

An aerial photograph of a geothermal field. The landscape is covered in green grass and small shrubs. Several white, conical vents of steam or gas rise from the ground, creating a stark contrast with the green terrain. The sky is a pale, hazy blue. The text is overlaid on this image.

Geothermal Power-Green Power for the 21st Century

Bright Horizons Cruise #6

December 6, 2009

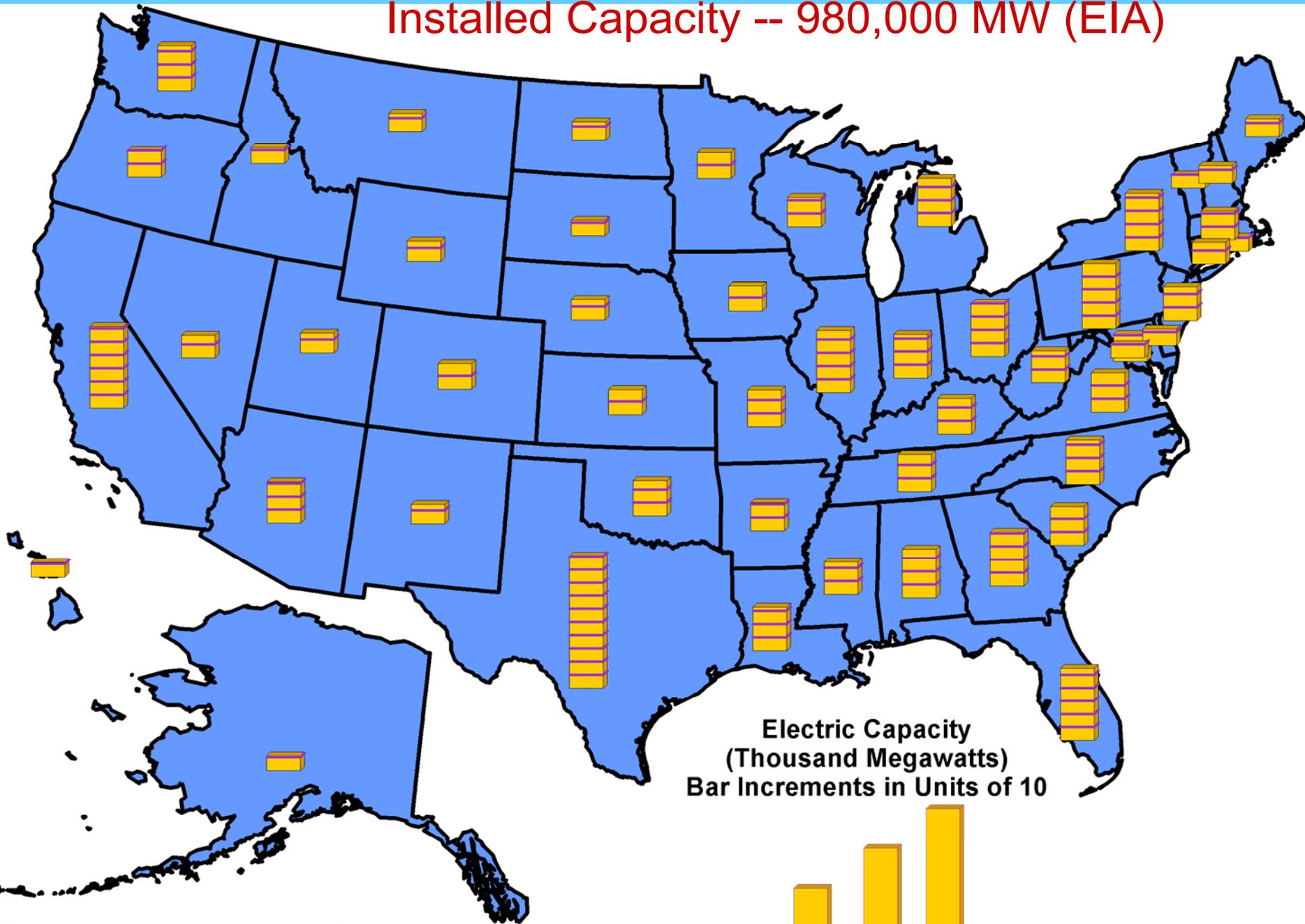
David Blackwell

SMU Geothermal Laboratory

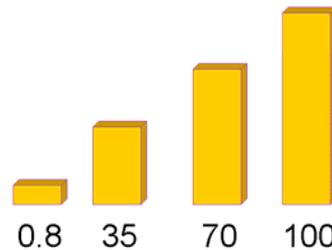


The Geysers, California, 1962, Power for 25,000 households

Installed Capacity -- 980,000 MW (EIA)



Texas has 10% of installed capacity!



➤ US Electrical Energy Capacity

➤ Sources of Our Electrical Energy

- Coal

- Nuclear

- Hydro

- Renewables

 - Wind

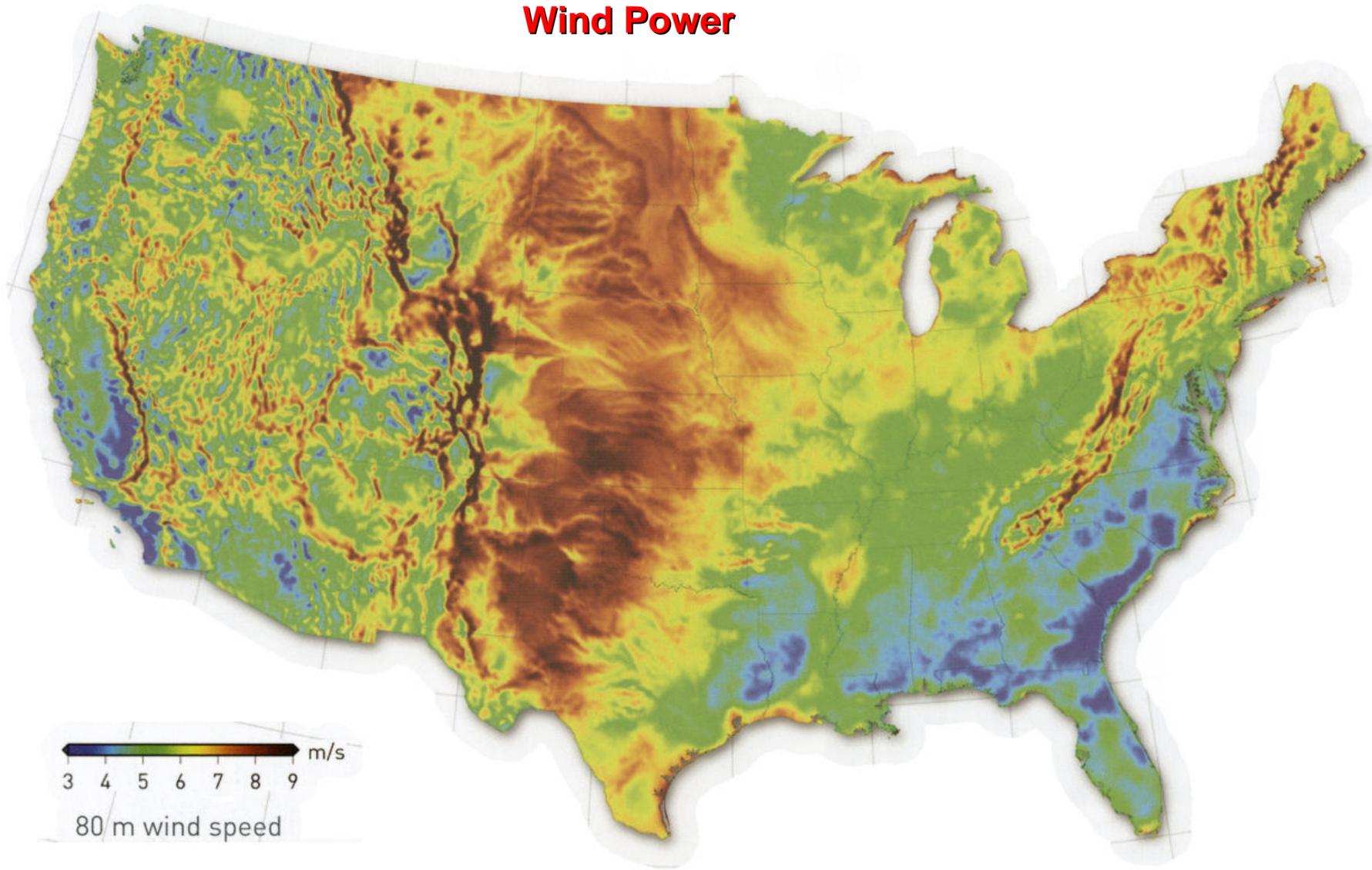
 - Solar

 - Geothermal

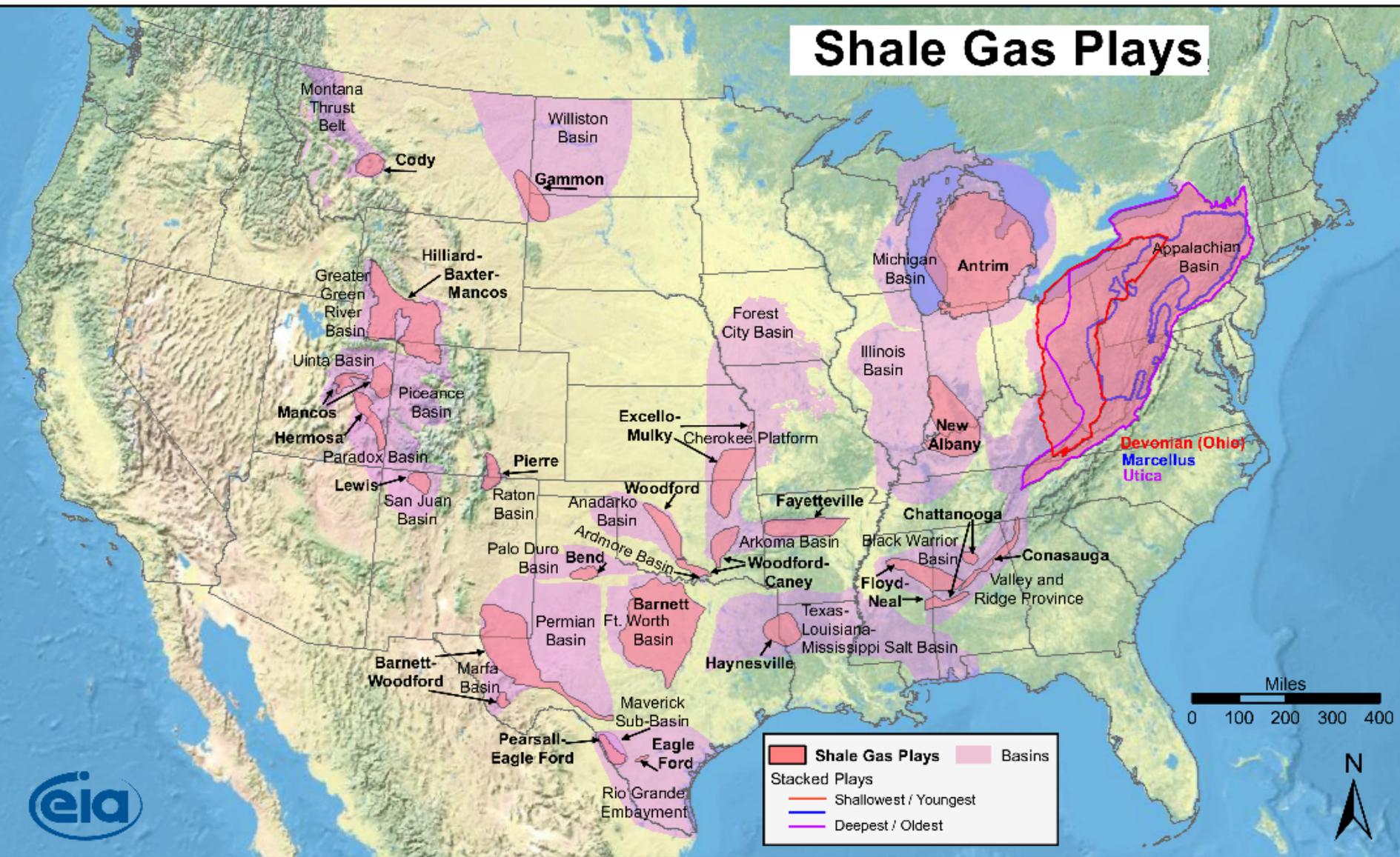
Energy Forms

- **Gas-too expensive(?), too valuable-Peaking**
- **Coal-"cheapest" -Baseload**
- **Nuclear-expensive, most dangerous-Baseload**
- **Wind-not base load, 40% max**
- **Solar-solar-thermal, not baseload**
- **Geothermal-Baseload**
 - **hydrothermal (conventional)**
 - **Enhanced (Engineered) GS**
 - **Geopressure**
 - **Coproduced**
 - **Ground Source Heat Pumps**

Wind Power

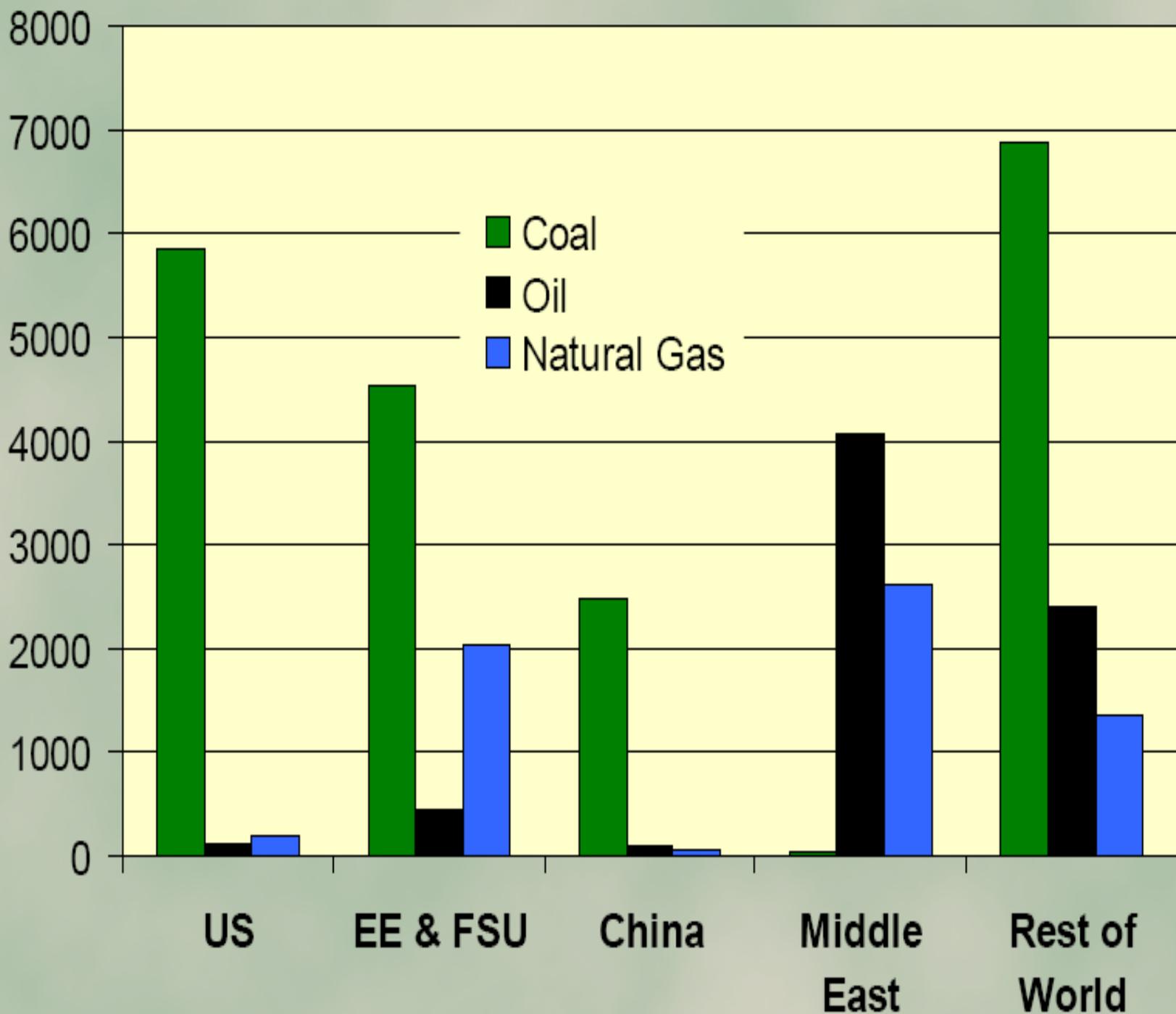


Shale Gas Plays



**Approximately 1000 Tcf (Trillion cubic feet, current use is 10 Tcf
(1mcf =1000 cubic feet))**

Quadrillion (10^{15}) Btu



THE US IS THE SAUDI ARABIA OF COAL

What are the Implications for the Oil Industry

- High oil prices and National Security will drive gasification of coal and production of synthetic diesel for DOD
- Environmental NGO's driving power companies to decarbonize fuel.... CO₂ sequestration
- Relatively cheap CO₂ available for EOR

FutureGen

Preliminary Federal Requirements

- **Design, construct, operate a 275-megawatt plant to produce electricity, hydrogen, and one to two and a half million metric tons per year of CO₂ with near-zero emissions.**
- **Establish capability to sequester at least 90 percent of plant's CO₂ emissions.**
- **Demonstrate fuel flexibility (coal, lignite etc)**
- **Prove the effectiveness, safety, and permanence of CO₂ sequestration.**
- **Establish standardized protocols for CO₂ measuring, monitoring, and verification.**

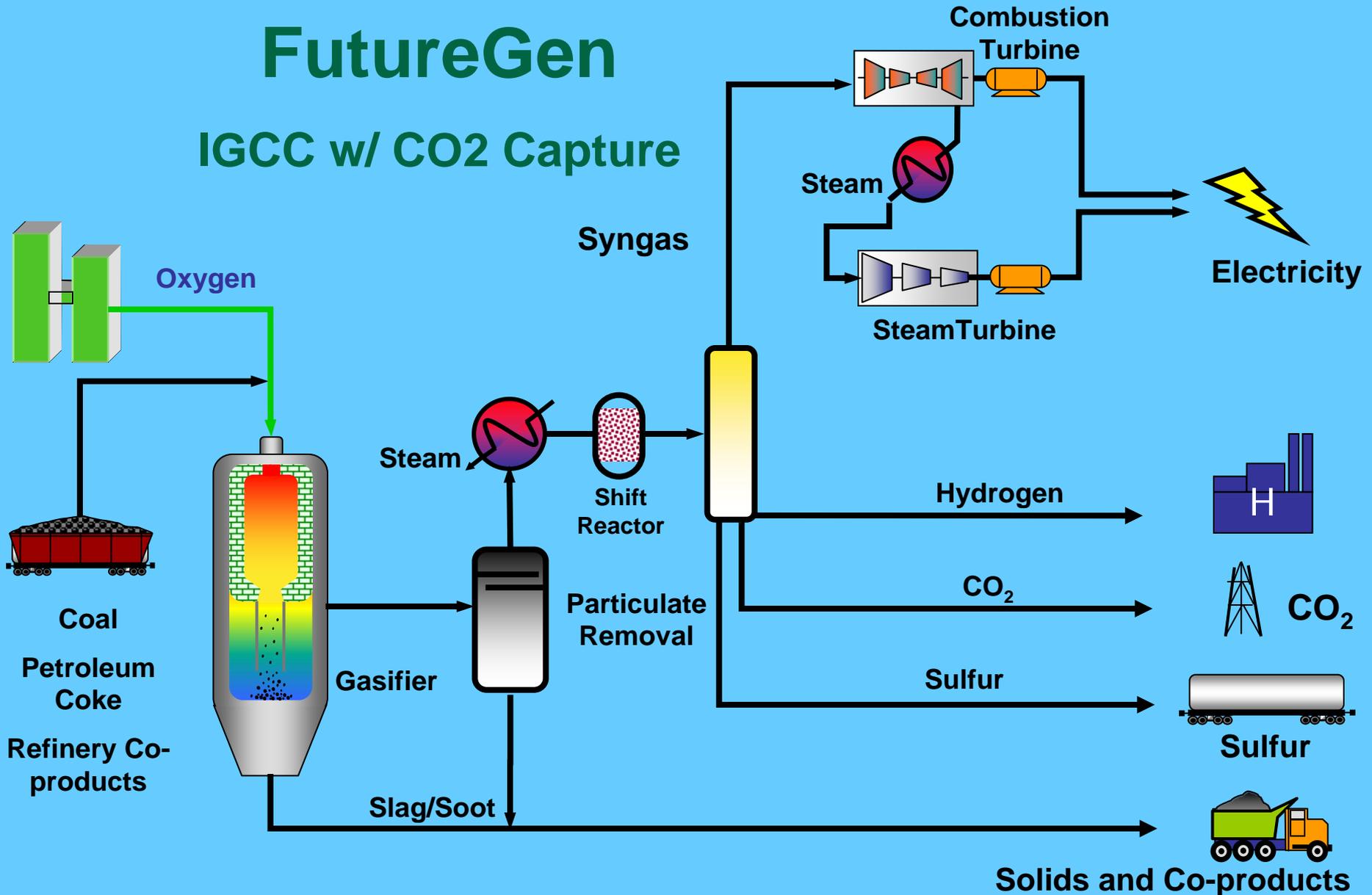
FutureGen

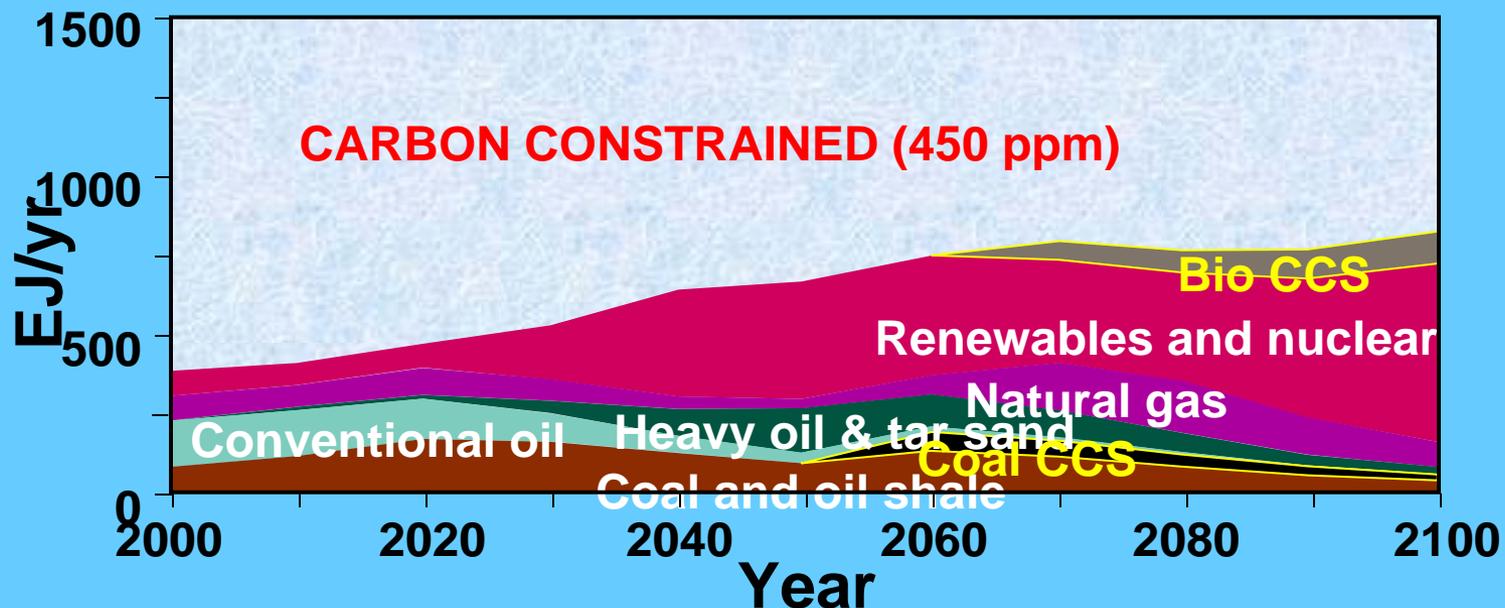
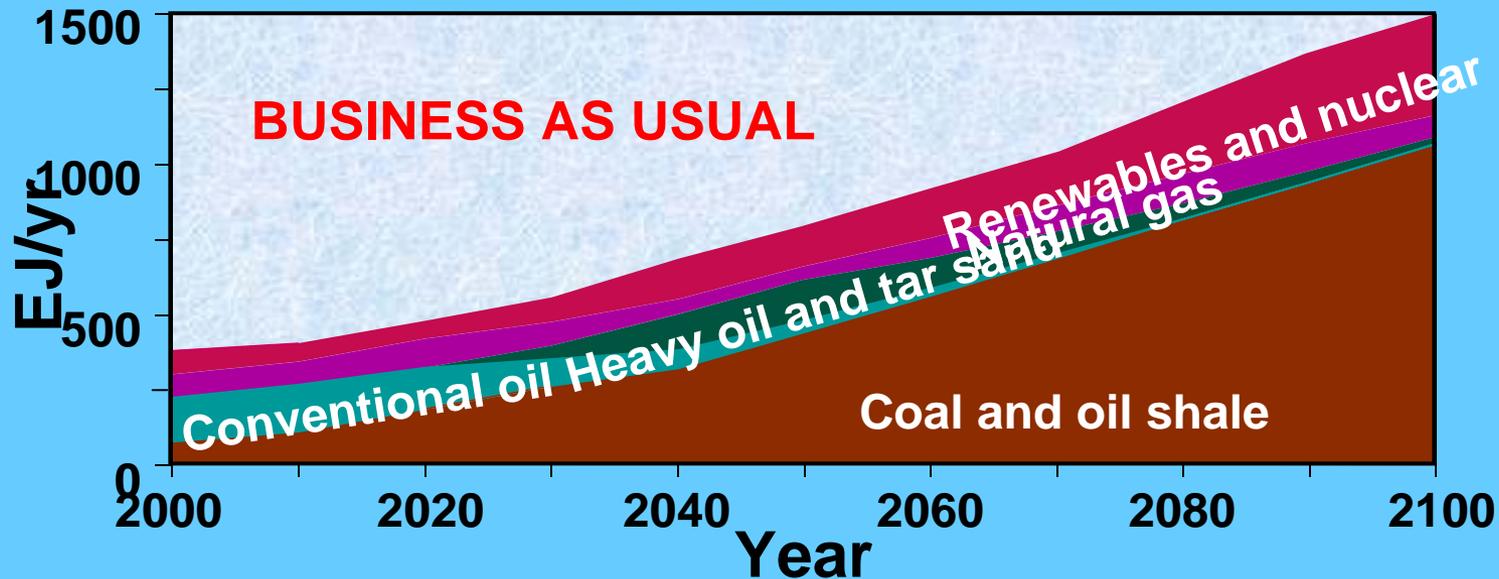
Commercial Details

- **\$1 billion DOE award**
 - **\$750 million from DOE**
 - **\$250 million from a private consortium**
- **Initial RFP expected early 2006**
- **30 day review and comment period**
- **120 day proposal preparation period**
- **120 day proposal evaluation period**
- **Award of the project is expected late summer of 2006**
- **This is subject to change.....**

FutureGen

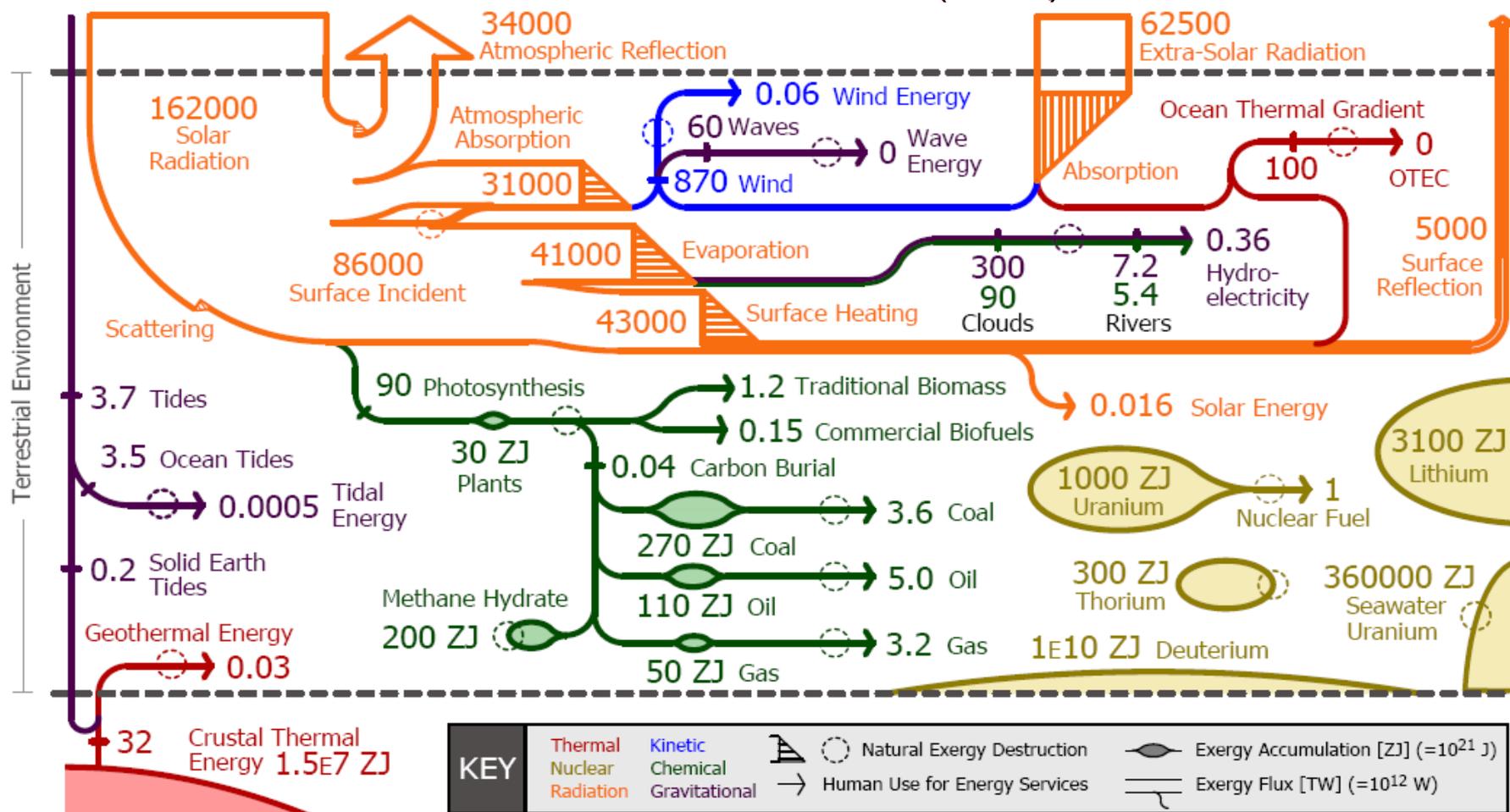
IGCC w/ CO₂ Capture





Global Exergy Flux, Reservoirs, and Destruction

Hermann and Simon (2007)



Exergy is the useful portion of energy that allows us to do work and perform energy services. We gather exergy from energy-carrying substances in the natural world we call energy resources. While energy is conserved, the exergetic portion can be destroyed when it undergoes an energy conversion. This diagram summarizes the exergy reservoirs and flows in our sphere of influence including their interconnections, conversions, and eventual natural or anthropogenic destruction. Because the choice of energy resource and the method of resource utilization have environmental consequences, knowing the full range of energy options available to our growing world population and economy may assist in efforts to decouple energy use from environmental damage.

IPCC SCOPING MEETING ON RENEWABLE ENERGY SOURCES PROCEEDINGS

Lübeck, Germany, 20 – 25 January, 2008

The possible role and contribution of geothermal energy to the mitigation of climate change

Ingvar B. Fridleifsson (United Nations University Geothermal Training Programme, Iceland),
Ruggero Bertani (Enel S.p.A., Italy), Ernst Huenges (GFZ Potsdam, Germany),
John W. Lund (Oregon Institute of Technology, USA), Arni Ragnarsson (ISOR, Iceland),
and Ladislaus Rybach (Geowatt AG, Switzerland).

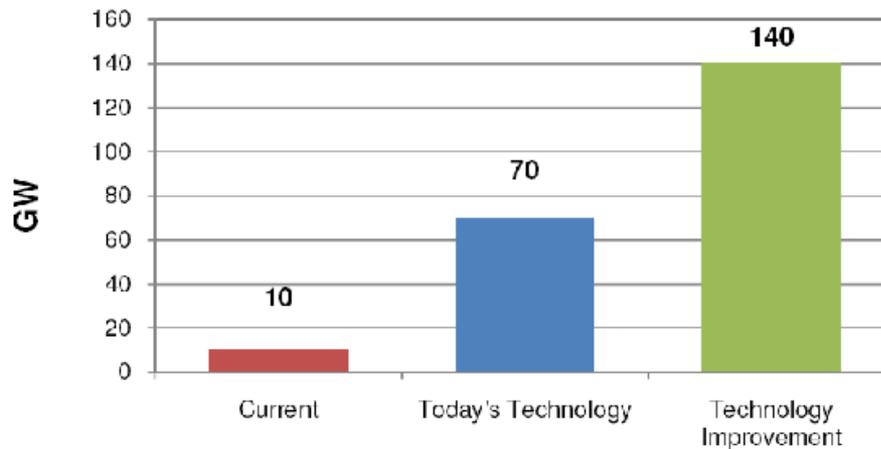


Figure 4. Estimated World geothermal electricity potential with present technology (blue) and with technology improvement (green). The current installed capacity is also shown (red).

**IPCC Estimate of
Conventional (?)
Geothermal
Resources, 2008**

DOE Funding Announced October 28, 2009

\$338M

2) Coproduced, Geopressured, and Low Temperature Projects

Universal GeoPower LLC	\$1,499,288	Liberty County	TX	Universal GeoPower LLC will utilize a modular low temperature binary unit to produce power from oil and gas wells in Liberty County, Texas.
University of North Dakota	\$1,733,864	Williston Basin, (Bowman County)	ND	The University of North Dakota will utilize a low temperature binary unit to produce power from oil and gas wells in Bowman County, North Dakota.
Louisiana Tank, Inc.	\$5,000,000	Cameron Parish	LA	Louisiana Tank, Inc. will demonstrate the feasibility of a geopressured power plant in Cameron Parish, Louisiana.
University of North Dakota	\$1,733,864	Williston Basin, (Bowman County)	ND	The University of North Dakota will construct a low temperature power plant in Bowman County, ND.

Texas wind power is blowing in the bucks

The economic downturn has had a bit of a silver lining for Texas' wind energy business.

Under the [American Recovery and Reinvestment Act](#) Texas wind projects have received nearly **\$400 million in funding** meant to stimulate the economy and create green jobs. That's 40 percent of the \$1 billion given out so far.



Wind turbines near Sterling City, Texas.(AP Photo/LM Otero, File).

\$114,071,646

The recipients include:

- Barton Chapel Wind Farm Jacksboro, TX \$72,573,627
- Bull Creek Wind LLC O'Donnell, TX \$91,390,497
- Pyron Wind Farm, LLC Roscoe, TX \$121,903,306
- Penascal Wind Energy Near Corpus Christi, TX

Oddly enough the [massive power line projects](#) designed to take West Texas' surplus wind power to the large cities in Texas that can use it seem to be [turning down the federal loan guarantees](#).

At a Public Utility Commission meeting last month developers indicated the strings that come attached to the \$750 million in federal loan backing are too onerous for them.

"Cost increases arising from this Buy American [rule] could quickly overcome the savings created by the lower cost of capital," Richard Roloff, vice president of finance at LS Power,

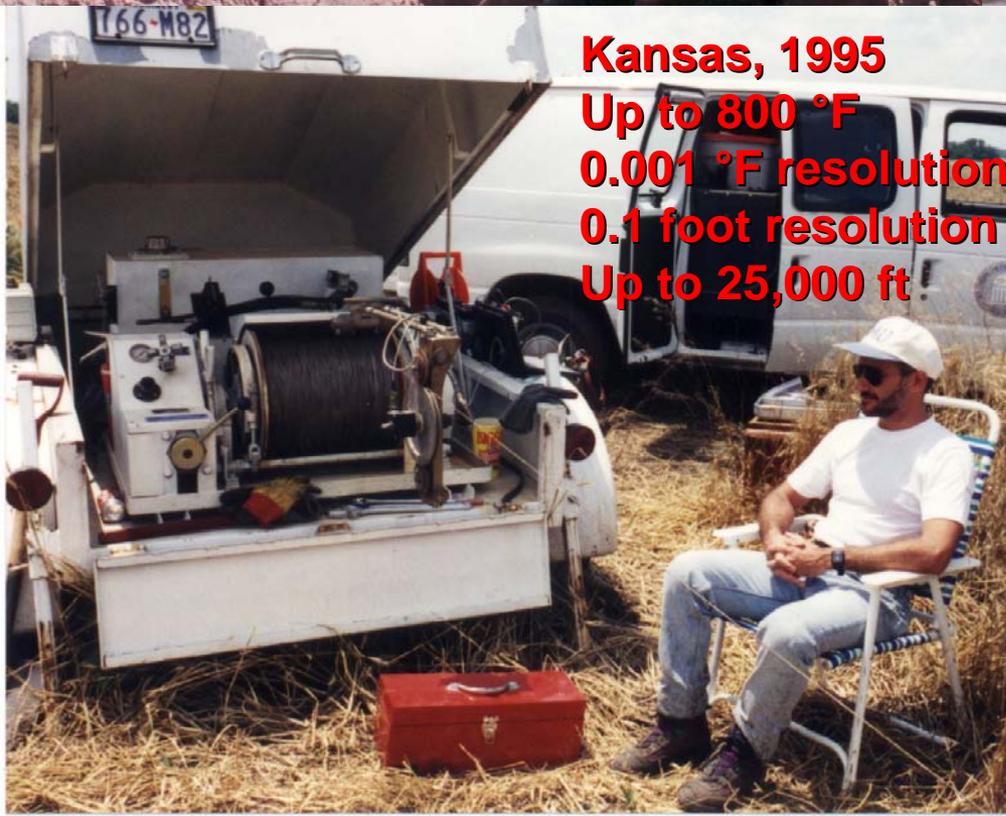
- **Barton Chapel:**
 - **\$72,573,627**
 - **Bull Creek:**
 - **\$91,390,497**
 - **Pyron Farm:**
 - **\$121,903,906**
 - **Penascal:**
 - **\$114,071,646**
- Total: ~\$400,000,000**



Oregon, 1971



Costa Rica, 1977

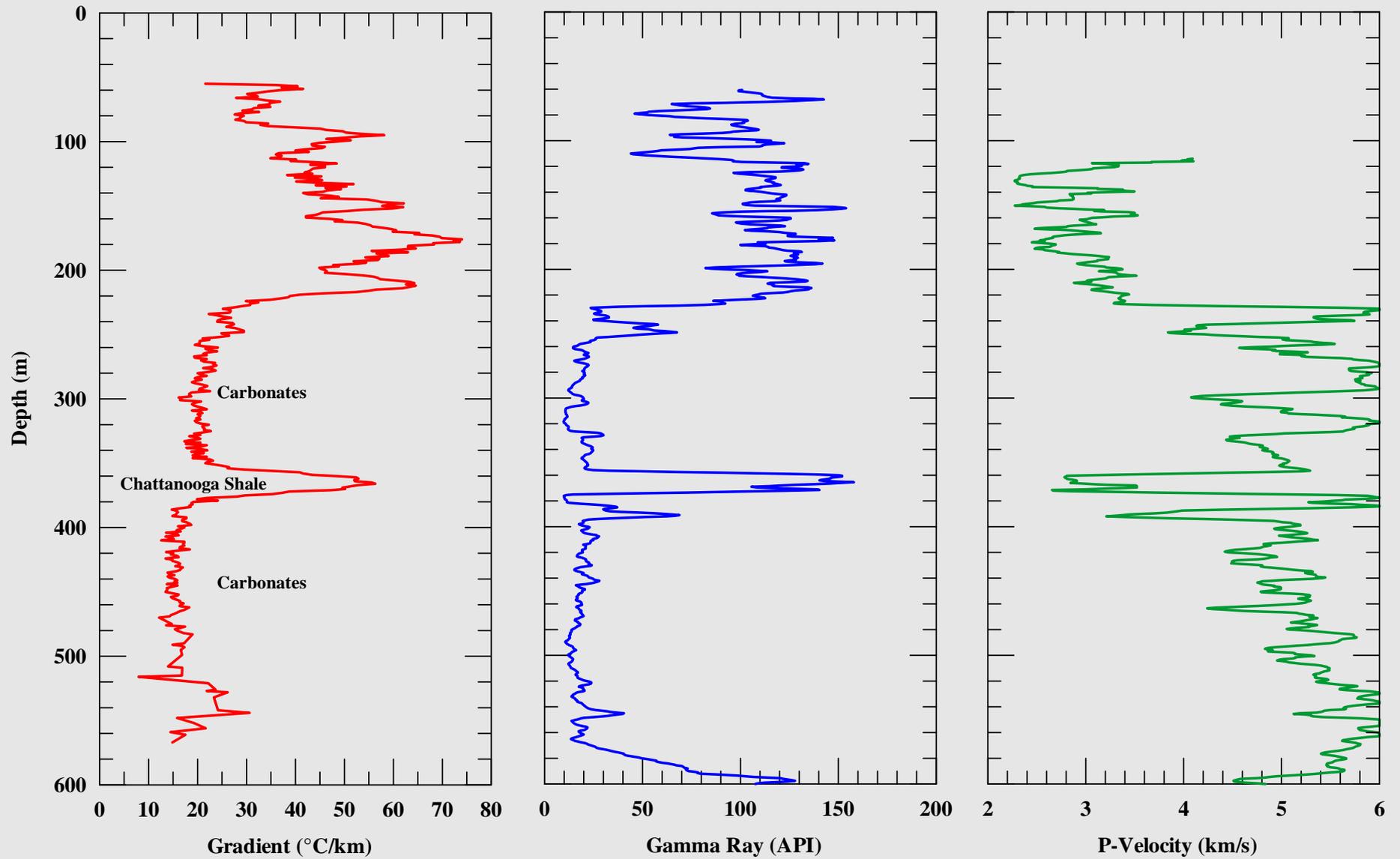


Kansas, 1995
Up to 800 °F
0.001 °F resolution
0.1 foot resolution
Up to 25,000 ft

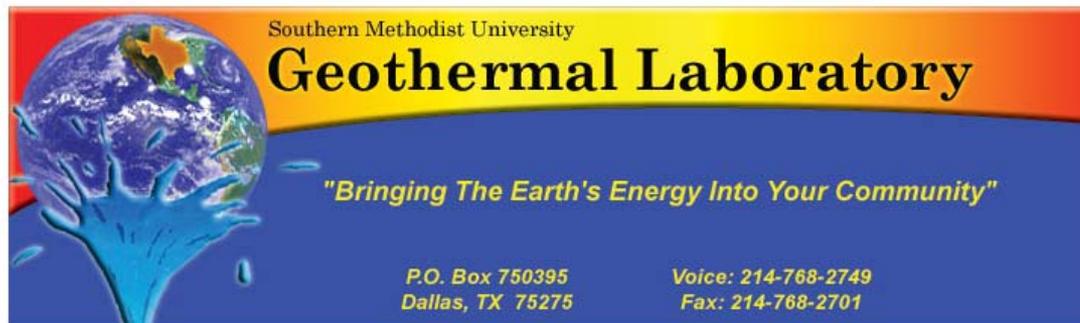


Oregon, 1984

Watson #1 Geophysical Well Logs



SMU Web site: <http://smu.edu/geothermal>



Southern Methodist University
Geothermal Laboratory
"Bringing The Earth's Energy Into Your Community"

P.O. Box 750395
 Dallas, TX 75275

Voice: 214-768-2749
 Fax: 214-768-2701

Site Map

(Click on plus signs for subcategories or words to link)

- + [SMU Geothermal Databases](#)
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- + [Geothermal Resources](#)
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- + [Teacher - Educational Materials](#)
- + [Temperature Logs](#)
- + [Texas Geothermal Outreach and Networking Program](#)

Conference News

**Geothermal Energy Utilization
 Associated with
 Oil & Gas Development**
 June 17-18, 2008

[Conference Details](#)

Previous Conferences

[Texas Renewables '07](#)

Conference Presentations

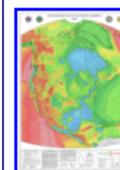
Abilene; November 13-14 2007

Geothermal talks:

[Geothermal Energy \(GSHP\)](#), Shawn Beard -
Energy America Geothermal;

[A Ground Source Heat Pump Initiative in the
 Blue Skyways Collaborative](#), James
 Yarbrough - *U.S. EPA*

Hot Topics



[Geothermal Map of
 North America](#)

Recent Press

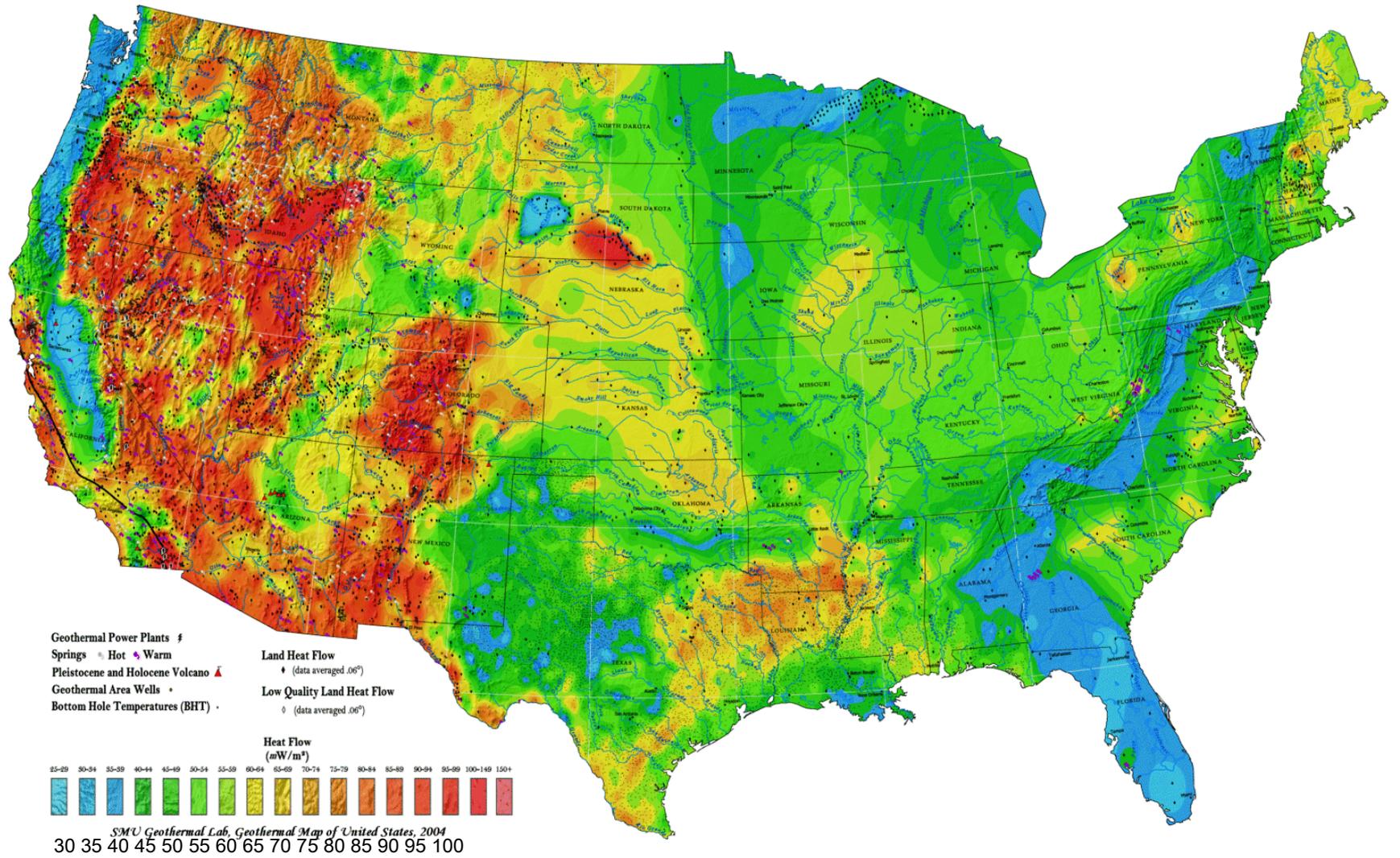
Google to Invest in Geothermal
 New York Times [8/19/08](#)

Google.org announcement [8/19/08](#)

Free to be Green
 DFW Chanel 33 News [7/25/08](#)

In the Push for Alternative Energy,
 What Happened to Geothermal?
 US News and World Report [7/21/08](#)

Oil, Gas and Geothermal Energy
 SMU Press Release [6/19/08](#)



2004 Geothermal Map of North America

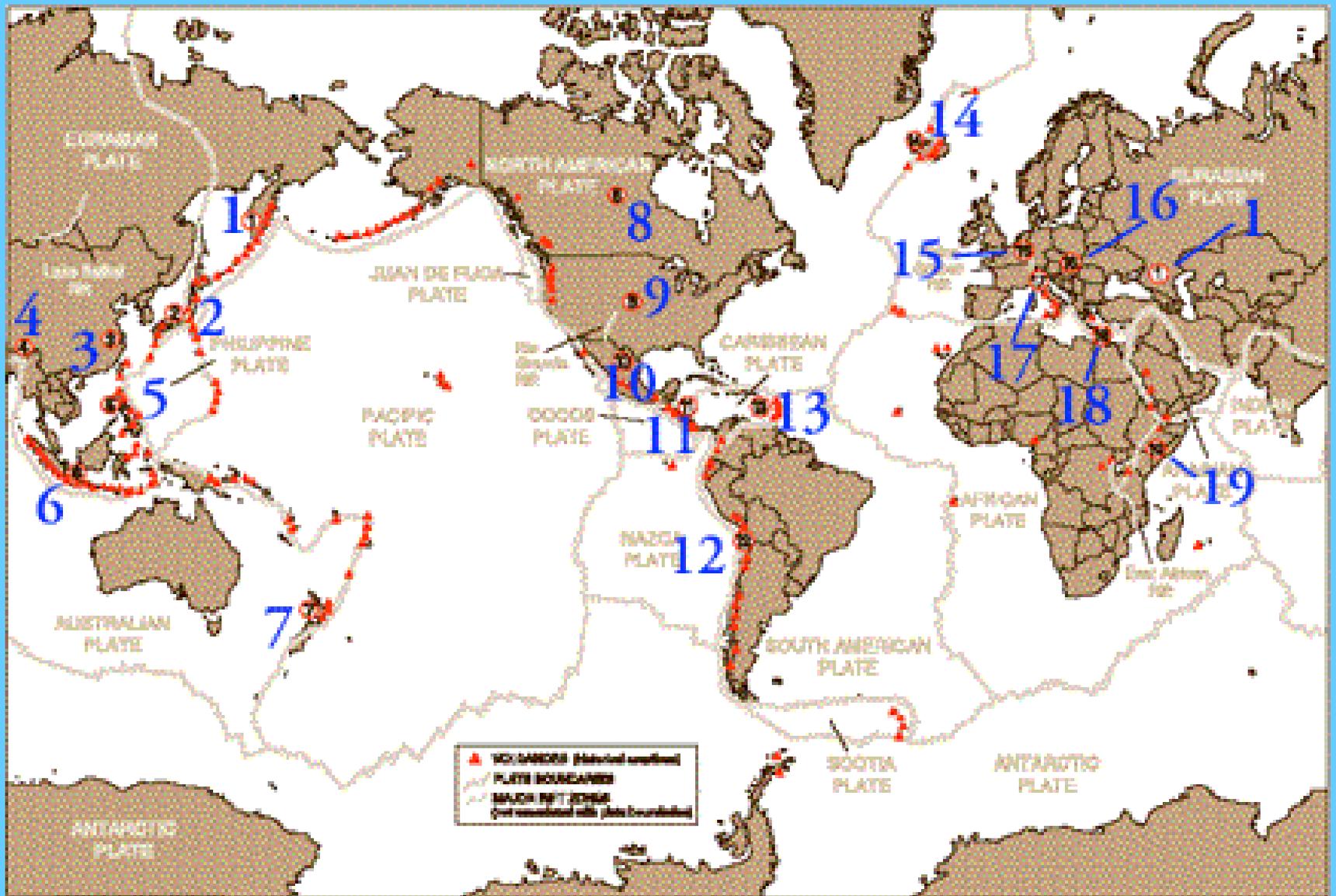
Conventional Geothermal Energy Types

- Dry Steam: The Geysers, Lardarello
- Wet Steam: Volcanic Arcs, Iceland, etc
- Hot Water: Nevada

1 Temperatures 250°C, 500°F

2 175-240°C, 350-480°F

3 80°C-175°C, 165°F-350°F



http://geothermal.marin.org/geomap_1.html

8,000 mW in 2005



Plate Boundary Between NA & Europe

Nesjavellir, Iceland





Hengill, Iceland





Nordica hotel



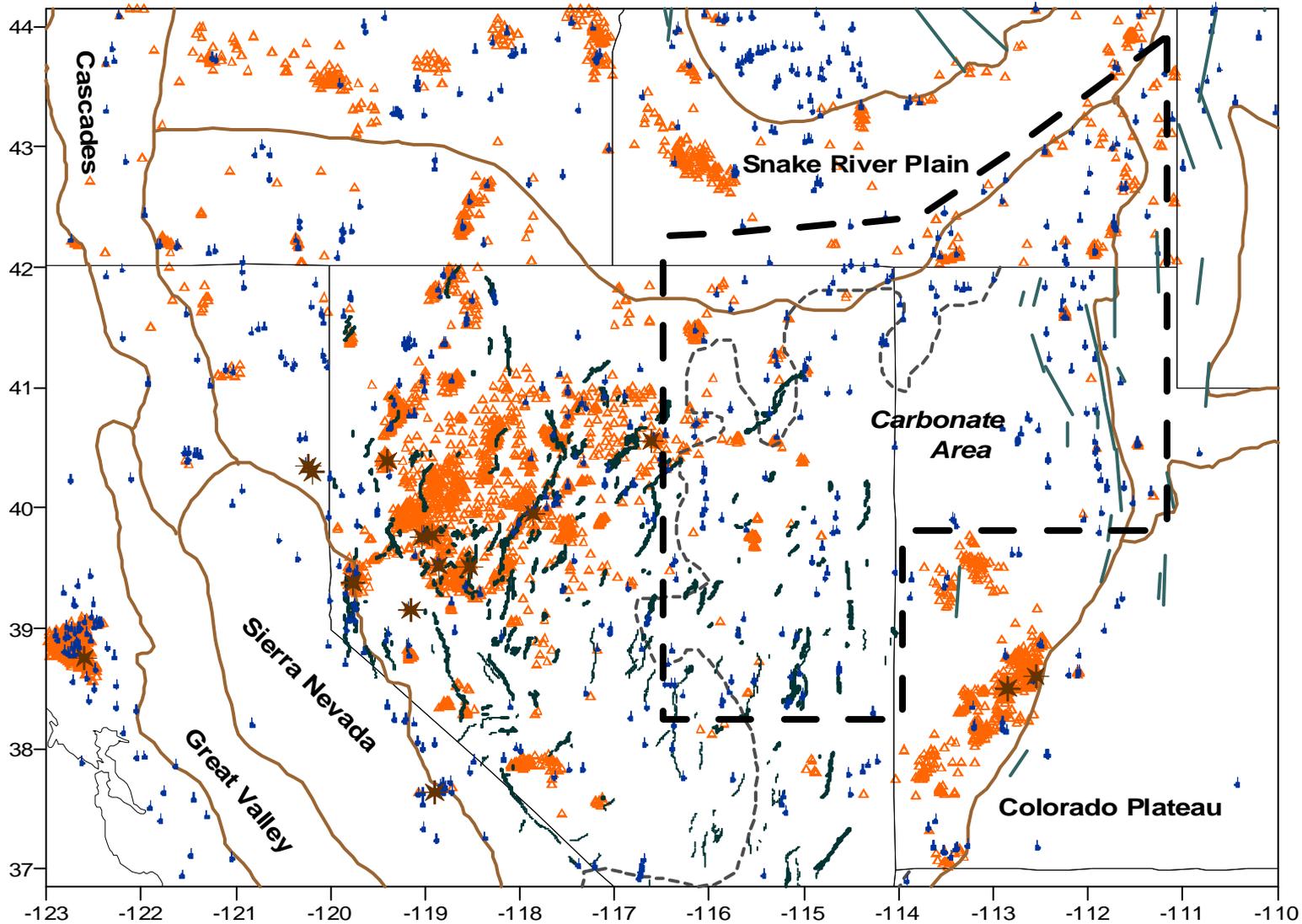
I DDP ?

Krafla

I DDP ?

Blue Lagoon





- | | | | |
|--------------------------|----------|-----------------------------------------|------------|
| Power Plants - | * | Pleistocene and younger Faults - | --- |
| Well Locations - | △ | Carbonate Aquifers Boundary - | ⋯ |
| Thermal Springs - | ▽ | Physiographic Boundaries - | — |
| | | Area of Study - | — — |

Beowawe, Nevada, 13 MW Dry Steam Geothermal Power Plant, 2000



Dixie Valley, Nevada

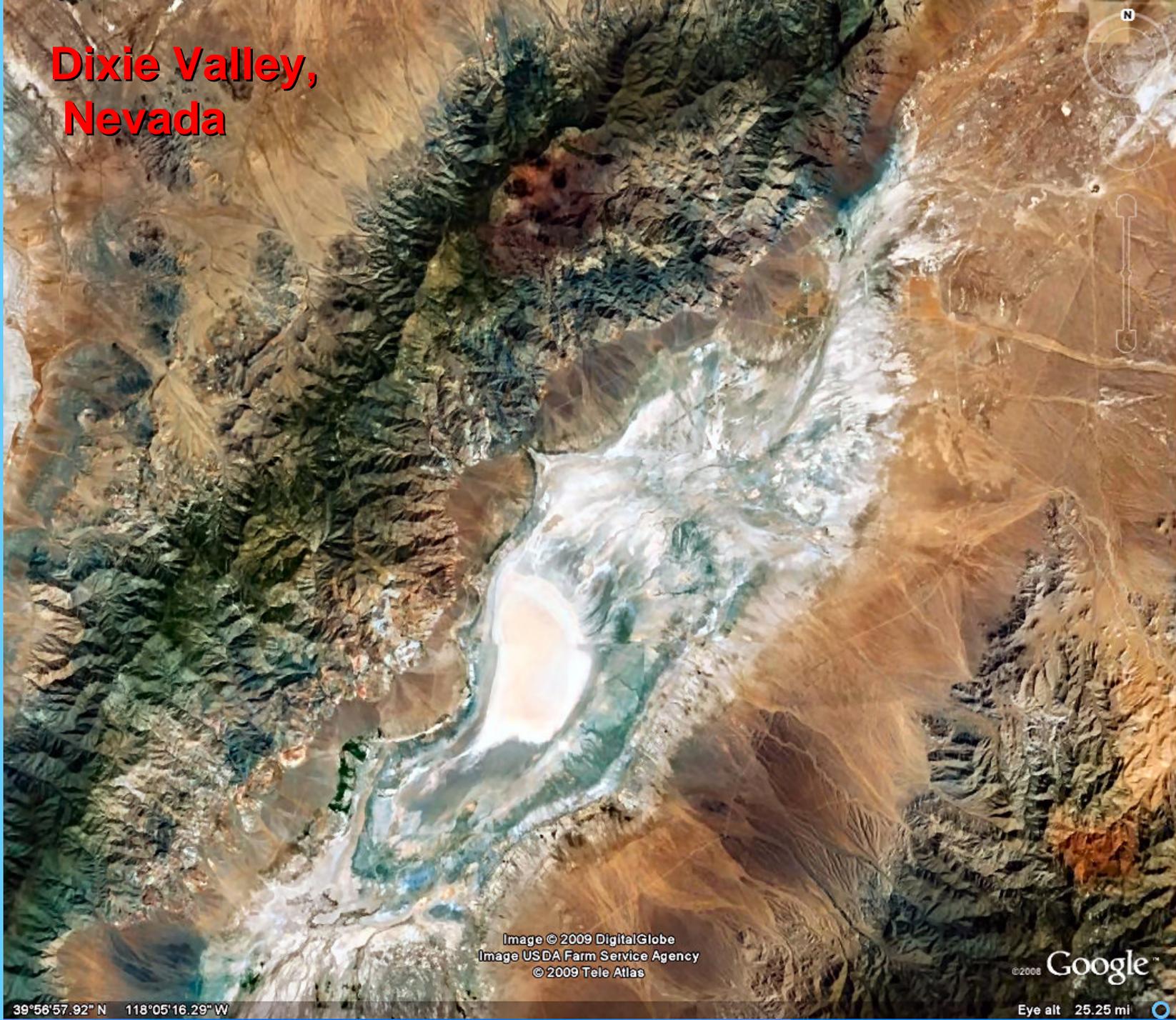


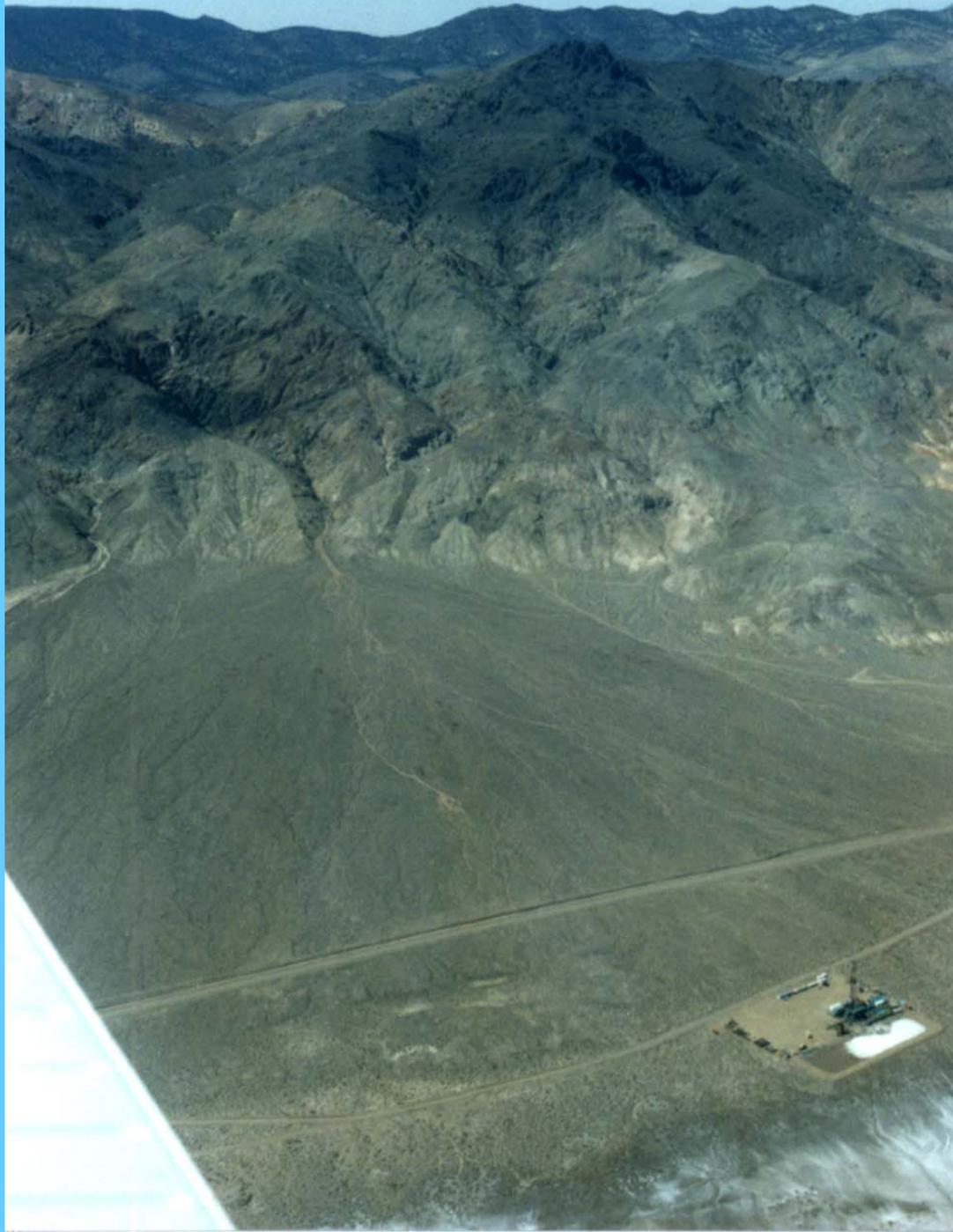
Image © 2009 DigitalGlobe
Image USDA Farm Service Agency
© 2009 Tele Atlas

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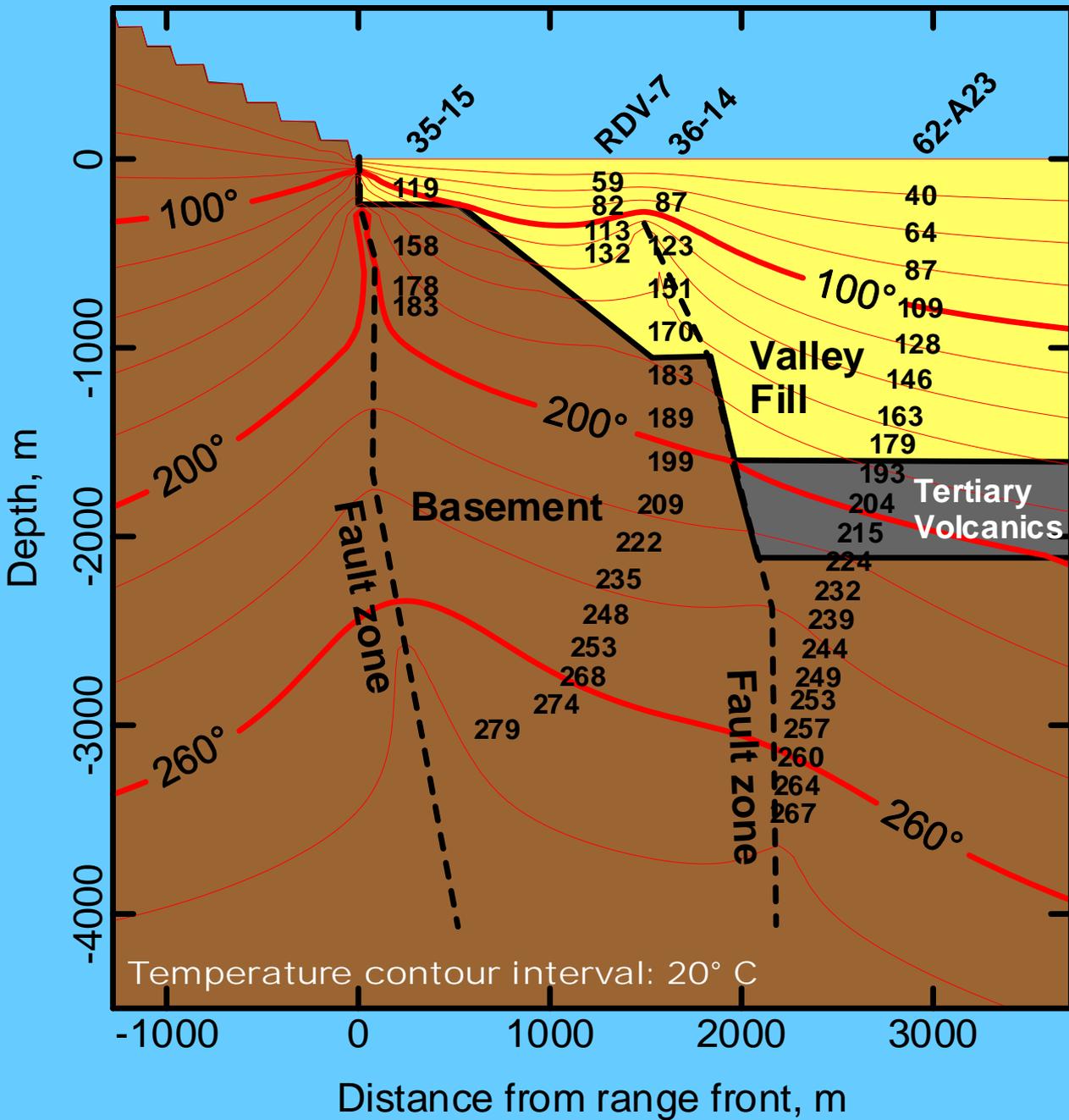
39°56'57.92" N 118°05'16.29" W

Eye alt 25.25 mi





Dixie Valley, Nevada





Brady Hot Springs, Nevada



General view from the back of ORMAT Brady's hot springs 5 MW (net) binary, air condensed power plant. Light colored tank is extra binary fluid.

Brady Hot Springs, Nevada Ormat Binary Power Generator



Conventional Hydrothermal

- Cost \$2-4,000,000/MW
- Pay for “fuel” up front, difficult to finance
- 2 wells drilled for every producer, i.e. reservoir uncertainty, \$5,000,000/well
- Wells 30% of cost
- Land access problems (Federal)
- Market limited to some extent
- Localized in Great Basin and west coast

The Future of Geothermal Energy

Impact of Enhanced Geothermal
Systems (EGS) on the United States
in the 21st Century

THE EGS SYSTEM
Introduction of water into
rock of limited
permeability (either tight
sediment or basement) in
a controlled fracture
setting so that this water
can be withdrawn in other
wells for heat extraction,
i.e. heat mining



DOT EARTH

Nine billion people. One planet.

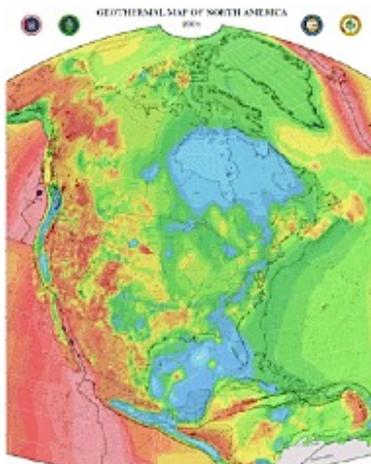
August 19, 2008, 2:04 PM

Google to Invest in Geothermal

By TOM ZELLER JR.

Google.org, the public-spirited division of Google.com, charged with addressing “climate change, poverty and emerging disease,” is using the backdrop of the National Clean Energy Summit here in Las Vegas to announce a new round of clean energy financing.

In a nutshell, the company is investing an arguably modest sum — a little over \$10 million — in the development of Enhanced Geothermal Systems, or EGS. The technology differs from “traditional” geothermal in that rather than exploiting existing wells of earthbound steam and hot water, EGS drills deep — miles down — to access layers of heated granite that exist underfoot everywhere on the planet. Water can be circulated downward for heating, and then upward to drive turbines and generate electricity.



[Efforts at mapping geothermal potential in North America at Southern Methodist University are receiving financial support from Google. \(Photo: Southern Methodist University\)](#)

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◀ **Energy Independence for Puerto Rico!**

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Denuded Islands, 'Planetary Emergencies' ▶

About Dot Earth

By 2050 or so, the world population is expected to reach nine billion, essentially adding two Chinas to the number of people alive today. Those billions will be seeking food, water and other resources on a planet where, scientists say, humans are already shaping climate and the web of life. In Dot Earth, reporter Andrew C. Revkin examines efforts to balance human affairs with the planet's limits. Supported in part by a John Simon Guggenheim Fellowship, Mr. Revkin tracks relevant news from suburbia to Siberia, and conducts an interactive exploration of trends and ideas with readers and experts.



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ABOUT THE PROGRESS
CATERPILLAR IS**

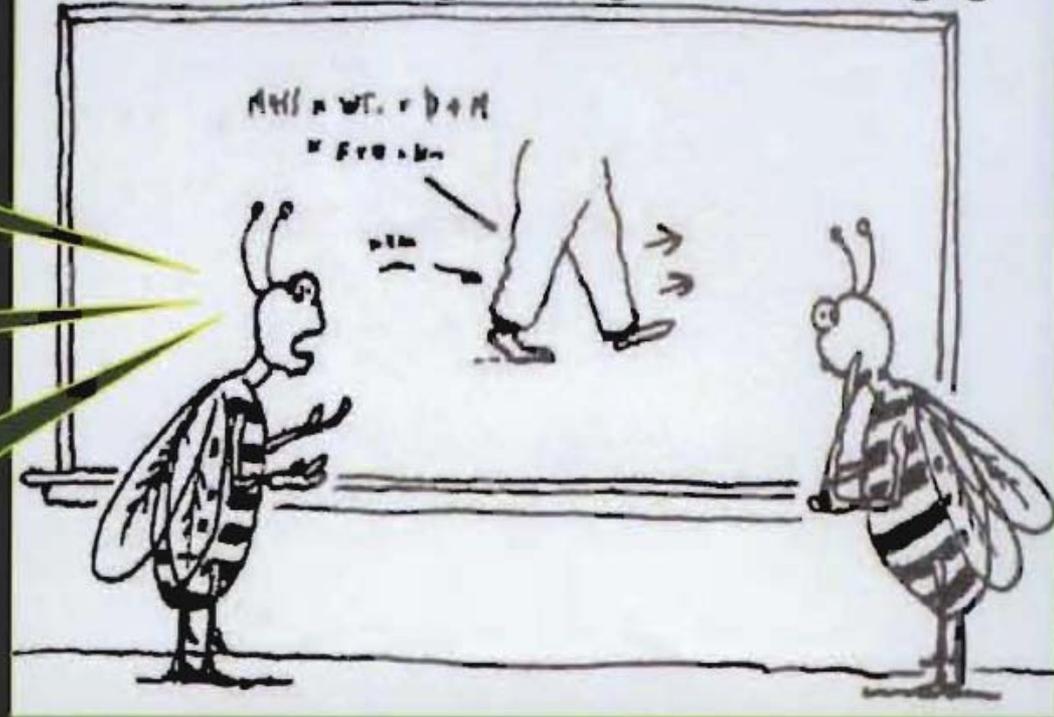
Hot Rocks Downunder – Evolution of a New Energy Industry

Visit: www.pir.sa.gov.au/geothermal/ageg

Stage 1:
This design
makes walking
impossible

Stage 2:
Yeah, possible
but impractical

Stage 3:
Told you this
would work!

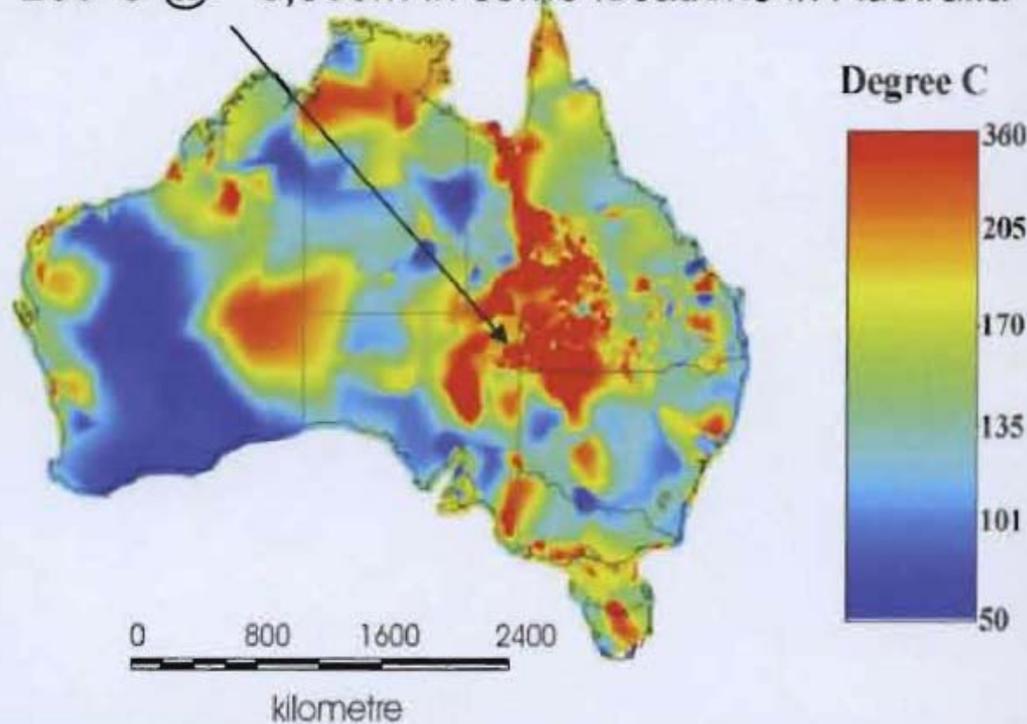


Barry Goldstein¹, Tony Hill¹, Alexandra Long¹, Mike Malavazos¹
Dr Anthony Budd² and Dr Bridget Ayling²

1. South Australian Government (PIRSA) & AGEG Secretariat
2. Geoscience Australia (Federal Government)

Why Hot Rocks in

>200°C @ < 3,500m in some locations in Australia

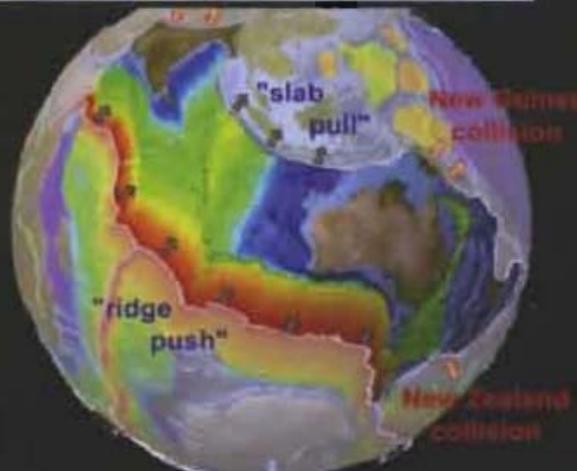


Below Ground Factors

- Extensive radiogenic basement at modest depths (heat source)
- Australia converging with New Guinea – giving rise to horizontal compression and common naturally occurring horizontal fractures (reservoir)
- Sedimentary cover (insulators) for hot sedimentary aquifer & hot rock EGS targets

Above Ground Factors

- Land access and title to resources
- Government stimulus for low emissions and renewable energy R, D, D & D
- Market recognition of comparative advantages – extensive, exploitable hot rocks
- Political will to attain energy security & mitigate risks of climate change
- Investors perceptions of risk: reward
- Growth in energy demand

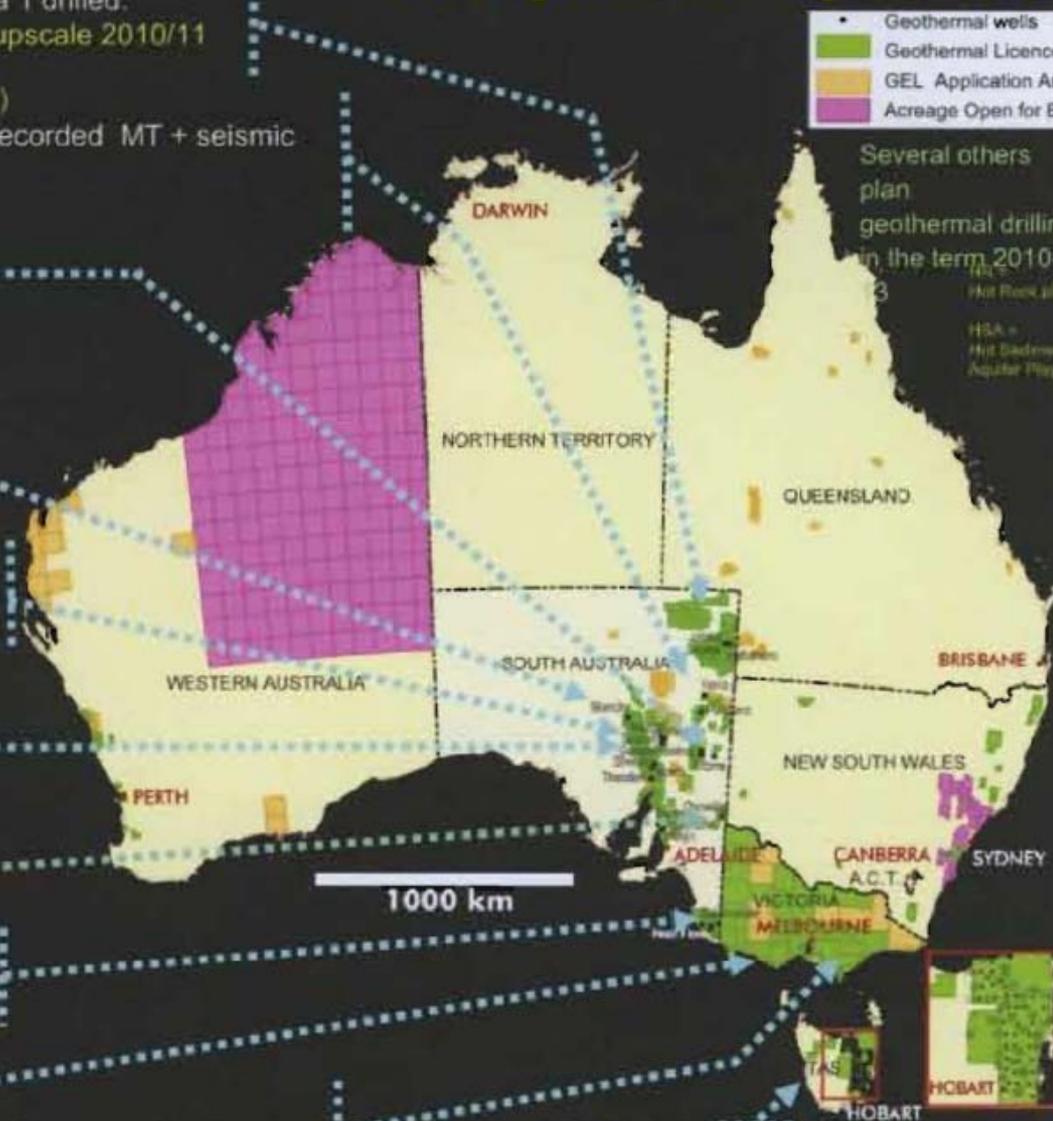


Geothermal Drilling & Geophysical Surveys to YE 09

- Geothermal wells
- Geothermal Licences
- GEL Application Area
- Acreage Open for Bids

Several others plan geothermal drilling in the term 2010-13

HSA = Hot Rock play
HSA = Hot Bedrock Aquifer Play



Geodynamics/Origin/Tata Power/Sentient-SunSuper (HR)

- 2003-5: Proved flow of geothermal energy with Habanero 1 & 2
- 2007-9: Habanero 1 - 3 closed loop flow, Jolokia 1 & Savina 1 drilled.
- Next: Two more deep wells, 1 MW deployment. Decision to upscale 2010/11

Petratherm/Beach Petroleum/TRUenergy (HR)

- 2005-7: Drilled Yerila and Paralana, deepened Paralana & recorded MT + seismic
- Next: Now drilling Paralana 2 to 4000m. Then Paralana 3

Geothermal Resources (HR)

- 2007-9: drilled 8 Frome area wells up to 1809m depth
- Next: Drill deep wells in the Frome area

Green Rock Energy (HR)

- Drilled and Mini-Frac'd - Blanche 1 to 1935m
- Next: Optimise plans for a deep well

Torrens Energy/AGL (HR)

- 2007-9: 20 wells north of Adelaide and Port Augusta. Parachilna holes to 1807m. Pt Augusta seismic survey
- Next: Drill deep Parachilna wells & Pt Augusta expl. holes

Inferus Resources (Southern Gold) (HR)

- 2008: Measured temperatures to 1 Km
- Next: Drill two deep wells in the Roxby project area

Eden Energy (HR)

- Drilled Chowilla 1 in Renmark region
- Now assessing options

Panax Geothermal (HSA)

- 2006 - 3 wells to 500m depth and an MT survey in SE SA
- Next - Drill deep, 4000m well (Salamander 1) in 2009

Hot Rock Ltd (HSA)

- Target defined
- Next: Drill 2 deep Koroit wells in 2010

Greeneath Energy Ltd (HSA)

- Target defined
- Next - Drill 2 deep wells in Geelong area in 2010

KUTH Energy Ltd (HR)

- 36 shallow holes + MT + aeromag.
- Next: Deep drilling in 2010

Progress is Measurable

Metrics	December 2007	September 2009	
Geothermal Licences	232 in Australia (198,000 km ²) 190 in SA (110,000 km ²)	391 in Australia (362,000 km ²) 279 in South Australia (130,000 km ²)	69% ↑ 47% ↑
Companies	31 Australia-wide 21 in South Australia	48 Australia-wide 28 in South Australia	55% ↑ 33% ↑
Geothermal Licence holders listed on ASX	9 Australia-wide 6 with equity in SA Licences	17 Australia-wide 12 have equity in SA Projects	89% ↑ 100% ↑
\$ Invested	Aus\$209 million in Australia (YE 07) Aus\$207 million (99%) in SA (YE 07)	Aus\$325 million in Australia (YE 08) Aus\$316 million (97%) in SA (YE 08)	55% ↑ 53% ↑
Forecast \$ 2002-12	Aus\$811 million Australia-wide Aus\$651 million in South Australia	Aus\$1,528 million Australia-wide Aus\$883 million in South Australia	88% ↑ 36% ↑
Government Grants	Aus\$48.2 million Australia-wide ^{Note 1} Aus\$29.4 million in SA (61% n SA) ^{Note 1} Qld's \$15 million grant for a geothermal research centre was part of the Australia-wide tally	Aus\$114 million Australia-wide ^{Note 2} Aus\$56.1 million in SA (73% of grants offered to 5 Aug 2009) ^{Note 2} Aus\$35 million of GDP yet to be awarded and this tally excludes \$435 REDP open for all forms of renewables bar solar	136% ↑ 91% ↑

Download AGEG-AGEA Geothermal Reserve & Resource Code:



- US Electrical Energy
- Nature of Geothermal Energy
- Future of Geothermal Energy
- Texas Opportunities
- SMU Opportunities