What Are We Missing in Developing Geothermal Reservoirs?

Engineered Geothermal Reservoirs, A Continuum of Opportunities

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- A commercially productive geothermal reservoir requires:
  - In situ permeability greater than 100mD, preferred 1,000 mD or more.
  - Reservoir Volume, sufficient to support long term production of fluid without constant re-investment of new wells or significant produced fluid temperature declines. (early Gulf Coast investigations estimated 3 cubic miles required, reservoir life should be greater than 20 years)
  - Produced fluid temperatures should exceed 300 degrees F, 150 degrees C.
- All in cost of production (LCOE) should be equal to or less than prevailing retail price of electricity in the project area. Baseload capability, zero emissions, small footprint provide opportunities for a premium to be included in the price of power.

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- Engineered geothermal systems represent a departure from passive capture of a thermal resource to active modification and creation of a reservoir having a value greater than the cost to create, capture and produce it.

- The commodity produced is thermal energy which is converted to primary electrical energy.

- EGS requires the application of sophisticated science, engineering and money to produce a commercial product that is competitive with other power production methods where otherwise, an economically competitive project would not be possible.

- The technological improvements arising from the Shale Gas Revolution have not been transferred to the geothermal industry.
- The geotechnical engineering of hydrofracturing and formation stimulation is still evolving, and is not completely predictive.
- The economics of power generation using EGS have not been clearly defined, but based on existing drilling and formation data, it is time to move toward (EXPAND) the opportunities for commercialization.

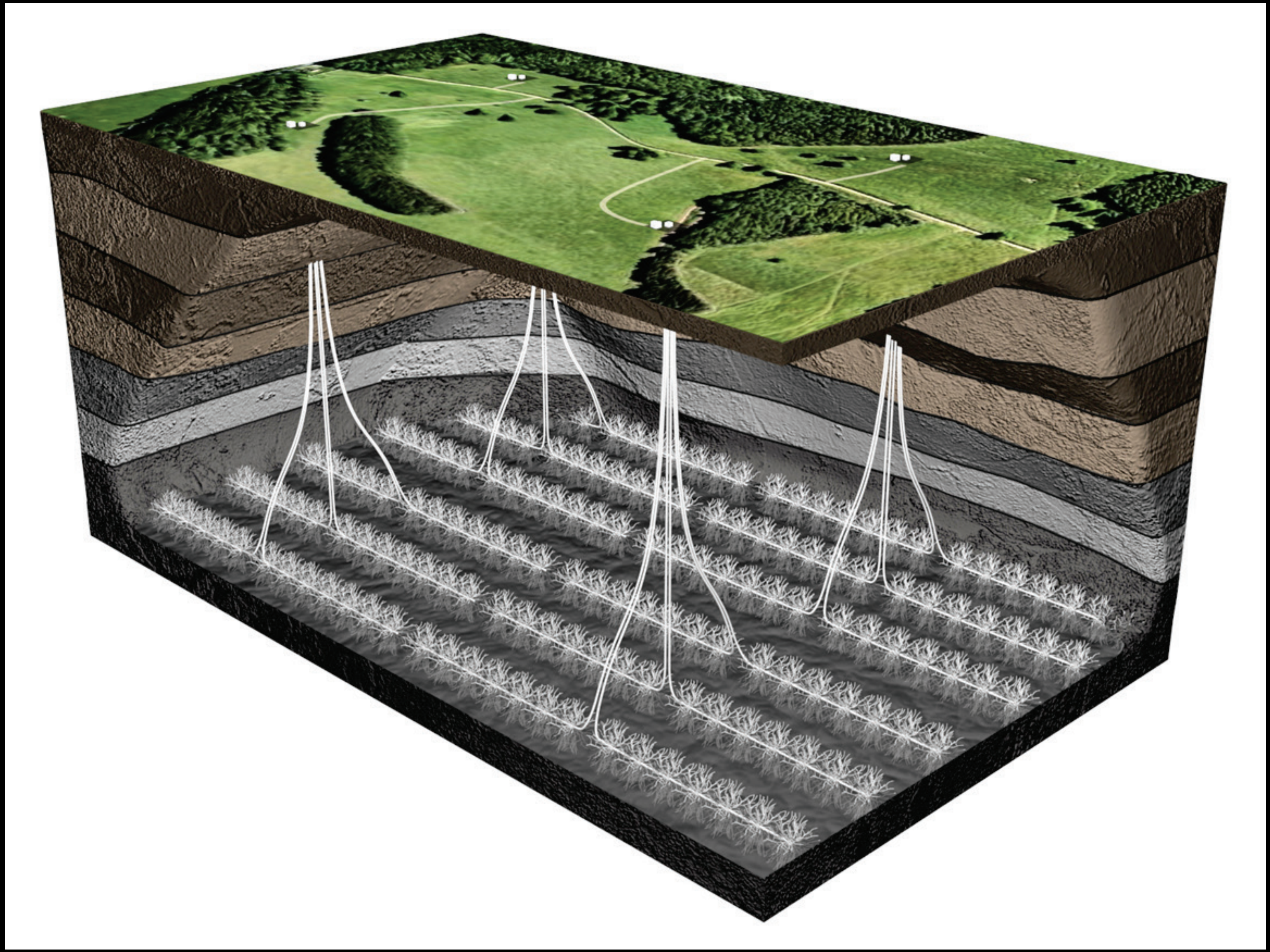
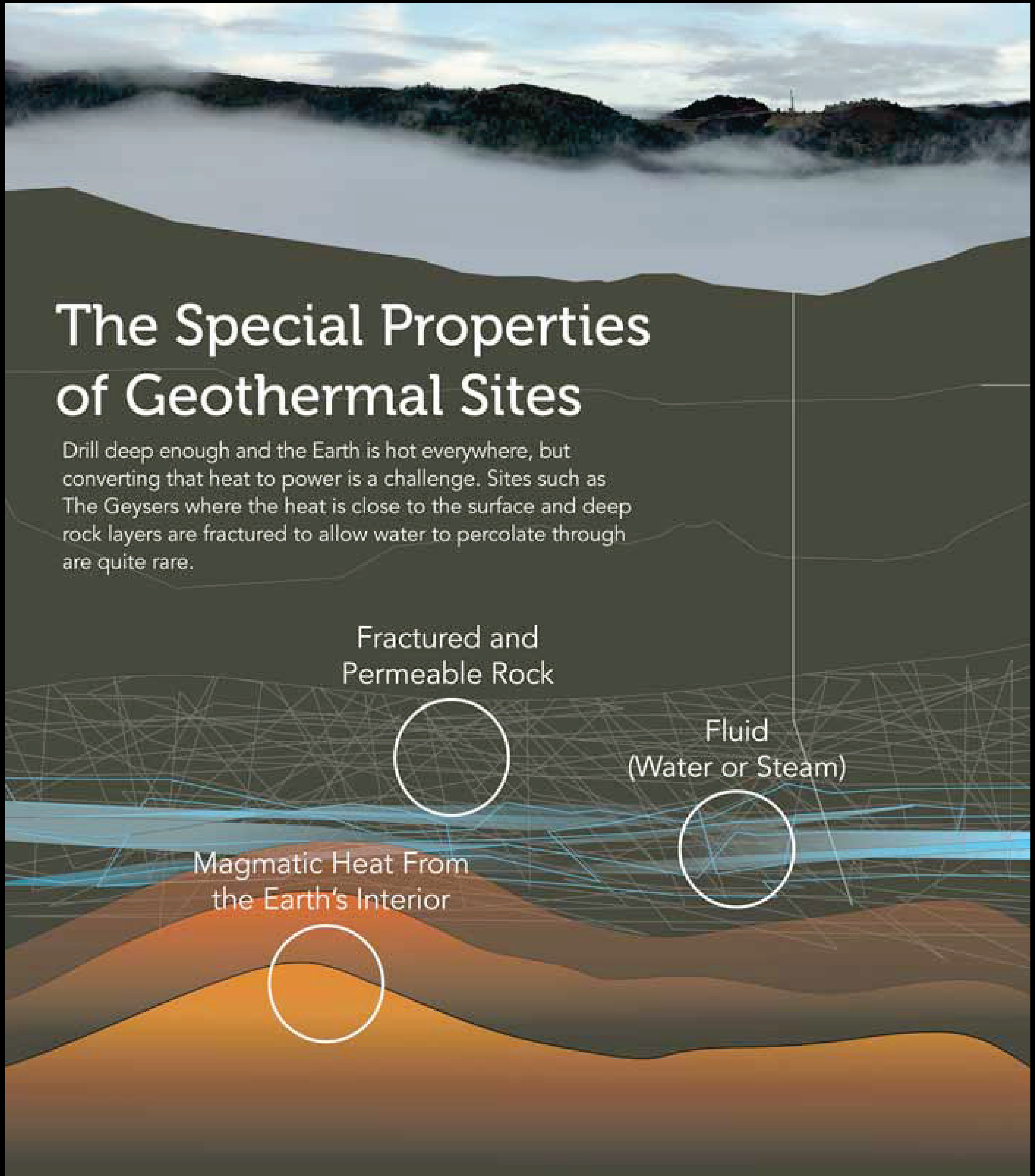


Figure Courtesy of Statoil

If only it were this easy



"The Traditional View"

The figure to the left is from Calpine, a company with significant ownership and operations at the Geysers area, California.

If their statement were true;

"Sites such as the Geysers, where the heat is close to the surface and deep rock layers are fractured to allow water to percolate through are quite rare."

Geothermal power generation would be forever relegated to a minor role in the energy segment of the world!

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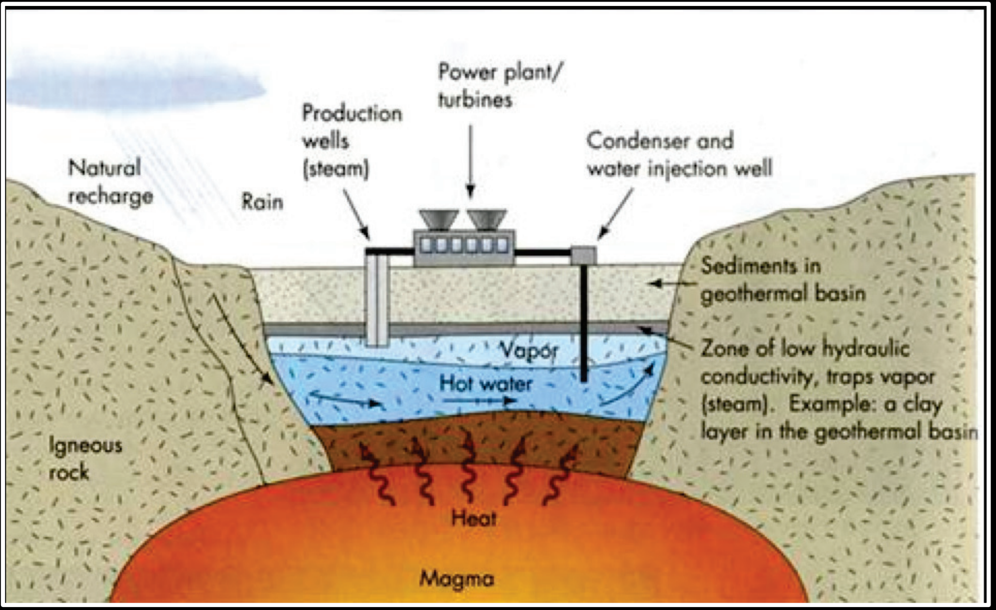
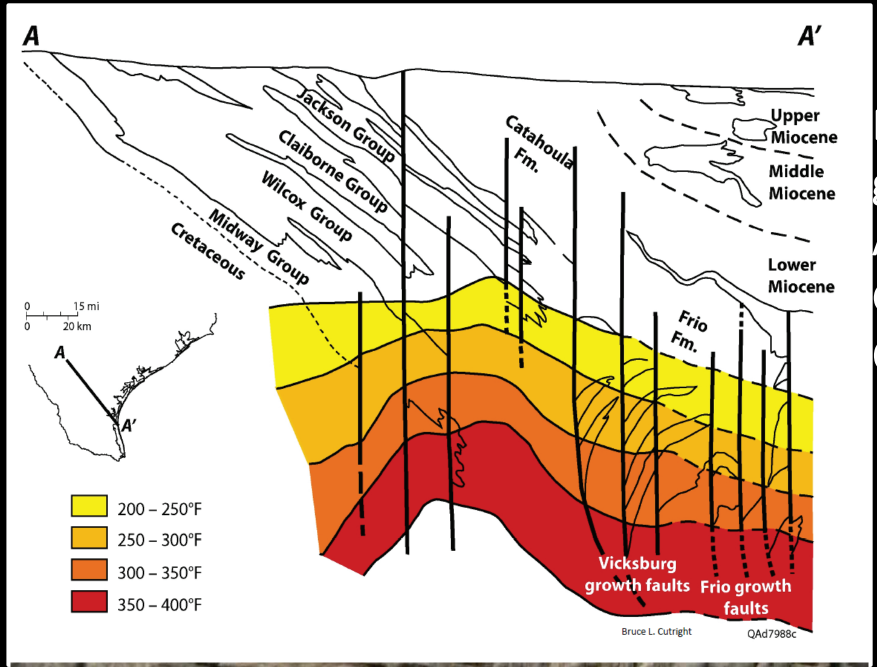
Types of geothermal reservoirs.



Volcanic or magmatic Reservoir, An example would be the Geysers in California

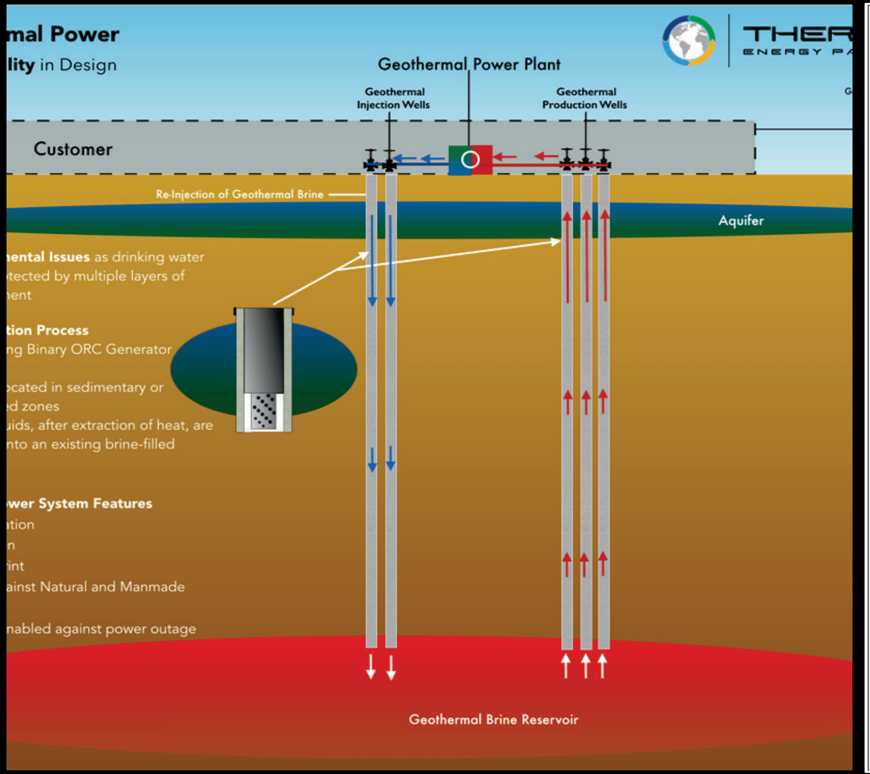


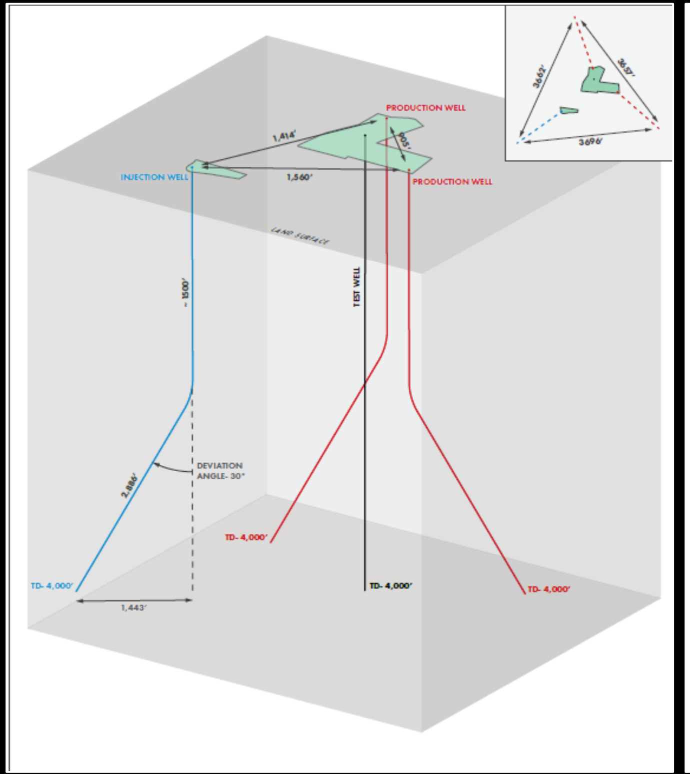
Deep, hot sedimentary geothermal reservoirs. An example is the South Germany or Texas Gulf Coast Area

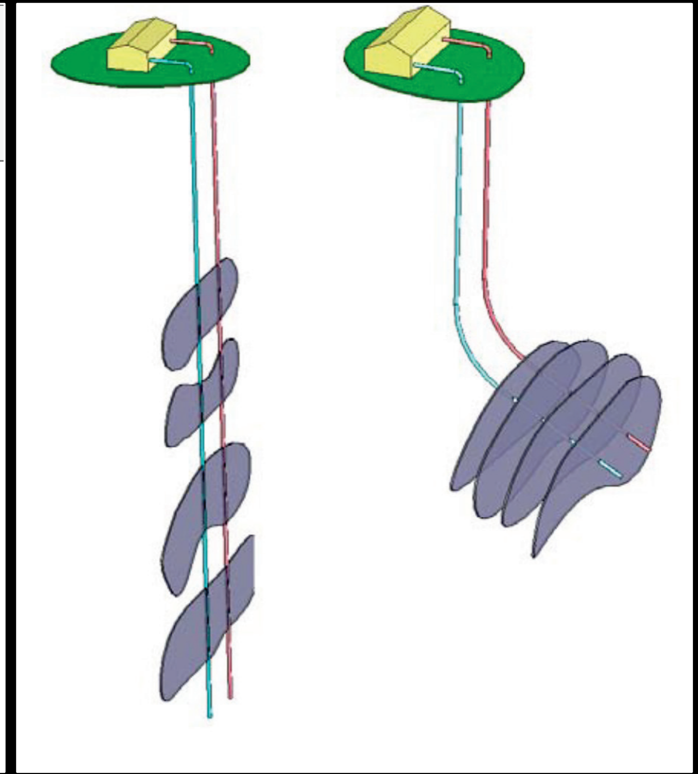
Regardless of the reservoir target, we must access the entrained heat via drilling

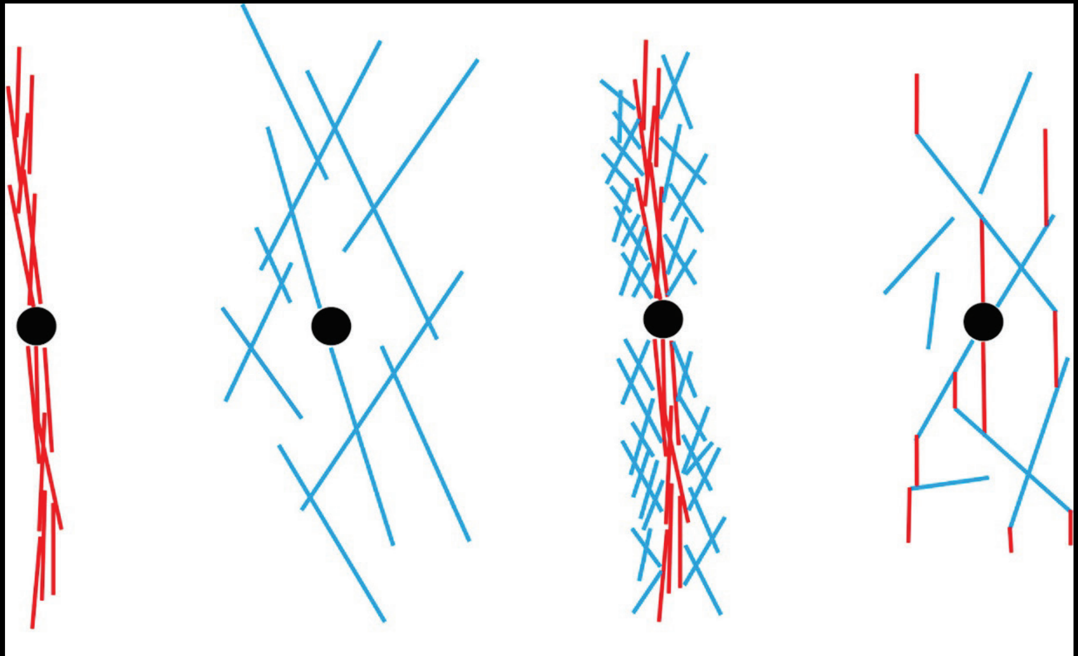
- Let’s look at the Continuum of production well options and their impact on the price of produced power:

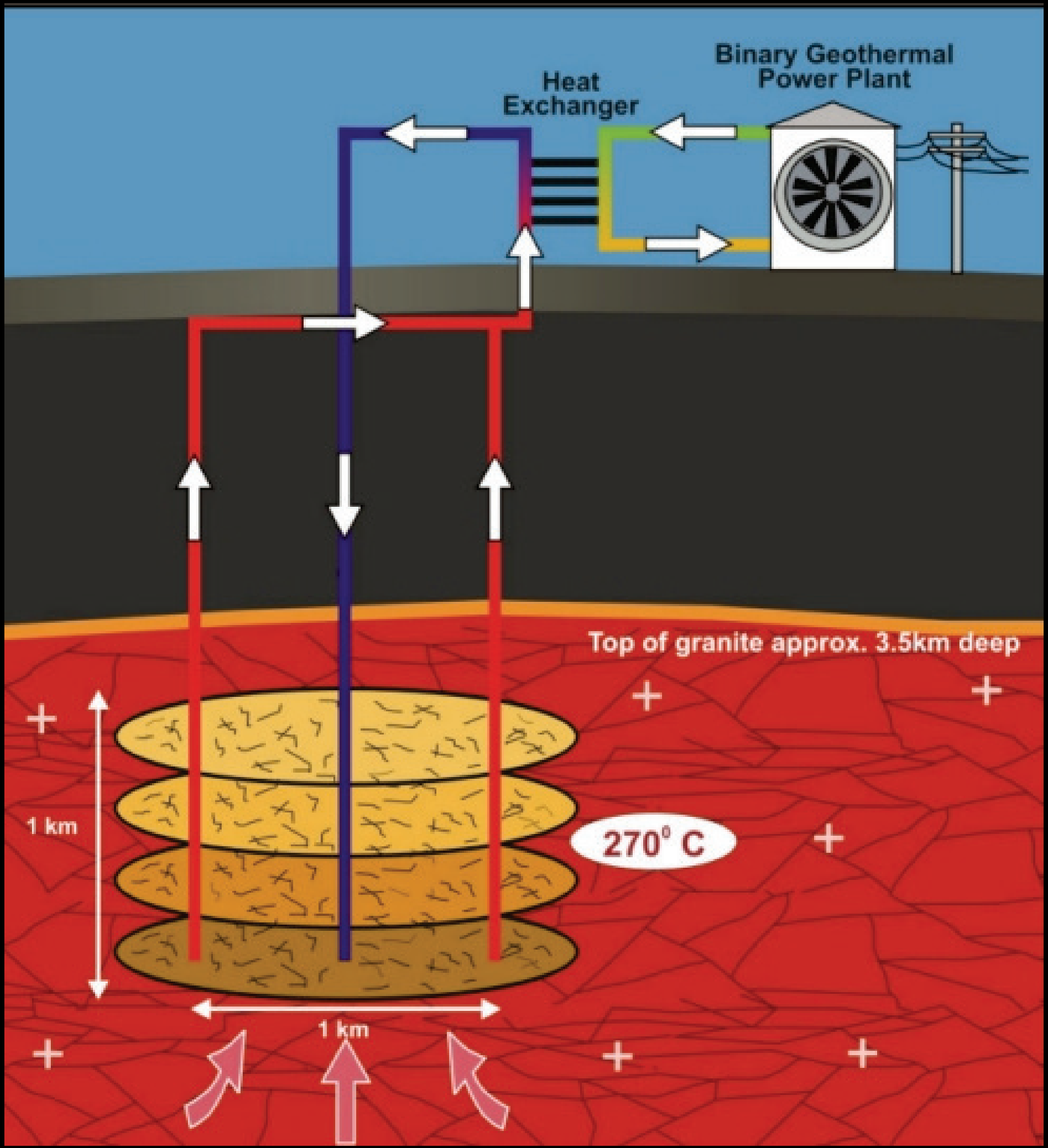
1) vertical well, 2) deviated well, 3) vertical or deviated stimulated well



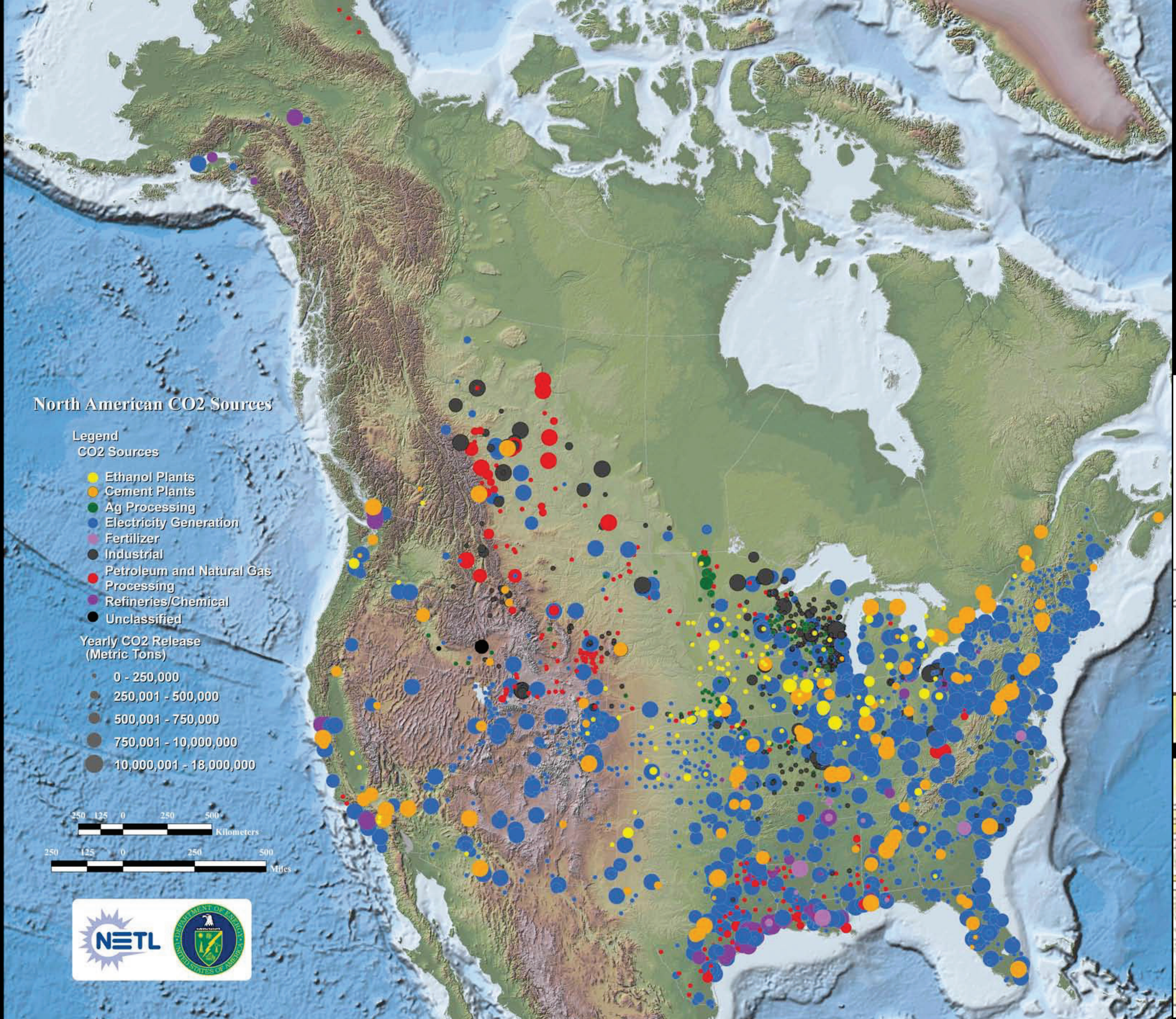






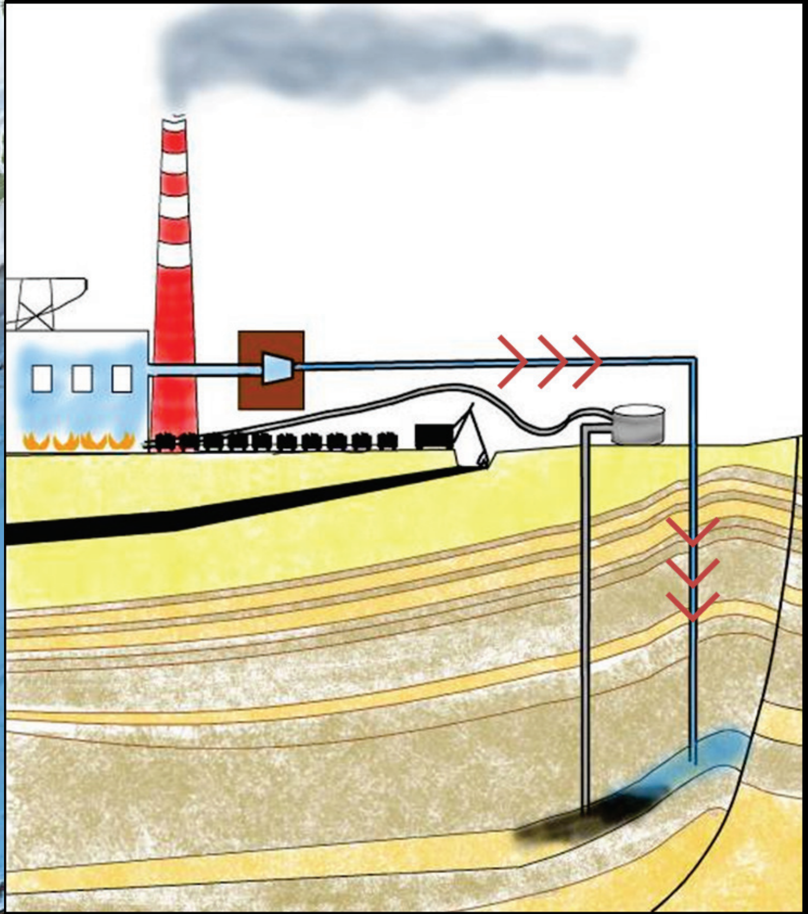

Binary Geothermal Power Plant
Heat Exchanger
Top of granite approx. 3.5km deep
1 km
270° C
1 km

Global map of existing geothermal power plants



From the NETL, sources of carbon dioxide emissions in north America.

The majority of these sources are coal-fired power plants.



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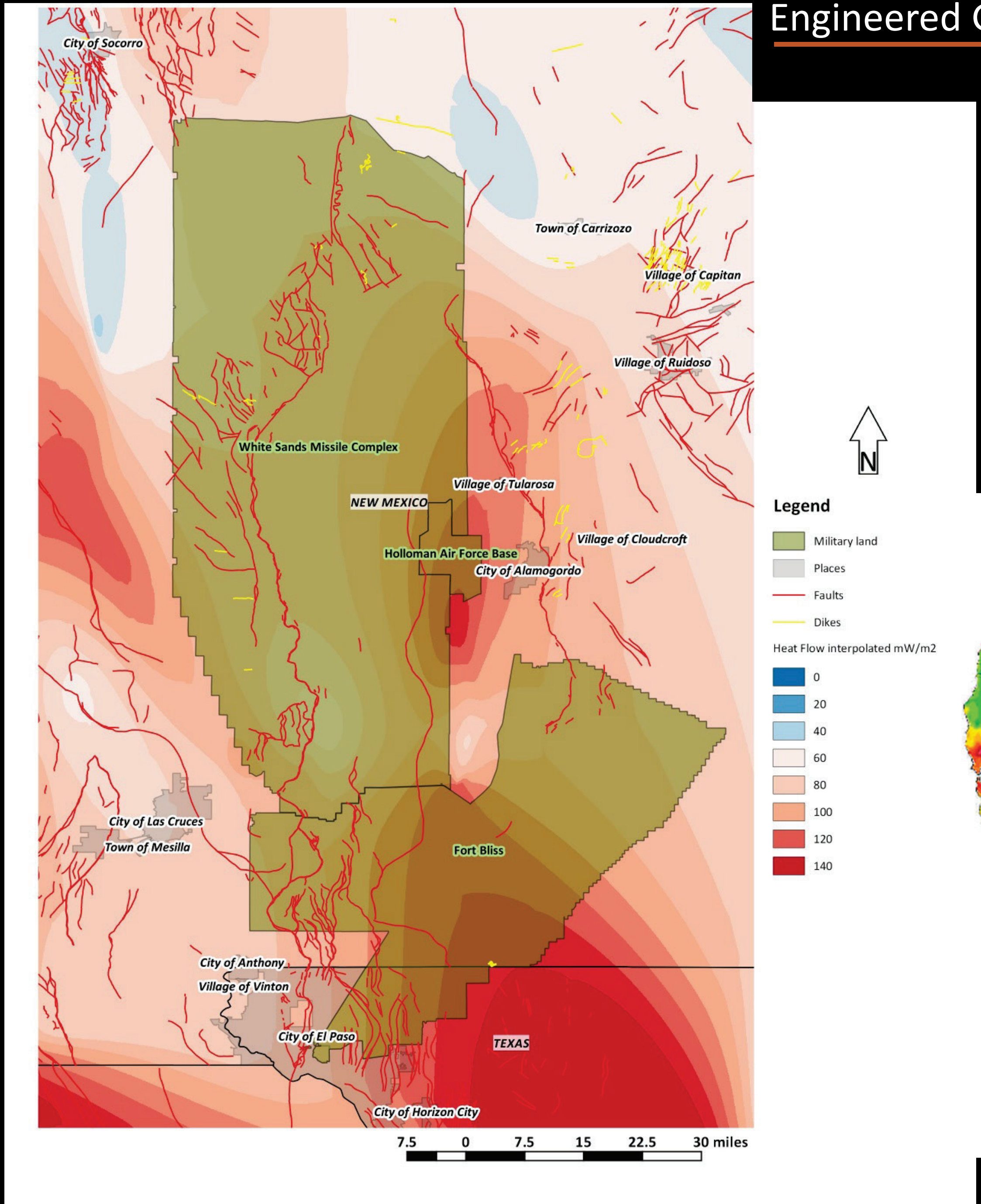
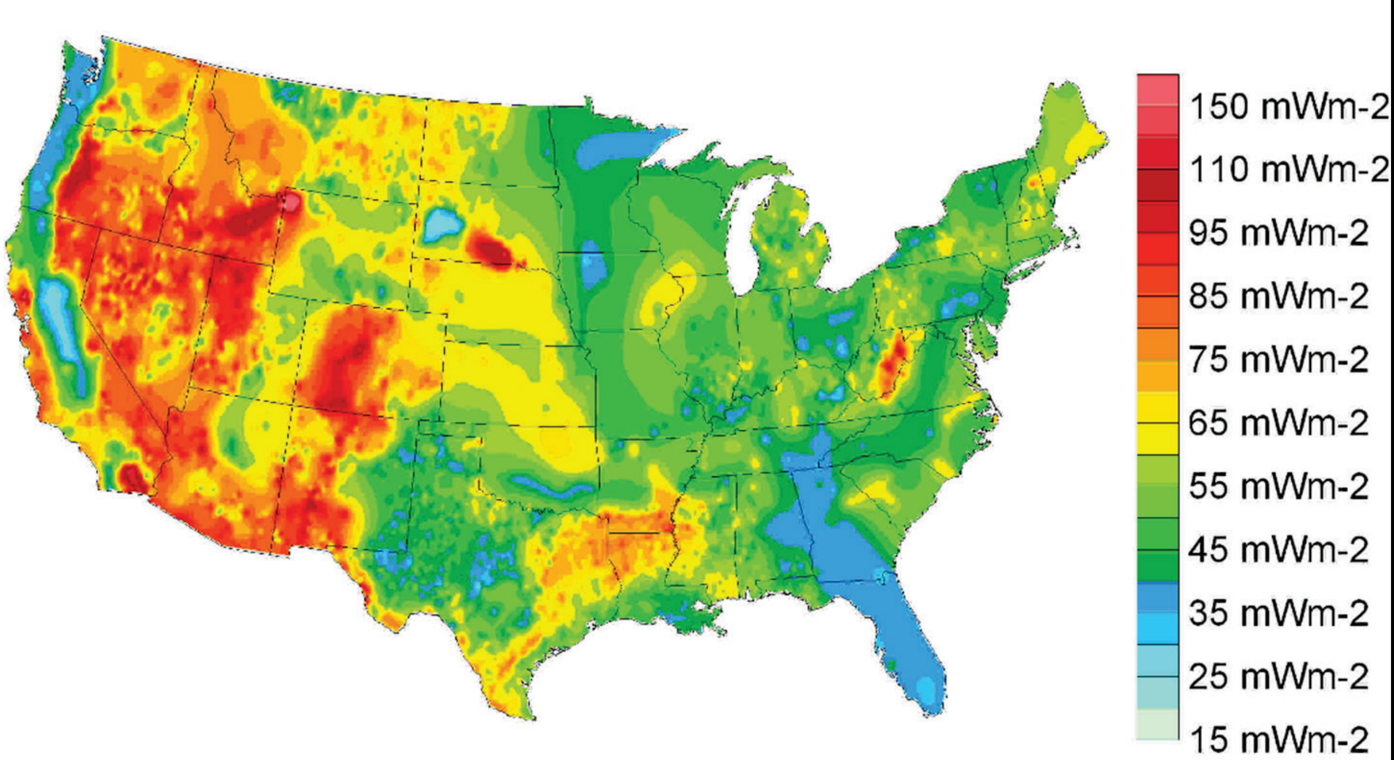
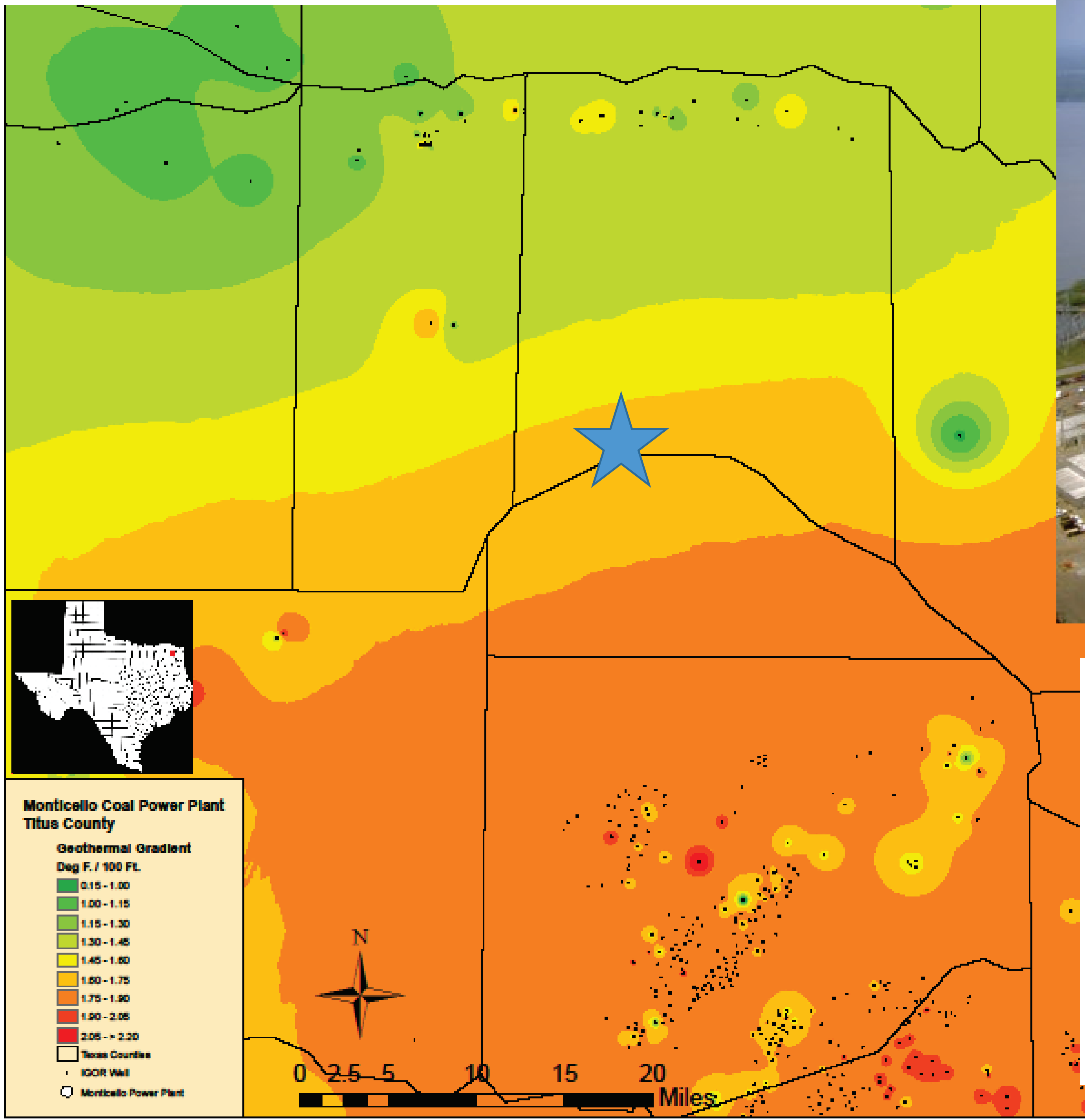
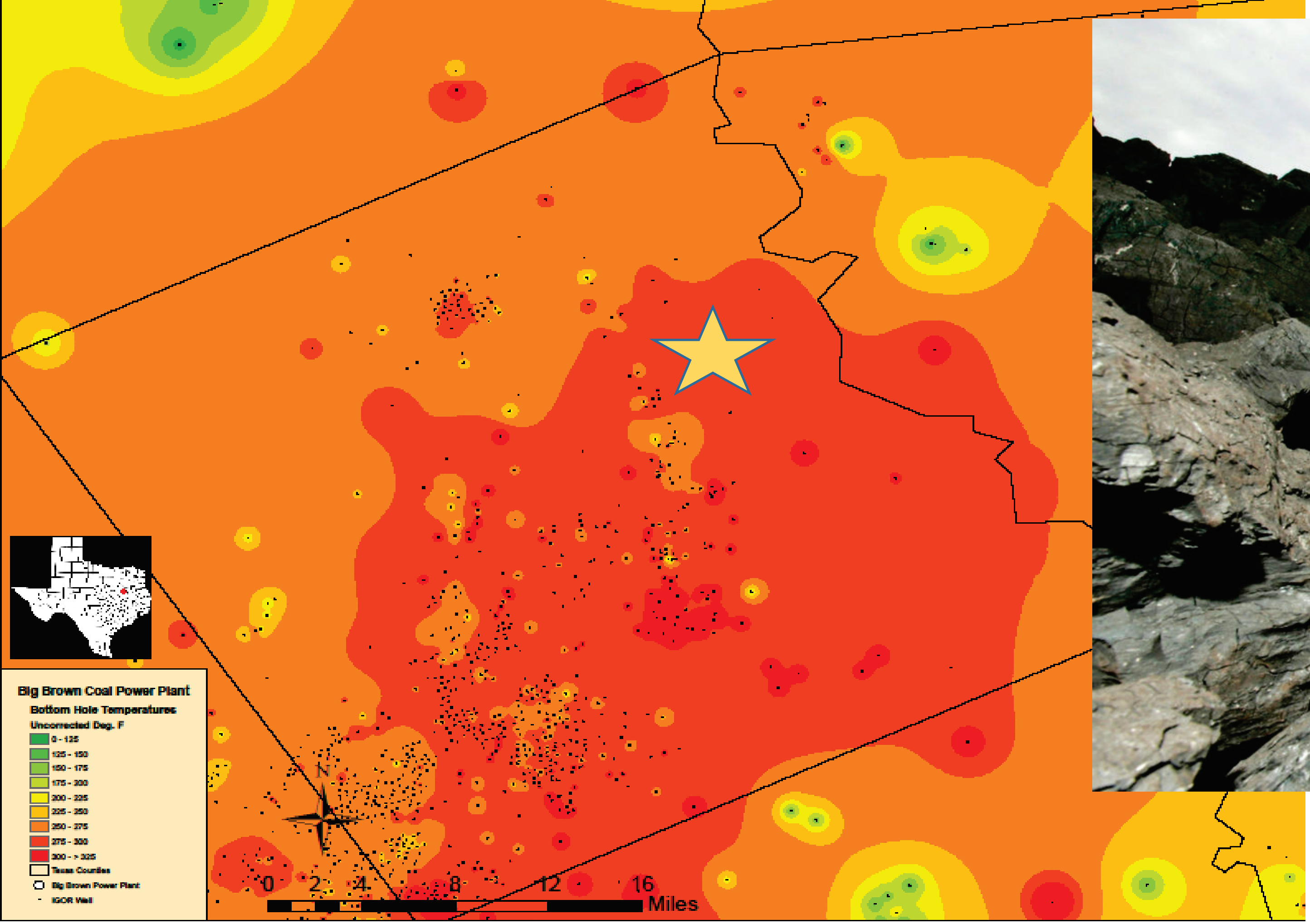






Monticello Power Plant

- 1,880 MWs Name Plate capacity
- Located in an area of above average geothermal gradients and promising deep geology.
- Would require nearly 660 MWs for full carbon capture.
- Reasonable geothermal power development could replace at least ½ of these parasitic power requirements.



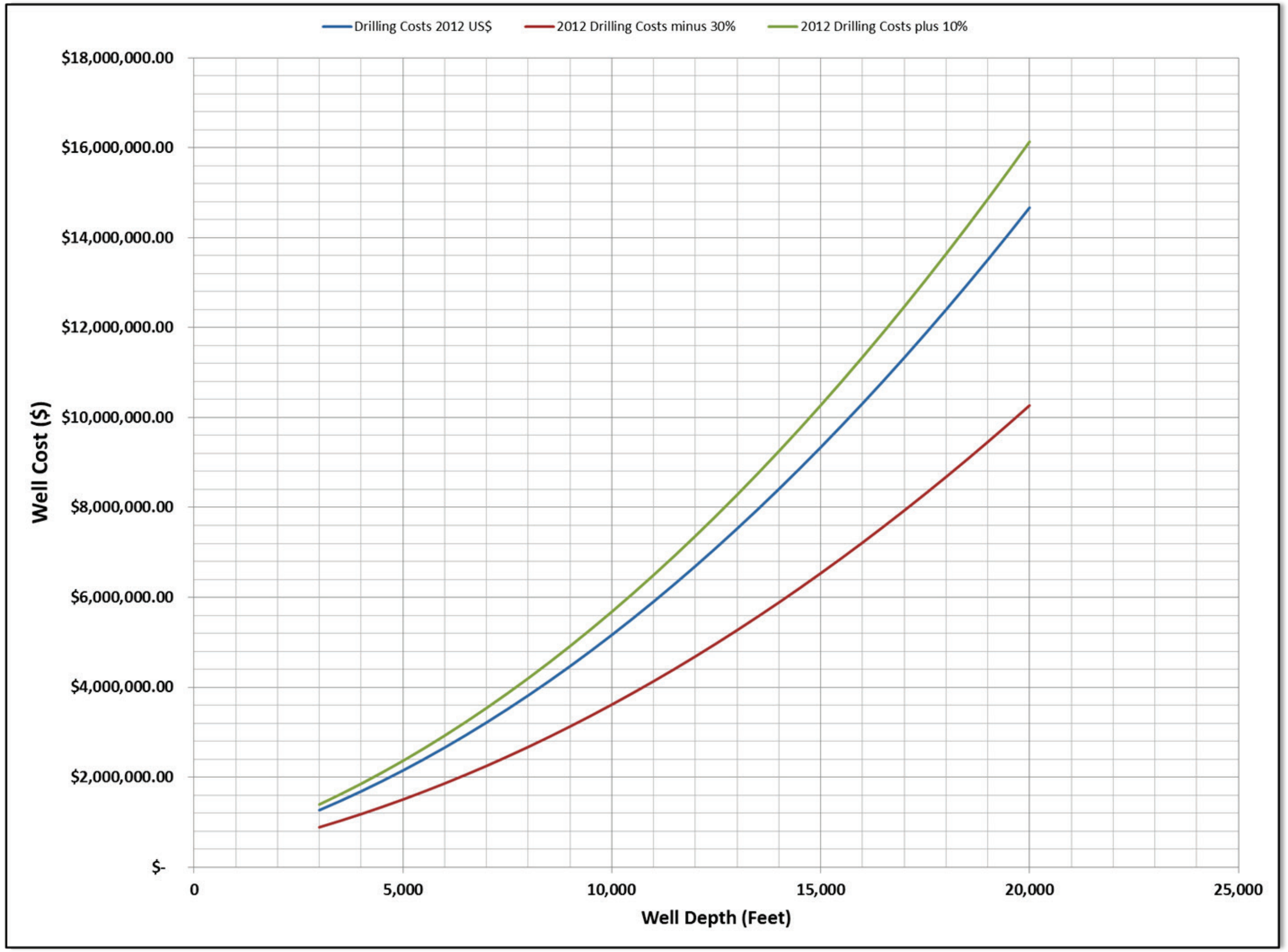
Big Brown Power Plant

- Name Plate Capacity 1,150 MWs
- Located in an above average heat flow and high gradient area
- Would require 300 MWs for full carbon capture and sequestration.
- Could easily produce Geothermal power to replace the parasitic energy cost of carbon capture.

THE ECONOMIC CONTEXT

1. Costs of Exploration
2. Costs of Well Drilling
3. Costs of transmission and delivery

- Drilling costs



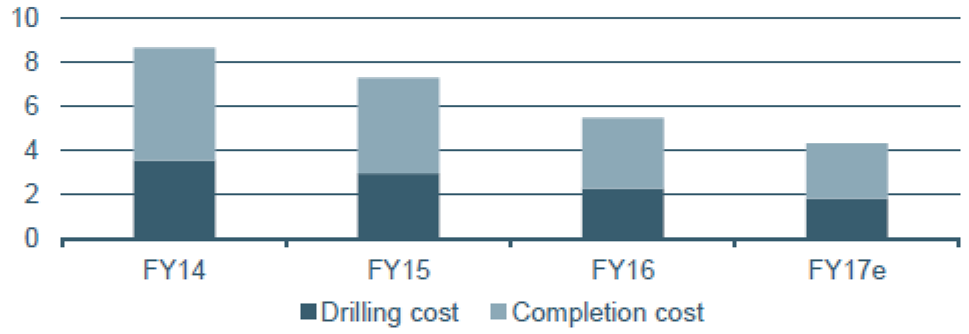
Target depths of 12,000 to 15,000 feet require well costs of $5.5 to $8 million per well.

Management of the drilling program, and drilling as a sequence of wells reduces the overall well cost to below $5.5 million per well.

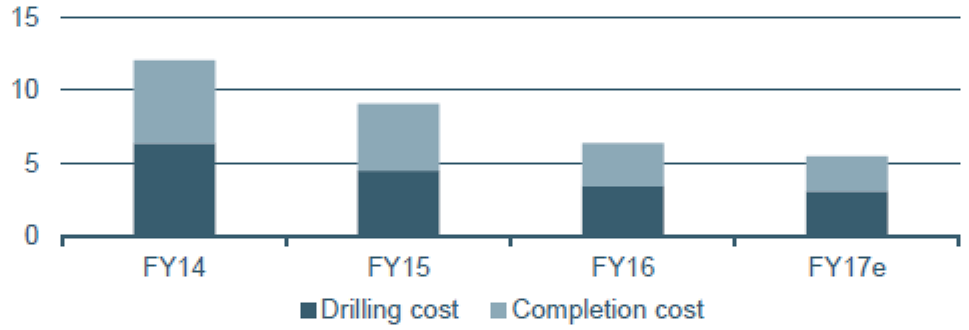
Continuing to deliver material well cost savings

- Well costs down ~40% over the past two years with further reductions in FY17
- Large portion of drilling cost reductions will be maintained independent of price environment
  - drilling rate increased up to 50%
  - rig move time reduced by ~50%
- Similar cost reductions achieved in well-site facilities

Reduction in Black Hawk well costs[1]
(US$ million, 100% basis)

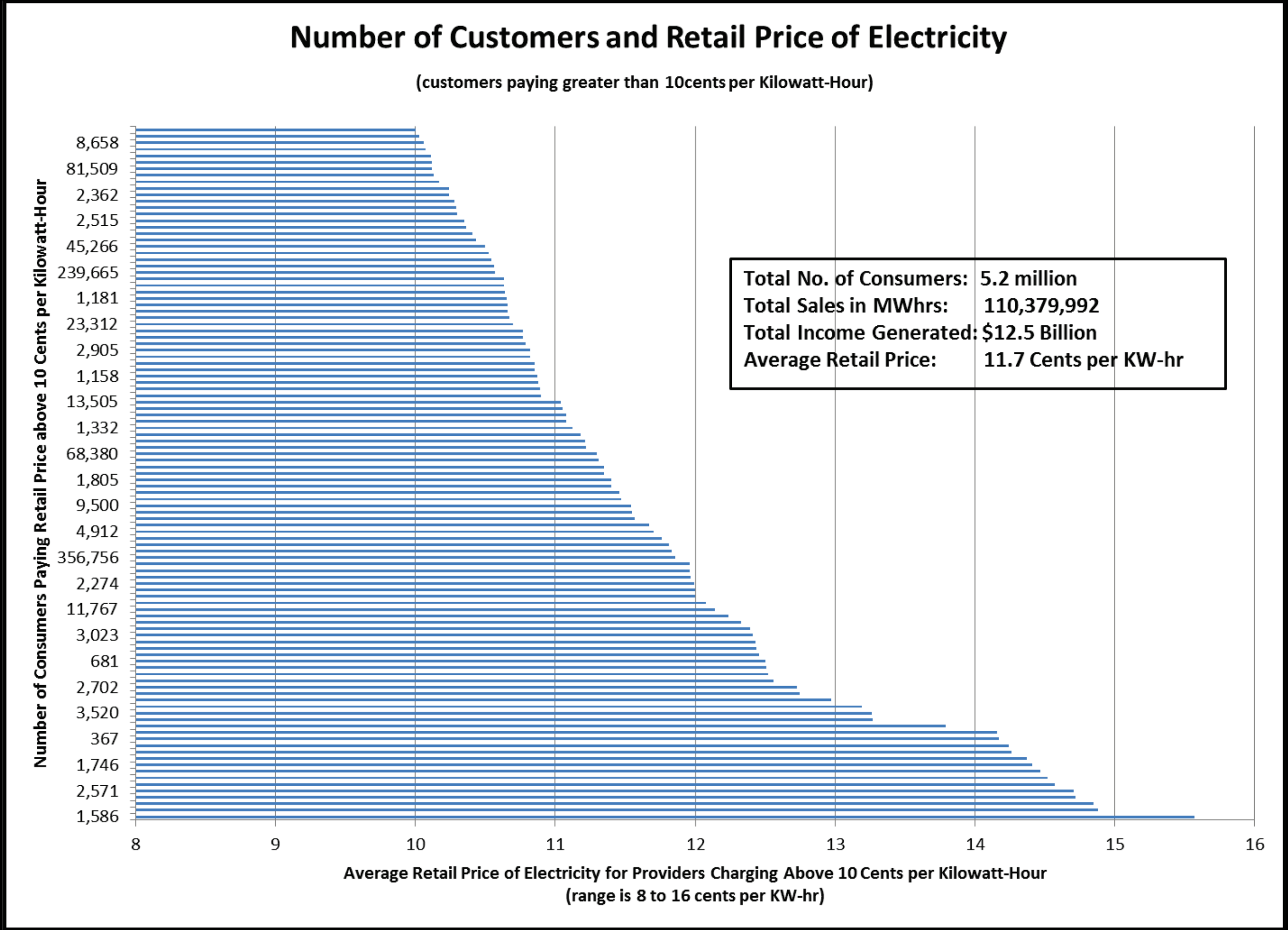


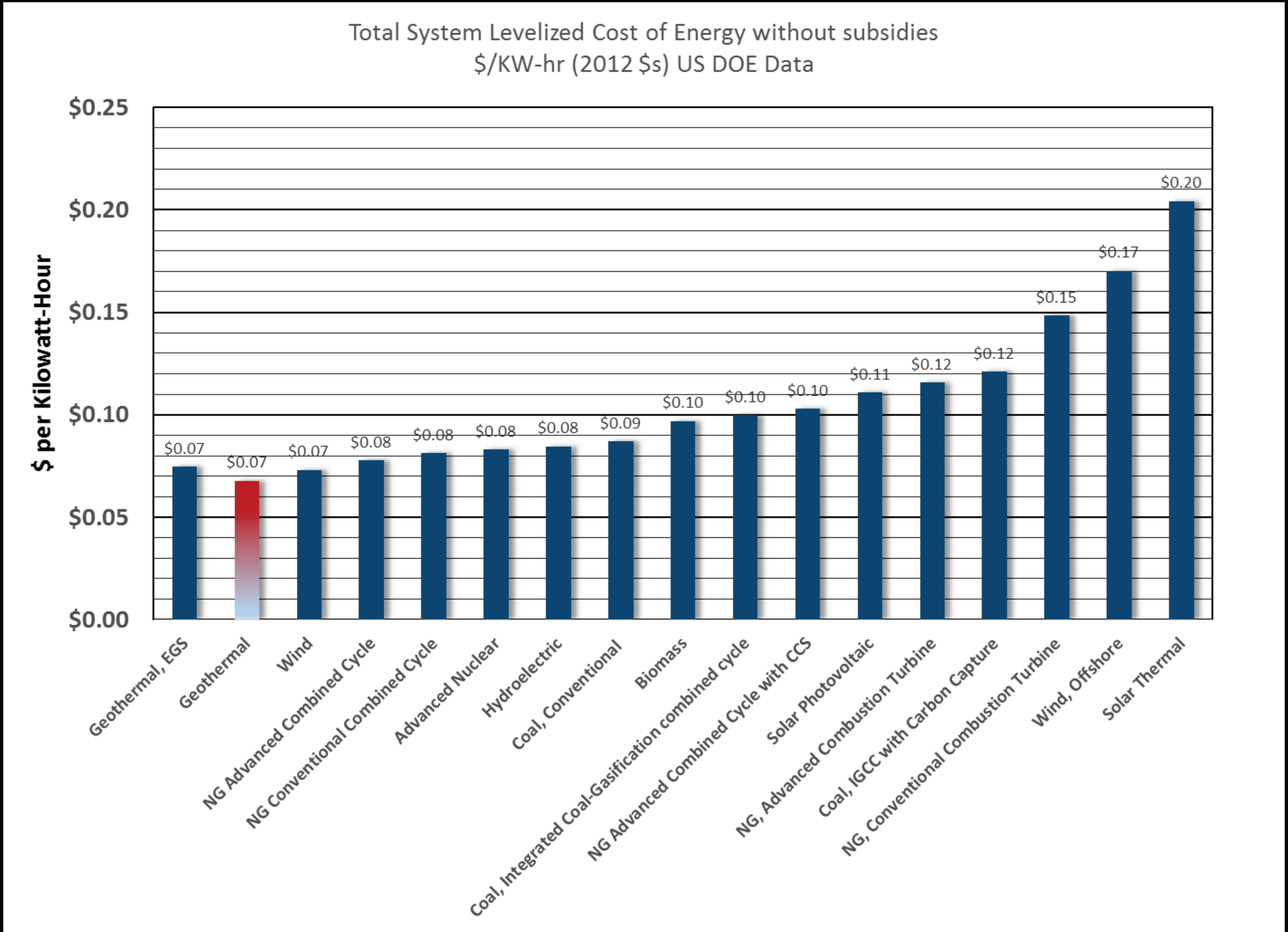
Reduction in Permian well costs[1]
(US$ million, 100% basis)



1. Drilling and completion costs are not normalised for lateral length. Black Hawk drilling cost calculated for 2-string wells only. Permian drilling and completion costs calculated using North Reeves activities. Completion costs exclude trials.

- Retail Power Pricing:
  - Over 5 million customers in the State of Texas pay greater than 10 cents per kilowatt-hour. ERCOT plans on providing power from their grid by 2020 at an average price of 14 to 15 cents per kilowatt-hour
  - "Enhanced" geothermal reservoirs can produce power at an all-in cost in the range of 5 to 15 cents per kilowatt-hour.




Total System Levelized Cost of Energy without subsidies
$/KW-hr (2012 $s) US DOE Data
$ per Kilowatt-Hour
$0.25
$0.20
$0.15
$0.10
$0.05
$0.00
$0.07
$0.07
$0.07
$0.08
$0.08
$0.08
$0.08
$0.09
$0.10
$0.10
$0.10
$0.11
$0.12
$0.12
$0.15
$0.17
$0.20
Geothermal, EGS
Geothermal
Wind
NG Advanced Combined Cycle
NG Conventional Combined Cycle
Advanced Nuclear
Hydroelectric
Coal, Conventional
Biomass
Coal, Integrated Coal-Gasification combined cycle
NG Advanced Combined Cycle with CCS
Solar Photovoltaic
NG, Advanced Combustion Turbine
Coal, IGCC with Carbon Capture
NG, Conventional Combustion Turbine
Wind, Offshore
Solar Thermal

- Conclusions:

➢ There is a continuum of drilling technologies that open broad geographic areas for the development of geothermal energy.

➢ All costs related to geothermal energy production have fallen significantly due to technology improvements.

➢ Geothermal power production is economically competitive with all existing traditional and renewable sources of power generation when the fully loaded "Levelized Cost of Energy" is included

Thank You. Bruce Cutright, CEO, Thermal Energy Partners.