Proposal

Continuation of Underground Coal Gasification Study in Western North Dakota

Submitted to:

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NDIC Lignite research program: $299,958
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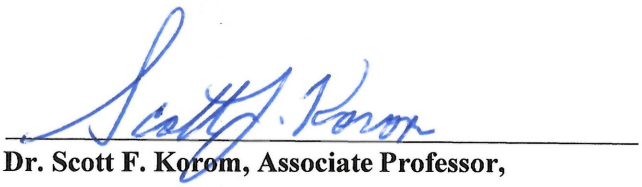

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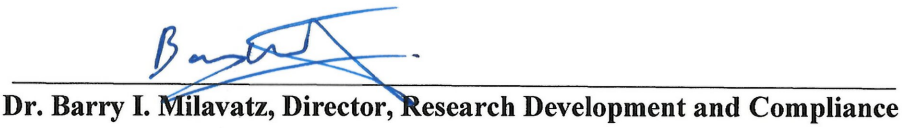

Dr. Barry I. Milavatz, Director, Research Development and Compliance **September 30, 2013**

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Abstract

The Harmon bed, Fort Union formation, in North Dakota has huge lignite reserves, most of which are too deep to be mined using conventional mining technologies. Underground coal gasification (UCG) provides a potential opportunity to economically recover this vast resource. The first phase of this project has provided initial information on the hydrogeology, geomechanics, and lignite reactivity that indicates a high potential for the clean and efficient utilization of deep lignite seams by underground gasification. Herein we propose a continuation project of our UCG feasibility study in McKenzie County, North Dakota, to provide important and timely data that complement our current UCG research work. Previous drilling and well logs indicated that there are two coal seams potentially suitable for UCG north of Grassy Butte (Township 147N Range 99W). The additional information provided by our continuation project will include more detailed site information on aquifer properties, groundwater quality, stratigraphy, lignite properties, and geomechanical properties. We plan to drill two wells to measure the hydraulic conductivities of the target coal beds, obtain additional stratigraphic information on any freshwater aquifers up to 300 ft below the deeper coal seam, measure baseline groundwater quality in the coal seams, recover additional cores from surrounding strata for geomechanical testing to help quantify subsidence amounts, should UCG be done in either or both coal seams, and recover additional lignite cores for property analysis and gasification testing. Utilizing the results of the gasification tests, an initial feasibility analysis will be performed for the conversion of UCG-produced syngas to liquid fuels and chemicals based on Front End Engineering Design (FEED) data and specifications of the Juniper gas-to-liquids (GTL) project in Louisiana, which is provided as in kind support and will enable the research team perform a more accurate and reliable feasibility study of the hypothetical UCG-based GTL

plant. The knowledge provided by our continuation study will significantly enhance our understanding of the selected area, offer key parameters necessary to design a UCG pilot plant and optimize its operation strategy to produce liquid fuels in an environmentally-responsible manner. In addition, we will take advantage of the upcoming summer field season to provide this knowledge is as timely a manner as possible.

The project is expected to be finished in 18 months, with a total budget of $449,970, including a cash support of $150,000 from Great North Properties. Additional in kind support of $270,000 is also provided. The in kind support will consist mainly of FEED data and specifications of the Junior GTL project. Participants include faculty and staff from the University of North Dakota (UND). The proposed and current projects will generate knowledge in syngas composition, hydrogeology, and structural stability, and these results will be used to better evaluate the feasibility of liquids production with UCG syngas produced from the Harmon coal bed, while minimizing risks to any potable groundwater in the area.

Project Summary

The current UCG feasibility study in UND, supported by North Dakota Lignite Research Council and Great Northern Properties, has indicated that there are two lignite seams that could be used for UCG development in the selected area (Township 147N Range 99W): the Harmon coal bed (about 960-1000 ft deep) and an upper coal bed (about 680-700 ft deep). To better assess the feasibility and provide more reliable data for a pilot project in the future, some vital and complementary information is needed: (1) hydraulic conductivity of the coal seams, (2) variation of the lignite properties, (3) variation of geomechanical properties of the surrounding rocks, (4) groundwater hydraulic heads and groundwater quality, and (5) additional stratigraphic information, particularly below the deeper coal seam. In this continuation project, we plan to conduct the following work to acquire the above information:

- Drill and screen a well in the upper 14-ft coal bed, obtain cores of lignite and surrounding rocks, monitor the hydraulic head and water quality in the unit for a one-year period, and perform slug tests in the upper coal bed to determine its hydraulic conductivity. A slug test is performed by causing a sudden change in the water level in a well and monitoring its recovery to initial conditions. Data from slug tests are used to calculate the hydraulic conductivity of a geologic unit. Knowing the rate of groundwater transmission through a coal seam is essential to the operation of a UCG plant producing syngas from it; if it produces too little water then another water source will be required for UCG; if it produces too much water then reactions may be quenched.
- Repeat the tasks described above for the lower 26-ft Harmon coal bed. In addition, drill at least 300 ft below the lower bed to check for any local aquifers.
- Perform additional gasification and geomechanical testing on the new cores.

- Perform an initial feasibility analysis of the conversion of UCG derived syngas to liquid fuels and chemicals. The analysis will be based on technologies used in the Juniper GTL project in Louisiana, a project supported by Great Northern Properties to produce fuels in a clean, safe, and economical manner. The Great Northern Properties will provide the FEED data and specifications of the Juniper project as an in kind support. Assuming that the hypothetical UCG-based liquids production plant will have the same design and specifications, the economics of the plant will be investigated.

Based on the bore hole drilled for our current project and other well logs ¾ - 4 miles away, the two coal beds are continuous in the selected area. They are also relatively uniform in depth and thickness, respectively. Therefore, it may be possible to design a UCG process that utilizes both coal beds in the same location, which will boost recoverable lignite reserves in the location, and improve the economics of the plant. However, the lithology facies in the Harmon bed can be highly variable over a short distance, which could present challenges in site characterization, plant design, and operation management. The proposed two wells will provide better coverage on the geological and hydrogeological information for the selected site.

The two wells drilled through the coal seams will be monitored on a quarterly basis for one year, with hydraulic heads being measured and groundwater samples collected. Groundwater samples will be analyzed for major inorganic ions and organic compounds. The sampling program will establish a baseline of groundwater levels and groundwater quality. These two wells may also be incorporated into a larger future groundwater monitoring network in the area with future UCG development.

The potential impact of the UCG of the lignite seams on nearby freshwater aquifers will be examined. Coring done last summer (2013) confirmed that the only potential aquifer above the

lower coal is, in fact, the upper coal seam. Based on our 3-dimensional geological model, the Fox Hills aquifer (and lower Hell Creek aquifer) is about 900 to 1000 ft below the Harmon bed, and covers the entire study area. The upper Hell Creek aquifer is about 300 to 400 ft below the Harmon bed, but is believed to be isolated from the lower coal seam by clays and other confining strata. The presence of smaller and scattered aquifers needs to be checked. One of the wells will be drilled to at least 300 ft below the Harmon bed, to investigate the existence of nearby aquifers. Drilling to this depth will also provide additional stratigraphic information to refine the already-built lithological model.

The proposed two wells will provide more cores and samples for gasification and geomechanical tests. A bench-scale, pressurized fixed reactor built at UND under the first phase of this project will be used to contrast and compare gasification rates, carbon conversion efficiency, and syngas composition for each seam. Gasification test result from different wells will be used to evaluate variation of the lignite properties and predict syngas composition. Cores of surrounding rocks will be tested for geomechanical properties using the same methods described in our current project. This information may be used in subsequent geomechanical models in two ways:

1. To design the spacing between UCG production zones to manage subsidence on the ground surface.
2. To determine if the subsidence may enhance the migration of groundwater contaminants above the UCG production zones.

Finally, the proposed continuation project will provide important and valuable knowledge to investigate the feasibility of UCG in North Dakota to produce liquid chemicals and fuels. Results generated from this project, together with those from the currently undergoing project, will

advance our study on UCG from the aspects of hydrogeology, gasification, and geomechanics, and produce key data for a future pilot-plant development.

Project Description

Objectives

1. Determine the hydraulic conductivities in the Harmon coal bed and the upper coal bed in the selected area;
2. Measure the hydraulic heads in the two coal seams every quarter for one year;
3. Recover additional cores from the lignite seams and surrounding rocks. Perform additional gasification and geomechanical tests on the new cores;
4. Drill 300 ft below the lower coal seam to verify the presence of confining layers that would restrict downward groundwater transport of contaminants and also to check for any localized aquifers.
5. Sample and analyze groundwater in the coal seams every quarter for one year to build a baseline data set of groundwater quality.
6. Obtain additional stratigraphic information of the strata in the selected site to refine our current 3-dimensional geological model.
7. Perform an initial feasibility analysis of the conversion of syngas to liquids based on technologies being utilized in the Juniper GTL project in Louisiana.

Methodology

The project would consist of 5 tasks, with a duration of 18 months. Scope of the tasks and methodologies are described below.

Task 1. Well Drilling, Slug Test, and Coring (01/01/2014-06/30/2014, 6 months)

The drilling sites will be selected in the area close to the first drilling location, which is in Township 147N Range 99W. The task is scheduled to start spring or summer 2014, depending on commencement of this project, the schedule of the well contractor, and weather conditions. Therefore, a flexible schedule of 6 months is planned for this task. The first well will be drilled to the upper coal bed (680~700 ft deep) and screened throughout its thickness. The second well will drilled at least 300 ft below the Harmon coal bed (1300 ft deep), and screened throughout the Harmon bed (970~1000 ft deep). Slug tests will be conducted in both coal seams. The measured parameters will be used to calculate their hydraulic conductivities. Cores of the lignite seams and overburden and underlayer will be recovered. The lignite seams will be sampled every 2 ft for proximate and ultimate analysis. If any sand is met during the drilling process, the sand will also be cored. During the drilling process, the drilling cuttings will be logged. The stratigraphic log of the wells will be used to refine our 3-D geological model of the formation.

Task 2. Well Sampling (01/01/2014-06/30/2015, 18 months)

The two wells penetrating the coal seams will be sampled on quarterly basis, for one year, and major ions and basic organic chemistry will be analyzed.

Task 3. Gasification Tests (07/01/2014-12/31/2014, 6 months)

The recovered lignite cores from the coal seams will be used in gasification tests. The tests will be conducted by a bench-scale pressurized fixed gasifier in UND. The tests will be performed under the simulated formation pressure, with different injection rates of air, oxygen, and steam. Compositions of produced syngas will be recorded. Reaction rates will be obtained for further modeling purposes. Test results for different cores will be compared.

Task 4. Geomechanical Tests (07/01/2014-03/31/2015, 9 months)

The recovered cores from the surrounding rocks will be used in geomechanical tests to measure some key parameters: porosity, permeability, static Young's modulus, static poison's ratio, uniaxial compressive strength, triaxial compressive strength, and tensile strength. These parameters will be used to predict the mechanical response of the formation to the UCG process. Induced stress and displacement fields will be calculated. Results of this work will provide detailed and fundamental knowledge for structural stability and risk prediction.

Task 5. Comprehensive Assessment (04/01/2015-06/30/2015, 3 months)

Sub-task 5.1 Assessment of UCG feasibility

With the results from the above four tasks and the current project, Task 5 will perform a comprehensive assessment to feasibility of UCG-based liquid production technology. The assessment will be performed from three aspects: hydrogeology, geomechanics, and gasification. Based on syngas composition, aquifer properties, induced stress and displacement fields, the performance and economics of a UCG reactor will be evaluated, possible risks will be predicted, and an optimized approach proposed.

Sub-task 5.2. Assessment of Chemical/Fuel Production Feasibility

The increasing adoption of synthetic fuel and chemical production from syngas through natural gas reforming suggests that UCG deployment for chemical/fuel production is the most feasible application. Syngas produced from UCG is assumed to be used in a hypothetical liquids production plant in North Dakota. In this sub-task the feasibility of UCG of lignite to produce fuels/chemicals will be evaluated using data from the currently planned Juniper GTL facility in Louisiana of which our project sponsor, Great Northern Properties, is a partner. FEED data and

specifications of the Juniper GTL project will be provided as in kind support ($270,000). Some key engineering data will be provided include:

- Process flow diagrams for the syngas conversion to liquid fuel process,
- Material and energy balances of the fuel reactor,
- Consumables and equipment definitions lists,
- Equipment cost and capital cost estimates.

The in kind support from the Juniper GTL project will be used to determine the water gas shift requirements for the UCG syngas as well as the costing for the downstream gas to liquid equipment. Utilizing the actual commercial data of the Juniper project will enable the project to perform a more thorough and reliable economic and technical feasibility analysis for a UCG-to-GTL facility in North Dakota.

The five tasks described above, together with the ongoing project, will evaluate the UCG-based liquids production from different aspects, and will allow us to look for possible optimization approaches for the UCG process based on operation requirement of the liquids manufacturing block. Figure 1 shows the methodology we are applying to the UCG feasibility study.

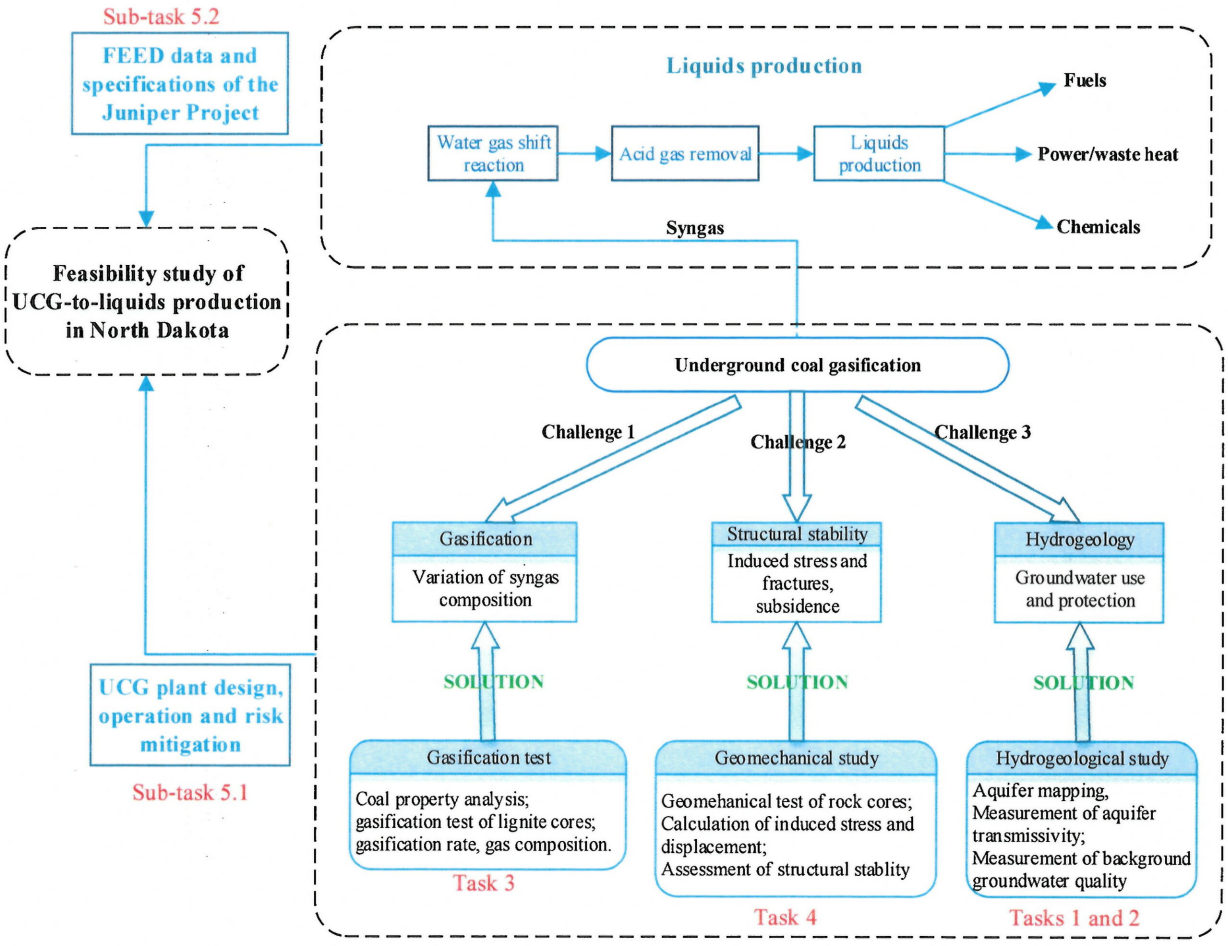

Figure 1. Methodology of UCG feasibility study

Anticipated Results

1. Hydraulic conductivities of the Harmon coal bed and upper coal bed;
2. Hydraulic heads of the Harmon coal bed and upper coal bed;
3. Gasification characteristics (kinetics and syngas composition) based on gasification test results;
4. Induced stress field and displacement field during and after the UCG process for a pilot plant having a simple configuration (one reactor in one coal seam);
5. Refined 3-D geological model of the coal beds, confining layers, and nearby aquifers;
6. Baseline of groundwater quality in coal seams;

7. Fundamental parameters for the technical performance of the plant, including recommended gasification pressure, oxidant composition and injection rate, and syngas production rates; and
8. Preliminary feasibility analysis of the conversion of syngas derived from the UCG of Harmon lignite to liquids based on technologies used in the Juniper GTL project in Louisiana.

Facilities

UND's College of Engineering and Mines is equipped with advanced experimental facilities and software packages with the capacity to support the proposed research by providing the ability to investigate the geomechanics, reservoir modeling/characterization properties, groundwater analysis, core analysis, and coal gasification of UCG. Introduction to the major facilities which will be used in the project is given below.

Hardware

- *AutoLab 1500*

  This Triaxial laboratory test system can perform standard petrophysical and rock mechanics experiments and measure most standard mechanical and petrophysical properties of formation rocks under formation pressure and temperature, such as bulk modulus, shear modulus, Young's modulus, Poisson's ratio, strength, permeability, resistivity, P- and S-wave velocities.

- *816 MTS Rock and Concrete Mechanic Testing System*

  This system has a high-capacity, high-stiffness load frame and can perform uniaxial tests for investigation of the complete deformation behavior of rock and concrete over a wide range of testing conditions.

- *Pressurized Fixed Bed Gasifier (built through our initially-funded project)*

  This gasifier will be used to host the lignite cores for gasification test under simulated in-situ conditions.

- *The Environmental Analytical Research Laboratory*

  The laboratory hosts an ion chromatograph (IC), a flame atomic adsorption spectrometer with a graphite furnace, a total organic carbon analyzer (TOC), a total sulfur analyzer, and ancillary equipment to support teaching, scientific research and engineering design projects in aqueous chemistry and water resources investigations.

- *Core preparation facilities*

  The core preparation facilities at UND have the capacity to prepare standard and custumized rock samples. Major facilities include rock cutting saws, core drillers of different sizes, core gridding, and sample storage equipment.

- *Porosity measurement system*

  This system measures the porosity of rock samples based on the Biot's law.

Software

- *Petra* (well log processing)
- *Interactive Petrophysics* (well log interpretation)
- *Petrel* (reservoir characterization)
- *CMG* (petroleum production/underground gasification modeling)
- *FLAC3D* (geomechanics analysis)
- *ANSYS* (geomechanics analysis)
- *Fluent* (fluid mechanics analysis)

- *Engineering Equation Solver* (thermodynamic analysis)

Environmental and Economic Impact

The current underground project of UCG feasibility study has indicated that there exist two coal seams in the selected area that might be suitable for UCG development: the Harmon coal bed (970 ft deep, 26 ft thick), and the upper coal bed (685-ft deep, 14 ft thick). Both beds are relatively continuous. This offers an opportunity to develop a UCG project utilizing both coal seams at one site. Such a "dual-layer" scenario can significantly boost the recoverable reserve and improve the economics of the plants. However, challenges to using UCG at this site exist because the properties of the lignite-bearing formations, and surrounding strata, are not well understood (that is, coal properties, hydrogeology and geomechanics). The first-hand experience of other UCG companies also highlighted the importance of hydrogeological properties of the strata. For example, the Cougar Energy suggested that a baseline groundwater investigation should be conducted before UCG commences, and groundwater monitoring wells should be setup prior to the construction and drilling of any panel (Moran et al., 2013). Other than the coring done last summer, the nearest bore hole is ¾ mile away, which is too far to prepare for a UCG pilot plant. Additional drilling and coring work will generate data to support a more detailed and reliable characterization of the site geology. Successful completion of this project will give a better understanding to these characteristics of the two coal beds and associated strata. These results will provide valuable information to improve the economic analyses of UCG projects in North Dakota, while reducing associated environmental risks caused by subsidence and groundwater pollution at our proposed site.

Standards of Success

1. Cores of lignite and surrounding rock recovered and tested;

2. Hydraulic conductivities of coal seams measured;
3. Groundwater in coal seams sampled and analyzed;
4. Reliable, reasonable and representative data generated from experiments and basic numerical modeling (that is of one UCG reactor in one coal seam); and
5. Reporting completed through reports, publications, and conference presentations.

Background

Underground Coal Gasification

UCG converts coal in-situ into a gaseous product, commonly known as synthesis gas or syngas through the same chemical reactions that occur in surface gasifiers (Burton et al., 2006). The UCG process involves drilling two or more wells into the coal seam from the surface (Figure 2). One well is used to inject air or oxygen that drives in situ combustion and gasification and the other is used to transport syngas to the ground surface. The UCG process can exploit coal deposits that are not accessible to current coal mining methods. These coal deposits are at depths greater than 300 ft and where the coal seam thickness is greater than 6 ft. Pollutants can be well controlled using the same method developed for surface gasification technologies. Concerning environmental issues related to groundwater, the reactor cavity is usually operated at pressures less than the hydrostatic pressure, which allows groundwater to flow into the gasification reaction zone (Friedmann et al., 2009), and thereby keeping contaminants from flowing into surrounding strata.

Approximately 85% of global coal resources are not economically mineable by conventional mining methods (Linc Energy, 2008); in North Dakota the amount is 98% (Murphy et al., 2006). UCG can utilize coal seams that are too deep to be economically mined, which significantly increases global recoverable coal reserves. Linc Energy (2008) estimated that there is over 5

million PJ of resource of UCG syngas in the US. It also reported that UCG technology can increase the recoverable reserves at least 3 to 4 times, indicating that 1.6 trillion tons of unminable coal in US could be recovered. UCG holds several advantages such as lower capital investment costs, no handling of coal and solid wastes at the surface, no human labor or capital for underground coal mining, minimum surface disruption, no coal transportation costs, and direct use of water and feedstock available in situ (Shafirovich and Varma, 2009).

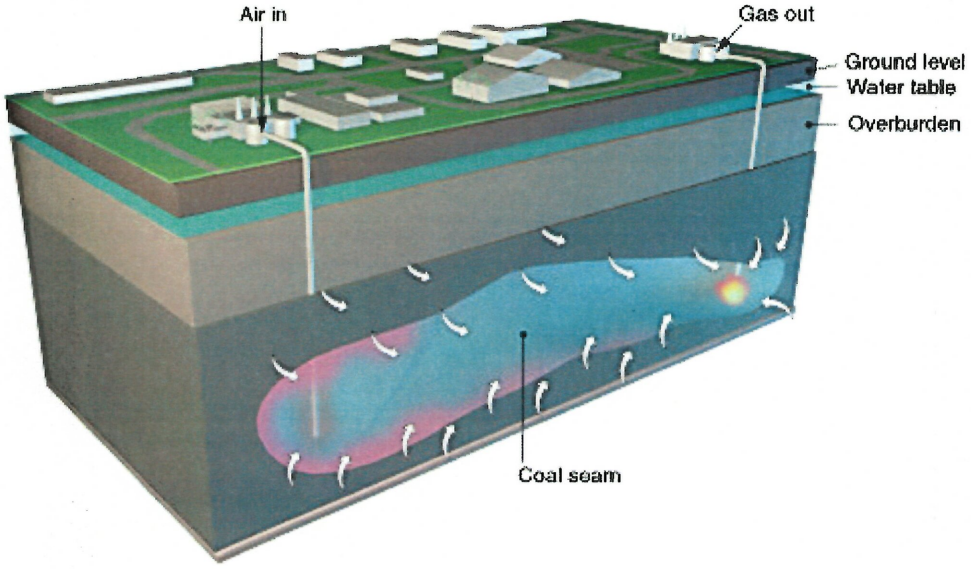

Figure 2. UCG process (Walter, 2007)

There are several key engineering and environmental issues that need to be resolved to commercialize the UCG technology. Based on a review of pertinent literature, there are four key technical issues for a successful UCG project: combustion control, wells linkage, site selection, and minimizing associated environmental issues. There is less control of the UCG combustion process than for surface gasifiers. Process parameters like water influx, the distribution of reactants in the gasification zone, and the growth rate of the cavity, can only be estimated from measurements of temperatures and product gas quality and quantity. Variation of permeability affects the flow rate of injected reactants and products. Consequently, variation of the product

volume and composition can introduce problems to the downflow utilization processes. Possible environmental issues associated with UCG are subsidence caused by gasification of coal seams and underground contamination caused by the exchange of underground fluids (Burton et al., 2006; Shafirovich and Varma, 2009). All of these potential problems can be minimized with a detailed and comprehensive understanding of the selected site.

Syngas is a versatile material and can be upgraded to different chemicals and fuels. Converting synthesis gas derived from coal gasification to liquid fuels and chemicals has been demonstrated and utilized successfully. The use of syngas derived from lignite has been reviewed by Benson and Sondreal (2010). The processes involved in converting synthesis gas to chemicals and fuels are summerized in Figure 3.

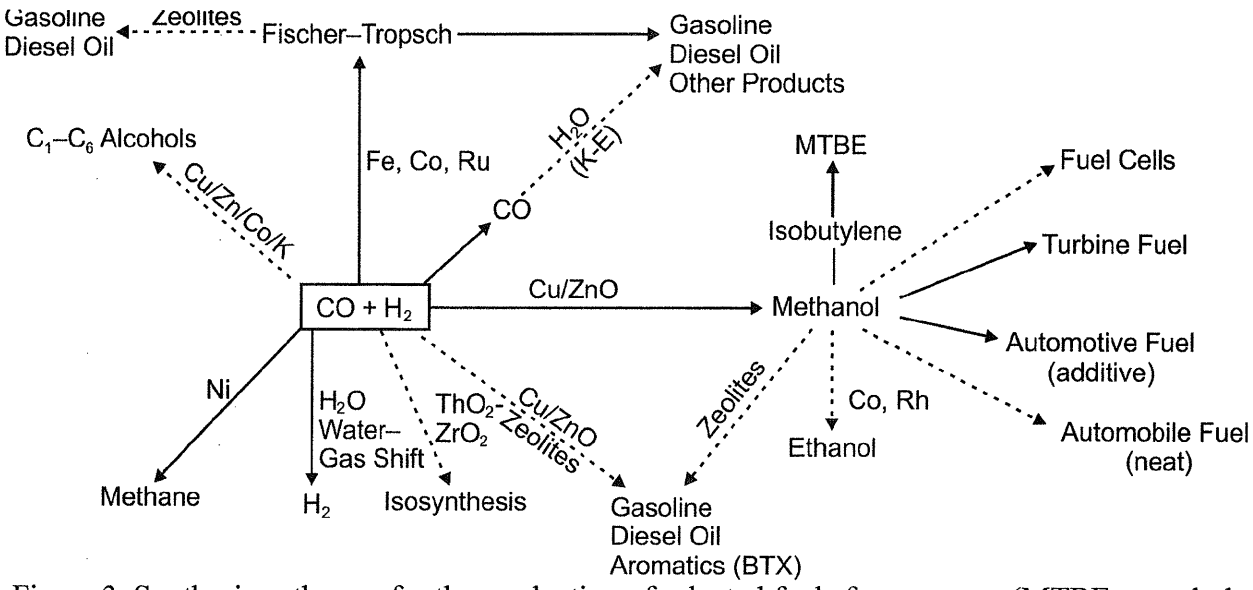

Figure 3. Synthesis pathways for the production of selected fuels from syngas (MTBE = methyl tertiary-butyl ether, BTX = benzene, toluene, xylene) (Wender, 1996)

The use of syngas produced from carbonaceous feedstocks began at the turn of the century with the production of methane through the reaction of H_2 with CO_2; followed by the production of ammonia; then the use of Fischer–Tropsch (F-T) synthesis to produce liquid fuels; and then in the 1980s, the synthesis of alcohols. The alcohols are a pathway to production of a wide range of

chemicals. The reactions of H_2 and CO as they are absorbed by various types of catalysts can be used to produce a large number of complex species both through homogeneous and heterogeneous catalysis.

The two most popular processes to synthesize liquid fuel are the Fischer-Tropsch process and methanol synthesis. The Fischer–Tropsch reaction utilizes syngas to produce a wide range of materials, including liquid fuels, naphtha, and waxes. The syngas can be processed to produce hydrogen for the production of ammonia and urea. Processing to produce a methanol intermediate is a path to a wide range of chemical feedstocks such as dimethyl ether, acetic acid, methyl acetate, and ethylene/propylene (Benson and Sondreal, 2010).

There has been a significant growth in the production of synthetic fuels from syngas thanks mainly to successful large scale investments in natural gas to liquid facilities around the world. The successes of some of these investments such as the SASOL Oryx facility in Qatar and the Shell PEARL facility in Qatar have demonstrated the good economics of producing synthetic fuels from natural gas based syngas. Currently, several similar large facilities are planned in Louisiana and around the world, and are largely driven by the good economics and low cost of natural gas feedstock for producing syngas. This has all led to a growing interest for investing in smaller scale GTL systems as is the case of the just-announced Juniper GTL project which is supported by Great Northern Properties, a partner on this project. The current commercial deployment of GTL systems is a huge opportunity for UCG as it ensures the maturity of syngas to liquids technologies while also defining the market for these liquid products. This would facilitate future development and deployment of UCG – GTL facilities which are expected to take off once the market prices of natural gas increase, making UCG derived syngas much more cost competitive. Moreover, UCG of lignite is expected to require fewer unit operations than

current GTL facilities as the syngas composition is better suited for liquids production (Pei et al., 2013).

Current UCG Research at UND

With the support from the North Dakota Lignite Research Council and Great Northern Properties, the Institute for Energy Studies at UND currently is conducting the research project "Geomechanical Study of Harmon Lignite and Surrounding Rocks for Underground Coal Gasification in Western North Dakota". This study plans to select an appropriate site and investigate the feasibility of UCG in the deep Harmon lignite bed. In May 2013, a bore hole was successfully drilled in McKenzie County, North Dakota (Figure 4A), and two lignite seams were found: the Harmon coal bed (970 ft deep, 26 ft thick), and the upper coal bed (685 ft deep, 14 ft thick). Lignite cores and rocks from surrounding strata were recovered for testing (Figure 4 B). The proximate and ultimate tests indicated that these two lignite seams have very similar properties. Also, based on their depth and thickness, both coal seams should have the potential for UCG utilization. These findings could lead to the development a "dual-layer" UCG project that uses both coal seams at one site.

With oil well logs ¾ - 4 miles away, and our bore hole drilled last summer, a 3-dimensional geological model was built to reveal aquifers, and to visualize geological facies in the selected area (Figure 5). The Fox Hill aquifer is about 900 to 1000 ft below the Harmon bed, and covers the entire selected area. The Hell Creek aquifer is about 300 to 400 ft below the Harmon bed, but relatively scattered and isolated by clays. There are also some other scattered smaller aquifers.

(A) Well drilling (B) Lignite core

Figure 4. Drilling and coring work done the summer of 2013

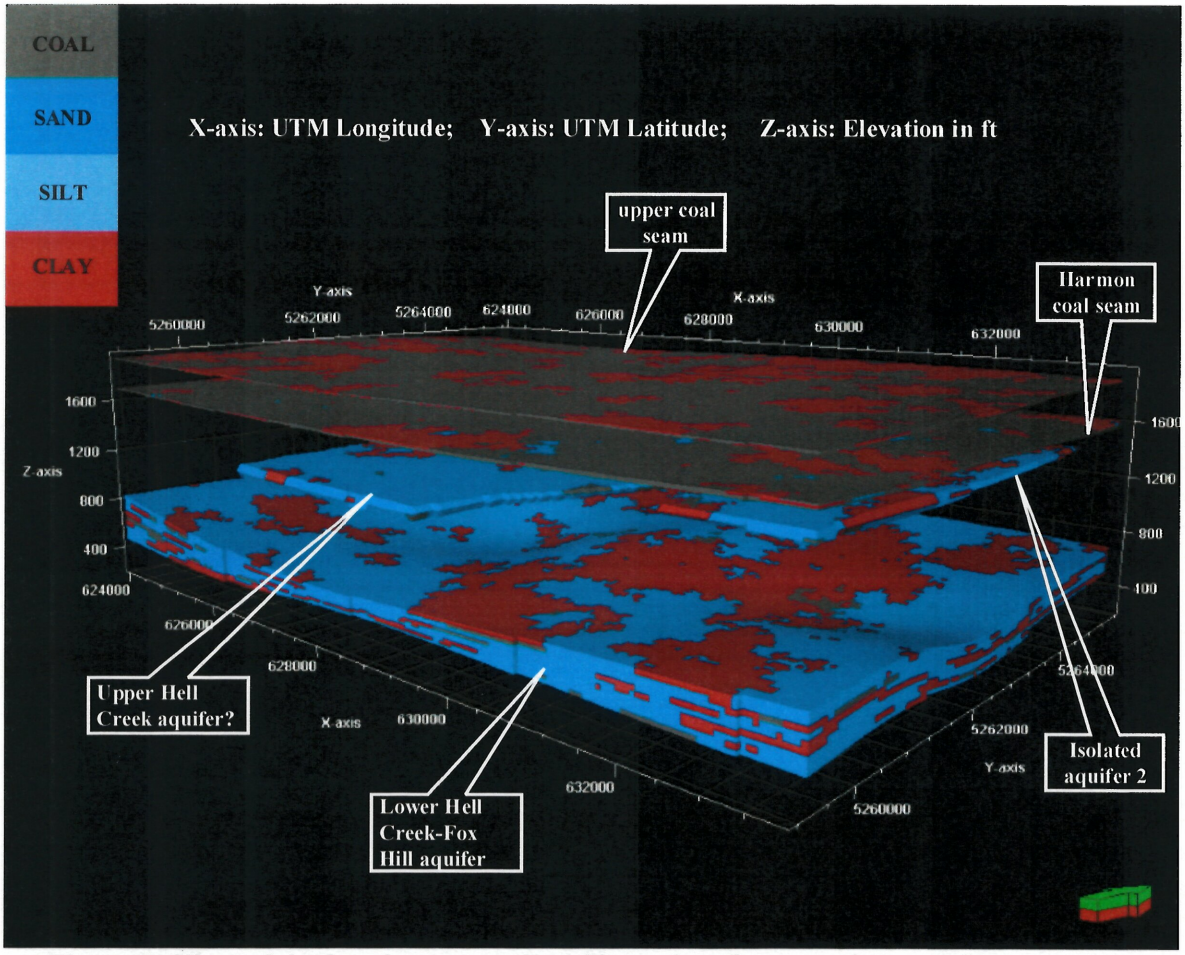

Figure 5. 3D model of coal seams and aquifers, view from southeast, 5 times vertical exaggeration, green arrow pointing to the North

In addition, a pressurized fixed bed reactor (Figure 6), that will be used for gasification tests is under construction. The rock samples collected last summer are also in preparation for geomechanical testing.

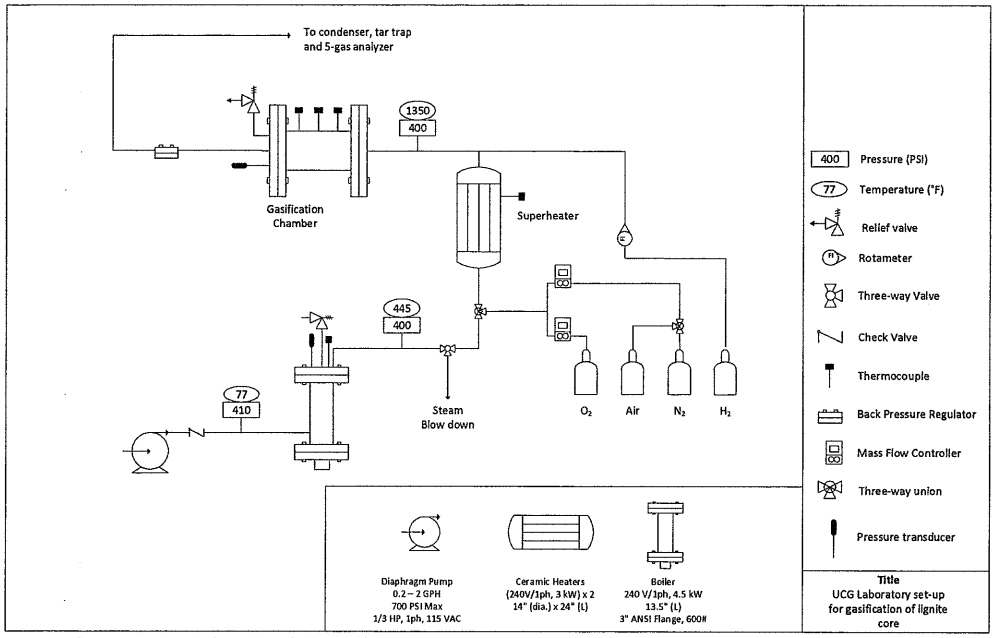

Figure 6. Schematic design of the bench-scale fixed bed gasifier

An analytical study was also performed to compare the production cost between UCG derived syngas and natural gas derived syngas (Pei et al, 2013). Assuming the produced syngas is used for liquid fuel production, the cost of producing syngas from natural gas conversion and cost of syngas from UCG based on Harmon bed are compared. A sensitivity analysis of UCG cost on coal bed depth and thickness was performed. A schematic block flow of the hypothetic UCG and liquid fuel production route is shown in Figure 7. The cost of UCG-derived syngas as a function of depth and thickness is shown in Figure 8.

Tasks for the current project underway include building equipment and identifying problems, and further research needs, such as more complex UCG modeling. With the experience and expertise we have developed, and in order to better characterize the site for a "dual-layer" UCG

plant, the proposed continuation project will obtain additional complementary and site-specific information.

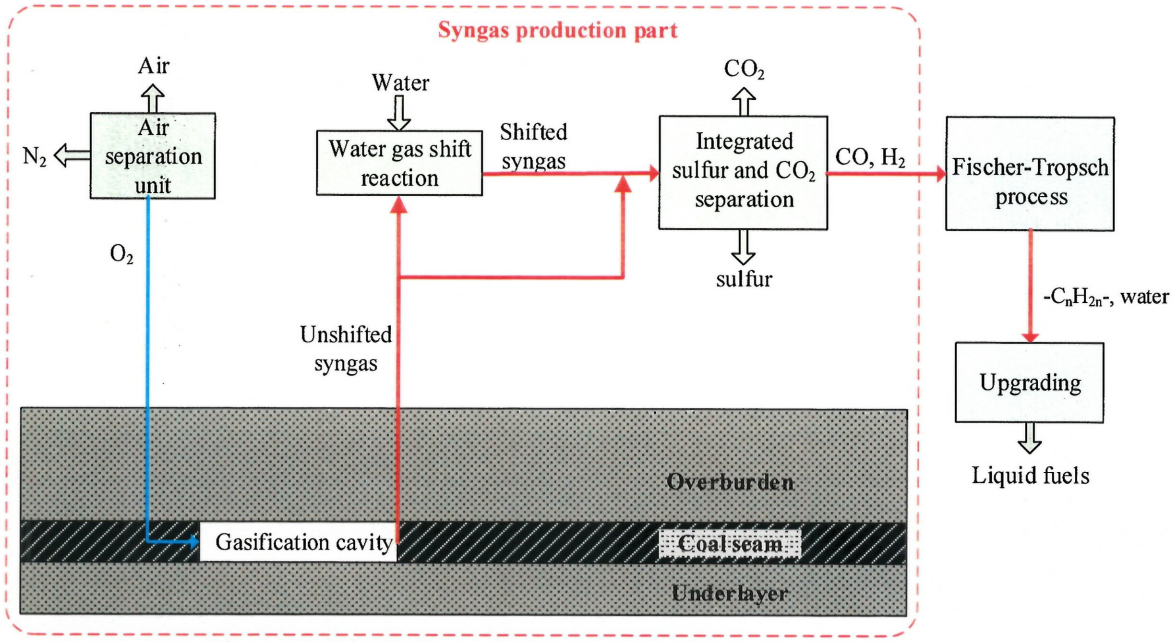

Figure 7. Block flow of UCG and liquid fuel production

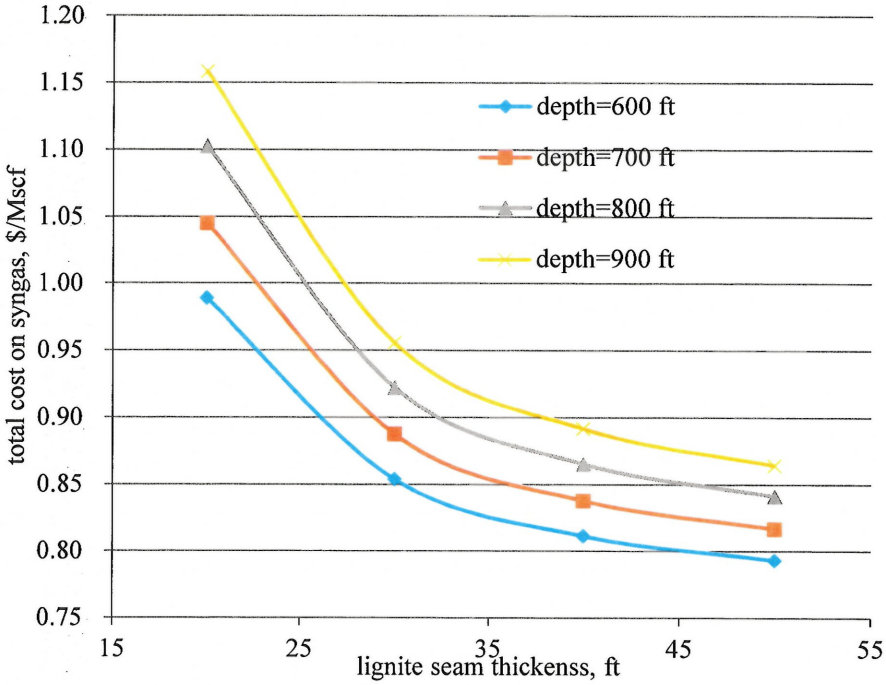

Figure 8. Cost of UCG-syngas as a function of coal seam depth and thickness (Pei et al., 2013)

Qualifications

The research team will include 5 key members: (1) Dr. Scott Korom (PI, Associated Professor in Petroleum & Geological Engineering), (2) Dr. Peng Pei (Research Engineer in IES), (3) Dr. Hadi Jabbari (Assistant Professor in Petroleum Engineering), (4) Dr. Jarda Solc (Senior Engineer in IES), and (5) Dr. Steve Benson, (Chair Petroleum Engineering Department and Director of IES).

Dr. Scott Korom is an expert in hydrogeology and environmental engineering. He has worked with North Dakota state agencies and international agencies on groundwater quality investigation and remediation projects. Dr. Korom is the PI of the UCG feasibility study currently ongoing in UND. Dr. Peng Pei's research area focuses on rock mechanics and advanced energy system. He has been actively involved in investigating potential application of UCG in North Dakota on several technical issues since 2009. He has conducted preliminary studies, including design of the research roadmap, calculated induced stress during UCG process, and the experimental study using rock samples from Harmon outcrops. Dr. Hadi Jabbari's research expertise is primarily in analytical and numerical modeling of transport phenomena in porous media and fractured reservoirs, and designing hydraulic fracturing stimulation in tight shale plays. He has worked as a petroleum engineer at various capacities. Dr. Jarda Solc has over 30 years of experience in design and management of groundwater and soil remediation technologies/site cleanup; water resource assessment, management, and development design; hydrology; borehole geophysics; site characterization and geotechnical evaluation specific to construction of industrial facilities. Dr. Solc participated in an oversea underground coal gasification project. Dr. Steve Benson is an expert in fuel resources, with specialties in coal gasification, environmental protection, and multidisciplinary project

management. He has many years of experience with the coal industry. Dr. Benson's participation in this project will greatly enhance the team's capacity in connection with the state and industry, and the application of state-of-art technology in modeling syngas production and processing. Detailed CVs of each key person are provided in Appendix 1.

In summary, this team has members with all the necessary expertise and background to conduct the proposed multidisciplinary research. Preliminary and current ongoing studies have generated good results, and a close relationship with the lignite industry, lignite council, and state agencies has been established.

Value to North Dakota

The North Dakota portion of the Williston Basin hosts significant resources of lignite in the Paleocene Fort Union Formation. Studies have indicated that there are huge lignite resources in North Dakota, estimated at 1.27 trillion tons. However, the economically recoverable reserves by surface mining is about 25 billion tons (Murphy, 2006). Due to its abundances, sufficient thickness, and good continuity in structure, the Harmon coal bed could be an ideal candidate for UCG utilization. The UCG plant has a smaller footprint than surface gasification plants. The high moisture content in the lignite may be used as a reactant in the gasification process, instead of functioning as a barrier during combustion in boilers. The produced syngas is versatile and can be used to generate electricity or upgrade to various chemical products and clean fuels such as hydrogen, substitute natural gas or liquid fuel through the Fischer-Tropsch process. Such a long industry chain can generate job opportunities and tax revenues for the state. Successful UCG projects will help convert lignite resources beneath North Dakota into huge economic benefits.

In recent decades, thanks to great technological advances such directional drilling, process monitoring, well linkage and computer modeling, UCG technology has received renewed interest and successful UCG projects are being conducted in Australia and South Africa (Burton et al., 2006; Shafirovich and Varma, 2009). These projects have provided valuable insight into UCG site selection, process design, and operation. With the significant unmineable lignite resource and rich experience rooted in lignite utilization and research, North Dakota can also become a leader in the application of UCG and other clean coal technologies, and help to contribute to the "Energy Independence" of the US.

The results of this continuation project will provide complementary knowledge to the current project, filling the gap between the current knowledge of the Harmon lignite-bearing beds and UCG feasibility. The project will train experts in UCG for North Dakota. Project results will provide support to UCG site selection, risk assessment and performance evaluation, and help investors design environmental-friendly and profitable UCG projects.

Management

The proposed project will be managed by the PI with counsel from the North Dakota Lignite Research Council and Great Northern Properties. The proposed project is scheduled to be completed in 18 months, and is divided into 5 tasks: (1) well drilling, coring, and slug tests, (2) well sampling, (3) gasification tests, (4) geomechanical tests, and (5) comprehensive assessment. Key persons involved include Dr. Scott Korom, Dr. Peng Pei, Dr. Hadi Jabbari, Dr. Jarda Solc, and Dr. Steve Benson.

The target project starting date is January 1, 2014. Once drilling sites are determined and appropriate permits are obtained, well drilling will be scheduled in late spring or early summer, depending on weather conditions and the schedule of the drilling contractor. Therefore, a flexible

period of six months is reserved for this task. The earlier the well drilling can start, the earlier the other tasks can commence. For Task 2, the water will be sampled very quarter for one year and it will overlap the other tasks. The equipment used in Tasks 3 and 4 has been built or developed under our current project, and will be ready for gasification and geomechanical tests when needed. The methodology and anticipated results are described in the sections above. Based on the data and results generated in Tasks 1 to 4, and the current project, Tasks 5 will involve a comprehensive assessment to the feasibility of UCG-based liquids production, the economics of the plant will be evaluated, possible risks will be predicted, and an optimized approach proposed. The project management chart is shown in Figure 9.

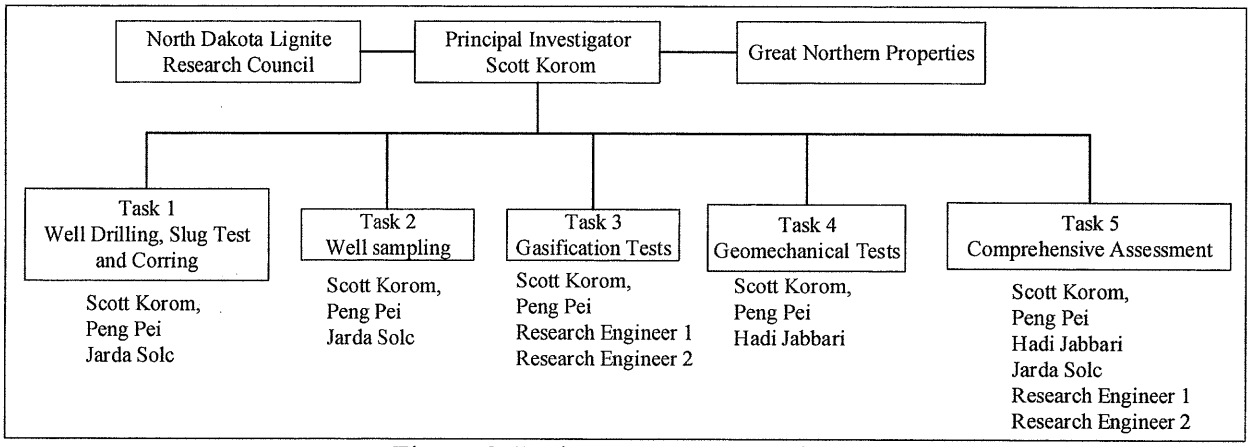

Figure 9. Project management chart

Timetable and Milestone log

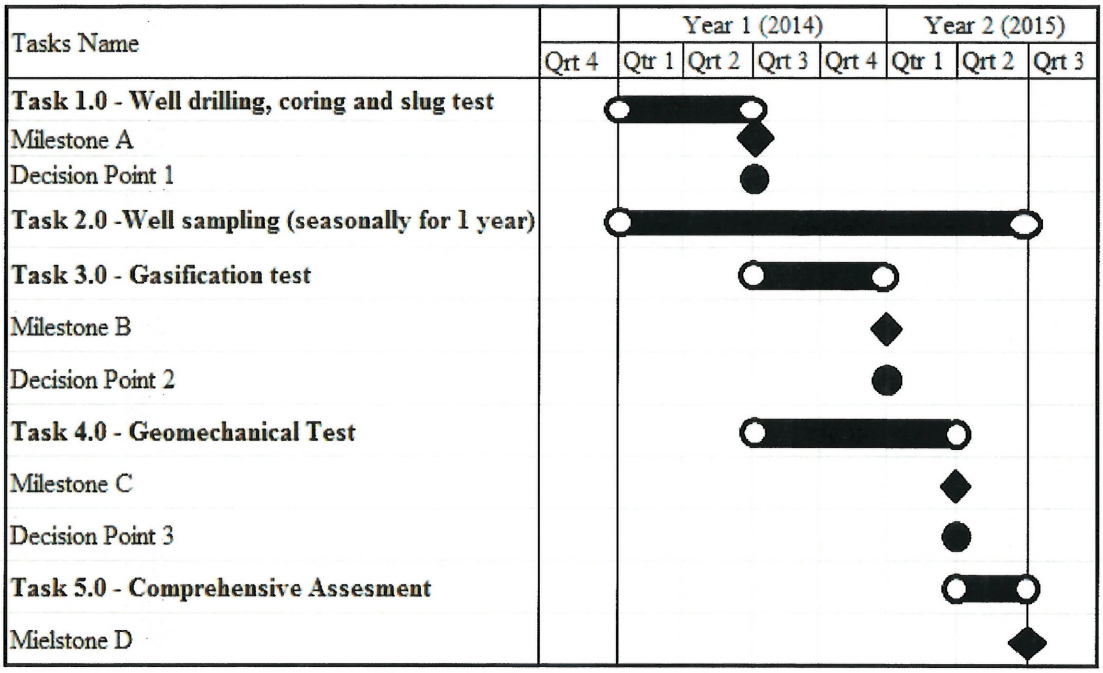

Figure 10. Project timetable

Table 1. Milestone log

ID	Task	Title/Description	Planned Completion Date
Milestone A	1	Well drilling, slug test and coring	09/30/2014
Decision Point 1	1	Cores recovered, and Hydraulic conductivity measured	09/30/2014
Milestone B	3	Complete gasification test	03/31/2015
Decision Point 2	3	Reliable data of gasification test generated	03/31/2015
Milestone C	4	Complete geomechanical test	06/30/2015
Decision Point 3	4	Reliable data of geomechanical test generated	06/30/2015
Milestone D	2 and 5	Obtain background groundwater quality, and Complete comprehensive assessment	09/30/2015

Budget Plan

The total cash budget for this project is $719,958. As required by the North Dakota Lignite Research Council, the budget is designed to have 1-to-1 matching funds. Therefore, Great North Properties will provide a cash support of $150,000 and an in kind support of $270,000. The

current F&A Rate at UND is 38%. The budget sheet and budget narrative are provided in Appendix 4.

Matching Fund

After initial review of the proposal, the Great Northern Properties LP is interested in supporting the project by providing needed matching fund. A letter of support is attached in Appendix 5.

Tax Liability

None

Confidential Information

None

References

Benson, S.A., and Sondreal, E.A., Gasification of Lignites of North America, Lignite Energy Council, 2010.

Burton, E., Friedmann, J., and Upadhye, R., 2006, Best practice in underground coal gasification, Contract W-7405-Eng-48, Lawrence Livermore National Laboratory: Livermore, CA.

Friedmann, S., Upadhye, R, Kong, F., 2009, Prospect for underground coal gasification in a carbon-constrained World, Energy Procedia, Vol.1, 4551-4557.

Linc Energy, 2008, Underground coal gasification: Industry review and an assessment of the potential of UCG and UCG value added products.

Moran, C., Costa, J., and Cuff, C., 2013, Independent scientific panel report on underground coal gasification pilot trials: http://mines.industry.qld.gov.au/assets/legislation-pdf/isp-final-report-cs-review.pdf.

Murphy, E.C., Kruger, N.W., Goven, G.E., Vandal, Q.L., Jacobs, K.C., and Gutenkunst, M.L., 2006, The lignite resources of North Dakota, Report of Investigation No. 105. North Dakota Geological Survey (NDGS), Bismarck, North Dakota.

Pei, P., Ling, K., Korom, S., and Nasah, J., 2013, Cost comparison of syngas production from natural gas conversion and underground coal gasification, Journal of Mitigation and Adaption Strategies for Global Change, in progress.

Shafirovich, E., and Varma, A., 2009, Underground coal gasification: a brief review of current status, Industry Engineering Resource, Vol.48, pp.7865-7875.

Walter, K., 2007, Fire in the hole, Science and Technology Review (April 2007), 12-18.

Wender, I., Reactions of Synthesis gas, Fuel Processing Technology 48 (I 996) 189-297.

Appendix 1: CVs of PI and Key Persons

CV of Dr. Scott Korom, PI

Associate Professor of Geological Engineering, University of North Dakota
Research Engineer, Institute for Energy Studies, University of North Dakota
scott.korom@engr.und.edu, 701.777.6156

Education

Ph.D. Civil and Environmental Engineering, Utah State University, 1992.
M.S. Civil Engineering, University of Akron, 1984.
B.S. Civil Engineering, University of Akron, 1982.

Professional Experience

Associate Professor of Geological Engineering, U. of North Dakota, 2000-present.
Assistant Professor of Geological Engineering, U. of North Dakota, 1994-2000.

Other Related Experience

Postdoctoral Research Fellow, Oak Ridge Associated Universities, Savannah River Site, Aiken, SC, 1992-1994. *Responsibilities*: Experimentally and numerically tested the use of anionic groundwater tracers to determine physical and chemical properties of contaminated aquifers.

Research Engineer, Utah State University, 1991-1992. *Responsibilities*: Groundwater hydrologist for a research project evaluating the effectiveness of bioremediation of a U.S. EPA Superfund site in Libby, MT. This was the first Superfund site for which bioremediation of groundwater was specified in the record of decision.

Selected Honors, Awards, and Grants

Authored or co-authored grants and contracts awarded for over $1,500,000, including the following:

Aquifer Assessment in Peru: Fate and Transport of Nitrate and Selenium. Ground Water International, Lima, Peru, $9,999, 10/06-8/07.

Collaborative Research on In Situ Denitrification & Glyphosate Transformation in Ground Water: NAWQA Eastern Iowa Basins, USGS, $91,988, 8/06-7/09, with P. Capel.

Effects of iron bacteria on subsurface tile drains: Influence on hydraulic efficiency and nutrient transport, US Bureau of Reclamation, $206,390 (UND portion: $88,500), 10/2007 to 12/2009, with F. Casey and A. Schlag.

Geomechanical study of Harmon Lignite and surrounding rocks for underground coal gasification in western North Dakota, ND Industrial Commission plus industrial match, $485,458, 6/12 to 6/14, with S.A. Benson.

Identified twice as one of UND's faculty "stars" by one or more Presidential Scholars, letters from President Kupchella, 1/4/08 and 1/9/06.

Selected as an "Expert of International Standing," Australian Research Council College of Experts, 4/2006.

UND Summer Graduate Research Professorship, 5/06 to 7/06.

Selected as a "Short List" candidate for the Ad Hoc Integrated Nitrogen Research Committee of the US EPA Science Advisory Board, fall 2005.

Cited for Excellence in Refereeing, letter dated 3/2/2010 by Mary P. Anderson, Editor in Chief, Ground Water.

North Dakota Spirit Faculty Achievement Award, 2011.

Scientific and Professional Societies

American Geophysical Union
American Society of Civil Engineers
National Ground Water Association
Tau Beta Pi National Engineering Honor Society

Selected Publications

1. Korom, S.F., Comment on "Modeling of multicomponent transport with microbial transformation in groundwater: The Fuhrberg case" by E. O. Frind et al., Water Resources Research, 27(12), 3271-3274, 1991.
2. Korom, S.F., Natural denitrification in the saturated zone: A review, Water Resources Research, 28(6), 1657-1668, 1992.
3. Korom, S.F., and R.W. Jeppson, Nitrate contamination from dairy lagoons constructed in coarse alluvial deposits, Journal of Environmental Quality, 23(5), 973-976, 1994.
4. Korom, S.F., and R.W. Jeppson, Nutrient leaching from alfalfa irrigated with municipal wastewater, Journal of Environmental Engineering, ASCE, 120(5), 1067-1081, 1994.
5. Korom, S.F., M.J. McFarland, and R. Sims, Reduced sediments: A factor in the design of subsurface oxidant delivery systems, Ground Water Monitoring and Remediation, 16(1), 100-105, 1996.
6. Seaman, J.C., P.M. Bertsch, S.F. Korom, and W.P. Miller, Physicochemical controls on non-conservative anion migration in coarse-textured alluvial sediments, Ground Water, 34(5), 778-783, 1996.
7. Korom, S.F., An adsorption isotherm for bromide, Water Resources Research, 36(7), 1969-1974, 2000.
8. Korom, S. F., K. F. Bekker, and O. J. Helweg, Influence of pump intake location on well efficiency, Journal of Hydrologic Engineering, ASCE, 8(4), 197-203, 2003.
9. Korom, S.F., A.J. Schlag, W.M. Schuh, and A.K. Schlag, In situ mesocosms: Denitrification in the Elk Valley Aquifer, Ground Water Monitoring and Remediation, 25(1), 79-89, 2005.
10. Korom, S.F., and E.J. Dodak. Numerical study of bromide as a tracer for aquifer macrodispersivity tests: Comparing conservative behavior to mildly nonlinear adsorption, Journal of Hydrologic Engineering, 14(12), 1383-1389, 2009.
11. Korom, S.F. Graphical solutions for hillslopes: Discharge, head and velocity diagrams, Journal of Irrigation and Drainage Engineering, 136(8), 563-566, 2010.
12. Gerla, P.J., M.U. Sharif, and S.F. Korom. Geochemical processes controlling the spatial distribution of selenium in soil and water, west central South Dakota, USA, Environmental Earth Sciences,62(7), 1551-1560, 2011.
13. Korom, S.F., W.M. Schuh, T.Tesfay, and E.J. Spencer. Aquifer denitrification and in situ mesocoms: Modeling electron donor contributions and measuring rates, Journal of Hydrology, 432-433, 112-126, 2012.
14. Korom, S.F., and J.C. Seaman. When "conservative" anionic tracers aren't, Ground Water, 50(6), 820-824, 2012.
15. Derby, N.E., S.F. Korom, and F.X.M. Casey. Field-scale relationships among soil properties and shallow groundwater quality, Ground Water, 51(3), 373-384, 2013.

Selected Institutional/Professional Service

Director, Geological Engineering, U. of North Dakota, 2009-2011.

Director, Graduate Programs in Environmental Engineering, U. of North Dakota, 2005-2007.

Director, Water Resources Research Laboratory, U. of North Dakota, 1998-2002.

Peer Referee for over 10 journals and for over 10 regional, national, or international research organizations.

Professional Registration

Licensed Professional Engineer, North Dakota, 1995-present.

CV of Dr. Peng Pei

Research Engineer, Institute for Energy Studies, University of North Dakota
Room 366, 243 Centennial Drive, Stop 8153,
Grand Forks, North Dakota 58202-8153 USA
peng.pei@engry.und.edu, (701)777-4022

Education

Ph.D, Engineering (Geological Track) , University of North Dakota, 2012
M.S., Mechanical Engineering, University of North Dakota, 2008
B.S,. Mechanical Engineering, North China Electrical Power University, 2005

Training

Research Experience in Carbon Sequestration (RECS 2012) June 2012
Field training in CO2 capture, transportation and enhanced oil recovery sponsored by the National Energy Technology Laboratory and Fossil Fuel Office of Department of Energy

Research Area

Energy-related rock mechanics, laboratory study of rock properties, advanced energy system and emission control technology, developing and testing of laboratory equipment and facilities.

Professional Experience

Research Engineer, Institute for Energy Studies, 2013-present
Graduate Research Assistant, University of North Dakota, 2008-2012

1. Modeling energy production, conversion, and emission control process, including underground coal gasification, CO_2 capture, tight gas/liquid production, and clean fuel combustion;
2. Designing and building laboratory equipment, and conducting experiments related to energy production processes;
3. Planning field test and investigation, sampling and data collection;
4. Feasibility and economic analysis of advanced energy production process;
5. Participating undergraduate teaching works, including courses and labs; and supervising undergraduate students in research projects;
6. Writing proposals, project reports, academic papers and conference presentations.

Selected Publications

1. Pei, P., Ling, K., Korom, S., and Nasah, J. 2013. Cost comparison of syngas production from natural gas conversion and underground coal gasification, Journal of Mitigation and Adaption Strategies for Global Change, in progress.

2. Pei, P. and Zeng, Z. 2012. Estimating mining recovery factor and cavity stability of commercial scale underground coal gasification plants, paper ARMA12-308, Proc. 46th U.S. and 5th U.S.-Canada Rock Mech. Symp., Chicago, Illinois, USA. June 24-27.
3. Pei, P., Zeng, Z., Liu, H. and Ahmed, S. 2012. Preliminary experimental study of surrounding rock properties for underground coal gasification in western North Dakota, paper ARMA12-200, Proc. 46th U.S. and 5th U.S.-Canada Rock Mech. Symp., Chicago, Illinois, USA. June 24-27.
4. Jensen, M.D., Pei, P., Snyder, A.C., Heebink, L.V. and Cowan, R.M. 2012. A phased approach to developing a pipeline network for CO2 transport during CCUS, Proc. AIChE 2012 Annual Meeting, Pittsburgh, Pennsylvania, USA. October 28 – November 2.
5. Pei, P., Zeng, Z., and He, J. 2011. Characterization of the Harmon lignite for underground coal gasification, Proc. 28th International Pittsburgh Coal Conference, Pittsburgh, Pennsylvania, USA. September 12-15.
6. Pei, P., Zeng, Z., and He, J. 2010. Feasibility study of underground coal gasification combined with CO2 capture and sequestration in Williston Basin, North Dakota, paper ARMA10-240, Proc. 44th U.S. and 5th U.S.-Canada Rock Mech. Symp., Salt Lake City, Utah, USA. June 27-30.
7. Pei, P., and Kulkarni, M. 2008. A model for analysis of integrated gasification combined cycle with carbon dioxide capture, paper POWER2008-60124, Proc. ASME Power 2008 Conference, Orlando, Florida, USA. July 22-24.
8. Pei, P., and Kulkarni, M. 2008. Modeling of ultra superheated steam gasification in integrated gasification combined cycle power plant with carbon dioxide capture, paper ES2008-54325, Proc. Energy Sustainability 2008 Conference, Jacksonville, Florida, USA. August 10-14.
9. Jensen, M.D., Cowan, R.M., Pei, P., Steadman, E.N, and Harju, J.A. 2011. Opportunities and challenges associated with CO2 compression and transportation during CCS activities: U.S. Department of Energy National Energy Technology Laboratory Cooperative Agreement No. DE-FC26-05NT42592, Grand Forks, North Dakota, Energy & Environmental Research Center, 30 p.
10. Cowan, R.M., Jensen, M.D., Pei, P., Steadman, E.N, and Harju, J.A. 2011. Current status of CO2 capture technology development and application: U.S. DOE-NETL Cooperative Agreement No. DE-FC26-05NT42592, Grand Forks, North Dakota, Energy & Environmental Research Center, 166 p.
11. Jensen, M.D., Pavlish, B.M., Pei, P., Leroux, K.M., Steadman, E.N, and Harju, J.A. 2009. Regional emissions and capture opportunities assessment—Plains CO2 Reduction Partnership: U.S. DOE NETL Cooperative Agreement No. DE-FC26-05NT42592, Grand Forks, North Dakota, Energy & Environmental Research Center, 128 p.

CV of Dr. Hadi Jabbari

Education

PhD

[2009-2013] University of North Dakota, Grand Forks, ND, USA

Petroleum Engineering

GPA: 3.84 / 4

Dissertation: Hydraulic Fracturing Design for Horizontal Wells in the Bakken Formation, Williston Basin.

Master of Science

[2004-2006] Sharif University of Technology (SUT), Tehran, Iran

Reservoir Engineering

GPA: 3.54 / 4

Thesis: Inflow Performance Relationships for Damaged or Improved Horizontal Wells Producing from Solution-Gas Drive Reservoirs.

Bachelor's Degree

[2000-2004] Petroleum University of Technology (PUT), Ahvaz, Iran

Petroleum Production Engineering

GPA: 3.22 / 4

BS Thesis: Developing a Computer Assisted Procedure for Well Test Interpretation, based on the analysis of Type-Curve Matching.

Professional Experience

[2013 – current] UND, Grand Forks, ND, USA

Assistant Professor

[Aug. 2009 – 2013] UND, Grand Forks, ND, USA

Graduate Research Assistant

- Working on various projects; ranging from Hydraulic Fracturing Design to Decline Curve Analysis as well as Well Test interpretation of NFRs.

[Jan-Dec. 2012] Energy & Environmental Research Center, Grand Forks, ND, USA

Reservoir Engineer (GRA)

- **Reservoir simulation:** Making dynamic models for some reservoirs including: a) sensitivity analysis (SA), b) history matching (HM) of production data, c) optimization (OP) for making more prolific field development plans, and d) uncertainty assessment (UA) for risk assessment.
- **CO2 EOR**: I have developed an interactive program that can analyze the CO2 PROPHET results in no time. Not only is it much easier to do CO2 EOR analyses using this program, but it can also manage history matching and CO2 EOR predictions with more accuracy.
- *Fracture modeling*, *Decline-Curve Analysis*, and *Well Test interpretation* for some fields.

[2010 – 2011] Petroleum Department, UND, Grand Forks, ND, USA

Teaching Instructor

- Teaching two courses at UND: ***Petrophysics*** and ***Introduction to Petroleum Engineering***.

[2008-2009 (Sep-Aug)] Petropars Ltd., Tehran, Iran

Reservoir Engineer

- Working as a reservoir engineer on the full-field reservoir simulation of "***South Pars / North Dome Gas-Condensate***".

[2008-2009] PUT Research Center, Tehran, Iran

Reservoir Engineer – Research Engineer

- Reservoir modeling in Thermal EOR processes (In-situ combustion & SAGD).

[2007-2008] Iranian Offshore Oil Company (IOOC)-NIOC, Sirri island, Persian Gulf

Production Engineer

Working on ***offshore platforms,*** being involved in production operations; such as well testing, wireline and completion.

Computer Skills

□ **Reservoir Simulation & Reservoir Modeling** – Expert in Reservoir Simulators (*CMG, ECLIPSE, CMOST*).

□ **Hydraulic Fracturing** - Conversant with *StimPlan* (hydraulic Fracture Simulation software).

□ **Geologic Modeling**– Familiar with *PETREL* (*Petrel RE*, Fracture modeling, Upscaling, 3D visualization, etc.).
□ **Well Test Interpretation** - Conversant with *FEKETE* and PanSys.
□ **Production Engineering-** Conversant with *PROSPER*.
□ **Programming-** Conversant with *MATLAB, Visual Basic, Excel VBA*.

Selected Publication

- **SPE Journal Reviewer (since January 2012)**

1) **Jabbari, H.** and S. Benson. 2013. **Hydraulic Fracturing Design Optimization—Bakken Case Study**, presented at the 47th ARMA held on 23-26 June 2013 in San Francisco, CA.
2) **Jabbari H.**, Z. Zeng, S.F. Korom, and M. Khavanin. 2012. **Well Test Analysis in Dual Porosity Aquifers with Stress Dependent Permeability,** "*Res. Journal of Envir.&Earth Sci.*" (in press).
3) **Jabbari H.** and Z. Zeng. *2011*. **Hydraulic Fracturing Design for Horizontal Wells in the Bakken Formation.** *ARMA 11-128*, presented at the 46th ARMA held 24-27 June 2012 in Chicago, IL.
4) **Jabbari H.**, Z. Zeng, and M. Ostadhassan. *2011*. **Incorporating Geomechanics into the Decline-Curve Analysis of Naturally Fractured Reservoirs.** *SPE-147008*, presented at the SPE ATCE 2011, Denver, Co. (Oct.30- Nov.2).
5) **Jabbari H.** and Z. Zeng. *2011*. **A Three-Parameter Dual Porosity model for Naturally Fractured Reservoirs**. *SPE-144560*, presented at the Western Regional Meeting held in Anchorage, Alaska (7-11 May).
6) **Jabbari H.**, Z. Zeng, and M. Ostadhassan. *2011*. **Impact of In-Situ Stress Change on Fracture Conductivity in Naturally Fractured Reservoirs.** *ARMA 11-239*, presented at the 45th ARMA held 26-29 June 2011 in San Francisco, CA.
7) Ostadhassan, M., Zeng, Z, **H. Jabbari**. *2011*. **Using Advanced Acoustic Data to Determine Stress State Around the Wellbore.** *ARMA 11-319*, presented at the 45th ARMA held 26-29 June 2011 in San Francisco, CA.
8) **Jabbari, H.**, R. Kharrat, Z. Zeng, V. Mostafavi, and A. Emamzadeh. *2010*. **Modeling the Toe-to-Heel Air Injection Process by Introducing a New Method of Type-Curve Match**. *SPE 132515*, presented at the Western Regional Meeting held in Anaheim, California, May 2010.
9) Alali N., M.R. Pishvaie, **H. Jabbari**. *2009*. **A New Semi-analytical Modeling of Steam-Assisted Gravity Drainage in Heavy Oil Reservoirs**. *Journal of Petroleum Science and Engineering (JOP Sci. & Eng)*, Sep.
10) **Jabbari H.**, IOOC, **M.J Economides**, *University of Houston. 2008*. **A New Approach to IPR Curves of Horizontal Wells in Two-Phase Reservoirs**. *SPE 115918*, presented at the SPE ATCE held in Denver, Co. 21–24 Sep.
11) **Jabbari H.** *2006*. **Inflow Performance Relationships in Damaged or Improved Horizontal Wells producing from Solution-Gas Drive Reservoirs.** M.Sc degree Thesis.
12) **Jabbari H.**, Aminshahidy B., Sharif University of Technology (SUT). *2005*. **Evaluation of Two-Phase IPR Correlations for Horizontal Wells.** Presented at the 4th Petroleum Engineering Student Conference, 5-7 December, PUT, Ahvaz, Iran.
13) **Jabbari H.** Sharif University of Technology (SUT). *2005*. **Application of New Type Curves for Well Test Interpretation Using MATLab software.** Presented at the 4th Petroleum Engineering Students Conference, 5-7 December, PUT, Ahvaz, Iran.

14) **Jabbari H.** *2004.* **Developing New Type Curve Match for Well Test Interpretation using MATLab Software.** BSc project.

CV of Dr. Jarda Solc

Senior Research Associate, Institute for Energy Studies, UND

Phone (701) 330 6664 E-Mail: jaroslav.solc@engr.und.edu

QUALIFICATIONS

Over 30 years of experience in design and management of groundwater and soil remediation technologies/site cleanup; water resource assessment, management, and development design; hydrology; borehole geophysics; site characterization and geotechnical evaluation specific to construction of industrial facilities. Project management experience from Americas, Europe, and Asia.

Mr. Solc worked at the forefront of a hands-on development, promotion, and application of efficient extraction and in-situ technologies in a variety of geological and environmental settings. He gained national and international recognition for his worldwide presentations, including courses on remediation strategies, technologies, and managerial and economic aspects. Mr. Solc has a record of providing unbiased technical and managerial reviews for industrial and regulatory entities.

EDUCATION

- Doctor of Natural Sciences, Dr. Diploma in Engineering Geology, Hydrogeology, and Geophysics, Charles University, Prague, 1985.

EMPLOYMENT HISTORY

1998 – to date	Senior Project Manager, President, Integrated Environmental Services, Inc.
2007 – to date	Senior Advisor, WCEC, Inc.
2012 – to date	Senior Research Associate, Institute for Energy Studies, UND
1999 – 2012	Senior Research Manager, Principal Hydrologist, EERC
1994 – 1999	Program Manager and Principal Hydrologist, EERC.
1991 – 1994	Hydrogeologist, Energy & Environmental Research Center (EERC), University of North Dakota (UND)
1988 – 1991	Project Manager, Aquatest, Inc., Prague.
1984 – 1988	Hydrogeologist and Geotechnical Engineer, Building Geology, Inc., Prague.

ADDITIONAL SKILLS

Fluent in Czech, limited fluency in French and Russian; orientation in Spanish, Polish, and German. Computer skills: Microsoft Office, statistics, CAD, and geochemical and hydrogeological modeling.

PROFESSIONAL MEMBERSHIPS

- International Association of Hydrological Sciences
- National Ground Water Association

UCG EXPERIENCE – TECHNICAL REPORTS, SELECTED PUBLICATIONS AND PRESENTATIONS

- Solc, J., Boysen, J.E, Steadman E.N., 1998, *Feasibility study for underground coal gasification at Krabi Mine, Thailand*: In *Proceedings of the 15th Annual International Pittsburgh Coal Conference*; Pittsburgh, PA, Sept 14–18, 1998.
- Solc, J. *et al.*, 1998, *Preliminary Economic Evaluation of UCG at Sin Pun – Nong Wa Deposit, Thailand.* EERC Publication 98-EERC-08-02; Energy & Environmental Research Center: Grand Forks, ND, Aug 1998.
- Boysen, J.E., Canfield, M.T., Solc, J., Poom-Im, S., Nakanart, A., Arunsrisanchai, W., and Vichakul, P., 1997, *Extending Thailand's natural gas reserves by the development of underground coal gasification for electric power and synthetic natural gas production*: Presented at the Thai Coal Conference, August 1997.
- Boysen, J.E, Solc, J., Schmit, C.R., Harju, J.A., Young, B.C., Canfield, M., and Kühnel, R.A., 1997, *A Feasibility Study for Underground Coal Gasification at the Krabi Coal Mine Site, Thailand; Final Report for Electricity Generating Authority of Thailand; EERC Publication 97-EERC-02-07; Energy & Environmental Research Center: Grand Forks, ND, Jan 1997.*
- Solc, J., Boysen, J.E, Young, B.C., Harju, J.A., Schmit, C.R., and Kühnel, R.A., 1996, *The commercial feasibility of underground coal gasification in southern Thailand*: Annual Pittsburgh Coal Conference, 13th, Pittsburgh, PA, September 3-7, 1996, Proceedings: p. 472–477.
- Young, B.C.; Harju, J.A.; Schmit, C.R.; Solc, J.; Boysen, J.; Kühnel, R.A.; Walker, L.K.; Komsartra, C. Rebirth of a 100-Year-Old Technology: Underground Coal Gasification. In *Proceedings of the 7th Australian Coal Science Conference*; The Australian Institute of Energy (Gippsland Group), Monash University, Gippsland, Australia, Dec 2–4, 1996; pp. 215–222.
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CV of Dr. Steven A. Benson

Director, Institute for Energy Studies, University of North Dakota
Chair, Department of Petroleum Engineering, University of North Dakota

Education
Minnesota State University, Chemistry, B.S. 1977
Pennsylvania State University, Fuel Science, Ph.D. 1987

Research and Professional Experience

2010 – present Director, Institute for Energy Studies – coordinate energy related education and research activities that involve faculty, research staff, and students.

2008 – present Professor, University of North Dakota -- Dr. Benson is responsible for teaching courses on energy production and associated environmental issues. Dr. Benson conducts research, development, and demonstration projects aimed at solving environmental, efficiency, and reliability problems associated with the utilization of fuel resources in combustion/gasification systems that include: transformations of fuel impurities; carbon dioxide separation and capture technologies, advanced analytical techniques, and computer based models.

1999 – 2008 Senior Research Manager/Advisor, Energy & Environmental Research Center, University of North Dakota (EERC, UND) -- Dr. Benson is responsible for leading a group of about 30 highly specialized group of chemical, mechanical and civil engineers along with scientists whose aim is to develop and conduct projects and programs on combustion and gasification system performance, environmental control systems, the fate of pollutants, computer modeling, and health issues for clients worldwide.

1994 – 1999 Associate Director for Research, EERC, UND -- Dr. Benson was responsible for the direction and management of programs related to integrated energy and environmental systems development. Dr. Benson led a team of over 45 scientists, engineers, and technicians.

1991 – Present President, Microbeam Technologies Incorporated (MTI) -- Dr. Benson is the founders of MTI whose mission is to conduct service analysis of materials using automated methods. MTI began operations in 1992 and has conducted over 1400 projects for industry, government, and research organizations.

1989 – 1991 Assistant Professor of Geological Engineering, Department of Geology and Geological Engineering, UND -- Dr. Benson was responsible for teaching courses on coal geochemistry, coal ash behavior in combustion and gasification systems, and analytical methods of materials analysis.

1986 – 1994 Senior Research Manager, Fuels and Materials Science, EERC, UND -- Dr. Benson was responsible for management and supervision of research on the behavior of inorganic constituents in fuels in combustion and gasification.

1984 – 1986 Graduate Research Assistant, Fuel Science Program, Department of Materials Science and Engineering, The Pennsylvania State University, Mr. Benson took course work in fuel science, chemical engineering (at UND), and ceramic science and performed independent research leading to a Ph.D. in Fuel Science.

1983 – 1984 Research Supervisor, Distribution of Inorganics and Geochemistry, Coal Science Division, UND Energy Research Center -- He was responsible for management and supervision of research on coal geochemistry and ash chemistry related to inorganic constituents and mineral interactions and transformations during coal combustion and environmental control systems.

1977 – 1983 Research Chemist, U.S. Department of Energy Grand Forks Energy Technology Center, Grand Forks, North Dakota -- He performed research on methods development for the characterization of coal and coal derived materials

Publications

1. Benson, S.A., Gasification of Lignites of North America, North Dakota Industrial Commission, 2010.
2. Pavlish, J.H., Laumb, J.D., and Benson S.A., Eds, Air Quality VI: Mercury, Trace Elements, SO3, Particulate Matter, & Greenhouse Gases, Special Issue of Fuel Process. Technol.; Elsevier Science Publishers: Amsterdam, 2009, Vol. 90, No. 11, 1327-1434.
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4. Benson, S.A., Pavlish, J.H., Holmes, M.J., Crocker, C.R., Galbreath, K.C., and Zhaung, Y., Mercury control testing in a pulverized lignite-fired system, Fuel Processing Technology, Volume 90, Issue 11, 2009, Pages 1378-1387.
5. Jones, M.L., Pavlish, B.M., Laumb, J.D., Lentz, N.B, and Benson, S.A., Fuel derived impurities impacts on CO2 separation and capture technologies, Prepr. Pap.—Am. Chem. Soc., Div. Fuel Chem. 2008, 53 (2), 812-813.
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7. Benson, S.A.; Holmes, M.J. Coproducing Electricity, Hydrogen, and Synthetic Fuels from Lignite with Carbon Dioxide Capture and Utilization. Presented at the Energy Generation Conference, Bismarck, ND, Jan 31 – Feb 1, 2007.
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9. Ma, Z.; Iman, F.; Lu, P.; Sears, R.; Vasquez, E.; Yan, L.; Kong, L.; Rokanuzzaman, A.S.; McCollor, D.P.; Benson, S.A. A comprehensive slagging and fouling prediction tool for coal-fired boilers and its validation/application, Fuel Process. Technol, 2007, 88, 1035–1043.
10. Steadman, E.; Benson, S. Gasification, CO2 Capture, and Sequestration. In Proceedings of the Symposium on Western Fuels: 20th International Conference on Lignite, Brown, and Subbituminous Coals Workshops; Denver, CO, Oct 23, 2006.
11. Olson, E.S.; Crocker, C.R.; Benson, S.A.; Pavlish, J.H.; Holmes, M.J. Surface Compositions of Carbon Sorbents Exposed to Simulated Low-Rank Coal Flue Gases. J. Air Waste Manage. 2005, 55 (6), 747–754.

Patents – 3 patents issued and several applications pending

7,574,968 - Method and apparatus for capturing gas phase pollutants such as sulfur trioxide.
7,628,969 - Multifunctional abatement of air pollutants in flue gas.
7,981,835 -System and method for coproduction of activated carbon and steam/electricity.

Appendix 2: Price List of Pump for Well Sampling

Rentals | Sales | Supplies & Safety | Built to SPEC | Repairs | Resources | Wireless

Search here...

Grundfos Redi-Flo 2 REEL E-Z System Sale

Air
Water
Soil
Survey & Measurement
Policies and Shipping
Terms and Conditions

REEL E-Z Specifications

GRUNDFOS Redi-flo Variable Performance Pumping Systems Brochure

Happy Hose Flyer

Contact an FEI location near you:

Pittsburgh, PA (HQ): 800-393-4009
Atlanta, GA: 866-620-6762
Houston, TX: 866-323-4006
Kansas City, KS: 866-580-5499
Los Angeles, CA: 866-278-2282
Minneapolis, MN: 866-580-5512
Philadelphia, PA: 866-648-8607
Seattle, WA: 855-398-5600

Subscribe to our e-newsletter for helpful business tips by adding your email below:

Email:

Subscribe

Privacy by SafeSubscribe℠
For Email Marketing you can trust

Pump Length	Purchase
Pump w/100' PVC Happy Hose (#3P015)	$4,446
Pump w/100' TLPE Happy Hose (#3P301)	$4,556
Pump w/150' PVC Happy Hose (#3P025)	$4,556
Pump w/150' TLPE Happy Hose (#3P302)	$4,782
Pump w/200' PVC Happy Hose (#3P030)	$4,809
Pump w/200' TLPE Happy Hose (#3P303)	$5,107
Pump w/250' PVC Happy Hose (#3P035)	$4,975
Pump w/250' TLPE Happy Hose (#3P304)	$5,416

The REEL E-Z system is ideal for one person sampling and purging applications. The REEL E-Z is a compact system designed to provide a convenient way to store and operate the Grundfos® RediFlo-2® Pump. When used with INW's HAPPY HOSE! (cable, tubing and safety cable bonded together) the system easily installs the pump in the well, locks it in place and allows for easy take up and cleaning without cable entanglement. The roller guide protects the cable from well damage and the REEL E-Z can accommodate both above and below-grade well applications. The REEL E-Z is also available with HAPPY CABLE! (combination electrical conductors and safety cable) for customers who want to use the system with various types of tubing.

Features

- Lightweight aluminum
- One-person portability
- 250' HAPPY HOSE! capacity
- Easy decontamination

Appendix 3: Quote of Well Drilling Service

(no subject)

DELETE REPLY REPLY ALL FORWARD ...

John Mohl <mohldrilling@westriv.com>
Sun 9/29/2013 5:42 PM

mark as unread

To: Pei, Peng;

You forwarded this message on 9/29/2013 6:28 PM.

1 attachment

UND Well Dr~.xlsx

Bing Maps + Get more apps

To: Pei Peng

Based on the attached spreadsheet, Mohl Drilling, Inc. proposes to do these two monitoring wells and one core hole at a cost not to exceed approximately $75,000.
This project is proposed in the same area as the deep core that was done in this spring.

Thank you for the opportunity to quote this project for you.

Sincerely,
John Mohl, Pr.
Mohl Drilling, Inc.
1710 Arikara Dr
Beulah ND 58523
701.870.5182 Cell

TOTAL COST		
2 Wells using 2" PVC tubing	$	68,595.25
with contingency, round up to		$75,000

Test Well 1 (to upper coal seam): 2" well, 700 ft deep, 4 days to drill				
Item	price rate	cost		note
mobile	$3.30/mi/vehicle	$	990.00	3 vehicles, 100 mile from Beluah to Watford City
Rig price	$350/hr	$	8,400.00	12 hours/day, 2 days to drill
Travel charge	$250/day	$	750.00	3 days on site
Lodging	$55/man/day	$	495.00	3 men, 3 days on site
Consumed material	15% of cost on job site	$	1,446.75	
Pipe for moitoring wells	$7 per ft	$	4,900.00	2" PVC tube, estimated $7 per ft
Grout and sand pack	$6/ft for 2" wells	$	4,200.00	grout and pack about 20 ft
coring	$350/hr	$	2,100.00	about 6 hours coring work
	Total cost of Well 1	**$**	**23,281.75**	

Test Well 2 (to Harmon bed): 2" well, 1300 ft deep, tubing to 1000 ft, 8 days to drill				
Item	price rate	cost		note
mobile	$3.30/mi/vehicle	-		NA
Rig price	$350/hr	$	21,000.00	12 hours/day, 5 days to drill
Travel charge	$250/day	$	1,500.00	6 days on site
Lodging	$55/man/day	$	990.00	3 men, 6 days on site
Consumed material	15% of cost on job site	$	3,523.50	
Pipe for moitoring wells	$7 per ft	$	7,000.00	2" PVC tube, estimated $7 per ft
Grout and sand pack	$6/ft for 2" wells	$	7,800.00	grout and pack about 20 ft
coring	$350/hr	$	3,500.00	about 10 hours coring work
	Total cost of Well 2	**$**	**45,313.50**	

Appendix 4: Budget Sheet and Narrative

BUDGET OUTLINE F&A (INDIRECT COST) RATE FOR PROPOSAL = 38.00%

DESCRIPTION	NDIC	GNP-CASH	GNP-IN KIND	TOTAL
SALARIES - REGULAR	89,491	0	0	89,491
SALARIES - OTHER	4,260	0	0	4,260
SALARIES - FACULTY	32,732	33,445	0	66,177
FRINGE BENEFITS	41,567	10,034	0	51,601
TOTAL PERSONNEL	168,050	43,479	0	211,529
TRAVEL	30,418	3,986	0	34,404
COMMUNICATIONS-PHONE	500	0	0	500
COMMUNICATIONS-POSTAGE	150	0	0	150
INSURANCE	0	0	0	0
RENTS/LEASES-EQUIPMENT & OTHER	0	0	0	0
RENTS/LEASES-BUILDING/LAND	0	0	0	0
OFFICE SUPPLIES	0	0	0	0
PRINTING-COPIES, DUPLICATING	0	0	0	0
REPAIRS	0	0	0	0
UTILITIES	0	0	0	0
SUPPLIES-IT SOFTWARE	0	0	0	0
SUPPLY/MATERIALS-PROFESSIONAL	0	0	0	0
SUPPLIES-MISCELLANEOUS	8,517	0	0	8,517
IT EQUIPMENT <$5,000	0	0	0	0
OTHER EQUIPMENT <$5,000	0	0	0	0
FEES-OPERATING FEES & SERVICES	0	0	0	0
FEES-PROFESSIONAL FEES & SERVICES	5,000	0	0	5,000
FEES-SUBCONTRACTS (see Note 1 below)	0	75,000	0	75,000
PROFESSIONAL DEVELOPMENT	0	0	0	0
FOOD AND CLOTHING	800	0	0	800
WAIVERS/SCHOLARSHPS/FELLOWSHPS	0	0	0	0
TOTAL OPERATING	45,385	78,986	0	124,371
EQUIPMENT >$5,000	5,416	0	0	5,416
IT EQUIPMENT >$5,000	0	0	0	0
TOTAL EQUIPMENT	5,416	0	0	5,416
TOTAL DIRECT COST	218,852	122,464	0	341,316
IN-KIND COST SHARE-GNP			270,000	270,000
F&A (INDIRECT COST) *	81,106	27,536	0	108,642
TOTAL COST	299,957	150,000	270,000	719,958

* F&A is applied to modified total direct costs, consisting of all salaries and wages, fringe benefits, materials, supplies, services, travel and subgrants and subcontracts up to the first $25,000 of each subgrant or subcontract (regardless of the period covered by the subgrant or subcontract). Modified total direct costs (MTDC) shall exclude equipment, capital expenditures, charges for patient care, tuition remission, rental costs of off-site facilities, scholarships, and fellowships, as well as the portion of each subgrant and subcontract in excess of $25,000.

Note (1)

Complete this Subcontract information section so that an accurate MTDC can be calculated:

F&A is applicable only to the first $25,000 of each subcontract, regardless of how many years a subcontract lasts.

Subcontract Amounts of $25,000 or less	YEAR 1	YEAR 2	YEAR 3	YEAR 4
Subcontract 1	0	25,000	0	0
Subcontract 2	0	0	0	0
Subcontract 3	0	0	0	0
Subcontract 4	0	0	0	0
Total	0	25,000	0	0

Example	*YEAR 1*	*YEAR 2*	*Notes*
ABC Corp.	*25,000*	*0*	*The subcontract with ABC is for $100,000 and is for 2 years. F&A will only be applied to first $25,000.*
XYZ, Inc.	*16,000*	*0*	*The subcontract with XYZ is for $16,000 and is for 1 year. F&A will be applied to the entire $16,000.*
Acme Co.	*19,000*	*6,000*	*The subcontract with Acme is for $50,000 and is for 2 years. Anticipate paying only $19,000 the first year and the rest the 2nd year. Only $6,000 will have F&A applied the 2nd year.*
Total amount that F&A can be applied to	*60,000*	*6,000*	

UNIVERSITY OF NORTH DAKOTA-INSTITUTE FOR ENERGY STUDIES
North Dakota Industrial Commission-Lignite Energy Council

"Continuation of Underground Coal Gasification Study in Western North Dakota"

January 1, 2014-June 30, 2015

Budget Narrative

The distribution of costs between budget categories (labor, travel, supplies, equipment, etc.) is for planning purposes only. Note: Budget category descriptions presented below are for informational purposes only; some categories may not appear in the budget.

Salaries

Salary estimates are based on the scope of work, a break down per labor category per hour per task is included after the budget, and actual annual salary rates are used. Estimates included salary for the principal investigator/project manager, faculty, research engineers, program resource manager, administrative assistant and may include time for a staff engineer, staff research engineer, and/or account technician. Estimated salary may be used for summer faculty salary.

Fringe

Fringe benefits are estimated on the basis of historical data and are changed as actual expenses for items such as health, life, and unemployment insurance; social security; workers' compensation; and UND retirement contributions. The following rates are based on the above information are 30% for faculty (including PI) and 35% for staff (including research engineers, engineers, program resource manager, administrative assistant), and 10% for undergraduate students.

Travel

Typically, travel is estimated on the basis of UND travel policies which can be found at www.und.edu/finance-operations/policy-division-catalog.cfm. Typically, estimates include GSA daily meal rates and hotels. Travel may include site visits, field work, meetings, and conference participation as indicated by the scope of work and/or budget. Travel for this effort will include budgets for three trips for two people. The following trips will be conducted: 1 trips from Grand

Forks to Bismarck, ND for a kick-off meeting; 4 trips to Watford City, ND associated with well sampling and well drilling, slug testing, and coring; and finally 1 trip to an annual UCG conference possibly in Denver CO.

Fees-Operating Fees & Services-Lab Fees

A budget was allocated water analysis.

Subcontractor

A budget has been allocated for Mohl Drilling to perform the drilling for the project.

Supplies and Materials

Supply and material estimates are based on prior experience and may include chemicals, gases, glassware, pH meters, solvents, hardware, nuts, bolts, piping, orther samling equipment, sensors, or incidental items not listed above. Computer supplies such as data storage, paper, memory, software, and toner cartridges. Minor equipment (less than $5000), Signage, posters for presentations and safety supplies for lab work which may include items such *as* steel toe boots, gloves, hard hats, and coveralls, etc. This category may also include organizational materials, books, subscriptions, and reference materials. Communication and postage is also included under this category and may include stamps or freight for project related items, teleconference fees and long distance charges. General purpose office supplies (pencils, pens, paper clips, stapes, and post-it notes, etc.) may also be included under this category.

Other

A budget has been allocated for food and beverage for business meetings.

Major Equipment >$5000

A budget for a submersible pump has been allocated, needed for testing.

Indirect Costs

The indirect cost rate of 38% included in this proposal is the federally approved rate for the University of North Dakota. Indirect costs are calculated based on the Modified Total Direct Costs (MTDC), defined as the Total Direct Costs of the project less individual items of equipment greater than $5000 and subcontracts in excess of the first $25,000 for each award.

Appendix 5: Letter of Support on Matching Fund

Great Northern Properties Limited Partnership
601 Jefferson Street, Suite 3600 • Houston, TX 77002
(713) 751-7500 • Fax (713) 751-7591

Charles H. Kerr
President & CEO

ckerr@gnplp.com
Direct: (713) 751-7590

September 30, 2013

Dr. Steven A. Benson, Director
Institute for Energy Studies
College of Engineering and Mines
University of North Dakota
Upson II Room 366
241 Centennial Drive Stop 8153
Grand Forks, ND 58202

Re: Support of the proposal entitled "Continuation Study of Underground Coal Gasification (UCG) in Western North Dakota"

Dear Dr. Benson:

Great Northern Properties Limited Partnership ("GNP") is pleased to support the continuation proposal from the University of North Dakota ("UND") that examines the technical feasibility of using the deep Harmon lignite-bearing formation as a site for underground coal gasification. The first phase of testing has provided initial information on the hydrogeology, geo-mechanics and lignite reactivity that indicates a high potential for the clean and efficient utilization of deep lignite seams by underground gasification. The proposed continuation project will provide important information that is complementary to the current UCG project being completed. We understand that the plan is to drill two wells to measure the hydraulic conductivity of the target coal beds, obtain stratigraphic information and baseline groundwater quality, recover additional lignite cores for property analysis and gasification testing, and obtain cores from surrounding strata for geomechanical testing. GNP is especially interested in the proposed efforts to perform an initial feasibility analysis of the conversion of lignite UCG syngas to liquids based on technologies being utilized in the Juniper GTL project in Louisiana.

GNP has a very strong interest in supporting the research and development efforts associated with the use of underground coal gasification since it has the potential to recover gas resources from unmineable coal seams to product liquid fuels. GNP is pleased to provide a total of $90,000 cash cost-share for the 18 month project and $270,000 in kind support to assess the feasibility of integrating the lignite UCG with a of the gas-to-liquids facility to produce chemicals and liquid fuels. This is subject to project award by the North Dakota Industrial Commission.

If you have questions and require additional information please contact me at your convenience.

Sincerely,

Charles H. Kerr

Great Northern Properties Limited Partnership

601 Jefferson Street, Suite 3600 • Houston, TX 77002
(713) 751-7500 • Fax (713) 751-7591

Charles H. Kerr
President & CEO

ckerr@gnplp.com
Direct: (713) 751-7590

October 17, 2013

Dr. Steven A. Benson, Director
Institute for Energy Studies
College of Engineering and Mines
University of North Dakota
Upson II Room 366
241 Centennial Drive Stop 8153
Grand Forks, ND 58202

Re: Support of the proposal entitled "Continuation Study of Underground Coal Gasification (UCG) in Western North Dakota"

Dear Dr. Benson:

Great Northern Properties Limited Partnership ("GNP") is pleased to support the continuation proposal from the University of North Dakota ("UND") that examines the technical feasibility of using the deep Harmon lignite-bearing formation as a site for underground coal gasification. The first phase of testing has provided initial information on the hydrogeology, geo-mechanics and lignite reactivity that indicates a high potential for the clean and efficient utilization of deep lignite seams by underground gasification. The proposed continuation project will provide important information that is complementary to the current UCG project being completed. We understand that the plan is to drill two wells to measure the hydraulic conductivity of the target coal beds, obtain stratigraphic information and baseline groundwater quality, recover additional lignite cores for property analysis and gasification testing, and obtain cores from surrounding strata for geomechanical testing. GNP is especially interested in the proposed efforts to perform an initial feasibility analysis of the conversion of lignite UCG syngas to liquids based on technologies being utilized in the Juniper GTL project in Louisiana.

GNP has a very strong interest in supporting the research and development efforts associated with the use of underground coal gasification since it has the potential to recover gas resources from unmineable coal seams to product liquid fuels. GNP is pleased to provide a total of $150,000 cash cost-share for the 18 month project and $270,000 in kind support to assess the feasibility of integrating the lignite UCG derived syn-gas with a gas-to-liquids facility to produce chemicals and liquid fuels. This is subject to project award by the North Dakota Industrial Commission.

If you have questions and require additional information please contact me at your convenience.

Sincerely,

Charles H. Kerr