Stranded Geothermal Energy

It's Importance For Electrical Power Generation And Conservation In An Energy Transitional Society

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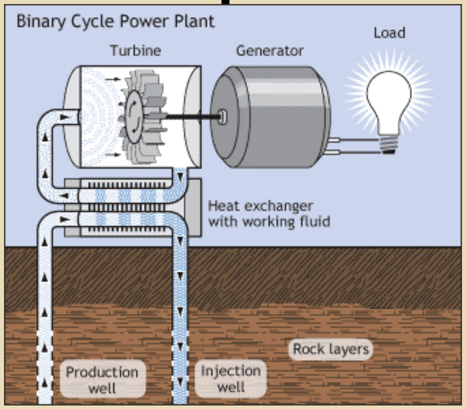

Geothermal Definitions

Comparison of USGS Geothermal Resouce Types	
Circular 726 - 1975	Circular 790 - 1979
Conductuctive transport of heat	Conduction-dominated thermal regime
Igneous-related systems	Igneous-related systems
Energy directly from molten igneous systems	NO EQUIVALENT
Hydrothermal convection system	Hydrothermal convection system (T ≥ 90°C)
NO EQUIVALENT	Low-temperature systems (T ≤ 90°C)
Onshore geopressured-geothermal resources	Geopressured-geothermal resources (thermal & chemical)

Comparison of NREL & MIT Geothermal Resource Categories	
NREL - 2006	MIT - 2007
Deep geothermal	Conduction-dominated EGS
	Sedimentary rock formations
	Crystalline basement rock formations
	Supercritical volcanic EGS (USGS 790)
Shallow hydrothermal (identified) > 90°C	Hydrothermal (USGS 726, 790)
Shallow hydrothermal (unidentified) > 150°C	
Co-produced & Geopressured	Coproduced fluids (McKenna, et al., 2005)
	Geopressured systems

Augmented MIT Geothermal Resource Categories
Conduction-dominated EGS
Sedimentary rock formations
Crystalline basement rock formations
Supercritical volcanic EGS (USGS 790)
Hydrothermal (USGS 726, 790)
Coproduced fluids (McKenna, et al., 2005)
Stranded geothermal resource
Geopressured systems
Hydrostatic systems

From R. Erdlac, 2007

Presentation Overview

- Geothermal Electrical Overview
- Texas Geothermal Potential – Sedimentary Basins
- Two Texas Geothermal Examples
  - Geopressured-Geothermal Energy
  - Deep Permian Basin
- Geothermal Energy Importance
  - Electric Generation
  - Avoided Power

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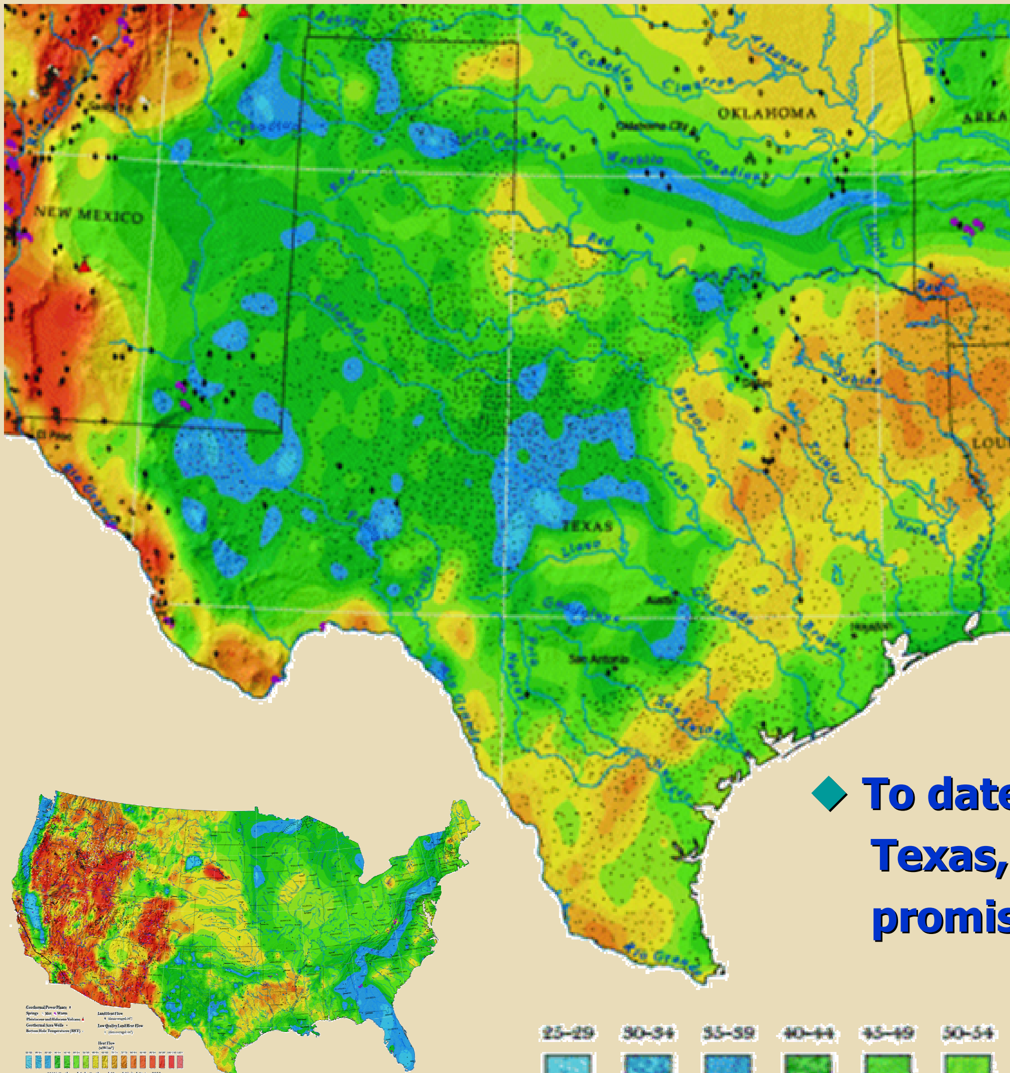
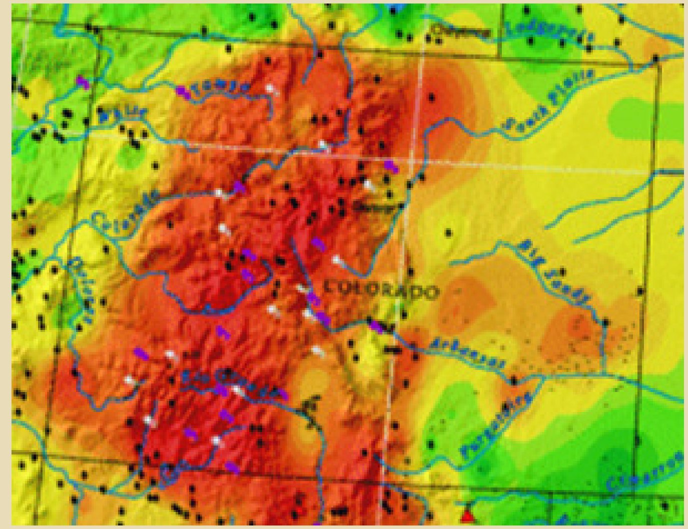
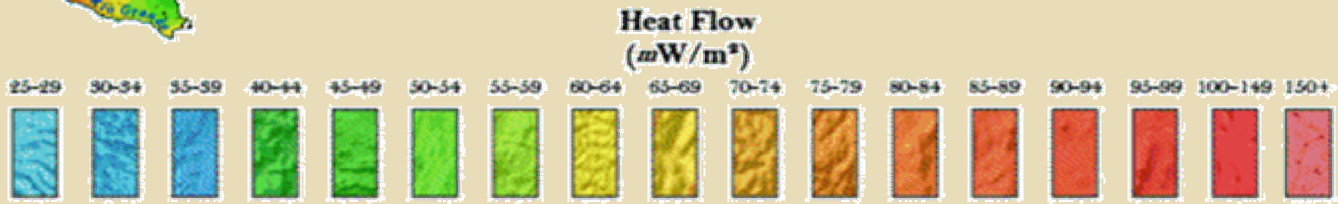
Geothermal Electrical Overview





- Existing geothermal power has focused on western states (California, Nevada, Utah).
- To date this has not included Colorado and Texas, even though both states show promising areas.



SMU Geothermal Lab, Geothermal Map of United States, 2004

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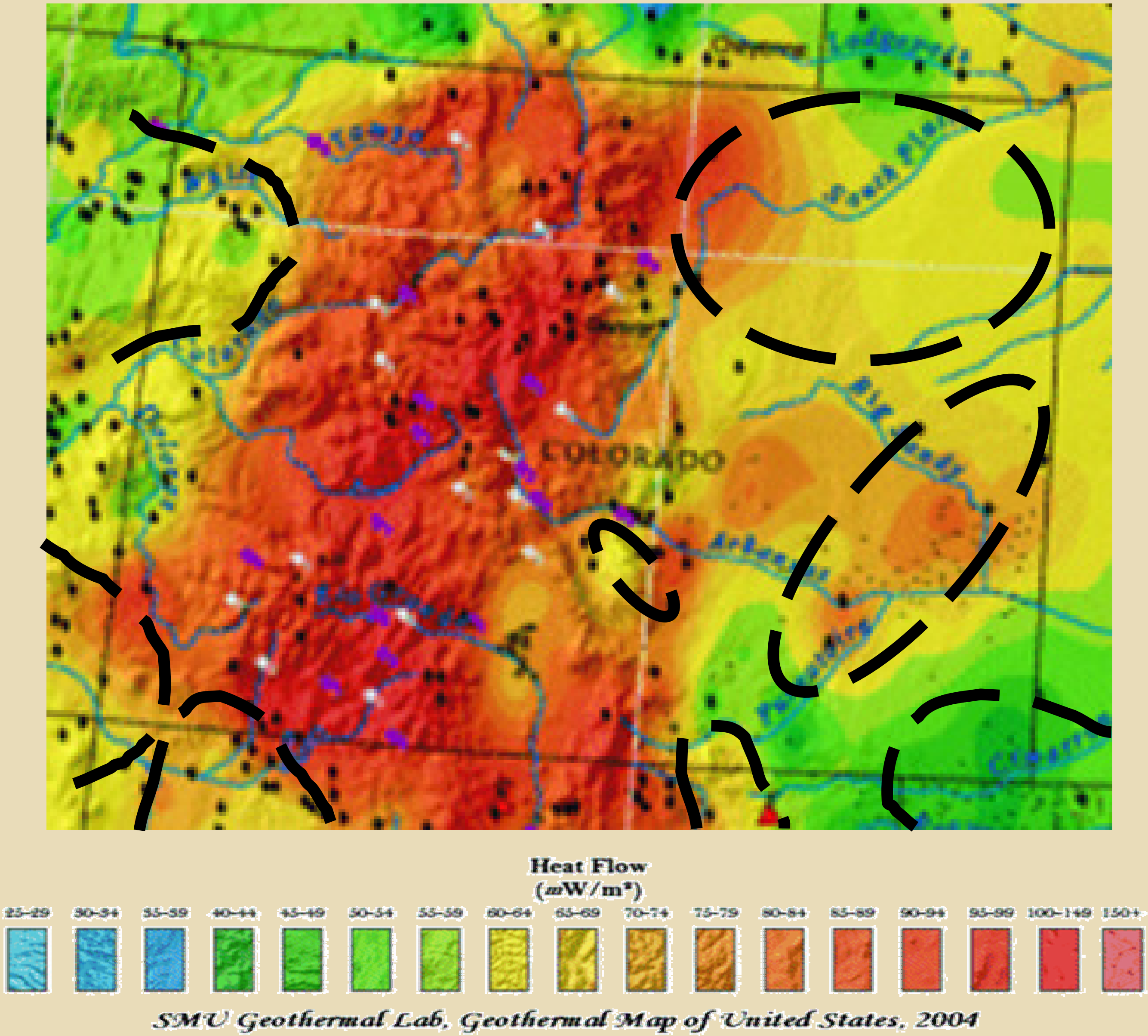
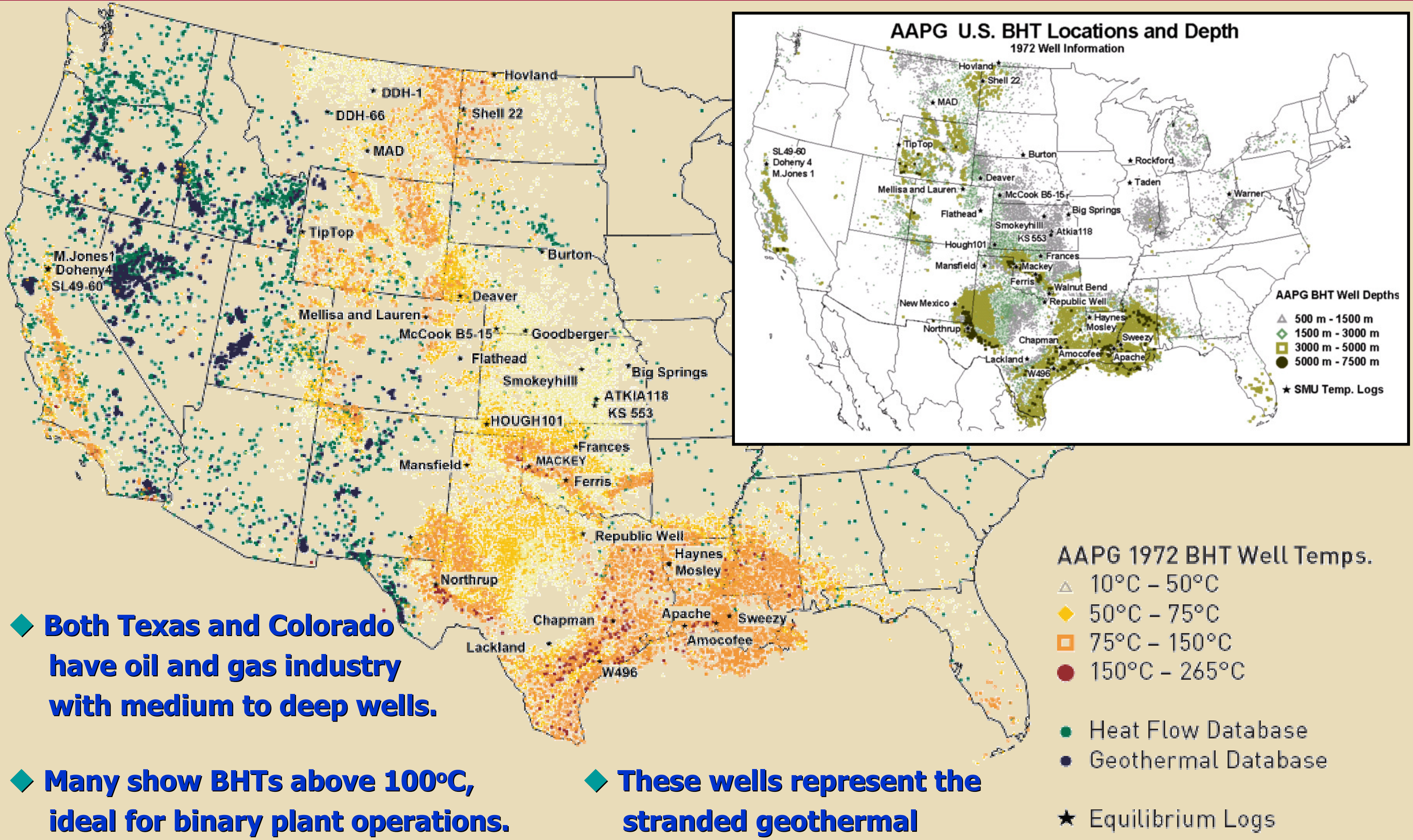
Colorado "Stranded" Geothermal



Geothermal Electrical Overview



- **Both Texas and Colorado have oil and gas industry with medium to deep wells.**
- **Many show BHTs above 100°C, ideal for binary plant operations.**
- **These wells represent the stranded geothermal energy resource.**

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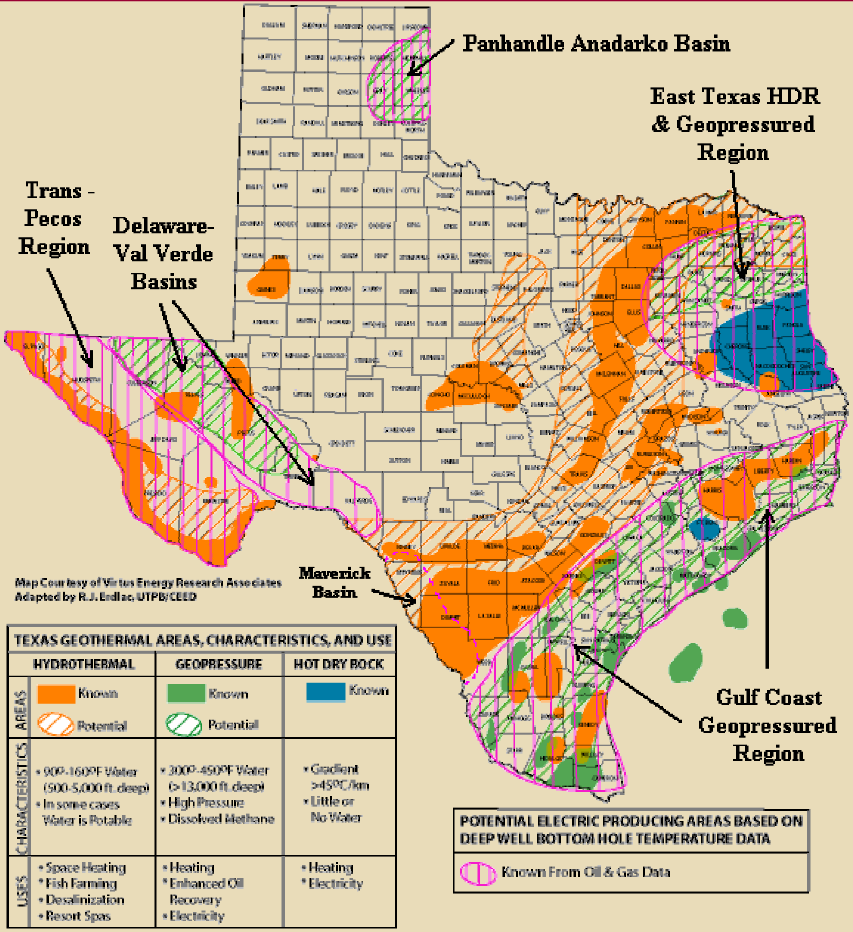
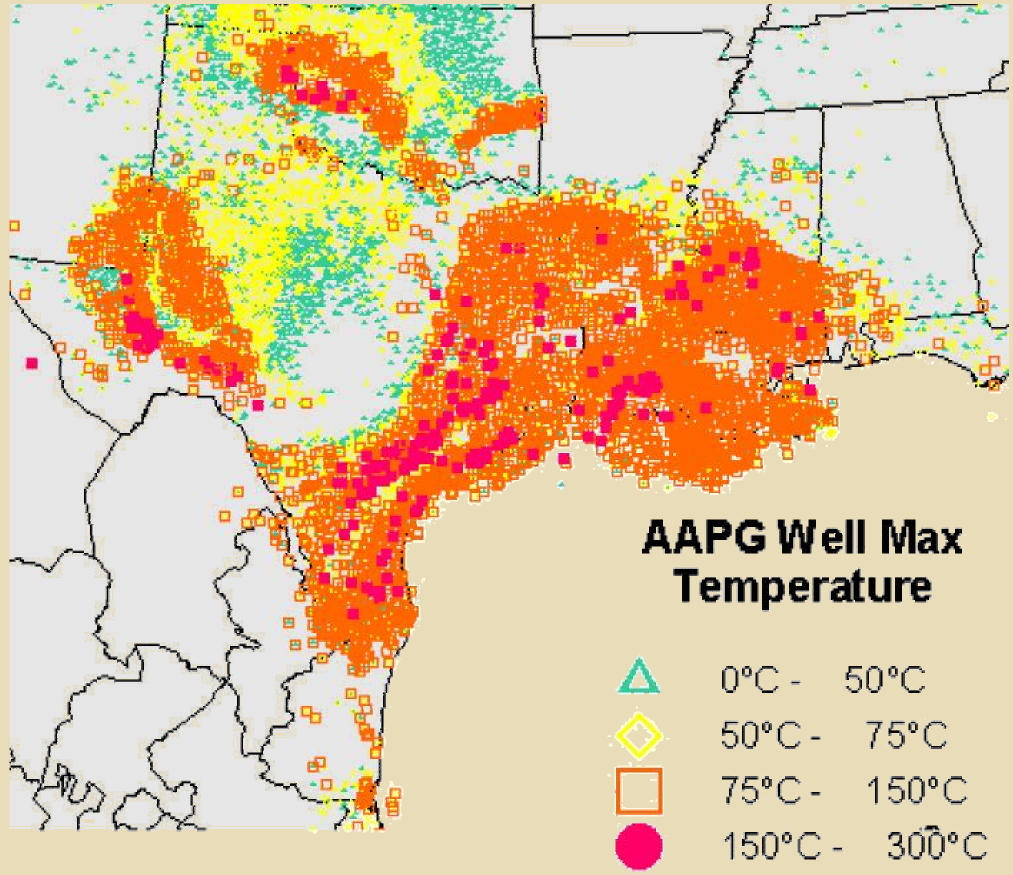
Texas Geothermal Potential – Sedimentary Basins





- Various areas in Texas hold the potential for a geothermal binary plant to be used for electric power production.

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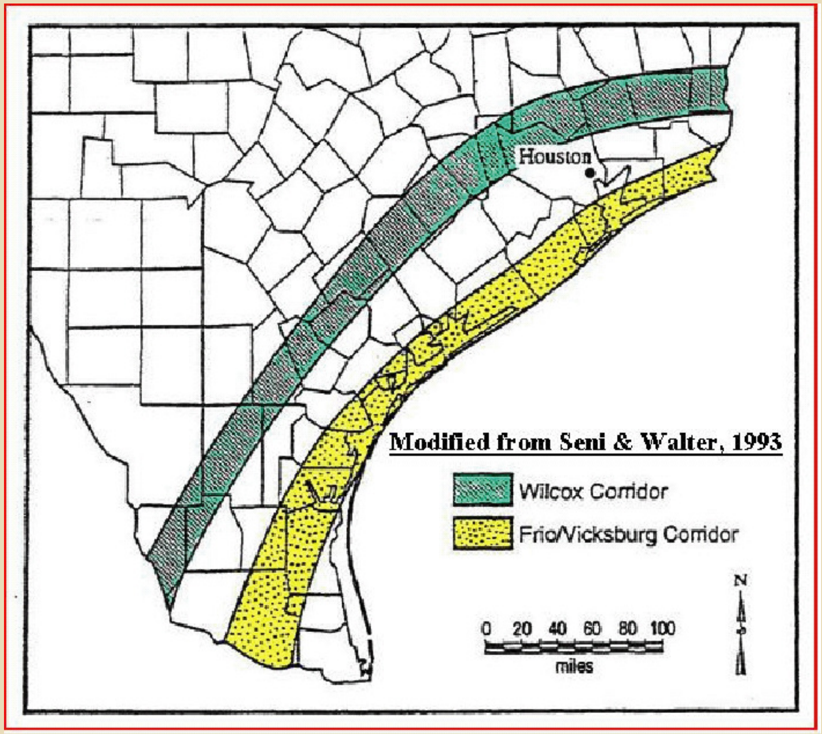
Two Texas Geothermal Examples:

Geopressured-Geothermal Energy



DOE 17-Year Program in Gulf Coast – $200 million.

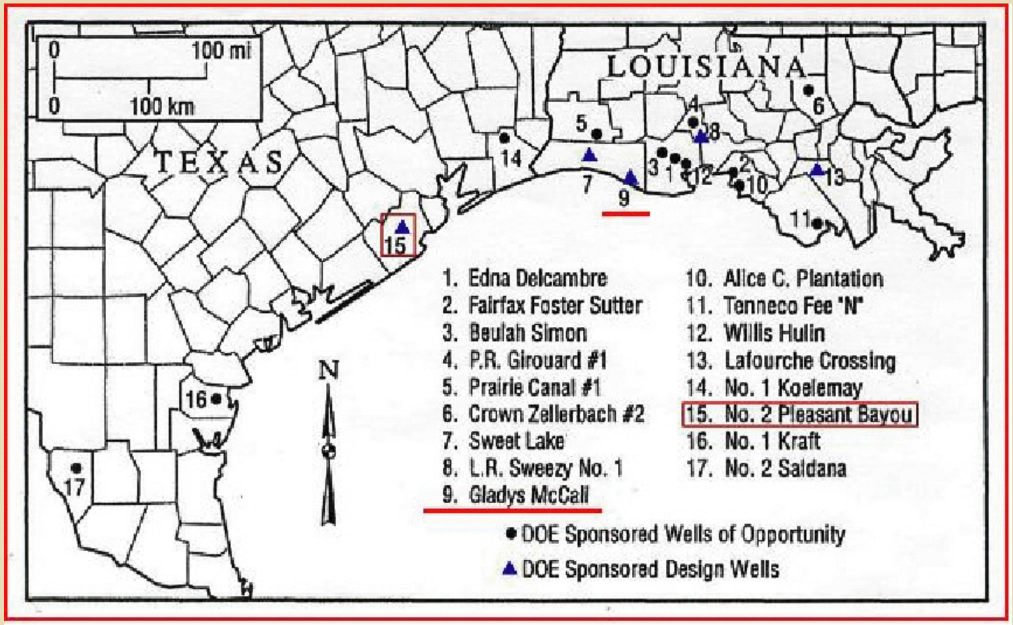
1) <u>Chemical energy</u> – dissolved methane.
2) <u>Thermal energy</u> – hot brine.
3) Mechanical energy – Hi P / Hi flow.

In Texas the focus was on Frio/Vicksburg and Wilcox sands.

Two testing programs were developed:

<u>Wells of opportunity</u> – oil and gas wells made available by industry.

<u>Design wells</u> – drilled on target site locations for testing geothermal energy recovery possibilities.



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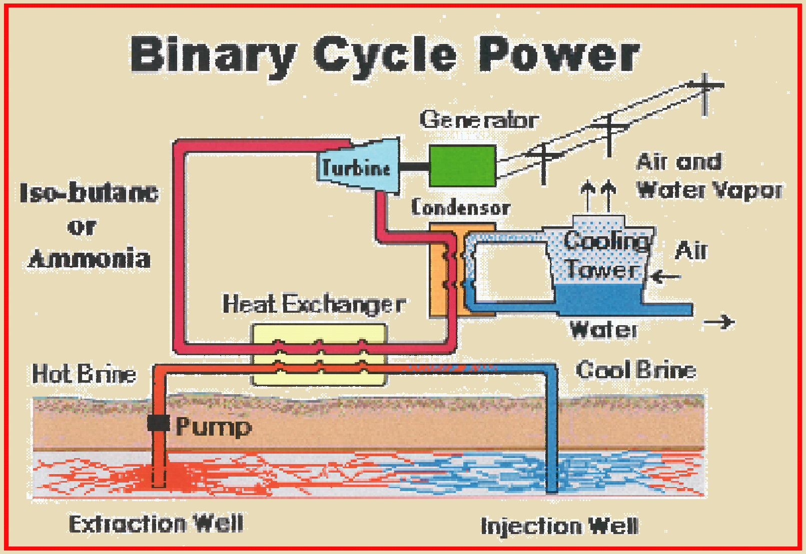
Two Texas Geothermal Examples:

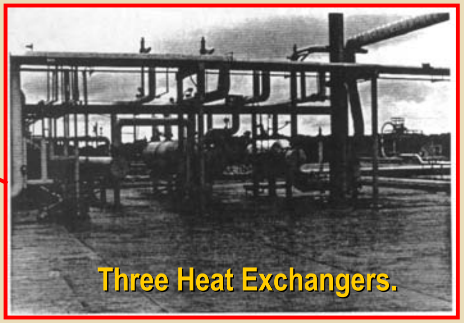
Geopressured-Geothermal Energy



A standard binary cycle power system relies on moving water from a well bore and through a heat exchanger to vaporize a working fluid like ammonia or isobutane. The brine is reinjected into the hot formation to be reheated and brought back to the surface. The vaporized working fluid is directed into the turbine for electrical power generation. The vapor is condensed and sent back to the heat exchanger to continue the cycle. Two independent closed loop fluids are used, hence the name binary cycle. At the Texas experiment, the only addition was a gas turbine to burn the entrained natural gas on site.


Condenser Units.


Fire Protection System.


Three Heat Exchangers.

Well was a technical successful at about 1.2 MW but was never commercialized due to the low cost of oil and gas. There was no Texas mandate for renewable energy production, nor were most people concerned about electricity availability. This was before the California and NE blackouts.

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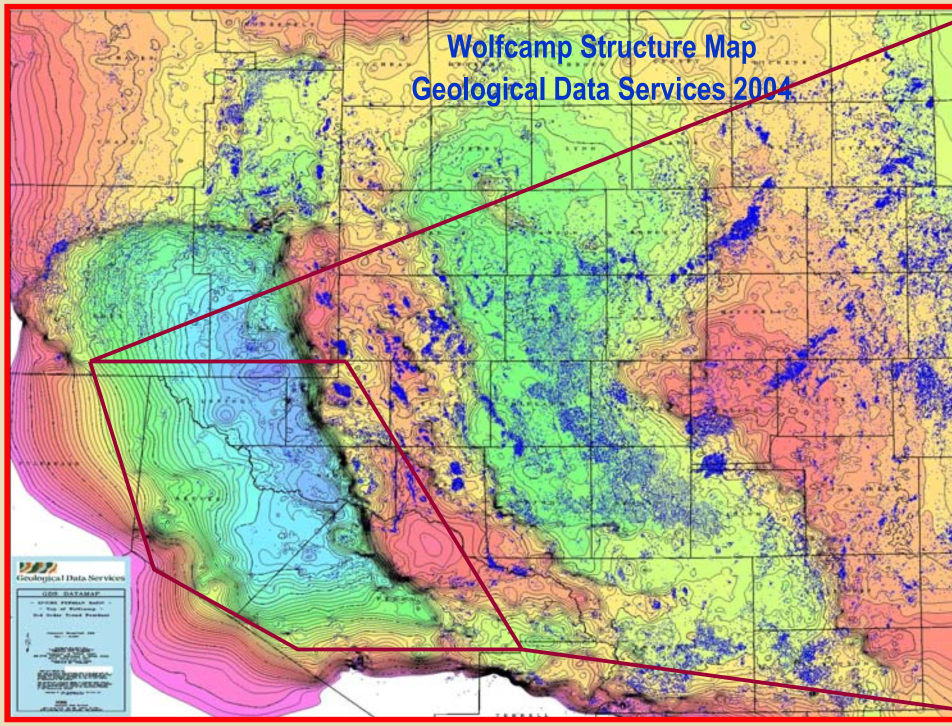
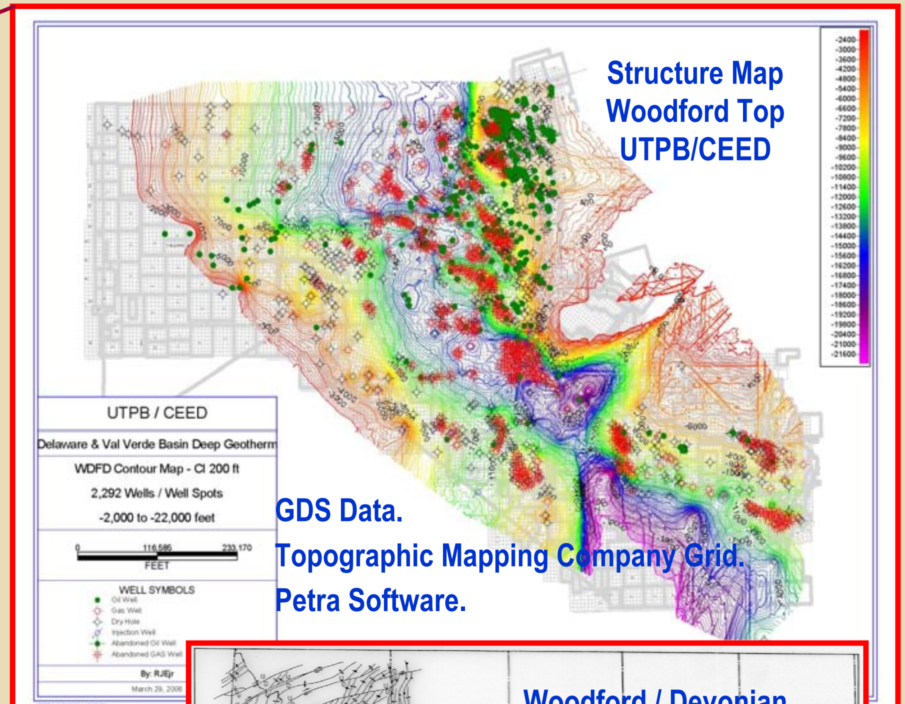
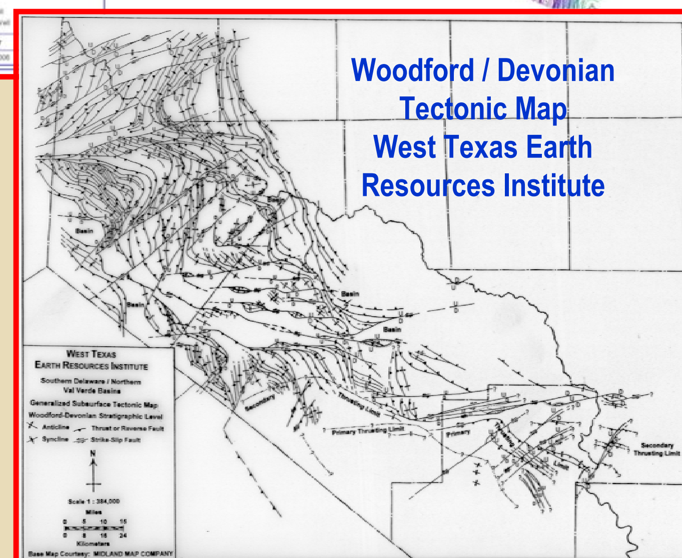
Two Texas Geothermal Examples:

Deep Permian Basin







The deep part of the Permian Basin is represented by the Delaware – Val Verde Basin complex. The Woodford Shale (Miss. – U. Dev.) can be some 22,000 ft deep, with hard rock basement being nearly 30,000 ft in depth. The basin complex is also complicated, with evidence of strike-slip, reverse or thrust faults, folds, and local normal faulting.

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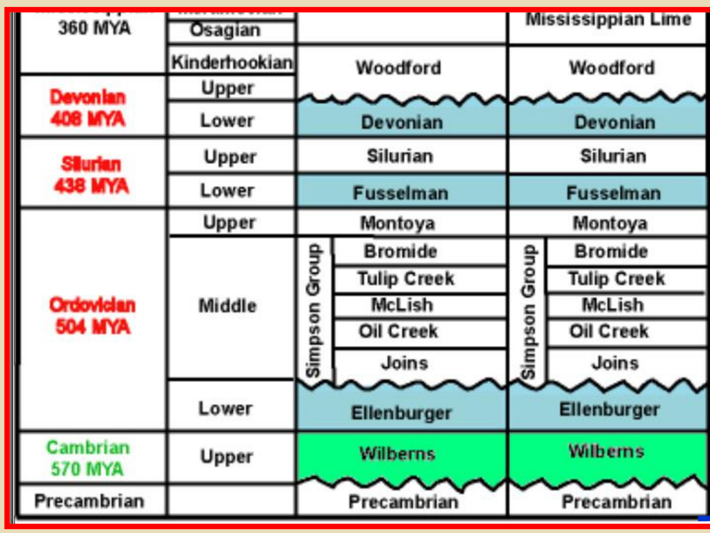
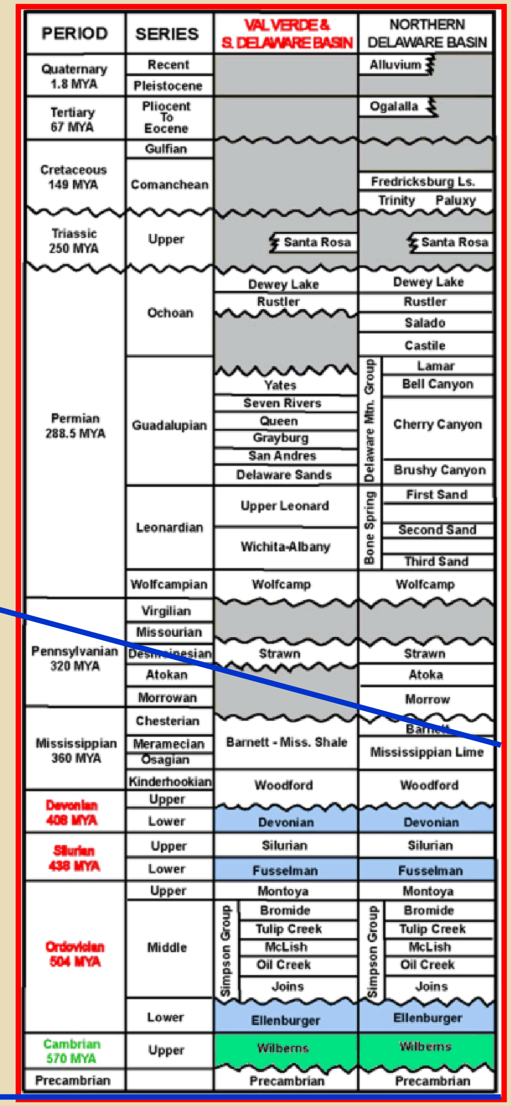
Two Texas Geothermal Examples:

Deep Permian Basin

Devonian	Porosity Range	2 to 25%
	Avg. Porosity	6 to 8%
	Fracture Permeability Range	1 to 2,840 md
	Avg. Permeability	10.5 md
Fusselman	Porosity	3 to 11%
	Avg. Porosity	4 to 5%
	Fracture Permeability Range	2 to 26 md
	Avg. Permeability	8.5 md
Ellenburger	Porosity	2 to 14%
	Avg. Porosity	4%
	Fracture Permeability Range	0.1 to 2,250 md
	Avg. Permeability	75 md

Several subsurface rock strata are potential target formations for geothermal electric power production.





Two Texas Geothermal Examples:

Deep Permian Basin

Plotting over 8,000 temperature-depth (t-d) points from over 5,000 wells in 8 counties gives log-normal distributions (rather than linear) for the data in each county. Depth is in meters and temperature is in °C.

Log-normal equation of the form:

$$z = (A)\mathrm{Ln}(T) - B$$

A and B are constants evaluated for each distribution; z is depth; T is temperature.

Equation is rewritten in the form:

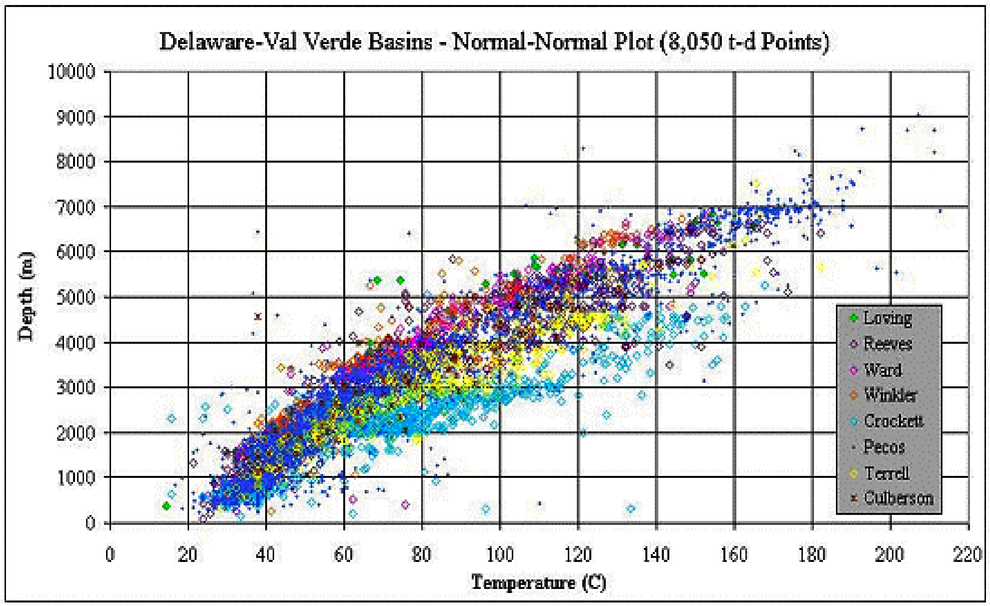
$$T = e^{C(z+B)}$$

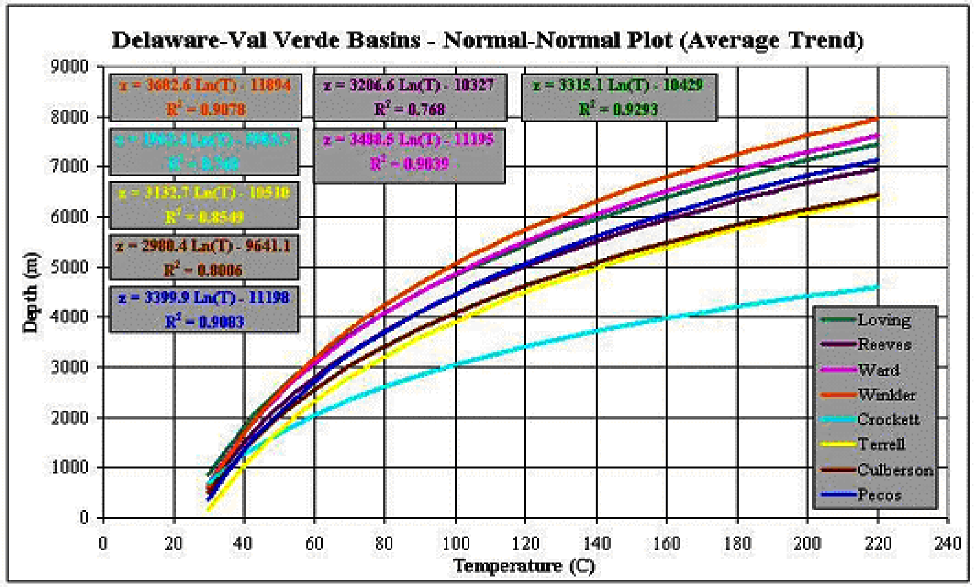
C is the new constant 1/A.

Taking derivative gives the form:

$$dT/dz = Ce^{C(z+B)} \text{ or } dT/dz = CT$$

by substitution.





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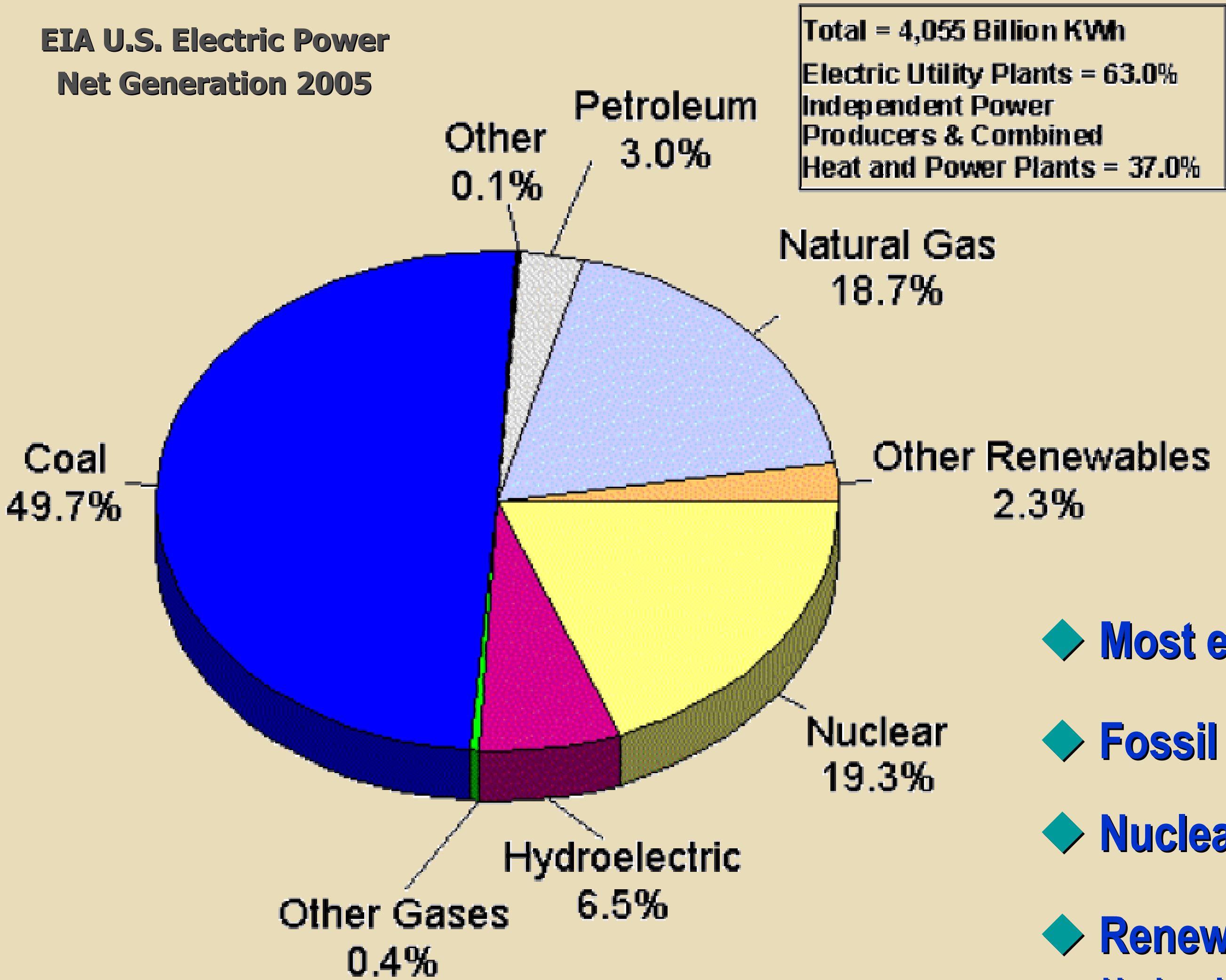
Geothermal Energy Importance

Electric Generation



- **Most electricity is from coal.**
- **Fossil fuels represent 72%.**
- **Nuclear contributes 19%.**
- **Renewable energy is 9%.**
  Hydroelectric = 75% of renewables.

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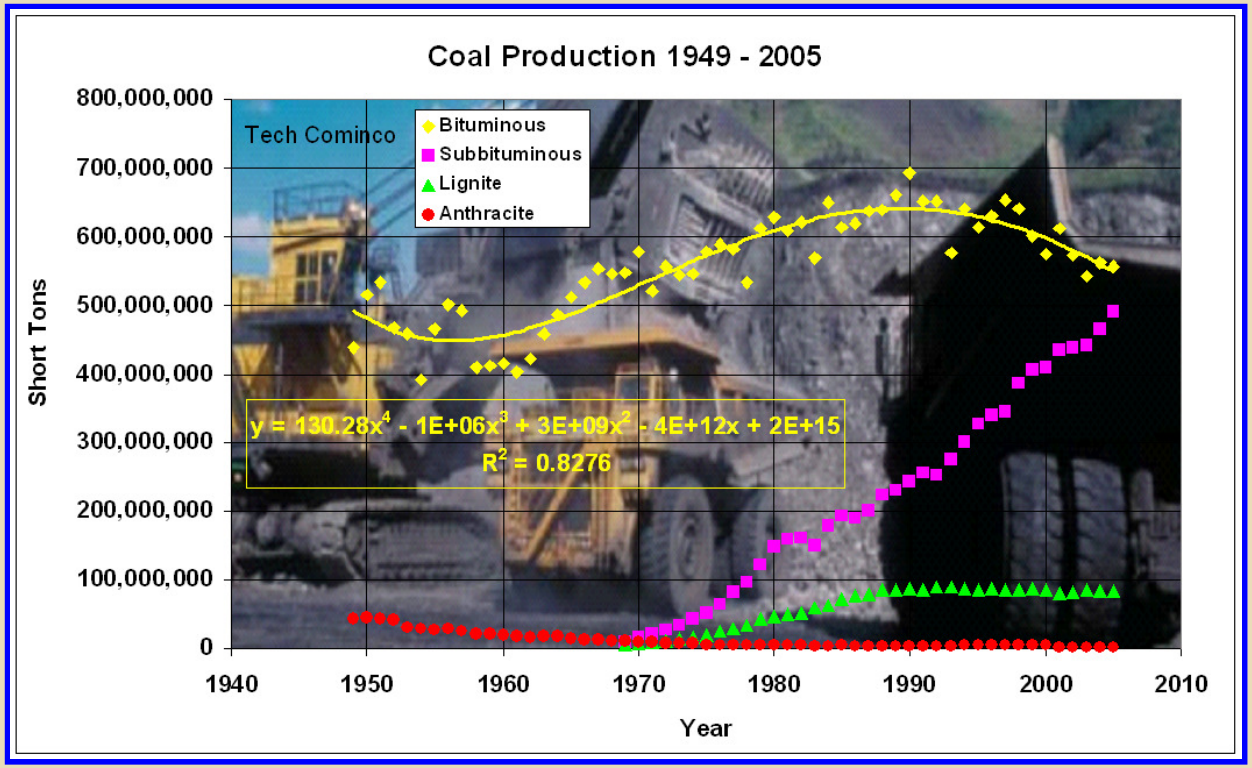
Geothermal Energy Importance

Electric Generation



1973 – "U.S. coal reserves will last over 500 years…" **(Congressional Rpt – National Fuels & Energy Policy Study Serial No. 93-9).**

2007 – "…U.S. has a 240 year supply of coal reserves" **(Energy Mineral Division, AAPG website).**

What happened?

- **Amount of production and consumption rates changed.**
- **Bituminous (most abundant) production has gone through a Hubbard peak?!**
- **This means a lower Btu content available for electrical production.**

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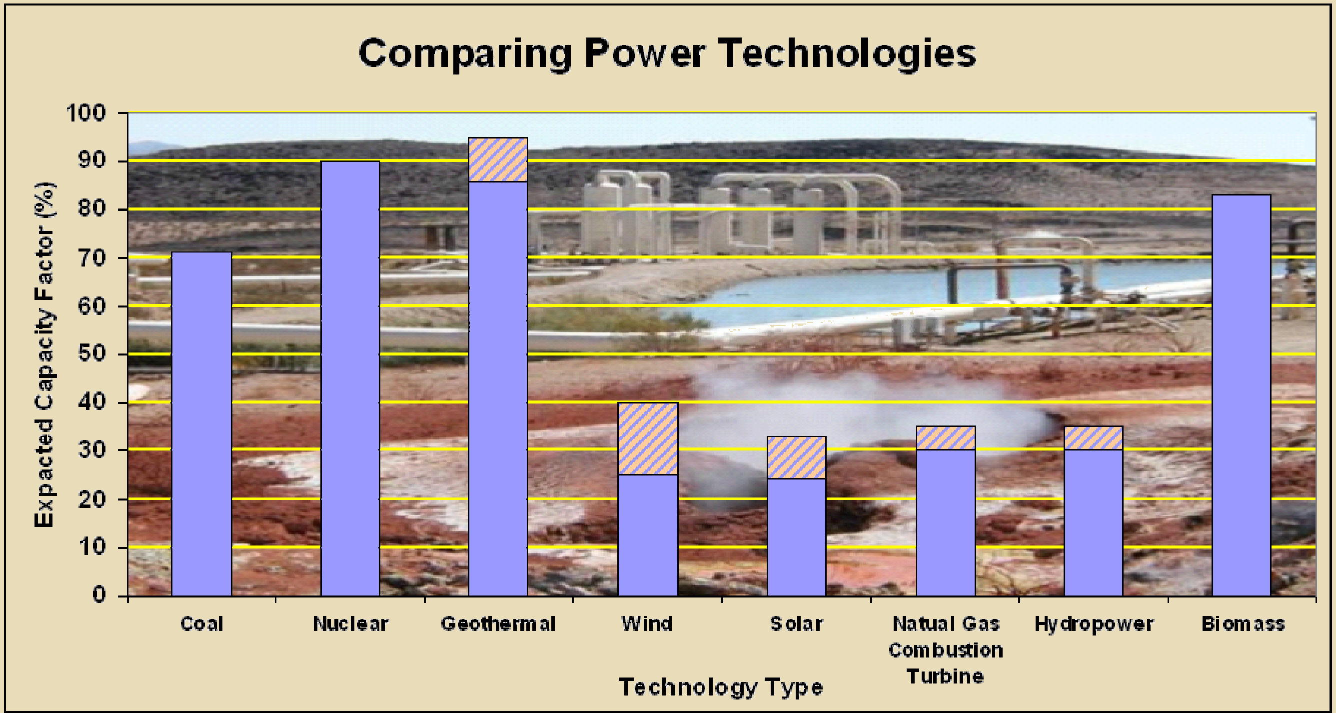
Geothermal Energy Importance

Electric Generation

Comparing Power Technologies	
Technology	Expected Capacity Factor (%)
Coal	71
Nuclear	90
Geothermal	86 - 95
Wind	25 - 40
Solar	24 - 33
Natual Gas Combustion Turbine	30 - 35
Hydropower	30 - 35
Biomass	83

Geothermal Energy Association, West Coast Geothermal Finance & Development Workshop, May 2007

- **A major importance of geothermal power production is that it has a high capacity factor.**
- **Thus geothermal impacts base load electrical demand.**



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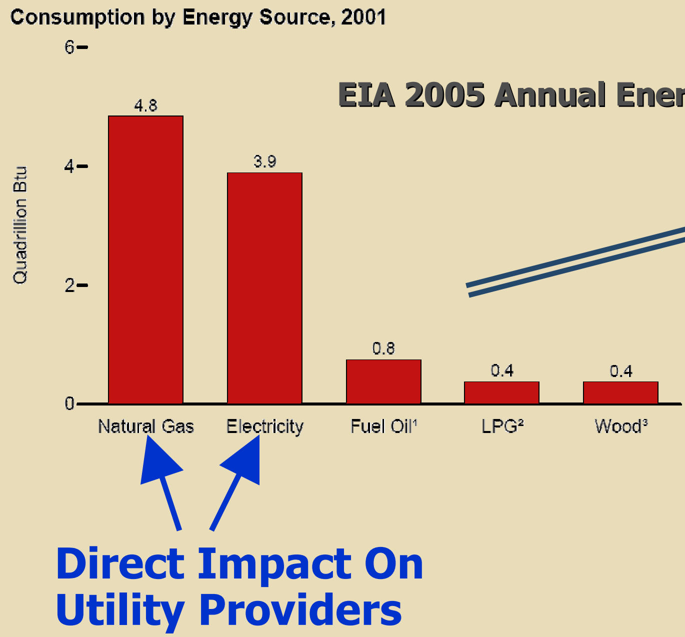
Geothermal Energy Importance

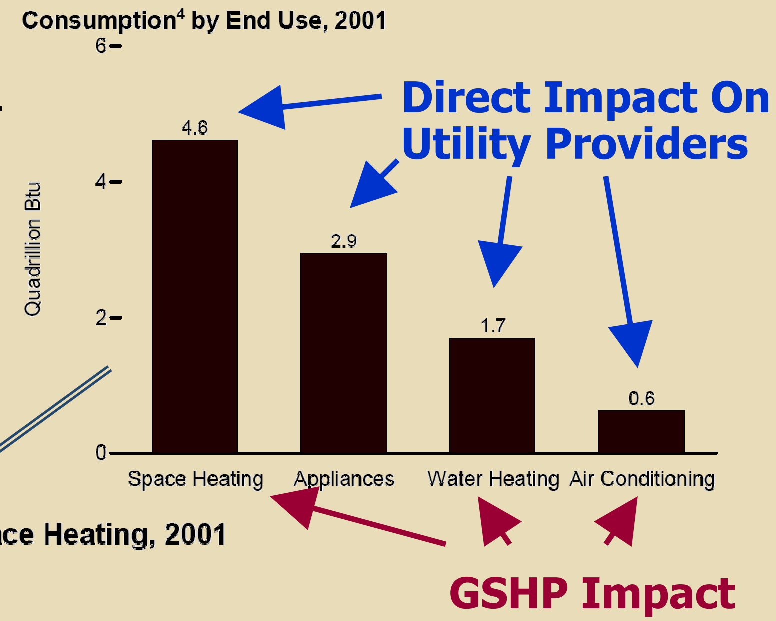
Avoided Power

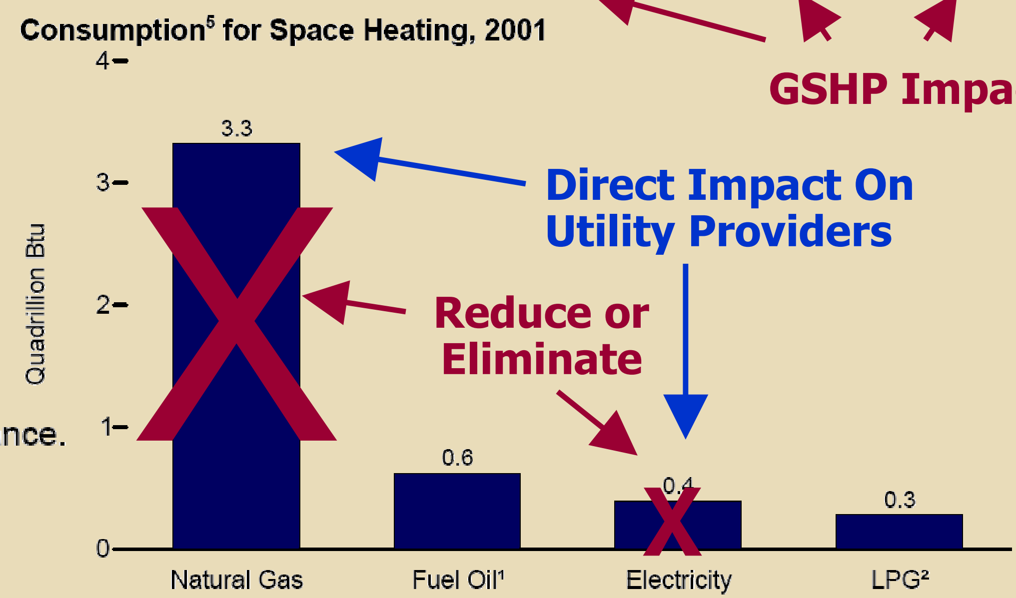
Geoexchange Systems

Example: Household Energy Consumption

EIA 2005 Annual Energy Review







[1] Distillate fuel oil and kerosene.
[2] Liquefied petroleum gases.
[3] Wood used for both space heating and ambiance.
[4] Does not include wood.

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Concluding Remarks

- Humanity began by discovering and harnessing renewable energy – agriculture, wind, solar, geothermal, biomass, water power.
- Our modern technology did not develop until electricity was produced from fossil fuels.
- Electrical power now provides the foundation for our technology, which is still mainly derived from fossil fuels.
- Renewable energy usage for electrical production must increase as fossil fuels acquire added importance in other product-focused industries.
- Geothermal energy assists the utility industry through avoided power and by direct power generation.
- Geothermal can be nested or combined with other renewable resources to help in offsetting the weaknesses of each resource.

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