Contract No. R-021-030
"Distributed Geothermal Power"
Submitted by University of North Dakota
Principal Investigator: Dr. Michael Mann

PARTICIPANTS

Sponsor	**Cost Share**
U.S. Department of Energy	$97,000* (cash)
Access Energy	$109,000* (in-kind)
University of North Dakota	~~$10,000*~~
Basin Electric Power Cooperative	$55,000* (cash)
Subtotal Cash Cost Share	$261,000
North Dakota Industrial Commission	$261,000*
Subtotal Renewable Energy Program	$261,000
Total Project Cost	$522,000*

Project Schedule – 24 months
Contract Date – October 13, 2014
Amendment Date - April 27, 2015
Start Date – October 1, 2014
Completion Date – September 30, 2016

Project Deliverables:
Status Report: December 31, 2014 ✓
Status Report: March 31, 2015 ✓
Status Report: June 30, 2015 ✓
Status Report: September 30, 2015 ✓
Status Report: December 31, 2015 ✓
Status Report: March 31, 2016 ✓
Status Report: June 30, 2016 ✓
Final Report: April 15, 2017* ✓

OBJECTIVE/STATEMENT OF WORK:
The primary objective of this project is to demonstrate the technical and economic feasibility of electrical power generation using the heat contained in oil field fluids. A geothermal system that has been designed and built through the combined efforts of UND & Access Energy will be installed at a Continental Resources, Inc. water supply well site near Marmarth. The system will generate a continuous 250 kW of electricity from non-conventional low temperature geothermal water. This is the final stage of a multi-phase project that began in 2010 and will have a total cost of over $3.4 million. If successful, this project could help meet growing demands for electricity in the Bakken without requiring transmission infrastructure as well as help establish utilization of geothermal energy in the State.

STATUS:
The contract was signed on October 13, 2014 authorizing funding of $100,230. An amendment was signed on April 27, 2015 increasing the funding for this project to $261,000. The additional funding was contingent upon confirmation that the applicant had received a "not to exceed" bid or a "fixed" bid for the work that is to be completed by the subcontractors and that copies of the bids are provided to the Industrial Commission.

December 31, 2014 Status Report received. It states in part:

The UND team has been working with Access Energy for four years under a contract with the US Department of Energy to design and construct the geothermal power plant that will be installed on a

Continental Resources site near Rhame, ND. Quarterly reports will reflect work that is being completed under the existing DOE contract in addition to the new work (system installation and data collection) that will occur under Contract No. R-021-030.

The UND team worked with Access Energy to finalize the design requirements for the data collection system. The base design that was proposed under the DOE was not set up to monitor and report all of the data that will be required to meet the specifications of the new award.

Access Energy continued construction of the system, with the goal of completing construction by March, 2015.

Due to a restructure at Access Energy, they will no longer serve as the overall project manager and have relinquished that role to UND. In working with the contractors who will be responsible for the installation, it was realized that the project is underfunded. UND will need to raise additional funding to allow the project to move forward.

March 31, 2015 Status Report received. It states in part:

Construction of the system has been completed. Schematic drawings are attached. (see report posted on website)

UND secured additional partners to help cover the costs of the system installation. A request will be submitted to the ND Department of Commerce to match this additional funding to provide the funding that is required to complete the project.

June 30, 2015 Status Report received. It states in part:

Access Energy has tested the system components at the factory. All systems have passed inspection. The system is being packaged for shipment. Access Energy and Olson Construction are coordinating schedules to ensure a crane is available to off-load the equipment once it arrives on site and that the system components are not sitting exposed to the elements as they await installation. The photos below (available on the website) show the containerized ORC engine and the system with the condenser installed.

Contracts have been put in place with Olson Construction for the installation of the system. These contracts are "not to exceed" as required by the terms of UND's contract with the NDIC.

September 30, 2015 Status Report received. It states in part:

Construction of the ORC system at Access Energy was completed. System checks were performed to verify system operations. The ORC was disassembled and shipped to the site. Olson Construction completed all of the site preparation work, received the ORC, and has begun assembly. The anticipated completion date for assembly of the ORC at the Continental site is November 1, 2015.

One issue that came up during the site preparation work was Continental Resources' desire for a separate cistern for the collection of water from the ORC in the event of a system shutdown. A cistern with the volume to handle at least two times the system volume was requested. A design was completed, added to the work scope of Olson Construction, and installation has been completed. This delayed the project and pushed the start-up date into November.

March 31, 2016 Status Report received. It states in part:

Due to the cold weather, there were no activities on the site during this reporting period.

June 30, 2016 Status Report received. It states in part:

Access Energy was on-site for commissioning and start-up of the units. While the units were brought up briefly, there were a number of issues identified that required corrective actions. Access Energy worked with personnel at Continental Resources to identify the main issues and order and install the inoperative parts. One of the parts required a 6 week lead time, which will push back the potential repair and startup until later in the summer.

The Geothermal Energy Association awarded The University of North Dakota/U.S. Department of Energy the 2016 Technology Advancement Award for launching the first commercial project coproducing geothermal power from an oil and gas well. The site was recognized as the first demonstration site to use low-temperature water produced in conjunction with oil extraction. The U.S. Department of Energy estimates that "25 billion barrels of hot water are produced annually from oil and gas wells in the United States." The award was presented at the June 2016 Baseload Renewable Energy Summit.

January 3, 2017. A request was made and granted for a no-cost extension to submit the final report on April 15, 2017. This would allow time for the University of North Dakota to include information in the final report on some potential paths forward for the technology developed through this project.

April 12, 2017. The final report was submitted. The report has been posted on the Renewable Energy Program website. The Executive Summary from that report states:

The UND-CLR Binary Geothermal Power Plant was a collaborative effort of the U.S. Department of Energy (DOE), Continental Resources, Inc. (CRL), Slope Electric Cooperative (SEC), Access Energy, LLC (AE), Basin Electric Cooperative (BEC), Olson Construction, the North Dakota Industrial Commission Renewable Energy Council (NDIC-REC), the North Dakota Department of Commerce Centers of Excellence Program (NDDC-COE), and the University of North Dakota (UND). The primary objective of project was to demonstrate/test the technical and economic feasibility of generating electricity from non-conventional, low-temperature (90 ºC to 150 °C) geothermal resources using binary technology. CLR provided the access to 98 ºC water flowing at 51 l s-1 at the Davis Water Injection Plan in Bowman County, ND. Funding for the project was from DOE –GTO, NDIC-REC, NDD-COE, and BEC. Logistics, on-site construction, and power grid access were facilitated by Slope Electric Cooperative and Olson Construction. Access Energy supplied prototype organic Rankine Cycle engines for the project.

The potential power output from this project is 250 kW at a cost of $3,400 per kW. A key factor in the economics of this project is a significant advance in binary power technology by Access Energy, LLC. Other commercially available ORC engines have efficiencies 8 to 10 percent and produce 50 to 250 kW per unit. The AE ORC units are designed to generate 125 kW with efficiencies up to 14 percent and they can be installed in arrays of tens of units to produce several MW of power where geothermal waters are available. This demonstration project is small but the potential for large-scale development in deeper, hotter formations is promising. The UND team's analysis of the entire Williston Basin using data on porosity, formation thicknesses, and fluid temperatures reveals that 4.0×10^{19} Joules of energy is available and that 1.36×10^{9} MWh of power could be produced using ORC binary power plants.

Much of the infrastructure necessary to develop extensive geothermal power in the Williston Basin exists as abandoned oil and gas wells. Re-completing wells for water production could provide local power throughout the basin thus reducing power loss through transmission over long distances. Water production in normal oil and gas operations is relatively low by design, but it could be one to two orders of magnitude greater in wells completed and pumped for water production. A promising method for

geothermal power production recognized in this project is drilling horizontal open-hole wells in the permeable carbonate aquifers. Horizontal drilling in the aquifers increases borehole exposure to the resource and consequently increases the capacity for fluid production by up to an order of magnitude.

Lessons Learned

1. Determine target formations. Data from oil and gas operators, state oil and gas regulatory agencies, and state geological surveys help to identify producing formations and their properties.
2. Determine the quantity of energy available in the target formations.
   a. A complete thermal analysis of the basin or region yields the most useful information.
   b. Critical data include bottom-hole temperatures, heat flow, stratigraphy, lithology, lithological properties, thermal conductivity, and subsurface structure.
3. Determine the potential for fluid production.
   a. State oil and gas regulatory agencies and state geological surveys have data on oil, gas, and water production. State water commission/agencies have data on water quality, aquifers, and regulations.
   b. Consider single horizontal wells, multiple conventional wells, and unitized fields.
4. Calculate energy production capacity of each formation based on different well combinations and power-plant scenarios. This is a broad overview rather than a site-specific analysis.
5. Research and understand the local electrical power industry. Obtain the PPA before committing to the project.
6. Work with the high-level personnel in the oil company partner. Obtain a memorandum of understanding that addresses all issues in the project, including what to expect if the company goes out of business or changes management.
7. Be prepared for project delay

This project is now complete and the contract has been closed.

Updated 7/21/2017