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

Jason Dietsch
Assistant Research Engineer
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

**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

**Steering Committee**
• Don Gaston, PSGC-CEO, Chair
• Kevin C O'Brien, UIUC
• Yongqi Lu, UIUC
• Alyssa Harre, PSGC Communications & Government Relations Director
• Helen Gallogher, 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

**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**
• OSBL preliminary design

**MITSUBISHI HEAVY INDUSTRIES ENGINEERING**
Mitsubishi Heavy Industries Engineering
FRONT-END ENGINEERING DESIGN STUDIES FOR CARBON CAPTURE SYSTEMS ON COAL AND NATURAL GAS POWER PLANTS

TECHNICAL BACKGROUND
Mitsubishi Heavy Industries’ (MHI) Advanced KM CDR Process™
Project Technology Development 1990 - present

- 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)

<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

<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>
</tr>
</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>
</table>
Key Activity

PROGRESS AND CURRENT STATUS
Carbon Capture Facility Location

Source: Google Earth
Carbon Capture Facility Location
Carbon Capture Facility Location
Duct Tie-in
OSBL
• Duct Tie-in
• Ductwork to facility
• Auxiliary Boilers
• Cooling Tower
• Administration Building
• Water Treatment
• Wastewater Treatment
• Raw Water Pipeline
• Raw Water Storage Pond
• Storage Tanks
• Utility Systems
• Fire Protection Layout
• Roads and Storm Drainage
• Site Lighting

ISBL
• Draft Fan
• Flue Gas Quencher
• Absorber
• Regenerator
• Product Compressor
Studies

Steam and Electric Sourcing Study
• Auxiliary Boiler
  – Purchasing power from the grid

Transportation Study
• Identified and evaluated transportation routes to bring equipment and modules to the site

Water Supply Study
• Draw raw water from the Kaskaskia River
• Build a storage pond for drought conditions
Studies

Water and Wastewater Treatment Study
• Selected the systems for treatment of incoming raw water and exiting wastewater

Cooling Water System Study
• Closed loop system with draft cooling tower

Compressor System Overpressure Relief
• Evaluation of overpressure relief locations long the compression path
Studies

Constructability Review

- Evaluate and identify construction access, lay-down areas, lift plans, and sequencing of construction work

Project Execution Schedule

- A detailed project schedule will be developed to aid in the overall construction timeline and costs associated with the contractors

Hazard and Operability (HAZOP) Review

- An in-depth examination of the ISBL section to identify and evaluate any process or equipment risks. Recommendations for changes to the system design or operation will be made based on the HAZOP findings
Key Activity

REMAINING TASKS
Moving Forward

• Continued Review of Design to Identify Ways to Lower Costs
• Contracting/Procurement Strategy
• Project Capital Cost Estimate (+/- 15%)
• Completion of Regulatory and Permitting Analysis
• FEED Study Package Completed
• Submission of Final Report
## Acknowledgements

<table>
<thead>
<tr>
<th>Name</th>
<th>Organization</th>
</tr>
</thead>
<tbody>
<tr>
<td>Andrew Jones</td>
<td>National Energy Technology Laboratory / U.S. Department of Energy</td>
</tr>
<tr>
<td>Don Gaston, Javier Arzola, Rich Meyer</td>
<td>Prairie State Generating Company</td>
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<td>Kevin O’Brien, Yongqi Lu, Vinod Patel, Stephanie Brownstein, Jason (Zhenxing) Zhang, Jason Dietsch</td>
<td>Prairie Research Institute / University of Illinois Urbana-Champaign</td>
</tr>
<tr>
<td>Tim Thomas, Tiffany Wu, Cole Maas</td>
<td>MHIA</td>
</tr>
<tr>
<td>Keisuke Iwakura, Shintaro Kiuchi</td>
<td>MHIENG</td>
</tr>
<tr>
<td>Matt Thomas, Alan Donovan, Bob Slettehaugh, Bryan Lofgreen</td>
<td>Kiewit Engineering Group</td>
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