U.S. EPA Coalbed Methane Outreach Program

Pre-feasibility Study for Coal Mine Methane Recovery and Utilization at Baganuur Mine, Mongolia

U.S. Environmental Protection Agency

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View of Pit at Baganuur Mine

Coal Loading at Baganuur Mine

Pre-feasibility Study for Coal Mine Methane Recovery and Utilization at Baganuur Mine, Mongolia

In Support of the Global Methane Initiative

Sponsored by: US Environmental Protection Agency
Prepared by: Raven Ridge Resources, Incorporated

December 2013

Disclaimer/Abstract/Acknowledgements

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Abstract

The United States Environmental Protection Agency (USEPA) and Raven Ridge Resources, Incorporated (RRR) recently concluded the Pre-feasibility Study for Coal Mine Methane Recovery and Utilization at Baganuur Mine, Mongolia. The Baganuur mine is a surface coal mine owned and operated by Baganuur Joint Stock Company (Baganuur JSC), located outside of Ulaanbaatar. The mine is 75 percent state owned and 25 percent privately owned. Baganuur mines 3.5 million tonnes of coal per year, with plans to increase production to over 6 million tonnes per year by 2020. After constructing a three dimensional geologic model, RRR estimated there are 248.97 million tonnes of coal within the Baganuur mining area. The expected service life of Baganuur is 60 years.

The prefeasibility study evaluated utilization of pre-drained CMM for on-site use to fuel an internal combustion power generation facility located in close proximity to the mine's surface facilities. In the production modeling performed for this study, a series of 19 wells are proposed, positioned along the western rim of the pit outside of the projected five-year mine plan. Total estimated CMM production is 54.3 million m^3 of methane over 10 years which is available for use to generate electricity. Operating 8,000 hours each year, once the project reaches peak production, 40,000 MWh of electricity would be generated annually. This equates to an installed capacity of approximately 5.0 MW of combined electrical and thermal generating capacity.

The proposed project capital costs are estimated to be $5.4 million USD with an IRR of 22.7 percent and a payback period of 4.32 years. The proposed power generation project is estimated to reduce CMM emissions by 104,500 tonnes of CO_2e over the project's 10 year life.

Acknowledgements

This publication was developed at the request of the United States Environmental Protection Agency. Through the Coalbed Methane Outreach Program, Raven Ridge Resources, Incorporated team members Raymond C. Pilcher, James S. Marshall, Candice L. M. Tellio, and Charlee A. Boger authored this report.

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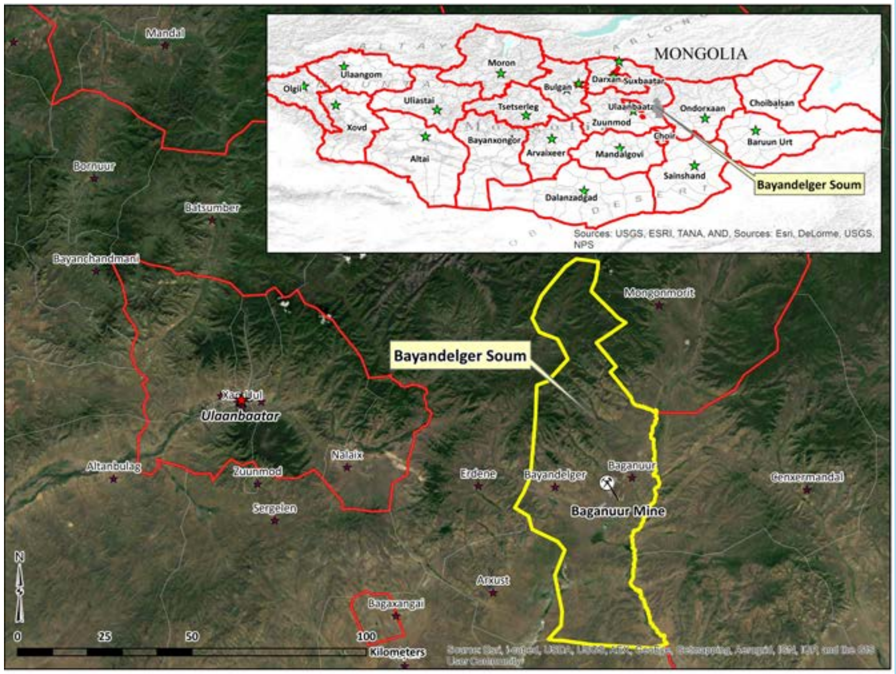
The Baganuur coal mine, owned by Baganuur Joint Stock Company (Baganuur JSC), was selected as the host mine for this study due to its established presence as an important and reliable coal mine, supplying most of Mongolia's central region coal demand for use in state-run thermal power plants serving Mongolia's main electricity grid, the Central Electricity System (CES). The analysis conducted as part of this study indicates coal mine methane (CMM) resources on par with other gassy coal basins such as the Powder River Basin (PRB) in the United States (US). Finally, Baganuur is situated geographically and with grid connections to provide additional CMM-fueled electricity to Mongolia's CES. With electricity costs for mines in Mongolia rising, self-supply of electricity from CMM is also attractive. Though mine management was engaged, available data was sparse. Existing data and information were provided to RRR and MNEC (the RRR team) to examine the potential for employing vertically drilled wells to capture methane gas prior to mining for use as fuel to generate power. RRR worked to fill informational gaps by conducting an extensive search for additional pertinent geologic data and information in order to better understand the factors that controlled the distribution and size of CMM resources that may be contained within the mine lease boundary. Results of this prefeasibility study are intended to provide a foundation for a full-scale feasibility study. The approach taken is designed to provide a product that attracts the attention of investors or other stakeholders such that a full-scale feasibility study and eventually a drainage and utilization project are funded and executed.

The Baganuur coal mine is located just south of the city of Baganuur in one of nine districts of the Mongolian capital city of Ulaanbaatar, Bayandelger soum[1], at the border between the Töv and Khentii aimags[2] (Erdenetsogt et al, 2009). The mine sits 127 km east of Ulaanbaatar (**ES Figure 1**), on the northwestern edge of the Choir-Nyalga coal basin, within the Eastern



ES Figure 1: Area Overview Map

Mongolian geologic province. The deposit is situated along a synclinal feature which trends NNE-SSW, is 15 km long and 4 km wide and covers approximately 60 km^2 (**Map 1**).

Within the province, all known coal occurrences are lignite and subbituminous coals. The province contains an estimated 108.3 billion tonnes of coal resources, of which 6.5 billion tonnes are classified as reserves.

The Baganuur deposit is comprised of three major coal seams, as much as 38 m thick, intercalated within two Lower Cretaceous sandstone and argillite formations named the Tsagaan-Tsav and Huhteeg formations. The strata atop the mineable coal seams, sandstones and gravels, are conduits for any gas originating in the mineable coal seams to escape to the atmosphere or be trapped within porous spaces as strata are dewatered prior to and during mining.

1 In Mongolia, a soum is a second level administrative subdivision, or district. The 23 aimags of Mongolia are divided into 329 soums.

2 In Mongolia, an aimag is the first-level administrative subdivision, of which there are 23.

Beginning in 1981, a series of water pumping and water monitoring wells were drilled by the mine to drain the coal seams prior to mining and to reduce water flow into the pit. Dewatering wells and pumps extract 3.8 – 4.0 million m^3 of groundwater from the mine, some of which is used by Baganuur's thermal power plant.

RRR used a hydrologic database of locations and water surface elevations from the mine's water pumping and monitoring wells to estimate the potentiometric surface (elevation of the top of the water surface) near the mine. As dewatering continues, the potentiometric surface will be drawn further away from the mining pit, dropping the pore pressure within the coals, causing desorption of methane gas contained by the coal seams. As the gas desorbs from the coal, it will likely travel up dip to the exposed high wall of the mine pit, or, up through the easternmost dewatering wells, eventually being emitted to the atmosphere. This may already be occurring, as the mine has reported anecdotal evidence of the smell of rotten eggs coming from nearby dewatering wells.

Mineable coal resources at Baganuur are comprised of coal seams 2, 2a and 3. According to the Mineral Resources Authority of Mongolia (MRAM), the mine contains 599 million tonnes of coal resources. Using geologic cross-sections and the five-year mine plan provided by the mine, RRR constructed a simple three-dimensional model of the mining area in order to estimate the potential coal and gas resources for developing a CMM recovery and use project. The mine has designated three areas, Mining Section 1, Mining Section 2 and New Mining Section (**Map 2**). **ES Table 1** shows the estimated coal resources by mining area. The cumulative coal resources calculated for the designated mining areas from all targeted coal seams is approximately 250 million tonnes. This differs from the coal resources reported by MRAM which include the entire Baganuur coal deposit.

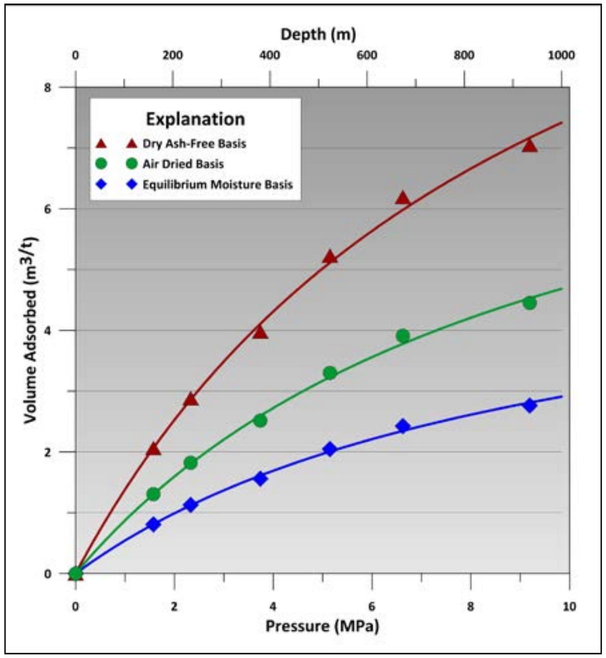
ES Table 1: Estimated Coal Resources within Designated Mining Areas

Mining Section	Coal Seam 2 (t)	Coal Seam 2a (t)	Coal Seam 3 (t)	Total (t)
1	38,377,984	75,599,885	34,638,432	148,616,301
2	24,853,323	18,408,092	Above Potentiometric Surface	43,261,416
New	27,865,692	29,224,458	Above Potentiometric Surface	57,090,150
Total	91,096,999	123,232,435	34,638,432	248,967,866

This coal resource estimate served as the basis for calculating in-place gas resources at the Baganuur mine. A widely accepted way of estimating the gas resource associated to the coal is to multiply the coal mass by the gas content; however, other than the desorption testing conducted by MNEC and RRR in 2012[3], verifiable in-situ gas content measurements are not available for the mine. A methane adsorption isotherm test was conducted to provide a broader frame of reference in which RRR estimated the potential gas-in-place (GIP) of Baganuur's coal resources. Results of the test are shown in **ES Figure 2**. An adsorption isotherm test mathematically describes the relationship between pressure and gas storage capacity under equilibrium conditions at a stable temperature representing the reservoir conditions of the coal seam at the depth of the sample. This adsorption isotherm indicates the gas capacity of one coal sample taken at the mine and may not accurately depict the situation for other coal seams; however, the rank and coal quality of other samples studied in the analogous PRB in the US provided a wider sample set. Therefore, available isotherm constants (Langmuir pressure and Langmuir volume) were used for similarly ranked coal deposits occurring in the PRB along with the Baganuur isotherm to perform a statistical analysis that provided a stochastically derived Langmuir pressure and Langmuir volume. These constants were used to estimate a range of gas content values for coal occurring at a given depth at Baganuur.

The curves shown on **ES Figure 2** relate gas content of the coal sample to

3 Coal Mine Methane (CMM) Resource Assessment and Emissions Inventory Development in Mongolia, https://www.globalmethane.org/projects/projectDetail.aspx?ID=1200



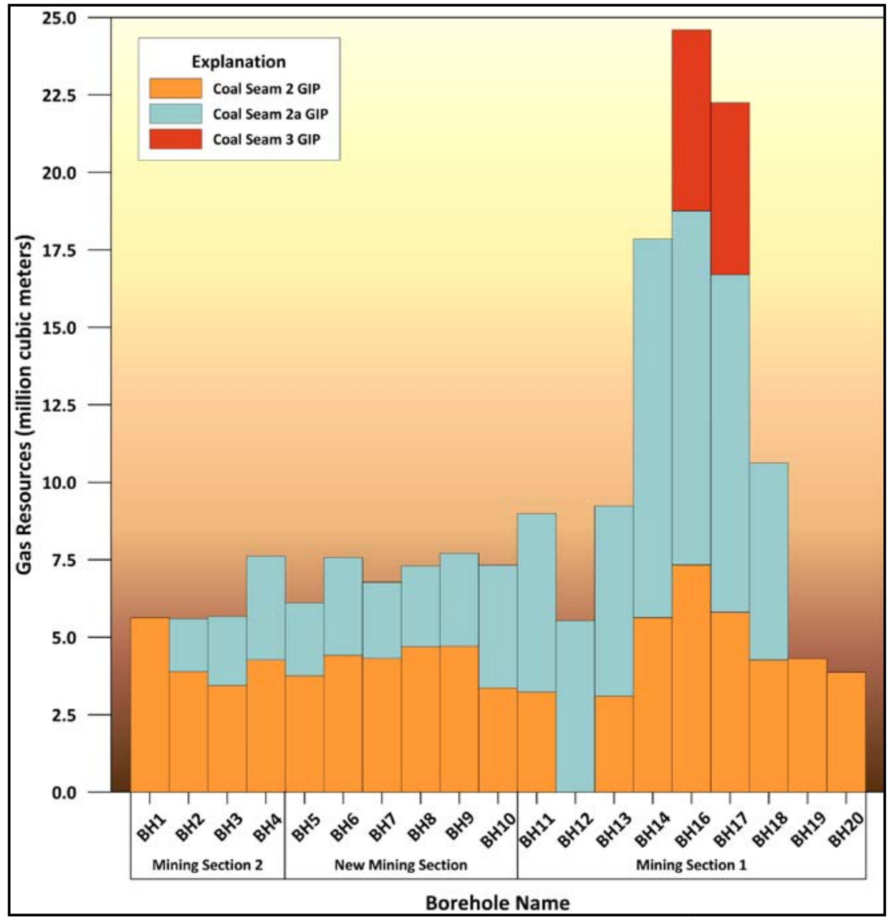
ES Figure 2: Adsorption Test Results

the expected content at a given mining depth. For the purposes of this study the blue curve is considered to best represent the gas capacity of coal as it predicts the gas content at equilibrium moisture conditions without correcting for ash content.

In order to estimate GIP, the previously described coal resource calculation results were multiplied by a probability distribution representing the range of gas content values. The probabilistic approach to estimating the GIP takes into account the uncertainty of the coal density and the gas content values of the mineable coal. The total GIP gas resource forecast of Mining Section 1, Mining Section 2 and the New Mining Section (**Map 2**) ranges from 233.8 up to 784.4 million m^3 (p90 through p10).

This study proposes drilling vertical surface pre-drainage wells in order to recover CMM. Based on the depth of the intersection of each proposed borehole and the midpoint of the measure of coal within the estimated drainage area, RRR applied the appropriate gas content value in the gas resource calculations. The resultant estimates of GIP per drainage area of each proposed borehole are shown in **ES Figure 3**. The total estimated GIP for the drainage areas of the proposed borehole program is 174.6 million m^3.

Coal seam 3 is shown only to contain gas within boreholes BH 14 and BH 16. This is because RRR accounted for coal resources lying below the potentiometric surface and much of coal seam 3 was already eroded from the southern extent of the mine.



ES Figure 3: Estimated GIP by Proposed Borehole, Coal Seams 3, 2a and 2

Scientists and engineers from the former Soviet Union began developing the Baganuur coal deposit between 1975 and 1978. The first coal was produced in 1978 and sent to the coal-fired power plant in Ulaanbaatar. This process continues today as a special purpose train delivers the coal from the pit to the power generation stations. Currently Baganuur mine is 75 percent state owned and 25 percent privately owned, and operating under the guidance of Director N. Mergenbaatar. The mine is an open cast or surface mine, using dragline excavators and self-unloading trucks to extract the coal which is primarily used to power CES sub-stations. The mine managers believe the service life of the mine is 60 years, during which 210 million tonnes of mineable coal may be produced from coal seams 2, 2a and 3.

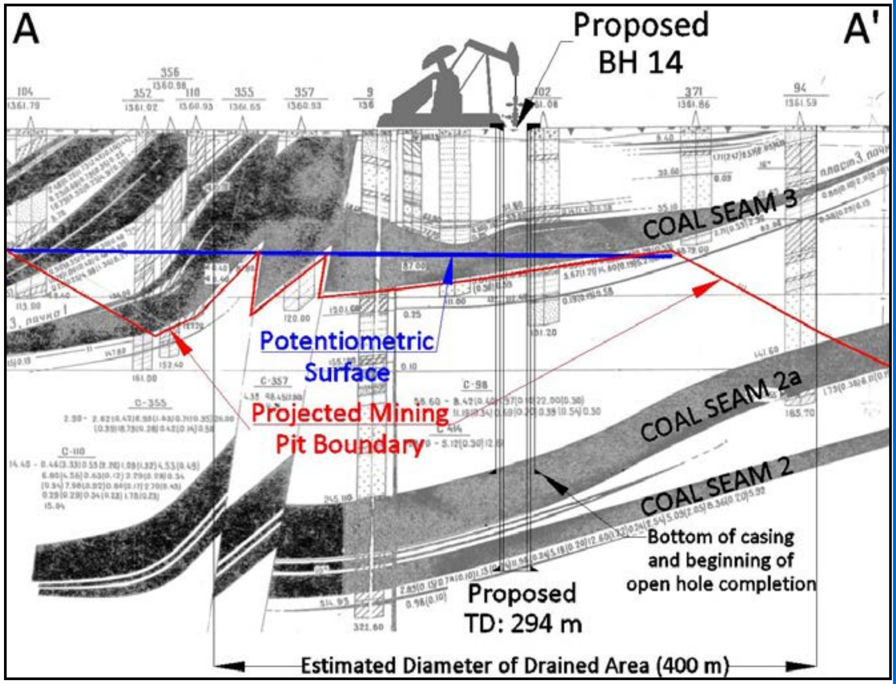
If left unmanaged, up to 4.3 million m^3 of water would flow into the mine pit annually. In order to manage this, the mine implemented a dewatering program so that 3.8 to 4.0 million m^3 of water annually are pumped from a series of water production and monitoring wells. Mine needs consume some of the extracted groundwater and the remaining 2.5 – 2.7 million m^3 are discharged into a holding pond and the nearby Herlen River.

According to mine manager's latest projections, the mine will increase production to 6.13 million tonnes by 2022. **Map 2** shows the areas from which the mine will extract coal for the next five years. **ES Table 2** shows the projected production by coal seam.

ES Table 2: Projected Coal Production

Coal Seam	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Seam 2 (Mt)	-	1.13	1.50	1.51	1.44	0.81	1.05	1.96	1.26	0.91
Seam 2a (Mt)	1.31	0.76	0.57	0.64	-	0.81	0.36	0.08	0.78	1.17
Seam 3 (Mt)	2.26	1.63	2.23	3.35	4.07	3.89	4.23	4.01	3.97	4.04
Total (Mt)	3.57	3.52	4.30	5.51	5.51	5.51	5.64	6.05	6.00	6.13

In order to capture CMM that would otherwise be released by projected future mining activities, this study concludes that gas could be drained from the down dip extent of the coal contained in Mining Section 1, Mining Section 2 and New Mining Section if 19 vertical wells are drilled. Pre-mine drainage is the only viable option for capturing and using gas that would otherwise be released during mining. The proposed wells are drilled 400 meters apart, providing for a drainage area of approximately 16.2 hectares per borehole. Locations for these proposed wells are shown



ES Figure 4: Example proposed BH 14 Showing the Potentiometric Surface with Respect to the Structural Tops of Coal Seams 3, 2a and 2

on Map 3. **ES Figure 4** is an example cross section showing the proposed placement of borehole BH 14; the location of section, A-A', is delineated on Map 2. The borehole placement with respect to the potentiometric surface and of the intersection of the targeted coal seams is also shown. Each well is forecast to produce CMM for 10 years, with individual well gas production peaking in year four as the reservoir is de-watered. The produced water will have to be pumped to a local containment pond where it will be stored and made available for use by the mine or others.

As there is no active coalbed methane (CBM) production in Mongolia, and sufficient information and data was not available for reservoir simulation modeling; a producing CBM field which is analogous to the Baganuur mine property was used for production profile modeling. The Wyodak-Anderson coals of the Upper Cretaceous Fort Union Formation along the eastern margin of the PRB in eastern Wyoming are similar in rank and depth to those found at Baganuur, have comparable gas contents, and have been exposed to similar tectonic events during its burial history. RRR developed a distribution of production profile outcomes (p10, p50, p90) for all PRB wells with similar characteristics: 1,484 wells were selected from an initial population of 1,974.

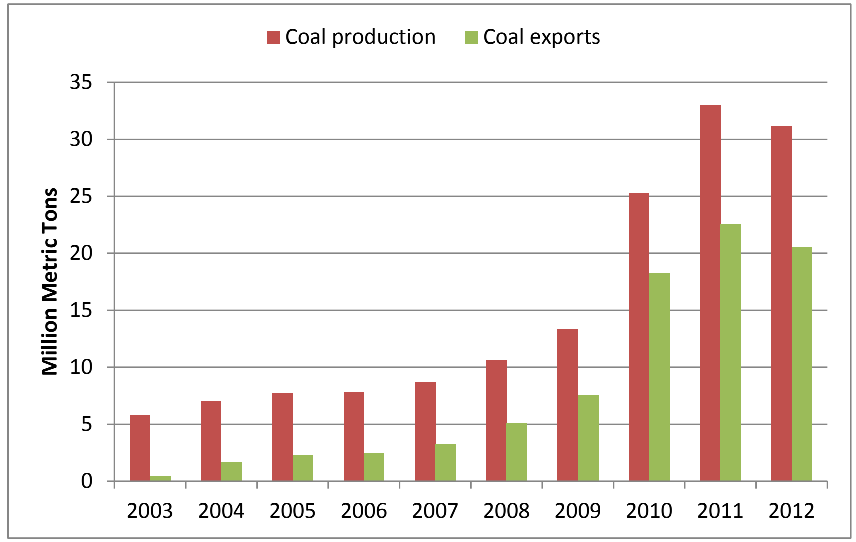
Based on the proposed boreholes and their drilling schedule, **ES Table 3** shows the forecasted annual gas and water production.

ES Table 3: Gas and Water Production Forecast Results

Production Forecasts	YEAR									
	1	2	3	4	5	6	7	8	9	10
Annual Gas (million m^3)	2.05	4.93	7.35	9.27	8.38	6.48	5.29	4.44	3.69	3.13
Annual Water (thousand m^3)	31.3	70.3	104.0	132.2	117.8	98.5	83.7	71.3	62.0	52.5

The production forecast results are different from the GIP calculations, because the GIP estimates represent the total amount of gas present within the mineable coal seams occurring within the mining areas. Whereas, the gas production forecast represents the p50 gas production forecast that could be drained by the proposed borehole plan. The total forecasted gas production for the proposed 19 borehole drilling and utilization project is 54.3 million m^3 of methane. Forecasted water production totals 823.7 thousand m^3.

Mongolia's coal market is growing rapidly, ensuring demand for Baganuur's coal. Mongolia produced over 31 million tonnes of coal in 2012, more than tripling production since 2008 (EIA, 2013). Mongolia's energy needs are met primarily by coal; seven coal-fired combined heat and power plants produce 829 MW of 1,062 MW installed capacity. The market for Baganuur's coal, specifically, is guaranteed as Baganuur currently provides 70 percent of coal required to operate power plants in Ulaanbaatar (Mongolia Mining Journal, 2013). Mongolia is also a significant coal exporter, with most exports supporting China's steel industry, and other exports to Russia.



ES Figure 5: Mongolia's Coal Production and Exports. Source: MRAM (2013)

Mongolia's total electricity demand is expected to reach 1,375 MW in 2015 due to Mongolia's rapidly developing mining-based economy and urbanization acceleration. Mongolia's main electricity grid is the CES which covers 80 percent of Mongolia's electricity supply and includes five coal-fired power plants and an interconnection with Russia for import of electricity, utilized during peak load periods.

Mining accounts for 40 percent of Mongolia's energy consumption, and electricity prices for mining companies that tap into the CES will rise by as much as 30 percent according to Mongolia's Energy Regulatory Commission (Kohn, 2013). Electricity demand has increased at an average annual rate of 2.9 percent since 2005, a trend that is expected to continue through 2020.

Baganuur is perfectly situated geographically and with grid connections to provide additional, CMM-fueled electricity to the CES. The government has designated the Baganuur area to develop into an educational and technology center and electricity demand in the area is expected to grow rapidly. Production of clean energy from CMM in Baganuur would allow the mine to displace dependence on coal-fired electricity and provide much needed electricity to the local area or the CES grid. It would also reduce the pollution arising from coal-fired power generation.

With favorable market conditions and appropriate infrastructure for electricity project development, one outstanding challenge is the legal and regulatory environment for CMM and CBM in Mongolia. Multiple agencies claim rights to granting permission for gas exploration and development activities. MRAM is an implementing agency of the federal Ministry of Mining (MOM), as is the Petroleum Authority. MRAM is responsible for development of minerals such as coal under the Minerals Law (2006), and the Petroleum Authority, under authority of the Petroleum Law (1991), governs the production of liquid and gaseous hydrocarbons. Though previous CBM activity has been managed by the Petroleum Authority of the MOM, the Ministry of Energy (MOE) claims rights relating to granting permission for research and exploration of methane resources. Additionally, both the Minerals Law and the Petroleum Law are being revised. A revised draft of the Minerals Law was published in December, 2012. The Minister of Mining submitted the renewed composition draft bill of the Petroleum Law to parliament on June 27, 2013. Despite undeveloped CMM licensure policies, Mongolia has a number of favorable tax incentives and foreign investment policies.

ES Table 4: Power Generation Option Base Case Forecast Results

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 CO_2e (x thou.)	104.5
Carbon Sales Price (USD)	$1.00
Plant Size (MW)	5.00
CAPEX/Tons CO_2e	0.05
Electricity Sales Price (Tugrik/kWh)	130
Electricity Sales Price ($/kWh)	$0.09
NPV/Tons CO_2e	0.02
NPV (Million USD)	1.93
IRR (%)	22.7%
Return on Investment (%)	35.6%
Payback Period (years)	4.32

The end-use options for the CMM drained from the Baganuur mine are limited as there is no existing infrastructure in the region that would enable the mine to transport produced gas to market, the recommended option is for on-site use to fuel an internal combustion power generation facility located in close proximity to the mine's surface facilities.

Average capital and operating costs from two western suppliers of power generation equipment were used for the prefeasibility study economic analysis. Operating 8,000 hours each year, once the project reaches peak production, 40,000 MWh of electricity would be generated annually. This equates to an installed capacity of approximately 5.0 MW of combined electrical and thermal generating capacity. According to the p50 production forecast, 54.3 million m^3 of methane could be drained and used to generate electricity; a total of 800 thousand barrels of associated water could also be produced, which would be stored in a containment pond on-site for use at the mine. All electricity generated will be used by the mine, so the sales price of electricity used in this analysis is 130 Tugrik/kWh (0.094 USD), which is the price that the mine would otherwise have to pay to the grid. **ES Table 4** shows results of the economic analysis.

In conclusion, after constructing a relatively simplistic three dimensional geologic model, RRR estimated that the proposed project could produce enough gas to fuel a 5.0 MW power generation facility to be used by the mine. The capital costs are estimated to be $5.4 million USD. At the p50 production rate, the project returns a positive value for the NPV at 1.93 million USD, an IRR of 22.7 percent with a payback period of 4.32 years. Carbon emissions would be reduced by 104,500 tonnes of CO_2e over the project's 10 year life. In order to minimize the geologic uncertainty which might affect the success of the coal mine methane drilling and recovery campaign,

In order to minimize the geologic uncertainty which might affect the success of the coal mine methane drilling and recovery campaign, such as the proposed drilling program, a comprehensive data collection program should be carried out first. This program should include several different types of testing and sampling:

- Gas desorption testing: currently, there is very little gas content data available. An extensive campaign should be designed and carried out to collect gas content data for all coal seams at depths of 100 m and greater over the entire license block.

- The desorbed gas from select desorption samples should be tested for gas composition including nitrogen, carbon dioxide, hydrogen sulfide and other hydrocarbons.
- Injection fall-off testing should be carried out in one or more test drillholes to better understand the gas flow capacity (gas producibility) of the coal, average reservoir pressures, and the impacts that drilling and completion related stresses will have on the reservoir permeability.
- All planned exploration drillholes should be rotary drilled, rather than cored, and a full suite of geophysical logs should be run over the entire openhole section for each drillhole.
- A three dimensional seismic acquisition program should be designed and carried out over the entire mine lease to identify and determine the extent and impact of faulting, fracturing, and folding on the coal-bearing strata. This is key to mine planning and CBM development.

Acronyms and Abbreviations

CBM	coalbed methane
CES	Central Electricity System
CMM	coal mine methane
CO_2e	carbon dioxide equivalent
GIP	gas in place
GMI	Global Methane Initiative
IRR	internal rate of return
km	kilometers
km^2	square kilometers
kV	kilovolt
kWh	kilowatt hour
m	meters
m^3	cubic meters
MOE	Ministry of Energy
MOM	Ministry of Mining
MRAM	Mineral Resources Authority of Mongolia
MW	megawatt
MWh	megawatt hour
NNE	north-northeast
NNW	north-northwest
NPV	net present value
NW	northwest
OHTL	overhead transmission line
p10	Indicates a 10% chance that forecast will be ≥ to the p10 amount
p50	Indicates a 50% chance that forecast will be ≥ to the p50 amount
p90	Indicates a 90% chance that forecast will be ≥ to the p90 amount
PSC	production sharing contract
SE	southeast
SSW	south-southwest
USD	United States dollar
USEPA	United States Environmental Protection Agency

1. Background

This prefeasibility study was sponsored by the United States Environmental Protection Agency (USEPA) under the auspices of the Global Methane Initiative (GMI), of which both the United States (US) and Mongolia are members. The study was conducted by Raven Ridge Resources, Incorporated (RRR), with support from the Mongolia Nature and Environment Consortium (MNEC).

The Baganuur coal mine is a highly productive surface mine, supplying most of Mongolia's central region coal demand that consists of four major cities including the capital city, Ulaanbaatar. Baganuur's main customers are state-run thermal power plants that use approximately 5 million tons of coal each year to generate heat and power. Baganuur has historically produced approximately 3 million tonnes of coal per year and plans to increase production further, reaching over 6 million tonnes annually. The mine is expected to continue operation for at least 60 years, as the Baganuur deposit contains 599 million tonnes of coal resources according to the Mineral Resources Authority of Mongolia (MRAM), and the mining plan area contains 210 million tonnes of proved, mineable reserves according to the mine. In addition to being an established mine with a reliable future, initial investigations of coal characteristics and gas content, as well as anecdotal evidence 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. Finally, Baganuur is perfectly located geographically and has grid connections that will allow a CMM project to provide additional, gas-fueled electricity to Mongolia's main electricity grid, the Central Electricity System (CES). The electricity market in Mongolia is projected to grow and has already exceeded domestic supply, relying on expensive imports from Russia. Additionally, electricity prices for mines will rise up to 30 percent according to Mongolia's Energy Regulatory Commission, making self-supply of electricity using CMM an attractive prospect for Baganuur.

Having identified Baganuur as the prefeasibility study host mine, the RRR and MNEC (the RRR team) discussed with managers of the mine's owner, Baganuur Joint Stock Company (Baganuur JSC), the benefits of assessing CMM resources and determining an appropriate approach to recovery and use. The mine agreed to participate, providing data remotely and hosting a site visit for information exchange.

2. Introduction

The objective of this prefeasibility study is to examine the potential for employing vertically drilled wells to capture methane gas prior to mining for use as fuel to generate power at the Baganuur surface coal mine.

This report is the result of investigations that entail:

- Field visits to the mine;
- Translation and review of technical documents;
- Estimates of the in situ methane resources and forecasts of production based on statistical analysis of the gas that may be contained by the coal resources and the potential for pre-mine methane drainage via surface drilled wells; and,
- Analysis of the economic performance of a proposed gas-to-electricity pilot project based on current energy markets and quotes from vendors

Results of this prefeasibility study are intended to provide a foundation for a full-scale feasibility study. The approach taken is designed to develop a product that attracts the attention of investors or other stakeholders such that a full-scale feasibility study and eventually a drainage and utilization project are funded and executed.

3. Geologic Setting

3.1. Location

The Baganuur mine sits 127 km east of Ulaanbaatar just south of the city of Baganuur (**Figure 1**) on the northwestern edge of the Choir-Nyalga coal basin within the Eastern Mongolian geologic province. The mine is located in Bayandelger soum[1], one of nine districts of the Mongolian capital city of Ulaanbaatar, at the border between the Töv and Khentii aimags[2] (Erdenetsogt et al, 2009). The Baganuur coal deposit is mined along the eastern flank of a synclinal feature which trends NNE-SSW, and is 15 km long and 4 km wide and covers approximately 60 km^2 (**Map 1**).

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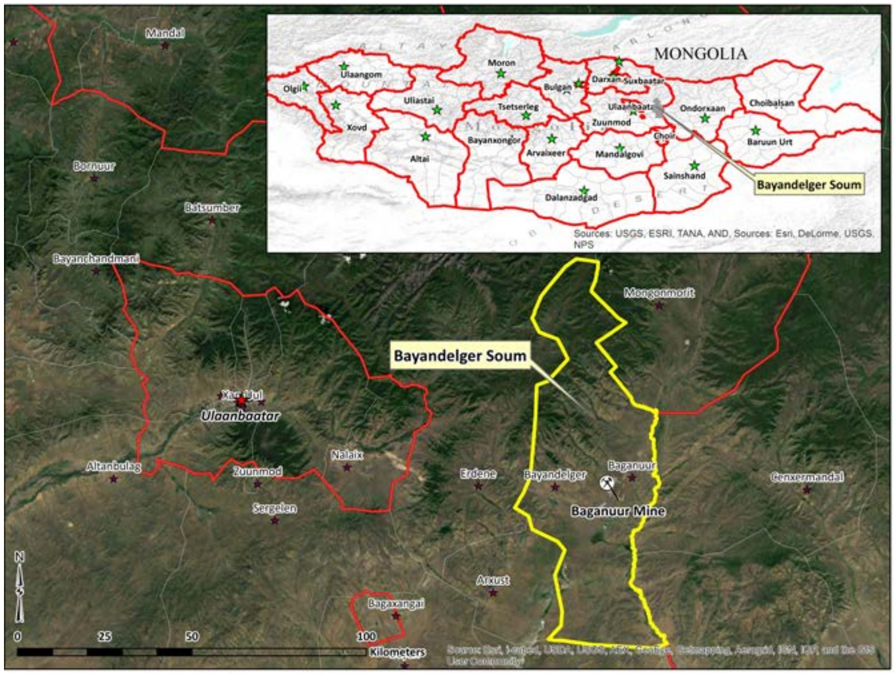

Figure 1: Area Overview Map

3.2. Regional Geology

Extensive field studies performed in Mongolia over the past century have resulted in mapping of large scaled geologic features that provide clues to tectonic controls of the evolution of depositional systems, burial history and subsequent deformation and collapse of basins where important coal deposits are found. Many studies have been published describing the structural evolution of the geologic terrain that comprises Precambrian to Tertiary strata in Mongolia.

Mongolia comprises complex terrain sandwiched between the amalgamated lower Paleozoic terrains of the Siberian craton lying to the north and the middle Paleozoic-Tertiary tectonic elements sutured to northern China lying to the south. Compression and uplift in the region during the Permian cut off marine deposition in Mongolia, where an unconformity found in Late Permian strata marks the beginning of nonmarine sedimentation that continues today (Sladen and Traynor, 2000). During the Mesozoic, the southern part of the country was subjected to widespread volcanism caused by tectonic forces that eventually lead to basin subsidence. The igneous activity is attributed to the closure of the paleo-Asian and/or Mongolia-Okhotsk Oceans (Dill et al, 2004). Sustained compression, folding and uplift throughout the Triassic and Early Jurassic periods caused most of Mongolia to experience widespread erosion, resulting in the formation of large lakes controlled, in part by preexisting crustal-scale weaknesses (Erdenetsogt et al, 2009). **Figure 2** provides a summary of the geologic age and the tectonic systems that controlled the deposition of the coal-bearing strata occurring throughout Mongolia.

In southern and eastern Mongolia, rifting and synrift deposition produced an extensive belt of Mesozoic basins; which would become depositional centers for nonmarine sedimentation. Throughout the late Jurassic and early Cretaceous,

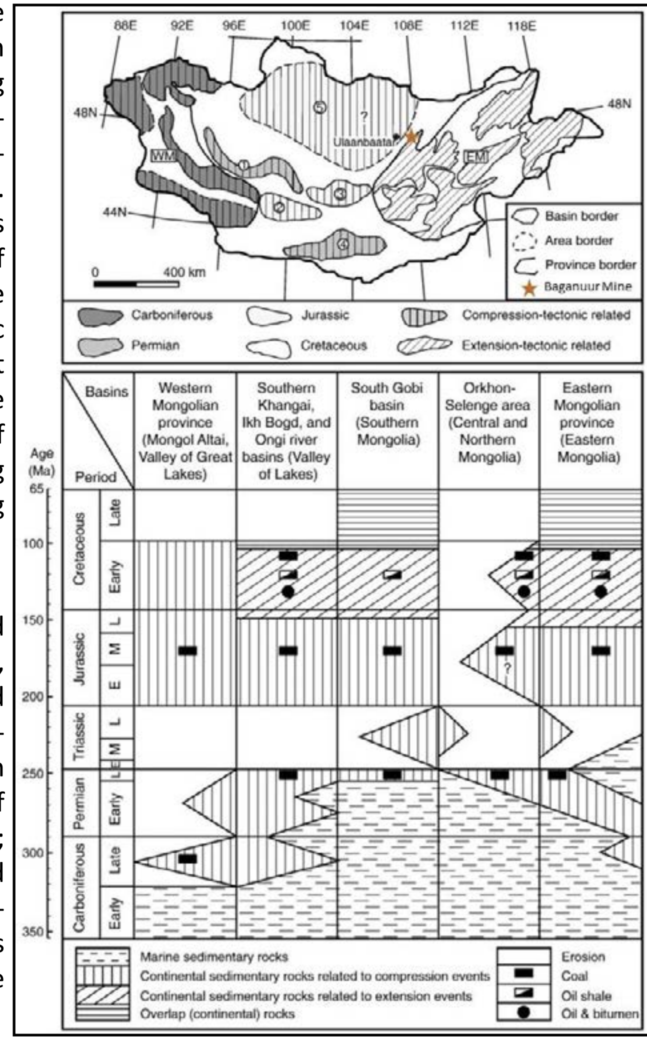

Figure 2: Age and Tectonic Summary of Coal-bearing Strata throughout Mongolia (modified from Erdenetsogt et al, 2009)

both subduction-related (back arc extension) and strike-slip-related extension that was located along many older major faults that bounded foundered plate fragments. This extension formed basins that provided conditions ideal for lacustrine sedimentation and accumulation. These depositional centers provided the perfect environment for the accretion of coal, oil and oil shale-bearing Lower Cretaceous sequences in the Eastern Mongolian province (Sladen and Traynor, 2000).

The Baganuur coal mine lies near the northwest border of the Choir-Nyalga basin, within the Eastern Mongolian geologic province. The Eastern Mongolian geologic province comprises six separate coal and oil-shale bearing basins. The coal deposits of the Choir-Nyalga basin are mainly associated with the Lower Cretaceous Zuunbayan volcano-sedimentary group. Within the province, the rank of the coal deposits range from lignite to subbituminous. The province contains an estimated 108.3 billion tonnes of coal resources, of which 6.5 billion tonnes are classified as reserves. The Baganuur coals were deposited in a fluvio-lacustrine environment during the late Jurassic and early Cretaceous periods. The Lower Cretaceous and Jurassic coals are classified as thermal coals—meaning that the coal will be used for heat and power generation (Erdenetsogt et al, 2009).

3.3. Mining Geology

3.3.1. Structural Geology

Baganuur JSC provided unpublished Mongolian language manuscripts documenting work that was done beginning in 1925. Situated in the structural center of the Choir-Nyalga basin's Mesozoic rift, the Baganuur mine shows evidence of rift expansion which likely began around the end of the Jurassic and continued throughout the early Cretaceous. During the expansion period, the lowland areas formed with the rift basin accumulated coal in a fluvio-lacustrine environment with climates ranging from semi-arid to warm temperate. The Baganuur coal deposit is situated in a graben-synclinorium structure oriented in NNE-SSW direction, and is comprised of three major coal seams, as much as 38 m thick, intercalated with two Lower Cretaceous sandstone and argillite formations named the Tsagaan-Tsav and Huhteeg formations. The coal bearing sequences are overlain by Quaternary gravels and sand as much as 6 m thick (Dill et al, 2004).

The Baganuur coal deposit is situated on the down-thrown block of a synclinal structure formed during the late Mesozoic. The deposit has been mapped as an asymmetric syncline with a NNE-SSW trending axis approximately 14 km long, where the eastern limb moderately dips 8 – 10 degrees, while the western limb rises 45-50 degrees and as much as 70 degrees. The synclinal structure is cut by a steeply dipping northward trending fault, which displaced the eastern side of the deposit upward 40 – 140 m. Coal seam 3 has been eroded from this eastern upthrown block of the syncline.

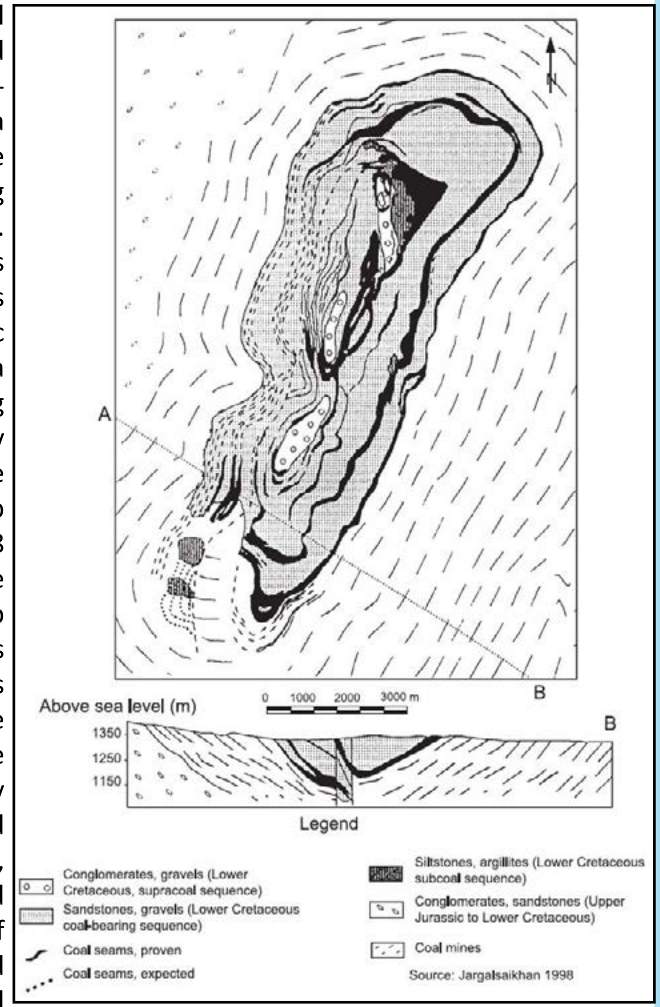

Figure 3: Map Showing Baganuur Coal Deposit and Associated Rocks with a Cross Section through the Southern Part of the Basin (Dill et al, 2006)

3.3.2. Coal Bearing Strata

Baganuur coal mine extracts coal from the Lower Cretaceous Huhteeg and Tsagaan-Tsav formations (**Figure 4**). The older Tsagaan-Tsav formation comprises alternating siltstone, sandstone, mudstone, and small to

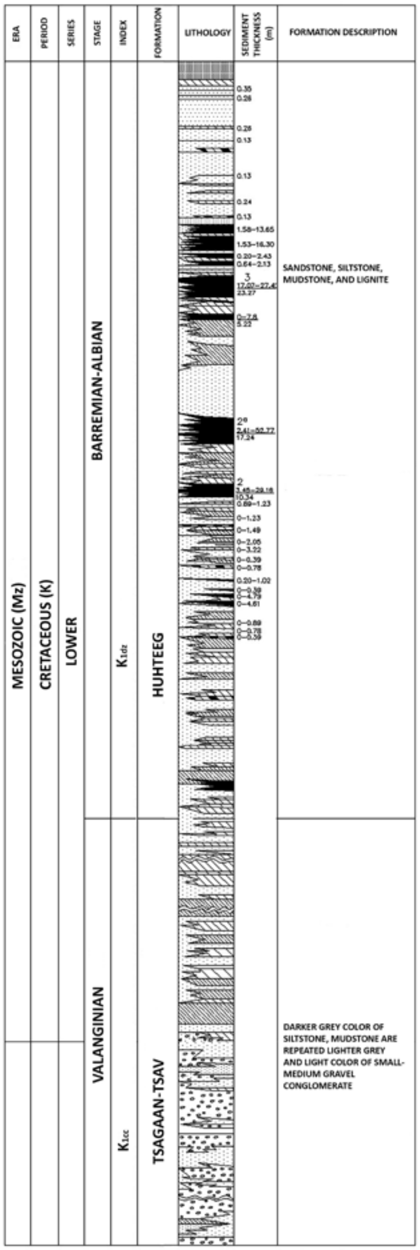

Figure 4: Stratigraphic Column of the Baganuur Coal Mine Area

medium-sized gravel conglomeratic beds.

The Huhteeg formation, which overlies the Tsagaan-Tsav, contains coal seams 2, 2a and 3, which are targeted for mining. The Huhteeg Formation is comprised of sandstone, siltstone, mudstone and lignite to subbituminous C coal seams (Hill et al, 2006). The basal mineable seam, coal seam 2, ranges in thickness from 3.5 to 29.2 m, with an average thickness of 10.3 m. Coal seam 2a, the middle mineable seam, ranges from 2.4 to 52.8 m in thickness, averaging 17.2 m. The uppermost mineable seam, coal seam 3 ranges from 17.1 to 27.4 m thick and averages 23.3 m. Coal seams 2 and 2a are primarily interbedded with siltstone and mudstone, while seam 2a and 3 are separated by sandstone and mudstone. Overlying coal seam 3 are sandstone and gravel beds.

The strata atop the mineable coal seams, sandstone and gravel beds, are conduits for gas originating in the mineable coal seams, allowing escape to the atmosphere or trapping within porous spaces as dewatering takes place during mining.

3.3.3. Thickness and Physical Properties

The lowermost coal seam, seam 2, is the most suitable for commercial extraction because of its thickness and gross caloric value. Coal seam 2 ranges in thickness from 3.5 to 29.2 m, with an average thickness of 10.3 m. The seam is continuous with consistent thickness throughout the mining area, and RRR estimates there are 91.1 million tonnes of coal resources occurring in coal seam 2.

Coal seam 2a, lying 45 m above coal seam 2, ranges in thickness from 2.4 to 52.8 m, averaging 17.2 m thick. Although the overall thickness of seam 2a is greater than coal seam 2, a persistent coal parting within seam 2a makes the mineable thickness less consistent and continuous.

The uppermost coal seam, coal seam 3, lies 84 m above coal seam 2a. The majority of resource from coal seam 3 occurs in the northeast portion of the mining area. Erosion has removed coal seam 3 from the southern portion of the mining area. Coal seam 3 contains multiple partings, but ranges in thickness between 17.1 and 27.4 m, averaging 23.3 m.

MRAM reports that the coal mined at Baganuur ranges in rank from lignite to subbituminous C, with ash content ranging from 12 to 17 percent, moisture ranges from 31.8 to 35.9 percent and a calorific values ranging from 2,783 to 3,615 kcal/kg. At shallow depths down to 25 m, the calorific value of the coal decreases to as low as 2,000 kcal/kg due to weathering and oxidation.

3.4. Hydrology

The mining area is bisected by the Herlen River, which runs NW-SE and almost entirely through the longitudinal center of the property. Springs, small lakes and marshes occur along the trace of the river drainage. The width of the watercourse varies between 40 -100 m with a depth of 1 – 3 m.

Beginning in 1981, a series of water pumping and water monitoring wells were drilled by the mine on the west flank of the Baganuur structure. These wells are designed to drain the coals prior to mining to reduce water flow into the pit. The Baganuur hydrologists maintain a database of locations and water surface elevations for each of the mine's water pumping and monitoring wells and RRR used this data to estimate the potentiometric surface near the mine. As dewatering continues, the potentiometric surface will be drawn down and further away from the pit; draw down of the water surface drops the pore pressure within the coal seams causing desorption of methane gas, allowing the gas to migrate into other strata. As the gas desorbs from the coal, it will likely migrate up dip toward the exposed high wall of the pit, and potentially to the easternmost dewatering wells where it will accumulate and subsequently be released as the water is produced. This process may already occur, as the mine has reported anecdotal evidence of the smell of rotten eggs coming from nearby dewatering wells. The rotten egg smell possibly indicates hydrogen sulfide, a gas that arises from the decomposition of organic material such as coal and is often associated with biogenic methane gas. **Figure 5** is a map of the locations of the water pumping and monitoring wells; the estimated potentiometric surface contours are drawn on the map as well as the proposed gas drainage wells and pipelines.

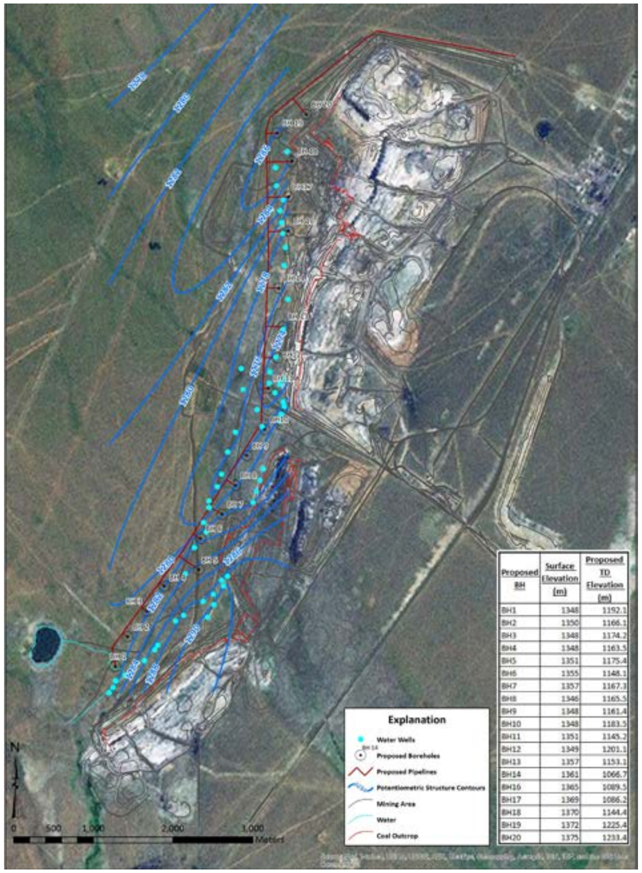

Figure 5: Map Showing the Potentiometric Surface Contours and the Proposed Drilling Plan Layout

4. Coal Resources

Mineable coal resources at Baganuur comprise coal seams 2, 2a and 3. Seams 2 and 2a are exposed at the surface consistently throughout the mining area, while seam 3 is found primarily in the northeastern portion of the mine. According to MRAM, the mine contains 599 million tonnes of coal resources.

Using geologic cross-sections and the five-year mine plan provided by the mine, RRR constructed a simple three-dimensional model of the mining area in order to estimate the potential coal and gas resources. Baganuur JSC has divided the mine into three sections: Mining Section 1, Mining Section 2, and New Mining Section. RRR used these sections as the basis for coal and gas resource estimates. The locations of the geologic cross-sections, the designated mining areas as well as the five-year mine plan are shown on **Map 2.** The cross-sections are constructed such that the line of section is directly down dip, thus reducing the distortion that would occur if the section was constructed along the strike of the beds i.e., a line oblique to the bedding dip. **Figure 6** is an example cross-section used in the coal resource calculations.

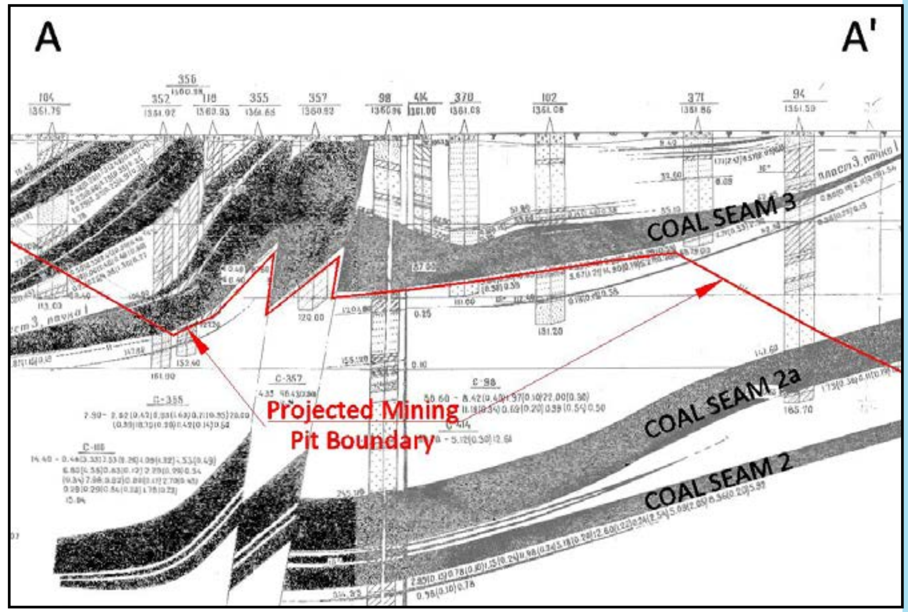

Figure 6: Example Cross-section Used in Coal Resource Calculations

AutoCAD™ was used to trace the tops and bottoms of the mineable coal seams and construct a numerical model of their three-dimensional surfaces in order to estimate the volume of coal lying within each of the mining sections. The mass of in-place coal resource in tonnes was estimated by multiplying the volume of the coal by its average density. The average density of coal of the given rank is 1.35 tonnes per cubic meter. The values reported as coal resource include not only the coal, but the ash contained in partings or as finely distributed non coal material. In other words, the actual coaly material that is extracted for supplying customers will later be separated by washing or some other method to provide the customer with a suitable product.

Figure 7 depicts the coal resources estimated within the three mining sections and within each of the proposed boreholes by mineable coal seam. **Table 1** shows the estimated coal resources by mining area. The cumulative coal resource estimated for the mineable coal seams within the mining areas is 248.97 million tonnes. This differs from the coal resources reported by MRAM, 599 million tonnes, which include the entire Baganuur coal deposit.

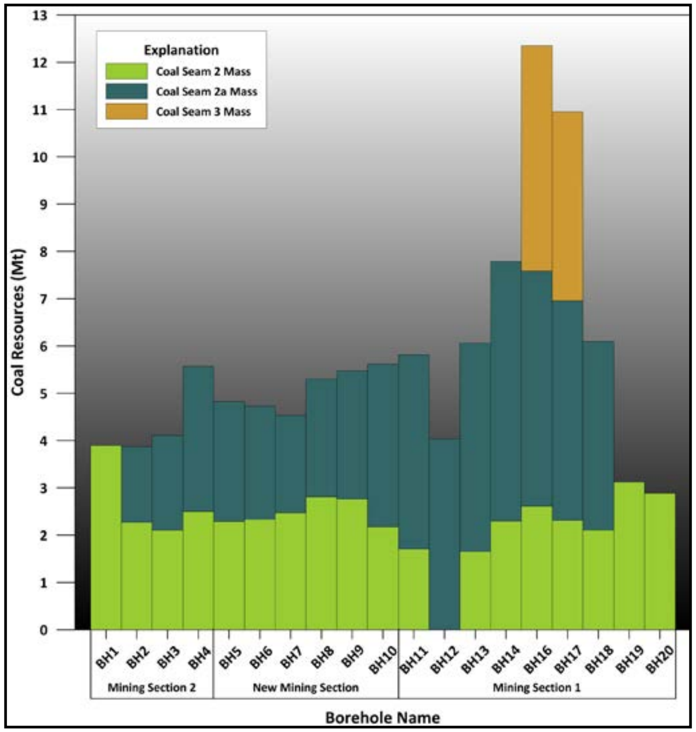

Figure 7: Coal Resources within Proposed Borehole Drainage Areas

Table 1: Estimated Coal Resources within Designated Mining Areas

Mining Section	Coal Seam 2 (t)	Coal Seam 2a (t)	Coal Seam 3 (t)	Total (t)
1	38,377,984	75,599,885	34,638,432	148,616,301
2	24,853,323	18,408,092	Above Potentiometric Surface	43,261,416
New	27,865,692	29,224,458	Above Potentiometric Surface	57,090,150
Total	91,096,999	123,232,435	34,638,432	248,967,866

5. Gas Resources

The coal resource estimate described in the previous section served as the basis for calculating in-place gas resources at the Baganuur mine. A widely accepted way of estimating the gas resource associated to the coal is to multiply the coal mass by the gas content; however, other than the desorption testing conducted by MNEC and RRR in 2012, verifiable in situ gas content measurements are not available for the mine. In August of 2012, one of the samples collected for desorption testing was submitted for adsorption isotherm testing to the Xi'an Research Institute of China Coal Technology & Engineering. Results from the testing were used as a reference for the amount of gas that may be present in the coal seams and will otherwise be released during mining if not recovered before extraction begins. Results of this test are shown in **Figure 8**.

Methane adsorption isotherm testing was conducted to provide a broader frame of reference that RRR used to estimate the potential gas-in-place (GIP) of Baganuur's coal resources. An adsorption test mathematically describes the relationship between pressure and gas capacity under equilibrium conditions at a stable temperature, usually chosen to represent the reservoir conditions of the coal seam occurring at the depth from which the sample was taken. This adsorption isotherm indicates the gas capacity of one sample taken from the coal at the mine and may not accurately depict the situation for other coal seams; however, the rank and coal quality of other coal seams occurring at Baganuur are similar. Furthermore, as mentioned previously, the Baganuur coal field shares many characteristics

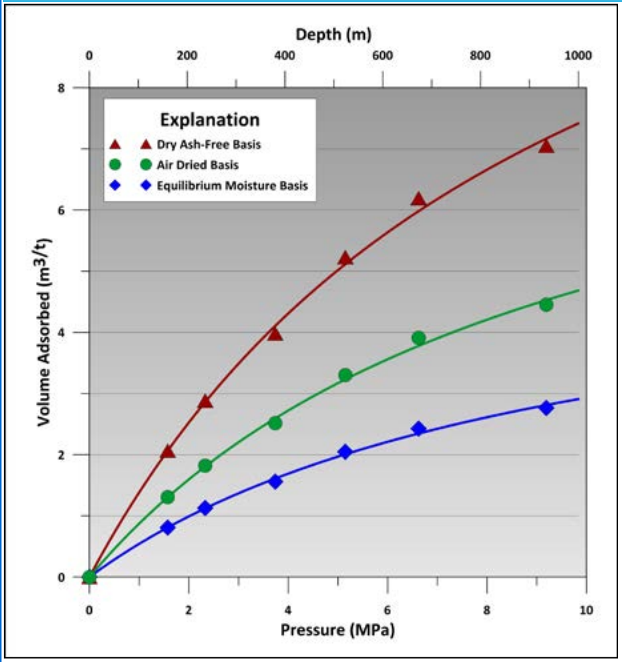

Figure 8: Adsorption Testing Results

that are analogous to the PRB in Wyoming, for which there are numerous published reports containing results of adsorption testing which provide a wider sample set for study. RRR used the available isotherm constants (Langmuir pressure and Langmuir volume) resulting from the tests of the Baganuur sample and those taken from similar rank coal deposited under similar geologic conditions within the PRB to perform statistical analysis. Analysis of the larger sample set afforded the most likely Langmuir pressure and Langmuir volume constants resulting from coal occurrences occurring under similar conditions used to calculate the gas content. The Langmuir equation below was used to calculate the gas content of coal at a given depth.

V = VL * P / (PL + P); where

V = gas content (m^3/t)

VL = Langmuir volume constant (m^3/t)

P = reservoir pressure (MPa)

PL = Langmuir pressure constant (MPa)

For the purposes of this study, pressure was converted into depth of burial by assuming a normal hydrostatic gradient . The curves shown on **Figure 8** relate gas content of the coal sample to the expected content at a given mining depth. The red curve has been adjusted to reflect the gas capacity for the coal on a dry, ash free basis, allowing the results of this test to be compared to any other isotherm testing results conducted on a coal sample from anywhere in the world. Ash content data is not readily available for the explored extent of all three mineable coal seams so the estimate of the coal and gas resources is done on an in situ basis and remains uncorrected for ash content.

Therefore, for the purposes of this study the blue curve is considered to best represent the gas capacity of coal as it predicts the gas content at equilibrium moisture conditions without correcting for ash content. In other words, in order to represent the in situ conditions of the coal seam we used the Langmuir constants reported on an as received-equilibrium moisture basis, thus accounting for the diminished gas content associated with the contained ash.

As described in **Section 4 Coal Resources** and related to coal resource calculations, RRR calculated the tonnage present in the mineable coal seam within the designated mining sections. In order to estimate GIP, the coal resource contained therein was multiplied by a probability distribution representing the range of gas content values for each depth of occurrence obtained from the adsorption isotherm values of the Baganuur mine and PRB.

Figure 9 charts the

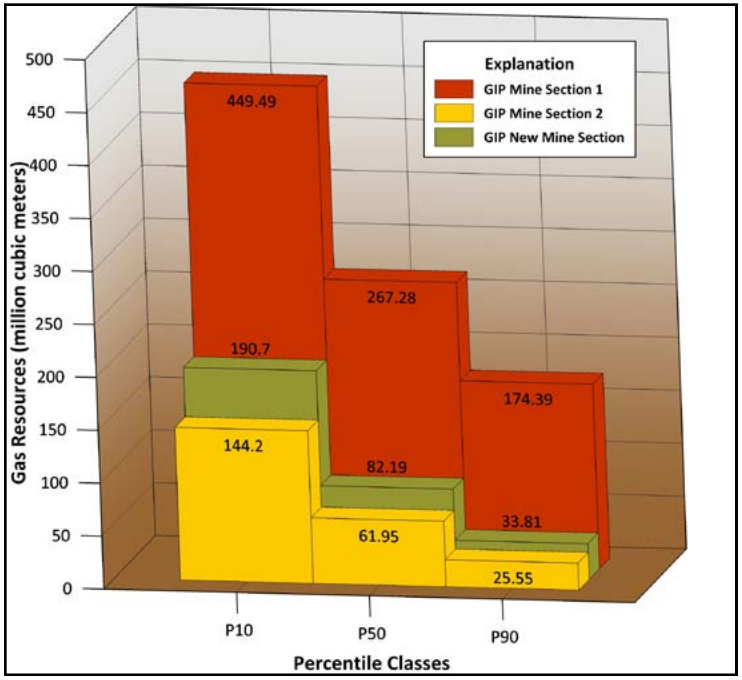

Figure 9: Probability Forecast of Estimated GIP Shown by Mining Section

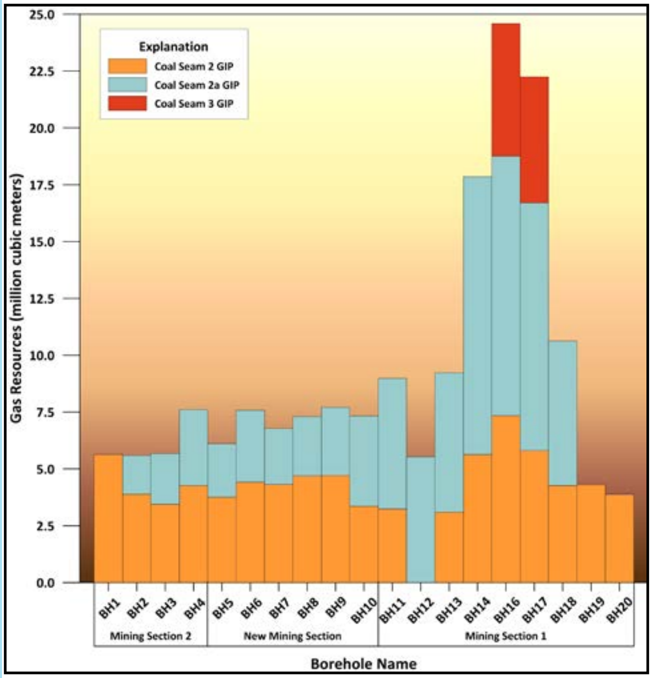

Figure 10: Estimated GIP by Proposed Borehole, Coal Seams 3, 2a and 2

probability based estimate of the GIP for each of the p10, p50 and p90 percentiles of the designated mining sections. The probabilistic approach to estimating the GIP takes into account the uncertainty of the coal density and the gas content values of the mineable coal. The chart shows that the total GIP gas resource forecasts ranges from 233.8 up to 784.4 million m^3 (p90 through p10).

This study proposes drilling vertical surface pre-mining drainage wells in order to recover CMM before extraction (described in detail in **Section 7 Potential Gas Production**). The GIP was calculated for the coal resource that may be drained by each proposed borehole. The appropriate gas content was chosen using the mid-point of the intercept depth of the top and bottom of the coal seam. Depth was converted to hydrostatic pressure and the gas content was calculated using the Langmuir isotherm. The total estimated p50 GIP of the drainage area for the proposed borehole program is 174.6 million m^3.

It is apparent in **Figure 10** that coal seam 3 is shown only to contain gas within BH 14 and BH 16. This is because RRR mapped and identified where the coal resources for each seam lies below the potentiometric surface. As discussed in **Section 3.3.3**, coal resources lying below the potentiometric surface are most likely to contain the original gas-in-place. The gas resource contained by coal seam 3 is further diminished as much of coal seam has been eroded from the southern extent of the mining property.

6. Coal Mining

6.1. History

Original discovery of Baganuur coal resources occurred by chance. Preliminary research for geographical, topographical and anthropological purposes began prior to the first discovery of lignite in 1925 by B.M. Kupletskii. Early discoveries of lignite were discounted as having no future, and consequently, coal resource exploration and characterization did not occur until the mid-1960s by a team led by P.V. Osokina and A.A. Harapov. Using seven drill cores (50 – 80 m) seven exploration trenches and limited geophysical data, the team was able to identify the Baganuur area contained Lower Cretaceous age coal ranging from 0.5 to 39.6 m thick and concluded that subsequent research was necessary. Scientists from the former Soviet Union began the development of the Baganuur coal deposit between 1975 and 1978, where the first production started in 1978. The produced coal was sent to the coal-fired power plant in Ulaanbaatar, where it continues to be used today.

6.2. Mining Conditions

Currently Baganuur mine is 75 percent state owned and 25 percent privately owned. The mine is an open cast or surface mine, using dragline excavators and self-unloading trucks to extract the coal which is primarily used to power the CES sub-stations. The mine managers believe the service life of the mine is 60 years, from which 210 million tonnes of mineable coal can be produced from coal seams 2, 2a and 3.

6.2.1. Management of Produced Water

If left unmanaged, up to 4.3 million m^3 of water would flow into the mine pit annually. In order to manage this, beginning in 1981 the mine implemented a dewatering program so that 3.8 - 4.0 million m^3 of water is pumped from a series of water production and monitoring wells annually. A total of 54 dewatering wells running with 3 pumps, along with the plan the drill and implement 8 – 12 additional wells per year keep the water from affecting the mining operations. Of the extracted groundwater, Baganuur thermal power plant's internal consumption amounts to 0.8 – 1.1 million m^3 annually, while 0.5 million m^3 of water was used to recreate the Bagagun Lake. The remaining 2.5 – 2.7 million m^3 are discharged into a holding pond and the nearby Herlen River.

6.3. Projected Coal Production (Mining Plan)

According to the mine manager's latest projections, the mine will increase production to 6.13 million tonnes by 2022. **Map 2** shows the areas from which the mine will extract coal for the next five years. **Table 2** shows the projected production by coal seam.

Table 2: Projected Coal Production

Coal Seam	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Seam 2 (Mt)	-	1.13	1.50	1.51	1.44	0.81	1.05	1.96	1.26	0.91
Seam 2a (Mt)	1.31	0.76	0.57	0.64	-	0.81	0.36	0.08	0.78	1.17
Seam 3 (Mt)	2.26	1.63	2.23	3.35	4.07	3.89	4.23	4.01	3.97	4.04
Total (Mt)	3.57	3.52	4.30	5.51	5.51	5.51	5.64	6.05	6.00	6.13

7. Potential Gas Production

RRR estimates the potential gas resources within Mining Section 1, Mining Section 2 and the New Mining Section at Baganuur mine to range from 233.8 to 784.4 million m^3. This estimate includes gas from coal seams 2, 2a and 3 that lie below the potentiometric surface.

7.1. Drilling

Locating the proposed boreholes to intersect the targeted coal seams below the potentiometric surface, (**Section 3.3.3 Thickness and Physical Properties**).

The lowermost coal seam, seam 2, is the most suitable for commercial extraction because of its thickness and gross caloric value. Coal seam 2 ranges in thickness from 3.5 to 29.2 m, with an average thickness of 10.3 m. The seam is continuous with consistent thickness throughout the mining area, and RRR estimates there are 91.1 million tonnes of coal resources occurring in coal seam 2.

Coal seam 2a, lying 45 m above coal seam 2, ranges in thickness from 2.4 to 52.8 m, averaging 17.2 m thick. Although the overall thickness of seam 2a is greater than coal seam 2, a persistent coal parting within seam 2a makes the mineable thickness less consistent and continuous.

The uppermost coal seam, coal seam 3, lies 84 m above coal seam 2a. The majority of resource from coal seam 3 occurs in the northeast portion of the mining area. Erosion has removed coal seam 3 from the southern portion of the mining area. Coal seam 3 contains multiple partings, but ranges in thickness between 17.1 and 27.4 m, averaging 23.3 m.

MRAM reports that the coal mined at Baganuur ranges in rank from lignite to subbituminous C, with ash content ranging from 12 to 17 percent, moisture ranges from 31.8 to 35.9 percent and a calorific values ranging from 2,783 to 3,615 kcal/kg. At shallow depths down to 25 m, the calorific value of the coal decreases to as low as 2,000 kcal/kg due to weathering and oxidation.

Hydrology is crucial in order to assume methane present in the coal seam has not already desorbed and migrated up dip and been released to the atmosphere at the ground surface or via the face of the mine pit's highwall.

In order to capture CMM that would otherwise be released by projected future mining activities, RRR proposes drilling 19 vertical wells from which gas will be drained from the down dip extent of Mining Section 1, Mining Section 2 and the New Mining Section. Pre-mine drainage is the only viable option for capturing and using gas that would otherwise be released during mining. The proposed wells are drilled on centers at 400 meter spacing between wells, providing for a drainage area of approximately 16.2 hectares per borehole. Locations for these proposed wells are shown on **Map 3**. **Figure 11** is an example cross section showing the proposed placement of borehole BH 14; the location of section, A-A', is delineated on **Map 2**. The borehole placement with respect to the potentiometric surface and of the intersection of the targeted coal seams is also shown.

In the production modeling performed for this study, a series of 19 wells are proposed, positioned along the western rim of the pit outside of the projected five-year mine plan. The placement of the boreholes is designed to effectively drain the target seams 2, 2a and 3 (**Map 2**). Each well is drilled to a total depth just below the basal target seam (ranging in depth from 148 to 294 m), at which point casing is set just above the seam and the well is completed openhole, relying on natural fractures to enable gas migration to the borehole. In 13 of the 19 boreholes a second seam is present that is stratigraphically above the basal target seam; this seam, which is behind casing, is perforated and completed through the casing. A downhole pump will be placed at the bottom of the well and produced water is pumped to the surface facilitating the production of gas from the coal. Each well is forecast to produce CMM for 10 years, with individual well gas production peaking in year four as the reservoir is de-watered. The produced water will have to be pumped to a local containment pond where it will be stored and made available for use by the mine. All costs associated with both the gas and water production are incorporated into the economic analysis.

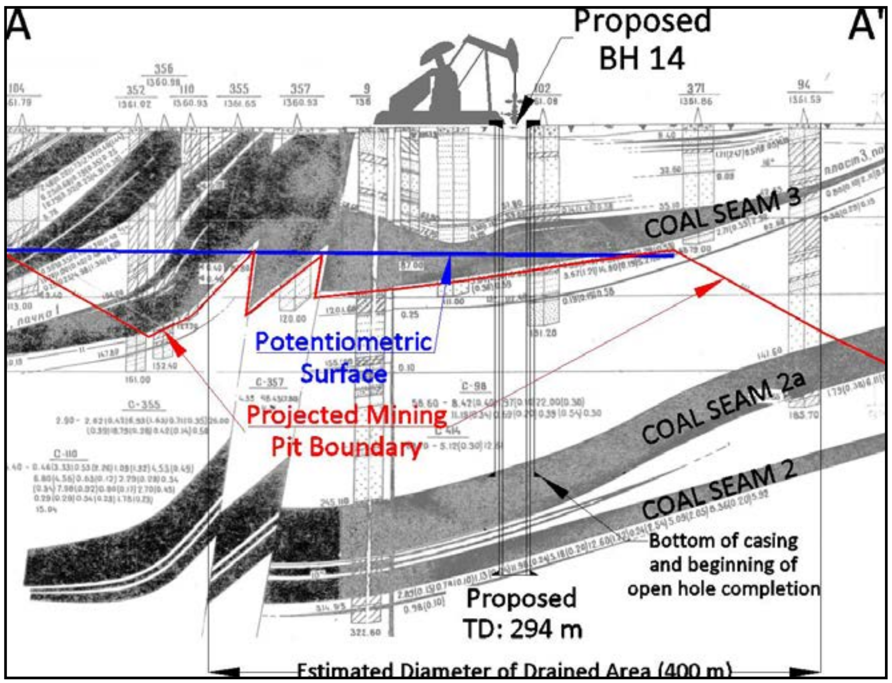

Figure 11: Example of proposed BH 14 Showing the Potentiometric Surface with Respect to the Structural Tops of Coal Seams 2, 2a and 3

7.2. Gas Production Forecast

7.2.1. Approach to Forecasting Gas Production

Future gas production can be predicted using several approaches, the most common are: basing future production on actual past production of wells in the field being studied; reservoir simulation modeling using early production and/or geologic and engineering data acquired through field testing; or using production profiles from wells that were drilled in areas exhibiting similar geologic and reservoir conditions. There is no active CBM production in Mongolia, and sufficient information was not available for reservoir simulation modeling; therefore, in order to develop gas production profiles for this project, an analogous field to the Baganuur mine property with developed CBM production was identified and used for production profile modeling. The Wyodak-Anderson coals of the Upper Cretaceous Fort Union Formation along the eastern margin of the PRB in eastern Wyoming are similar rank and occur at similar depths to those found at Baganuur, have comparable gas contents, and have been exposed to similar post-depositional tectonic events. The PRB is a tectonic foreland basin and an asymmetrical syncline, characterized by a gently dipping eastern limb and a steeper dipping western limb. The Fort Union Formation is composed of interbedded sandstones, siltstones, and carbonaceous shales, with numerous coal beds ranging in total thickness from 15 to 30 m, and gas contents ranging from 0.25 to 1.04 m^3 per metric ton (Stricker et al, 2006). The rank of the coals is subbituminous with low sulfur content primarily used for electric power generation.

There is a long history of CBM development in the PRB with extensive production from the coals of the Fort Union Formation in advance of mining taking place at open cast coal mines. **Figure 12** is a map showing the wells used in the gas and water production decline analysis. RRR developed a distribution of production profile outcomes (p10, p50, p90) for all the producing PRB wells with similar characteristics. 1484 wells selected from an initial population of 1974 were chosen for comparison with Baganuur coalfield based on the following criteria:

- CBM produced ahead of the highwall with at least five years of production;
- Total depth of the wells was no greater than 183 m; and
- The wells were producing from the Wyodak, Canyon or Anderson coalbeds.

Potential Gas Production

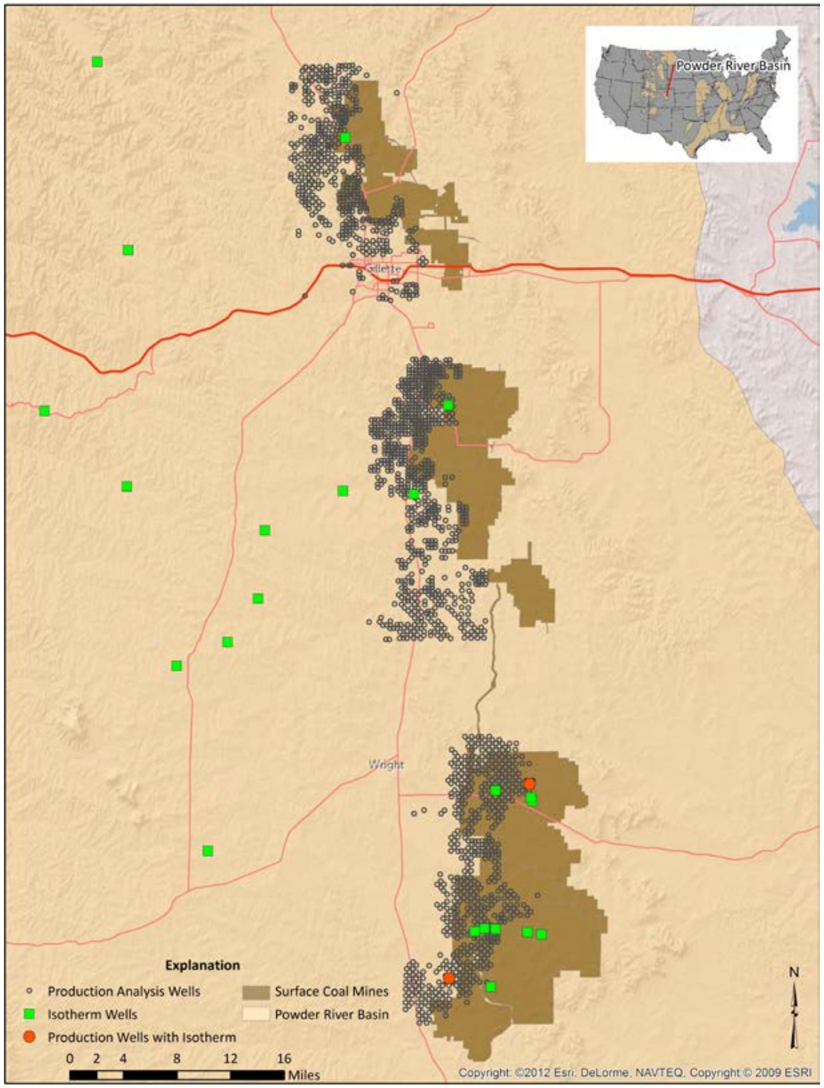

Figure 12: Map Showing Wells Used in Gas Production Forecast Analysis

The average monthly production was calculated and used to establish a percentile distribution and group p10, p50 and p90 production wells. From these percentile groups, monthly median gas and water production values were utilized to generate p10, p50 and p90 model wells. The gas and water estimated ultimate recovery was estimated for these model wells using exponential decline curve models. From this distribution, the p50 gas production profile and the associated water production was selected for use in the economic analysis for comparison with Baganuur Mine (**Figure 13** and **Figure 14**).

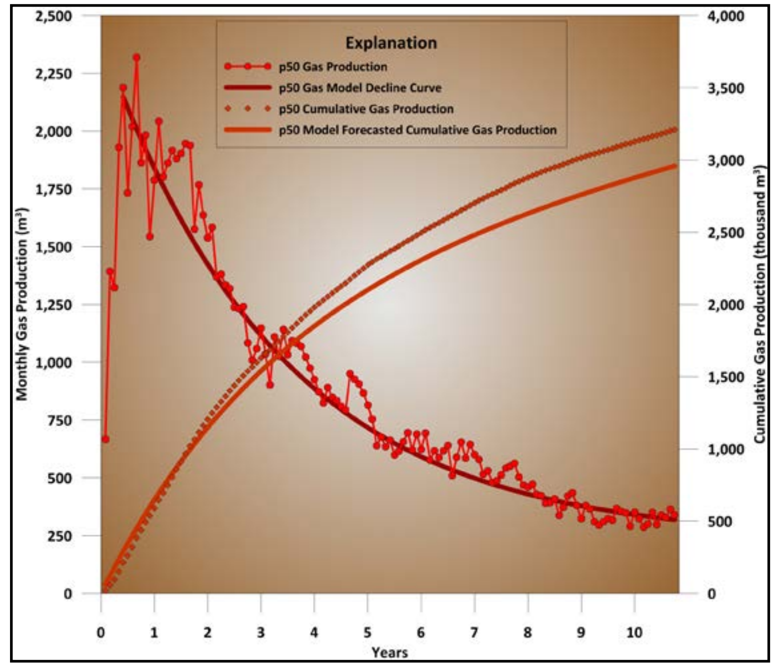

Figure 13: Powder River Basin p50 Gas Production Decline Curve Model Showing Cumulative Production of a Single Well for 10 years

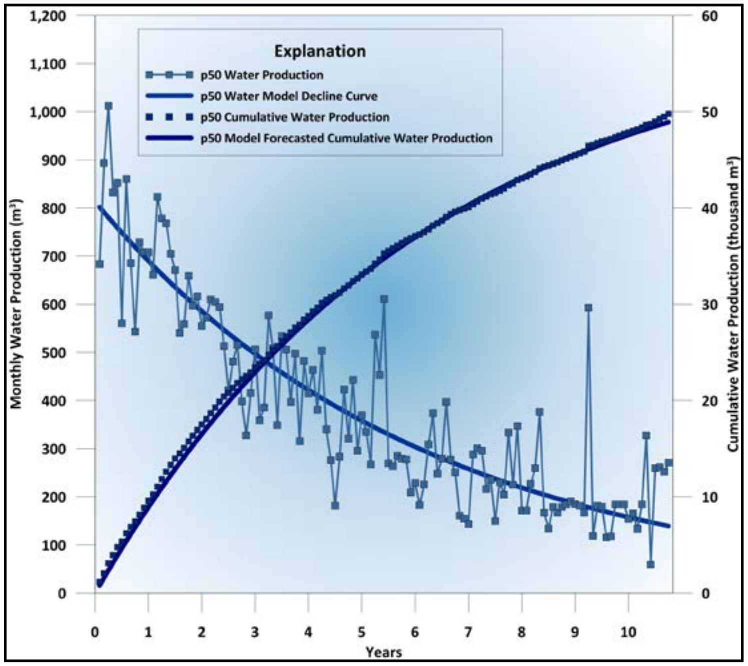

Figure 14: Powder River Basin p50 Water Production Decline Curve Model Showing Cumulative Production of a Single Well over 10 years

7.2.2. Gas Production Forecast Results

Based on the comparison of the Baganuur coalfield to the analogous PRB, gas and water production forecasts were generated. These production forecast results are different from the GIP calculations, because the GIP estimates represent the total amount of gas present within the mineable coal seams and within the mining areas, whereas the gas and water production forecasts represent only the volume of gas and water that may be drained by the proposed borehole plan. Based on the proposed boreholes and their drilling schedule, **Table 3** shows the forecasted annual gas and water production.

The total forecasted gas production for the proposed 19 borehole drilling and utilization project is 54.3 million m^3 of methane. Forecasted water production totals 823.7 thousand m^3. Given the estimated p50 GIP and the p50 forecasted gas production, the drainage efficiency over the 10 year project life is 32 percent.

Table 3: Gas and Water Production Forecast Results

Production Forecasts	YEAR									
	1	2	3	4	5	6	7	8	9	10
Annual Gas (million m^3)	2.05	4.93	7.35	9.27	8.38	6.48	5.29	4.44	3.69	3.13
Annual Water (thousand m^3)	31.3	70.3	104.0	132.2	117.8	98.5	83.7	71.3	62.0	52.5

8. Energy Markets

8.1. Coal Market

Mongolia has estimated coal resources of 173.3 billion tonnes (MRAM, 2013) with proved coal reserves of 12.2 billion tonnes, including 2 billion tonnes of coking coal and 10.1 billion tonnes of thermal coal (IEEJ, 2012) in over 370 deposits and occurrences in 15 different basins. Over 40 companies are involved in Mongolia's coal production, including wholly state-owned Erdenes Tavan Tolgoi, partly state-owned Baganuur and Shivee Ovoo, as well as national and foreign invested private sector companies such as Energy Resources LLC, Tavan Tolgoi JSC, MAK LLC, Qinhua-MAK-Naryn Sukhait LLC, Southgobi Sands LLC, and MoEnCo LLC.

Mongolia produced over 31 million tonnes of coal in 2012, more than tripling production since 2008 (EIA, 2013). Mongolia's energy needs are met primarily by coal; seven coal-fired combined heat and power plants produce 829 MW of 1,062 MW installed capacity. Baganuur currently provides 70 percent of coal required to operate power plants in Ulaanbaatar (Mongolia Mining Journal, 2013). Mongolia's total electricity demand is expected to reach 1,375 MW in 2015 due to Mongolia's rapidly developing mining-based economy and urbanization acceleration. Mining companies account for 40 percent of Mongolia's total electricity consumption (Kohn, 2013). Mongolia's domestic coal demand is expected to rise significantly with increased power demand; however, most coal will still be exported. Mongolia consumed only 10 million tonnes of 2012 coal production.

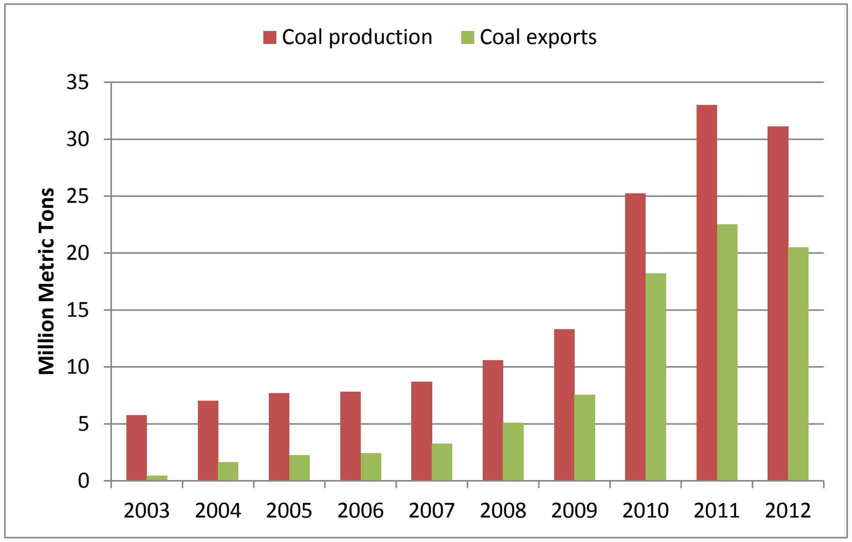

Figure 15: Mongolia's Coal Production and Exports. Source: MRAM (2013)

In 2009 it was reported that almost all of Mongolia's exported coal went to China (Liu, 2012). China's domestic coal production and transport capacity has strained to keep pace with demand in recent years and as a result, China has been transformed from a net coal exporter into the world's largest importer, with net imports reaching 168 million tonnes, or 4.8 percent of total consumption on a physical quantity basis, and over 5 percent on a heat value basis in 2011. China has historically produced its own coking coal; however, growing demand for coking coal due to a rapid increase in steel production has led to demand for imports from Australia and Mongolia. In 2008, Mongolia supplied over half of China's coking coal imports and maintained its position as top exporter until the first half of 2013, when Mongolia's exports of coking coal to China fell by 36 percent while Australia's doubled. Despite the shorter distance to China's steel mills, Mongolian coal must be trucked to the Chinese border increasing the cost compared to Australia's seaborne coal. It is expected that installation of a railway will increase the competitiveness of Mongolia's coal in China (Ng, 2013).

Though thermal power generation has been the most important driver for coal industry expansion in China, accounting for approximately half of total consumption in recent years, imports are consumed primarily in the southern and eastern coastal cities. Thus the market for exports of thermal coal from Mongolia to China is not as significant, and will depend on the particular grades of coal, the costs of transport, and the prices of coal and electricity in China.

Thermal coal from Prophecy Coal's Ulaan Ovoo mine, 420 km NNW of Ulaanbaatar, has previously been exported to Russia and will resume under two export contracts with a buyer in Russia's Buryatia region. Coal deliveries of 5,000 tonnes per month will be exported through Northern Mongolia's Sukhbaatar rail station in November, 2013 (Dodson, 2013). It may be possible to realize higher prices for Mongolian coal by exporting to Japan and Korea, or other international markets; but, this would depend on the price of rail freight through China or Russia.

Exporting electricity to China is another option for utilization of Mongolian thermal coal. The Mongolian Government has sought to develop a 3,600 MW power plant and transmission line at Shivee Ovoo to export electricity to China (World Bank, 2009) with a memorandum of understanding with China's State Grid Corporation (IEEJ, 2012). Additional plants could be profitable as it may be cheaper to export coal as electricity rather than by rail freight.

8.2. Electricity Market

Mongolia's installed power capacity is 1,062 MW, most of which is provided by coal (see **Figure 16**); however, only 836 MW (80 percent) is available due to aging power plants operating below design capacity. Mongolia's electricity transmission network connects approximately 70 percent of the country's population, but is considered unreliable, fraught with frequent blackouts occurring in major cities due to aging infrastructure (IEEJ, 2012). Mining accounts for 40 percent of Mongolia's energy consumption, and electricity prices for mining companies that tap into Mongolia's Central Electricity System (CES) will rise by as much as 30 percent according to Mongolia's Energy Regulatory Commission (Kohn, 2013). Electricity demand has increased at an average annual rate of 2.9 percent since 2005, a trend that is expected to continue through 2020.

Mongolia's main electricity grid is the CES which covers 80 percent of Mongolia's electricity supply and includes five coal-fired power

Energy Markets

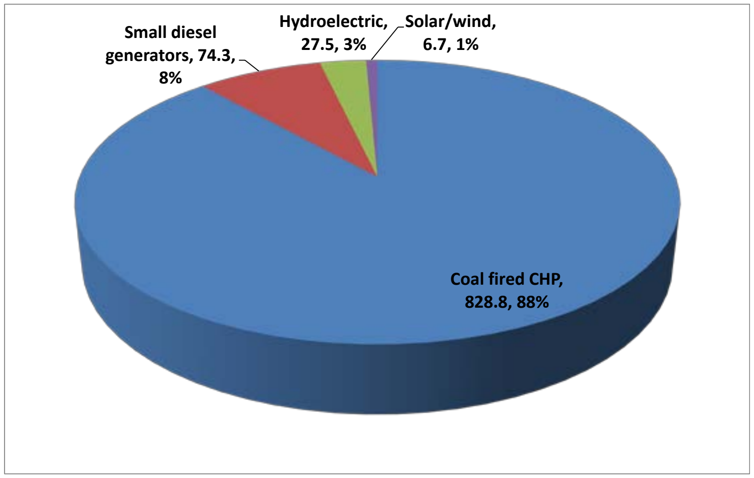

Figure 16: Mongolia's Electricity Supply. Source: IEEJ (2012)

plants and an interconnection with Russia for import of electricity. It has a basic transmission grid of 220 kV and 110 kV over head transmission lines (OHTL). A 220 kV ring system connects the principal generation and load centers of Ulaanbaatar, Darkhan and Erdenet and additional 220 kV connections with load centers of Baganuur and Choir. The Baganuur substation is linked with Power Plant #4 in Ulaanbaatar by a 220 kV two circuit OHTL approximately 130 km long. During peak load periods, electricity is imported from the Russian Federation in order to meet and regulate electricity demand of the system (Prophecy, 2013). Maximum current import capacity from Russia of 255 MW is expected to be reached (IEEJ, 2012); however, increased imports from Russia are not considered an option for

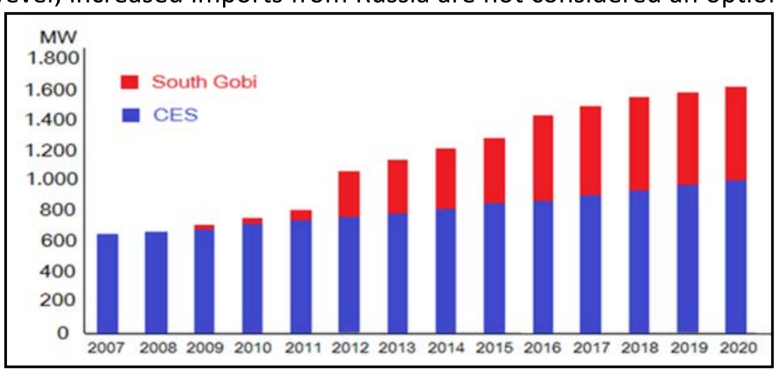

Figure 17: Mongolia's Energy Demand in the CES and South Gobi Areas (IEEJ, 2012)

meeting demand as the Mongolian government is concerned about supply security risks attached to reliance on Russian imports as well as the increased expense of Russian electricity. **Figure 17** shows the expected increase of energy demand in the CES and South Gobi Areas.

Baganuur is perfectly situated geographically and with grid connections to provide additional, CMM-fueled electricity to the CES. As the Baganuur area develops into an educational and technology center, electricity demand in the area is expected to grow rapidly. The Government of Mongolia issued Resolution 367 in 2011 to construct a university campus in Baganuur. The campus and associated town infrastructure are to be built on a footprint of 20,000 hectares (**Figure 18**) (Info Mongolia, 2013).

Figure 18: General Plan for the University Campus Town in Baganuur

Production of clean energy from CMM in Baganuur would allow the mine to displace dependence on coal-fired electricity and provide much needed electricity to the local area or the CES grid.

Mongolia's mineral resources are federally owned and administered through the Ministry of Mining (MOM). MRAM and the Petroleum Authority are implementing agencies under the MOM, and are charged with responsible development of mineral and petroleum resources through licensure, and the enforcement of regulations governing development. MRAM is responsible for development of minerals such as coal under the Minerals Law (2006), and the Petroleum Authority, under authority of the Petroleum Law (1991), which governs the production of liquid and gaseous hydrocarbons. To date there has been no commercial CBM or CMM activity; however, there have been CBM exploration and Production Sharing Contracts (PSC) such as that entered into by Storm Cat Energy with the Petroleum Authority in 2004. Storm Cat Energy explored for CBM both near Ulaanbaatar (Tsaidam block area) and in the South Gobi region near the present Naryn Sukhait surface coal mine (SEC, 2005). No exploration or PSC have been negotiated for resources distinguished as CMM; however, members of the MRA have indicated that there are regulations which require coal lease holders to not only assess the value of coal within their leasehold, but also estimate the methane resources associated with coal and surrounding strata.

Both the Minerals Law and the Petroleum Law are being revised. A revised draft of the Minerals Law was published in December, 2012. The Minister of Mining submitted the renewed draft bill of the Petroleum Law to parliament in June 2013.

Though previous CBM activity, such as that conducted by Storm Cat Energy,has been managed by the Petroleum Authority of the MOM, the Ministry of Energy (MOE) claims rights relating to granting permission for research and exploration of methane resources. The primary focus of the MOE is supply and distribution of energy. It includes a Fuel Policy Group that is concerned with CBM development CBM research and asserts that CBM exploration must be permitted through the MOE. In 2010, Korean Gas concluded an agreement for joint research and exploration to develop CBM in Mongolia with the MOE (KOGAS, 2010). Uncertainty regarding the legal framework surrounding CMM leasing could be challenging to project developers.

Despite undeveloped CMM exploration and licensing policies, Mongolia has several laws and resolutions that favor foreign investment in CMM projects. For instance, under the 1993 Law on Foreign Investment, an investor may request a stability agreement providing the investor a legal guarantee for a stable fiscal environment and protection from changes in taxation policy for 10 to 15 years. In addition, Parliament Resolution #140 (June 2001) includes oil and gas production and pipeline construction as "favored industries" for foreign investment. Mongolia's Department of Fuel Regulation Policy has outlined various development goals which include extraction of petroleum products from coal (Ganbaatar, 2005).

Mongolia's tax policy also appears to be favorable towards CMM project development. Materials and equipment necessary to conduct petroleum operations that are imported by contractors are exempt from customs taxes, value added taxes, and excise taxes. Contractors' earnings from petroleum shares are exempt from income taxes.

9. Proposed End-use Option and Economic Performance

The end-use options for the CMM drained from the Baganuur mine are limited as there is no existing infrastructure in the region that would enable the mine to transport produced gas to market. Therefore, the recommended option is on-site use, either direct use of the gas for heating or for electricity generation.

9.1. Power Generation Option

The most viable option for utilization of CMM produced in advance of mining is to use it to fuel an internal combustion power generation facility located in close proximity to the mine's surface facilities. The mine's current electricity consumption was not available; however, with the projected growth of the mine in the next few years, it is assumed that all electricity generated would be consumed on-site, and supplant electricity that would otherwise have to be purchased from other sources.

The following sections discuss basic background information of the proposed project as well as all inputs and assumptions used in the production forecasting and the economic analysis, followed by a discussion on the economic performance of the proposed project.

9.1.1. Technology and Deployment

Power generating equipment from two western suppliers was evaluated based on price and performance. Average costs from the two systems (USD/kWh installed) were used in the analysis. This equipment has a fuel consumption factor of 0.2475 m^3 of methane per kWh installed. Operating 8,000 hours each year, once the project reaches peak production, 40,000 MWh of electricity would be generated annually. This equates to an installed capacity of approximately 5.0 MW of combined electrical and thermal generating capacity.

The unit costs for this equipment were derived from correspondence with a representative of a western company with offices in Asia. Included in the capital cost estimate are equipment purchase, installation and testing, gas gathering, as well as all drilling and completion costs. Installation of the proposed internal combustion power generation facilities is scheduled in the first year.

9.1.2. Risk Factors and Mitigants

As with any project there are risks associated with developing a successful CMM recovery and use project. **Table 4** lists the risks that have been identified, an assessment of the level of risk, and possible mitigants to each identified risk. Overall, RRR has determined that the risks associated with technology and implementation are low to moderate, but other than using the electricity generated on-site, the risks associated with market issues are high.

Table 4: Risk Factors and Mitigants: Power Generation and Use Options

Risk	Assessment	Mitigant
Market:		
Access to and the ability to dispatch all available generated power to the national grid	High	Use power on-site, and avoid sale to national grid.
Ability to sell excess power to local villages	High	Laws regulating sale of electricity from independent power producers are not yet formulated; use power on-site.
Policy:		
Rights to CMM extraction and use	Moderate to High	Careful planning, meetings with cognizant agencies, obtain the hydrocarbon rights along with rights to the coal
Technology:		
Reliability and dependability of equipment	Low	Very dependable equipment, train local technicians to monitor, maintain, and repair engines and associated systems.
Fluctuations in gas concentrations	Low	The concentrations of gas drained in advance of mining if managed properly, should not fluctuate significantly.
Implementation:		
Fluctuation in pricing of equipment and services	Moderate	Current trend for prices is downward; Procure contracts that lock in favorable prices.
Procurement of permits and rights-of-way	Low	Develop timeline that incorporates time necessary to secure all necessary permits and right-of-ways, allow for delays.
Delays in deliverability of equipment	Low	Detailed planning; incorporate necessary lead time into orders.
Delays in installation	Low	Detailed planning.

9.2. Economic Analysis

The proposed project was modeled to determine the economic performance of generating power for on-site use. The subsections below list the assumptions and inputs used for the modeling, followed by a subsection reporting the assessment of economic performance.

9.2.1 Inputs and Assumptions

Inputs and assumptions used to model this option are listed in **Table 5**. When available, actual costs and pricing are used in the model, otherwise reasonable estimates based on industry standards were used. The drilling costs used in the economic model were derived from a drilling engineer with extensive drilling and oil and gas project management experience in Asia.

The proposed project evaluation period is 10 years, where drilling of all the wells is completed by the end of the fourth year, and installation of the main gas transmission line and water retention pond is installed immedi.

Table 5: Inputs and Assumptions Used in Economic Model

Project duration	10 years	
Gas production available to project	Based on analogous p50 production forecast from the PRB in the U.S.	
Drilling Costs	140 USD / meter	Quote from drilling contractor with experience in Asia
Casing Costs	100 USD / meter	
Production well operating costs	700 USD / well / month	
Drilling rig mob / demob	150,000 USD	
Gas hook-up lines	25,000 USD / km	Industry standard "rule of thumb" costs
Main gas gathering line	100,000 USD / km	
Water production costs	0.67 USD per cubic meter produced and transported	Industry average costs
Plant construction	Site construction and installation is conducted in the first year, additional generator sets are installed in years two, three and five.	
Capital Investment for p50 scenario	Power Stations & auxiliary facilities includes drilling and completing 19 production wells: 5.41 million USD	Power station investment based on unit costs 916.23 $/kW
Annual power sales	Electricity generated available to mine: 40,000 MWh	
Annual operating hours	8,000 per year	
Gas consumption efficiency	0.2475 m^3 per kWh generated Utilizes 5.0% of gas stream as fuel for compressors.	Based on manufacturer's representatives.
Power sales price, avoided cost	130 Tugrik per kWh (0.09 USD)	Avoided cost that mine would have paid to grid.
Annual project operating and maintenance costs	25 percent of capital costs for gensets annually. 700 USD per well per month for producing wells.	Based on information provided by manufacturer's representative and drilling contractor
VER sales price	1.00 USD per ton of CO_2e	
Federal tax rate	10 percent	

ately upon project start-up, and each well's gathering line is installed after the well is drilled. In the economic model power generation equipment is scheduled for installation in the first and second years.

According to the p50 production forecast, 54.3 million m^3 of methane could be drained and used to generate electricity; a total of 800 thousand barrels of associated water is also produced, which is stored in a containment pond on-site for use at the mine.

All generated electricity would be used by the mine, so the sales price of electricity used in this analysis is 130 Tugrik/kWh (0.094 USD), the price that the mine would otherwise have to pay to the grid. Annual project operating costs are assumed to be twenty-five percent of the capital costs

9.2.2. Probabilistic Economic Forecast Results

Table 6 below summarizes the results of the modeling performed to determine the economic performance of a power generation option. Using the p50 CMM production forecast, a series of internal combustion engines are installed at the mine, totaling 5.0 MW, fueled by all available CMM. At the p50 production rate, the proposed project returns a positive value for the NPV at 1.93 million USD, an IRR of 22.7 percent with a payback period of 4.32 years.

Table 6: Power Generation Option Base Case Forecast Results

Evaluation Scenario	Base Case - p50
Annual Operating Hours	8,000
Gas Forecast-Project (million m^3)	54.3
Water Forecast-Project (million m^3)	0.8
Total CAPEX (million USD)	5.41
Tons of CO_2e (x thou.)	104.5
Carbon Sales Price (USD)	$1.00
Plant Size (MW)	5.00
CAPEX/Tons CO_2e	0.05
Electricity Sales Price (Tugrik/kWh)	130
Electricity Sales Price ($/kWh)	$0.09
NPV/Tons CO_2e	0.02
NPV (Million USD)	1.93
IRR (%)	22.7%
Return on Investment (%)	35.6%
Payback Period (years)	4.32

9.2.3. Sensitivity Analysis of Power Generation Option

RRR performed a sensitivity analysis on the power generation option, utilizing the p10 and p90 10 year well production forecasts to determine the impact of varying methane production on project economics (**Table 7**). For the p10 scenario, the total 10 year production summary is over twice that of the p50 scenario, with an NPV of 4.38 million USD, and IRR of 28.2 percent and a payback period of 4.29 years. The return on investment is 45.3 percent, which is substantially greater than the 35.6 percent of the p50 scenario. The p90 scenario does not result in favorable economic conditions, even if operated for 10 years.

Table 7: Comparison Table of Economic Indicators with Varying Gas Forecast

Evaluation Scenario - Gas Forecast	p10	Base Case-p50	p90
Gas Forecast-Project (million m^3)	124.0	54.3	18.6
Water Forecast-Project (million m^3)	1.3	0.8	1.1
Total CAPEX (million USD)	9.99	5.41	3.58
Tons of CO_2e (x thou.)	195.4	104.5	24.4
Plant Size (MW)	9.00	5.00	2.00
CAPEX/Tons CO_2e	0.05	0.05	0.15
NPV/Tons CO_2e	0.02	0.02	-0.22
NPV (Million USD)	4.38	1.93	-5.44
IRR (%)	28.2%	22.7%	N/A
Return on Investment	45.3%	35.6%	-140.6%
Payback Period (yrs)	4.29	4.32	10+

10. Conclusions and Recommended Next Steps

The Baganuur coal mine is located 130 kilometers southeast of Ulaanbaatar. The mine has resources of 600 million tonnes of sub-bituminous coal, and produces approximately 3 million tonnes annually, with plans to increase to six million tonnes annually by 2020. Gas desorption testing demonstrated that methane is present in the coal at depths as shallow as 100 m and will be released to the atmosphere as surface mining takes place, unless a methane drainage program is adopted by mine operators.

RRR evaluated the sparse data provided by the mine's technical staff, as well as conducted an extensive search for additional pertinent geologic data and information in order to better understand the factors that controlled the distribution and size of CMM resources contained within the mine lease boundary. After constructing a relatively simplistic three dimensional geologic model, RRR estimated that the proposed project could produce enough gas to fuel a 5.0 MW power generation facility: the energy produced by this facility would be used by the mine. The capital costs are estimated to be $5.4 million USD with an IRR of 22.7 percent and a payback period of 4.32 years. Carbon emissions would be reduced by 104,500 tons of CO_2e over the project's 10 year life by using the methane that would otherwise be released by mining.

Conclusions and Next Steps

In order to minimize the geologic uncertainty which might affect the success of the coal mine methane drilling and recovery campaign, such as that proposed, a comprehensive data collection program should be carried out first. The different types of testing and sampling in this program should include:

- Gas desorption testing: currently, there is very little gas content data available. An extensive campaign should be designed and carried out to collect gas content data for all coal seams at depths of 100 m and greater over the entire license block. This program could be integrated with coal exploration and reserve confirmation drilling campaigns, with negligible additional cost.
- The desorbed gas from select desorption samples should be tested for gas composition.
- Injection fall-off testing should be carried out in one or more test drillholes to better understand the gas flow capacity (gas producibility) of the coal, average reservoir pressures, and the impacts that drilling and completion related stresses will have on the reservoir permeability.
- All planned CMM exploration drilling should be rotary drilled, rather than cored, and a full suite of geophysical logs should be run over the entire openhole section for each drillhole.
- A three dimensional seismic acquisition program should be designed and carried out over the entire mine lease to identify and determine the extent and impact of faulting, fracturing, and folding on the coal-bearing strata.

Once this data is collected and integrated into the existing geologic model and interpreted, a full technical and economic feasibility study should be conducted. Afterwards and if the project proves feasible, a methane recovery program can be carried out with a higher likelihood of success. Methane production from the proposed 19 well program is modeled to peak in year four with sufficient gas to fuel a 6.5 MW plant, before declining to sustained levels that fuel the 5.0 MW plant. If drilling were to continue beyond year four, the estimated production would most-likely result in sufficient volumes to sustain the 6.5 MW plant through the 10 year life of the project.

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DISCLAIMER: This map is designed to be an informational tool for the purpose of displaying design schematics, and is not intended to be used as a surveyed or engineered design plan. The information presented was provided by source(s) listed below and is believed to be accurate and suitable for modeling purposes, and is subject to the limitations stated above.

Explanation

91a
- Desorption Sample
- Water
- Coal Outcrop
- Mining Activity

RAVEN RIDGE RESOURCES INCORPORATED

БАГАНУУР ХК

U.S. EPA Coalbed Methane OUTREACH PROGRAM

Global Methane Initiative

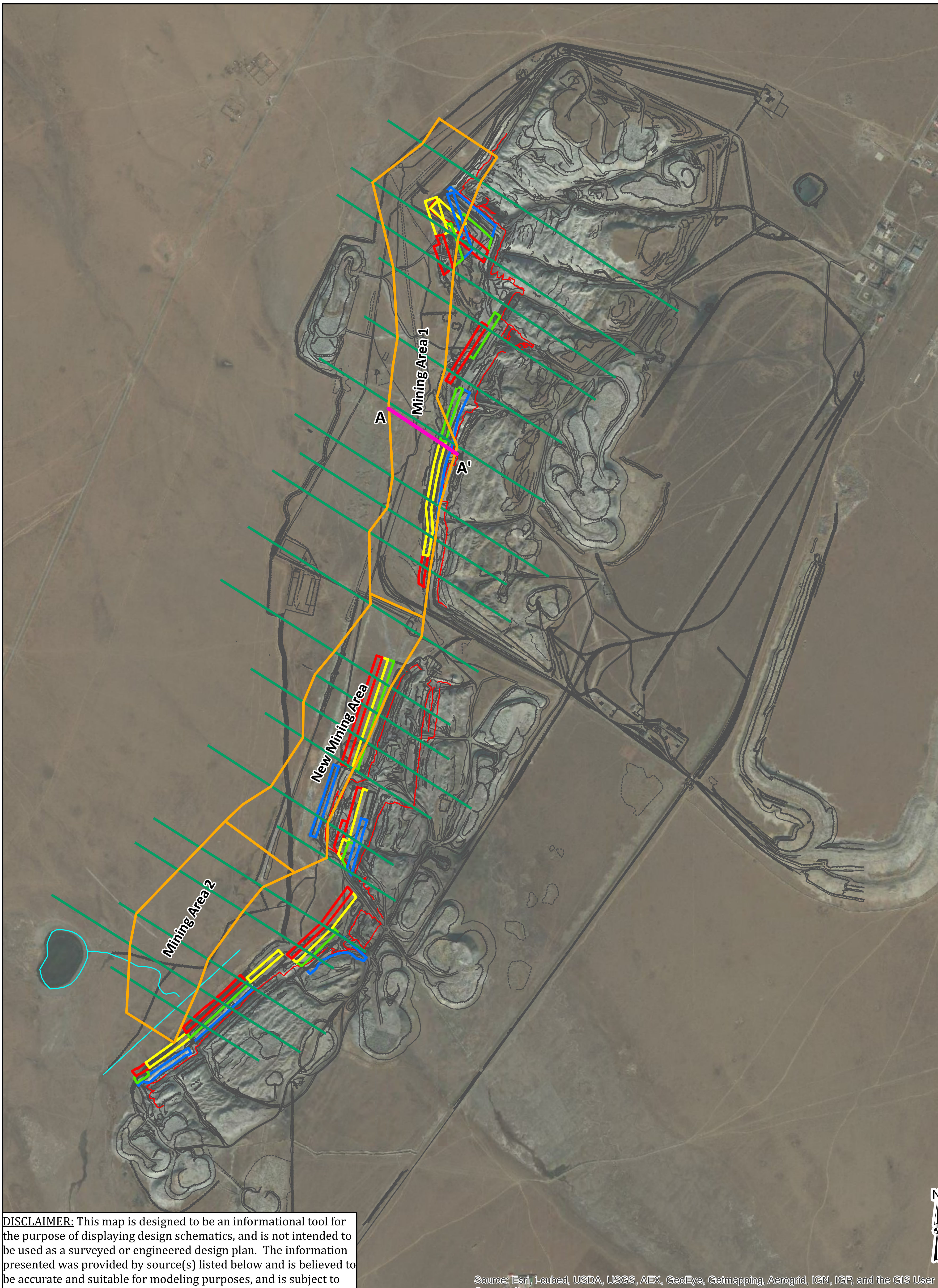
MNEC

MAP 1:Baganuur Coal Mine Base Map

SCALE 1:30,000

0 250 500 1,000 Meters

MONREF 1997 UTM Zone 49N;
False Easting 499850.0, Latitude of Origin 45.134



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Explanation

- Geologic Cross-Sections
- Example Cross-Section (A – A')
- Water
- Coal Outcrop
- Mining Activity
- Mining Areas
- 2013 Mining
- 2014 Mining
- 2015 Mining
- 2016 Mining
- 2017 Mining

RAVEN RIDGE RESOURCES INCORPORATED

БАГАНУУР ХК

U.S. EPA Coalbed Methane OUTREACH PROGRAM

Global Methane Initiative

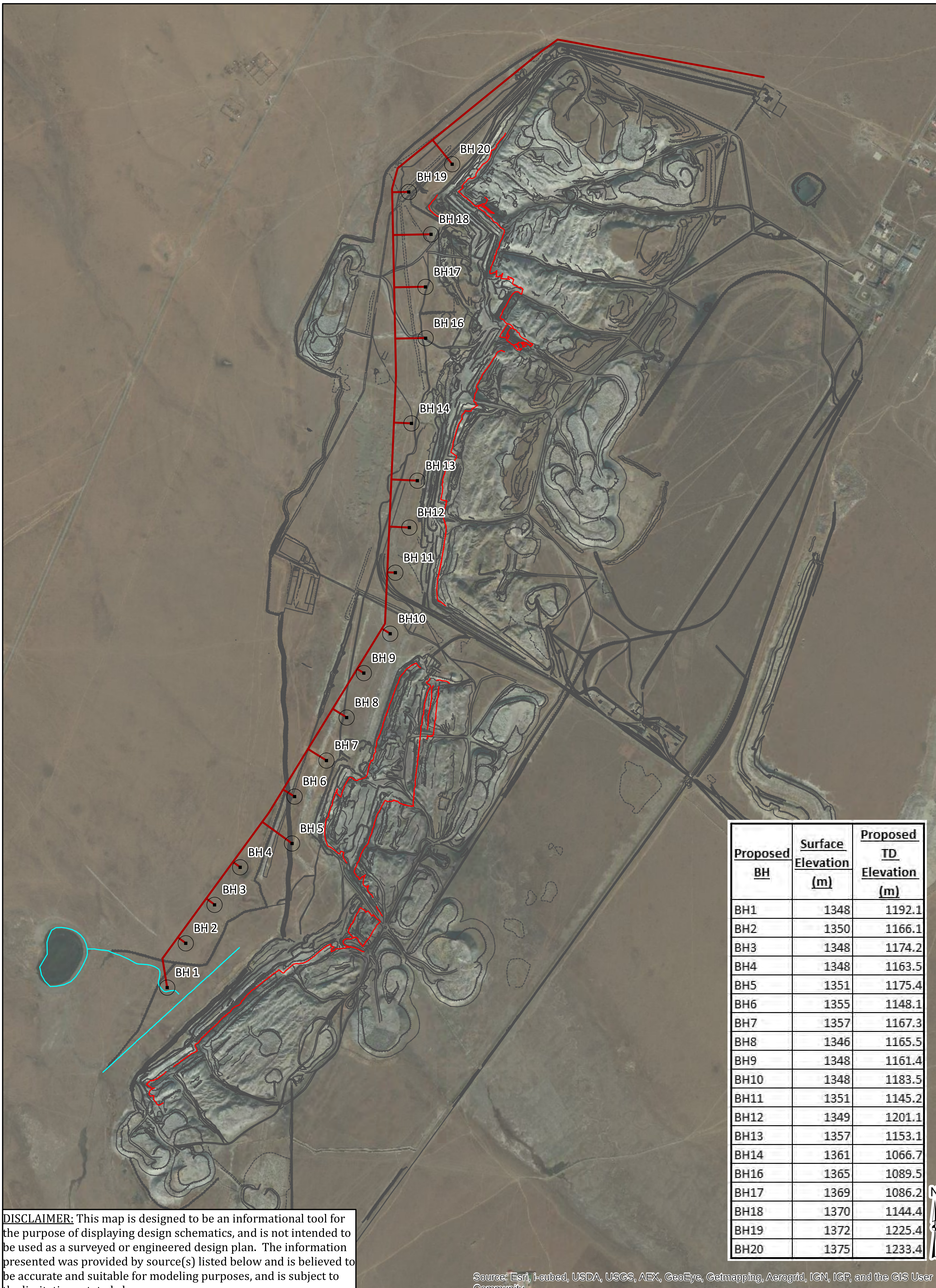
MNEC

MAP 2:Baganuur Coal Mine Mine Plan

SCALE 1:30,000

0 250 500 1,000 Meters

MONREF 1997 UTM Zone 49N;
False Easting 499850.0, Latitude of Origin 45.134



Proposed BH	Surface Elevation (m)	Proposed TD Elevation (m)
BH1	1348	1192.1
BH2	1350	1166.1
BH3	1348	1174.2
BH4	1348	1163.5
BH5	1351	1175.4
BH6	1355	1148.1
BH7	1357	1167.3
BH8	1346	1165.5
BH9	1348	1161.4
BH10	1348	1183.5
BH11	1351	1145.2
BH12	1349	1201.1
BH13	1357	1153.1
BH14	1361	1066.7
BH16	1365	1089.5
BH17	1369	1086.2
BH18	1370	1144.4
BH19	1372	1225.4
BH20	1375	1233.4

DISCLAIMER: This map is designed to be an informational tool for the purpose of displaying design schematics, and is not intended to be used as a surveyed or engineered design plan. The information presented was provided by source(s) listed below and is believed to be accurate and suitable for modeling purposes, and is subject to the limitations stated above.

Explanation

- Proposed Boreholes
- Proposed Pipelines
- Water
- Coal Outcrop
- Mining Activity

RAVEN RIDGE RESOURCES INCORPORATED
БАГАНУУР ХК
U.S. EPA Coalbed Methane Outreach Program
Global Methane Initiative
MNEC

MAP 3: Baganuur Coal Mine Proposed Drilling Program

SCALE 1:30,000

0 250 500 1,000 Meters

MONREF 1997 UTM Zone 49N;
False Easting 499850.0, Latitude of Origin 45.134