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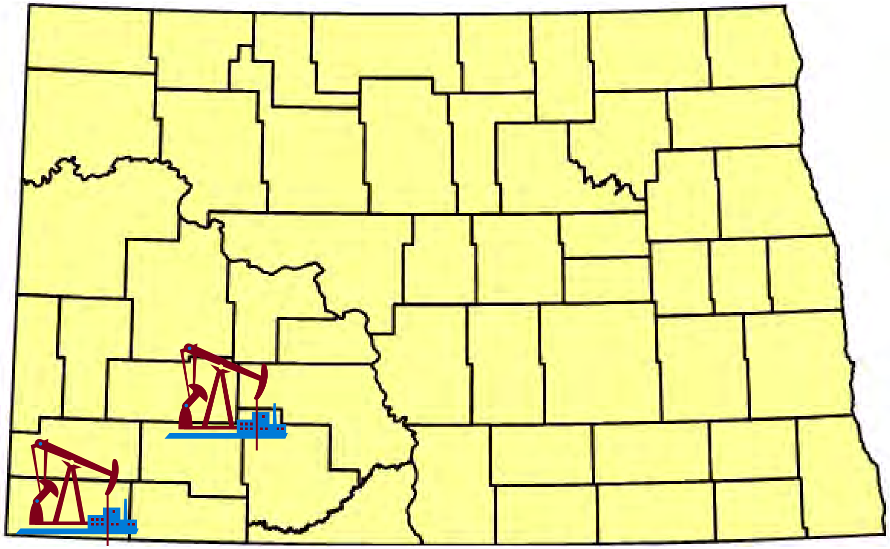

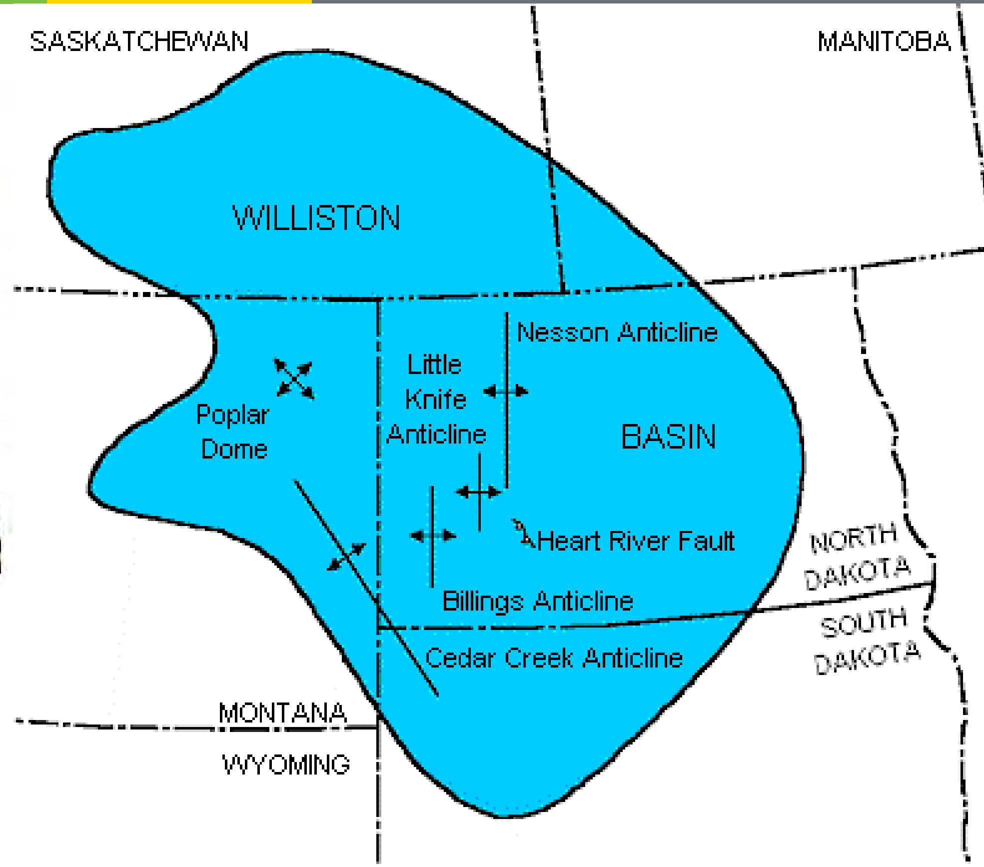

Demonstration Projects
DE-EE0002731 Co-Produced
DE-EE0002854 Low-Temperature

Electric Power Generation from Co-Produced and Other Oil Field Fluids

Project Officer: Sara Gonnion
Total Project Funding: $1,733,961 x 2
April 22, 2013

William Gosnold
UND Geothermal Laboratory
The University of North Dakota

Track 1

Relevance/Impact of Research Project Objectives

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1. Demonstrate/test the technical and economic feasibility of generating electricity from low-temperature (150° F to 300° F) geothermal resources using binary power systems.

2. Demonstrate that the technology can be replicated within a wide range of physical parameters including fluid temperatures, flow rates, and the price of electricity sales.

3. Disseminate the results of this study by publishing and presenting in national, regional and local venues

4. Facilitate entrepreneurship in development of oil field geothermal resources

5. Train scientists and engineers in geothermics.

Scientific/Technical Approach DE-EE002854 Low Temperature

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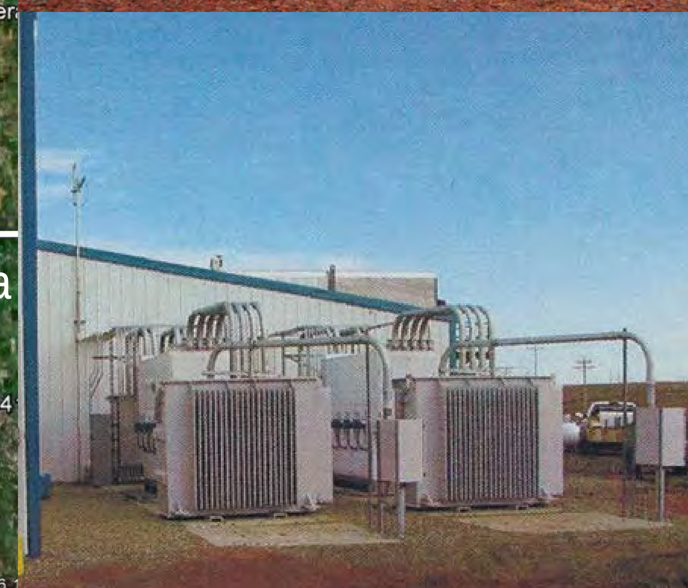
Continental RESOURCES

Slope Electric Cooperative, Inc.

ACCESSENERGY A CALNETIX COMPANY

Aqua Advisory Group

- Water Flood EOR
- Cedar Hills Oil Field
- Bowman, County, ND
- 210 °F, 875 gpm, low TDS water from Lodgepole Fm.
- One of five wells – total available water 1,750 gpm
- Two 125 kW ORC engines by Access Energy



Objective 1: Demonstrate Feasibility

Scientific/Technical Approach
DE-EE002731 Co-Produced

DE-EE0002731 Co-Produced

- Water Flood EOR
- Eland-Lodgepole Field
- Dickinson, ND
- 210 °F, 400 gpm, high TDS water from Lodgepole Fm.
- 12 oil wells
- 5 injection wells
- 1 gas flare

Original partners:

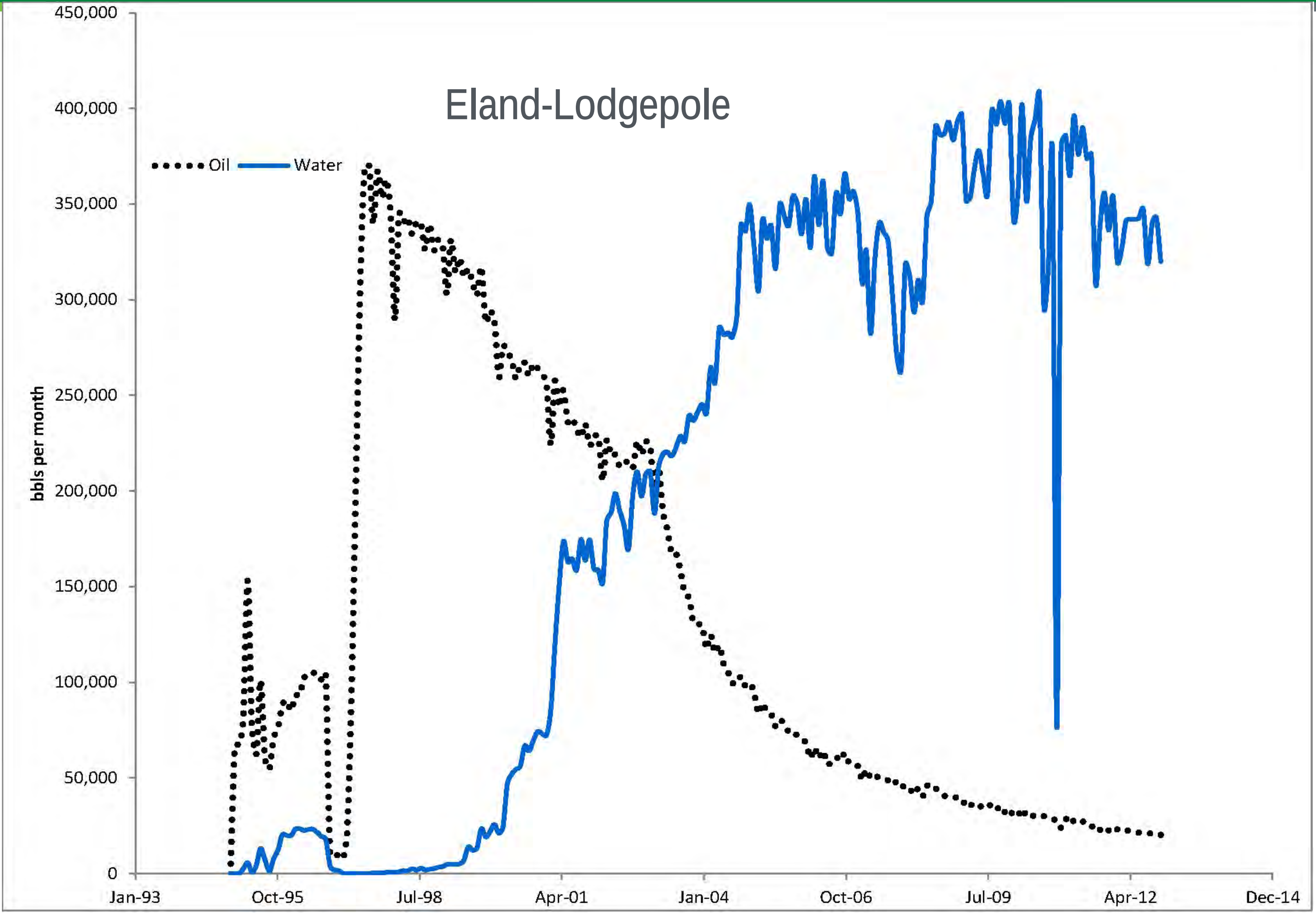
Encore, Inc.

Denbury, Inc.

West Plains Electric Coop. – Basin Electric

Objective 1: Demonstrate Feasibility

Scientific/Technical Approach
DE-EE002731 Co-Produced



Objective 1: Demonstrate Feasibility


EXXON Mobil
Encore
Dickinson, ND
Denbury

Scientific/Technical Approach
Identify resource and document temperatures

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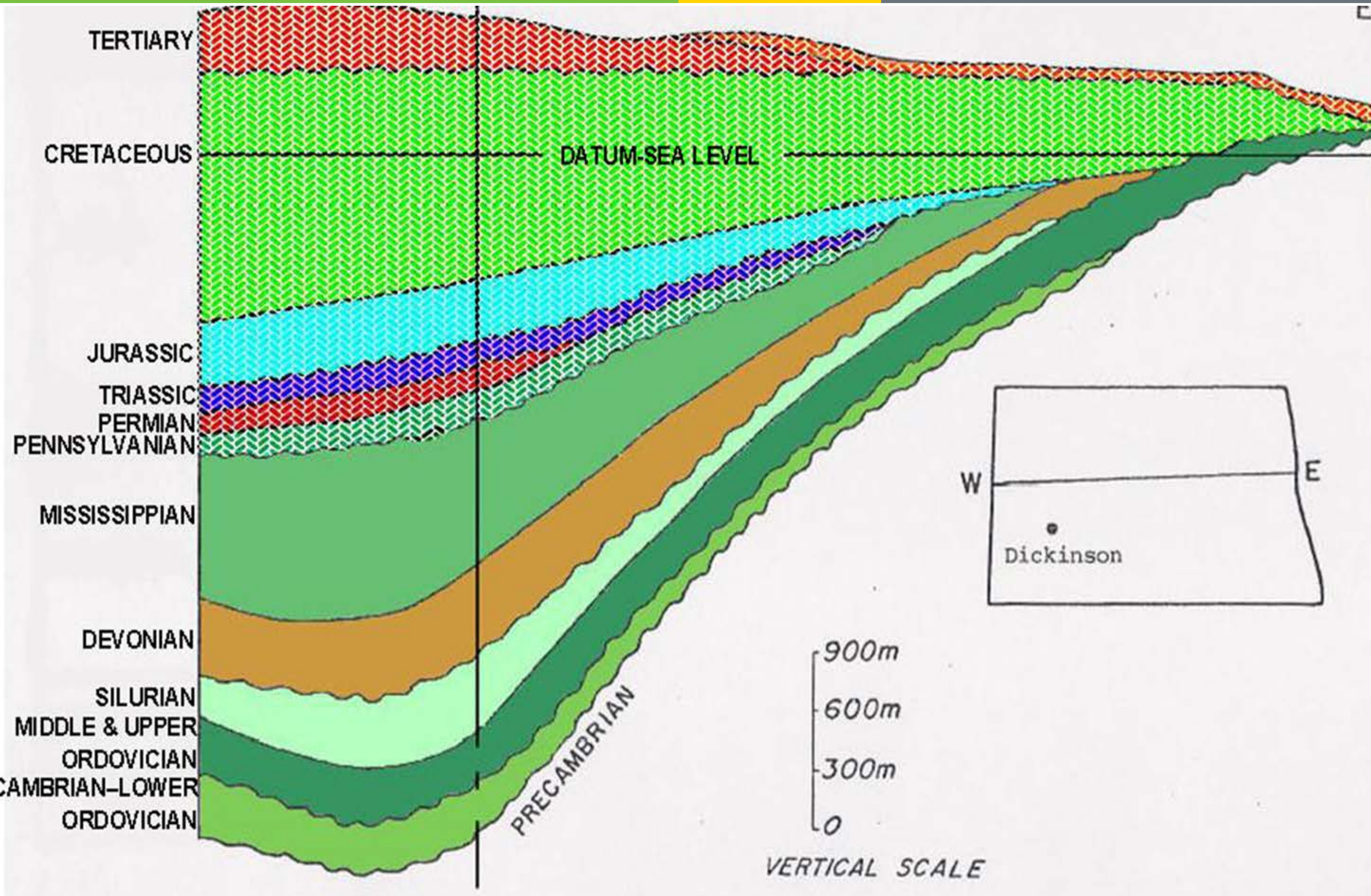
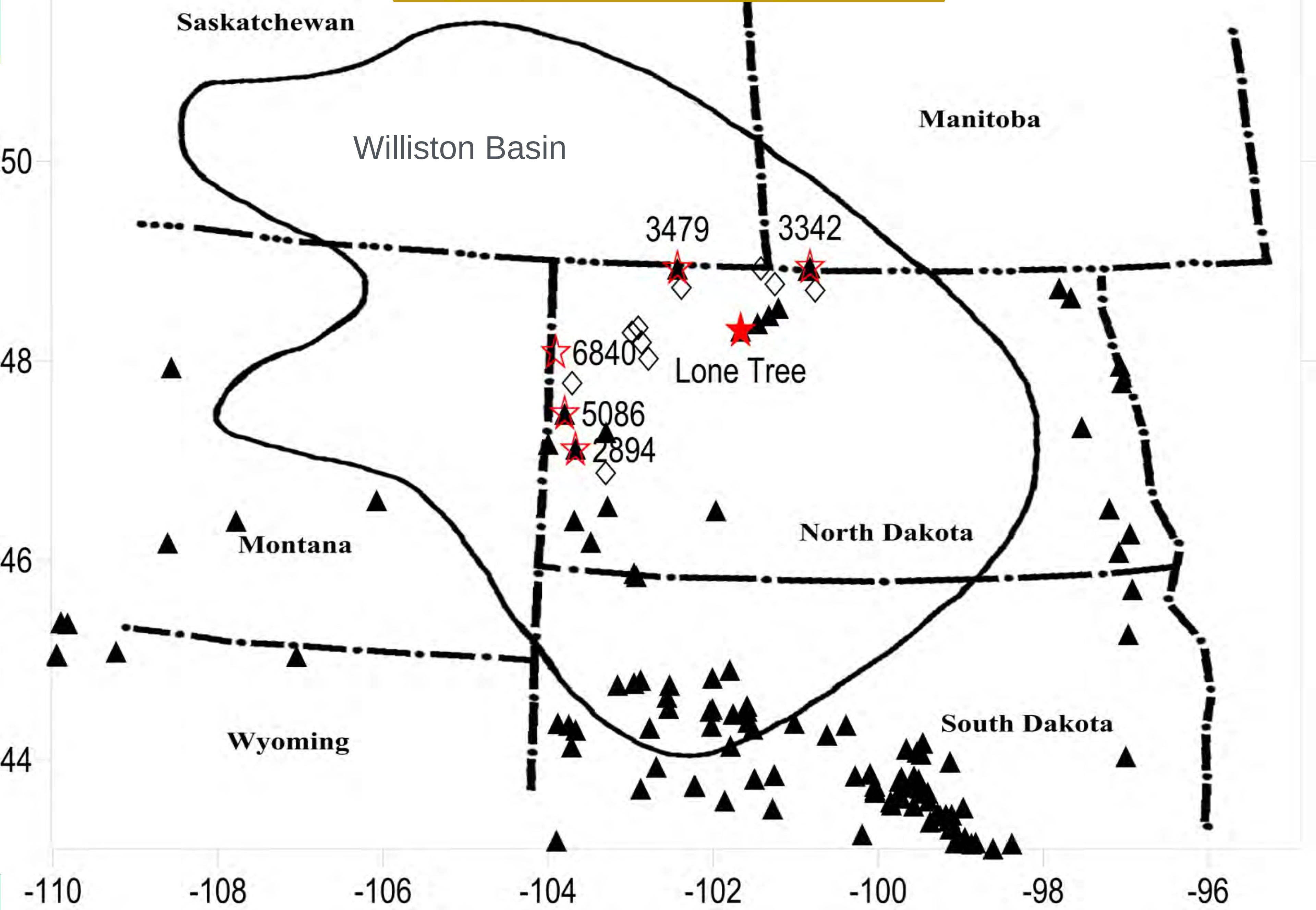


Objective 2: Demonstrate Wide Applicability

Heat Flow Observations



Scientific/Technical Approach
Identify resource and document temperatures

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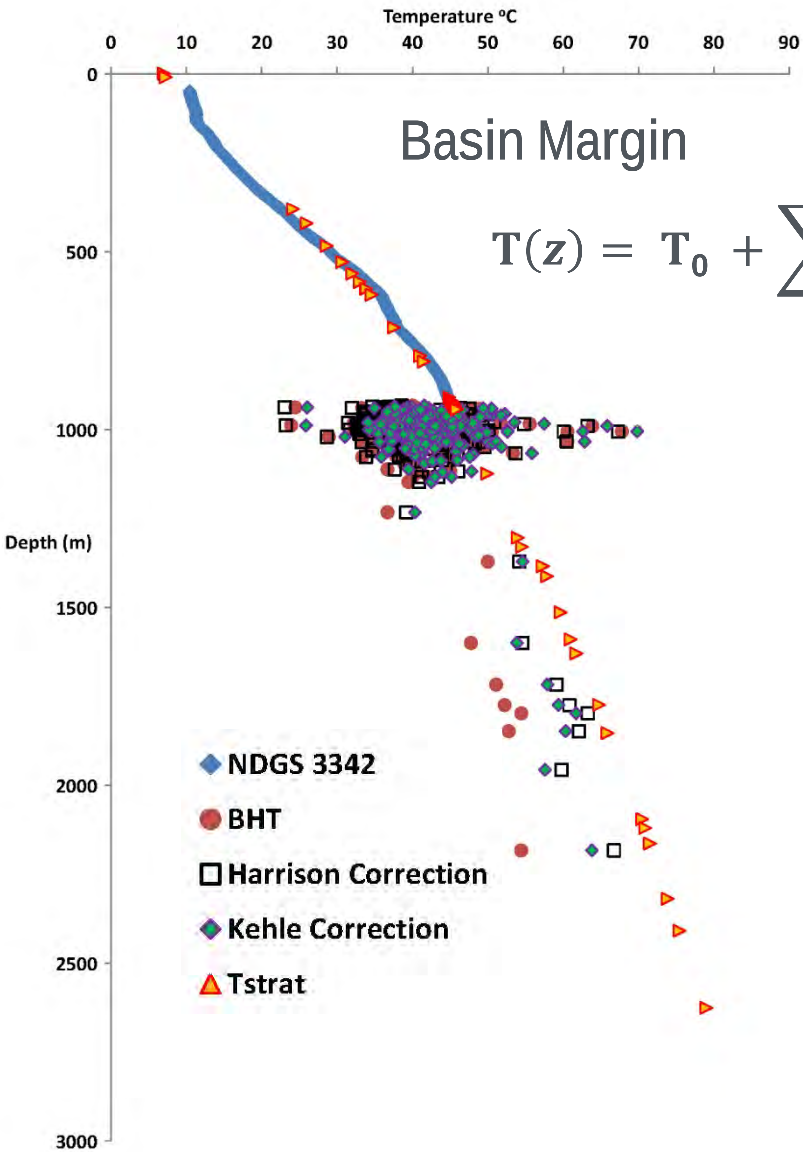
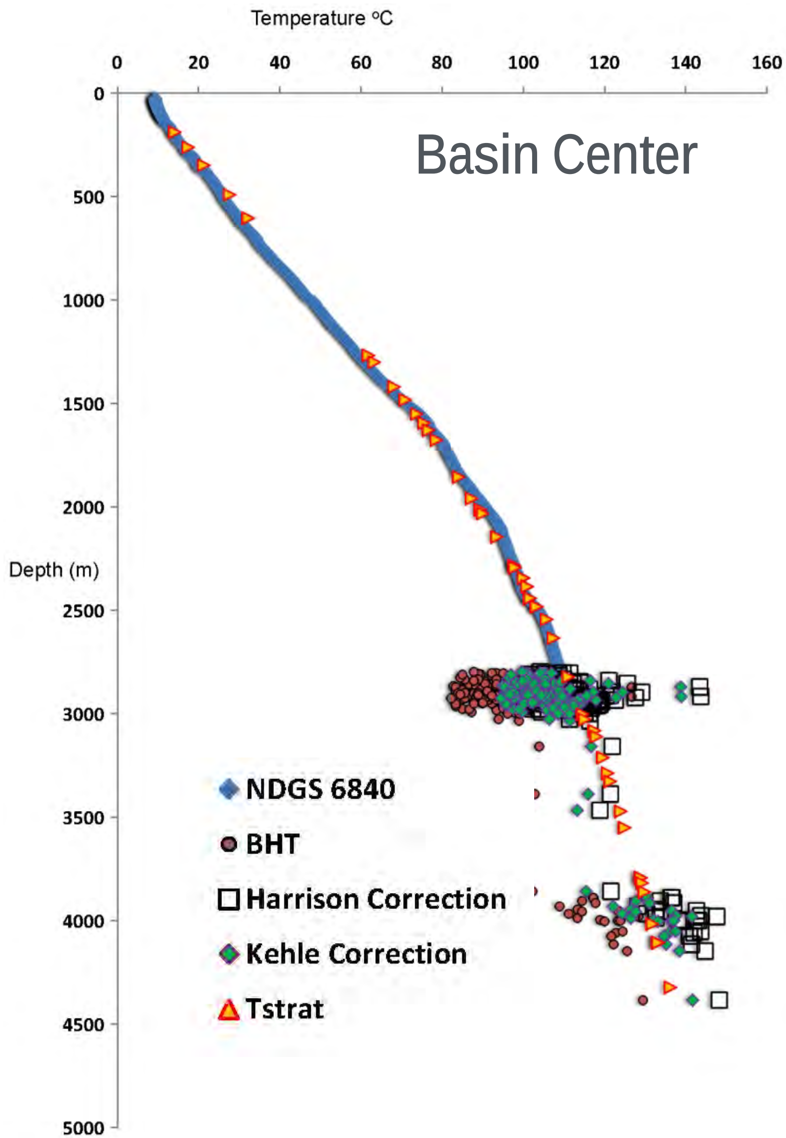
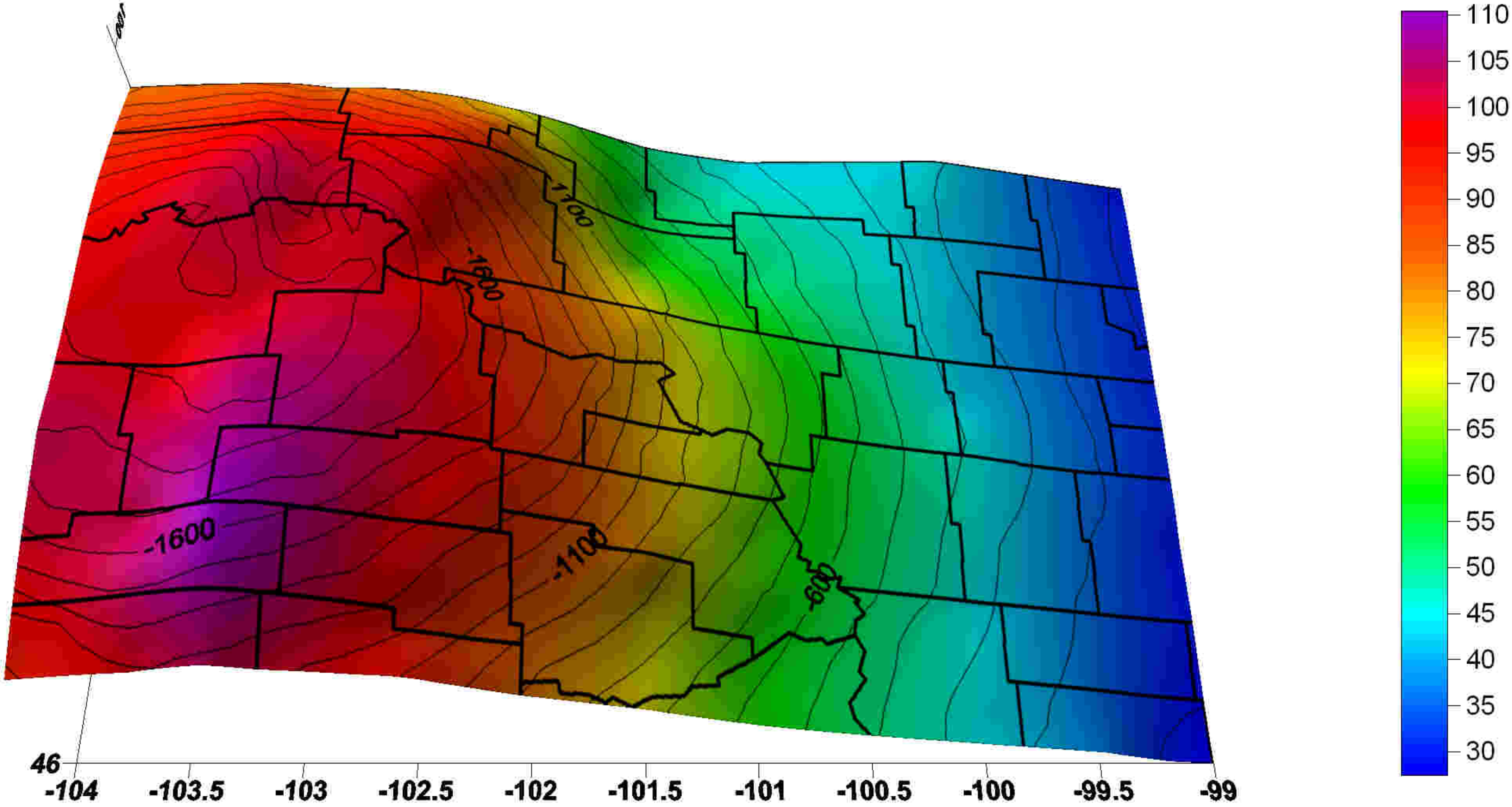


$$T(z) = T_0 + \sum_{i=1}^{n} \frac{qz_i}{\lambda_i}$$



Objective 2: Demonstrate Wide Applicability

This is an example of temperature contours (color) and structure contours for the Madison formation

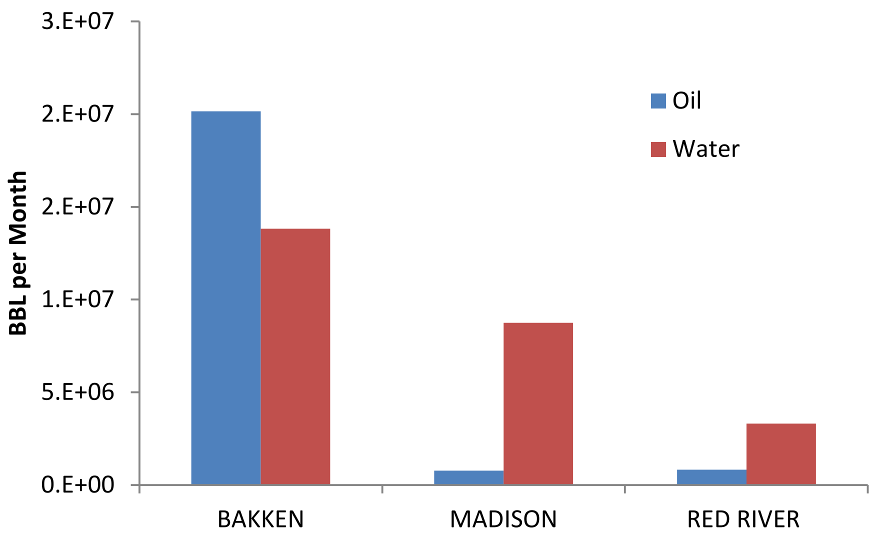


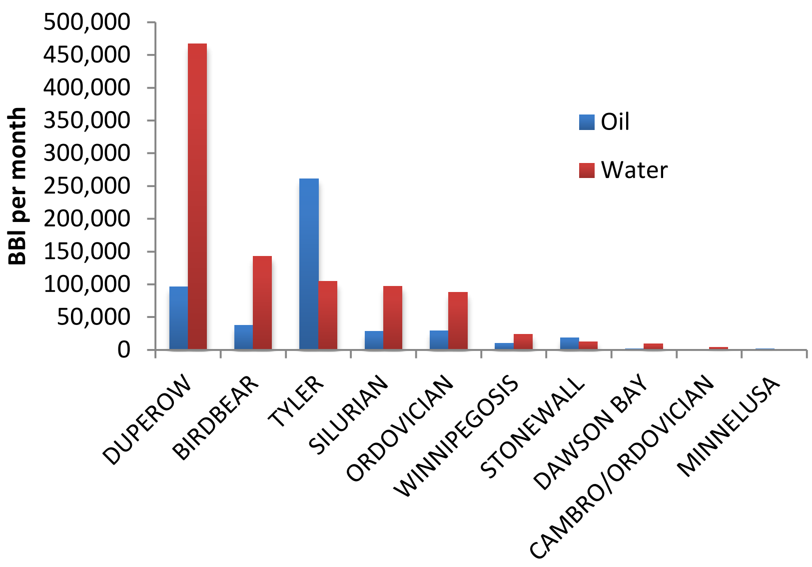
Scientific/Technical Approach
Identify main water producing formations

- The main oil and water producing formations in the Williston Basin are:

Pool	BBLS Oil	BBLS Water	WOR Ratio	BBl oil/well	BBl water/well
BAKKEN	20,046,962	13,818,929	0.7	4,163	2,869
RED RIVER	829,559	3,305,592	4.0	1,659	6,611
MADISON	699,470	8,119,405	11.6	366	4,253

Numbers are BBLS per month for 2012





Objective 2: Demonstrate Wide Applicability

The top producing oil wells in the Madison – Lodgepole formation do not yield sufficient water to be economic as a co-produced system. If the wells were produced solely for water at rates water wells in the Lodgepole are known to produce, the power production would be significant.

Madison	100 °C		H_2O		Co-produced	Moderate	High
Oil bbl/day	H_2O bbl/day	Fluid bbl/day	gpm	lb/hr	power (kW)	Rate (kW)	Rate (kW)
28	3511	3539	98	46809	110	2,200	22,000
92	3006	3099	84	40084	80	1,600	16,000
36	2722	2758	76	36287	73	1,460	14,600

Power Production from top Madison and Red River Units in Co-Production Scenario

Unit	Oil bbl	Water bbl	No. Wells	Oil gpm	Water gpm	Total gpm	kWe
Cedar Hills S. Red R. B	292,351	2,282,671	117	262	2,045	2,307	1,170
Cedar Hills N. Red R. B	385,634	605,212	115	346	542	888	426
Medicine Pole Hills W. Red R.	27,908	127,200	22	25	114	139	62
Unit	Oil bbl	Water bbl	No. Wells	Oil gpm	Water gpm	Total gpm	kWe
Renville Madison Unit	10,009	786,028	18	9	704	713	384
T.R. Madison Unit	24,564	416,072	23	22	373	395	235
Eland Lodgepole Unit	21,388	318,719	12	19	286	305	146

Accomplishments, Results and Progress
Total Fluid Production and Power Estimates

- Temperatures were determined from corrected BHTs; production data from NDIC Oil & Gas web site

Pool	BBLS Oil	BBLS Water	Max T °C at 1 Σ	Min T °C at 1 Σ	Avg T °C
BAKKEN	20,046,962	13,818,929	128	116	122
RED RIVER	829,559	3,305,592	147	113	130
MADISON	768,496	8,691,561	118	92	105

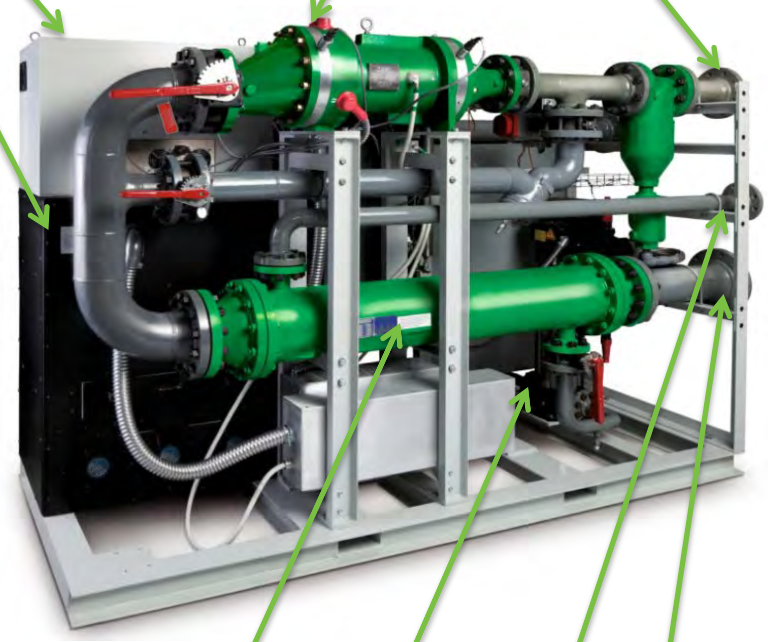
Heat Source		Bakken	Red River	Madison	Cedar Hills
ORC Efficiency (20 F)	%	13.5%	14.4%	11.6%	11.0%
ORC Power Output (20 F)	kW	12,523	2,172	4,308	407
ORC Modules (20 F)	#	100	17	34	3
ORC Efficiency (40 F)	%	11.8%	12.7%	9.9%	9.2%
ORC Power Output (40 F)	kW	10,946	1,916	3,676	341
ORC Modules (40 F)	#	88	15	29	3
ORC Efficiency (70 F)	%	9.4%	10.3%	7.4%	6.7%
ORC Power Output (70 F)	kW	8,720	1,554	2,748	248
ORC Modules (70 F)	#	70	12	22	2

Accomplishments, Results, Progress

Thermapower™ MT ORC Module Product Specifications

- Patented IPM consisting of high speed turbine and high efficiency generator
- IPM utilizes magnetic bearings – yields high efficiency and eliminates gearbox and lubrication
- 18 MW of capacity sold globally
- Proven on wide variety of heat sources

Parameters	Thermapower™ MT ORC Module
Power	125 kW Gross
Voltage	3Ø, 400 to 480 V L-L (Nominal)
Frequency	50/60 Hz
Input Temperature	250 F (121 C) to 350 F (177 C)
Organic Working Fluid	Closed Loop, Non-Ozone Depleting Refrigerant
Module Weight (approx)	6,500 lbs (2,948 kg)
Module Dimensions	113 in (287 cm) x 50 in (127 cm) x 80 in (203 cm)



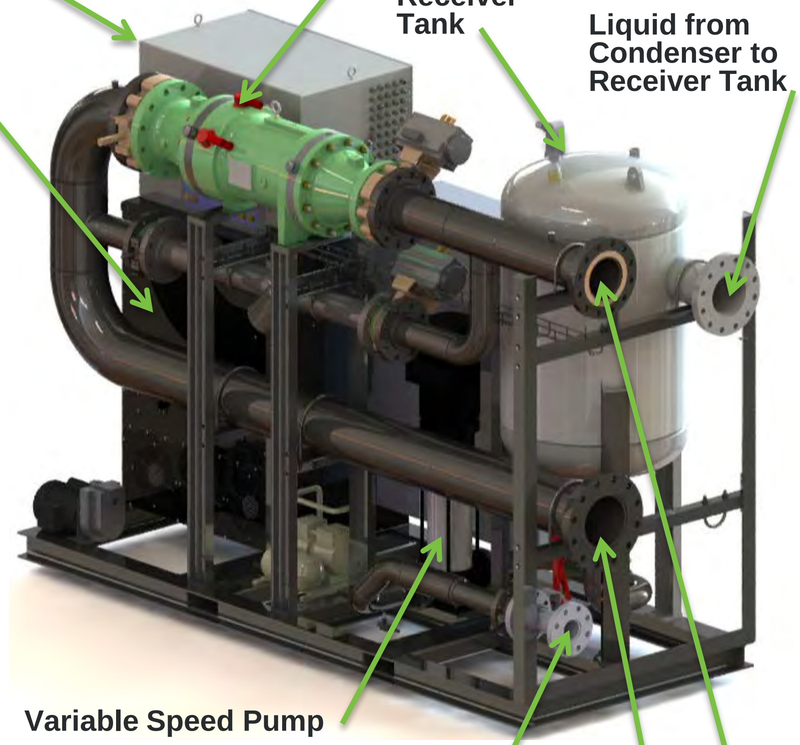
Accomplishments, Results, Progress

Thermapower™ XLT ORC Module Product Specifications

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

- Patented IPM consisting of high speed turbine and high efficiency generator
- IPM utilizes magnetic bearings – yields high efficiency and eliminates gearbox and lubrication
- New development
- Release expected Q4 - 2013

Parameters	Thermapower™ XLT ORC Module
Power	125 kW Gross
Voltage	3Ø, 400 to 480 V L-L (Nominal)
Frequency	50/60 Hz
Input Temperature	180 F (82 C) to 220 F (104 C)
Organic Working Fluid	Closed Loop, Non-Ozone Depleting Refrigerant
Module Weight (approx)	6,500 lbs (2,948 kg)
Module Dimensions	113 in (287 cm) x 50 in (127 cm) x 80 in (203 cm)



Efficiency of the Thermalpower™ XLT ORC

Heat Source Supply Temp (F)	Theoretical Rankine Efficiency	Estimated Thermapower™ ORC Efficiency
280	17.2%	15.2%
275	17.0%	15.0%
270	16.7%	14.7%
265	16.4%	14.4%
260	16.1%	14.1%
255	15.8%	13.8%
250	15.5%	13.5%
245	15.2%	13.2%
240	14.9%	12.9%
235	14.6%	12.6%
230	14.3%	12.3%
225	13.9%	11.9%
220	13.6%	11.6%
215	13.3%	11.3%
210	13.0%	11.0%
205	12.6%	10.6%
200	12.3%	10.3%
195	12.0%	10.0%
190	11.6%	9.6%
185	11.3%	9.3%
180	10.9%	8.9%

Assumptions:
1) Ambient Temp 20 F
2) Evaporator Temp Pinch 10 F
3) Condenser Temp Pinch 20 F

Heat Source Supply Temp (F)	Theoretical Rankine Efficiency	Estimated Thermapower™ ORC Efficiency
280	15.6%	13.6%
275	15.3%	13.3%
270	15.0%	13.0%
265	14.7%	12.7%
260	14.4%	12.4%
255	14.1%	12.1%
250	13.8%	11.8%
245	13.5%	11.5%
240	13.2%	11.2%
235	12.9%	10.9%
230	12.6%	10.6%
225	12.2%	10.2%
220	11.9%	9.9%
215	11.6%	9.6%
210	11.2%	9.2%
205	10.9%	8.9%
200	10.6%	8.6%
195	10.2%	8.2%
190	9.9%	7.9%
185	9.5%	7.5%
180	9.1%	7.1%

Assumptions:
1) Ambient Temp 40 F
2) Evaporator Temp Pinch 10 F
3) Condenser Temp Pinch 20 F

Accomplishments, Results and Progress

Widely Disseminate the Results

- Faculty and students have produced 15 journal articles and 45 presentations at national and regional meetings. Two GRC presentations and one AGU presentation received awards for best paper in session.

Develop a Skilled a Work Force

- Thirty students (5 PhD, 9 MS and 16 BS) representing five different academic disciplines and six degree programs have participated in our geothermal projects. Ten of these have completed or are completing graduate degrees with geothermal thesis topics

Help Geothermal Entrepreneurs

- We have encouraged entrepreneurship through support for designing the Low-Temperature, High-Efficiency Access Energy ORC (**Thermapower™ XLT ORC**) and collaboration with Advanced Aqua Group in testing a produced water clean-up system.

Future Directions

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- Phase III, installation and monitoring of power production will begin during the summer of 2013 and continue through August 2015.
- The North Dakota Industrial Commission projects that the state will need at least an additional 500 MW of power to produce oil from the Bakken formation. This is a great opportunity to establish a network of distributed power systems with co-produced fluids from quad and larger drill pads.
- Three electric cooperatives in the oil patch have expressed interest in the project. Slope Electric Cooperative; West Plains Electric Cooperative; Rough Rider Electric Cooperative
- Cooperate with AAG to install produced water cleanup systems powered by a combination of geothermal ORCs and waste gas generators.
- Continue to publish and present information on the project at national, regional and local venues.

Summary Slide

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- We have compiled data and developed methods that have enabled us to reach a clear understanding of the geothermal potential of the Williston Basin.
- Power production from co-produced fluids is feasible and could be economic in unitized fields with multi-well drill pads.
- Distributed binary systems in unitized or watered-out fields could provide a significant power resource.
- The driver in development should be the electrical power industry. The petroleum industry has a low level of interest.
- The Access Energy XLT IPM ORC offers an increase in power production through greater efficiency.

The University of North Dakota

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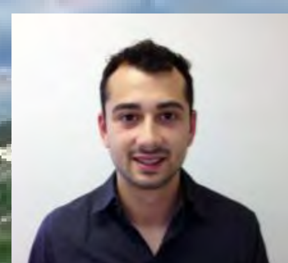

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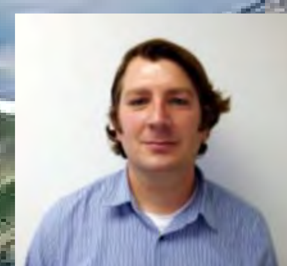
Project Engineer



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