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

Kevin C O'Brien, PhD
Director, Illinois Sustainable Technology Center
Director, Illinois State Water Survey
Prairie Research Institute
University of Illinois at Urbana-Champaign

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Cooperative Agreement No. DE-FE0031841

PROJECT OVERVIEW

Funding: $17,509,676
DOE: $14,004,676
20% Cost Share: $3,505,000 (PSGC)
Work Period: 1 Jan 2020 – 31 Dec 2021

PROJECT OBJECTIVES:

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 O'Brien
Dr. Yongqi Lu
- Project management
- Host site coordination
- Permitting/regulatory concerns
- Assist with technology commercialization

MITSUBISHI
SUBAWARDEE
Mitsubishi Heavy Industries America, Inc. (MHIA)
- ISBL detailed design and engineering of CC components

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

MITSUBISHI HEAVY INDUSTRIES ENGINEERING
Mitsubishi Heavy Industries Engineering

Sargent & Lundy
- OSBL preliminary design

Steering Committee
- Don Gaston, PSGC-CEO, Chair
- Kevin C O'Brien, 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
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.

- **KS-21™ solvent** which has similar characteristics to KS-1™ but is more stable
- **Heat integration** system to reduce steam consumption

- Automatic load adjustment control
- Amine filtration and purification systems
- Proven tower design for even gas/liquid distribution
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
- 2006 - two 450 tpd plants in India
- 10 tpd coal pilot test at Matsushima - 2006
- 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
- 2012 - 450 tpd plant in India
- Plant Barry 500 tpd demonstration project – 2011-2014
- 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™)

<table>
<thead>
<tr>
<th>Parameters Relative to KS-1™</th>
<th>KS-1™</th>
<th>KS-21™</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volatility</td>
<td>100</td>
<td>50-60</td>
</tr>
<tr>
<td>Thermal degradation rate</td>
<td>100</td>
<td>30-50</td>
</tr>
<tr>
<td>Oxidation rate</td>
<td>100</td>
<td>70</td>
</tr>
<tr>
<td>Heat of absorption</td>
<td>100</td>
<td>85</td>
</tr>
</tbody>
</table>

✓ **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*

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

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

<table>
<thead>
<tr>
<th>Description of Risk</th>
<th>Probability</th>
<th>Impact</th>
<th>Risk Management Mitigation and Response Strategies</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Technical / Scope Risks</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Insufficient water supply</td>
<td>Low</td>
<td>Low</td>
<td>• Studies outlined in SOPO - explore various options to source the cooling and makeup water demands of the capture system including supply from host site vs. an external source.</td>
</tr>
<tr>
<td>Uncertainty associated with the need of identifying steam and electric sourcing</td>
<td>Low</td>
<td>Low</td>
<td>• Studies outlined in SOPO - explore options to address these issues. Can apply learnings from Petra Nova Project.</td>
</tr>
<tr>
<td><strong>Costs / Schedule Risks</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Project cost and/or schedule overruns</td>
<td>Low</td>
<td>High</td>
<td>• Team has previous experience conducting FEED studies on budget and on time</td>
</tr>
<tr>
<td><strong>Management / Planning Risks</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Availability of key personnel for project</td>
<td>Low</td>
<td>Medium</td>
<td>• Commitments received from partner organizations</td>
</tr>
<tr>
<td>Uncertainty of permitting agencies and timelines</td>
<td>Low</td>
<td>Low</td>
<td>• Meetings with relevant agencies for previous projects enabled baseline knowledge for timelines and requirements</td>
</tr>
<tr>
<td><strong>EH&amp;S Risks</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Air (amine and CO₂) emission management</td>
<td>Low</td>
<td>Low</td>
<td>• Leverage experience from Petra Nova Project to meet strict VOC permit requirements</td>
</tr>
<tr>
<td>Wastewater stream management</td>
<td>Low</td>
<td>Medium</td>
<td>• Built into ISBL design criteria</td>
</tr>
<tr>
<td><strong>External Factors Risks</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Negative stakeholder response to FEED study</td>
<td>Low</td>
<td>Low</td>
<td>• Studies outlined in SOPO – explore options to address these issues</td>
</tr>
<tr>
<td><strong>Financial Risks</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost share for project not obtained or insufficient</td>
<td>Low</td>
<td>High</td>
<td>• Cost share authorized by host site’s Board of Directors</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Host site is financially stable</td>
</tr>
</tbody>
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Kiewit  
Mitsubishi Heavy Industries America  
Illinois Prairie Research Institute  
Prairie State Generating Company  
National Energy Technology Laboratory  
U.S. Department of Energy
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
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
## Acknowledgements

<table>
<thead>
<tr>
<th>Name</th>
<th>Organization</th>
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<tr>
<td>Andrew Jones</td>
<td>National Energy Technology Laboratory / US Department of Energy</td>
</tr>
<tr>
<td>Don Gaston, Javier Arzola, Rich Meyer</td>
<td>Prairie State Generating Company</td>
</tr>
<tr>
<td>Yongqi Lu, Vinod Patel, Stephanie Brownstein, Jason Dietsch, Jason (Zhenxing) Zhang</td>
<td>Prairie Research Institute / University of Illinois Urbana-Champaign</td>
</tr>
<tr>
<td>Tiffany Wu, Tim Thomas, Cole Maas</td>
<td>MHIA</td>
</tr>
<tr>
<td>Keisuke Iwakura, Shintaro Kiuchi</td>
<td>MHIENG</td>
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<td>Matt Thomas, Alison Brown, Bob Slettehaugh</td>
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