Front-End Engineering & Design: Project Tundra Carbon Capture System

Gerry Pfau
Minnkota Power Cooperative

U.S. Department of Energy
National Energy Technology Laboratory
Carbon Management and Natural Gas & Oil Research Project Review Meeting
Virtual Meetings August 2 through August 31, 2021
# Funding and Cost Profile

<table>
<thead>
<tr>
<th></th>
<th>2019</th>
<th>2020</th>
<th>2021</th>
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<tr>
<td></td>
<td>Oct-Dec</td>
<td>Jan-Mar</td>
<td>Apr-Jun</td>
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<td><strong>Baseline Cost Plan</strong></td>
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<td>Federal Share</td>
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<td>Nonfederal Share</td>
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<td>26,600</td>
<td>111,001</td>
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<tr>
<td><strong>Total</strong></td>
<td>27,063</td>
<td>133,001</td>
<td>555,004</td>
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<tr>
<td>Cumulative Federal</td>
<td>21,650</td>
<td>128,051</td>
<td>572,054</td>
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<tr>
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<td>5,413</td>
<td>32,013</td>
<td>143,014</td>
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<tr>
<td>Cumulative Total</td>
<td>27,063</td>
<td>160,064</td>
<td>715,068</td>
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<tr>
<td><strong>Actual Incurred Cost</strong></td>
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New budget under development with recently approved extension to 12/31/21
Performance Dates, Project Team and Objective

Project Performance Dates
12/19/19 – 12/31/21

Objective
Complete a FEED study on the addition of post-combustion CO₂ capture for the Milton R. Young Station’s Unit 2 (MRY2)

Project Team

David Greeson Consulting
Hunt International Energy Services
Capture Technology: Fluor’s Econamine FG Plus℠

Site: Milton R. Young Station Unit 2, 455 MW, lignite

MRYS is uniquely suited:

- Very high historical and projected capacity factor
- State of ND is extremely supportive and has been a leader in development of policy to incentivize carbon capture, utilization & storage
- Unique Williston Basin geology: EOR and saline storage both opportunities
Integration and Economics

- **Integration**: Both steam cycle integration and natural gas boilers were considered in this project. Economics from pre-FEEDs were comparable, but gas boilers offered more flexibility and lower risk to overall project. Recent cost updates from the FEED have put steam extraction back on the table.

- **Storage**: Saline formation geologic storage directly beneath MRYS and surrounding area.

- **Economics**: Targets set based on $50/ton 45Q tax credit
  - Economy of scale: ~2.5X size of Petra Nova in a single train design
  - Preliminary financial modeling shows 45Q can be sufficient to finance the project without increasing member electricity rates
  - FEED cost estimate to be converted to lump sum EPC price
Milestones & Success Criteria

<table>
<thead>
<tr>
<th>Task No.</th>
<th>Description</th>
<th>Planned Completion Date</th>
<th>Actual Completion Date</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>Cooperative Agreement Signed</td>
<td>12/19/2019</td>
<td>12/19/2019</td>
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<tr>
<td>2</td>
<td>Design Manual Completed</td>
<td>02/28/2020</td>
<td>02/10/2020</td>
</tr>
<tr>
<td>3</td>
<td>Permitting Meeting with NDDEQ*</td>
<td>07/30/2020</td>
<td>07/29/2020</td>
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<tr>
<td>3</td>
<td>Permitting Strategy Finalized</td>
<td>05/31/2021</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>FEED Report Submitted</td>
<td>11/30/2021</td>
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</table>

Success Criteria

- Sufficient detail for a decision on the commercial project
- Sufficient detail to provide all technical information necessary for permitting
- Completion of design basis for post-combustion capture at MRY2
- Accurate FEED-level cost estimate for simple transition to lump sum EPC
- Support a pathway to achieve DOE cost of capture goals of $30/tonne by 2030

* ND Department of Environmental Quality
# Significant Project Risks and Mitigation Strategies*

<table>
<thead>
<tr>
<th>Perceived Risk</th>
<th>Probability</th>
<th>Impact</th>
<th>Overall</th>
<th>Mitigation Strategy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Personnel availability</td>
<td>Low</td>
<td>High</td>
<td>Low</td>
<td>Capitalize on internal Minnkota expertise to support project objectives.</td>
</tr>
<tr>
<td>Insufficient budget to meet objectives</td>
<td>Low</td>
<td>Medium</td>
<td>Low</td>
<td>The scope of work has been scaled to fit the existing budget.</td>
</tr>
<tr>
<td>Site accessibility</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Minnkota personnel are available to provide site and data access.</td>
</tr>
<tr>
<td>Unforeseen Risks, e.g., natural disasters; social, legal, or technical challenges</td>
<td>Low</td>
<td>Medium</td>
<td>Low</td>
<td>Regular updates with DOE and project partners will help solve issues as they arise.</td>
</tr>
</tbody>
</table>

* Note: This is a paper/desktop study, and therefore all risks identified have low overall risk rating
Project Tasks

• **Task 1** – Project Management and Planning

• **Task 2** – Engineering and Design
  – Subtask 2.1 – Project Design Basis
  – Subtask 2.2 – Carbon Capture System (CCS) Design
  – Subtask 2.3 – Steam Source Selection & Design
  – Subtask 2.4 – BOP Integration and Design

• **Task 3** – Development of Permitting Strategies
  – Subtask 3.1 – Air Emissions
  – Subtask 3.2 – Water Discharge
  – Subtask 3.3 – Waste Disposal Planning

• **Task 4** – Project Tundra Cost Estimating
Task 1 – Project Management and Planning

• New vendors; Nels Consulting, Siemens Energy and General Electric, added to assist in the engineering and design work under Task 2

• Reviewing impact of project completion delays on schedule and budget
Project design basis

• Key decisions prior to commencing FEED
  – Water source selection & discharge
  – Steam source selection
  – Oxygen levels in the CO₂ product specification

• A design manual was developed in conjunction with Hunt International and Burns & McDonnell
  – Includes specific requirements for cold weather
  – Being used by Fluor and Burns & McDonnell for capture system design, water treatment, and balance of plant design
Water source selection

- The water source for the CCS was chosen as Nelson Lake adjacent to the plant
  - Sufficient water retention and short pipeline requirement
- Pre-treatment was selected as cold lime softening
  - Ability to lower amount of cooling tower make-up and eventual cooling tower blowdown rates
- Cooling tower blowdown that can’t be utilized by the power plant will be deep well injected (Class I well), which is anticipated to be the lowest cost
Steam source selection

- Direct extraction from MRY2 steam turbine and auxiliary natural gas package boilers considered
- Natural gas boilers were initially selected as best option
  - Significantly lower technical risk
  - Improved CCS and MRY operational flexibility
  - Potentially improved economics from pre-FEED work
- Extraction steam being reevaluated due to updated economics from FEED work
Oxygen specification for CO$_2$ product

- It was determined that catalytic deoxygenation is not required for geologic storage
  - Short pipeline
  - No oil miscibility concerns in this scenario

- Flexibility will be built into the design to add catalytic deoxygenation in the future for an EOR scenario
Capture island design status

- All PFD, HMB, UFD and P&IDs completed
- Preliminary 2D and 3D plot plans completed
- Modular study was completed
- Major equipment specifications completed
- Major equipment bid packages sent out and preliminary bids received
- Material takeoffs completed
- Level II Process Hazard Analysis HAZOP completed
- Reliability, Availability, & Maintenance (RAM) study completed
BOP design status

• Water treatment system preliminary design completed
• Initial water balance of facility completed
• Wastewater, including tower blowdown will be combined with existing scrubber pond water
• Preliminary design for deep well injection of final wastewater from scrubber pond water almost complete
• Interfaces to existing plant utilities identified and preliminary design completed
• Determined existing plant fire system can supply needs of CCS island
Air emissions

- Held meetings with NDDEQ to discuss monitoring requirements and general permitting questions and overview
- Air dispersion modeling completed by AECOM
- Minnkota contracted with Agora Environmental (formerly RMB Consulting) to develop a monitoring strategy/plan – still underway
Task 3 – Development of Permitting Strategies (continued)

Water supply
• Information was finalized for water appropriation permit to increase the allocation of Missouri River water

Water discharge (zero discharge target)
• Golder Associates finalized information for the Class I wastewater injection well permit
  – Targeting the Inyan Kara formation (~3600-3800 ft. depth) for injection

Waste disposal
• Analysis of waste from the solvent maintenance system is still underway (produced during pilot testing under separate efforts)
Task 4 – Project Tundra Cost Estimating

Preliminary FEED report provided by Fluor

• Cost was higher than anticipated
• Large effort initiated on value engineering to reduce cost with minimal impact to reliability and performance
  – Already found 15% reduction with limited or no impact on system
• Earlier this year, Fluor informed us that due to their current business position they were no longer able to be the fixed price constructor for the project
• Efforts underway to find a construction contractor to finalize the FEED quality estimate
• Continue efforts to finalize additional owner’s cost for items outside of Fluor’s scope
Next Steps

- Finalize selection of new construction contractor
- Determine schedule and cost impacts to FEED study to evaluate and implement value engineering/cost optimization changes to the scope of facilities and to obtain input from the selected construction contractor
- Finalize owner’s cost estimates
- Complete the FEED with the revised scope of facilities
Summary

• Project Tundra is a bold initiative to build the world’s largest carbon capture and storage facility in North Dakota
• FEED completion delays due to change in Fluor’s construction status
• Still have parties interested in investing in the project

Contact Information:
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701-794-7234
gpfau@minnkota.com
APPENDIX
Project Organizational Chart

Lead Organization
Minnkota Power Cooperative (MPC)
Principal Investigator
Gerry Pfau

Project Participants/Sponsors
Fluor Enterprises, Inc. (Fluor)
Energy & Environmental Research Center (EERC)
Golder Associates
AECOM
Agora Environmental
Nels Consulting
Siemens Energy
General Electric
North Dakota Industrial Commission
U.S. Department of Energy

Project Consultants
David Greeson Consulting (DGC)
Hunt International Energy Services (Hunt)

Owner's Engineer
Burns & McDonnell (BMcD)

Task 1: Project Management and Planning
Lead: G. Pfau (MPC)
Assist: J. Laumb (EERC),
D. Greeson (DGC)

Task 2: Project Engineering and Design
Lead: R. Graebe (Fluor)
Assist: G. Pfau (MPC), R. Bryant (BMcD), S. Reddy (Fluor)

Task 3: Permitting Strategy
Lead: G. Pfau (MPC)
Assist: S. Hopfauf (MPC)

Task 4: Project Cost Estimation
Lead: R. Graebe (Fluor)
Assist: G. Pfau (MPC), R. Bryant (BMcD)
| Task/Milestone Description                  | Start Date | End Date | Estimated Cost | Jan-20 | Feb-20 | Mar-20 | Apr-20 | May-20 | Jun-20 | Jul-20 | Aug-20 | Sep-20 | Oct-20 | Nov-20 | Dec-20 | Jan-21 | Feb-21 | Mar-21 | Apr-21 | May-21 | Jun-21 |
|-------------------------------------------|------------|----------|----------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| **Task 1 - Project Management and Planning** | 12/19/19   | 06/30/21 | $3,251,043     |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |
| **Milestones/Deliverables**               |            |          |                |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |
| M0 - Cooperative Agreement Signed         | 12/19/19   |          |                |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |
| D1 - Updated PMP                          | 01/31/20   |          |                |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |
| D4 - Final Report                         | 06/30/21   |          |                |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |
| **Task 2 - Project Engineering and Design** | 12/19/19   | 05/31/21 | $8,446,119     |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |
| **Subtask 2.1 - Project Design Basis**    | 12/19/19   | 02/28/20 |                |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |
| **Subtask 2.2 - Carbon Capture System Design** | 04/30/20   | 05/31/21 |                |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |
| **Subtask 2.3 - Steam Source Selection & Design** | 12/19/19   | 05/31/21 |                |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |
| **Subtask 2.4 - BOP Integration and Design** | 12/19/19   | 05/31/21 |                |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |
| **Milestones/Deliverables**               |            |          |                |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |
| M1 - Design Manual Completed              | 02/28/20   |          |                |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |
| D2 - Design Manual                        | 02/28/20   |          |                |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |
| **Task 3 - Permitting Strategy**          | 12/19/19   | 05/31/21 | $923,445       |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |
| **Subtask 3.1 - Air Emissions**           | 03/01/20   | 05/31/21 |                |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |
| **Subtask 3.2 - Water Discharge**         | 12/19/19   | 05/31/21 |                |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |
| **Subtask 3.3 - Waste Disposal Planning** | 06/01/20   | 05/31/21 |                |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |
| **Milestones/Deliverables**               |            |          |                |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |
| M2 - Permitting Meeting with NDDEQ        | 07/30/20   | 05/31/21 |                |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |
| M3 - Permitting Strategy Finalized        | 05/31/21   |          |                |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |
| **Task 4 - Project Cost Estimation**      | 06/01/20   | 05/31/21 | $437,435       |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |
| **Milestones/Deliverables**               |            |          |                |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |
| M4 - FEED Report Submitted                | 05/31/21   |          |                |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |
| D3 - FEED Study                           | 05/31/21   |          |                |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |

New schedule under development with recently approved extension to 12/31/21
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