



Geothermal

Energy

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

Dr. Richard J. Erdlac, Jr.
Energy America Geothermal
Midland, Texas

* **Peter Gross**
Energy America Geothermal
Houston, Texas

* **Speaker**

Energy America Inc.

Energy America Geothermal

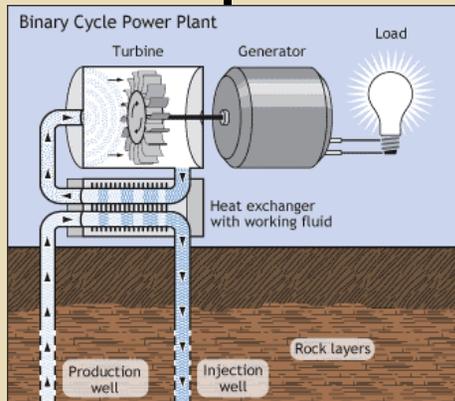


Trading & Supply



POWER

GEOEXCHANGE



Geothermal Definitions

Comparison of USGS Geothermal Resource Types	
Circular 726 - 1975	Circular 790 - 1979
Conductive 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 ($T \geq 90^\circ\text{C}$)
NO EQUIVALENT	Low-temperature systems ($T \leq 90^\circ\text{C}$)
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) $> 90^\circ\text{C}$	Hydrothermal (USGS 726, 790)
Shallow hydrothermal (unidentified) $> 150^\circ\text{C}$	
Co-produced & Geopressured	Coproduced fluids (McKenna, et al., 2005)
	Geopressured systems

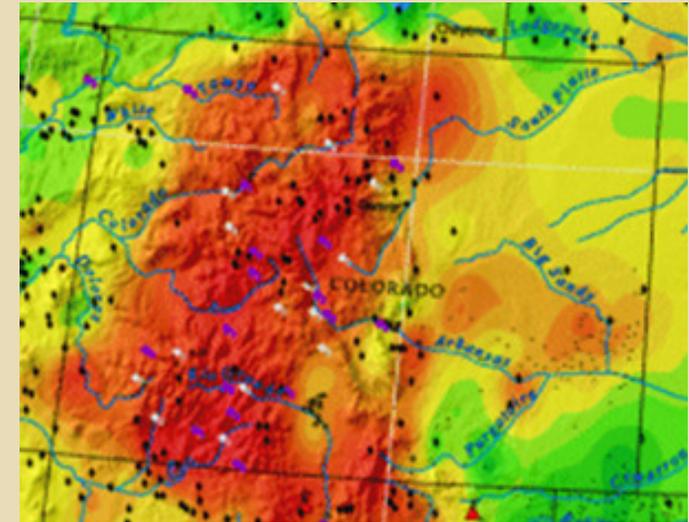
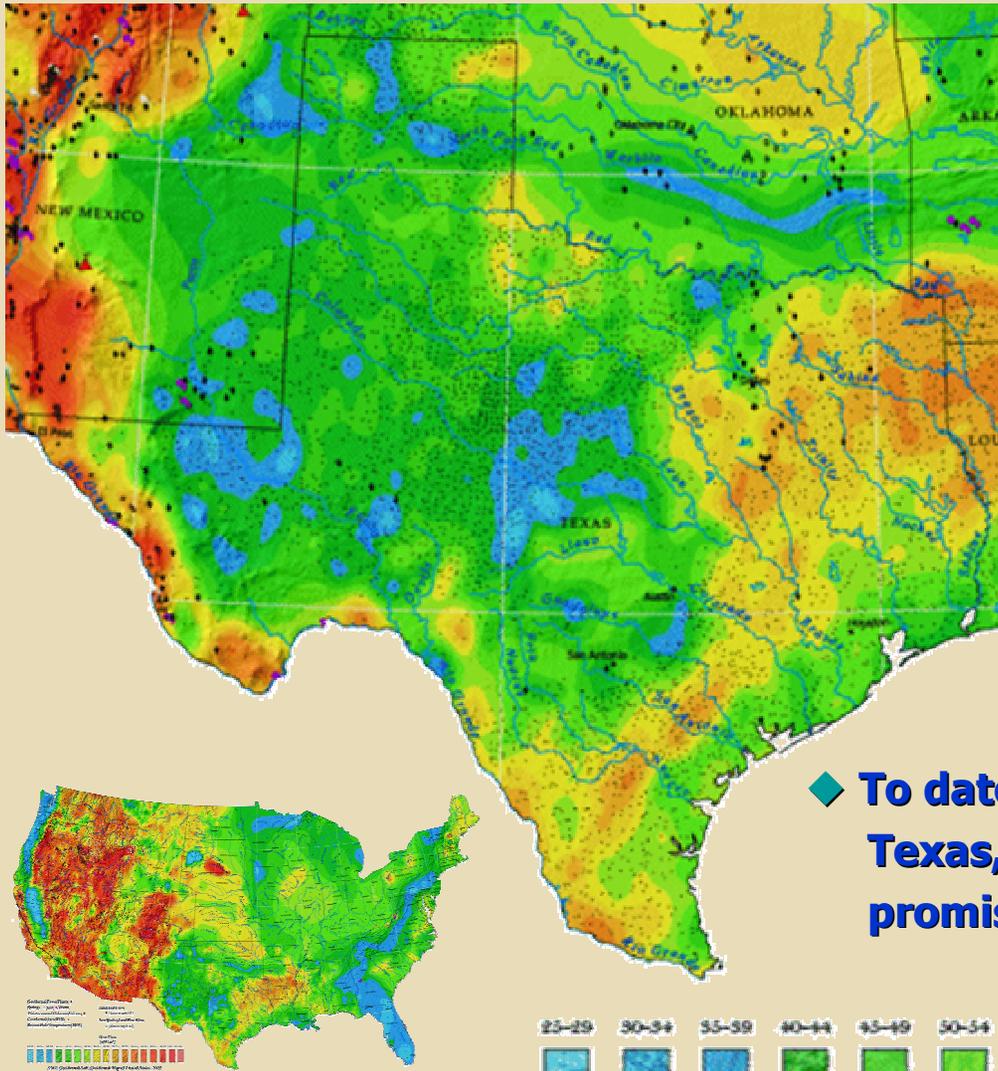
Augmented MIT Geothermal Resource Categories
Conduction-dominated EGS
Sedimentary rock formations
Crystalline basement rock formations
Supercritical volcanic EGS (USGS 790)
Hydrothermal (USGS 726, 790)
Coproduced fluids (McKenna, et al., 2005)
Stranded geothermal resource
Geopressured systems
Hydrostatic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

From R. Erdlac, 2007

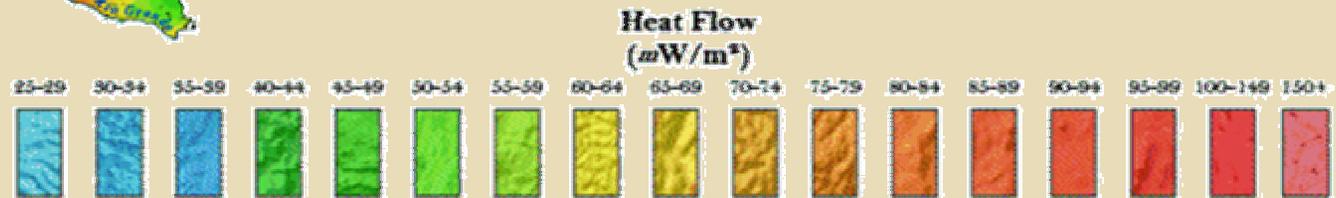
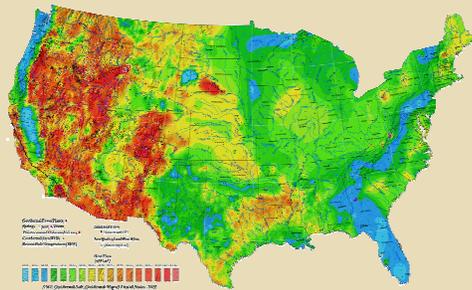
Presentation Overview

- ◆ **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

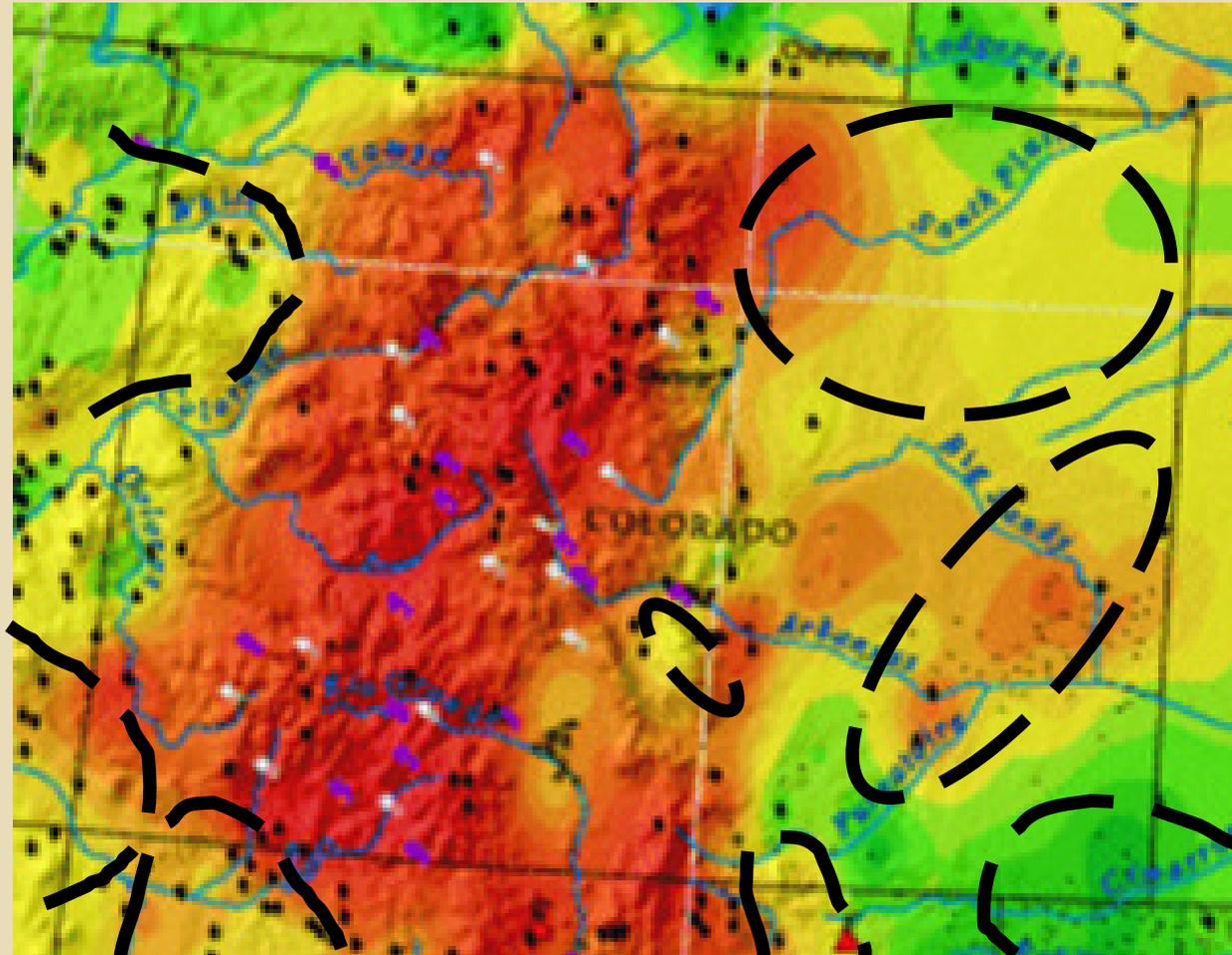
Geothermal Electrical Overview



- ◆ 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.

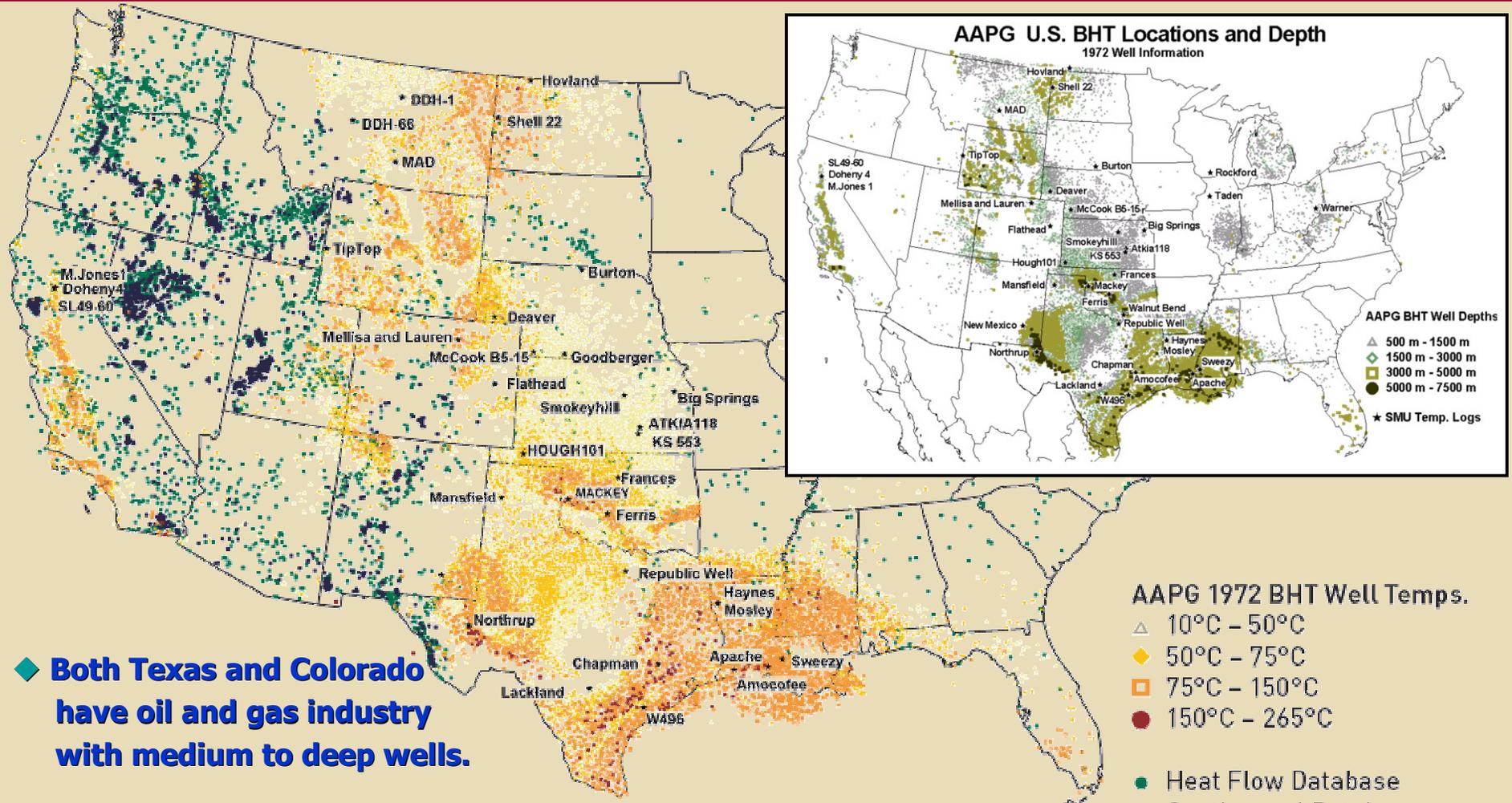


Colorado **“Stranded”** Geothermal



SMU Geothermal Lab, Geothermal Map of United States, 2004

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.

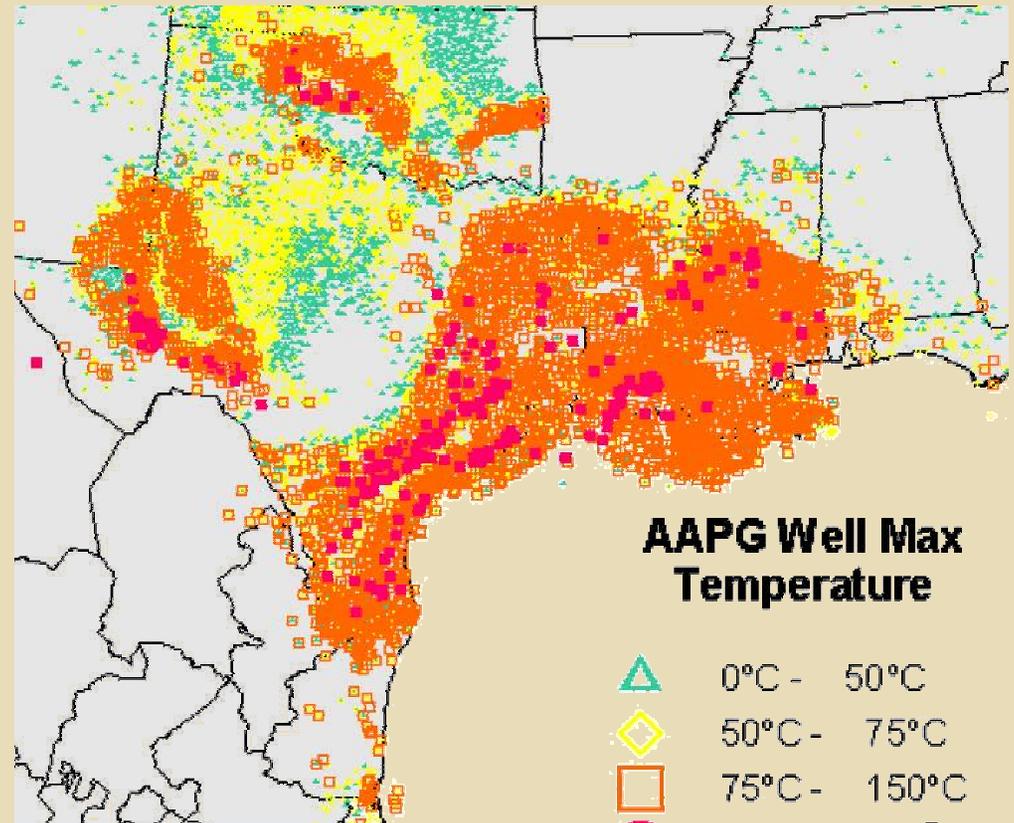
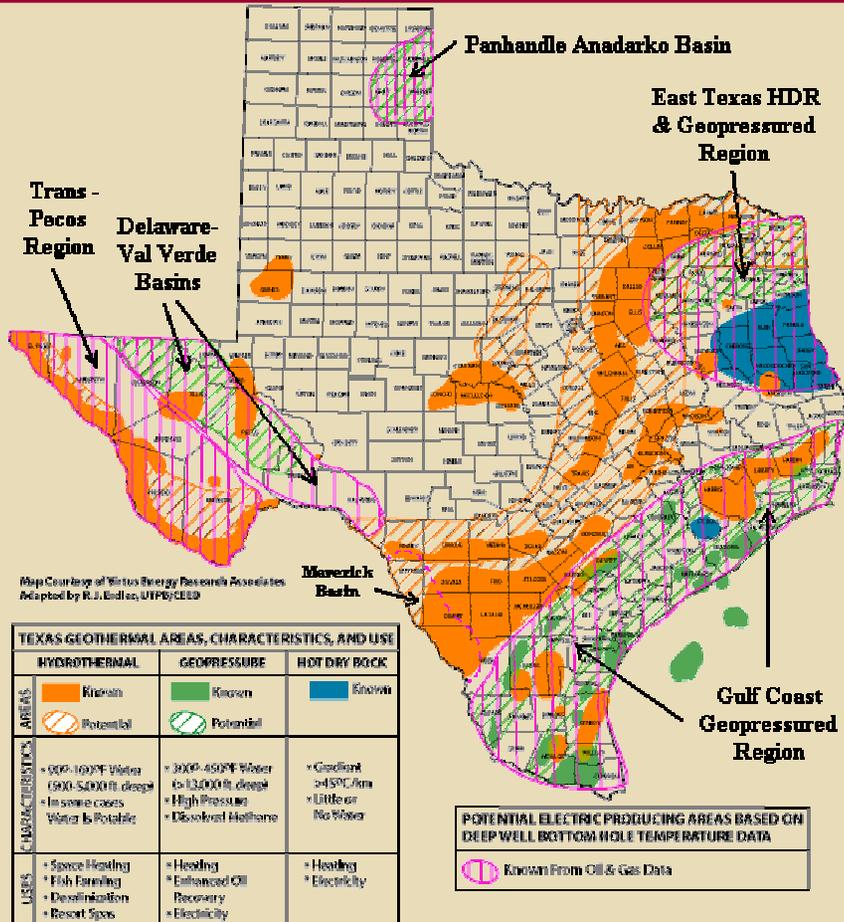
◆ These wells represent the stranded geothermal energy resource.

AAPG 1972 BHT Well Temps.

- △ 10°C – 50°C
- ◆ 50°C – 75°C
- ◻ 75°C – 150°C
- 150°C – 265°C

- Heat Flow Database
- Geothermal Database
- ★ Equilibrium Logs

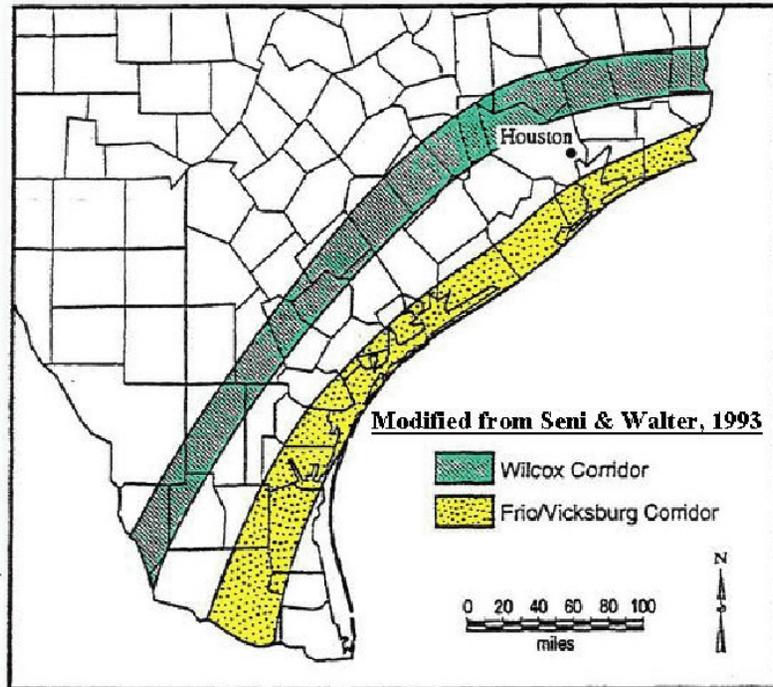
Texas Geothermal Potential – Sedimentary Basins



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

Two Texas Geothermal Examples:

Geopressured-Geothermal Energy



Two testing programs were developed:

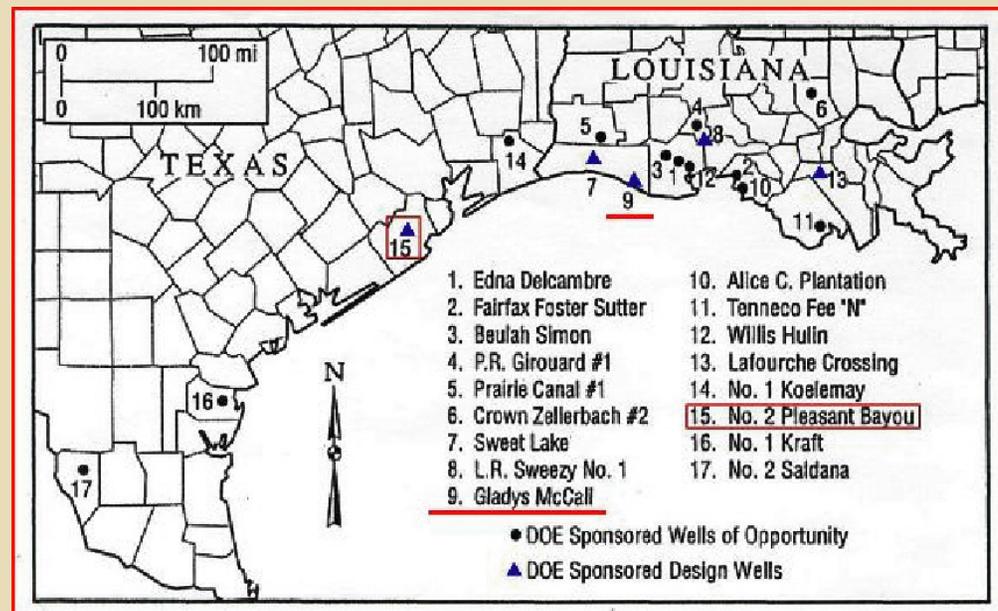
Wells of opportunity – oil and gas wells made available by industry.

Design wells – drilled on target site locations for testing geothermal energy recovery possibilities.

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

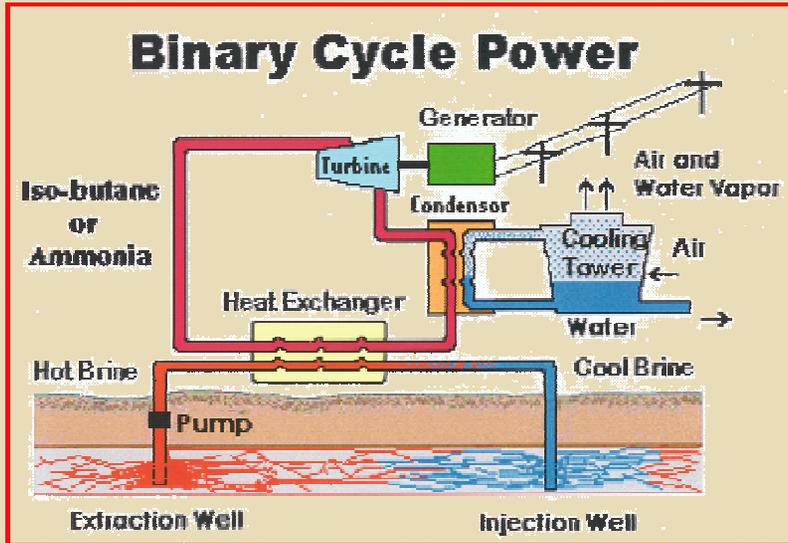
- 1) Chemical energy – dissolved methane.
- 2) Thermal energy – hot brine.
- 3) Mechanical energy – Hi P / Hi flow.

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

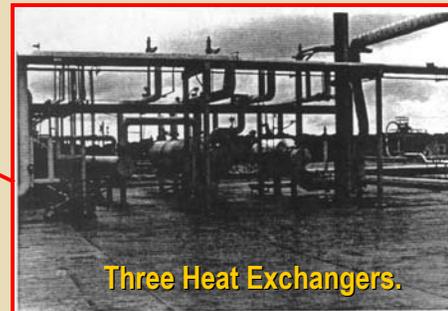


Two Texas Geothermal Examples:

Geopressured-Geothermal Energy



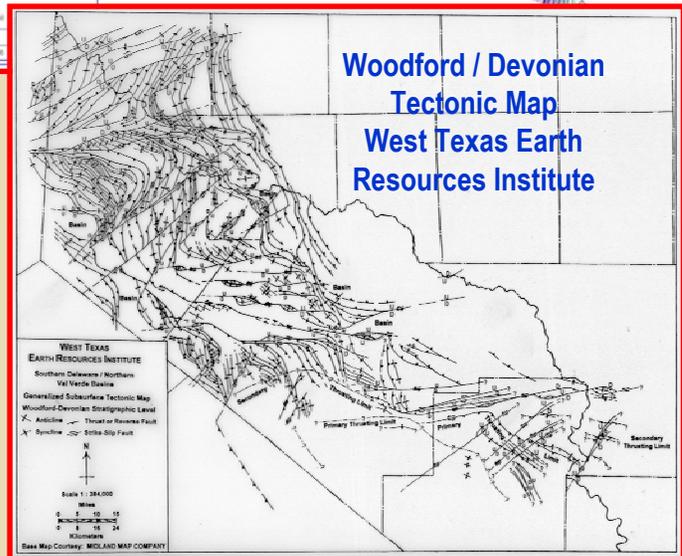
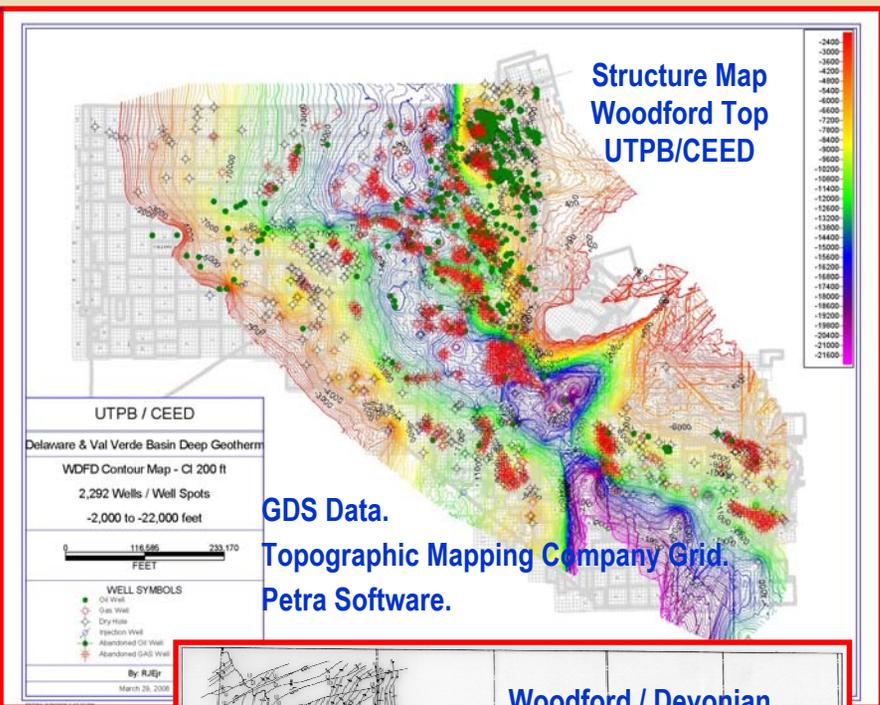
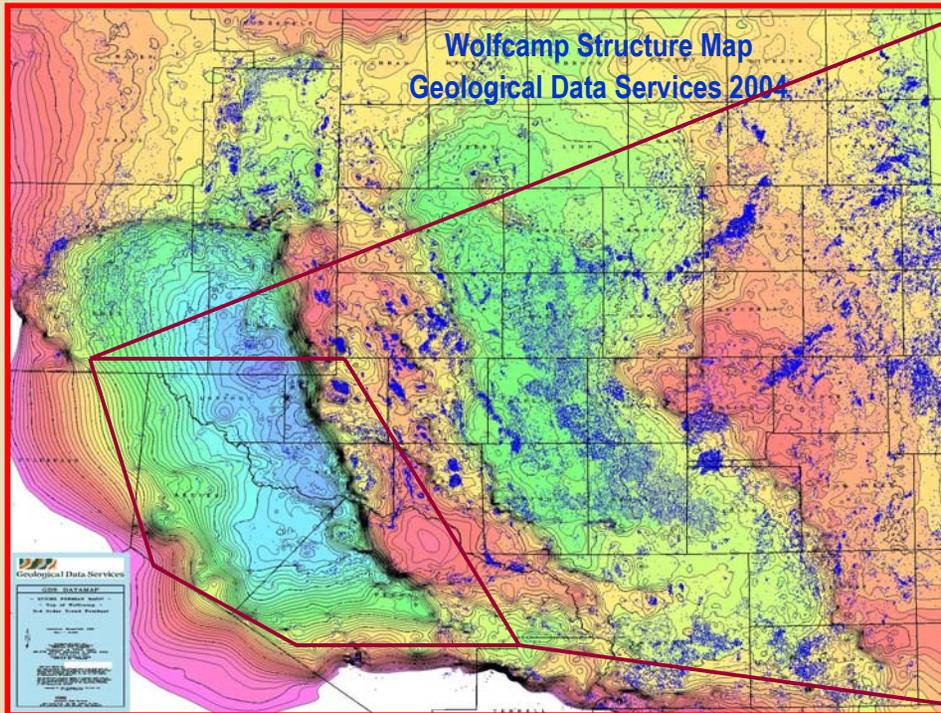
A standard binary cycle power system relies on moving water from a well bore and through a heat exchanger to vaporize a working fluid like ammonia or isobutane. The brine is reinjected into the hot formation to be reheated and brought back to the surface. The vaporized working fluid is directed into 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.



Well was a technical success 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.

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.

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

PERIOD	SERIES	VAL VERDE & S. DELAWARE BASIN	NORTHERN DELAWARE BASIN	
Quaternary 1.8 MYA	Recent		Alluvium	
	Pleistocene			
Tertiary 67 MYA	Pliocene to Eocene		Ogalalla	
	Gulfian			
Cretaceous 149 MYA	Comanchean		Fredricksburg Ls. Trinity Palluxy	
Triassic 250 MYA	Upper	Santa Rosa	Santa Rosa	
Permian 288.5 MYA	Ochoan	Dewey Lake	Dewey Lake	
		Rustler	Rustler	
		Salado	Salado	
	Guadalupian	Delaware Min. Group	Castile	Castile
			Lamar	Lamar
			Bell Canyon	Bell Canyon
			Cherry Canyon	Cherry Canyon
			Brushy Canyon	Brushy Canyon
			First Sand	First Sand
			Second Sand	Second Sand
	Leonardian	Bone Spring	Upper Leonard	Upper Leonard
			Wichita-Albany	Wichita-Albany
	Wolfcampian		Wolfcamp	Wolfcamp
	Pennsylvanian 320 MYA	Virgilian		
		Missourian		
Desmoinesian		Strawn	Strawn	
Atokan			Atoka	
Mississippian 360 MYA	Morrowan		Morrow	
	Chesterian			
	Meramecian	Barnett - Miss. Shale	Barnett	
	Osagian		Mississippian Lime	
	Kinderhookian	Woodford	Woodford	
Devonian 408 MYA	Upper	Devonian	Devonian	
	Lower	Devonian	Devonian	
Silurian 438 MYA	Upper	Silurian	Silurian	
	Lower	Fusselman	Fusselman	
Ordovician 504 MYA	Middle	Simpson Group	Montoya	Montoya
			Bromide	Bromide
			Tulip Creek	Tulip Creek
			McLish	McLish
			Oil Creek	Oil Creek
	Joins	Joins		
	Lower		Ellenburger	Ellenburger
Cambrian 570 MYA	Upper	Wilberns	Wilberns	
Precambrian		Precambrian	Precambrian	

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

360 MYA	Osagian		Mississippian Lime	
Devonian 408 MYA	Kinderhookian	Woodford	Woodford	
	Upper			
Silurian 438 MYA	Lower	Devonian	Devonian	
	Upper	Silurian	Silurian	
Ordovician 504 MYA	Lower	Fusselman	Fusselman	
	Middle	Simpson Group	Montoya	Montoya
			Bromide	Bromide
			Tulip Creek	Tulip Creek
			McLish	McLish
			Oil Creek	Oil Creek
	Joins	Joins		
Lower		Ellenburger	Ellenburger	
Cambrian 570 MYA	Upper	Wilberns	Wilberns	
Precambrian		Precambrian	Precambrian	

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:

$$z = (A)\ln(T) - B$$

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

Equation is rewritten in the form:

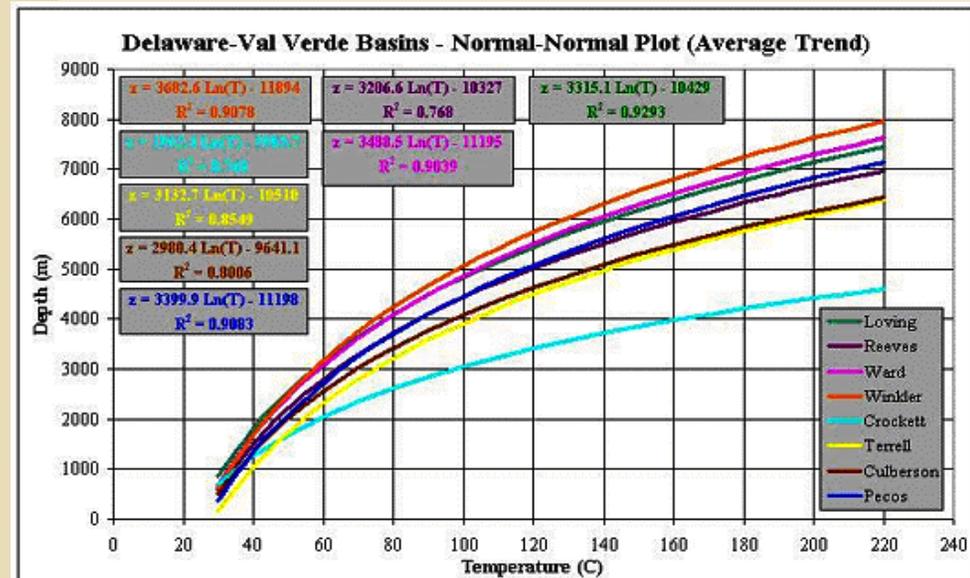
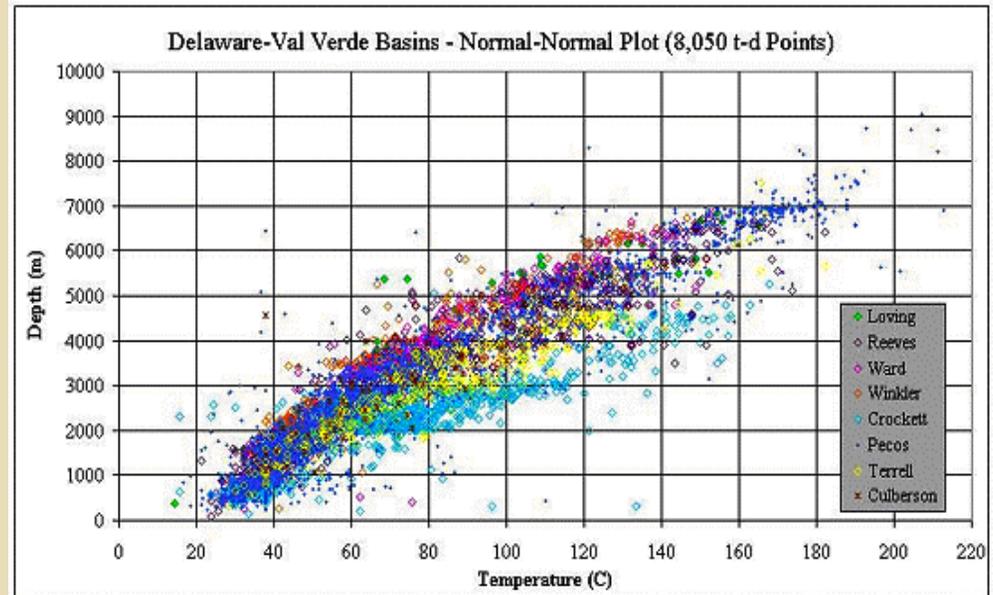
$$T = e^{C(z+B)}$$

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.

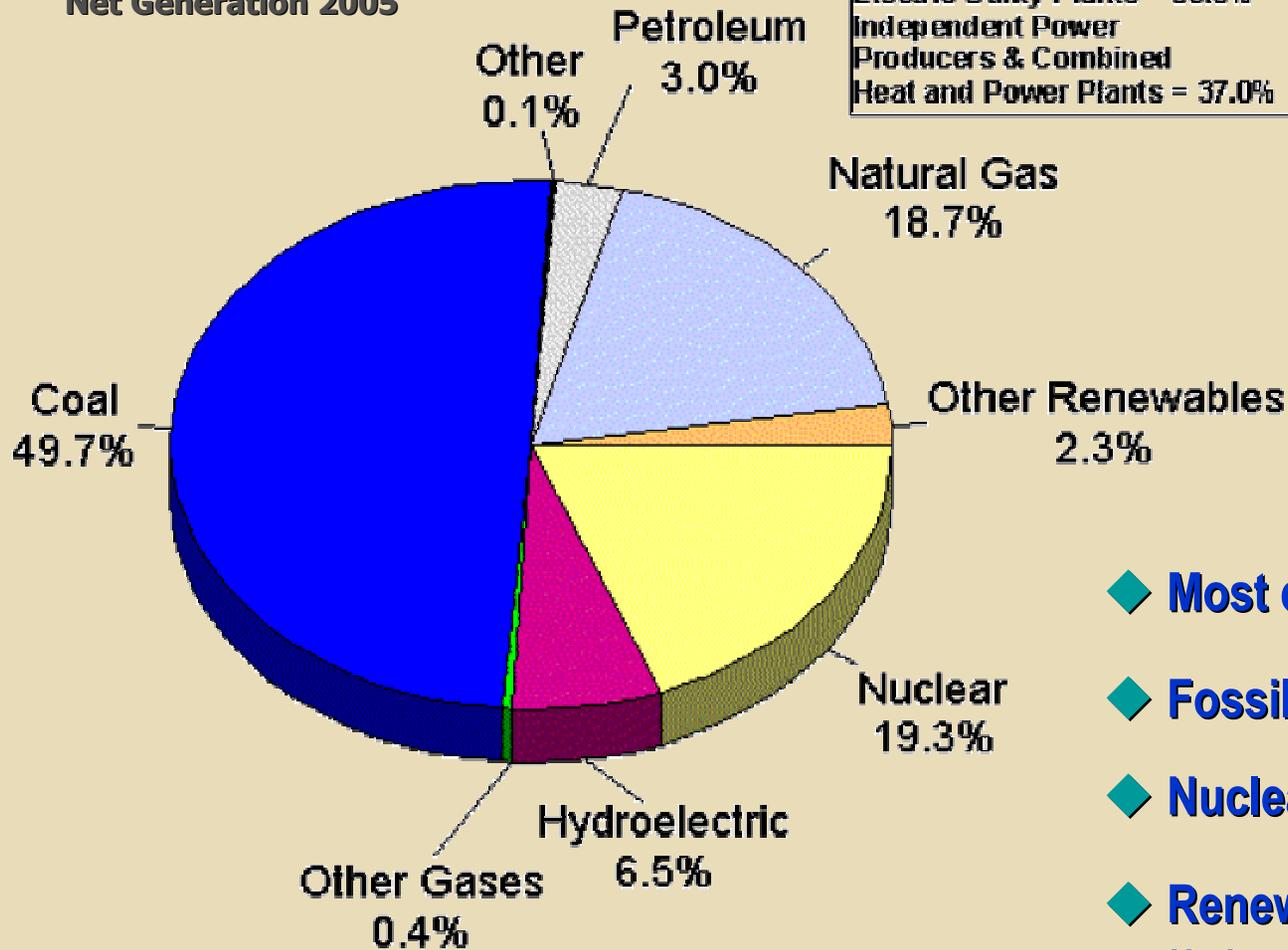


Geothermal Energy Importance

Electric Generation

EIA U.S. Electric Power
Net Generation 2005

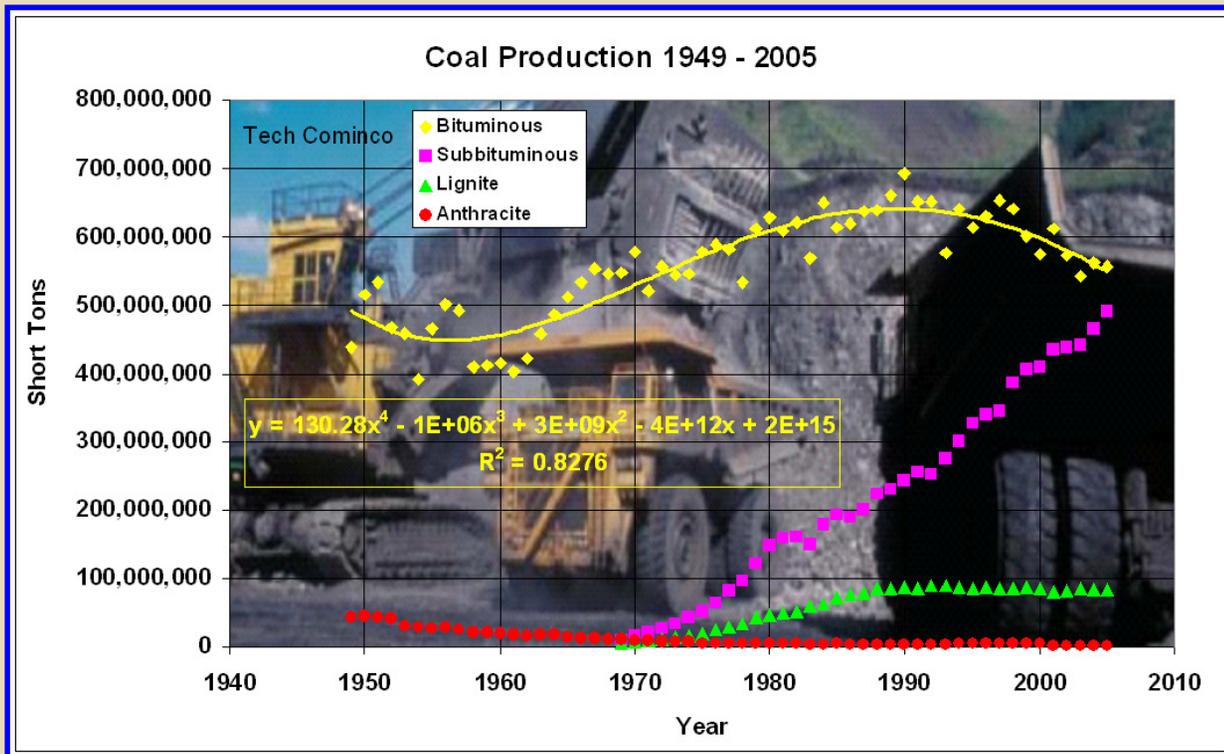
Total = 4,055 Billion KWh
Electric Utility Plants = 63.0%
Independent Power
Producers & Combined
Heat and Power Plants = 37.0%



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

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.

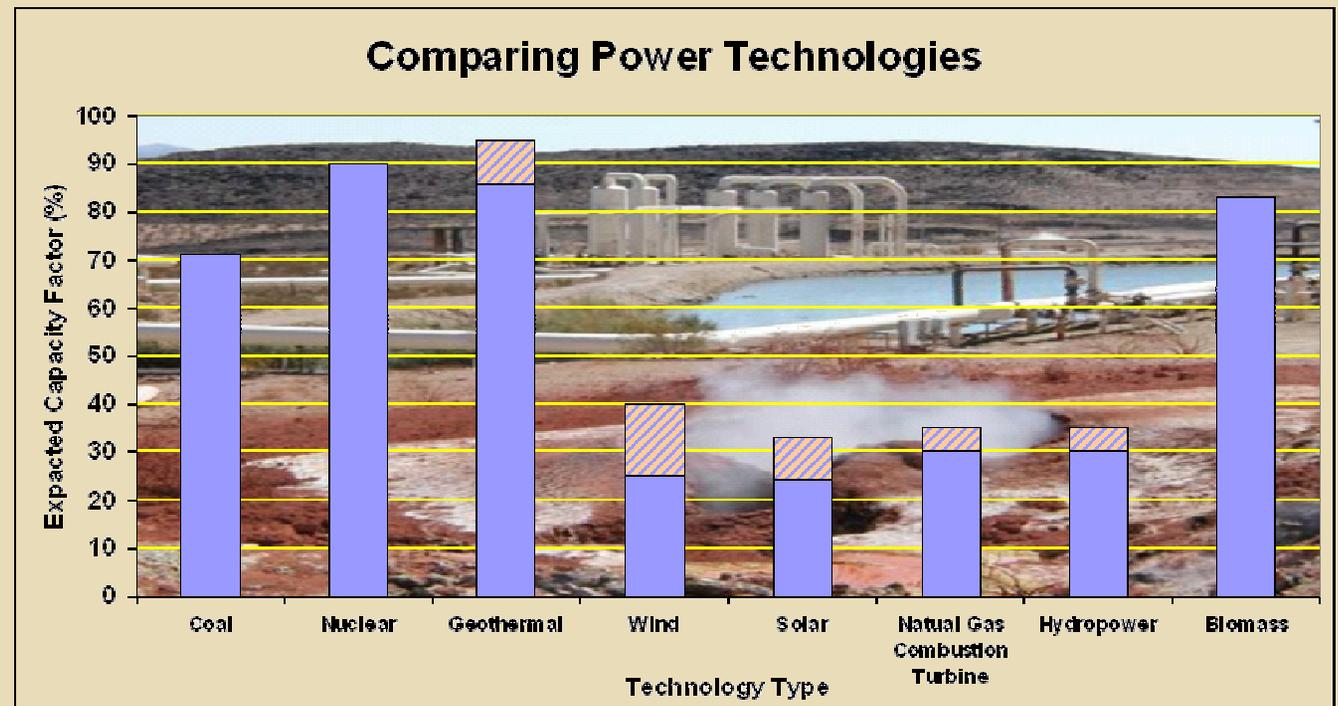
Geothermal Energy Importance

Electric Generation

Comparing Power Technologies	
Technology	Expected Capacity Factor (%)
Coal	71
Nuclear	90
Geothermal	86 - 95
Wind	25 - 40
Solar	24 - 33
Natural 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.**



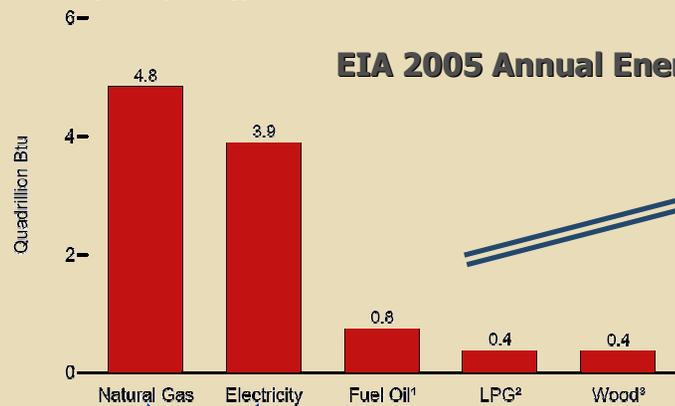
Geothermal Energy Importance

Avoided Power

Geoexchange Systems

Example: Household Energy Consumption

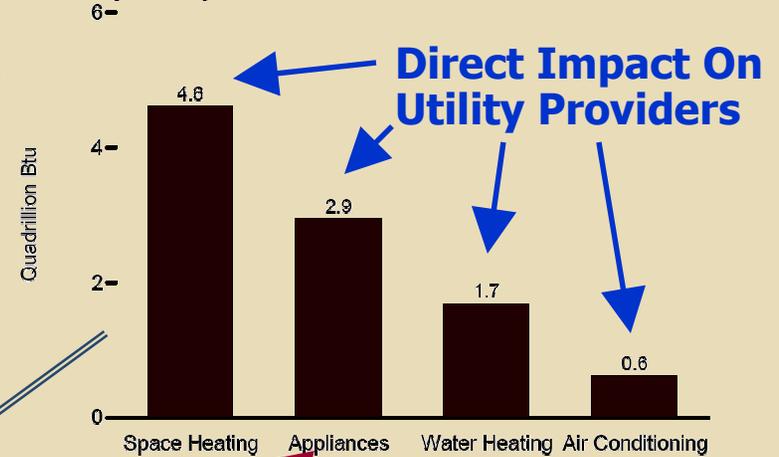
Consumption by Energy Source, 2001



Direct Impact On Utility Providers

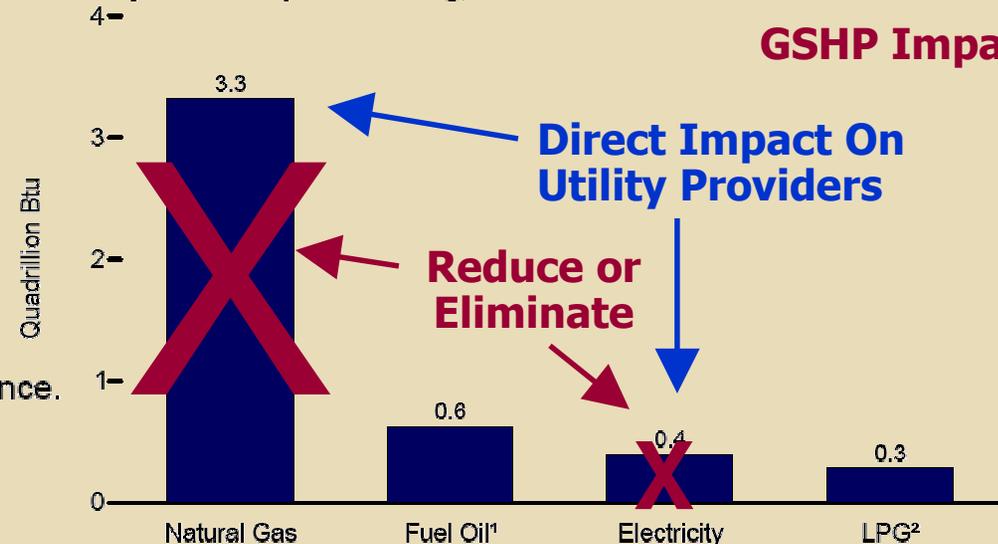
- ¹ Distillate fuel oil and kerosene.
- ² Liquefied petroleum gases.
- ³ Wood used for both space heating and ambiance.
- ⁴ Does not include wood.

Consumption⁴ by End Use, 2001



Direct Impact On Utility Providers

Consumption⁶ for Space Heating, 2001



GSHP Impact

Direct Impact On Utility Providers

Reduce or Eliminate

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.**