps.

Definitions:

STP – Standard temperature and pressure (15°C, 1 atmosphere [atm]).

Pure Solvent – Chemical agent(s), working alone or as a component of a working solution, responsible for enhanced CO_2 absorption (e.g., monoethanolamine [MEA] in an aqueous solution).

Manufacturing Cost for Solvent – Estimated manufacturing cost for new solvents, or the estimated cost of bulk manufacturing for existing solvents.

Working Solution – The solute-free (i.e., CO_2-free) liquid solution used as the working solvent in the absorption/desorption process (e.g., the liquid mixture of MEA and water).

Absorption – The conditions of interest for absorption are those that prevail at maximum solvent loading, which typically occurs at the bottom of the absorption column. These may be assumed to be 1 atm total flue gas pressure (corresponding to a CO_2 partial pressure of 0.13 bar) and 40°C; however, measured data at other conditions are preferable to estimated data.

Desorption – The conditions of interest for desorption are those that prevail at minimum solvent loading, which typically occurs at the bottom of the desorption column. Operating pressure and temperature for the desorber/stripper are process-dependent (e.g., an MEA-based absorption system has a typical CO_2 partial pressure of 1.8 bar and a reboiler temperature of 120°C). Measured data at other conditions are preferable to estimated data.

Pressure – The pressure of CO_2 in equilibrium with the solution. If the vapor phase is pure CO_2, this is the total pressure; if it is a mixture of gases, this is the partial pressure of CO_2. Note that for a typical pulverized coal power plant, the total pressure of the flue gas is about 1 atm and the concentration of CO_2 is about 13.2%. Therefore, the partial pressure of CO_2 is roughly 0.132 atm or 0.130 bar.

Concentration – Mass fraction of pure solvent in working solution.

Loading – The basis for CO_2 loadings is moles of pure solvent.

Estimated Cost – Basis is kg/hr of CO_2 in CO_2-rich product gas; assuming targets are met.

Flue Gas Assumptions – Unless noted, flue gas pressure, temperature, and composition leaving the FGD unit (wet basis) used in the FEED study design basis should be assumed as:

Pressure	Temperature	Composition						
		vol%					ppmv	
psia	°F	CO_2	H_2O	N_2	O_2	Ar	SO_x	NO_x
11.97	127	9.93	17.16	66.91	5.98	—	19.2	106

Chemical/Physical Solvent Mechanism – Chemical absorption

Solvent Contaminant Resistance – Low solvent degradation.

Solvent Foaming Tendency – Ordinary.

Flue Gas Pretreatment Requirements – Desulfurization.

Solvent Makeup Requirements – Periodically.

Waste Streams Generated – Reclaimed waste.

Process Design Concept – Block flow/process flow diagrams shown in Figures 1 and 2.

Proposed Module Design – Partial Module Design.

TABLE 2: POWER PLANT CARBON CAPTURE ECONOMICS

Economic Values	Units	Target Value ($2019) [1] (@ 85% Capacity Factor)
Total Project Cost	$	1,295,280,000
Capital Annualization Factor	--	0.1243
Annualized Capital Cost	$/yr	161,000,000
Annual O&M Cost	$/yr	99,939,000
Total Annual Cost	$/yr	260,939,000
CO_2 Captured	mmscfd	312.45
Annual CO_2 Captured	tonnes	6,000,000
Cost of Carbon Captured	$/tonne	43.49

[1] Note that target values are based on the pre-feasibility study performed prior to the DOE award (July 2019) as the project team has not finished capital and O&M cost development deliverables.

Definitions:

Cost of Carbon Captured – Projected cost of capture per mass of CO_2 captured under expected operating conditions.

Calculations Basis – The economic calculation performed for the pre-feasibility study utilized many similar references as the Performance Baseline for Fossil Energy Plants Volume 1: Bituminous Coal and Natural Gas to Electricity report Rev 2 and 3, including similar annualization factor for high-risk capital investment and 85% referenced capacity factor. Overall economics were developed using AACE Class 5 accuracy for retrofitting the existing San Juan Generating Station Units 1 and 4. For all calculation basis information, refer to the publicly available study "Enchant Energy, San Juan Generating Station – Units 1 & 4, CO_2 Capture Pre-Feasibility Study, FINAL."

Scale of Validation of Technology Used in TEA – Costs were developed using publicly available cost information for commercially available amine-based solvent systems scaled for the size and characteristics of the SJGS facility. For information regarding capital cost development, refer to the publicly available study "Enchant Energy, San Juan Generating Station – Units 1 & 4, CO_2 Capture Pre-Feasibility Study, FINAL."

Qualifying Information or Assumptions – Information prepared during the pre-feasibility study was not prepared in conjunction with MHI for the KM-CDR™ Process. Costing was based on 90% capture for the flue gas design basis provided in the pre-feasibility report, not herein. For all assumptions used to develop these costs, refer to the publicly available study "Enchant Energy, San Juan Generating Station – Units 1 & 4, CO_2 Capture Pre-Feasibility Study, FINAL."

technology advantages

- FEED studies for carbon capture systems at this site will provide the U.S. Department of Energy (DOE) with a more detailed understanding of carbon capture costs in a commercial application, thereby enabling DOE to better design its research and development (R&D) program to reduce those costs for similar carbon capture technologies being developed in its R&D portfolio.
- This FEED study could lead to the largest carbon capture project in the world, and with its 95% CO_2 capture rate, it could be the lowest-emitting CO_2-per-MWh large-scale, fossil-fueled power plant.
- Adding carbon capture technology will allow SJGS to meet and exceed the stringent CO_2 emissions standards of the New Mexico Energy Transition Act and will also allow for electricity sales delivered across the west, including into California under its stringent decarbonization standards.

R&D challenges

- To deploy the post-combustion amine technology on coal-fired gas while adequately managing accumulation of impurities in the exhaust without excessive cost.
- Ensuring reliable operation over a long period at large scale.

status

The design basis documents were completed, including flow diagrams, heat and material balances, equipment and instrument lists, and the preliminary plot plan. Stack testing was performed to optimize CO_2 recovery and modest design changes are expected to increase the CO_2 capture percentage from 90% warranted to the target of 95%. A hazard and operability study (HAZOP) was completed. Balance of plant planning, design, and engineering are ongoing to incorporate the CO_2 capture technology into the existing SJGS facility. Various studies and investigations are underway to provide key decisions on scope of work or selection of project-specific needs. A report of carbon production intensity was completed.

available reports/technical papers/presentations

"Preliminary Assessment of Post-Combustion Capture of Carbon Dioxide at the San Juan Generating Station: An Independent Assessment of a Pre-feasibility Study Conducted by Sargent & Lundy for Enchant Energy,"12 December 2019, Los Alamos National Laboratory. *https://www.lanl.gov/science-innovation/science-programs/applied-energy-programs/_assets/docs/preliminary-technical-assessment-december2019.pdf*.

"Enchant Energy, San Juan Generating Station – Units 1 & 4, CO_2 Capture Pre-Feasibility Study, FINAL," July 8, 2019, Project No. 13891-001, Prepared by Sargent & Lundy. *https://www.enchantenergy.com/wp-content/uploads/2019/07/Enchant-Energy_SJGS-CO2-Pre-feasibility-Study_FINAL-Rev-0-7-8.pdf*.

"Large-Scale Commercial Carbon Capture Retrofit of the San Juan Generating Station," DOE Project Kickoff Meeting, May 22, 2020. *https://www.netl.doe.gov/projects/plp-download.aspx?id=10879&filename=Large-Scale+Commercial++Carbon+Capture+Retrofit+of+the++San+Juan+Generating+Station.pdf.*

"Large-Scale Commercial Carbon Capture Retrofit of the San Juan Generating Station," 2020 NETL Project Review Meeting - CCUS Integrated Projects, August 17, 2020. *https://netl.doe.gov/sites/default/files/netl-file/20CCUS_Selch.pdf*.

"Update on Large-Scale Commercial Carbon Capture Retrofit of the San Juan Generating Station," 2021 NETL Carbon Management and Oil and Gas Research Project Review Meeting - Integrated CCUS Projects and FEED Studies, August 2, 2021. *https://netl.doe.gov/sites/default/files/netl-file/21CMOG_CCUS_Mandelstam.pdf*.