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April 30, 2014

Ms. Karlene Fine
Executive Director
North Dakota Industrial Commission
State Capitol – Fourteenth Floor
600 East Boulevard Avenue
Bismarck, ND 58505

Dear Ms. Fine:

Subject: University of North Dakota proposal entitled "Distributed Geothermal Power"

Enclosed please find two copies of the subject proposal entitled "Distributed Geothermal Power" which is being submitted to the NDIC Renewable Energy Council. This proposed work will result in the demonstration of technology that can produce renewable geothermal energy using heat that is currently being wasted in the Bakken Oil fields. Our partners for this effort include Access Energy, Continental Resources, and the US Department of Energy. Enclosed is the $100 application fee.

If you have any questions, please contact me by telephone at (701) 777- 3852 or by e-mail at michael.mann@engr.und.edu.

Sincerely,

Michael D. Mann
Executive Director
Institute for Energy Studies

Barry Milavetz
Associate Vice President for Research &
Economic Development

Renewable Energy Program

North Dakota Industrial Commission

Application

Project Title: Distributed Geothermal Power

Applicant: University of North Dakota

Principal Investigator: Michael Mann

Date of Application: April 30, 2014

Amount of Request: $100,230

Total Amount of Proposed Project: $200,835

Duration of Project: 2 years

Point of Contact (POC): Michael Mann

POC Telephone: 701-777-3852

POC Email: michael.mann@engr.und.edu

POC Address: Upson II, Rm 165
243 Centennial Drive, Stop 8155
Grand Forks, ND 58202-8155

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ABSTRACT

Objective:

The primary objective for this project is to demonstrate the technical and economic feasibility of electrical power generation using the heat contained in oil field fluids. The long-range goal is to encourage development of distributed geothermal power systems in producing oil fields with private sector companies operating the power plants in cooperation with oil industry partners. Two high-efficiency ORC engines will convert heat extracted from a co-produced water stream to 250 kW of electricity which will be used on site by Continental Resources, Inc. The project, which is partially funded by the Department of Energy and by the UND Petroleum Research Education and Entrepreneurship Center (PREEC), is a collaborative effort with Continental Resources, Inc., and Access Energy LLC. The ORC system has been designed, optimized and built. This is a proposal for funds to assist installation and performance monitoring of a geothermal power demonstration plant at a Continental Resources, Inc. water supply well site in Bowman County, ND. The commissioning date is tentatively scheduled for July, 2014, and we plan to invite a number of dignitaries for the ribbon cutting ceremony including: the

Governor, the North Dakota Congressional delegation, North Dakota Department of Commerce, electric power representatives and Department of Energy officials.

Expected Results:

Successful operation of the demonstration plant for a period of two years will achieve our goal of demonstrating the capability of binary ORC technology to generate electricity economically and as a base load power source. The demonstration would lead to progress on the long-term goal of stimulating development of distributed geothermal power systems. Our analysis of the geothermal potential for the Williston Basin is that a distributed network of binary ORC power plants could generate approximately 2,900 MW at a levelized cost of electricity of $0.05 per KWh. Production of the 2,900 MW by geothermal power would avoid generation of approximately 10 million metric tons of CO_2 that would be generated by burning lignite. On a different scale, operation of the demonstration plant for two years would displace approximately 4,380 metric tons of CO^2 that would be generated by burning lignite.

Duration:

The project will run for two years after startup.

Total Project Cost:

The total project cost which began in 2010 is $3,758,195. Fifty percent of the original funding was received from the Department of Energy. The remainder of the funding was supplied by Access Energy and UND. The amount requested from the Renewable Energy Council to complete the installation and capture the key performance data is $95,417 which will be equally matched with new money.

Participants:

University of North Dakota
Access Energy
Continental Resources

PROJECT DESCRIPTION

Objectives:

The primary objective of this project is to demonstrate the technical and economic feasibility of generating electricity from non-conventional low temperature (150° to 300°F) geothermal resources using binary ORC technology. Historically, these applications have not been economically viable primarily because of the low price received for electricity generated and the lack of commercially available electric generating equipment. A second objective is to demonstrate that the technology can be replicated within a wider range of physical parameters including geothermal fluid temperatures, flow rates, and the price of electricity sales. Our proposed application at the Davis site provides us the opportunity to test the ORC technology under various operating conditions found in lower temperature geothermal resources and apply the results to other applications. A third objective is to widely disseminate the results of this study. If the U.S. is to broadly accept and adopt geothermal technology, success stories and guidelines for developing viable projects are a necessity. In addition, the development of a skilled work force will be needed.

The University of North Dakota and its partners, Continental Resources Inc. (CRI), Access Energy, and the North Dakota Geological Survey (NDGS), propose to accomplish these objectives by generating a continuous 250 kW of electricity from non-conventional low temperature (T~210 ºF) geothermal water using binary organic Rankine cycle technology with air as the condensing medium. We propose to install an ORC electric power generating unit at a CRI water-flood site near Marmath, North Dakota. The project will develop and disseminate a model that can be used to facilitate the installation of similar ORC systems in other oil and gas settings.

Funding from this request will be used to install and monitor the operation of two Access Energy 125 kW ORC engines at the Davis site operated by Continental resources.

Methodology:

The geothermal system has been designed and built through the combined efforts of UND and Access Energy. A summary of this work is presented in the background section. For the phase of work proposed here, the ORC system will be delivered and installed. The project team including representatives from CRI, Access Energy, and UND, will meet to review the startup and operational procedures and develop a set of standard operating procedures (SOP). The primary team will be present and use these procedures to commission the equipment. Commissioning will be considered successful when all components meet design specifications and guarantees. A primary deliverable from this test is a working ORC system.

The ORC system is designed to operate 24 hours a day, 7 days a week. The ORC system will be equipped to allow off-site monitoring of all major functions of the equipment. Remote access will be granted to CRI, UND and Access Energy. CRI's on-site personnel will provide periodic monitoring/visual inspection of the ORC system. Data will be collected and analyzed to allow site-specific information to be extracted and used in replication of the ORC system. The project will run for two years after startup and will feature continual monitoring of all essential systems:

- geothermal fluid flow (kg s^{-1})
- geothermal fluid temperature (°C)
- geothermal fluid temperature drop in the heat exchanger (°C)
- quantity of heat extracted
- temperature of the working fluid (°C)
- temperature of the vapor (°C)
- ambient air temperature (°C) and relative humidity (%)
- temperature of the condensed working fluid (°C)
- electrical power generated (kWh)
- electrical power time series (kW s^{-1})
- system efficiency (%)
- Routine maintenance visits / and duration /
- Parts and supplies needed routine replacement / and typical annual cost
- Level of supervision required (number of hours per month Continental personnel have had to look at it and respond)
- Annual down time
- Capacity factor (the total annual electricity produced divided by the name plate capacity) [this would take into account season variability, down time for maintenance, process upsets cause by the well side, etc.)

A detailed record of routine/preventive maintenance as well as unscheduled maintenance will be kept along with length of outages and cost of repairs. This data will be used to help develop availability and reliability curves and system operating costs; to detail fault codes and develop trouble shooting procedures; and to identify ways to prevent failures in the future. While it is expected that system data will be monitored and collected for the life of the system (estimated to be 20 years or greater), under this project, the primary deliverable will be reported data for a period of two years.

Dissemination of the results of this demonstration project is critical. Future development of the resource will require substantial commitment by the public sector. Consequently, making the results of the project available for all potential developers in the electrical power, petroleum, and geothermal industries and for local, state, and federal regulatory agencies will be a key element of this objective. A report detailing the economic and technical performance and the operational characteristics of the geothermal ORC system will be prepared. This report will include all technical and economic assumptions used. A sensitivity analysis will be performed for those variables that are thought to be site specific to better characterize the technical and economic risk. The report will document the lessons learned during this project with a level of detail to allow this project team and other geothermal ORC system developers to determine the potential for replicating this project at other sites. In addition, dissemination of information on the project will employ press releases, presentations at local and state Chambers of Commerce, publication in the electrical power, petroleum, and geothermal literature, and presentations at national and regional meetings.

Anticipated Results:

The primary result from this project is anticipated to be a working ORC engine that is producing electricity at a cost that will make the ORC an economic option for generating renewable electricity to meet the growing electricity demands of the oil fields in Western North Dakota. The more important

long-term result will be the duplication of this site at many other locations throughout the Williston Basin.

Facilities:

Access Energy has a package system that has been engineered and redesigned specifically to optimize it for the low temperature conditions typical of the co-produced and water flood in Western North Dakota - 180º to 240ºF. The power output is designed to put on the local grid at 480V at 50hz or 60Hz. Their system is totally self-contained, including the air-cooled condensing system, and housed in a standard 40-foot ISO container (see figure 1), and therefore does not require a building. The system can be set on a gravel foundation, and does not require a concrete slab. The only on-site preparation required is to provide piping of the hot geothermal resource to and from the system. Essentially, the only site requirement for the system is hot water at a specified minimum pressure. This greatly minimizes the on-site preparation and cost, and is a distinct advantage of the Access Energy system.

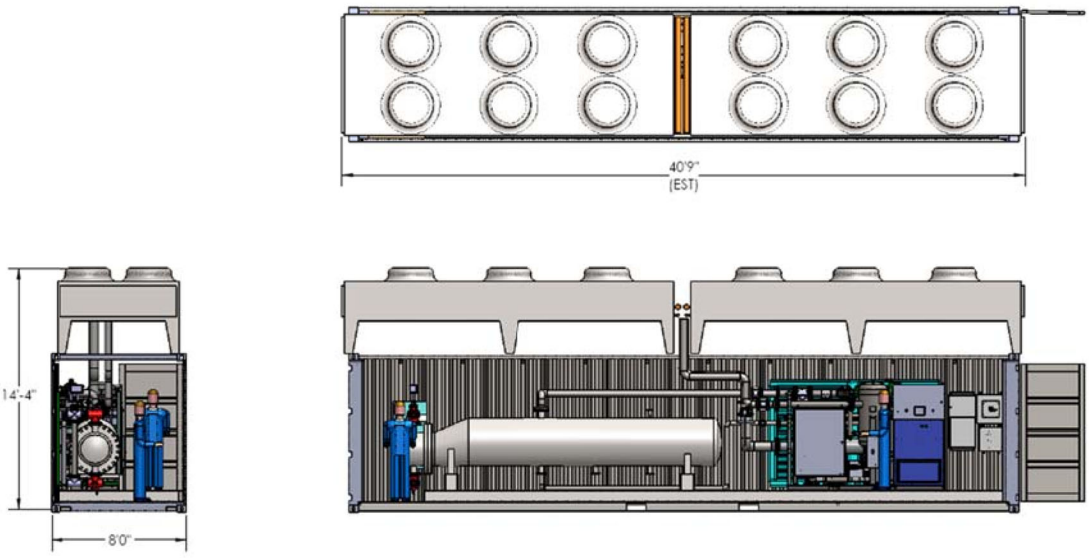

Figure 1. Schematic of the Access Energy geothermal system

Other salient features of the Access Energy system include easy to clean shell-and-tube heat exchangers. They are designed to be cleaned either physically or chemically, and will allow flexibility to

use a range of water quality from the geothermal resource. The system is also designed with warning systems and control schemes will allow the system to be brought off line without interfering with the production of oil. The system is expected to have 25 year minimum life with minor service required every 3 to 5 years.

The system design is optimized using 134a as the working fluid at the low temperatures and for this project, hence the system will not go sub atmospheric at any of the expected operating temperatures. The system is designed with a variable hot water flow and a variable speed turbine which allows the system to generate either near constant electrical output year round (i.e. minimizes reduction of power in the summer due to the high ambient air temperature) or can deliver more than the specified output during the low ambient temperature winter months.

Resources:

The project team and the resources committed to this effort are outlined below. Each of the three primary project partners has already shown support to the project by their significant contributions to the cost share requirements for the original DOE funded project ($1,733,861 from DOE, $1,000,000 from Access Energy, and $733,861 from UND).

Continental Resources, Inc. will provide the site to support the proposed project. This commitment will include using their personnel to assist in the day-to-day site-specific activities required to facilitate design and installation of the plant. CRI will also provide the operation support for the project once it becomes fully operational.

The *University of North Dakota* will provide the technical knowledge to support the proposed work. A team headed by a geophysicist, an energy/chemical engineer, and an electrical engineer will take the lead on the project design and management. The Petroleum Research, Education and Entrepreneurship Center (PREEC) team at UND has access to a wide array of resources including students from a wide range of disciplines, and access to the UND's Center of Innovation (COI).

Access Energy is a developer of renewable energy systems. They provide access to an experienced project development team and capital. They provide the experience needed to make the proposed effort a commercialization project, rather than a research project. With experience in a wide range of activities from obtaining electrical interconnection access, negotiating a purchase power agreement, providing management and engineering support, to raising project capital; Access Energy fills a critical need to fully develop this project.

The *North Dakota Geological Survey* has also agreed to participate as a part of the project team. As a state entity, their efforts in support of the project have the goal of increasing economic development within the state. They will provide access to all records of oil, gas, and other wells that have potential to produce geothermal energy, and will play an integral role in the characterization and dissemination of the available geothermal resources where this concept can be replicated.

Techniques to Be Used, Their Availability and Capability:

UND has been working with its team from Access Energy and CRI to ensure a successful installation of the system can be accomplished on the CRI Davis site. The project team will utilize contractors currently working with CRI to minimize logistical issues related to providing access to the CRI site, liability, permitting, and other related issues. With regard to analysis of the system performance, data will be continuously monitored and supplied to UND and Access Energy for analysis. The DOE CREST model is one tool that will be used to calculate the levelized cost of electricity and generate 20 year cash flow projections. The team will also use standard engineering analysis to evaluate and report the technical and economic performance of the system.

Environmental and Economic Impacts while Project is Underway:

The primary purpose of the project is to promote the long-term implementation of geothermal energy in the western part of the state. The economic benefits while the project is underway are minimal, and consist primarily of the electricity generated from the geothermal plant. The economic

benefits to be realized are long-term. Operation of the demonstration plant for two years would displace approximately 4,380 metric tons of CO^2 that would be generated by burning lignite.

Ultimate Technological and Economic Impacts:

Successful operation of the demonstration plant for a period of two years will achieve our goal of demonstrating the capability of binary ORC technology to generate electricity economically and as a base load power source. A successful demonstration will lead to progress on the long-term goal of stimulating development of distributed geothermal power systems. The Department of Energy CREST model was used to calculate annual cash flow and other project metrics. This analysis shows a positive cash flow for all years of the project for the base conditions[1]. Our analysis of the geothermal potential for the Williston Basin is that a distributed network of binary ORC power plants could generate approximately 2,900 MW at a levelized cost of electricity of $0.05 per KWh. Production of the 2,900 MW by geothermal power would avoid generation of approximately 10 million metric tons of CO_2 that would be generated by burning lignite.

Why the Project is Needed:

As the development of the oil fields in the Williston Basin continues, there will be an increasing demand for power. This demand could be met with additional fossil-based generation, but would result in increased CO_2 emissions. This would also require building of significant transmission infrastructure which would be abandoned in place at the end of the well life. Another option is the use of diesel gen-sets, which will require transport of diesel to the sites. Extraction of the geothermal heat will not require the transport of fuel to the site and eliminate the need for costly transmission infrastructure. In addition, at the end of the well life, the ORC systems can be moved to another site if there is still useful

[1] Based conditions: 50:50 debt:equity; 7% interest on debt; 12% after tax IRR; 35% federal tax rate; 6.5% state tax rate; 25 yr project life; 95% C.F.; no ITC; 50% bonus depreciation in year 1; 5 yr MACRS depreciation for the power plant and 15 yr MACRS depreciation for the interconnect. There was no cost assigned to completing the wells since for this type of installation, the wells will be in place and no well replacement allocated to the projects since the quality of the resource (the water flow rate) will increase over time rather than become depleted as is the case for conventional geothermal systems. The temperature of the water was assumed to remain constant over the life of the project.

life remaining in the unit. The primary need for this project is to provide the technical and economic data required for project developers, oil field operators, electric cooperatives, and others to invest in this technology.

STANDARDS OF SUCCESS

This project will be successful with the operation of a 250 kW geothermal plant located at CRI's Davis site in Bowman county. Success is also measured by the dissemination of results to the broader community with significant detail to allow any entity contemplating the use of the ORC to make a sound technical and economic decision. This technology has the potential to spawn a new geothermal power industry in North Dakota. The demand for electricity will be substantial, and this renewable resource is readily available. The inclusion of Access Energy as a primary partner in this venture indicates the commercial viability of this project. Should this project prove successful, Access Energy and other manufacturers of ORC engines will have commercial products that can be installed. While the manufacturing of these engines will likely take place outside of North Dakota, it is expected that a large service industry will be developed to support the installation, operation, and maintenance of these systems.

BACKGROUND/QUALIFICIATIONS

This project was initially funded by the U.S. Department of Energy. Work to date has progressed through vendor selection, preliminary economic assessment, equipment design and prototype construction. Results are summarized here with details published elsewhere.[2]

Seven ORC vendors were evaluated based upon 29 separate factors considered relevant to overall costs, operation and long-term viability of the project. The DOE CREST model was used to

[2] Barse, K., Mann, M. D., Gosnold, W., Salehfar, H., 2011 AIChE Annual Meeting, "Evaluation Of Organic Rankine Cycle Geothermal Power Plant and Considerations," AIChE, Minneapolis, MN. (November 2011).
Barse, K., Mann, M. D., Gosnold, W., Salehfar, H. 2011 Energy, Utility & Environment Conference, "Feasibility of Geothermal Power from Low Temperature Resources Including the Effect Of Working Fluid on Organic Rankine Cycle Efficiency," Phoenix, AZ. (January 2011).

perform an economic evaluation and cash flow analysis for each system. Based upon these 29 factors, Access Energy was chosen to supply the ORC geothermal system. Access Energy committed to conducting research and development on their machines with the goal of maximizing efficiency and developing a competitive product for oil-field geothermal applications. The Access Energy system planned for operation with the 100 °C water at the CRI site will have an efficiency 15 to 30% more than competing technologies.

The CREST model shows that based upon the equivalent nominal levelized tariff rate, the Access Energy system offers the potential for the lowest rate at 4.45 ¢/kWh. The Access Energy system had the earliest breakeven point. Sensitivity analyses showed that the cost of electricity would vary from 4.45¢/kWh at a capital cost of $3000/kW, but would only increase to 5.65¢/kWh if the capital cost is $4000/kW. Variations in operating costs over this range would have minimal impacts on the cost of electricity, ranging from 4.15 to 4.75 ¢/kWh. Investment Tax Credits have the potential to significantly reduce the levelized cost of electricity, down to 3.65 ¢/kWh at a 15% ITC and 2.85 ¢/kWh at a 30% ITC. The sensitivity analyses showed that the project as proposed represents minimum risk due to variations in capital and operating costs, and has the potential to generate higher returns depending upon the availability of Investment Tax Credits.

The project also investigated a series of interconnect service options that are viable for the proposed system including net metering, standby generation, stand-alone service, standby with stand-alone, and buy back. The electrical interface required to connect the geothermal power plant with utility's electric network has been designed and simulated.[3]

QUALIFICATIONS, CAPABILITIES AND EXPERIENCE

[3] Dahal, S.; Salehfar, H.; Gosnold, W.; Mann, M.; "Modeling and Simulation of the Interface between Geothermal Power Plant Based on Organic Rankine Cycle and the Electric Grid," GRC Ann Mtg. Oct. 2010

The team assembled for this project includes a broad spectrum of talents necessary to address all aspects of the project, including, resource assessment, analysis and design of equipment, long-term operation and maintenance of the facility, and the important component of project development and business planning.

Michael Mann, PhD, Professor of and Chair of the Department of Chemical Engineering and Executive Director of the Institute for Energy Studies has been involved in various aspects of energy production for the past 30 years. His primary expertise is in the development and integration of energy systems. Much of his work has focused on system and life-cycle analysis, including the coupling of thermodynamic and economic modeling as an optimization methodology. He has supervised a number of large research projects, including the design, installation, and operation of a 1 MWth circulating fluidized bed combustor. His role will be to direct the performance of the feasibility study, with a focus on project optimization and replication and will provide the overall project management for the NDIC funded portion of this work.

William Gosnold, PhD, Professor of Geophysics and Chair of the Department of Geology and Geological Engineering and Project PI has been active in exploration for and assessment of low-to-intermediate geothermal resources since 1979. He conducted geothermal resource assessments for the U.S. Department of Energy for Nebraska, North Dakota, and South Dakota, and contributed significantly to the Geothermal Map of North America. From 2001 to 2004, Dr. Gosnold served as Interim Director of Research and Program Development at UND. Dr. Gosnold is currently lead PI of the Petroleum Research, Education, and Entrepreneurship Center at the University of North Dakota. Dr. Gosnold is the primary point of contact with DOE and has been responsible for information dissemination.

Hossein Salehfar, PhD, Professor of Electrical Engineering specializes in electrical power and energy systems, power electronics controls, and electric drives. Dr. Salehfar has over seventeen (17) years of academia and industry experience and has worked with the electric utilities and coal industry. His

research on various power systems and power electronics projects have been funded by the National Science Foundation and the US Department of Energy. Dr. Salehfar will perform the electrical power interconnection design and work with Slope Electric to link the ORC system with the power grid.

MANAGEMENT

Dr. Mann, the UND principal investigator will be responsible for the overall management of the project. He will work directly with a project manager from Access Energy to coordinate the installation and monitoring of the geothermal power plant. The team will follow the detailed task management plan will be developed as a part of the DOE funded portion of this work and used to ensure both the schedule and cost components of the project are met. Meetings will be scheduled on a monthly basis, with additional meetings called as needed to ensure successful installation and operation of the system. Dr. Mann will coordinate any publicity events related to this demonstration project with Ms. Karlene Fine or her designee to ensure the NDIC and the State of North Dakota are properly represented and acknowledged in this high profile venture. Reports and other deliverables will be provided in accordance with the DOE Federal Assistance Reporting Checklist and the NDIC.

TIMETABLE

The primary deliverables for this project will include installation of the geothermal system, quarterly technical and economical updates, and a final report at the end of the two year demonstration period.

System installed and fully operational	August 31, 2014
Quarterly reports	Nov, Feb, May and August
Final project report	August 31, 2016

BUDGET

Project Associated Expense	NDIC's Share	Applicant's Share (Cash)	Applicant's Share (In-Kind)	Other Project Sponsor's Share
Piping, fabrication installation	$75,400	$8,825	0	$66,575
Valves, reliefs, strainer	$15,205	$1,175		$14,030
Contractor Fee			$10,000	
F&A	$9,625			
Total	$100,230	$10,000	$10,000	$80,605

The proposed work will be performed under a subcontract to Access Energy. This arrangement was necessary to allow purchase of the site insurance and project bonding required by CRI. Access Energy will pay all sub-contractors for the site preparation, electrical installation, piping, and other associated costs. The salary of the faculty participants will be paid from non-cost-sharable funding, and is therefore not reflected in this budget. The other cost share represents $80,605 from the US Department of Energy and $10,000 from Access Energy (in-kind). The Department of Energy has already expended over $1.5 million in the development of this technology. Access Energy has committed $1 million, and UND $733 thousand.

CONFIDENTIAL INFORMATION

None

PATENTS/RIGHTS TO TECHNICAL DATA

None

April 30, 2014

Michael Mann, PhD
Distinguished Professor, Chemical Engineering
Executive Director, Institute for Energy Studies
University of North Dakota
Harrington Hall, Room 323
241 Centennial Drive, Stop 7101
Grand Forks, ND 58202-7101

RE: Proposal: North Dakota Industrial Commission: Distributed Geothermal Power

Dear Dr. Mann,

This letter of support is with regards to the proposal prepared by the University of North Dakota's Institute for Energy Studies for submission to the North Dakota Industrial Commission to help support the installation and monitoring of the geothermal plant in Bowman County, North Dakota. If UND is successful with their grant application, Access Energy will provide in-kind consultation for our role in monitoring the system performance. We will commit to providing consultation time with a billable value of $10,000. This may also include funds spent on travel related to the project.

If you have any questions or comments, please feel free to contact Dennis Strouse at (925) 683-8746 or dstrouse@calnetix.com.

Sincerely

Dennis Strouse
Chief Operating Officer
Calnetix Technologies