THE POTENTIAL OF GEOTHERMAL ENERGY

A ONCE AND FUTURE FOCUS
OF
THE BUREAU OF ECONOMIC GEOLOGY

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Geothermal Energy

A Once and Future Focus of the Bureau of Economic Geology

- Brief History of Geothermal Investigations and Research at the Bureau of Economic Geology
- Driving Forces
  - Past:
    - Economics
    - Relationship to Petroleum Yields and Reserves
    - Alternate source of energy
  - Now:
    - Economics and Energy Security
    - Economics and Carbon Emissions
    - Economics and Alternative Energy Resources
- Where are we going, now and in the Future?

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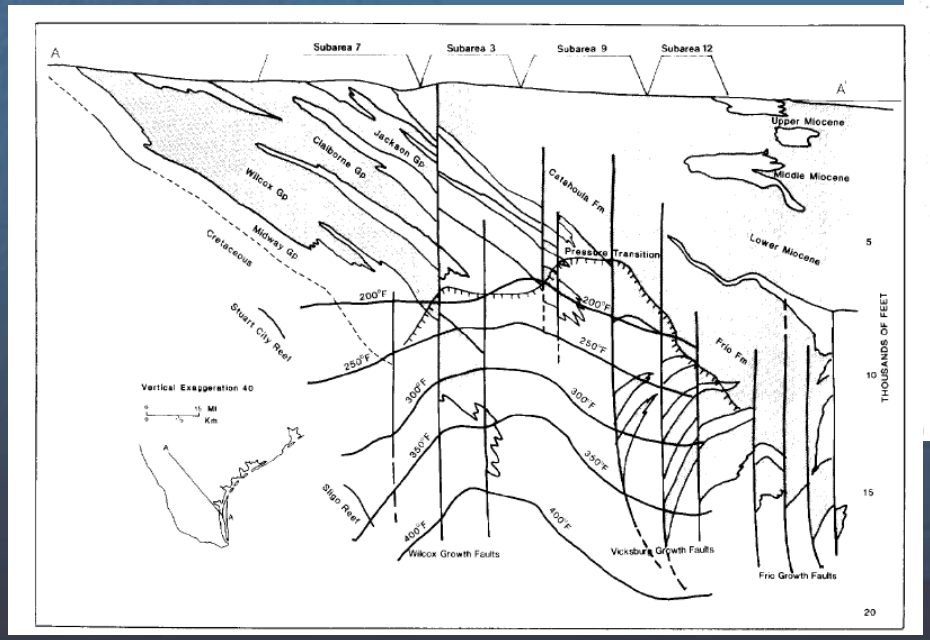
THE POTENTIAL OF GEOTHERMAL ENERGY

- Bureau of Economic Geology lead earlier studies during the late 1970s, 1980s and up to 1992 investigating the Geothermal Energy potential of the Northern Gulf of Mexico



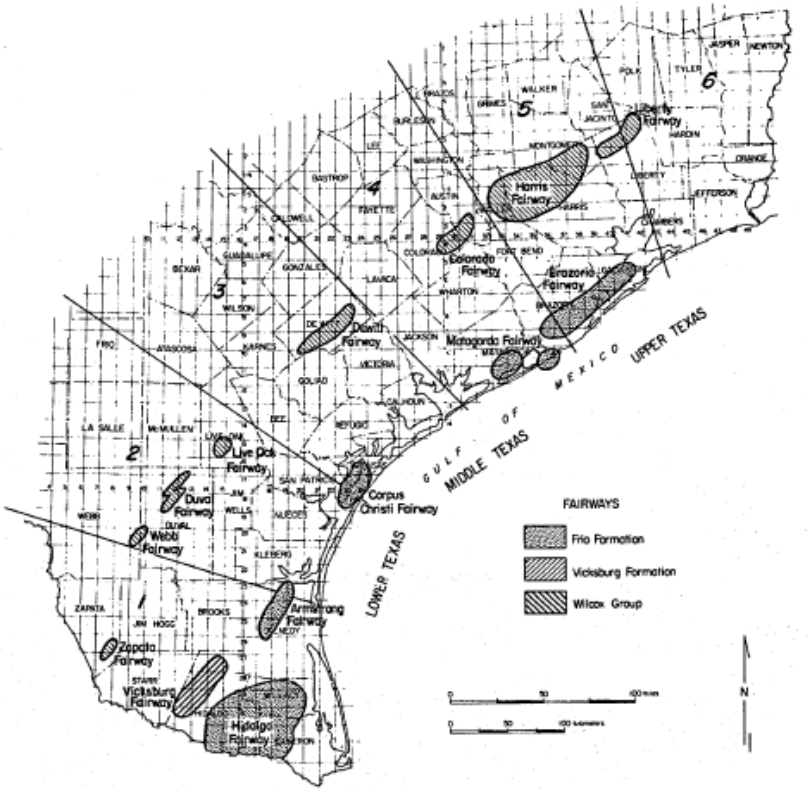


Figure 1. Area of investigation showing geopressured geothermal fairways and division of Lower, Middle, and Upper Texas Gulf Coast areas.

Bebout, Loucks, Gregory 1978

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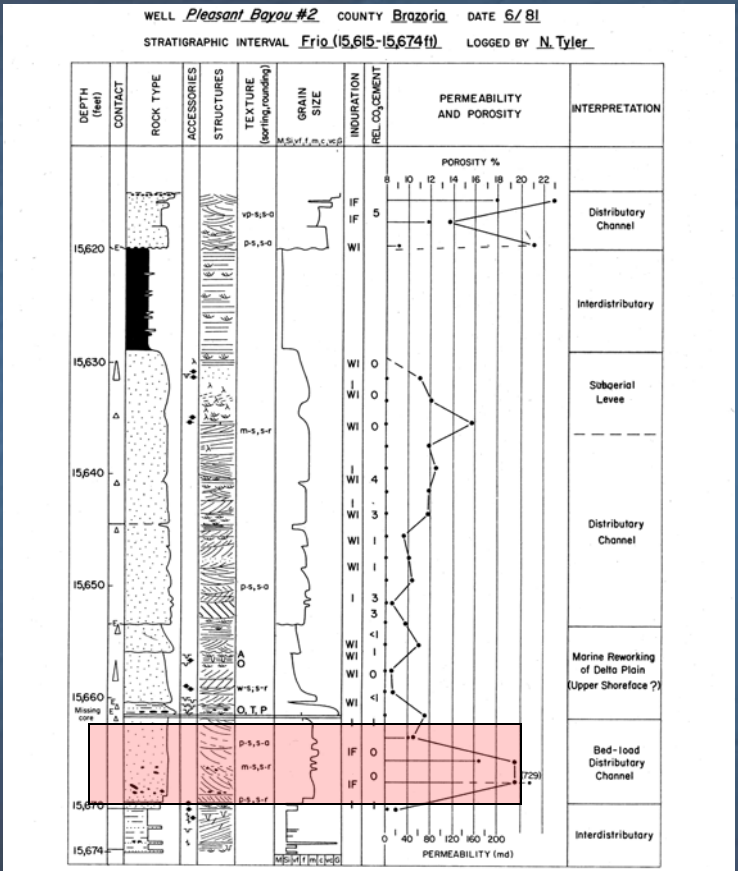

Figure 35. Detailed core description, pore properties, and interpretation of the lower part of the Frio F correlation interval (T5 unit). This composite sandstone shows a central decrease in porosity. Large-scale crossbeds (15,670 to 15,661 ft and 15,620 to 15,616 ft) have higher porosities and permeabilities than do small-scale crossbeds (15,653 to 15,640 ft). Trace fossils in the marine-reworked interval: A - *Arenicolites*, O - *Ophiomorpha*, T - *Thalassinoides*, and P - *Planolites*. See figure 31 for explanation of symbols.

- Among many beneficial results, the early investigations defined the “Geopressured-Geothermal” plays along the Northern Gulf of Mexico.
- Provided an envelop of conditions defining a promising zone for geothermal energy and gas production;
  - Reservoir volume at least 3 mi^3.
  - Permeability of at least 20md
  - Temperature of at least 300^0F

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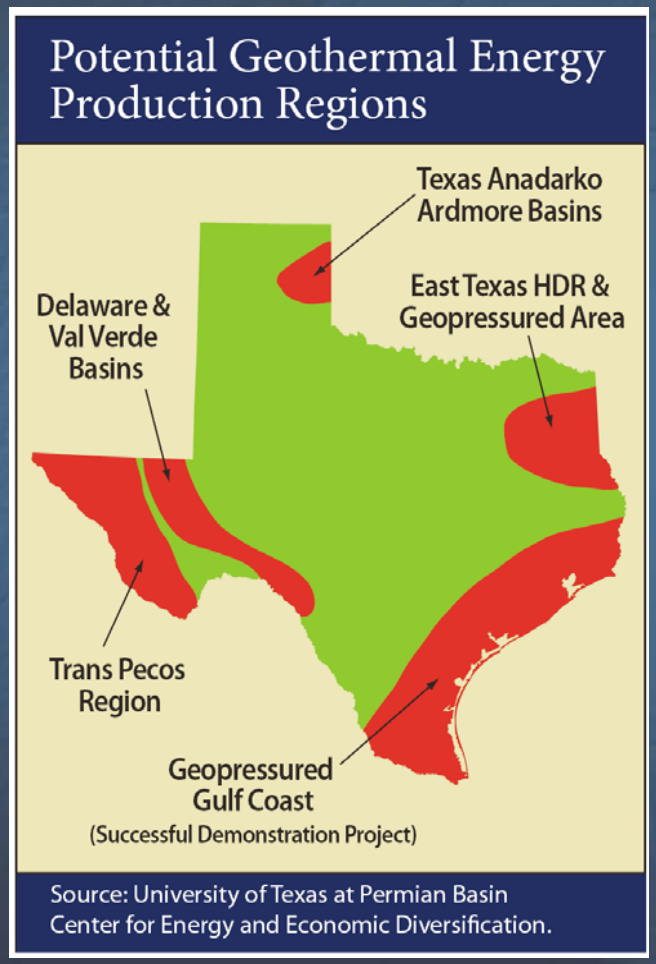

The Successful investigations in the early 1970s and 1980s clearly defined a unique set of source regions in Texas,

- From the deep, geopressured zones along the coast
- to deep circulating groundwaters in the Trans Pecos Regions and
- Hot Dry Rock areas in the north.

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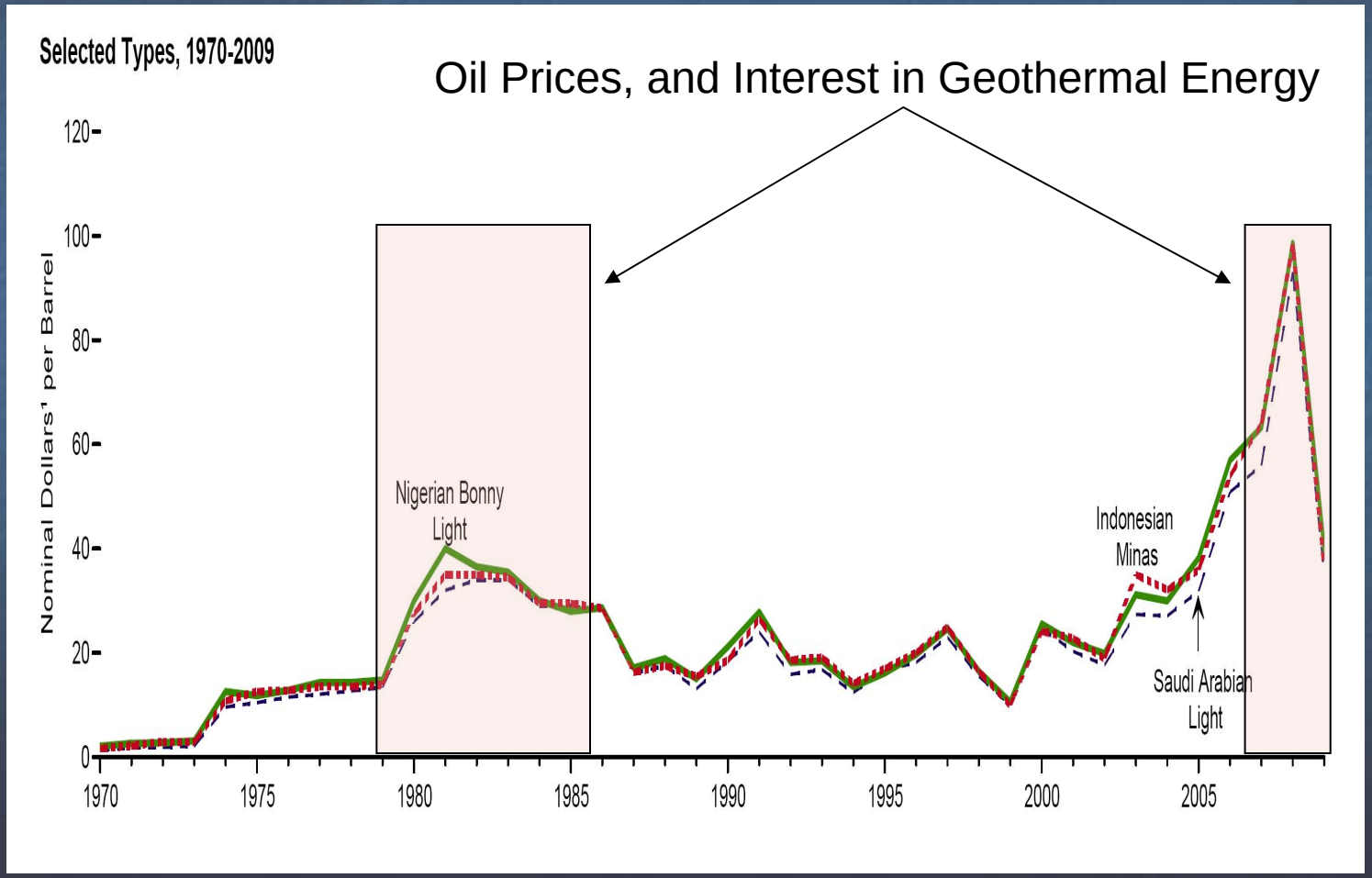
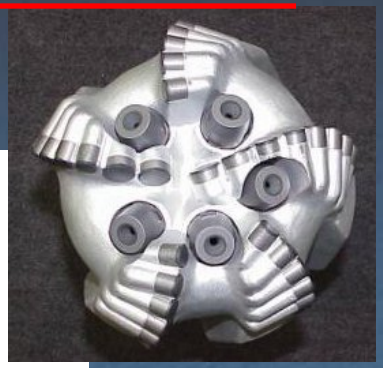


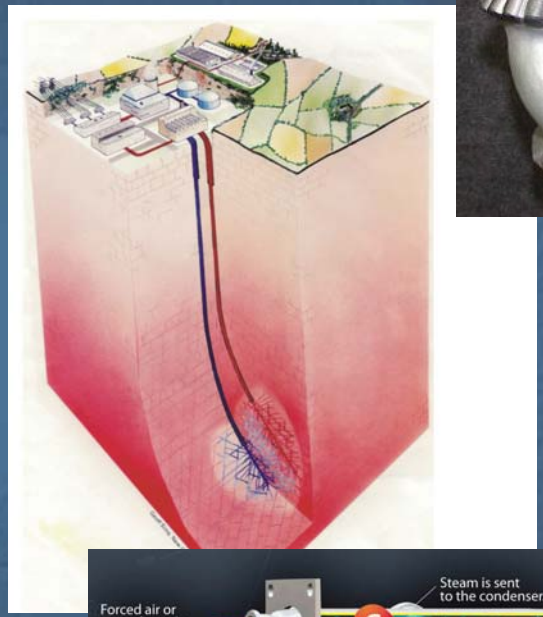
- What were the driving forces?
- Oil Prices then,
- and now?
- Carbon Emissions
- Energy Security
- Renewable Resources

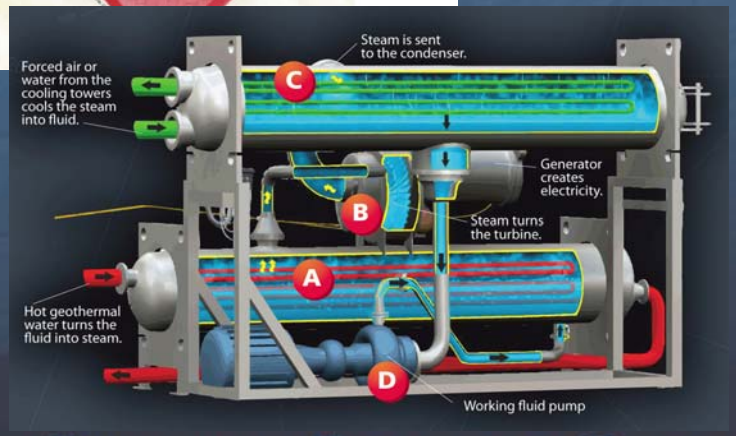
The Case for Geothermal Energy

What has changed from 1980 to Today?

- Advances in Drilling Technology makes 8 to 10km holes possible (polycrystalline diamond compact bits, slimhole drilling)
- Advances in controlled fracture development makes “Engineered Geothermal Systems” practical
- Advances in Binary-Cycle Heat Exchange Systems make 100^{o} C heat sources and up economical.







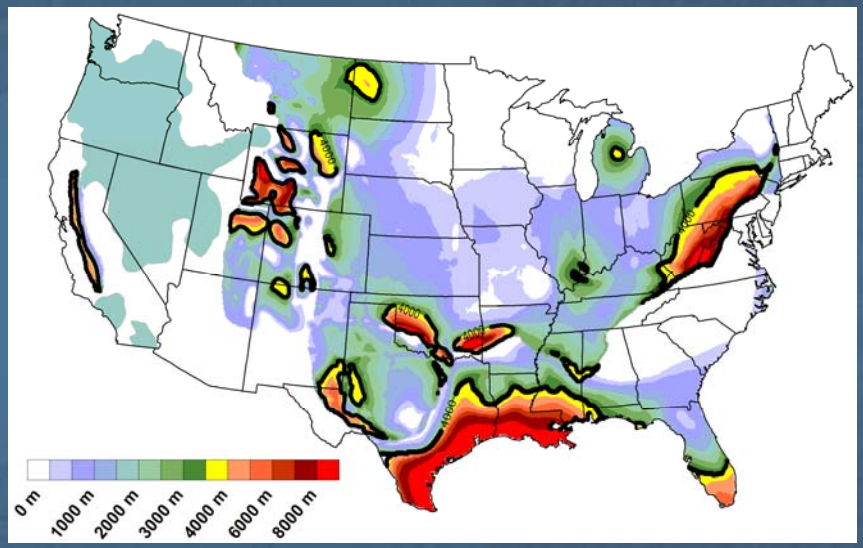
THE POTENTIAL OF GEOTHERMAL ENERGY

- **Critical Re-assessment:**

  DOE - MIT (2006) Study Found:

- **THE EXTRACTABLE RESOURCE BASE IS ESTIMATED AT 2,000 TIMES THE ANNUAL PRIMARY ENERGY CONSUMPTION OF THE UNITED STATES IN 2005.**

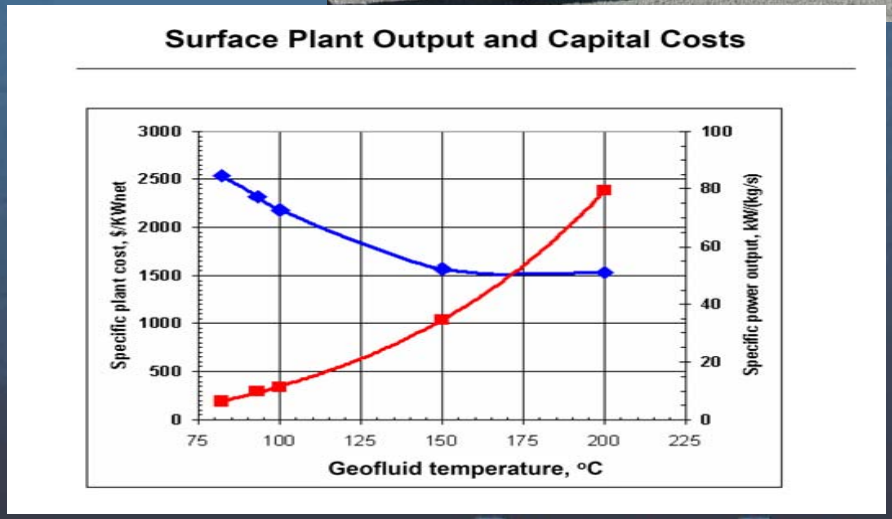
- **A SIGNIFICANT PORTION OF THIS ENERGY IS IN GEOPRESSURED ZONES IN THE NORTHERN GULF OF MEXICO**



Sediment Thickness Map of US

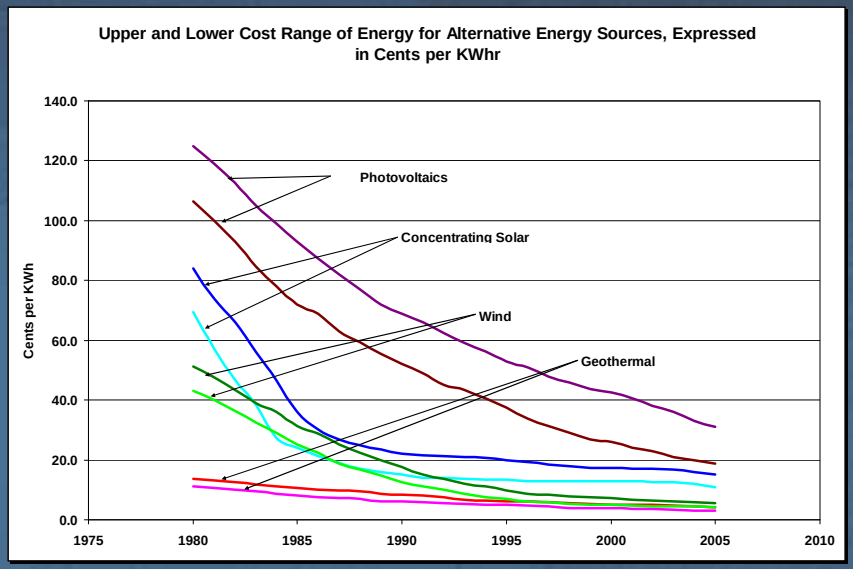
The Case for Geothermal Energy

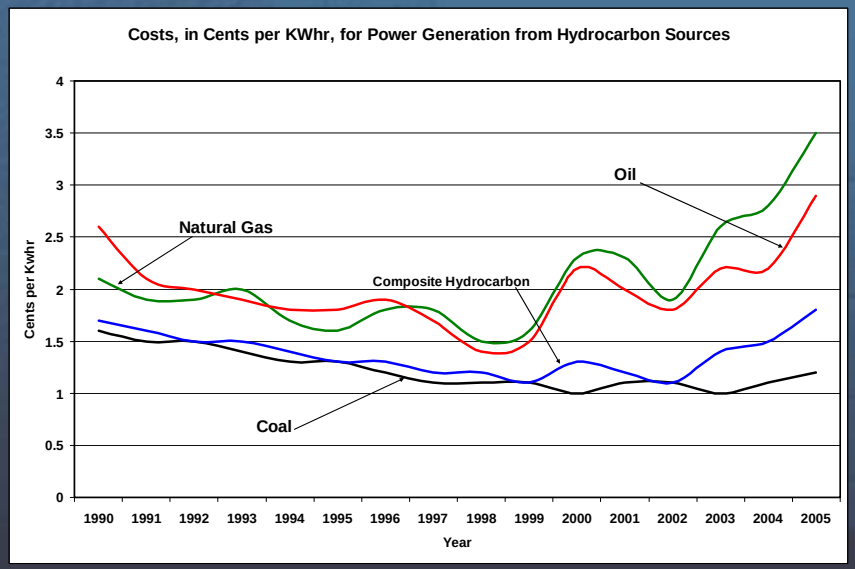
- Raser Technologies Hatch Geothermal Power Plant
- constructed in just six months
- Modular power plant design.
- Can produce power from geothermal resources that were previously thought to be not hot enough for commercial power production.



The Case for Geothermal Energy
The Impact of Technology Advancement

Comparison of the costs per kilowatt hour to generate electricity from alternative/renewable sources versus hydrocarbon sources





Geothermal is cost competitive with oil and natural gas and is less expensive than solar and wind. Only coal, without carbon tax costs, is less expensive than geothermal

Data from NREL in constant 2005 dollars

The Case for Geothermal Energy

Levelized Cost of Electricity Analysis (Source: Credit Suisse 1-19-2009)	*High Case*	*Base Case*	*Low Case*	*Minimum*
Solar Photovoltaic (crystalline)	$201	$153	$119	$119
Solar Photovoltaic (Thin Film)	$180	$140	$110	$110
Fuel Cell	$117	$90	$72	$72
Solar Thermal	$126	$90	$69	$69
Coal	$66	$55	$46	$46
Natural Gas (CCGT)	$64	$52	$40	$40
Nuclear	$64	$62	$35	$35
Wind	$61	$43	$29	$29
Geothermal	**$59**	**$36**	**$22**	**$22**
Conservation/Efficiency	$30	$15	$0	$0
(figures in dollars per MWhr)				

The Case for Geothermal Energy

- Why has there not been more focus on Geothermal Energy?
  - Deloitte Study (funded by DOE) found that uncertainty – perceived as risk - is the main reason why other alternative resources have received greater focus.
- Remember:

➢ Wind and Solar are Intermittent, geothermal is not

➢ Cost More than geothermal

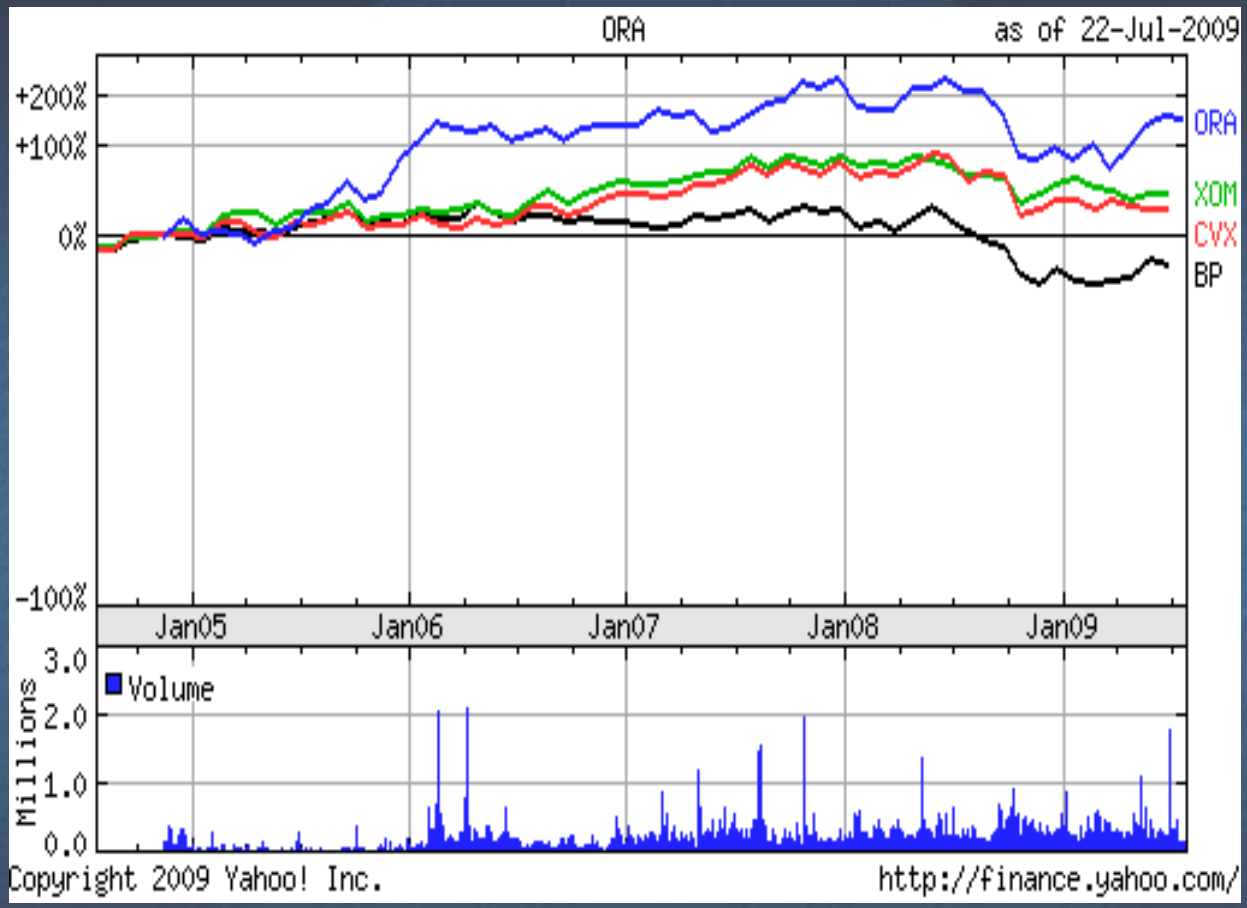
➢ Are Geographically Limited, while geothermal is not

➢ Require Large Land Areas, geothermal doesn't

Why Geothermal?
Why Now?

- **The Economics have changed**
  - **geothermal is now cost-competitive with petroleum, and lower cost than solar and wind.**
- **The Resource Base has changed**
  - **no longer only hydrothermal-magmatic but widely distributed geothermal heat flow is accessible**
  - **The extractable resource is (at least) 2000 times the annual demand of the US.**
- **The regulations have, or will change**
  - **Favoring non-CO_2 emitting energy sources**

What Is Business Doing



Five Year Stock Price Trends
ORA = Ormat Technologies (geothermal)
XOM = ExxonMobil
CVX = Chevron
BP = British Petroleum

What Our Partners are doing

- Chevron is the largest producer of geothermal energy in the world, with operations in Indonesia and the Philippines.
- US energy companies Unocal and Gulf Resources are willing to invest US$1.2 billion in geothermal and natural gas projects in the Philippines

Source: Chevron Geothermal

The Case for Geothermal Energy

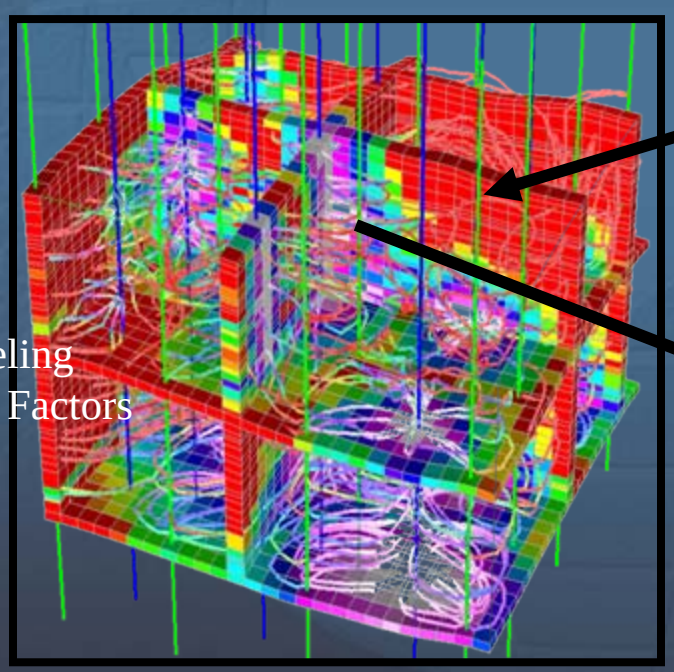
- What is the Bureau doing now?
  - Cooperative work with SMU to develop searchable, useful database of information critical for economic analysis
  - Concentrating on resource definition throughout the State, and nationally and internationally
  - Applying the skills in reservoir characterization that are essential in economic decision-making.

Where is the Cutting Edge?

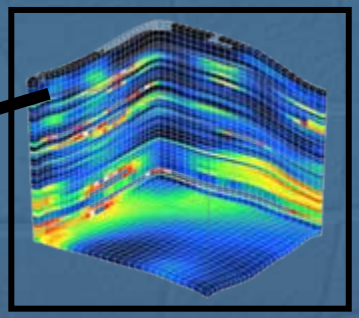
- Primary Focus is on Geopressured Zones having Thermal-Kinetic-Chemical Energy Content, next is deep sedimentary basins and then hot dry rock.
- Combining geothermal heat extraction using supercritical carbon dioxide may solve CO_2 problem, and provide more economical electricity generation.
  - Links geologic sequestration of CO_2 with non-polluting, renewable energy production
  - Results in improvement of heat extraction efficiency by 40% to 180% (Pruess, K. 2006)
  - Provides a methodology for coal fired power plants to recover the energy penalty incurred in CO_2 capture
- Metal – Organic heat carriers (MOHC) offer additional improvements in efficiency, at a cost.

The Bureau's Long Range Opportunities

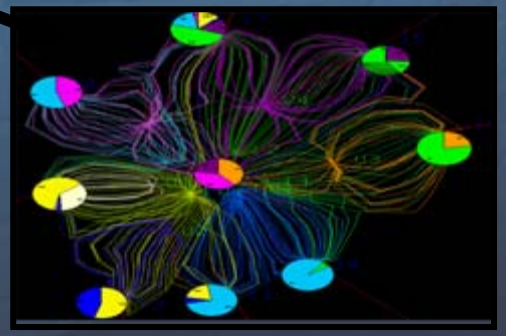
- Everything we have learned about petroleum reservoir characterization, development and production is applicable to Geothermal Development



Streamline Modeling of Fluid Allocation Factors



3-D Geo-Model



Streamline Fluid Allocation Factors

Source: BEG and I-Reservoir, Inc.

THE POTENTIAL OF GEOTHERMAL ENERGY
Summary

- Not just magmatic hot spots, not geographically limited
- Less costly than crude oil, solar or wind, in ¢ per KWhr
- Largest return on investment of R&D Dollars
- Renewable, small footprint, negligible emissions
- Existing skills in reservoir characterization, flow modeling and carbon sequestration are directly applicable to geothermal energy assessment and development.

Iceland

Thank you