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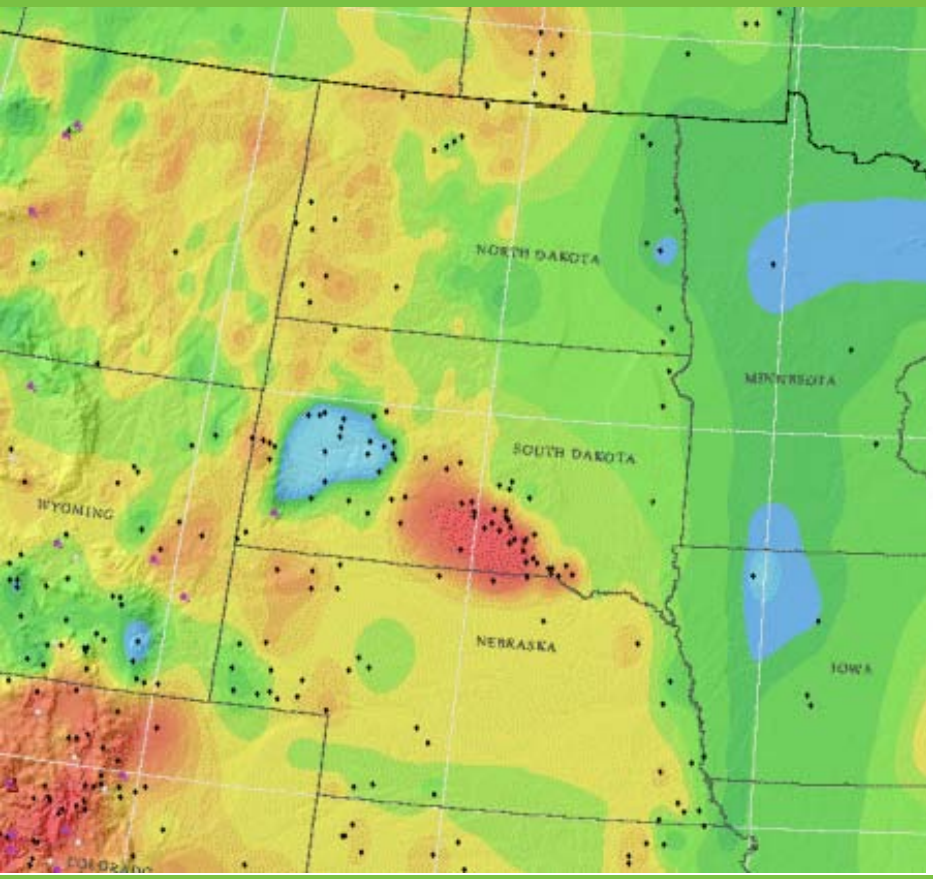

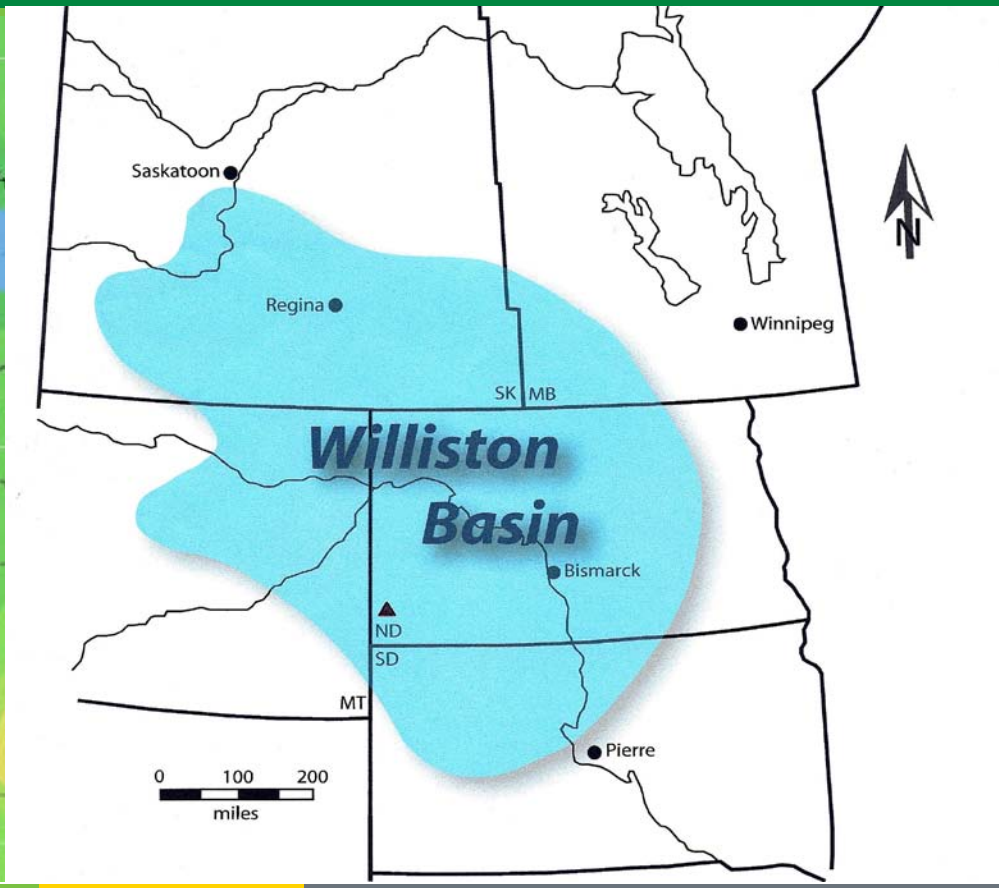

Electric Power Generation from Coproduced Fluids from Oil and Gas Wells

May 19, 2010

Principal Investigator
Will Gosnold
University of North Dakota

Low Temperature Demonstration Projects

Electric Power Generation from Coproduced Fluids from Oil and Gas Wells

- **Timeline**
  - Start date: 1/29/2010
  - End date: 1/31/2013
  - Percent complete: ~ 5%
- **Budget**
  - Total project funding: $3,467, 057
  - DOE share: $1,733,529
  - Awardee share: $1,733,529
  - Funding received in FY09: $0
  - Funding for FY10: $1,382,014
- **Barriers:** Electrical Interconnect – Price of Power
- **Partners:**
  - Petroleum Industry – CRI, DRI
  - Berrendo Wind Energy
  - North Dakota Geological Survey
  - North Dakota Dept of Commerce CoE Program

Project Timeline

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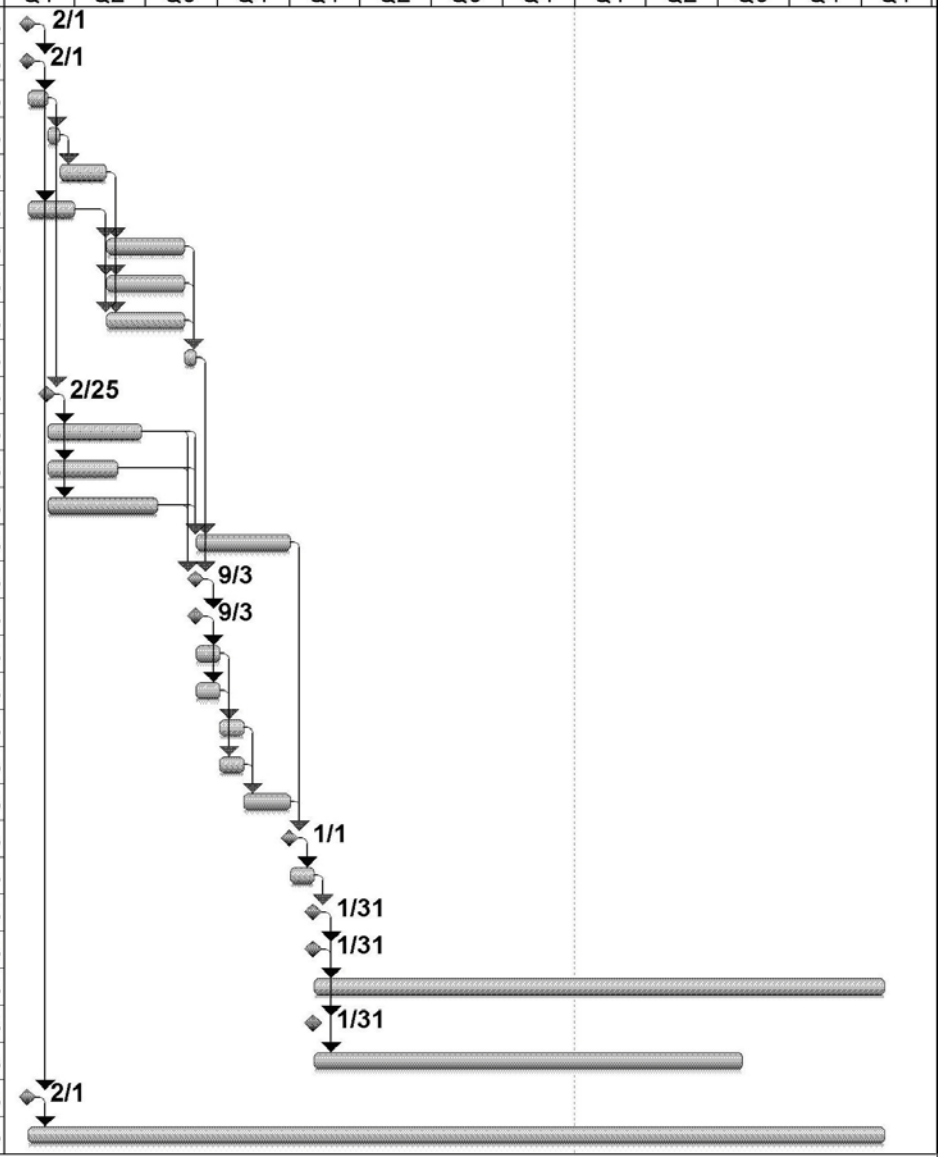
Task Name	Duration
Phase A1 - Feasilibity Study and Engineering Design	0 days
Task 1.0 - System Design and Project Feasibility	0 days
Site Assessment	25 days
Prepare Bid Package	15 days
ORC Manufacturer Bids	60 days
Electrical Interconnection Options	60 days
Preliminary Design	100 days
Replication and Optimization	100 days
Business Model	100 days
Go or No Go Milestone	15 days
Task 2.0 - Regulatory and Environmental Permitting	0 days
Development Agreement	120 days
Regulatory Permits (Identify and Submit)	90 days
Interconnection Requests	140 days
Power Purchase Agreement	120 days
Phase A2 - Procurement, Installation, and Commissioning	0 days
Task 3.0 - Procurement and Installation	0 days
Final Design	30 days
Bidding of Major Equipment	30 days
Bidding of Contractors	30 days
Construction Permits	30 days
Construction	60 days
Task 4.0 - System Commissioning	0 days
Commissioning	30 days
Phase A3 - Operation and Maintenance	0 days
Task 5.0 - General Operation and Systems Analysis	0 days
General Operation and Systems Analysis	730 days
Task 6.0 - System Validation	0 days
System Validation	548 days
Task 7.0 - Project Management and Reporting	0 days
Project Management and Reporting	1095 days



Relevance/Impact of Research

- **Project 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 ºF) geothermal resources in oil and gas settings.

- Evaluate the power production potential of different commercial power conversion systems: Organic Rankine Cycle, Kalina Cycle, Thermal Hydraulic Engine
- Develop economic models for long-term operation of the optimum system
- Establish an LLC for commercial operation at the end of the two-year demonstration phase.
- Develop contractual relationships between oilfield operators, geothermal owners, and investors in Cedar Creek Geothermal LLC

- **Project Objectives**

– 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 site provides an excellent opportunity to test geothermal power technology under various operating conditions found in low-temperature geothermal resources and in the widely varying continental climate setting of North Dakota.

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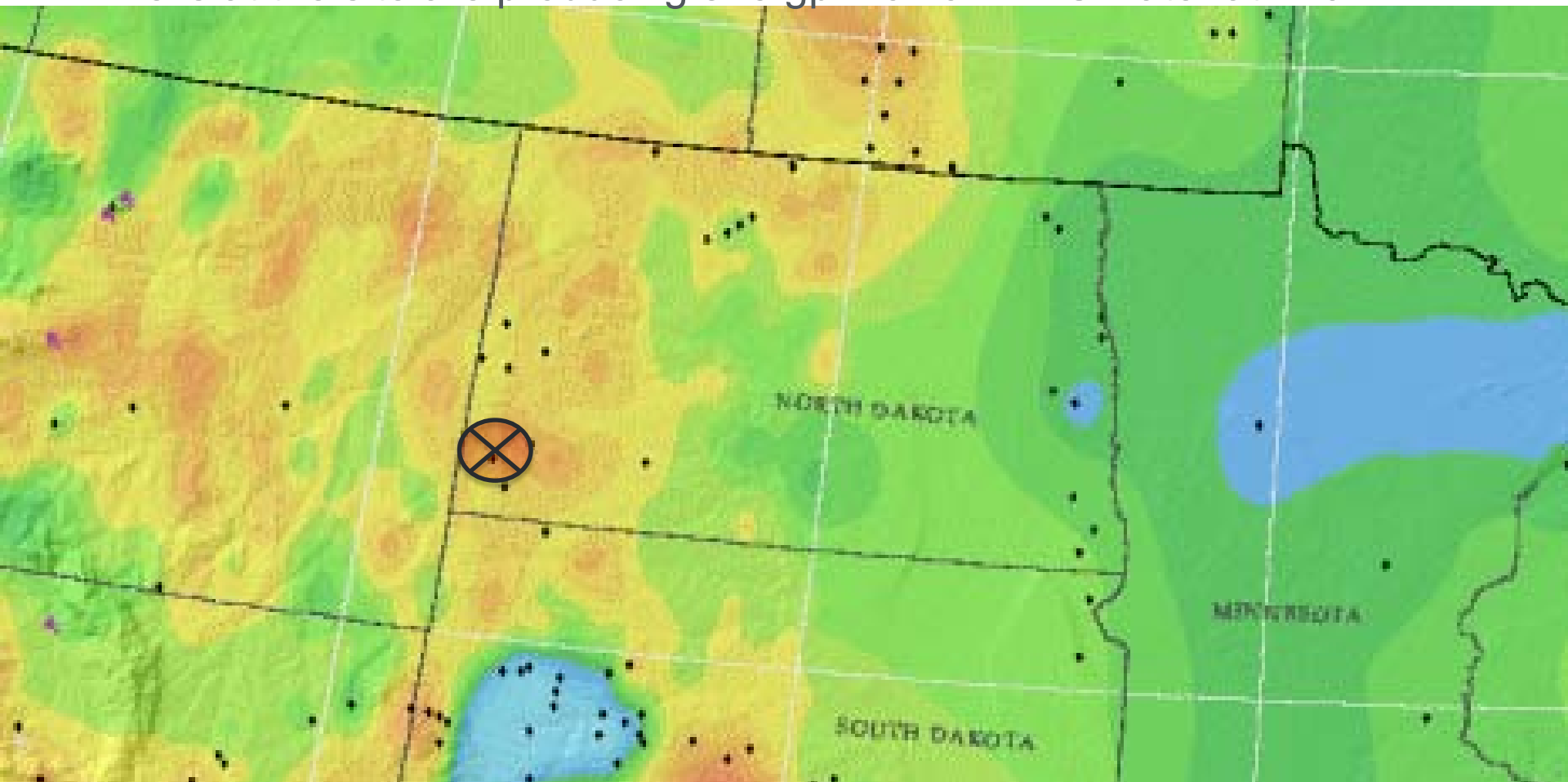
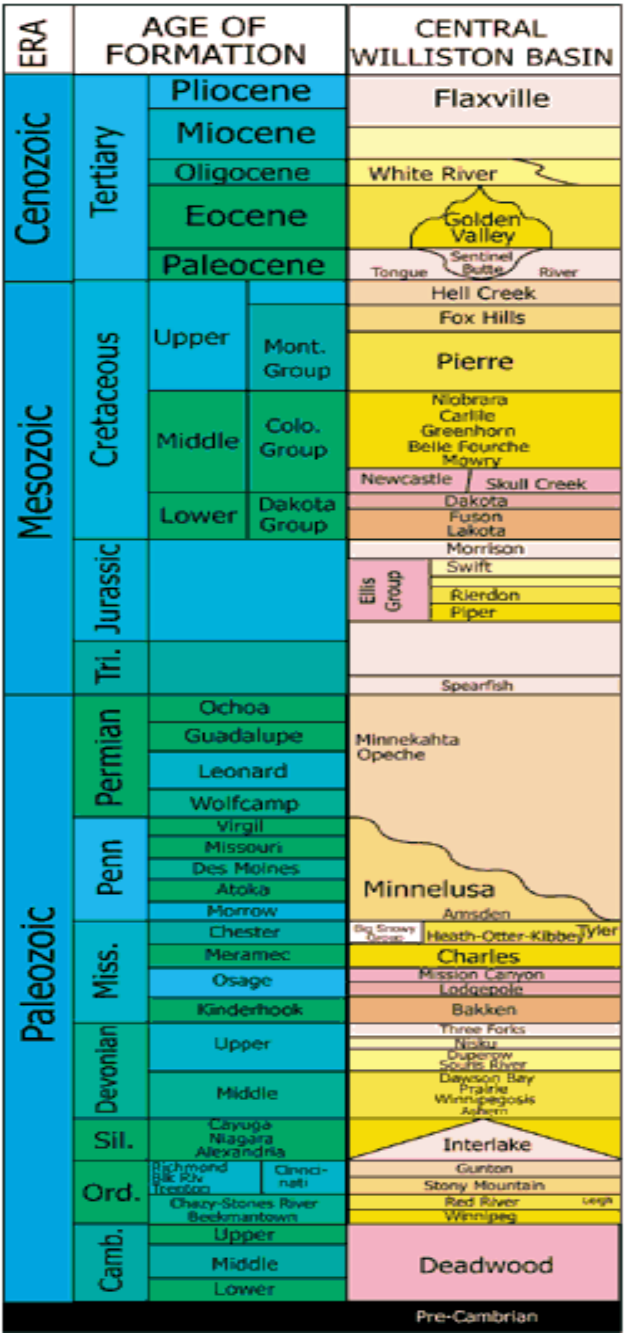
- **Project Objectives**

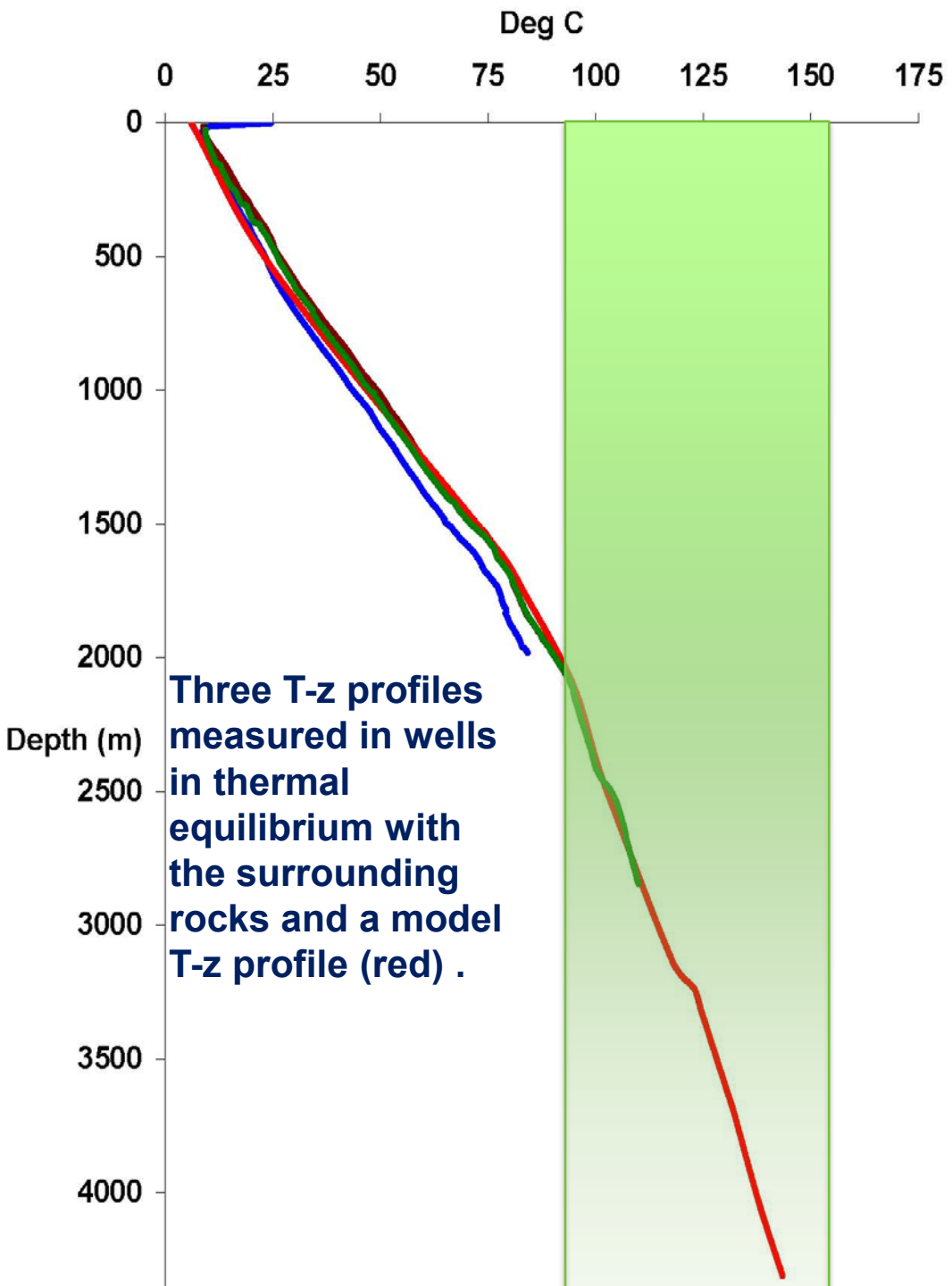
- A third objective is to widely disseminate the results of this study.
  - If the U.S. is to broadly accept and adopt geothermal technology, success stories and guidelines for developing viable projects are a necessity.
  - Development of a skilled work force for this industry will be needed, and therefore facilitating entrepreneurship in development of oil field geothermal resources and training engineers in geothermal energy are included as objectives for this project.

Scientific/Technical Approach

The geothermal power system will be installed at an oil field in western North Dakota where geothermal fluids at 100 ºC (210 ºF) occur in sedimentary formations at depths of 3 km (10,000 ft). Wells at the site are producing 875 gpm of low TDS water at 210 ºF.







Three T-z profiles measured in wells in thermal equilibrium with the surrounding rocks and a model T-z profile (red) .

DELIVERABLES

- Detailed equipment design and layout
- Site specific design elements relevant to replicating the project
- A record of routine/preventive and unscheduled maintenance and length of outages
- A listing of all permits required and the permitting agency
- Capital costs for the installed system reported at the major component level
- A sensitivity analysis of site specific variables that may affect technical and economic risk
- A 20-yr life-cycle expense/revenue model along with an estimated ROI for the project
- A business plan that includes the potential number of replicate sites and investment opportunities state wide
- Number of direct and indirect jobs created during the design, construction, and installation phase of the system
- Potential for job creation based upon business plan for replication of system
- Potential job development for reservoir engineering and technology development
- An operating 1 MW geothermal system with an expected lifetime of 20 years

▪Team Qualifications

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

- **University of North Dakota School of Engineering and Mines**
- **Petroleum Research, Education and Entrepreneurship Center**
- **Berrendo Geothermal**
- **North Dakota Geological Survey**
- **ND Petroleum Industry – CRI, DRI**

▪Team Qualifications

- **University of North Dakota School of Engineering and Mines**

• DOE Project Faculty

- **Will Gosnold**, **PhD, Prof**., Geophysics, Geol. &Geol. Engr. Dept.
- **Michael Mann**, **PhD, Prof**., Energy Engineering, Chemical Engr. Dept.
- **Hossein Salehfar, PhD, Prof**., Electrical Engineering, Elec. Engr. Dept.

• PREEC Faculty

- **Richard LeFever**, **PhD, Prof**., Petrol Geol, Geol. &Geol. Engr. Dept.

• Graduate students

- **GGE: 1 PhD -** Mark McDonald: **4 MS** - Robert Klenner , Nicholas Low, Anna Crowell, Joshua Crowell
- **EE: 1 PhD -** Samir Dahal
- **ChE: 1 PhD -** Kirtipal Barse

▪Team Qualifications

Berrendo Geothermal

Developer of renewable energy projects. They provide an experienced project development team and capital for the project.

- **Joel Johnson, PE –CEO and Founder**
- `26 years of experience in management, operations, and technical consulting

- **Andrew Wernsdorfer - Founder, Managing Director**
- 26 years of international investing and banking experience

- **Warren Wendling - PE, Director of Transmission & Utilities Planning**
- 25 years of experience in utility regulation

- **Richard Moutou - Project Energy Engineer**
- 10 years experience in renewable energy engineering and advanced research

▪Team Qualifications

North Dakota Geological Survey

- Access to records of oil, gas, and other wells relevant geothermal fluids
- Access to core samples
- Initiate contacts with petroleum industry
- Key role in dissemination of information to the public.

Lorraine Manz, PhD – Geologist
Dr. Manz is the principal contact and administrator for the North Dakota geothermal regulatory program.

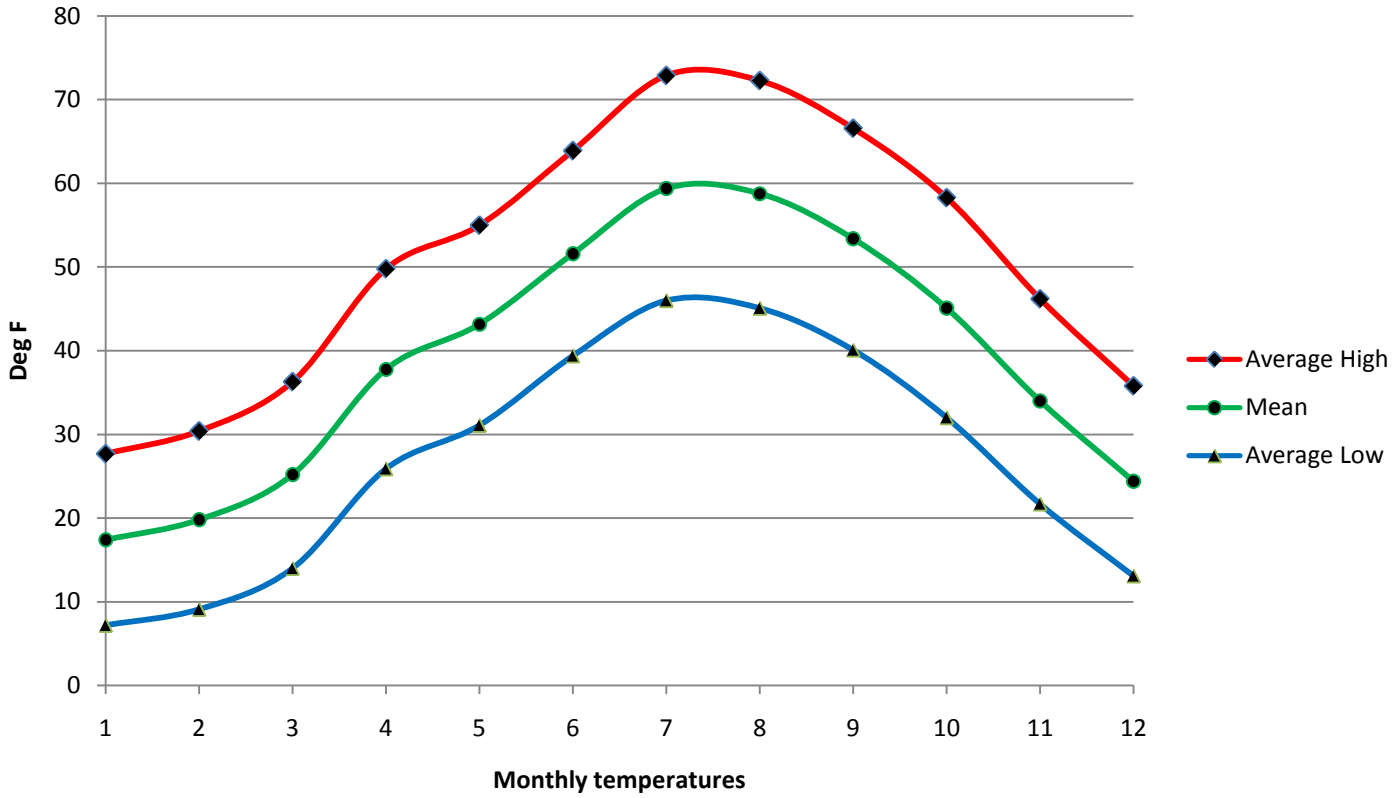
Julie LeFever, MS – Director of NDGS Core and Sample Library

Ed Murphy, PhD – State Geologist

Lynn Helms, PhD – Director North Dakota Industrial Commission

Future Directions

- Development of geothermal power using ORC technology throughout the Williston Basin appears highly promising due to the region's cool climate (mean annual temperature of 50 ºF) and the availability of geothermal fluids at 150-300 F in a number of oil producing formations.



Future Directions

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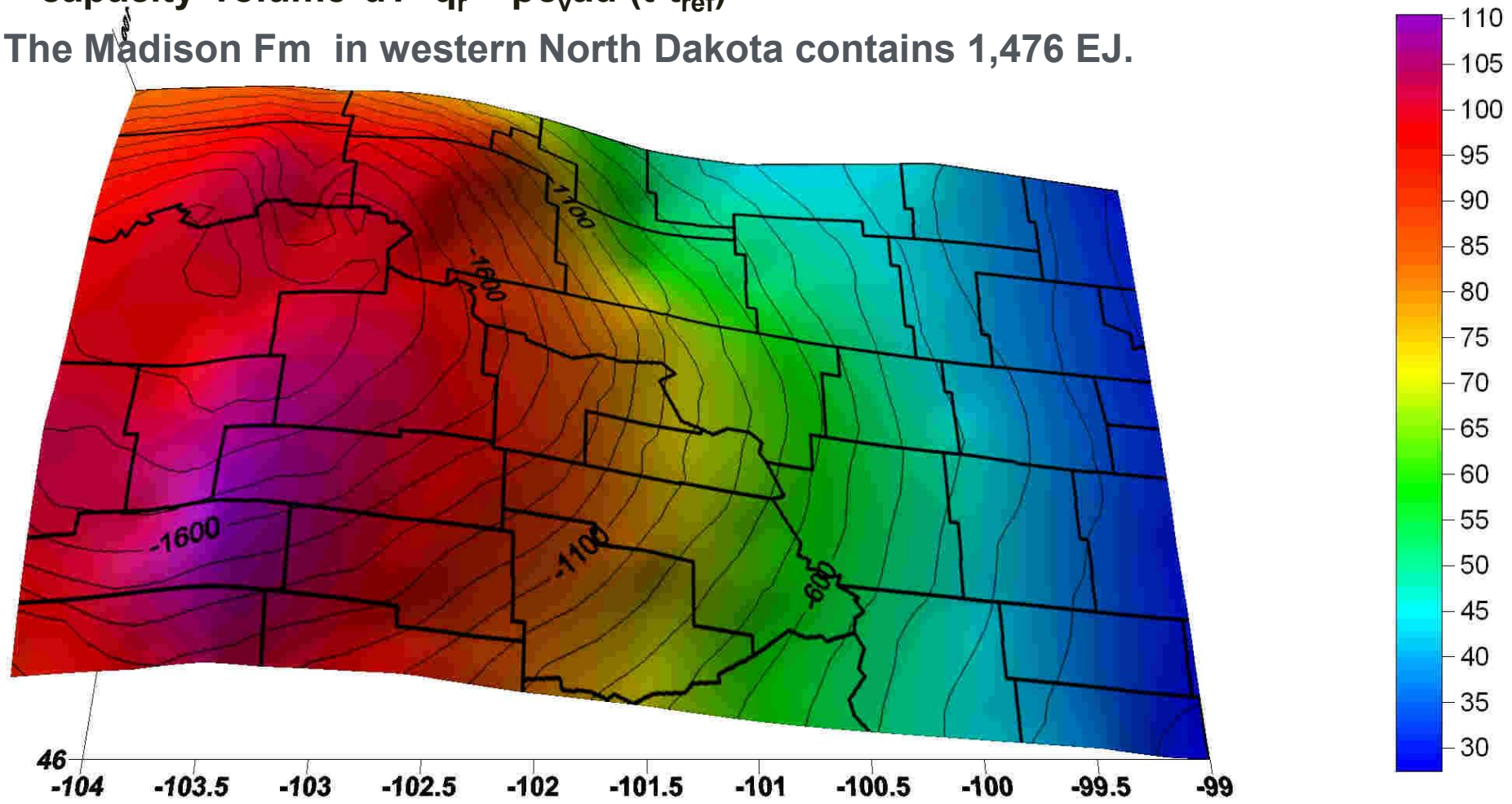
The energy resource in Joules is the product of density*volumetric heat capacity*volume*dT $q_r = \rho c_v a d (t-t_{ref})$

The Madison Fm in western North Dakota contains 1,476 EJ.



Colors are temperature, contours are depth (m), lines are county boundaries

Project Management/Coordination

- The UND principal investigator is responsible for the overall management of the project.
- UND and Berrendo work together on all tasks of the project. Regular weekly teleconferences are held with all three UND Principal Investigators meetings and Berrendo personnel.
- A detailed task management plan to ensure both the schedule and cost components of the project are met is in preparation as a part of Phase A1.
- Detailed guidelines regarding DOE's special performance and reporting requirements for this project have been issued to each of the project partners.

Mandatory Summary Slide

- This project will increase our understanding of the potential for oil field geothermal power.
- The Williston Basin has good potential for binary power plant operations due to: fluid temperatures, depth of resource, active drilling, and cool ambient temperatures.