Comparison and Discussion of USEPA/GMI Feasibility and Prefeasibility Studies: Songzao, Naryn Sukhait, and Baganuur

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*Mongolia Coal Mine Methane Recovery and Utilization*

Ulaanbaatar, Mongolia
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Presentation Outline

- Introduction
- Nahryn Sukhait Prefeasibility Study
- Baganuur Prefeasibility Study
- Songzao Prefeasibility Study
- Project Comparison and Key Points
Introduction

• Feasibility and prefeasibility studies mentioned in this presentation were developed in support of the Global Methane Initiative (GMI) by Raven Ridge Resources (RRR) under contract to the United States Environmental Protection Agency’s (USEPA) Coalbed Methane Outreach Program (CMOP)

• In each case, these studies have been used by the mine operators for discussion and project planning

• The feasibility and prefeasibility studies are also useful as case studies and can be used as templates for similar mines.
Challenges and Considerations of Methane Resources at Songzao Mines

• Songzao Coal and Electric Company Ltd. (SCEC) identified and targeted for LNG using drained methane and/or VAM project by Methane to Markets (presently GMI)

• Songzao coal basin is remote and located in mountainous terrain, slopes are steep

• SCEC mining complex extends ~25 km along the length of the basin. Six separate mines are producing and new mine construction underway at time of study

• Population is concentrated near mining development and roads connect mines along drainages

• Prime agricultural development neighbors mining in south and is important to local economy. Conflicts may arise over land use
Challenges and Considerations of Methane Resources at Songzao Mines

Metered Residential Use

Unmetered Residential Use
Feasibility Study Approach

• Submitted detailed questionnaire
• Met with mine players of CQEIG and SCEC. Visited each mine and potential construction sites.
• Detailed evaluation of previous studies.
• Conducted market analysis, gathered costs for equipment and construction.
• Drafted prefeasibility study
• Reported results to CQEIG and SCEC upper management
• Management chose best end use option(s) and RRR finalized conceptual design and costing
• Revised economic analysis, drafted, and submitted final report; the report is available in English and Chinese
Trends in SCEC Coal and Gas Production

- Plans are underway to increase drained gas concentration and volume
- Coal production may increase to nearly 9 million tons per annum over the next 10 years
- Gas production may increase to over 300 million cubic meters per annum
Input Probability Distributions for Forecasting Gas Available for New Project End Use

- Coal production (based on plans for expansion)
- Gas drained per tonne of coal mined
- Gas concentration
- VAM emitted
- VAM concentration
- Ratio of gas drained to VAM emitted (drainage efficiency)
- Gas Used at CMM power facilities
- Residential and Commercial Use (metered and unmetered)
Forecast of Coal, Gas Production and Use
**End-use Options**

- Power Generation Only
- LNG Only
- Optimized mix of LNG and power production
CAPEX and NPV per tCO$_2$e Reduced for Each End-use Option

<table>
<thead>
<tr>
<th></th>
<th>Optimized Use</th>
<th>Only Power Generation</th>
<th>Only LNG</th>
</tr>
</thead>
<tbody>
<tr>
<td>p10 CAPEX $s / t CO2e</td>
<td>$3.33</td>
<td>$3.24</td>
<td>$3.16</td>
</tr>
<tr>
<td>p10 $s NPV / t CO2e</td>
<td>$2.82</td>
<td>$1.32</td>
<td>$3.46</td>
</tr>
<tr>
<td>p50 CAPEX $s / t CO2e</td>
<td>$4.28</td>
<td>$3.57</td>
<td>$4.14</td>
</tr>
<tr>
<td>p50 $s NPV / t CO2e</td>
<td>$1.91</td>
<td>$1.09</td>
<td>$2.89</td>
</tr>
<tr>
<td>p90 CAPEX $s / t CO2e</td>
<td>$5.59</td>
<td>$4.04</td>
<td>$5.52</td>
</tr>
<tr>
<td>p90 $s NPV / t CO2e</td>
<td>$0.56</td>
<td>$0.55</td>
<td>$1.62</td>
</tr>
</tbody>
</table>
Conclusions and Lessons Learned

• For 15 year life of project and p50 gas production forecast:
  – 44.1 million tonnes of CO$_2$e emission reduction average 3 million tonnes per annum after 2015 (emissions reduction are less than 2 million tonnes CO$_2$e until full production is achieved and equipment is installed)

• Range in investment from $150 to 225 million USD

• Project economic performance is most sensitive to gas sales price.

• The project NPV is sensitive to post 2012 emissions reductions market. VERs or CERs are important to overall economic performance.

• Project easily demonstrates financial additionality under present economic conditions in China.

• Civil use of gas is often not metered, and prices are artificially low, often free. Therefore, cost recovery of drained gas and subsequent treatment is difficult. Difficult to determine costs and sales prices
PREFEASIBILITY STUDY:
CMM RESOURCES AND END USE OPTIONS AT NAHRYN SUKHAIT MINE
Methane Resources at Naryn Sukhait Mine

• Initial investigations of coal characteristics and gas content, indicate coal mine methane (CMM) may occur at Naryn Sukhait Mine

• Open pit production capacity is 3 million metric tons per year and is expected to increase to 5-8 million tons per year upon installation of a railway system to transport coal

• Minable coal resources estimated to be contained by Coal Seam 5 are 225 million metric tons from surface to -150m depth throughout the licensed area
Example Cross-Section Used in Coal and Gas Resource Estimations

- Coal resources were estimated between -150m to -450m.
- These limits comprise the limits of the coal resources that are likely to contain gas that will migrate up dip and be lost to the atmosphere if not pre-drained and used prior to dewatering and strata relaxation that will occur during the mining process.
- The cumulative Coal Seam 5 resources calculated between -150m and -450m is **253.05 million tonnes**.
Gas Resources and Production Modeling

- Raton Basin coal in south-central Colorado are similar in rank and depth, have comparable gas contents, and have been exposed to similar tectonic activities during its depositional history.

- Long history of CBM development in the Raton Basin with extensive production from the coals of the Raton Formation were used to forecast a distribution of production profile outcomes (p10, p50, p90).

- 12 vertical wells from which gas will be drained from the down dip extent of the planned mining area were proposed.

Forecast GIP for Proposed Pre-mine Drainage Wells

<table>
<thead>
<tr>
<th>Percentile Class</th>
<th>p90</th>
<th>p50</th>
<th>p10</th>
</tr>
</thead>
<tbody>
<tr>
<td>GIP per 32.4 hectare well location</td>
<td>5,639,982</td>
<td>12,073,142</td>
<td>18,043,670</td>
</tr>
<tr>
<td>Potential Drainage Efficiency</td>
<td>37%</td>
<td>57%</td>
<td>85%</td>
</tr>
</tbody>
</table>
End-use Option and Economic Performance

**On-site Power Generation**
- Install a CMM-fueled internal combustion power generation facility in close proximity to the mine’s surface facilities.
- Designed to supply power to the mine as well as sell any unused electricity to the grid.
- With peak production, 68,400 MWh of electricity could be generated.
- 8.55 MW of combined electrical and thermal generating capacity.

**Economic Performance**

<table>
<thead>
<tr>
<th>Power Generation Option</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evaluation Scenario</td>
</tr>
<tr>
<td>Annual Operating Hours</td>
</tr>
<tr>
<td>Gas Forecast-Project (million m³)</td>
</tr>
<tr>
<td>Total CAPEX (million USD)</td>
</tr>
<tr>
<td>Tons of CO₂e (x thou.)</td>
</tr>
<tr>
<td>Carbon Sales Price (USD)</td>
</tr>
<tr>
<td>Plant Size (MW)</td>
</tr>
<tr>
<td>CAPEX/Tons CO₂e</td>
</tr>
<tr>
<td>Electricity Sales Price (₹/kWhr)</td>
</tr>
<tr>
<td>NPV/Tons CO₂e</td>
</tr>
<tr>
<td>NPV (Million USD)</td>
</tr>
<tr>
<td>IRR (%)</td>
</tr>
</tbody>
</table>
Conclusions and Recommendations

• Installation of a CMM drainage system could produce 144.9 million m³ methane over 15 years

On-site Power Generation

• 68,400 MWh of electricity generated annually
• CAPEX of 7.77 million USD with an IRR of 16.1% and a payback period of 6.75 years
• Carbon emissions reductions of 187.9 thousand tons of CO₂e over the project’s 15 year life

Recommendations

• A comprehensive data collection program should be carried out and incorporated into mine’s geologic model
• Commission a technical and economic feasibility study that will determine the potential for developing a cost effective plan to construct and operate a CMM-fueled power generation facility
Methane Resources at Baganuur Mine

- Initial investigations of coal characteristics and gas content, indicate coal mine methane (CMM) may occur at Baganuur in a manner similar to mines in the coalbed methane (CBM)- rich Powder River Basin (PRB) of the US
- Mine plans to increase the present rate of mining from 3 million metric tons annually to 6 million metric tons per year in the near future
- Baganuur is an established presence as an important and reliable coal mine, supplying most of Mongolia’s central region coal demand for use by in the country’s main electricity grid, the Central Electricity System (CES)
  - Geographically located to allow a CMM project to provide additional, gas-fueled electricity to the CES electricity grid
MRAM estimates 599 million tonnes of coal resources within the entire Baganuur mine property

Proposed 19 vertical pre-mine boreholes on the western side of the mine pit based on analysis of geologic maps and hydrologic data from mine

Potentiometric surface was used to assure proposed boreholes were sited below this surface and within mineable coal seams
Coal and Gas Resources within Proposed Boreholes

- 19 well production forecasts over 10 year project life
- 55.01 million m³ methane
- 823.7 thousand m³ water
- 32% drainage efficiency

<table>
<thead>
<tr>
<th>Borehole Name</th>
<th>Mining Section 2</th>
<th>New Mining Section</th>
<th>Mining Section 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal Seam 2 Mass</td>
<td>Explanation</td>
<td>Coal Seam 2g GIP</td>
<td>Coal Seam 3 GIP</td>
</tr>
<tr>
<td>Coal Seam 3a Mass</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coal Seam 3 Mass</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Production Forecasts</th>
<th>YEAR</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual Gas (million m³)</td>
<td></td>
<td>2.05</td>
<td>4.93</td>
<td>7.35</td>
<td>9.27</td>
<td>8.38</td>
<td>6.48</td>
<td>5.29</td>
<td>4.44</td>
<td>3.69</td>
<td>3.13</td>
</tr>
<tr>
<td>Annual Water (thousand m³)</td>
<td></td>
<td>31.3</td>
<td>70.3</td>
<td>104.0</td>
<td>132.2</td>
<td>117.8</td>
<td>98.5</td>
<td>83.7</td>
<td>71.3</td>
<td>62.0</td>
<td>52.5</td>
</tr>
</tbody>
</table>
**On-site Power Generation**

- Install a CMM-fueled internal combustion power generation facility in close proximity to the mine’s surface facilities.
- Designed to supply power to the mine as well as sell any unused electricity to the grid.
- With peak production, 40,000 MWh of electricity could be generated.
- 5.0 MW of combined electrical and thermal generating capacity.

**Evaluation Scenario** | **Base Case-p50**
---|---
Annual Operating Hours | 8,000
Gas Forecast-Project (million m³) | 54.3
Water Forecast-Project (million m³) | 0.8
Total CAPEX (million USD) | 5.41
Tons of CO₂e (x thou.) | 104.5
Carbon Sales Price (USD) | $1.00
Plant Size (MW) | 5.00
CAPEX/Tons CO₂e | 0.05
Electricity Sales Price (Tugrik/kWh) | 130
Electricity Sales Price ($/kWh) | $0.09
NPV/Tons CO₂e | 0.02
NPV (Million USD) | 1.93
IRR (%) | 22.7%
Return on Investment (%) | 35.6%
Payback Period (years) | 4.32
Conclusions and Recommendations

• Installation of a CMM drainage system could produce 55.01 million m³ methane over 10 years

**On-site Power Generation**

• 40,000 MWh of electricity generated annually
• CAPEX of 5.41 million USD with an IRR of 22.7% and a payback period of 4.32 years
• Carbon emissions reductions of 104.5 thousand tons of CO₂e over the project’s 10 year life

**Recommendations**

• A comprehensive data collection program should be carried out and incorporated into mine’s geologic model
• Commission a technical and economic feasibility study that will determine the potential for developing a cost effective plan to construct and operate a CMM-fueled power generation facility
## Project Comparison

<table>
<thead>
<tr>
<th>MINE</th>
<th>STATUS OF MINE DEVELOPMENT (coal type)</th>
<th>STATUS OF CBM/CMM EXPLORATION</th>
<th>METHANE RESOURCES ESTIMATE</th>
<th>GAS PRODUCTION</th>
<th>POTENTIAL EMISSIONS</th>
<th>END-USE OPTIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Songzao</td>
<td>mature-underground (anthracite)</td>
<td>mature</td>
<td>7 Bm³ entire mining property</td>
<td>100 Mm³/year</td>
<td>350Mm³/y all mines in 2007</td>
<td>electricity production direct use, LNG</td>
</tr>
<tr>
<td>Nahryn Sukhait</td>
<td>young-surface (bituminous)</td>
<td>early</td>
<td>729 Mm³ one seam</td>
<td>none</td>
<td>729Mm³ if no project</td>
<td>electricity production</td>
</tr>
<tr>
<td>Baganuur</td>
<td>mature-surface (subbituminous)</td>
<td>early</td>
<td>175 Mm³ pilot area</td>
<td>none</td>
<td>175 Mm³ pilot area</td>
<td>electricity production</td>
</tr>
</tbody>
</table>
Key Points

• Data needed for prefeasibility studies need not be expensive to acquire and training for collecting the data and testing samples is not costly

• Surface mine methane recovery employs technology that is proven and available in Mongolia

• Energy market conditions will support development of CMM/CBM in Mongolia; environmental concerns provide justification for government facilitation

• Designing underground coal mines to coproduce methane is less expensive and easier than waiting until the mine is in the mature stage of its life cycle
Thank you!

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