Full-Scale FEED Study For a 816 MWe Capture Plant at the Prairie State Generating Company Using Mitsubishi Heavy Industries of America Technology

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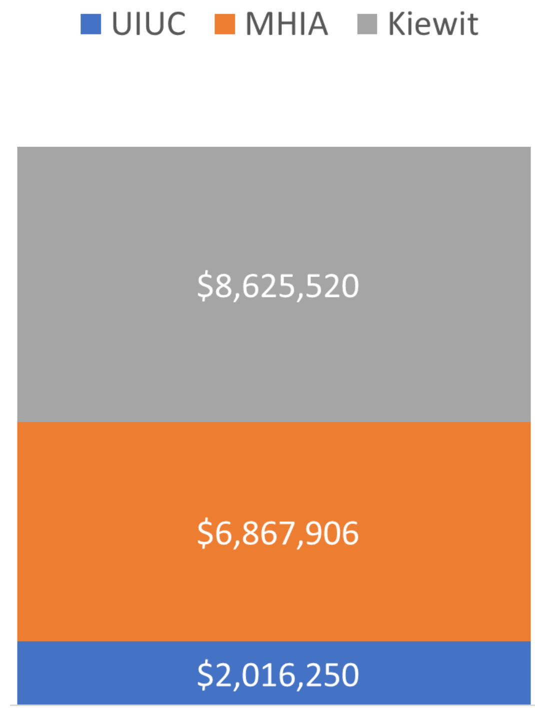
<u>PROJECT OVERVIEW</u>

Funding: $17,509,676

DOE: $14,004,676

20% Cost Share: $3,505,000 (PSGC)

Work Period: 1 Jan 2020 – 31 Dec 2021



<u>PROJECT OBJECTIVES</u>:

Overall: Perform a Front-End Engineering Design (FEED) study for the retrofit of the Prairie State Generation Company's (PSGC) coal-fired power plant with post-combustion carbon capture. The FEED study will outline the use of Mitsubishi Heavy Industries' (MHI) Advanced KM CDR Process™ to retrofit one of PSGC's two generating units (approximately 816 MWe). The FEED study will enable PSGC to move forward with actual build/operate in future work.

Project Team Management Structure

Well-defined roles based on relevant capabilities

Prairie State Generating Company

PSGC Host Site

- 816 MWe Pulverized Coal-fired Plant
- Equipped with FGD, ESP, baghouse, SCR

Illinois Prairie Research Institute

AWARDEE

University of Illinois (UIUC)

Dr. Kevin C OBrien

Dr. Yongqi Lu

- Project management
- Host site coordination
- Permitting /regulatory concerns
- Assist with technology commercialization

Steering Committee

- *Don Gaston, PSGC-CEO, Chair*
- *Kevin C OBrien, UIUC*
- *Yongqi Lu, UIUC*
- *Alyssa Harre, PSGC Communications & Government Relations Director*
- *Helen Gallagher, PSGC General Counsel*
- *Tim Thomas MHIA*
- *Paula Guletsky, S&L*
- *Matthew Thomas, Kiewit*
- *J. Todd Morley, Chairman, G2 Investment Group*
- *Dick Gephardt, CEO, The Gephardt Group.*

Mitsubishi Heavy Industries America, Inc.

SUBAWARDEE

Mitsubishi Heavy Industries America, Inc. (MHIA)

- ISBL detailed design and engineering of CC components

Mitsubishi Heavy Industries Engineering

Mitsubishi Heavy Industries Engineering

Kiewit

SUBAWARDEE

Kiewit Engineering Group Inc.

- OSBL detailed design
- ISBL and OSBL capital cost estimates
- Operating and maintenance costs estimates
- Assist with procurement and construction timeline

Sargent & Lundy LLC

Sargent & Lundy

- OSBL preliminary design

Kiewit | Mitsubishi Heavy Industries America | Illinois Prairie Research Institute | Prairie State Generating Company | National Energy Technology Laboratory | U.S. Department of Energy

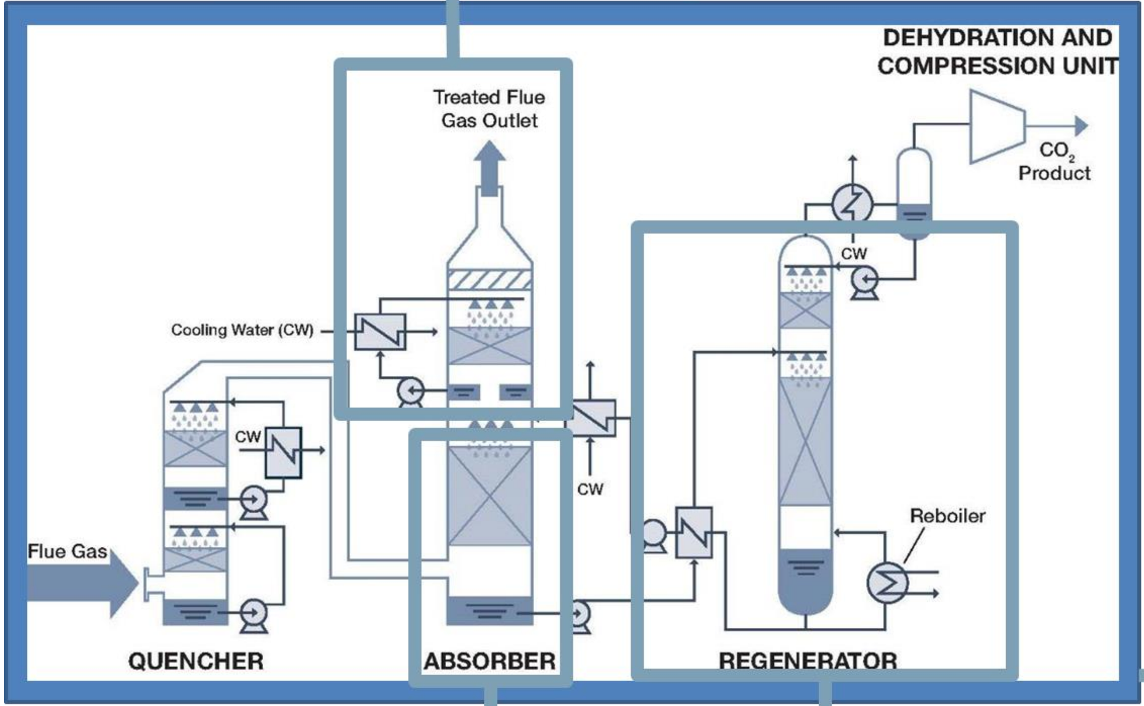
FRONT-END ENGINEERING DESIGN STUDIES FOR CARBON CAPTURE SYSTEMS ON COAL AND NATURAL GAS POWER PLANTS

TECHNICAL BACKGROUND

Solvent and System Designed for Improved Performance

Benefits over other capture options

Amine washing system reduces VOC emissions and amine loss



Proven at the 240 MWe level now enhanced with an advanced solvent to produce an even more cost-effective solution for carbon capture. Vital when scaling to an 816 MWe capture plant.

- Automatic load adjustment control
- Amine filtration and purification systems
- Proven tower design for even gas/liquid distribution

KS-21™ solvent which has similar characteristics to KS-1™ but is more stable

Heat integration system to reduce steam consumption

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Project Technology Development 1990 - present

Matured and ready for proposed large scale testing

- Began R&D with Kansai Electric Power Co. - **1990**
- 2 tpd pilot plant at KEPCO's Nanko Power Station - **1991**
- Developed KS-1™ and KM CDR Process™ - **1994**
- **1999** - 200 tpd plant in Malaysia
- 1 tpd coal pilot test at Hiroshima R&D Center - **2002**
- Developed proprietary energy efficient process - **2003**
- **2005** - 330 tpd plant in Japan
- 10 tpd coal pilot test at Matsushima - **2006**
- **2006** - two 450 tpd plants in India
- Large absorber flow test at Mihara works - **2008**
- **2009** - 450 tpd plant in India; 450 tpd plant in Bahrain
- **2010** - 400 tpd plant in UAE; 240 tpd plant in Vietnam
- **2011** - 340 tpd plant in Pakistan
- Plant Barry 500 tpd demonstration project – **2011-2014**
- **2012** - 450 tpd plant in India
- **2014** - 500 tpd plant in Qatar
- **2016** - **Petra Nova Project** – 4,776 tpd plant in Texas

Opportunity to Evaluate Improved Solvent (KS-21)

Many advantages over the solvent used at Petra Nova (KS-1™)

Parameters Relative to KS-1™	KS-1™	KS-21™
Volatility	100	50-60
Thermal degradation rate	100	30-50
Oxidation rate	100	70
Heat of absorption	100	85

✓ **Thermal stability**

- Reduce thermal degradation and allow higher stripping T and P, reducing compression work

✓ **Oxidative stability**

- Potentially more tolerant to impurities
- Reduce amine oxidation and HSS formation rate

✓ **Volatility**

- Reduce amine loss from emission and cost of water wash system
- Steam consumption savings outweigh cost increases due to higher solvent circulation

Key Activity

TECHNICAL APPROACH / PROJECT SCOPE

Project Tasks

Designed to address deliverables and transition to actual build / operate

Task #	Task
1.0	Project Management and Planning
2.0	Front-End Engineering Design (FEED) Study
2.1	Design Basis
2.2	Preliminary Engineering
2.3	ISBL Detailed Engineering
2.4	OSBL Detailed Engineering
2.5	Studies and Investigations
2.6	Cost Assessment
3.0	Regulatory and Permitting at Host Site
4.0	Final FEED Study Package

Project Milestones

Task / Subtask #	Deliverable Title	Due Date
~~1.0~~	~~Project Management Plan Update~~	~~3/3/2020~~
2.0	Design Basis Document Complete	10/30/20
2.0	Report on Utility Requirements	11/19/20
3.0	Preliminary Regulatory and Permitting Pathway	2/18/21
2.0	HAZOP Review	4/30/21
2.0	Impact on Kaskaskia Watershed Document Complete	5/28/21
2.0	Constructability Review Complete	6/30/21
3.0	Regulatory and Permitting Analysis Complete	8/6/2021
2.0	Detailed Engineering Document Complete	11/30/21
4.0	Final Report Submitted	12/31/21
4.0	FEED Study Package Complete	12/31/21

Risk & Mitigation Strategy

Description of Risk	Probability	Impact	Risk Management Mitigation and Response Strategies
Technical / Scope Risks			
Insufficient water supply	Low	Low	• Studies outlined in SOPO - explore various options to source the cooling and makeup the cooling and makeup water demands of the capture system including supply from host site vs. an external source.
Uncertainty associated with the need of identifying steam and electric sourcing	Low	Low	• Studies outlined in SOPO - explore options to address these issues. Can apply learnings from Petra Nova Project.
Costs / Schedule Risks			
Project cost and/or schedule overruns	Low	High	• Team has previous experience conducting FEED studies on budget and on time
Management / Planning Risks			
Availability of key personnel for project	Low	Medium	• Commitments received from partner organizations
Uncertainty of permitting agencies and timelines	Low	Low	• Meetings with relevant agencies for previous projects enabled baseline knowledge for timelines and requirements
EH&S Risks			
Air (amine and CO_2) emission management	Low	Low	• Leverage experience from Petra Nova Project to meet strict VOC permit requirements • Built into ISBL design criteria
Wastewater stream management	Low	Medium	• Studies outlined in SOPO – explore options to address these issues
External Factors Risks			
Negative stakeholder response to FEED study	Low	Low	• Discussions with elected officials have received very positive support
Financial Risks			
Cost share for project not obtained or insufficient	Low	High	• Cost share authorized by host site's Board of Directors • Host site is financially stable

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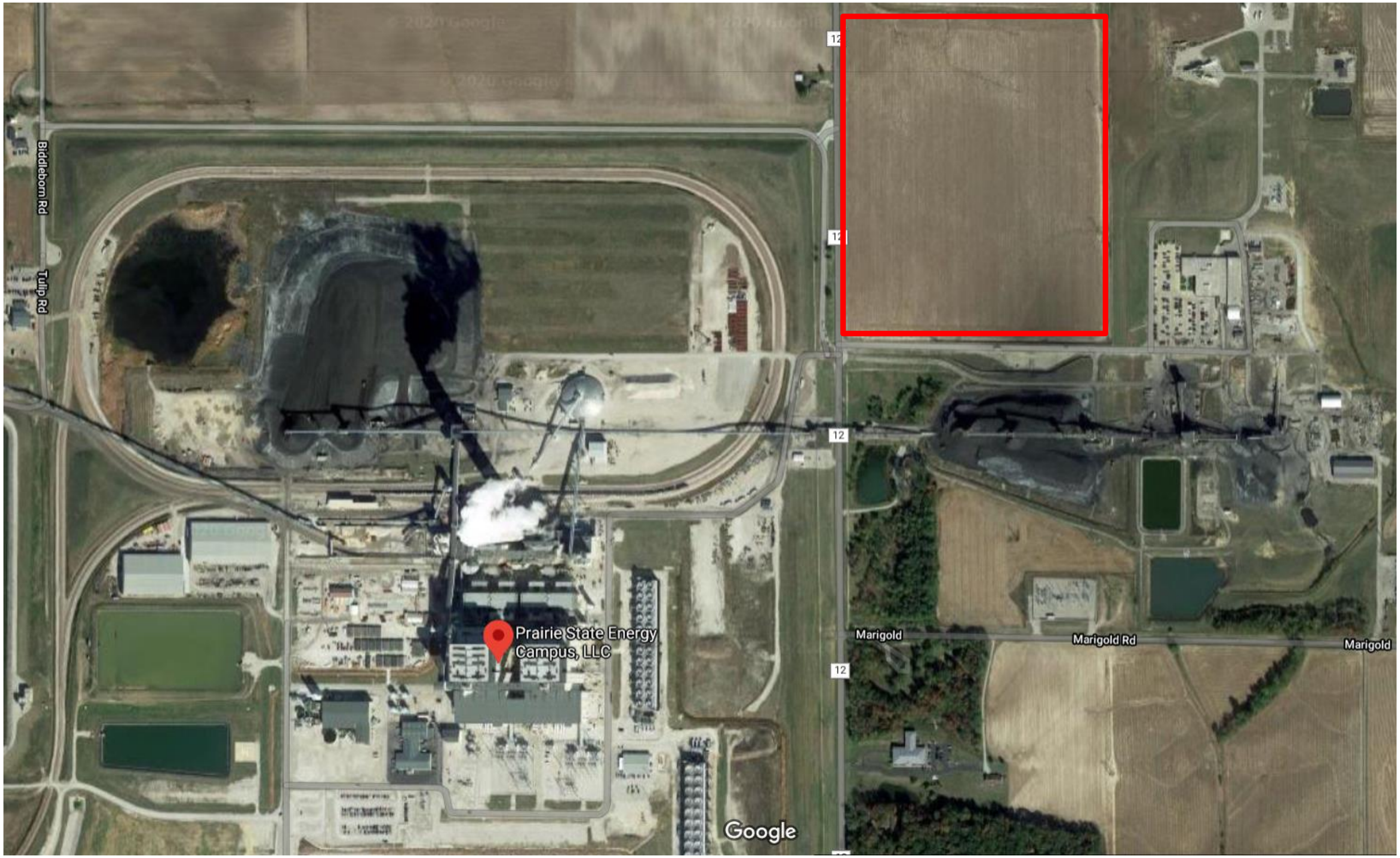
Key Activity

DESIGN BASIS

FEED Design Basis Overview

- Build Location at PSGC
  - CC Unit Footprint Concept
- OSBL / ISBL Design Basis
- CO_2 Product Specification
- Flue Gas Measurement
- Flue Gas Desulfurization (FGD) Selection
- Preliminary List of Waste Streams
- Steam and Electric Sourcing Study
- Transportation Study
- Estimate of Water Needs
  - Water Sourcing Options
  - Water Storage

Carbon Capture Unit Site Location



Source: Google Earth

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Design Basis

OSBL and ISBL Design Basis

- Design basis is nearly set, pending results from flue gas stack testing

CO_2 Product Specification

- The Carbon Capture Team worked with the CarbonSAFE team to select an appropriate CO_2 product specification that will allow for sequestration at various potential sites and for other beneficial use

Design Basis

Flue Gas Measurement

- Flue gas composition was analyzed at various operating conditions. The results will be used to determine design parameters

Flue Gas Desulfurization Selection

- Integrated FGD system that uses caustic soda

Preliminary Waste Streams

- Compiling a list of waste streams to work with regulators

Design Basis

Steam and Electric Sourcing Study

- Cogeneration; Steam and Electricity
- Auxiliary Boiler
  - Purchasing electricity from the grid

Transportation Study

- Evaluate the transportation infrastructure around PSGC to assess the routes for shipping materials and determine the maximum dimensions/weight for the equipment that will be shipped to the build site

Considerations Based on Estimate of Water Needs

Water Sourcing Options

- Community water supply reservoirs
- Tributary streams
- Groundwater in the Kaskaskia River valley
- Federal lakes (Lake Shelbyville and Carlyle Lake)

Water Storage

- 25-year Drought conditions
  - 26 days without being able to draw water
  - Reviewing options for mitigating risk

Key Activity

NEXT STEPS

Moving Forward

- Preliminary Engineering
- OSBL / ISBL Detailed Engineering
- Completion of all Studies and Investigations
  - HAZOP
  - Constructability
  - Impact on Kaskaskia Watershed
- Determine Regulatory and Permitting Pathway

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Matt Thomas, Alison Brown, Bob Slettehaugh	Kiewit Engineering Group
Paula Guletsky, Anthony Baker	Sargent & Lundy

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