Geothermal Resources from Resource Definition to Power Production in Texas

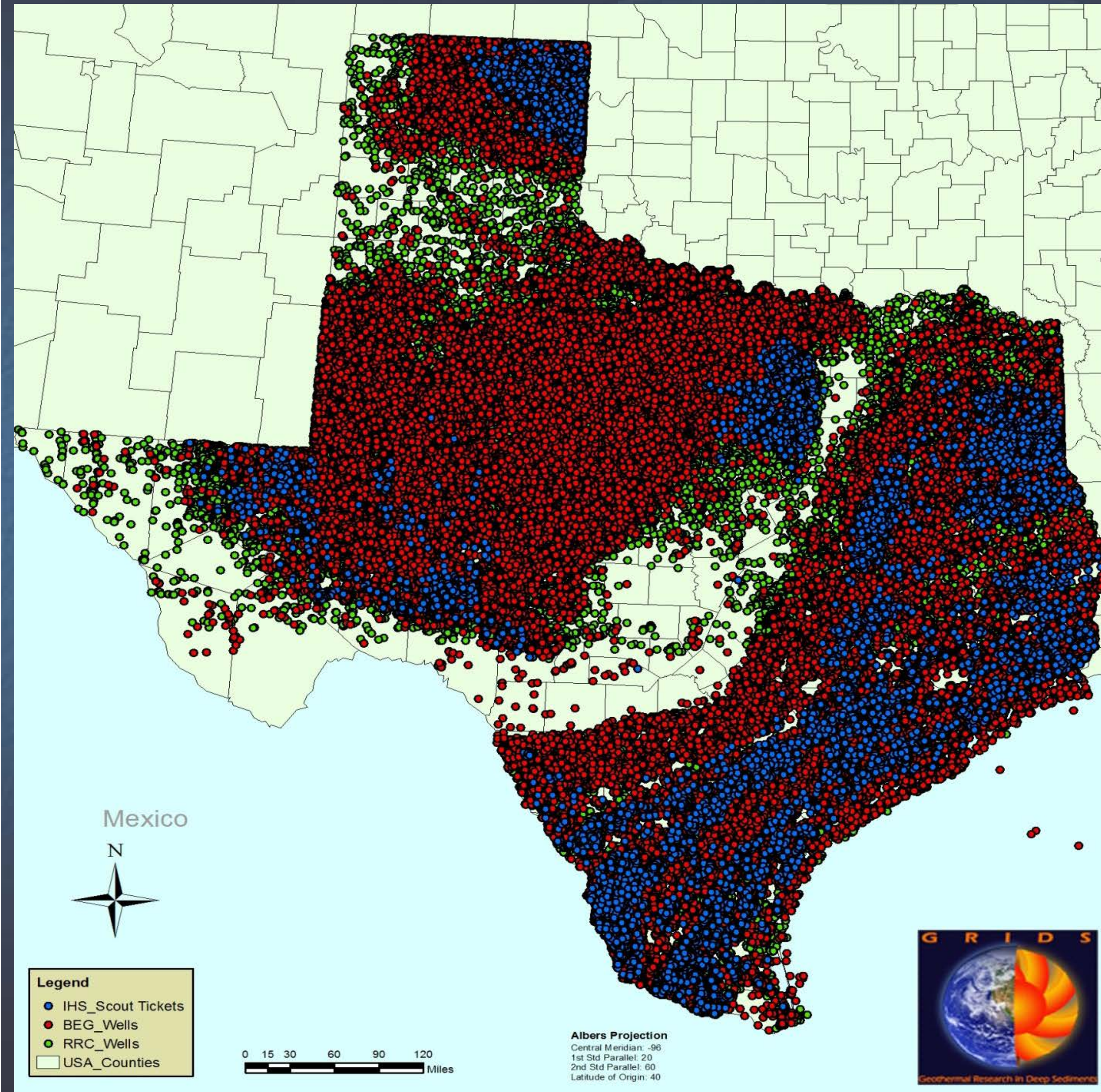
Bruce Cutright and the Geothermal Resources Team at the Bureau of Economic Geology, University of Texas, Austin Texas

March 14, 2013

Outline

- Statewide Database Compilation is complete and will be available by September, 2013
- Data Analysis Results
  - temperature, flow, existing infrastructure
- Site Identification
- Economics
  - How competitive is Geothermal Energy
- Alternative Heat Extraction Fluids; CO_2

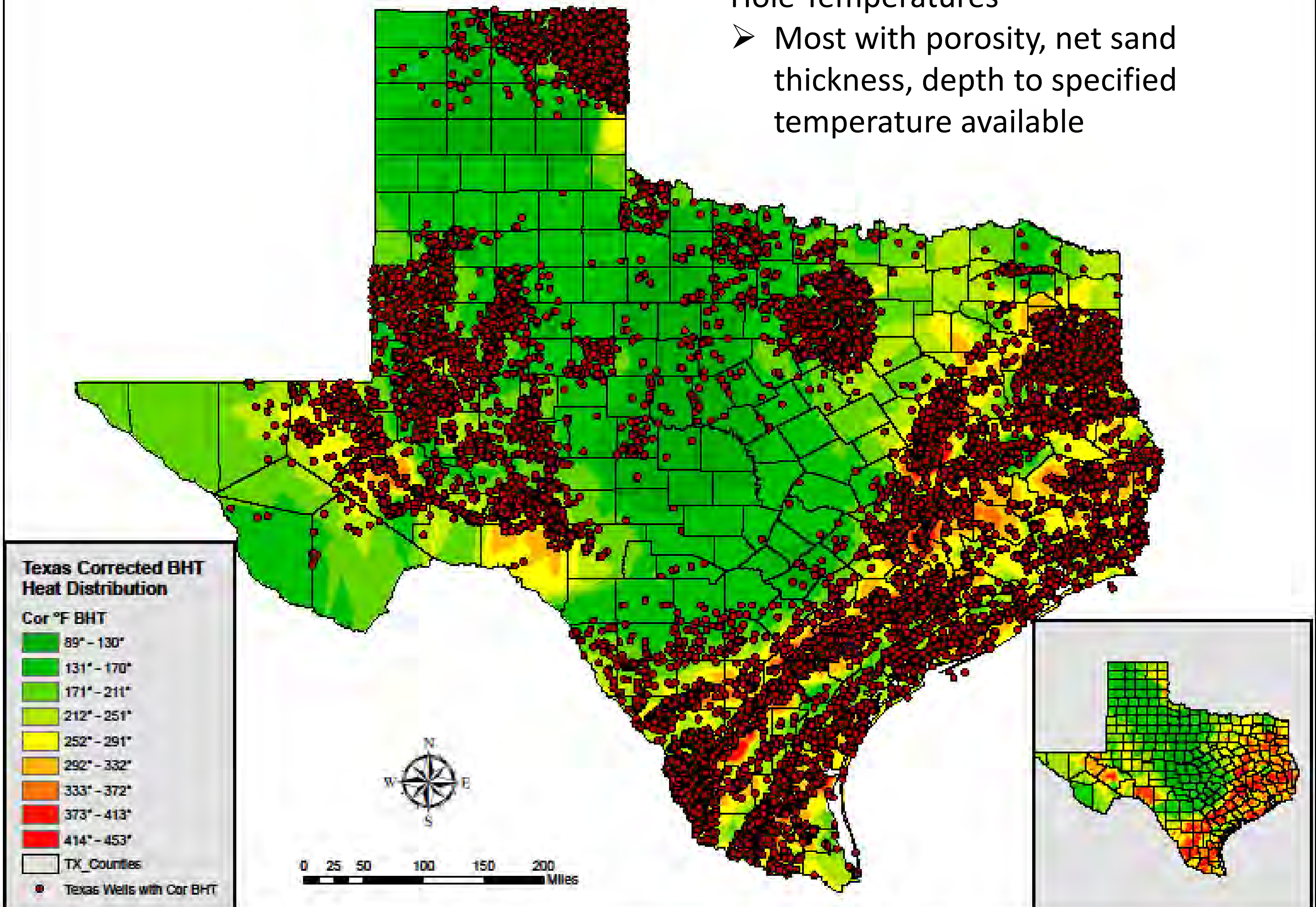
Database Compilation

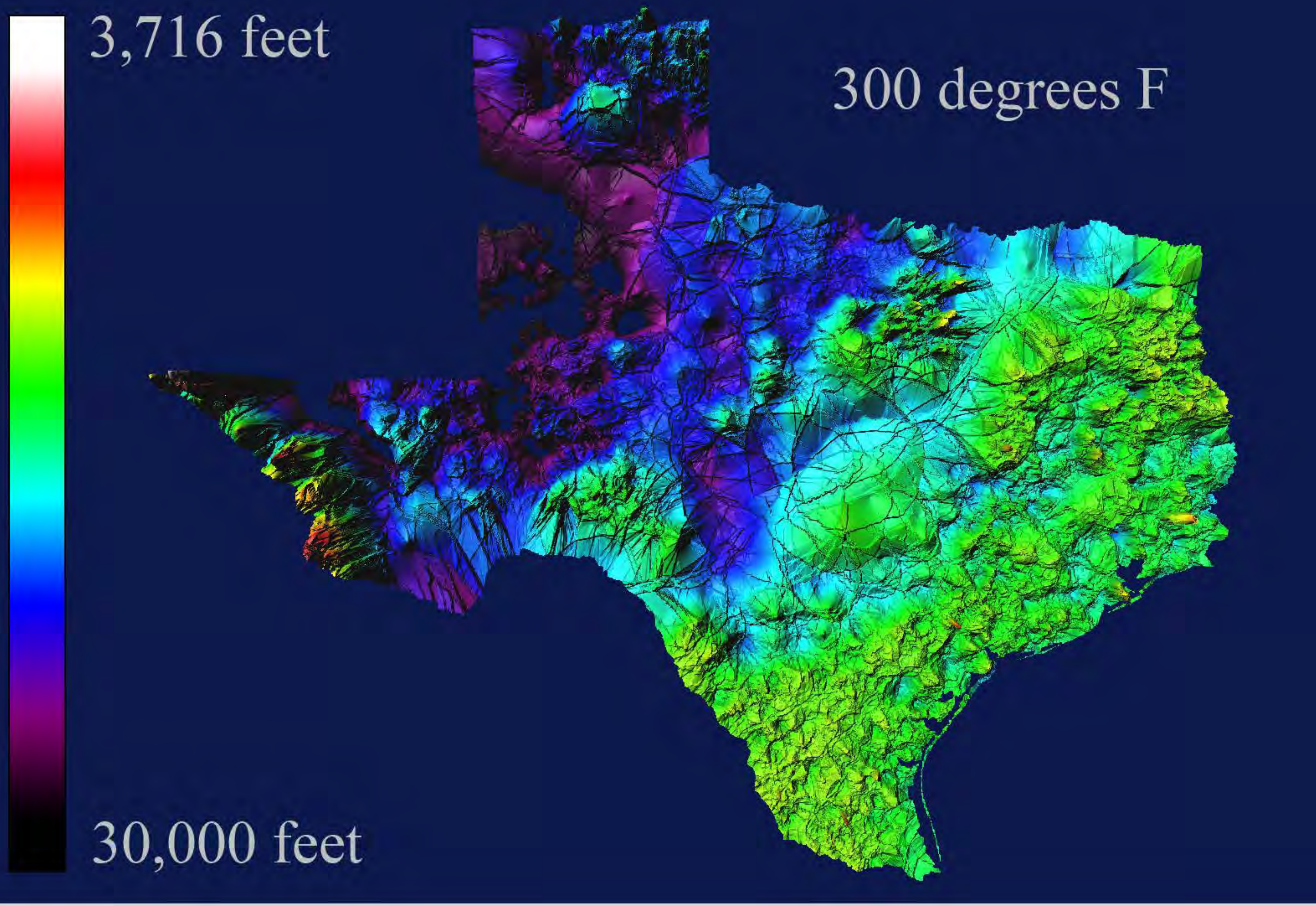


- National data set, between 4 to 5 million well records.
- Texas only:
  - 1.2 to 1.5 million Wells
  - Viable Records more in the range of 300K:

52,900 wells with corrected Bottom Hole Temperatures

- Most with porosity, net sand thickness, depth to specified temperature available

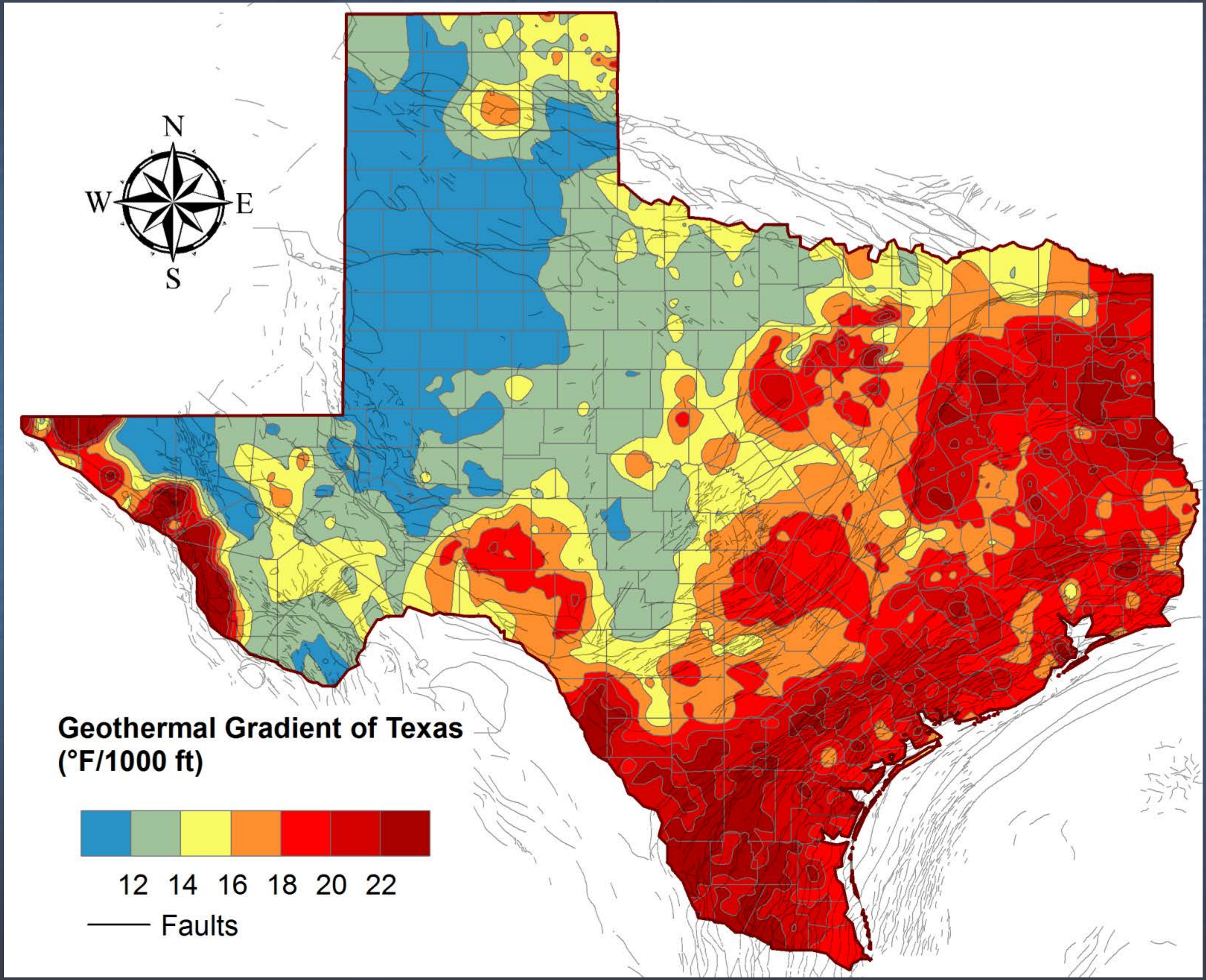



3,716 feet
300 degrees F
30,000 feet

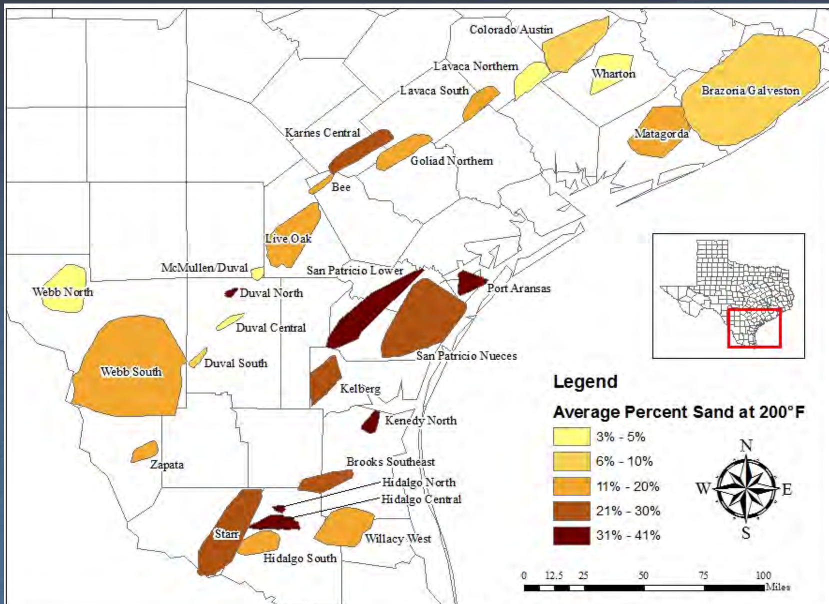
Data Analysis Overview

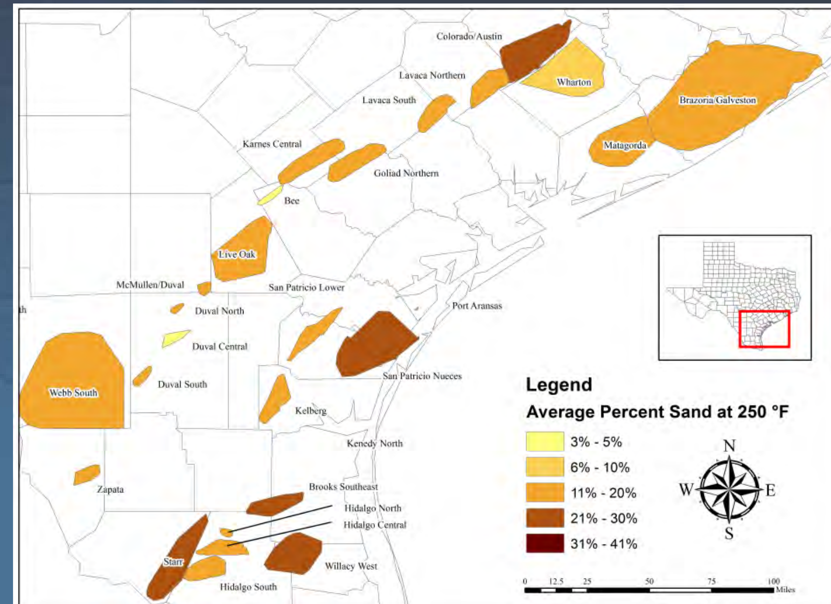
- Temperature Corrections
- Regional Reservoir Analysis
  - Compiled net sand thickness, porosity-permeability where available, flow test data, production data
- Derived Estimated of Time versus Yield, or Thermal Sustainability
- Cost Analysis using the US DOE Geothermal Electricity Technology Evaluation Model (GETEM)

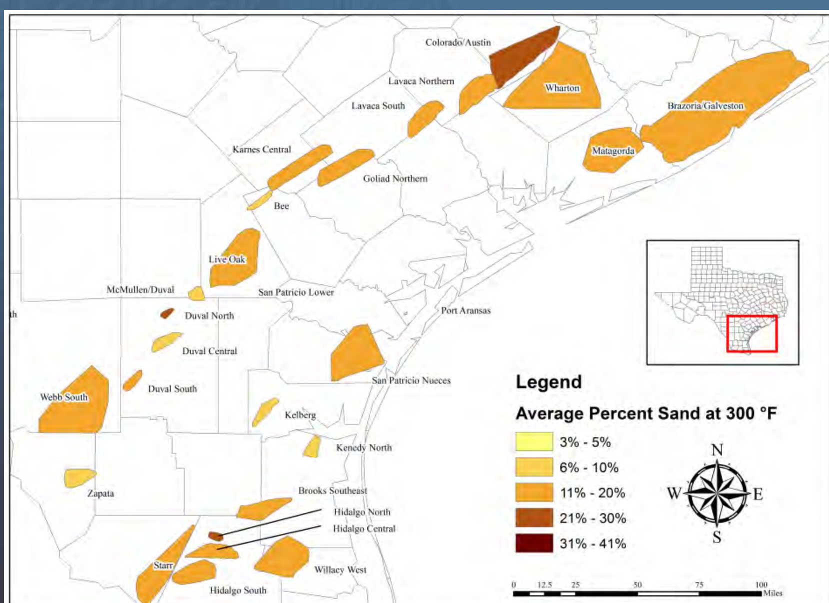
Temperatures and Gradients (Corrected Bottom Hole Temperatures)

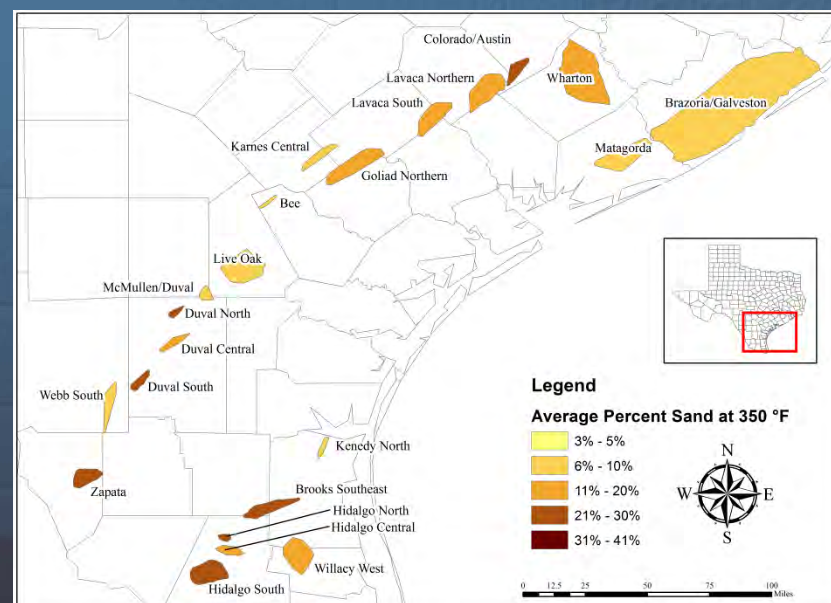


Flow Estimate by Porosity, Gulf Coast Fairways

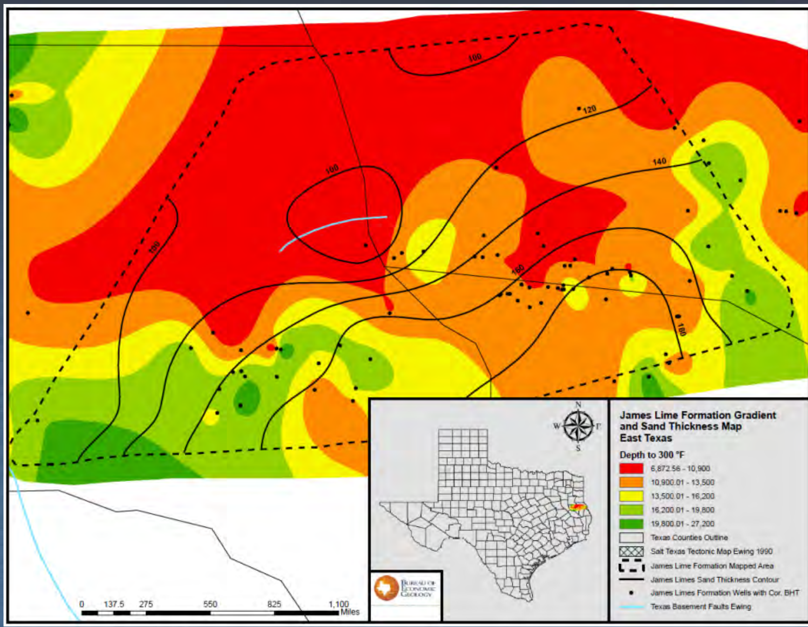




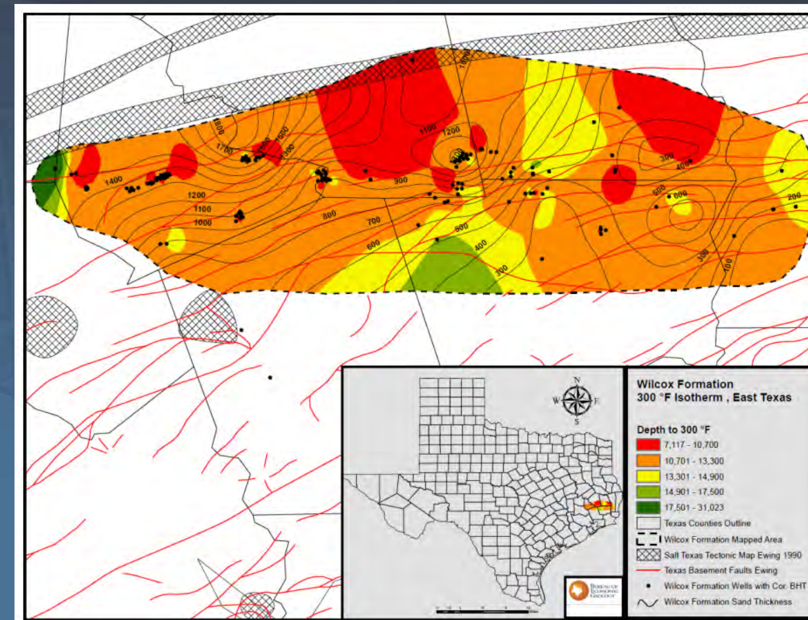




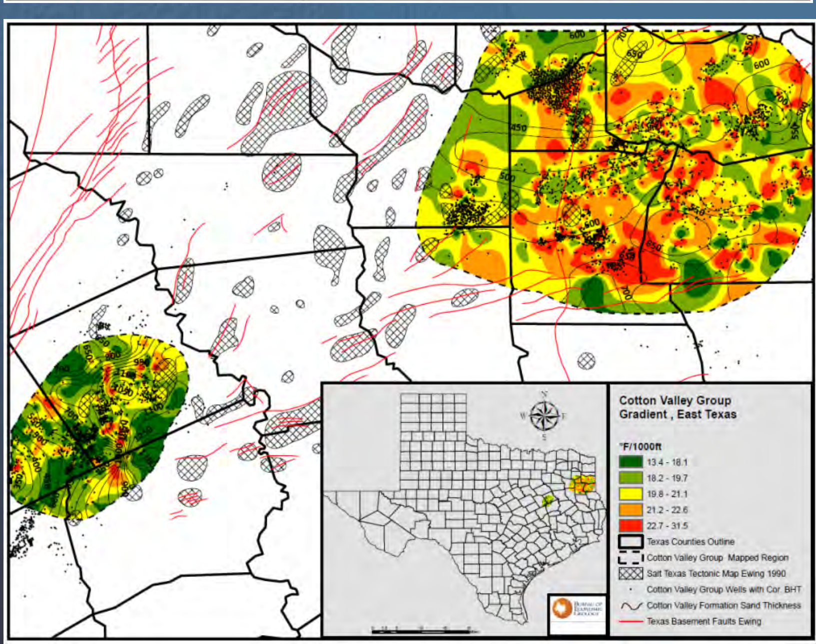
Selected East Texas Formations



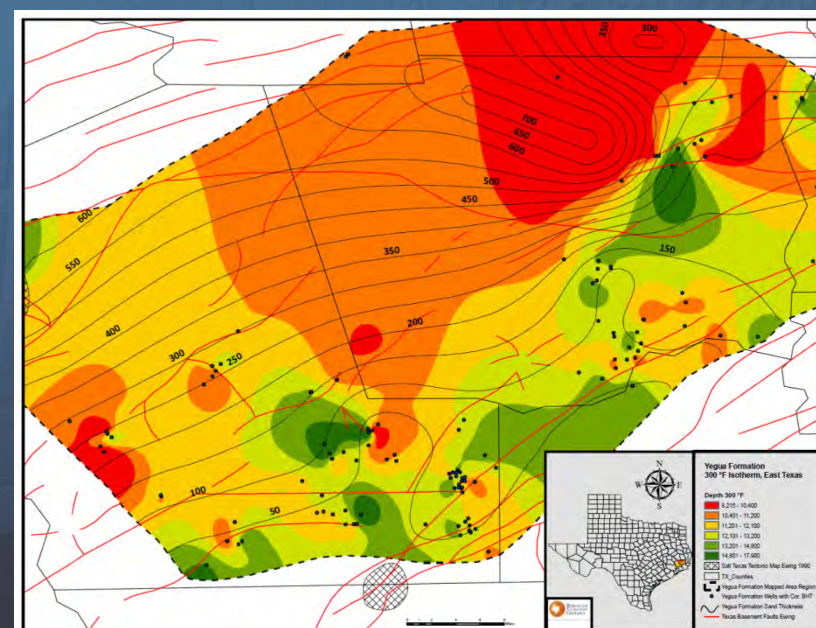
James Lime FM



Wilcox FM

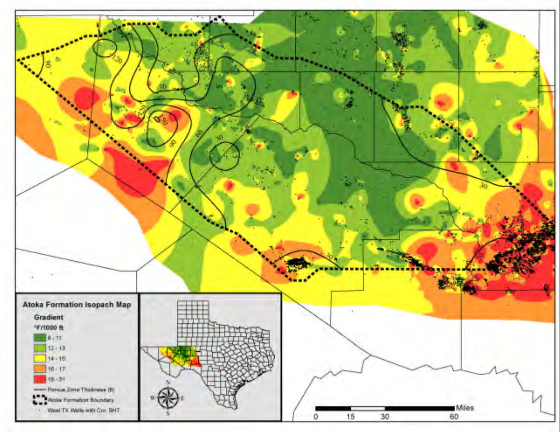


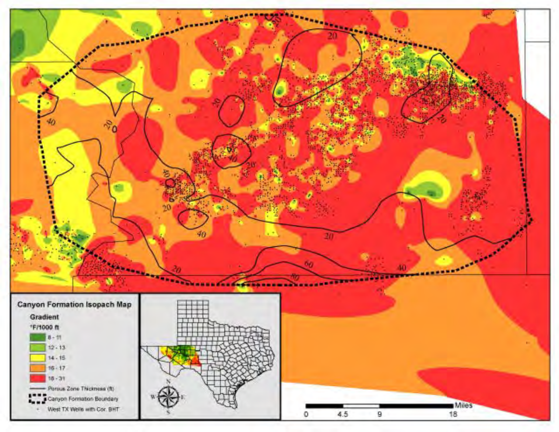
Cotton Valley Group

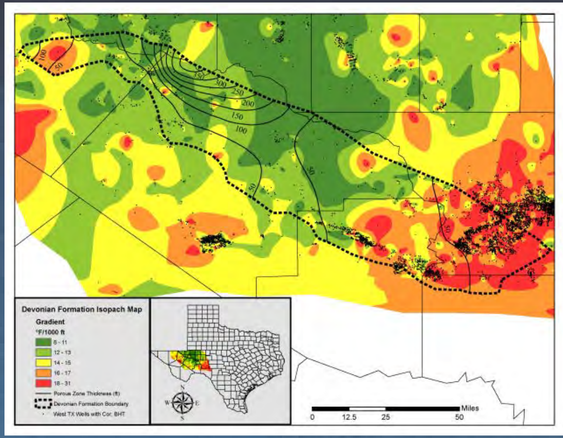


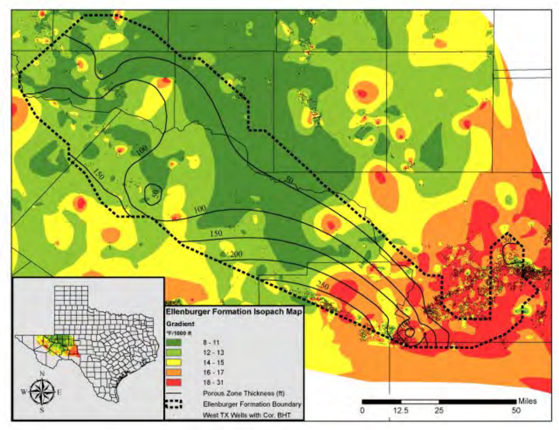
Yegua Fm

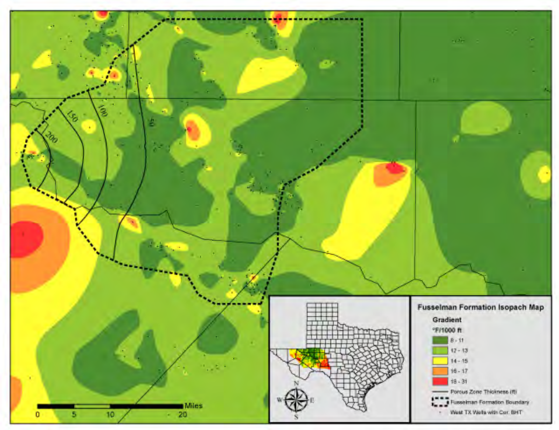
West Texas Example Formations

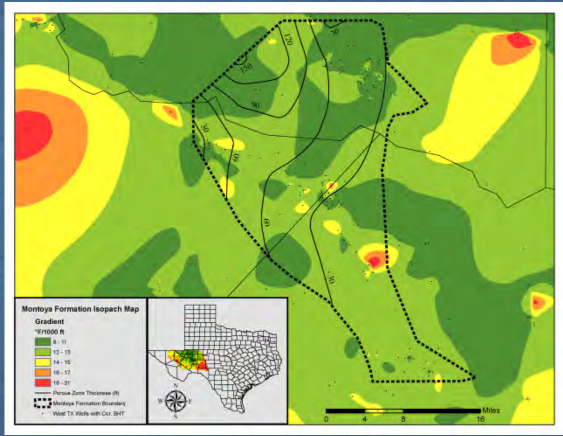


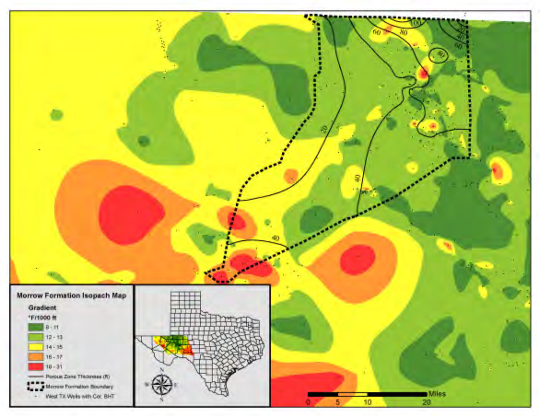


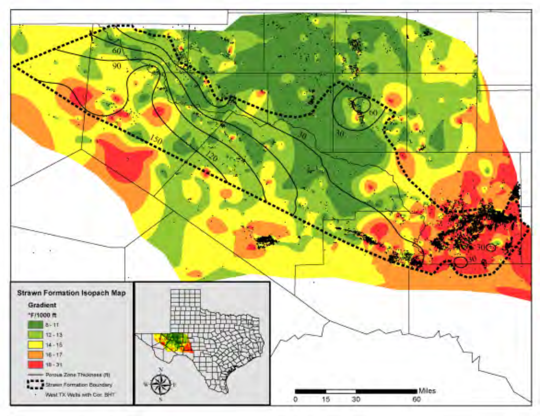






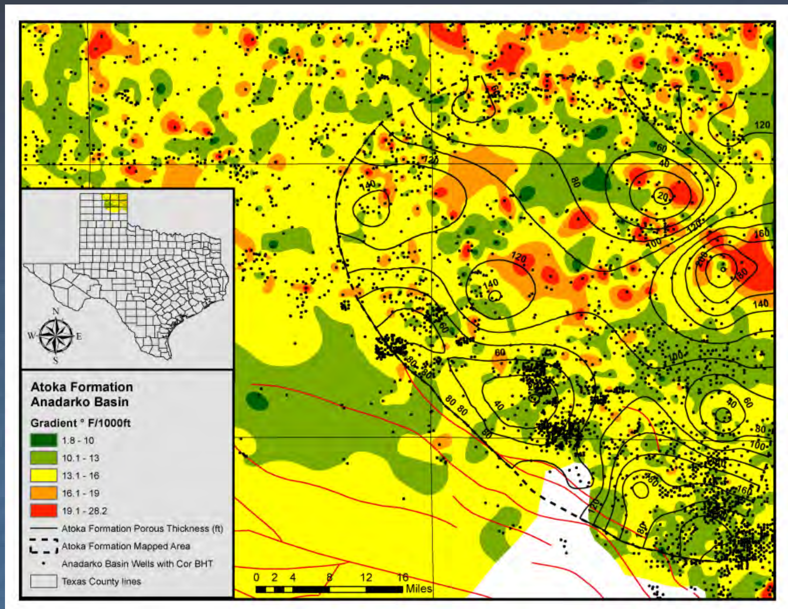


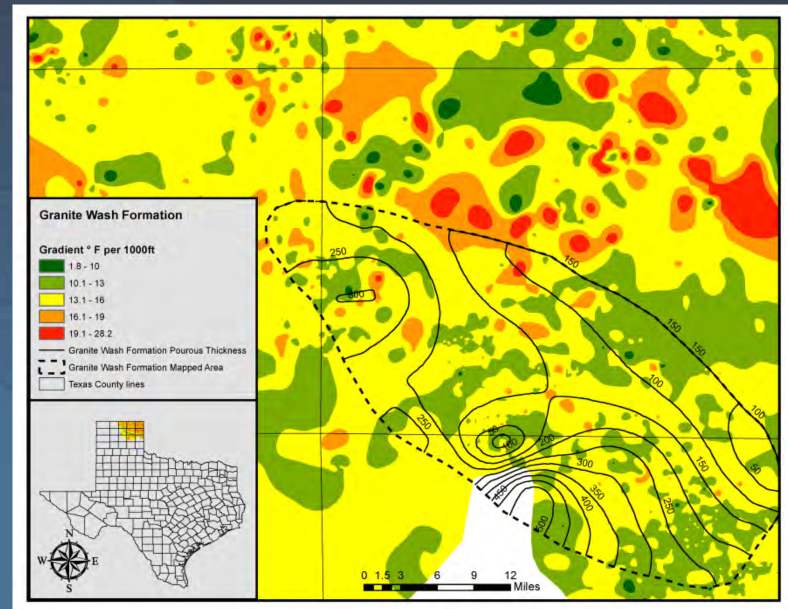


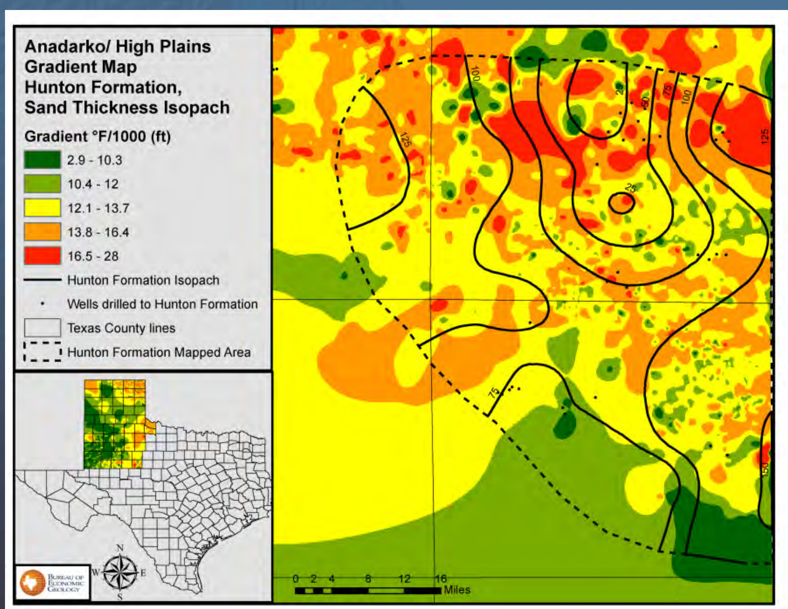


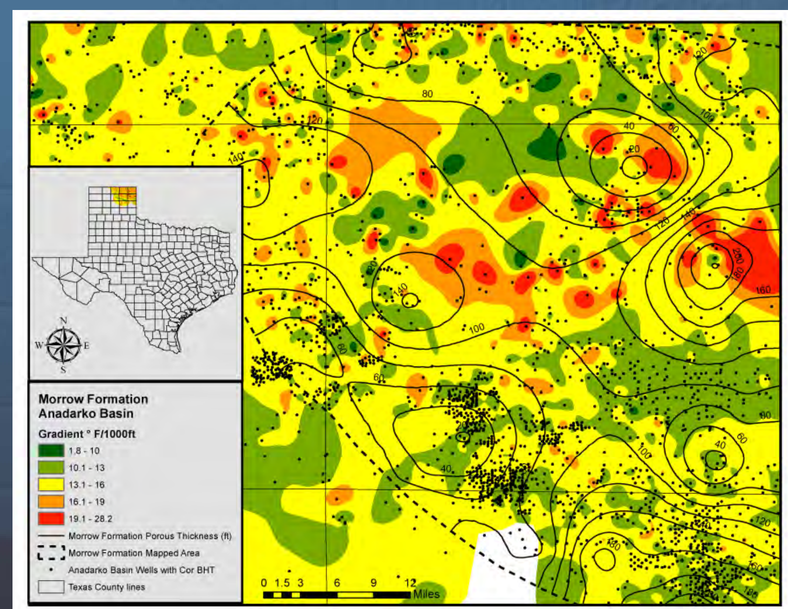
Additional Information for Atoka, Canyon, Devonian, Ellenburger, Fusselman, Montoya, Morrow Formations plus others

Anadarko Basin Formations









Selected example reservoir properties for Uddenberg model inputs

Initial Inputs Used in Matlab Model	Values	Units
Decision Variables		
Permeability	0.01	Darcies
Production	150000	kg/hr
Time	30	Years
Deltatemp	0.8	Percent temp change of fluid
Distance	5000	Meters between production and injection wells
...		
Intrinsic Properties		
Area	58058600	Square Meters
radius	4300	radius of reservoir in meters
Width	8600	meters
Length	5750	meters
radiuscasing	0.2	radius of casing in meters
height	45.72	Meters
...		
Initial Variable Values		
Pressure	36542213.7	Pa
Temperature	423	°K
Porosity	0.06	Decimal

Use of Existing Wells

- In Texas, the infrastructure for geothermal energy already exists in the form of pre-drilled wells, transmission lines, and resource-based knowledge.

Holes Plugged	2011	2010	2009
Oil	3,340	3,771	3,991
Gas	1,827	1,750	1,916
Other	394	493	464
Total	5,564	6,028	6,390

Latest Data from Railroad Commission (2012)	
Inactive Wells	41,123
Orphan Wells	5,892

From Texas RRC 2011 Drilling Summary:
http://www.rrc.state.tx.us/data/drilling/drillingsummary/2011/annual2011.pdf

- This acts as "low hanging fruit" for potential geothermal operations in Texas by reducing the drilling costs.

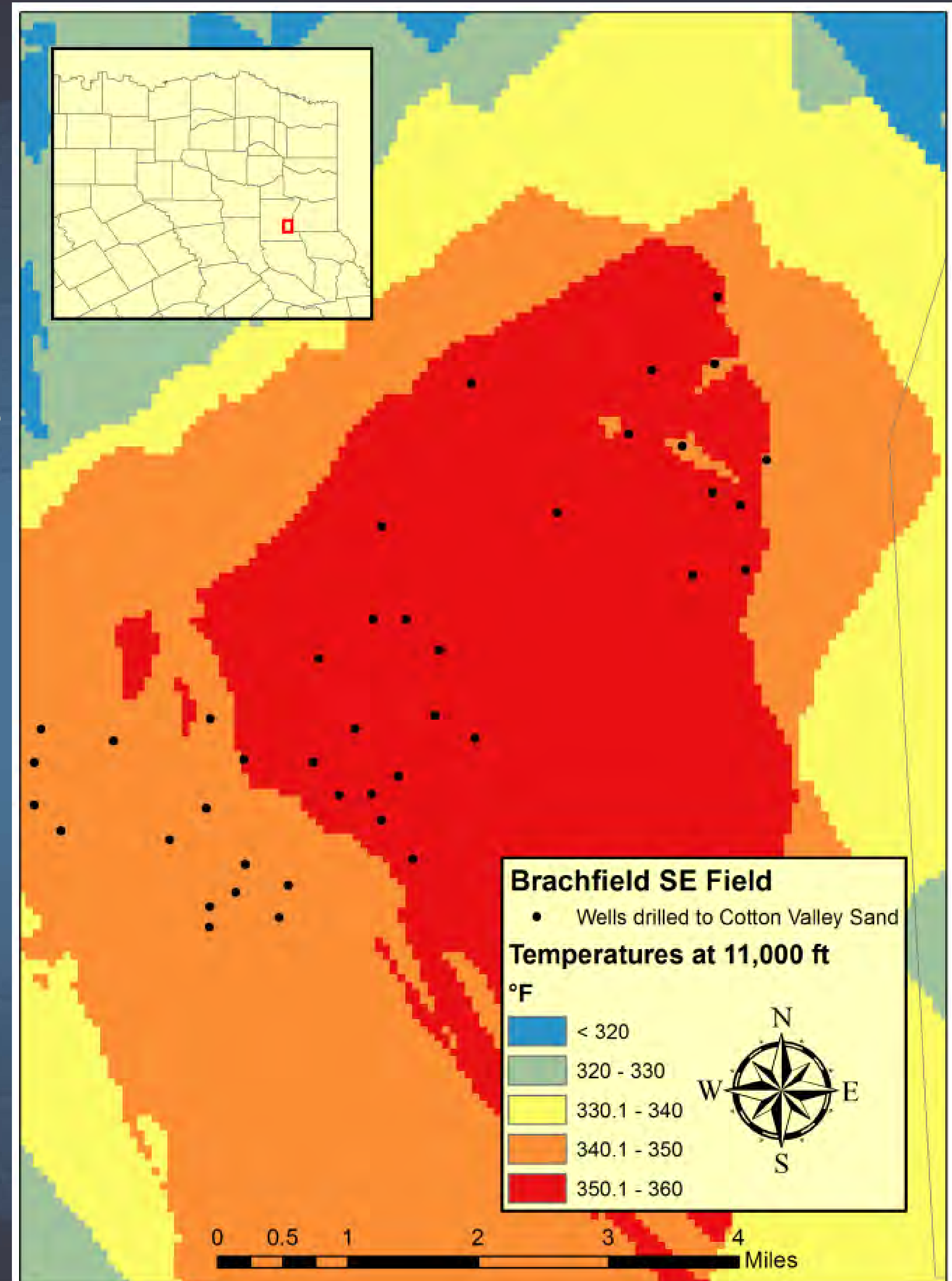
Cost Analysis

using as an example BrachField SE Field, Rusk County

Models

- GETEM Model
  - Geothermal cost model produced by the DOE
  - Takes into account flow rate, basic reservoir properties, life-cycle of equipment, and various development, exploration, and tax etc. costs.
  - Outputs cost in ¢/kw-hr, ideal power generation capacity, and annual costs and revenues.
- The Uddenberg (2012) Lumped Parameter Model
  - Designed to provide a rough estimate of production and injection well schemes to ensure the long-term sustainability of the thermal properties of a prospective reservoir.
  - Takes into account reservoir properties and distance between injection and production wells.
  - Assesses whether the scheme is sustainable before GETEM modeling with the flow rates and temperatures used.

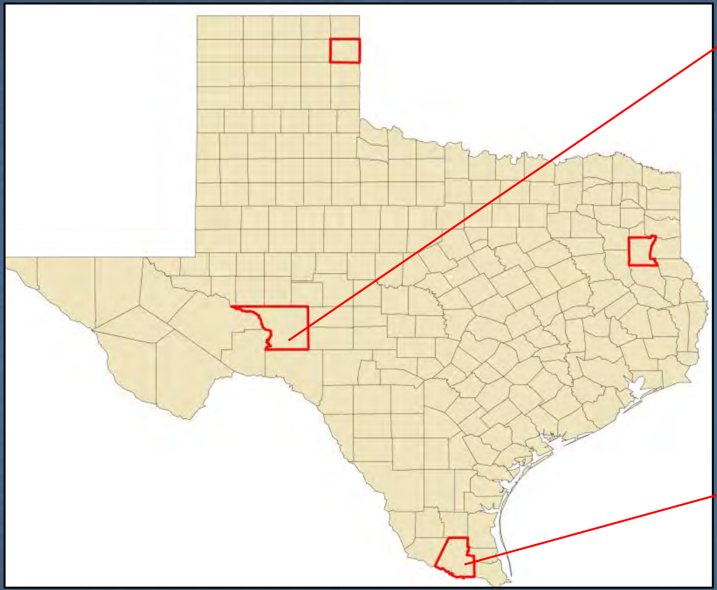
Brachfield SE Field, Rusk County, East TX



Example GETEM Estimates for LCOE and Generation Capacity

Brachfield Southeast Field, Rusk County (East Texas)			
Parameters/Results	Optimistic Case	Base Case	Conservative Case
Resource Temperature (°F)	360	345	330
Resource Depth (ft)	11,700	10,700	10,000
Production Well Flow Rate (gpm)	700 (24,000 bbls\day)	650 (22,285 bbls\day)	550 (18,857 bbls\day)
Number of Production Wells	5	4	3
LCOE (¢/kW-h)	**5.98**	**7.06**	**8.71**
Ideal Power Output (MW)	**11.37**	**8.53**	**5.96**

GETEM Estimates for LCOE



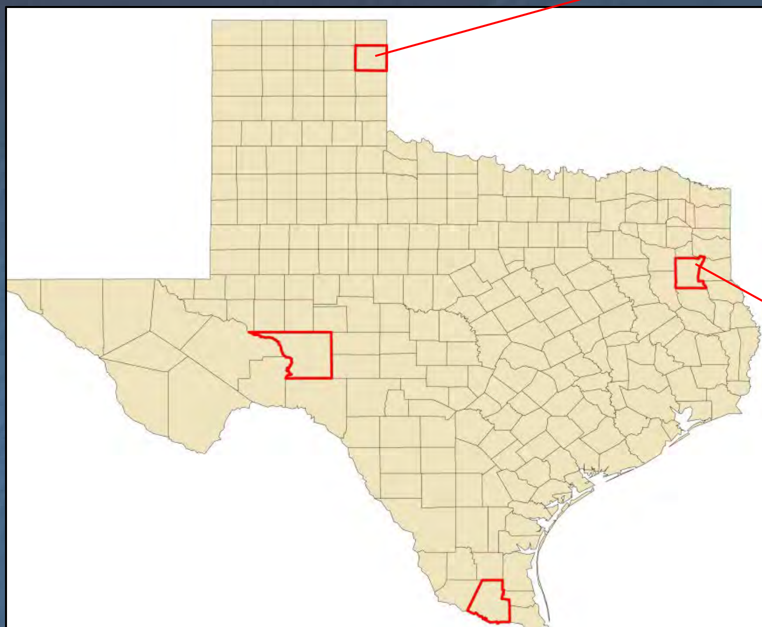
Will-O Field, Crockett County (West Texas)

Parameters/Results	Optimistic Case	Base Case	Conservative Case
Resource Temperature (°F)	340	325	310
Resource Depth (ft)	14,700	14,000	11,500
Production Well Flow Rate (gpm)	700	600	600
Number of Production Wells	5	4	3
LCOE (¢/kW-h)	6.65	8.4	10.256
Ideal Power Output (MW)	11.52	7.98	6.04

South Hidalgo Fairway, Hidalgo County (Gulf Coast)

Parameters/Results	Optimistic Case	Base Case	Conservative Case
Resource Temperature (°F)	375	350	300
Resource Depth (ft)	12,000	10,500	9,000
Production Well Flow Rate (gpm)	700	650	550
Number of Production Wells	5	4	3
LCOE (¢/kW-h)	5.28	6.52	10.34
Ideal Power Output (MW)	11.34	5.57	4.79

GETEM Estimates for LCOE



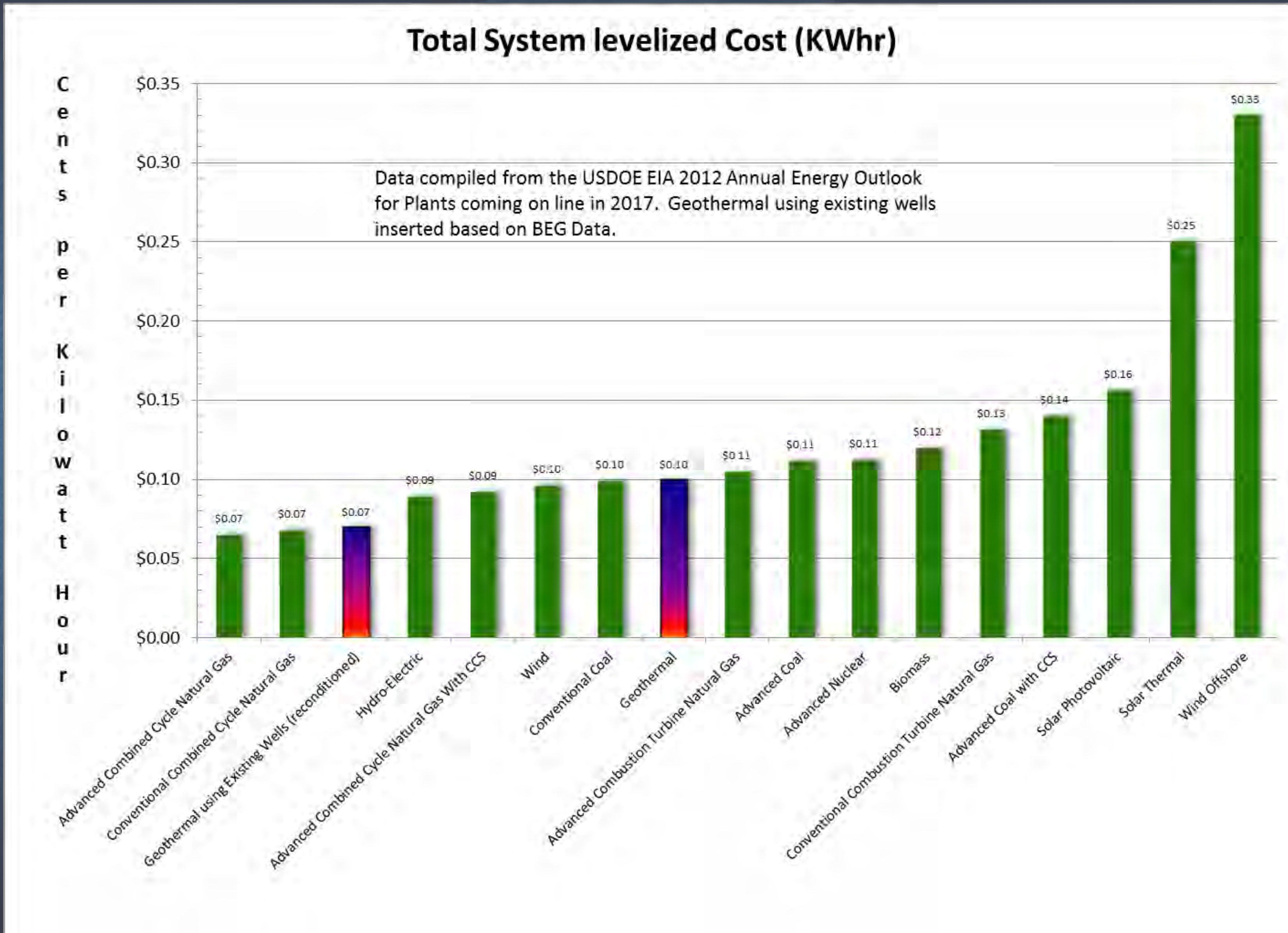
Mathers Ranch Field, Hemphill County (Anadarko Basin)

Parameters/Results	Optimistic Case	Base Case	Conservative Case
Resource Temperature (°F)	350	325	300
Resource Depth (ft)	17000	17,000	16,500
Production Well Flow Rate (gpm)	700	650	550
Number of Production Wells	5	4	3
LCOE (¢/kW-h)	6.34	8.46	11.11
Ideal Power Output (MW)	11.54	8.71	4.79

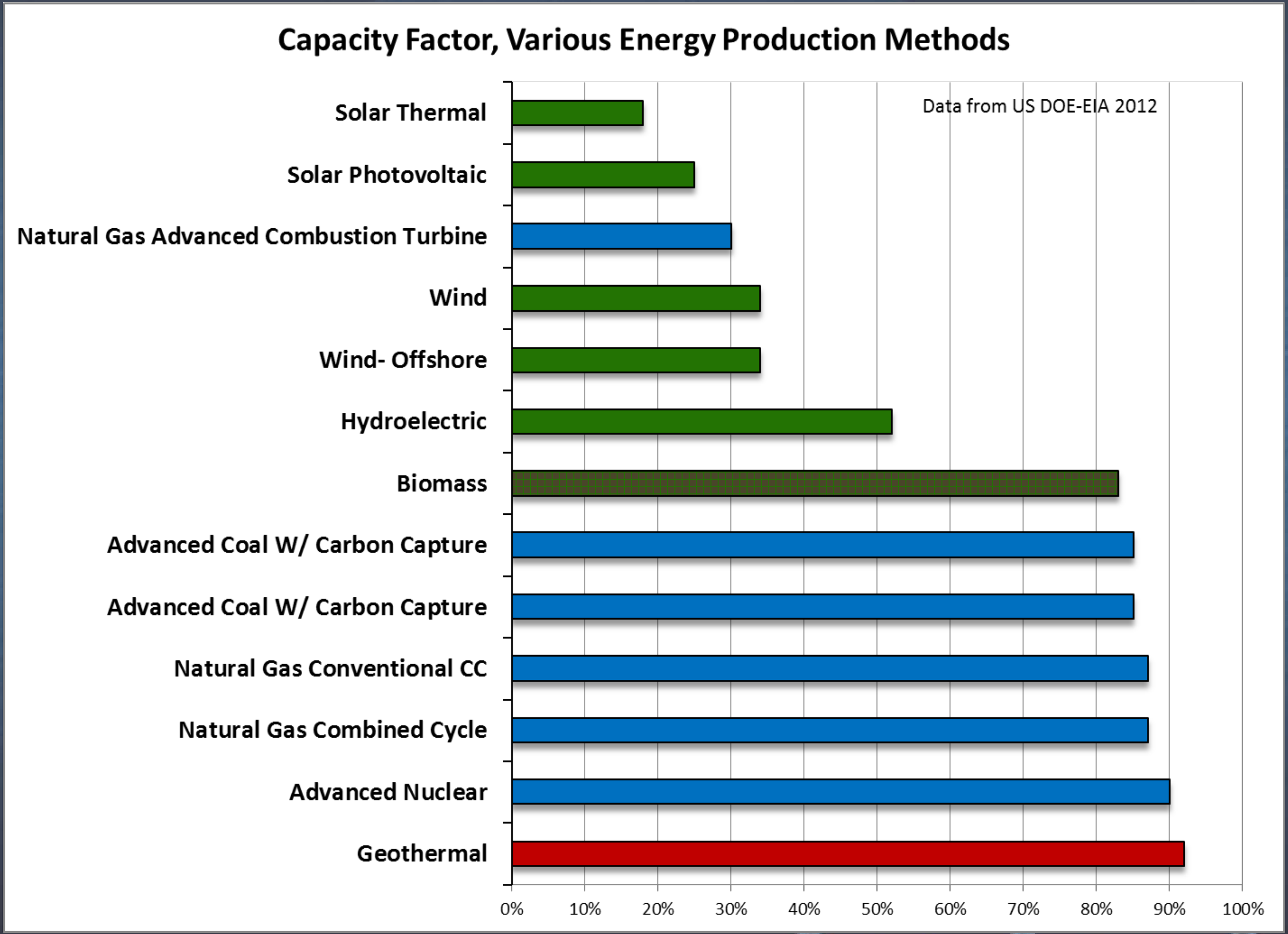
Brachfield Southeast Field, Rusk County (East Texas)

Parameters/Results	Optimistic Case	Base Case	Conservative Case
Resource Temperature (°F)	360	345	330
Resource Depth (ft)	11700	10,700	10,000
Production Well Flow Rate (gpm)	700	650	550
Number of Production Wells	5	4	3
LCOE (¢/kW-h)	5.98	7.06	8.71
Ideal Power Output (MW)	11.37	8.53	5.96

Summary Results of US DOE EIA Cost Data for Energy Production Methods



GEOTHERMAL OPPORTUNITIES



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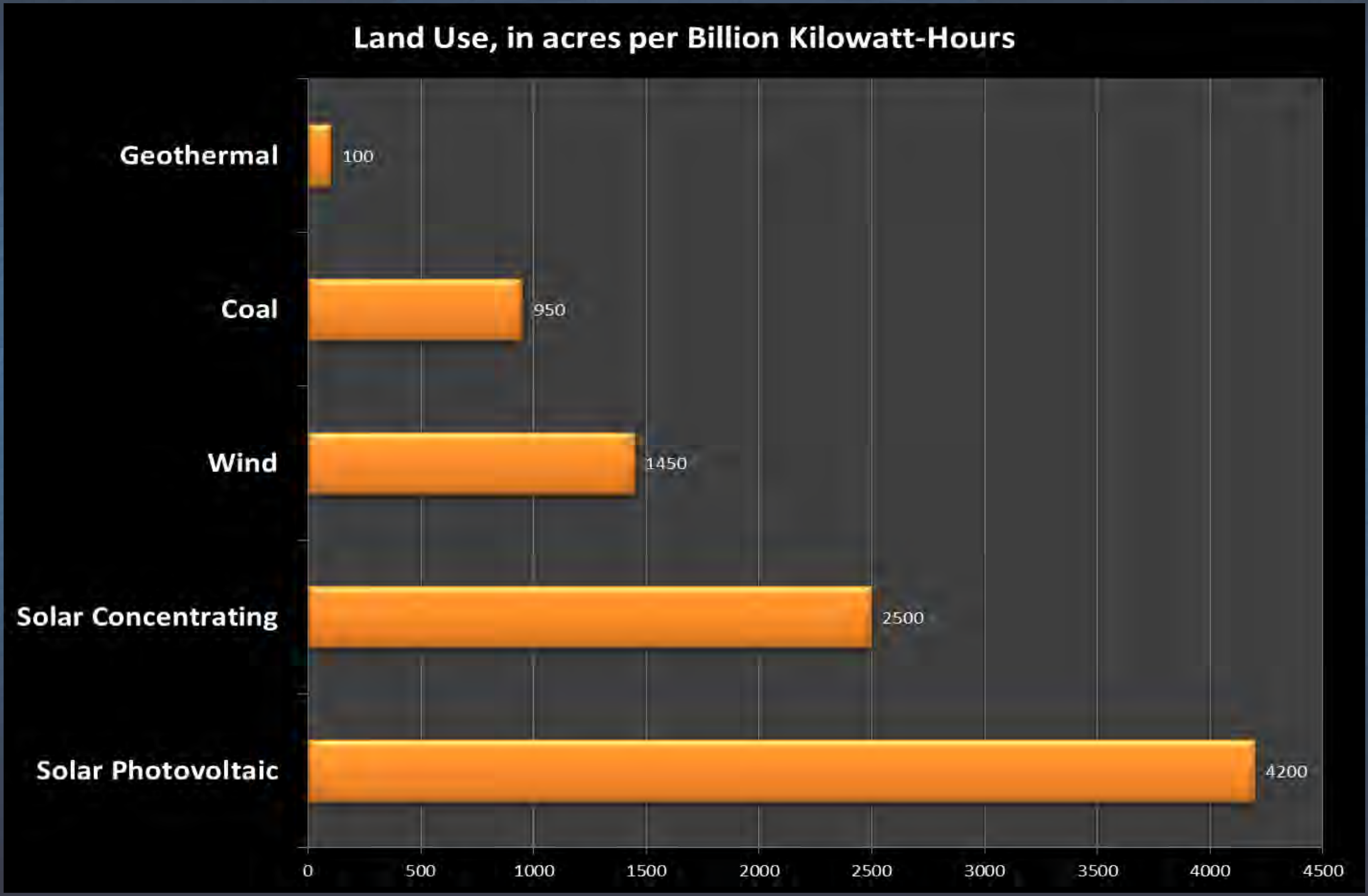
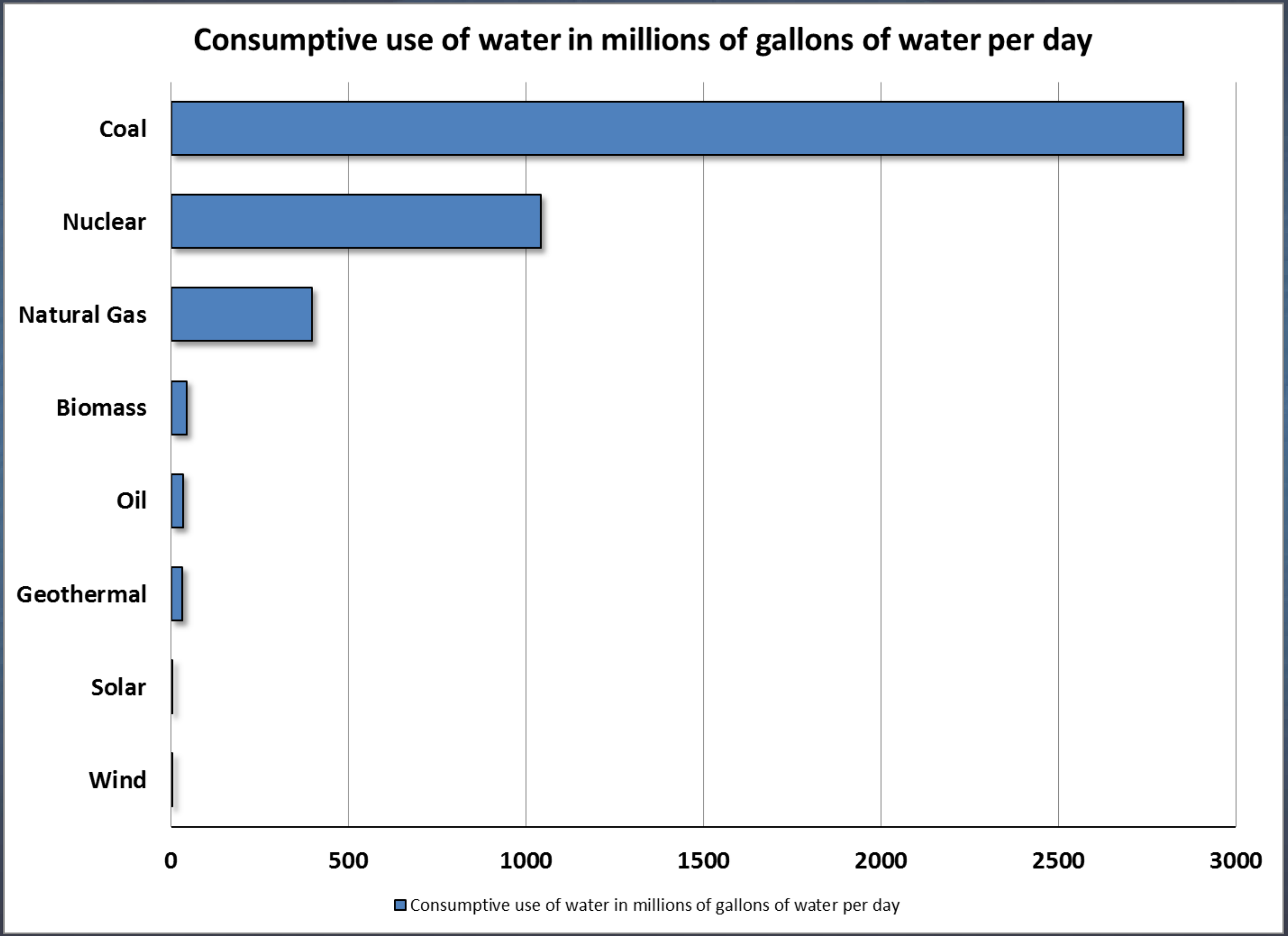
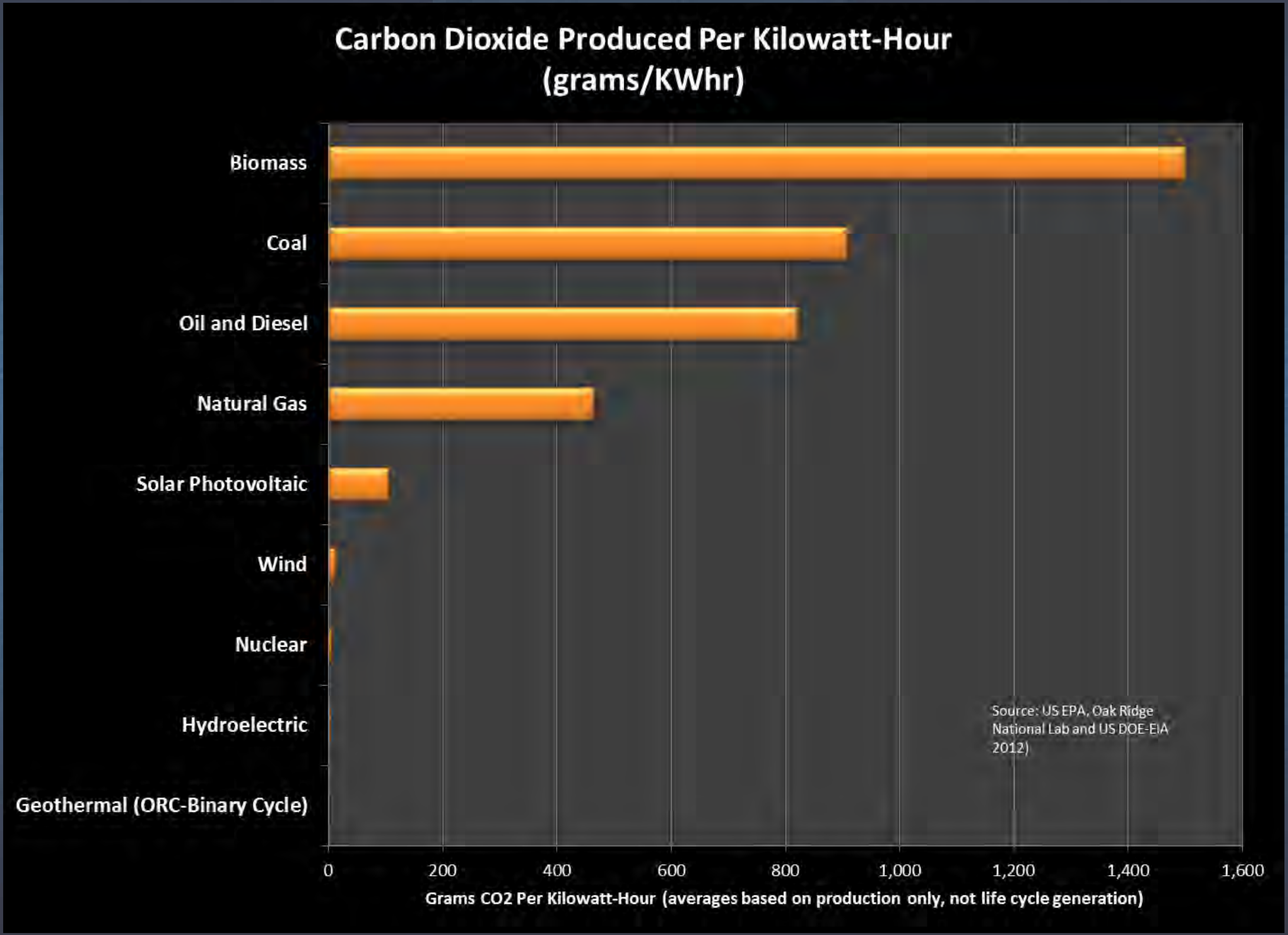
GEOTHERMAL OPPORTUNITIES



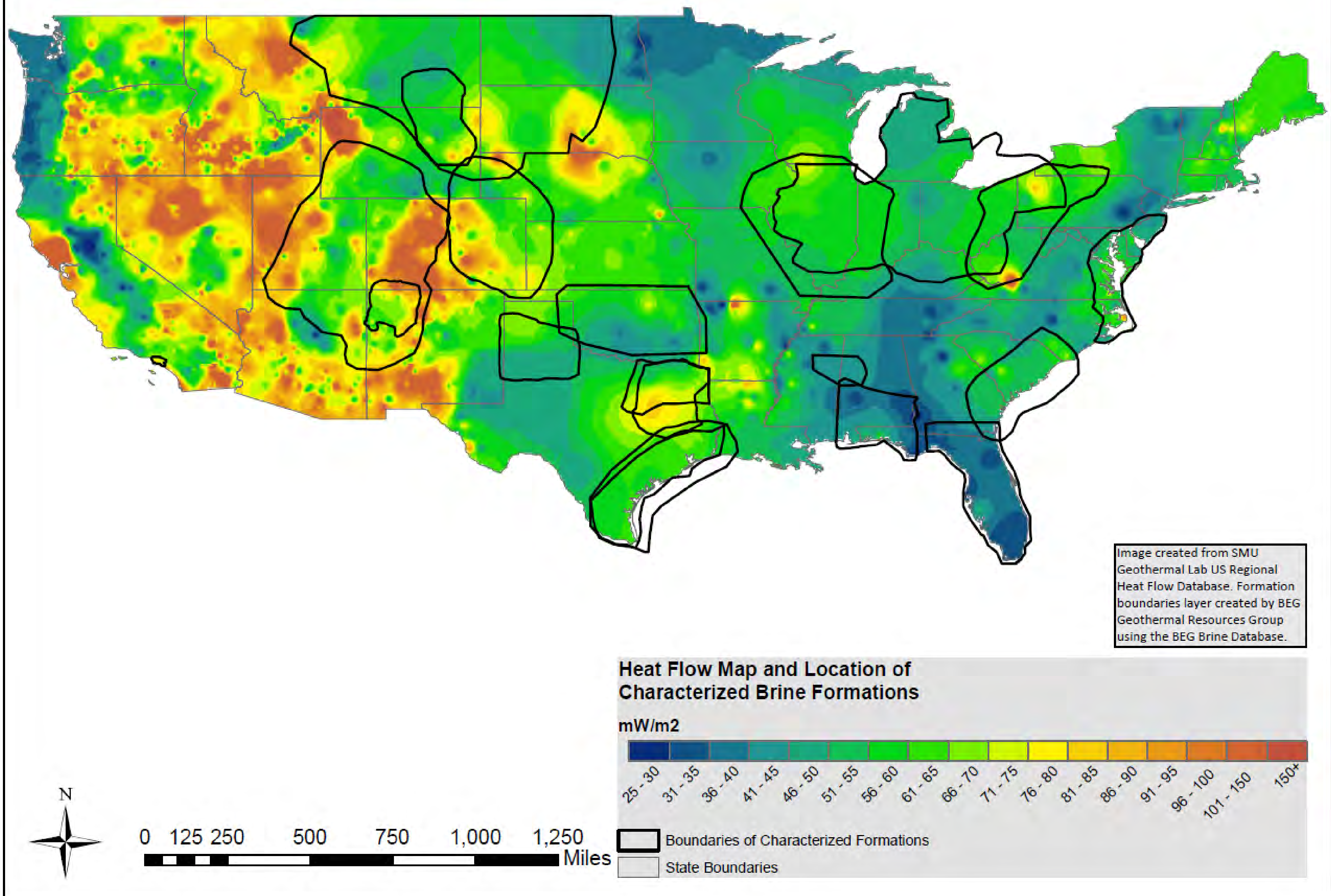
GEOTHERMAL OPPORTUNITIES



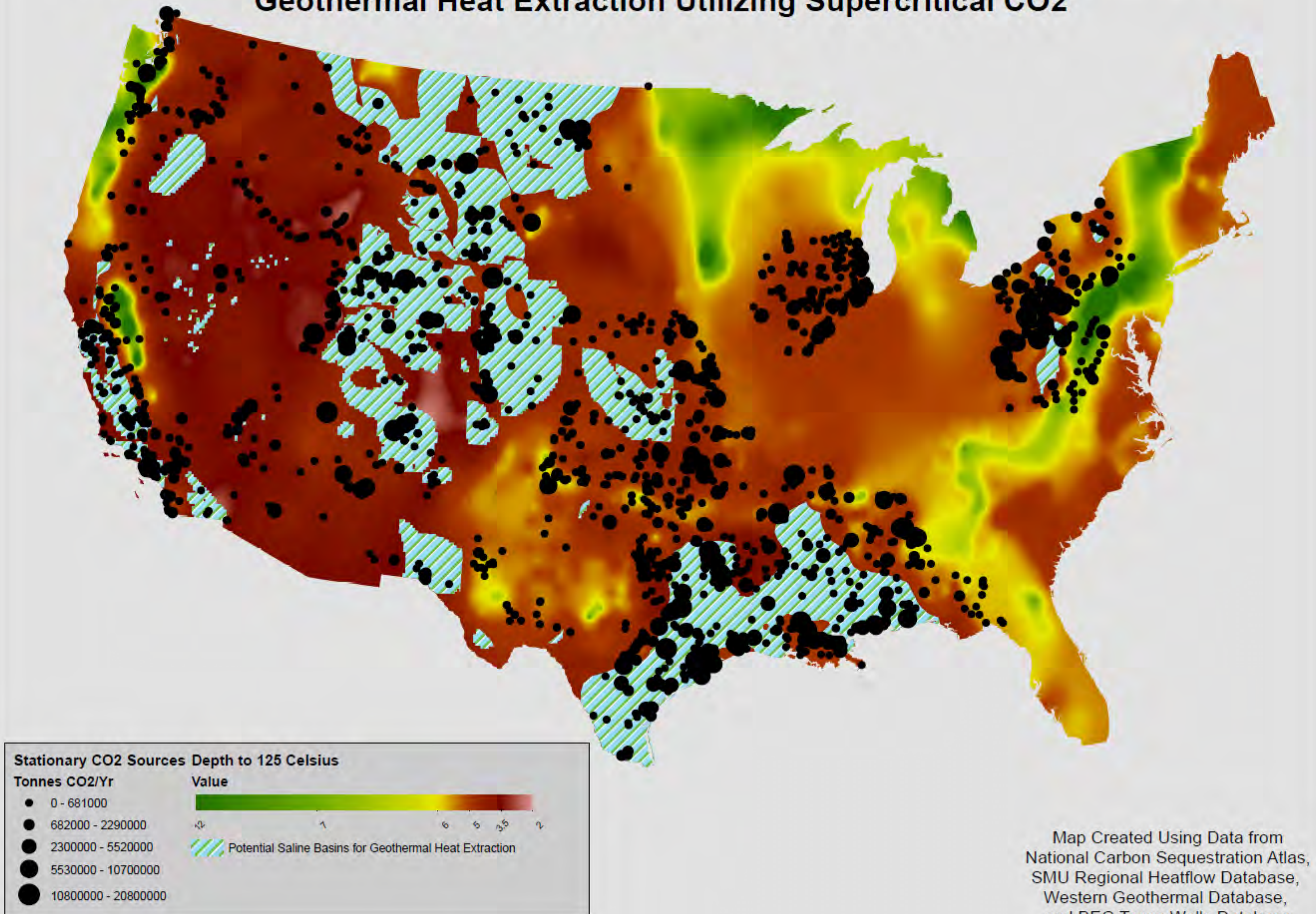
GEOTHERMAL OPPORTUNITIES



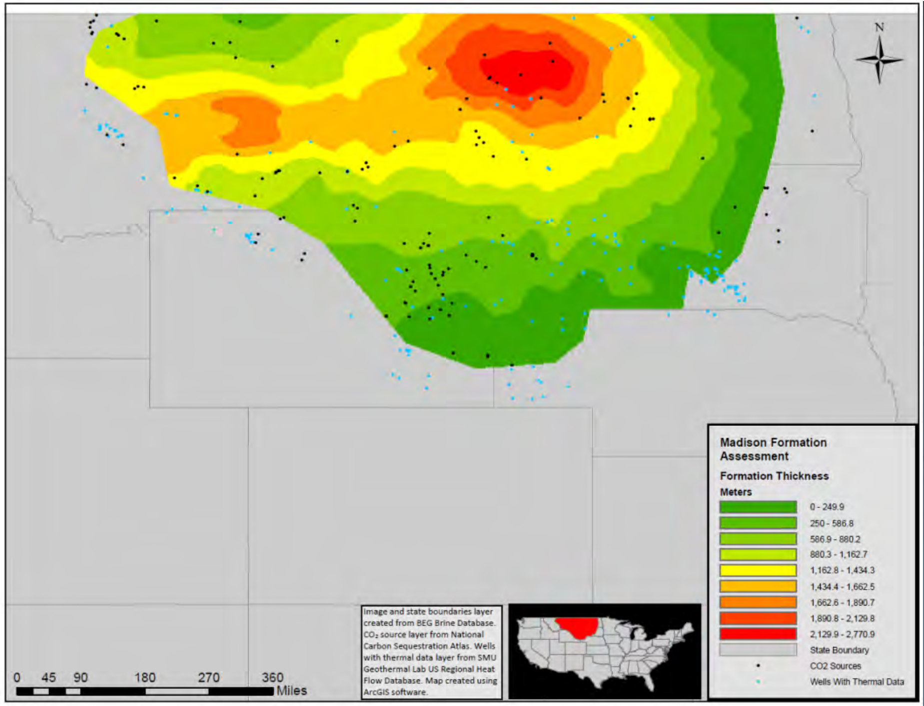
Other information available

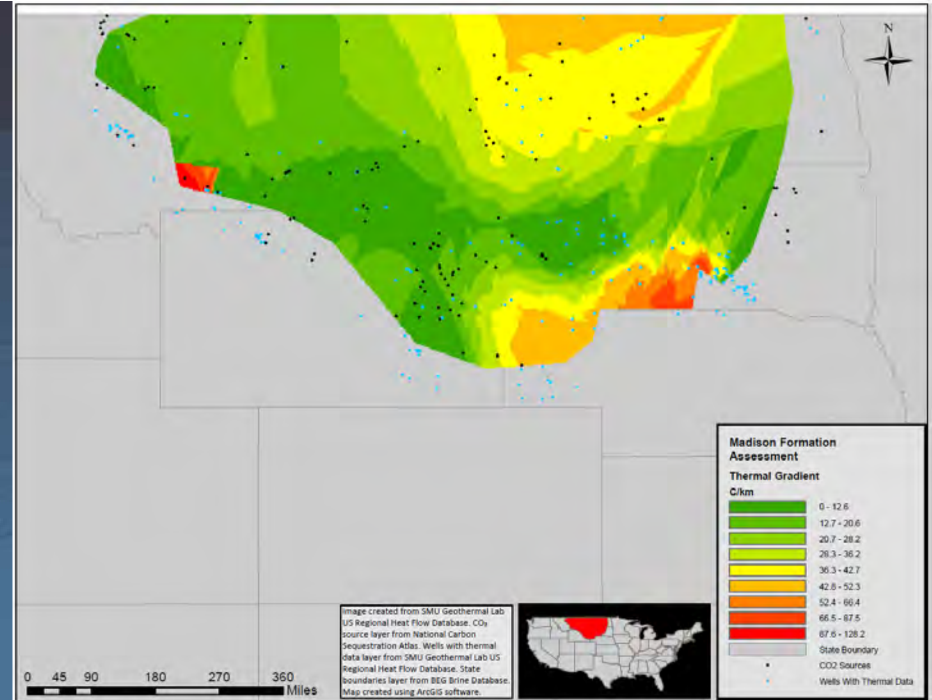


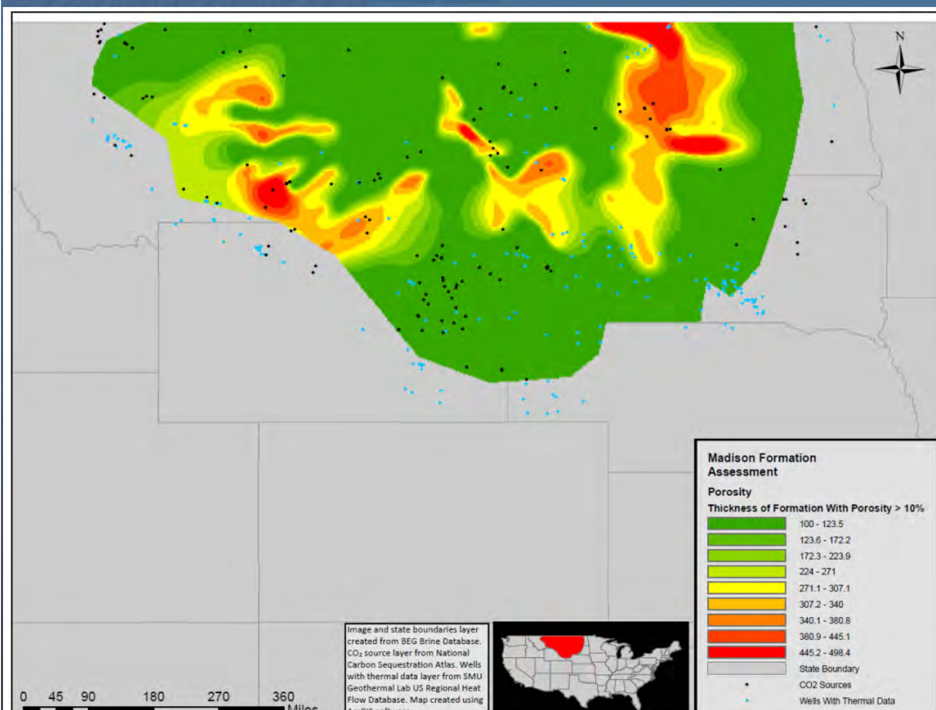
Stationary CO2 Sources in the Regions of Potential Onshore Saline Basins for Geothermal Heat Extraction Utilizing Supercritical CO2

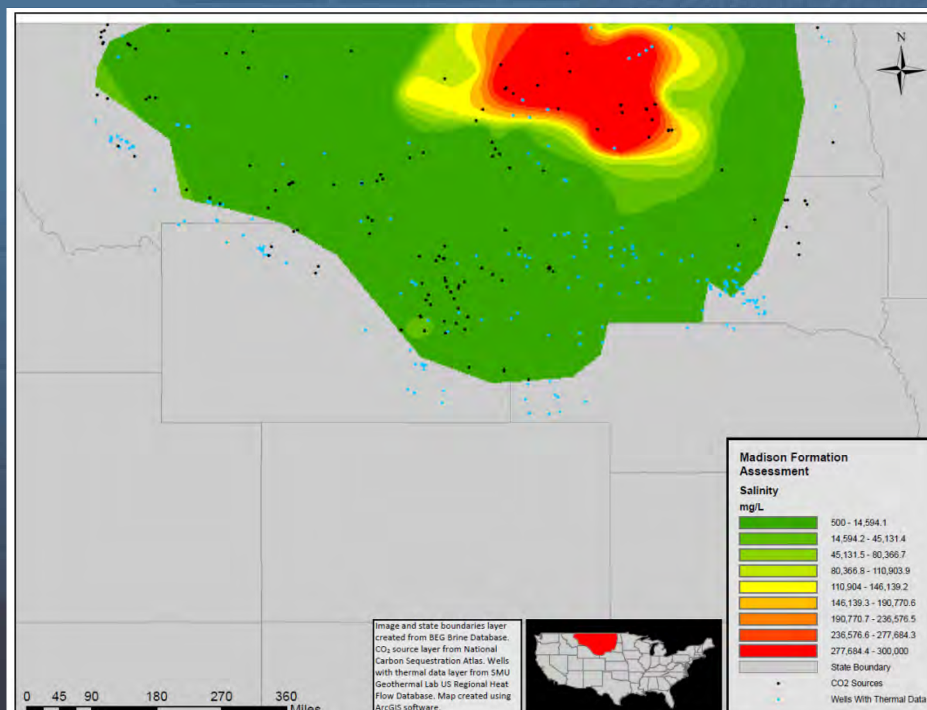


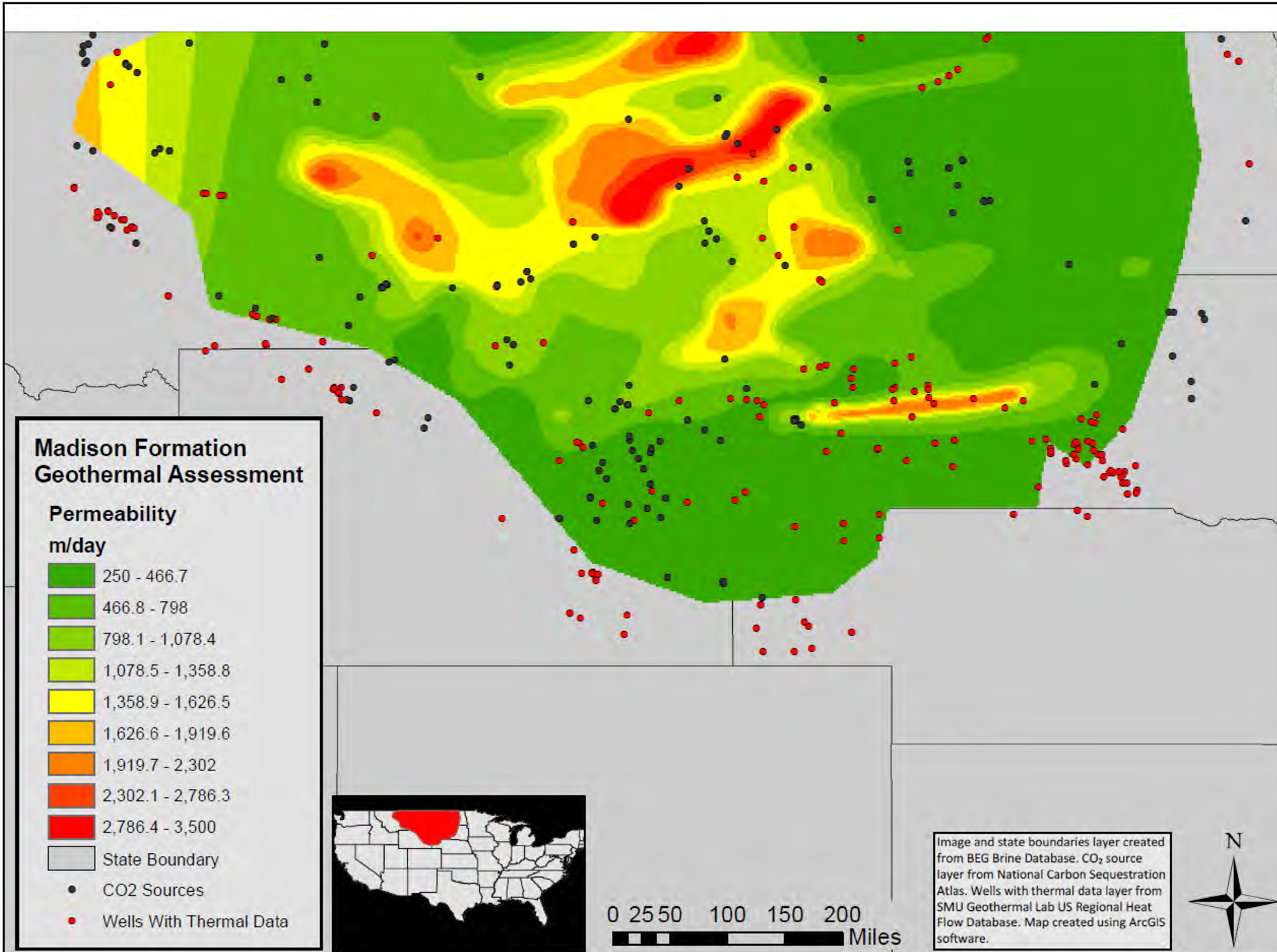
Map Created Using Data from National Carbon Sequestration Atlas, SMU Regional Heatflow Database, Western Geothermal Database, and BEG Texas Wells Database

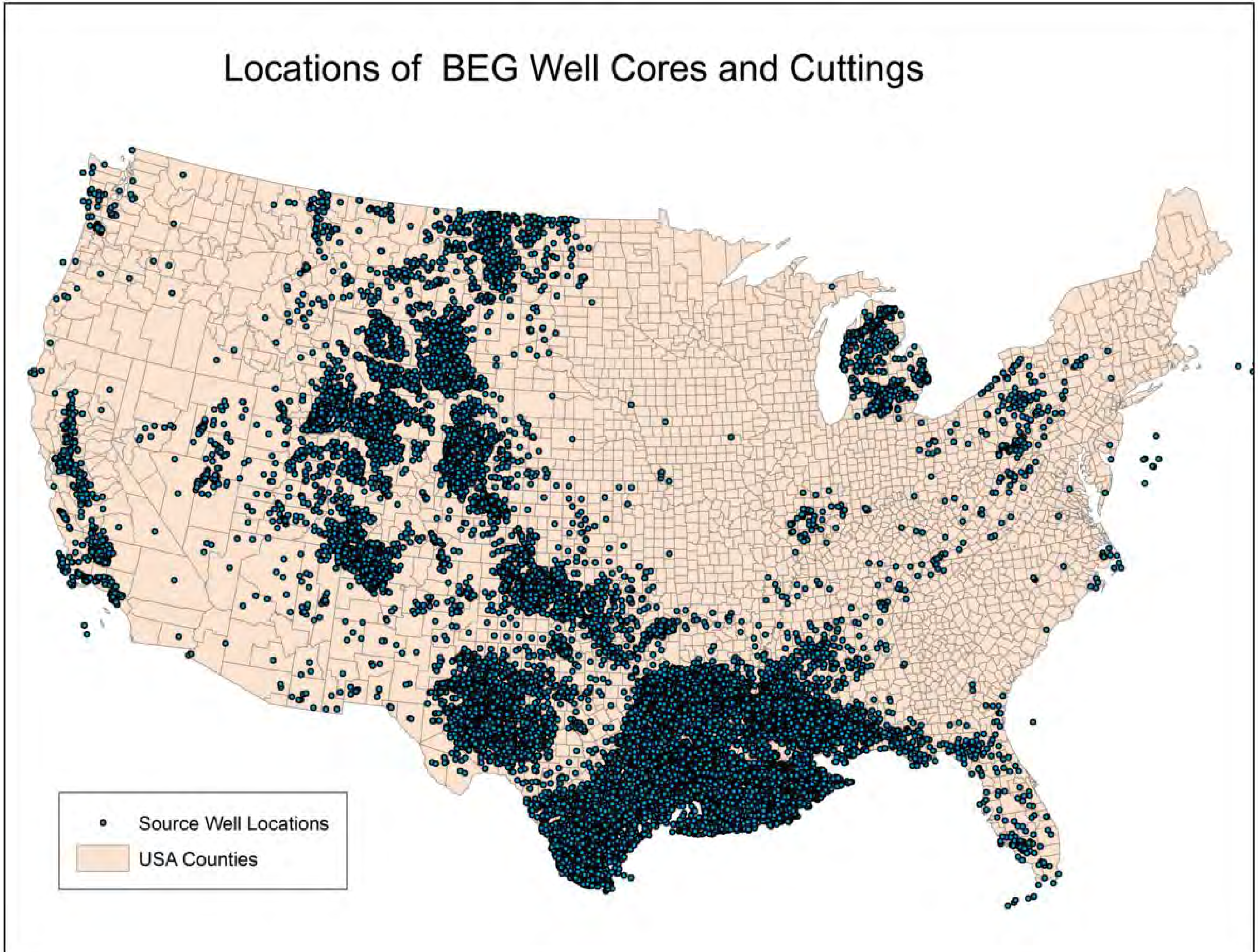

Madison Formation Assessment
Formation Thickness
Meters
0 - 249.9
250 - 586.8
586.9 - 880.2
880.3 - 1,162.7
1,162.8 - 1,434.3
1,434.4 - 1,662.5
1,662.6 - 1,890.7
1,890.8 - 2,129.8
2,129.9 - 2,770.9
State Boundary
CO2 Sources
Wells With Thermal Data
Image and state boundaries layer created from BEG Brine Database. CO₂ source layer from National Carbon Sequestration Atlas. Wells with thermal data layer from SMU Geothermal Lab US Regional Heat Flow Database. Map created using ArcGIS software.
0 45 90 180 270 360 Miles
N

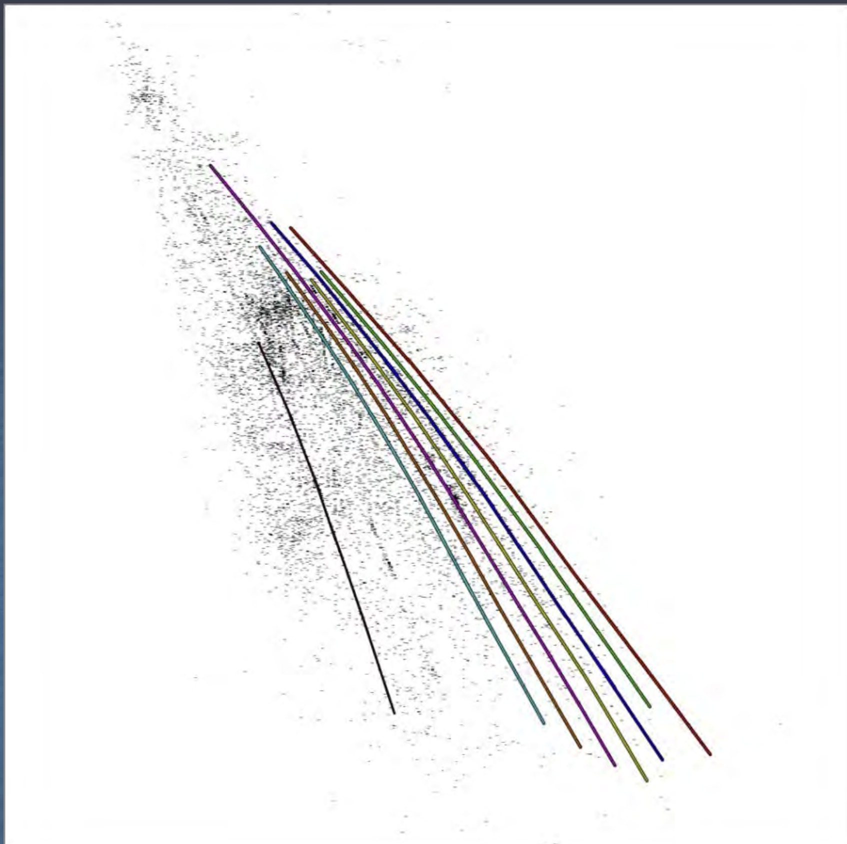

Madison Formation Assessment
Thermal Gradient
C/km
0 - 12.6
12.7 - 20.6
20.7 - 28.2
28.3 - 36.2
36.3 - 42.7
42.8 - 52.3
52.4 - 66.4
66.5 - 87.5
87.6 - 128.2
State Boundary
CO2 Sources
Wells With Thermal Data
Image created from SMU Geothermal Lab US Regional Heat Flow Database. CO₂ source layer from National Carbon Sequestration Atlas. Wells with thermal data layer from SMU Geothermal Lab US Regional Heat Flow Database. State boundaries layer from BEG Brine Database. Map created using ArcGIS software.
0 45 90 180 270 360 Miles
N

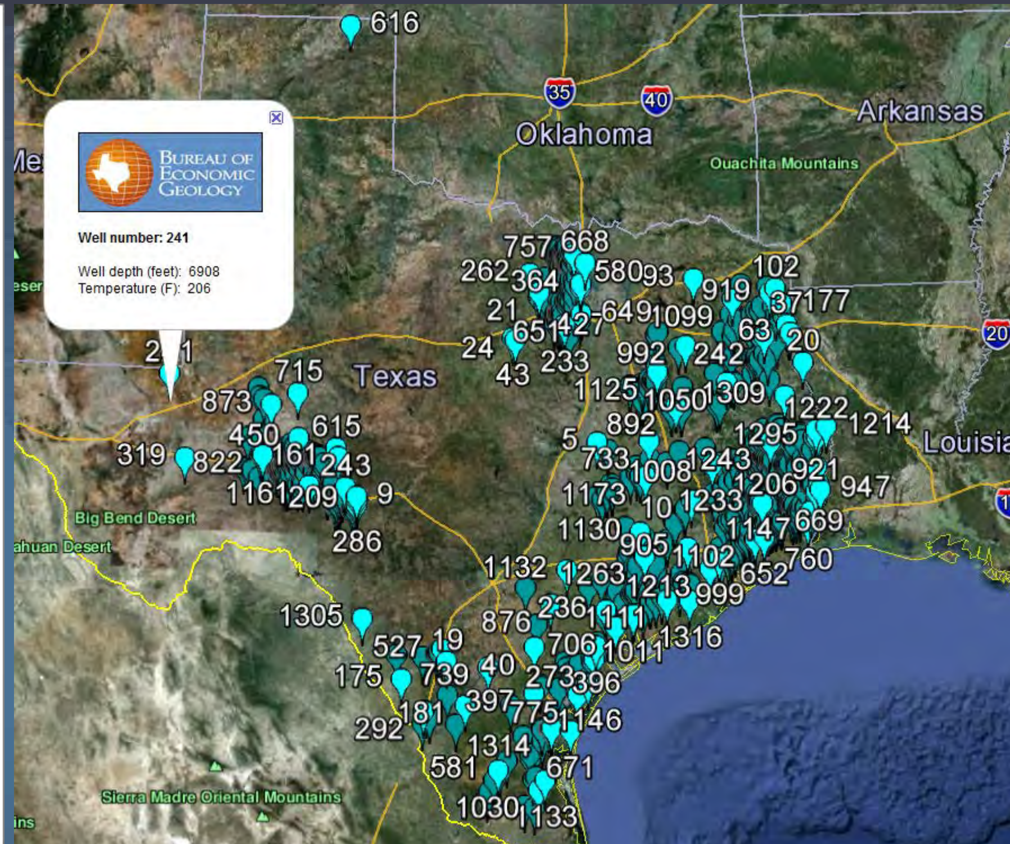

Madison Formation Assessment
Porosity
Thickness of Formation With Porosity > 10%
100 - 123.5
123.6 - 172.2
172.3 - 223.9
224 - 271
271.1 - 307.1
307.2 - 340
340.1 - 380.8
380.9 - 445.1
445.2 - 498.4
State Boundary
CO2 Sources
Wells With Thermal Data
Image and state boundaries layer created from BEG Brine Database. CO₂ source layer from National Carbon Sequestration Atlas. Wells with thermal data layer from SMU Geothermal Lab US Regional Heat Flow Database. Map created using ArcGIS software.
0 45 90 180 270 360 Miles
N


Madison Formation Assessment
Salinity
mg/L
500 - 14,594.1
14,594.2 - 45,131.4
45,131.5 - 80,366.7
80,366.8 - 110,903.9
110,904 - 146,139.2
146,139.3 - 190,770.6
190,770.7 - 236,576.5
236,576.6 - 277,684.3
277,684.4 - 300,000
State Boundary
CO2 Sources
Wells With Thermal Data
Image and state boundaries layer created from BEG Brine Database. CO₂ source layer from National Carbon Sequestration Atlas. Wells with thermal data layer from SMU Geothermal Lab US Regional Heat Flow Database. Map created using ArcGIS software.
0 45 90 180 270 360 Miles
N


Madison Formation
Geothermal Assessment
Permeability
m/day
250 - 466.7
466.8 - 798
798.1 - 1,078.4
1,078.5 - 1,358.8
1,358.9 - 1,626.5
1,626.6 - 1,919.6
1,919.7 - 2,302
2,302.1 - 2,786.3
2,786.4 - 3,500
State Boundary
CO2 Sources
Wells With Thermal Data
0 25 50 100 150 200
Miles
Image and state boundaries layer created from BEG Brine Database. CO₂ source layer from National Carbon Sequestration Atlas. Wells with thermal data layer from SMU Geothermal Lab US Regional Heat Flow Database. Map created using ArcGIS software.
N


Locations of BEG Well Cores and Cuttings
Source Well Locations
USA Counties



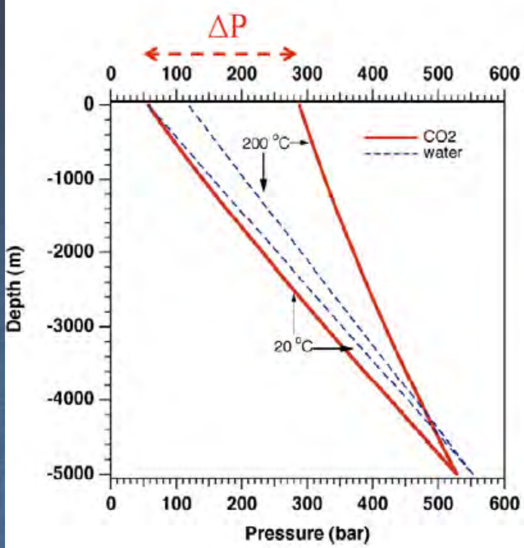


http://www.beg.utexas.edu/temp/bruce2/

http://igor.beg.utexas.edu/geothermalmap3/

Example of Bureau of Economic Geology web page under development, but soon to be accessible to the general public

Wellbore Flow: CO_2 vs. Water



Pressure difference between production and injection well

CO_2: 288.1 - 57.4 = 230.7 bar

water: 118.6 - 57.4 = 61.2 bar

CO_2 generates much larger pressures in production well, facilitating fluid circulation.

- Need a mass flow of approximately 20 tons of CO_2 per second, per GW electric power capacity.
- Expect a fluid loss rate of order 5%, or **1 ton per second of CO_2 per GW** of installed EGS capacity.
- This is equivalent to **CO_2 emissions from 3 GW** of coal-fired power generation.
- The MIT report (2006) projects 100 GW of EGS electric power by 2050.
- 100 GW of EGS with CO_2 would **store 3.2 Gt/yr** of CO_2, approximately **40 % of total current U.S. emissions**.

What can be done to address Hot, but Low permeability environments that, absent sufficient permeability, would be productive Geothermal Reservoirs?

- Formation Stimulation; i.e., Fracking, or
- Alternate Heat Mining Fluid; i.e., Supercritical Carbon Dioxide.

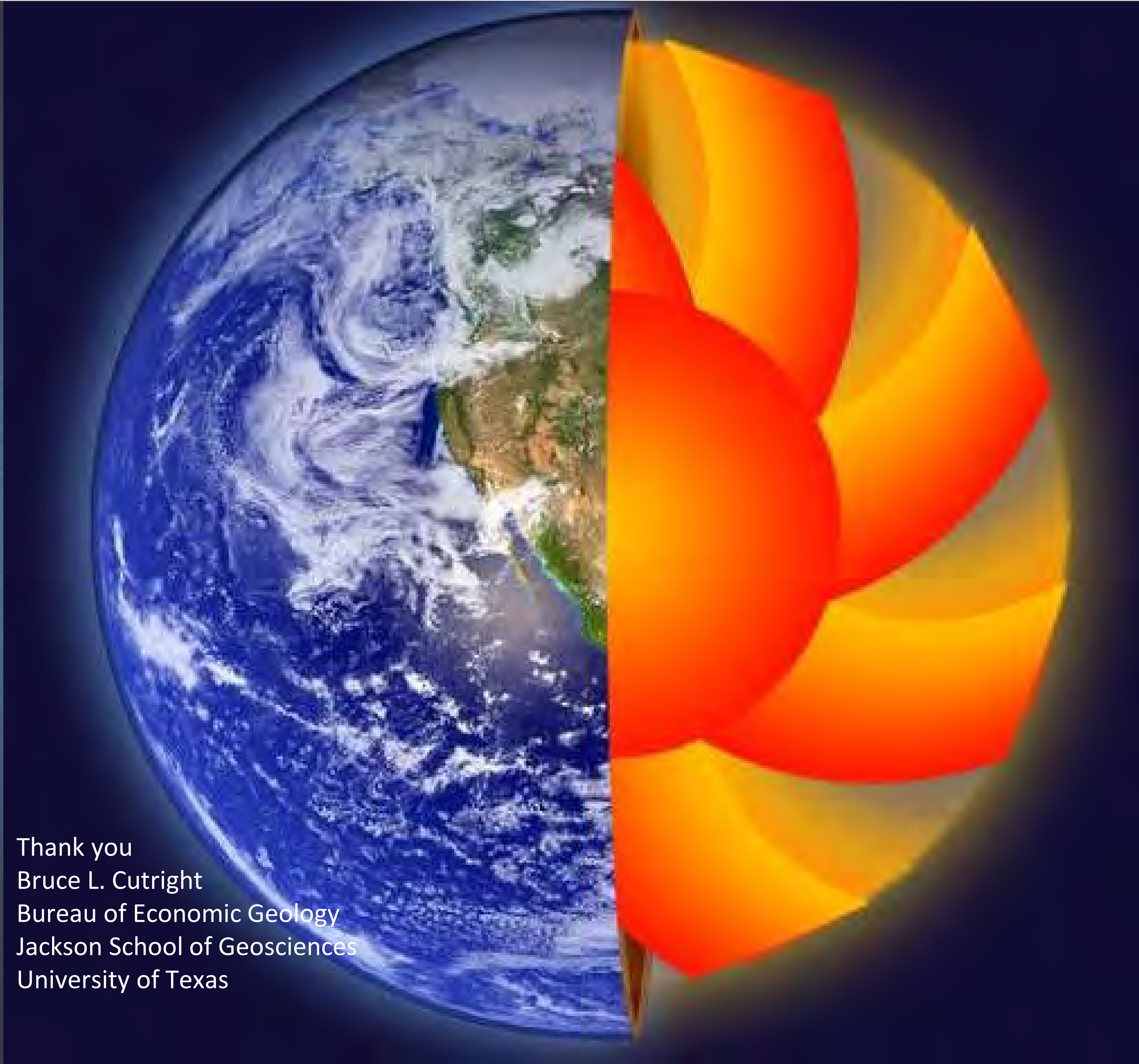
From Research Prof. Karsten Pruess, Lawrence Berkeley National Laboratory, Presented at the SMU 2008 Conference June, 2008






We have choices, each with advantages and disadvantages

Bureau of Economic Geology



Thank you

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University of Texas