An Overview of Renewable Energy and Research at Sandia National Laboratories

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Energy & Infrastructure Futures Group
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Sandia National Laboratories

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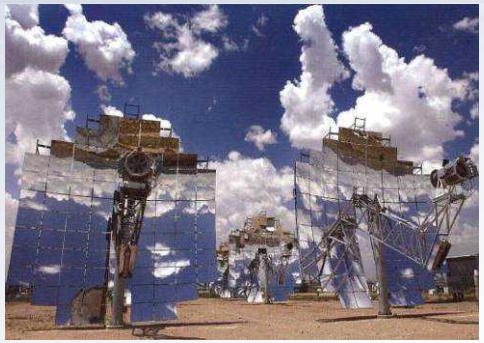
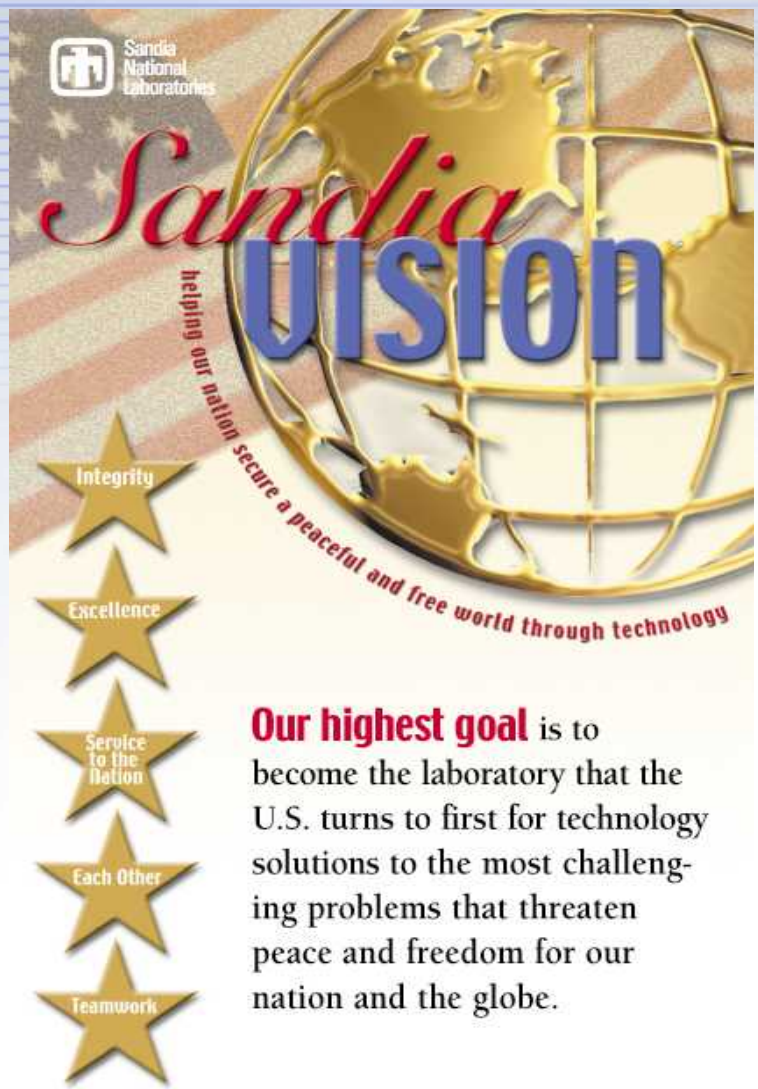
Sandia National Laboratories

Sandia National Laboratories

"Exceptional Service in the National Interest"

- National Security Laboratory
- Broad mission in developing science and technology applications to meet our rapidly changing, complex national security challenges
- Safety, security and reliability of our nation's nuclear weapons stockpile





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Energy & Infrastructure Future Group

6330
Energy & Infrastructure Future
Jeff Nelson, Acting

6337
Solar Technologies
Joe Tillerson, Acting

6335
Solar Systems Department
Charlie Hanley

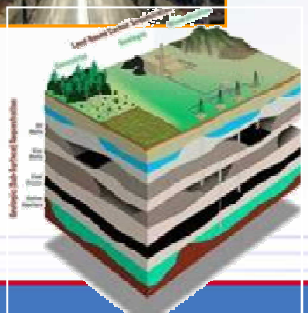
6333
Wind Energy Technology
Jose Zayas

6331
Geothermal Research
Douglas Blankenship

6336
Energy Infrastructure & DER
John Boyes

6332
Energy Systems Analysis
Juan Torres

6338
Fuels & Energy Transitions
Joe Tillerson



6339
Emerging Energy Technologies
Ellen Stechel

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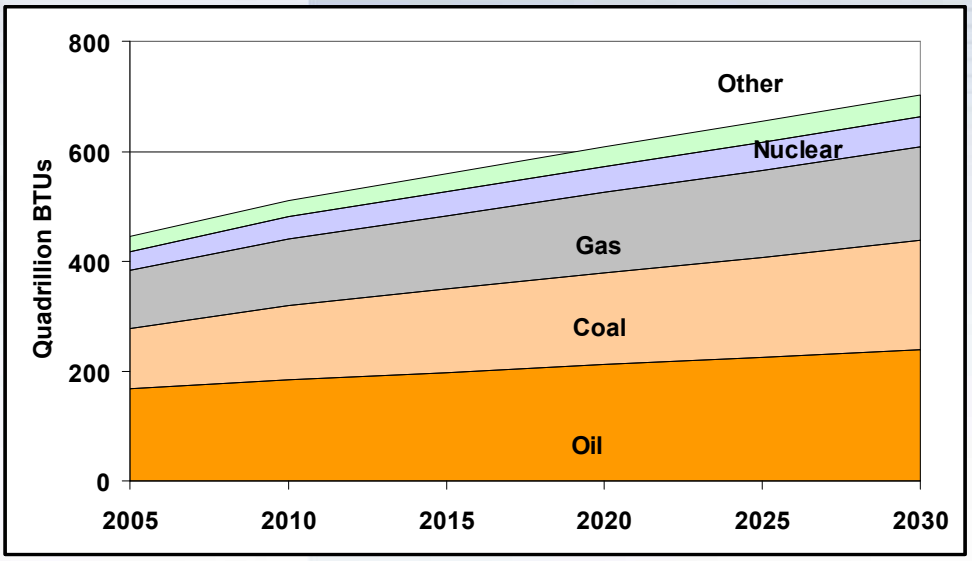
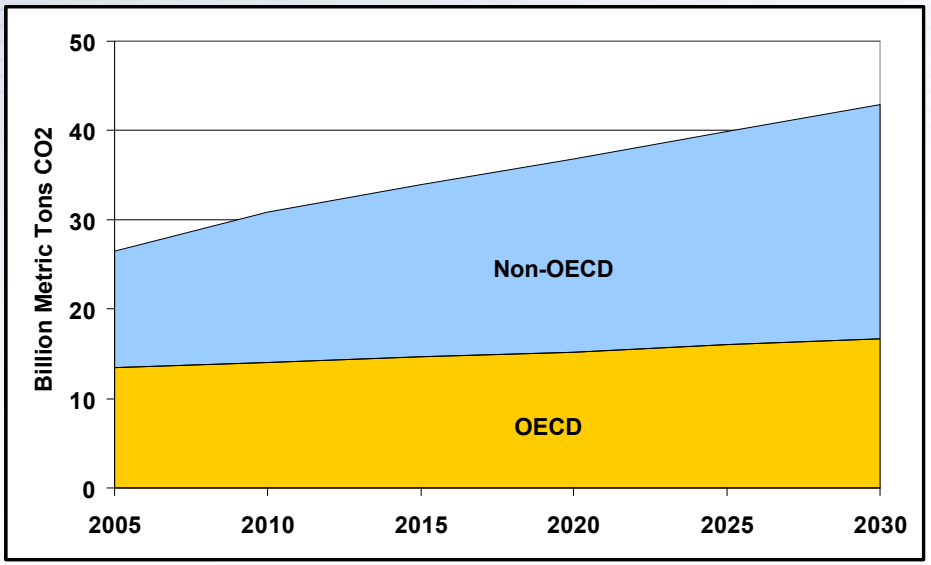
Between Now and 2030, World Energy Demand and Carbon Emissions Will Grow ~65%

Global Energy Demand



Global Carbon Dioxide Emissions



Source: USDOE EIA IEO 2006 Reference Case (updated October 2007)

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World Proven Fossil Fuel Reserves and Consumption

Have's (% of Global Reserves)

Area/Share	Oil	Gas	Coal
Key M. E.*	65	33	0
Saudi	26	4	0
Iran	9	16	**
Iraq	11	2	0
Kuwait	9	1	0
UAE	10	4	0
Qatar	**	6	0
Russia	5	33	16
China	2	1	12
US	2	3	25
Australia	**	1	9
ROW	25	29	38
Total	100	100	100

* Sum of Saudi Arabia through UAE

** Less than 0.5 %

Have not's (% Global Consumption of Oil)

US	26%
Japan	7%
China	6%
Germany	4%
Russia	3%

Sam Baldwin, DOE

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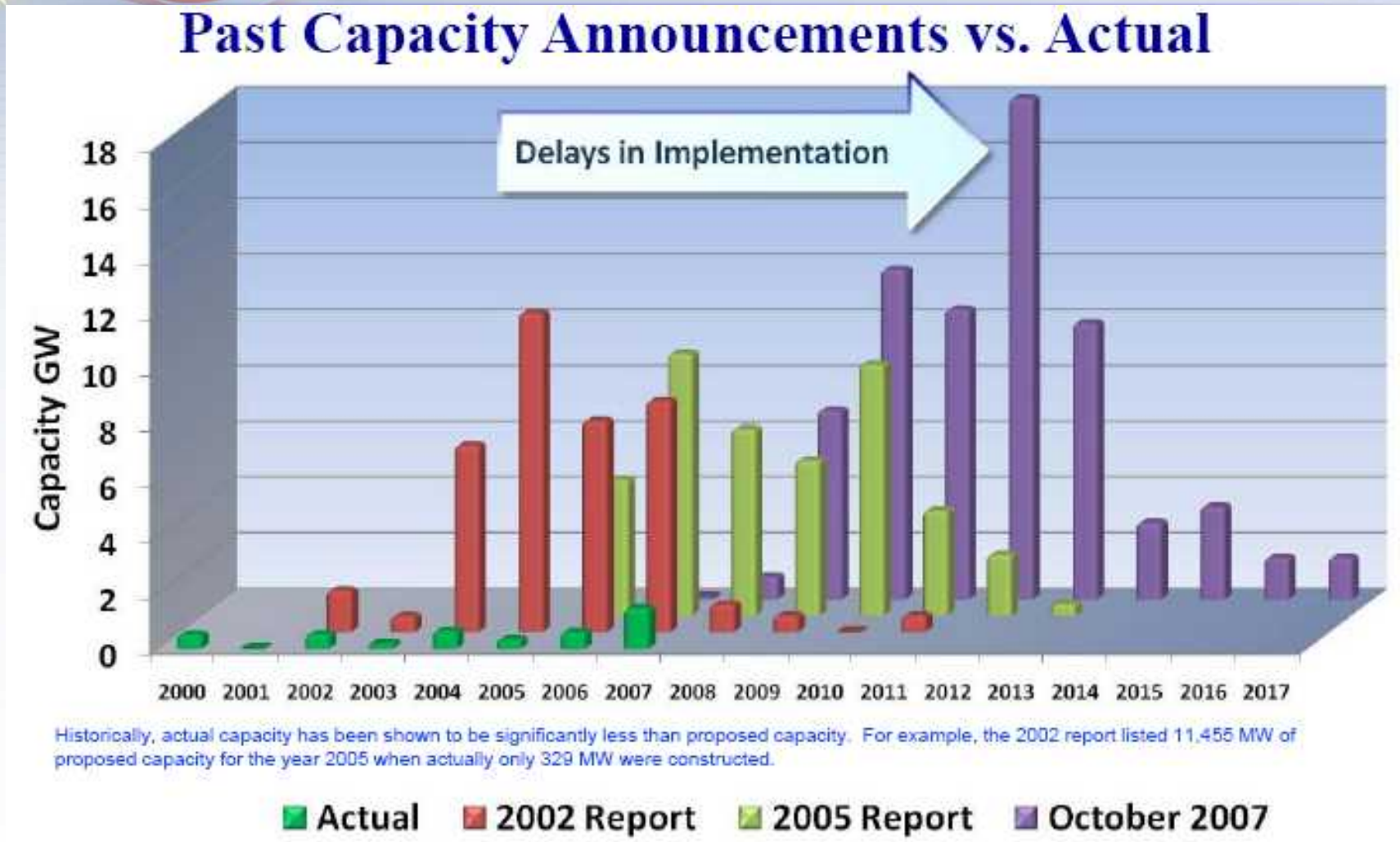
=SAND2001-0726P

Environmental and Economic Concerns With New Coal-Based Power Plants



Courtesy, Joe Strakey, NETL

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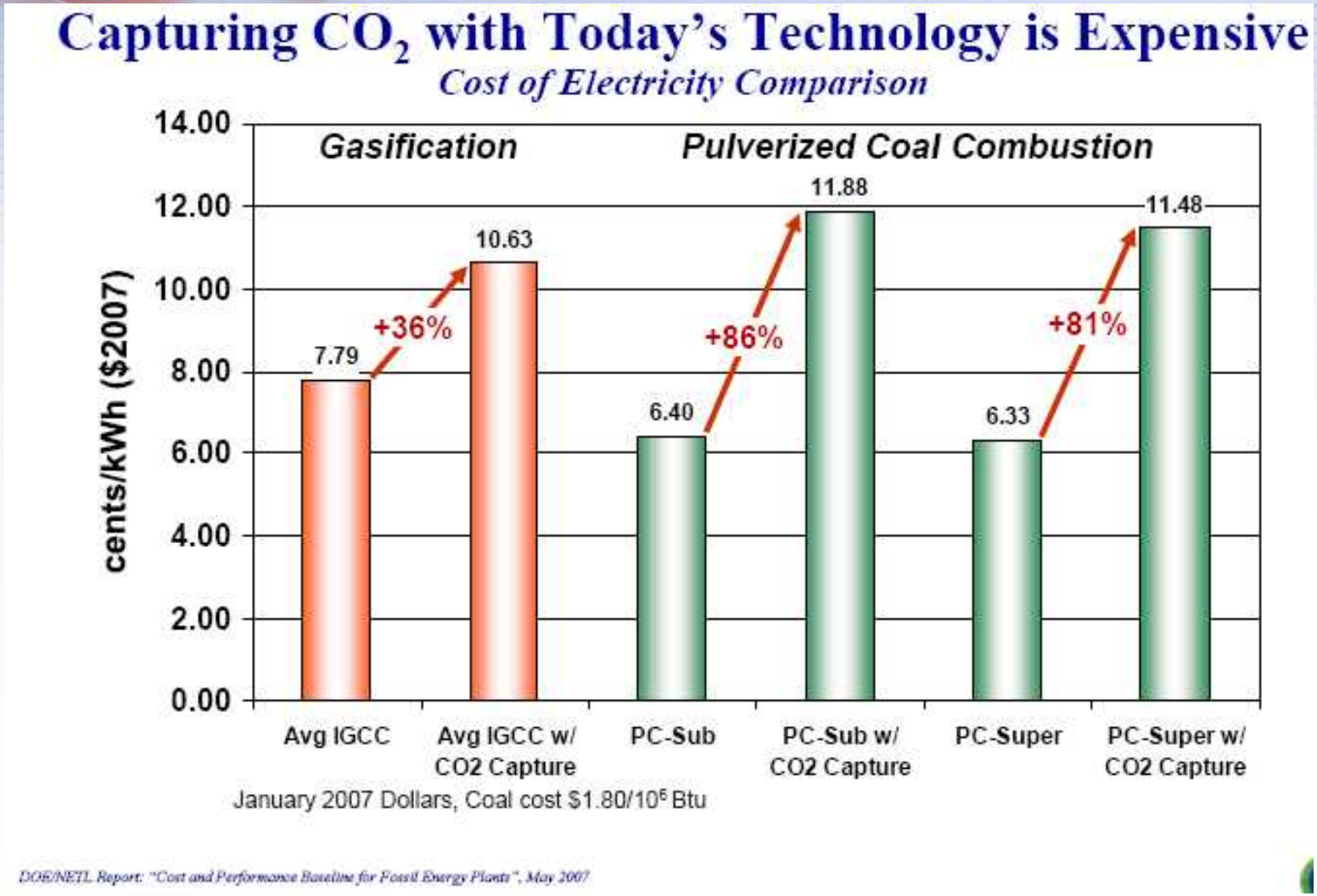
Coal Generation Costs will Increase with CO2 Capture



Courtesy: Joe Strakey, NETL

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Options & Challenges

- Continue to Buy Fossil Fuels from our "Neighbors"

  - *Energy Security and Economic Vulnerabilities*

- Begin Expanding our use of Unconventional Fossil Resources

  - *Increased Environmental Concerns*

- Expand Biofuels Efforts

  - *Land use; Water; Compatibility with existing infrastructure*

- Expand Nuclear Power Efforts

  - *Permitting; Waste Archival*

- Hydrogen

  - *R&D Advances Needed; Infrastructure*

- Expand Renewable Energy Content of our Infrastructure

  - *Intermittency; and Geographic Diversity;*

- Fusion Energy

  - *Fundamental materials and physics advances needed*

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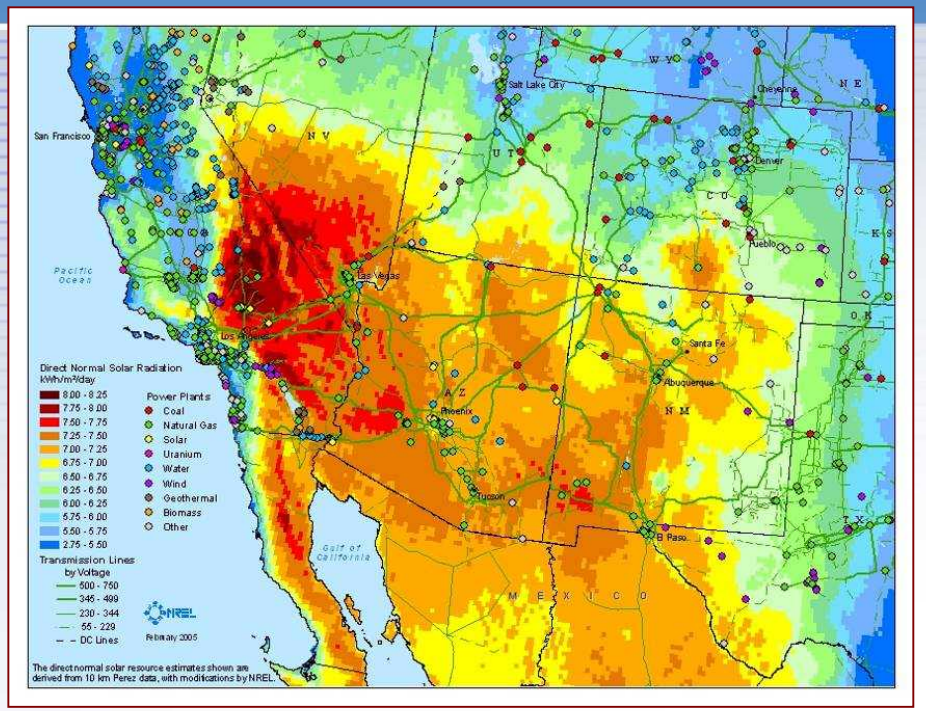
Solar Resource in the Southwest

Filters applied:

- Direct-normal solar resource.
- Sites > 6.75 kwh/m^2/day.
- Exclude environmentally sensitive lands, major urban areas, etc.
- Remove land with slope > 1%.
- Only contiguous areas > 10 km^2

State	Land Area (mi^2)	Solar Capacity (MW)	Solar Generation Capacity GWh
AZ	19,279	2,467,663	5,836,517
CA	6,853	877,204	2,074,763
CO	2,124	271,903	643,105
NV	5,589	715,438	1,692,154
NM	15,156	1,939,970	4,588,417
TX	1,162	148,729	351,774
UT	3,564	456,147	1,078,879
Total	53,727	6,877,055	16,265,611



Data and maps from the Renewable Resources Data Center at the National Renewable Energy Laboratory

Bottom Line:
Almost 7 TW Available Resource
(Total U. S. Capacity is 1 TW)

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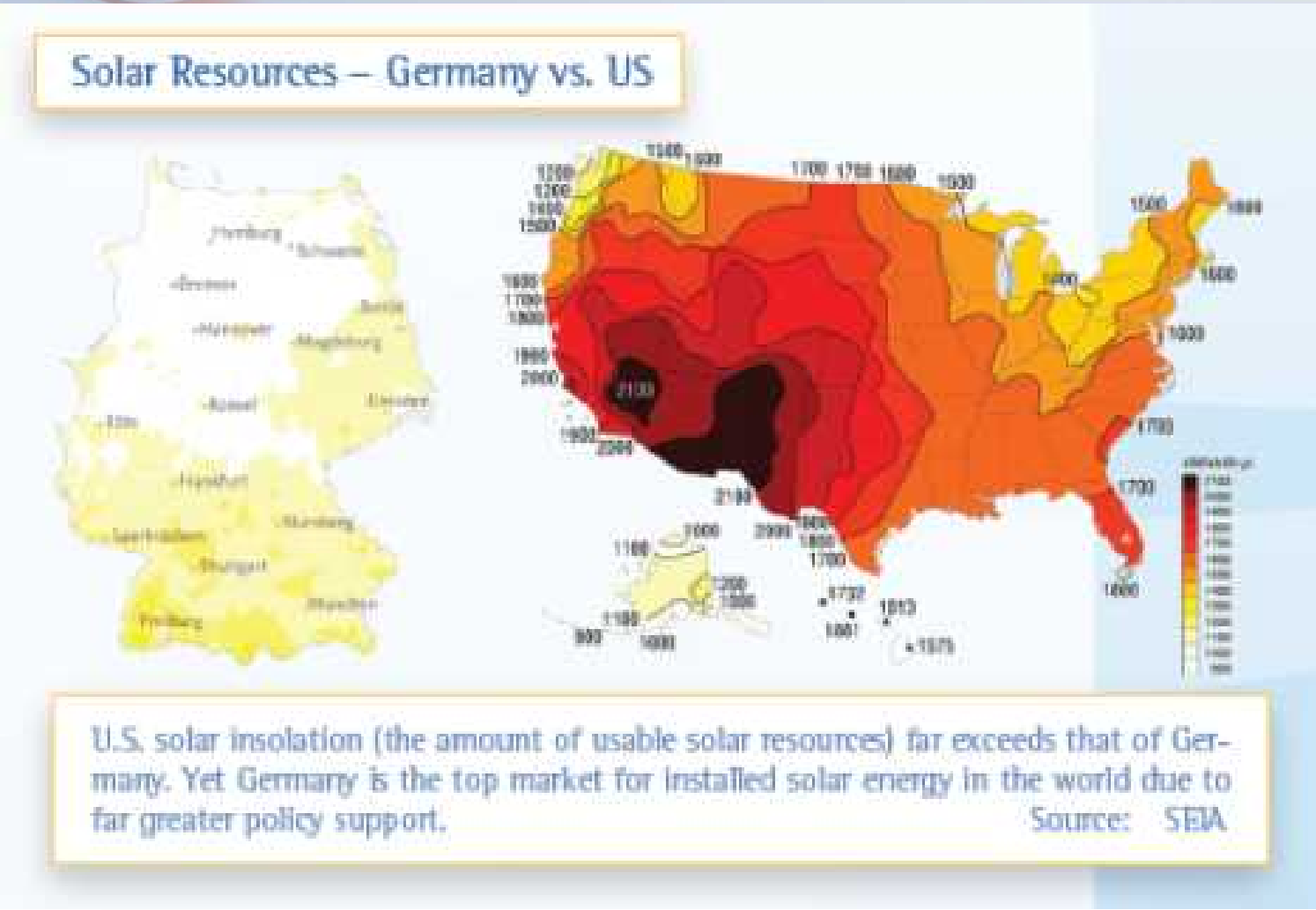
Germany leads in the Solar Markets



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Photovoltaic Markets in the US

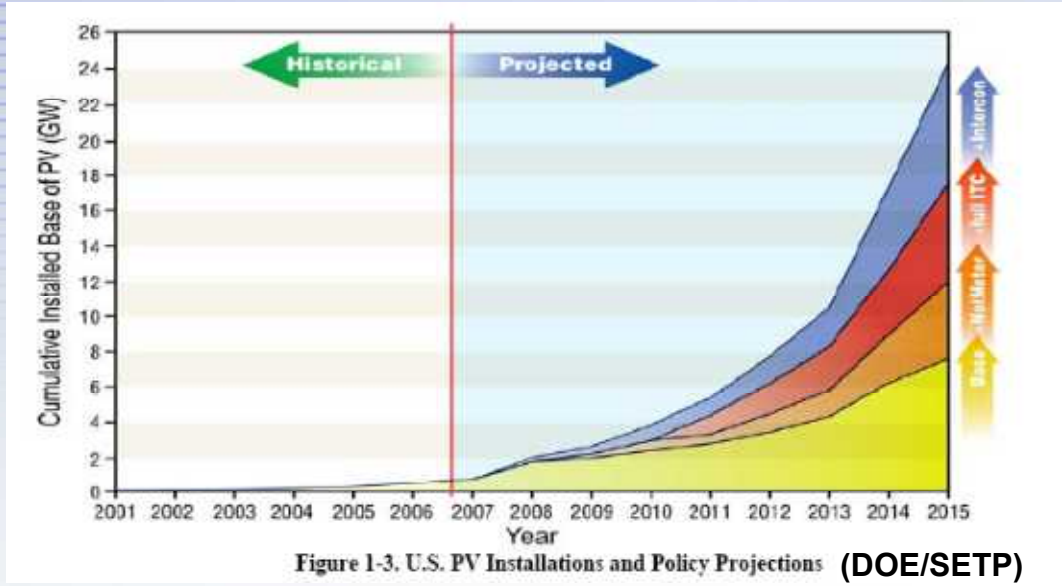
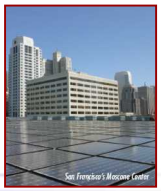


Figure 1-3. U.S. PV Installations and Policy Projections **(DOE/SETP)**

Market Sector	Current U.S. Market Price Range (¢/kWh)	Cost (¢/kWh) Benchmark 2005	Cost (¢/kWh) Target 2010	Cost (¢/kWh) Target 2015
Residential	5.8-16.7	23-32	13-18	8-10
Commercial	5.4-15.0	16-22	9-12	6-8
Utility	4.0-7.6	13-22	10-15	5-7



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Concentrating Solar Power (CSP) Systems are a Leading Source of Renewable Utility Scale Power

Trough

Dishes

Towers

2007 Costs for CSP Trough Plants: $0.13 – 0.18 / KWhr

Future Costs for CSP Plants: $0.05-0.10 / KWhr

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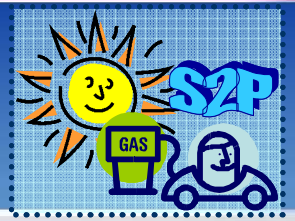
Solar Fuels: Sunshine to Petrol



Vision: To directly, efficiently, and cost effectively produce infrastructure compatible liquid fuels employing the same resources as nature (Sunlight, CO_2 and H_2O).

$$\text{Sunlight} + CO_2 + H_2O = \text{Fuel} + O_2$$

$$\text{Sunlight} + CO_2 + 2H_2O \rightarrow CO + 2H_2 + (3/2)O_2 \rightarrow CH_3OH \text{ (Methanol)}$$

Target

>10x sunlight to fuel efficiency than biomass

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Solar Technology

Technologies:

Photovoltaics

- Cells/Modules/Arrays
- Inverters/BOS
- Controls/Communication
- Systems

Concentrating Solar Power

- National Solar Thermal Test Facility (Tower)
- Troughs
- Dishes

Solar Hot Water

Activities:

Advanced R&D

- New systems integrations
- Hydrogen production
- New "smarts": controls, communications, security, power conversion, energy management

Modeling – performance prediction

Reliability engineering

Evaluations/characterizations of new components/products

In field performance evaluation

Barrier removal: codes, standards, certification, design assistance, technical support

Market Transformation

Customers:

DOE/EERE/OE …

DOD

Industry

NASA

National Nuclear Security Administration

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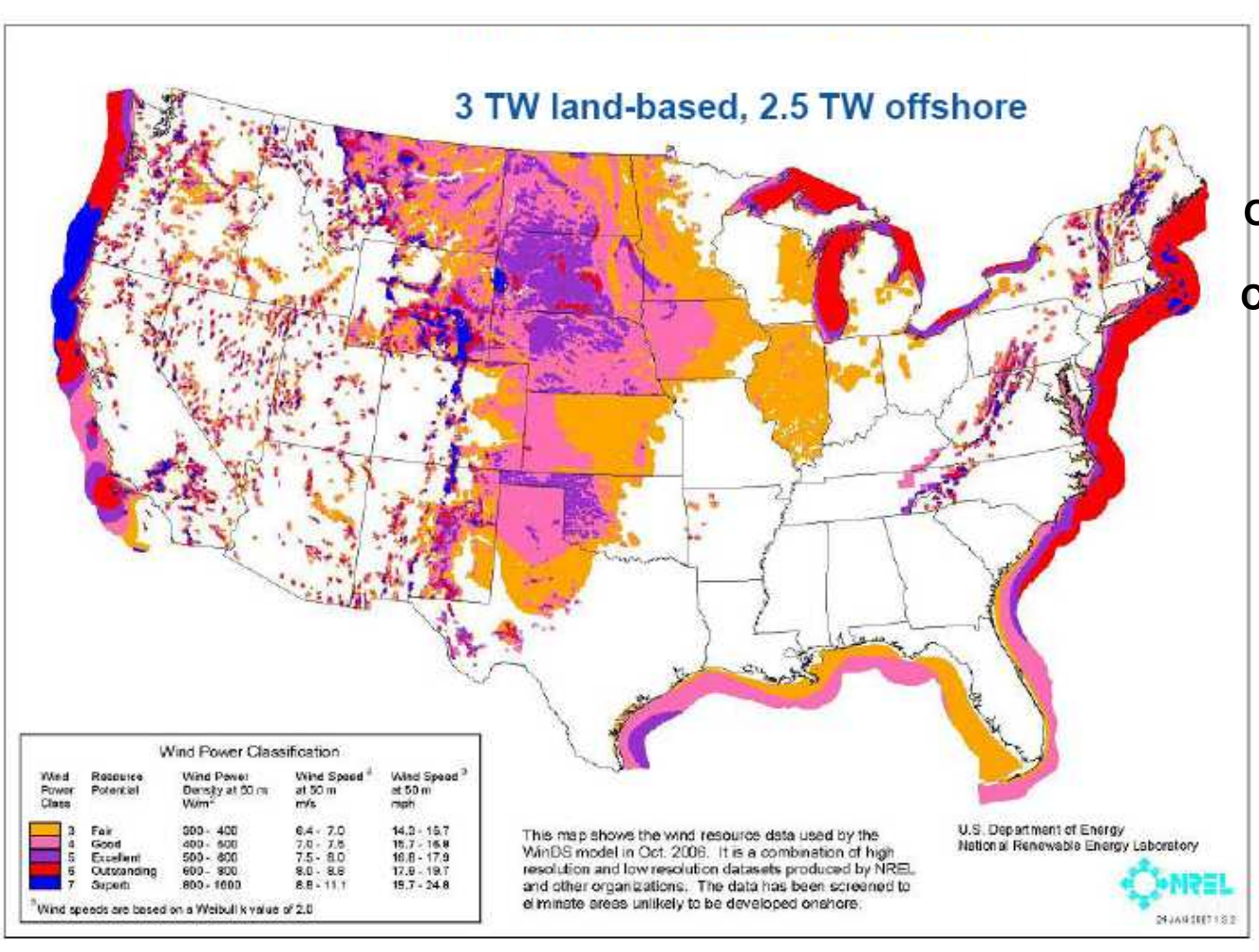
U.S Wind Energy Potential



Over 1100 MW Installed Capacity in NY

Courtesy: David Simms, NREL

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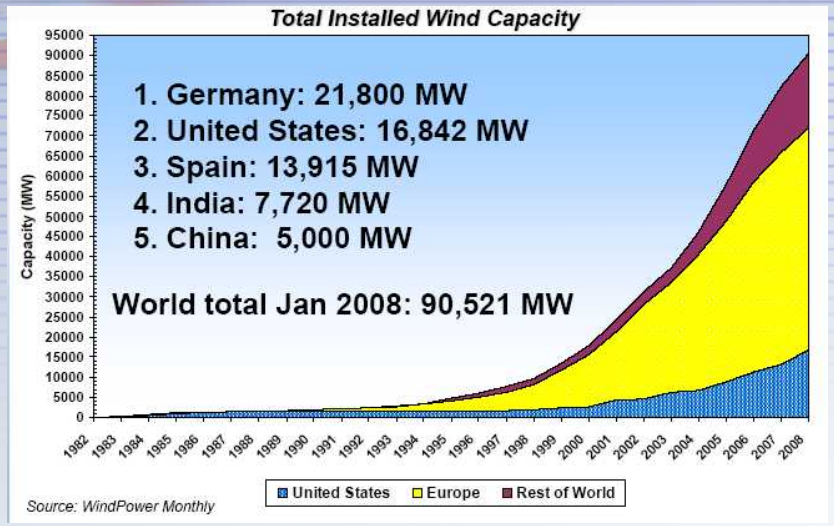
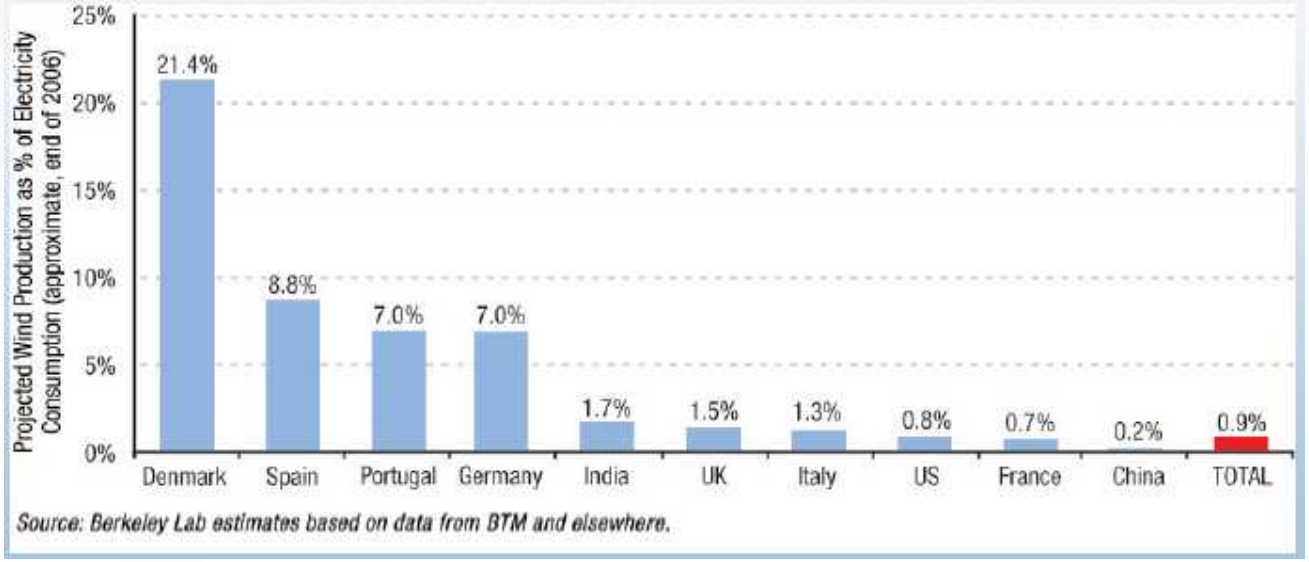
Growth of Wind Energy Capacity Worldwide



30% of new US generation was wind in 2007



Courtesy: David Simms, NREL

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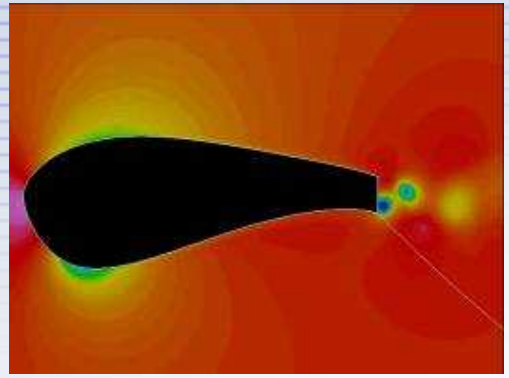
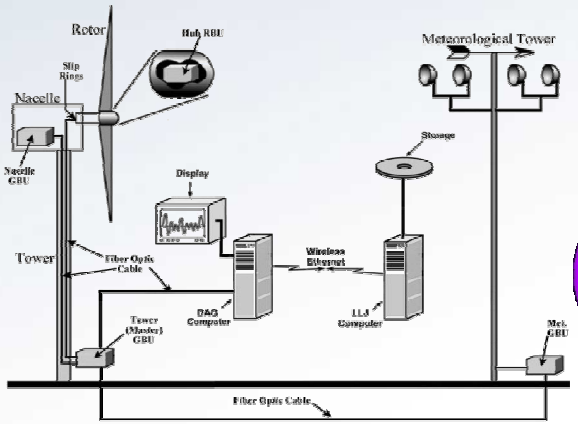
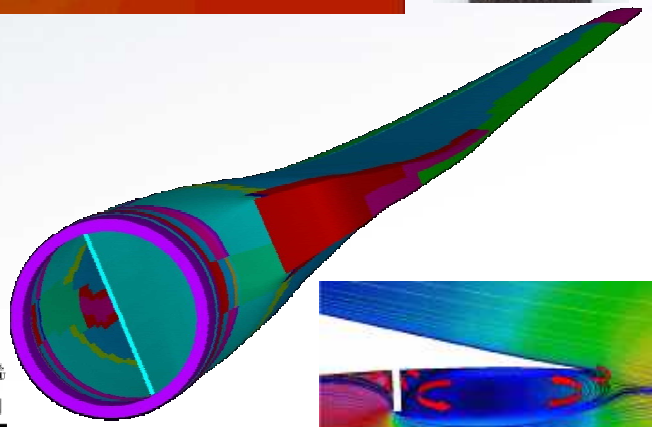
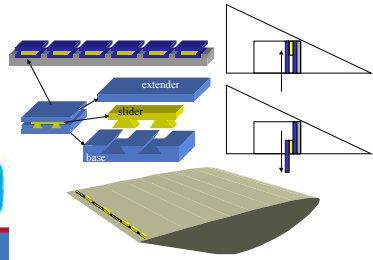
Wind Energy Technology

- **Blade Technology**
  - Materials and Manufacturing
  - Structural, Aerodynamic, and Full System Modeling
  - Lab - Field Testing and Data Acquisition
  - Sensors and Structural Health Monitoring
  - Advanced Blade Concepts
- **System Reliability**
  - Industry Data Collection
  - Improve reliability of the existing technology and future designs
- **System Integration & Outreach**
  - DOE/Wind M&O





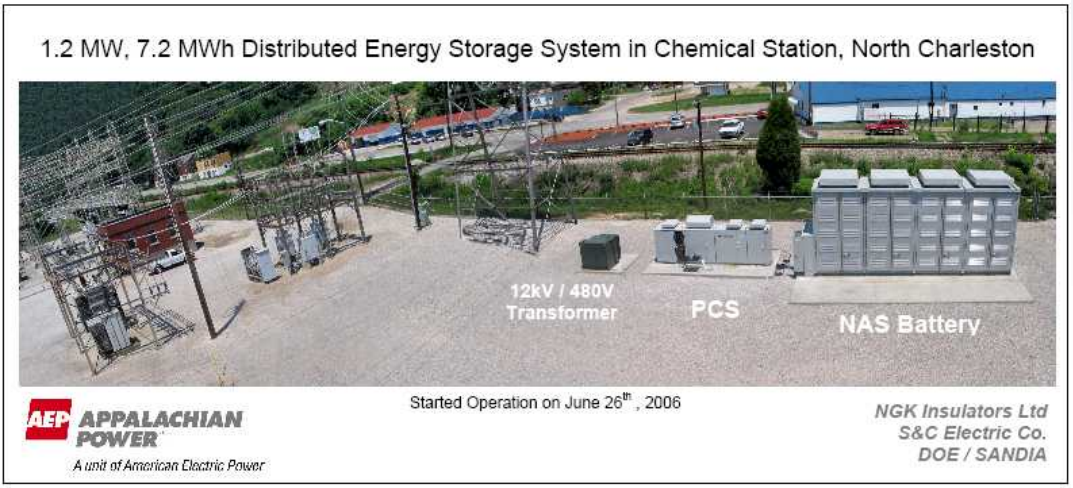




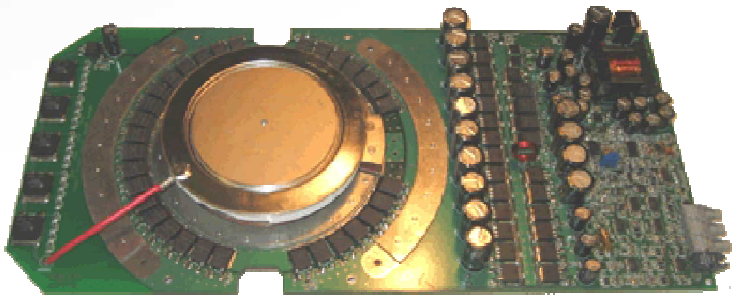
Energy Infrastructure and Distributed Energy Resources

S&C Purewave UPS System

- Distributed energy resources
- Power electronics
- Energy storage
- Energy Surety Microgrid



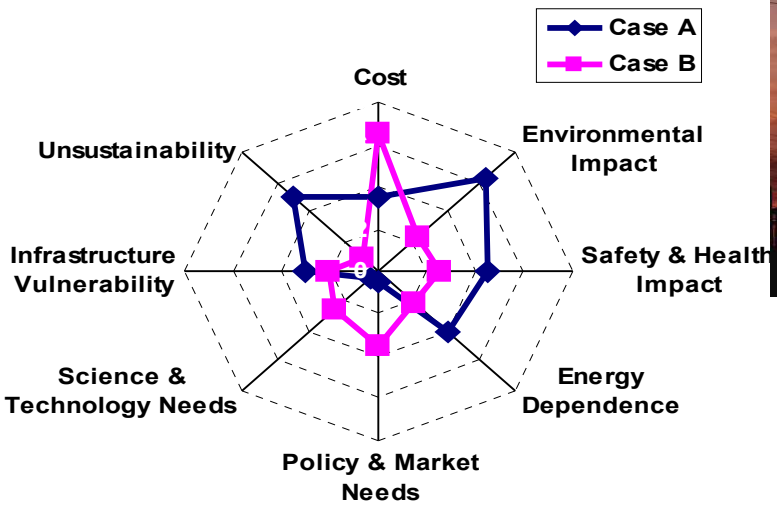
Application of Energy Storage



R&D 100: ETO High Power Switch

Energy Systems Analysis

- **Competencies:**
  - Power grid (generation, transmission, distribution) operations, modeling
  - Energy transport security (pipelines, power grid, marine, railways)
  - SCADA and control systems analysis and security
  - Energy system vulnerability, safety, and risk assessment
  - Energy system modeling and simulation
  - Energy systems analysis
  - Energy-Water Nexus issues



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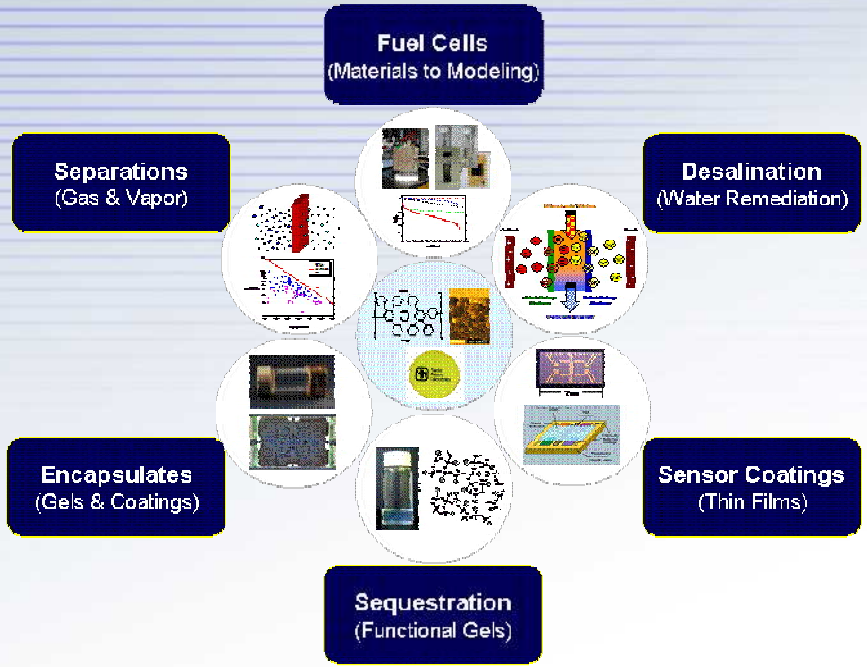
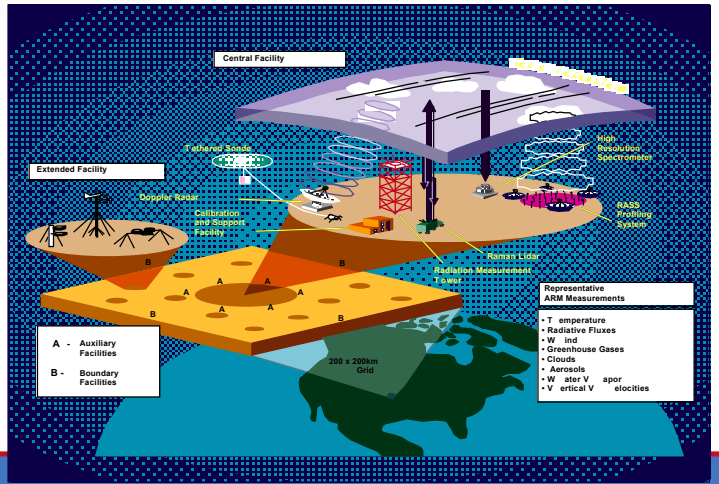
The Fuels & Energy Transitions

- Materials Membranes & Coatings
  - Synthesis & Characterization
    - Inorganic
      - Ceramics, Glasses, Metals
    - Organics
      - Synthetic & Natural Polymers
    - Hybrids
    - Nanomaterials
  - Wide Range of Applications
- Assembly & Testing
  - Fuel Cells
    - System Level including Modeling
  - Desalination
- Atmospheric Radiation Monitoring
  - DOE Facility on the North Slope of Alaska

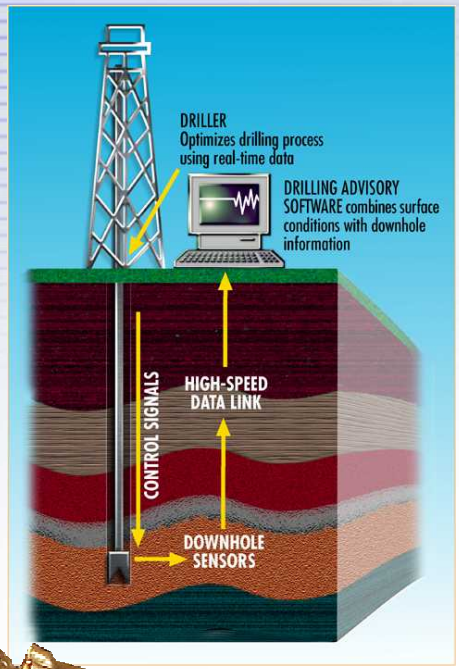




Geothermal Research

Drilling and Monitoring in Harsh Environments

- Well construction costs can exceed 50% of capital costs
- Sandia Focuses on geothermal well construction
  - High-Temperature Electronics
  - Diagnostics-While-Drilling
  - Rock Reduction Technologies
  - Wellbore Integrity and Lost Circulation
  - Drilling Dynamics Modeling and Simulation
  - Vibration Mitigation



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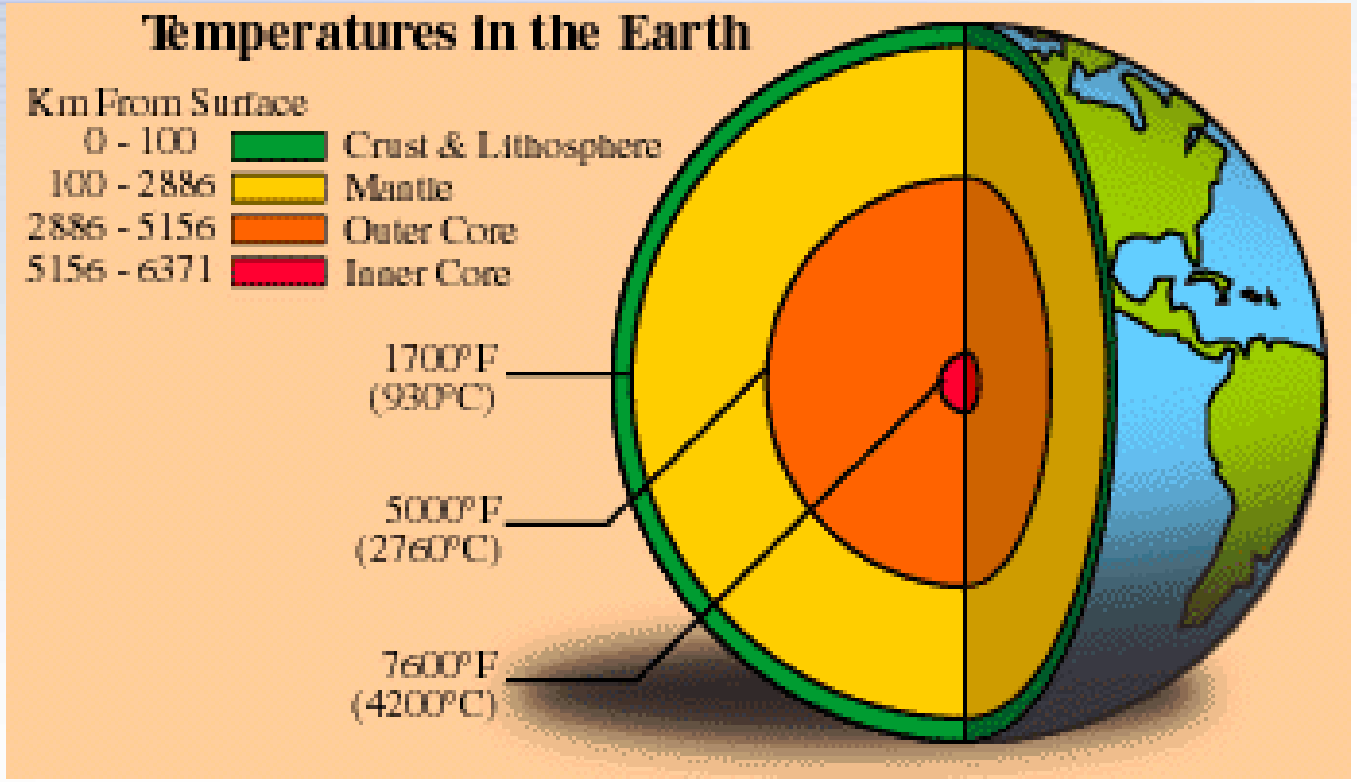
Geothermal Energy

Using the Earth's heat for electricity production, direct use applications, and as a heat exchange medium for geothermal heat pumps

The Earth's core is about the same temperature as the surface of the Sun



Courtesy: Geothermal Education Office

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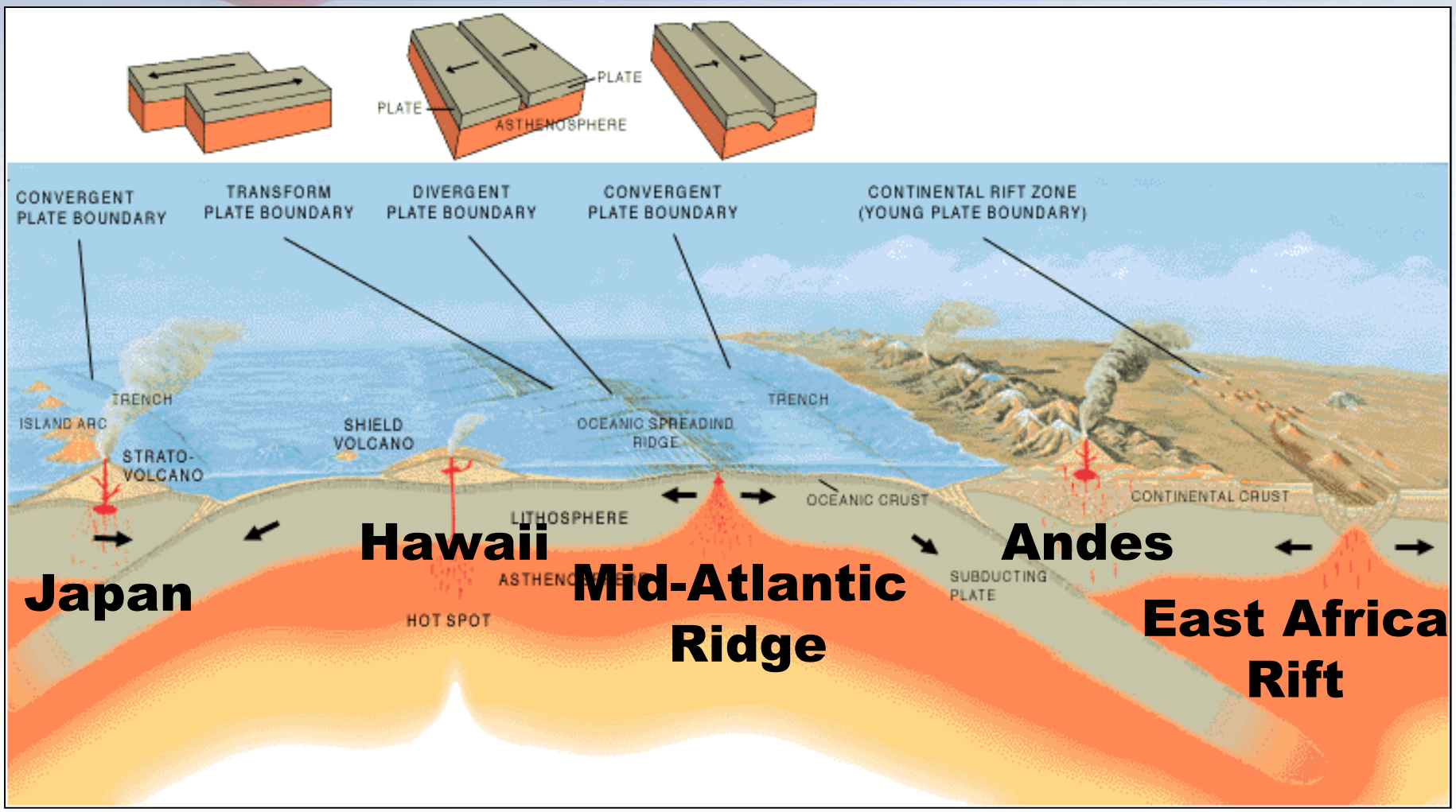
Heat Closest to the Surface at Plate Boundaries



Source: Fraser

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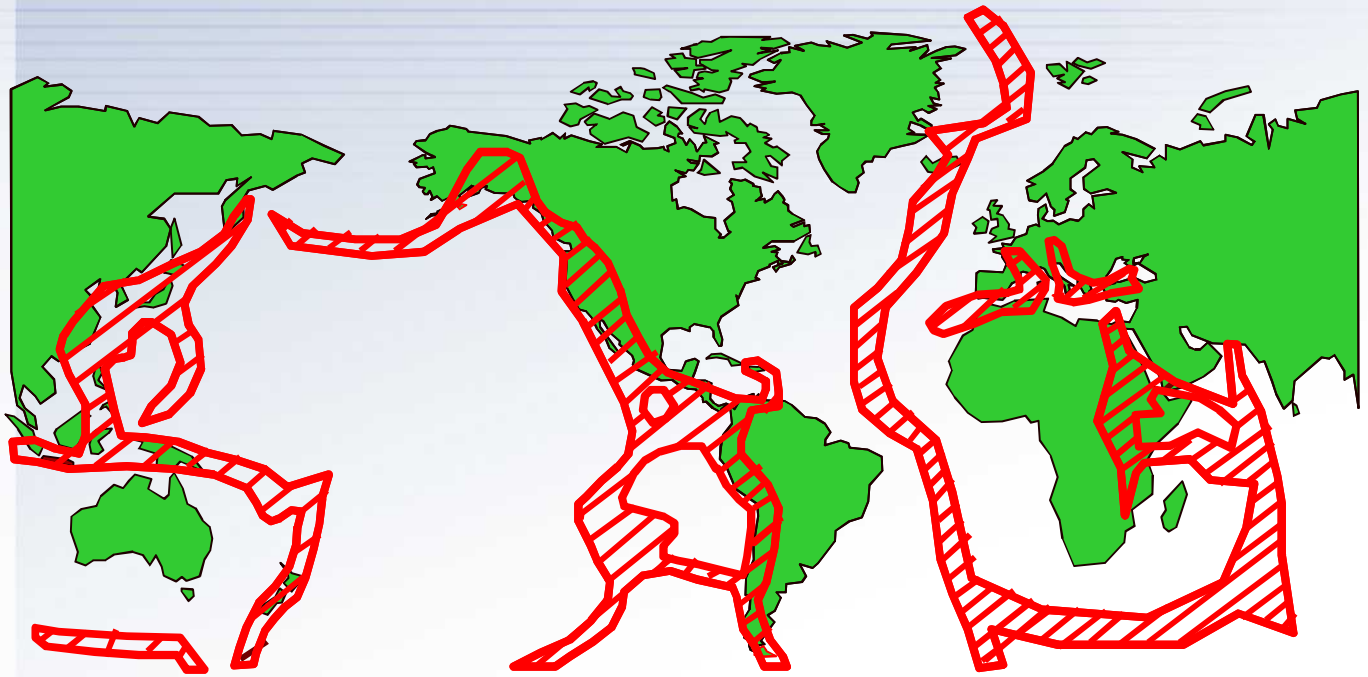
World Hydrothermal Resources

Worldwide Hydrothermal Electric Potential



Courtesy: Geothermal Education Office

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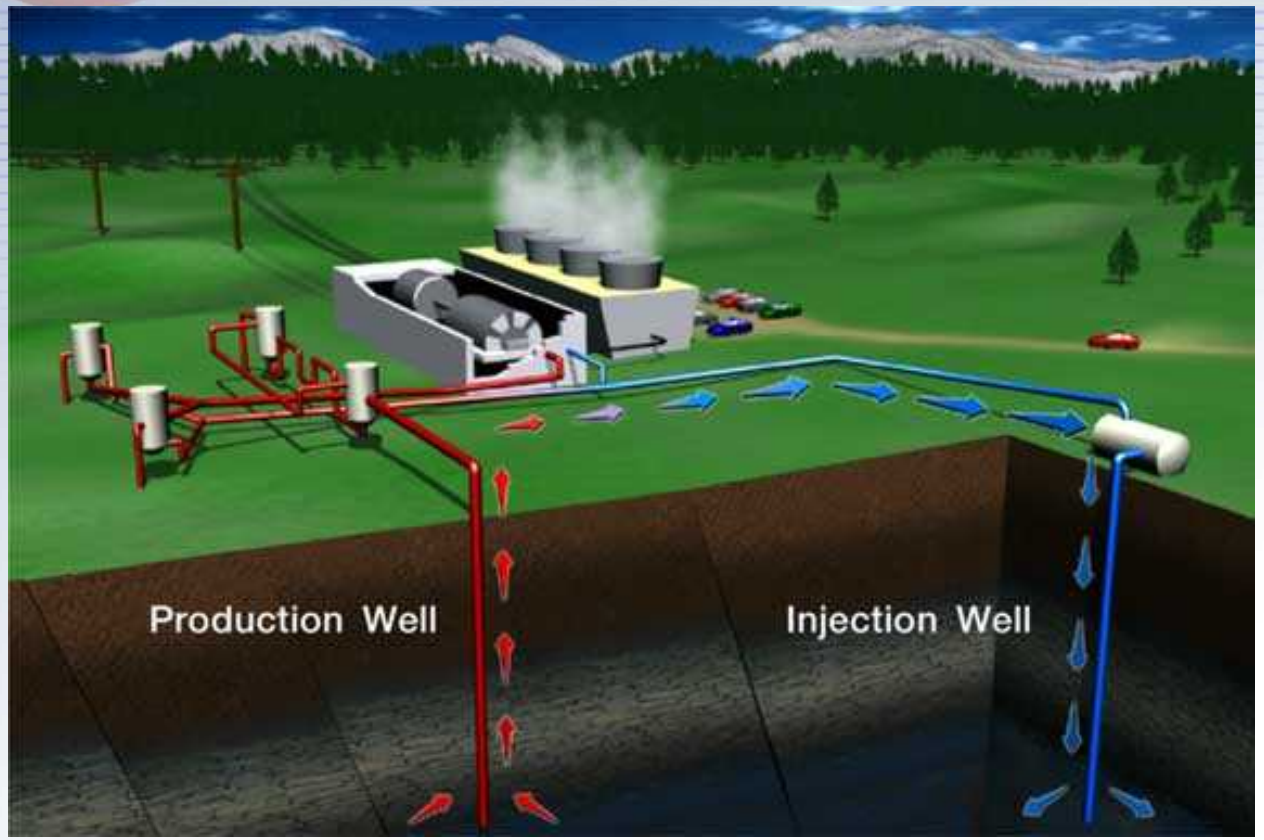
Geothermal Energy



Courtesy: Geothermal Education Office

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Geothermal Reservoir Requirements

- **Temperatures**
  - Greater than 350 °C to "warm"
    - Temperatures largely dictate use
      - Power generation to direct use
- **Permeability**
  - Measure of fluid transmission ability of the rock
    - Orders of magnitude variability
      - Tight to open
- **Fluid Availability**

Hydrothermal (current) → Enhanced Geothermal Systems (future)

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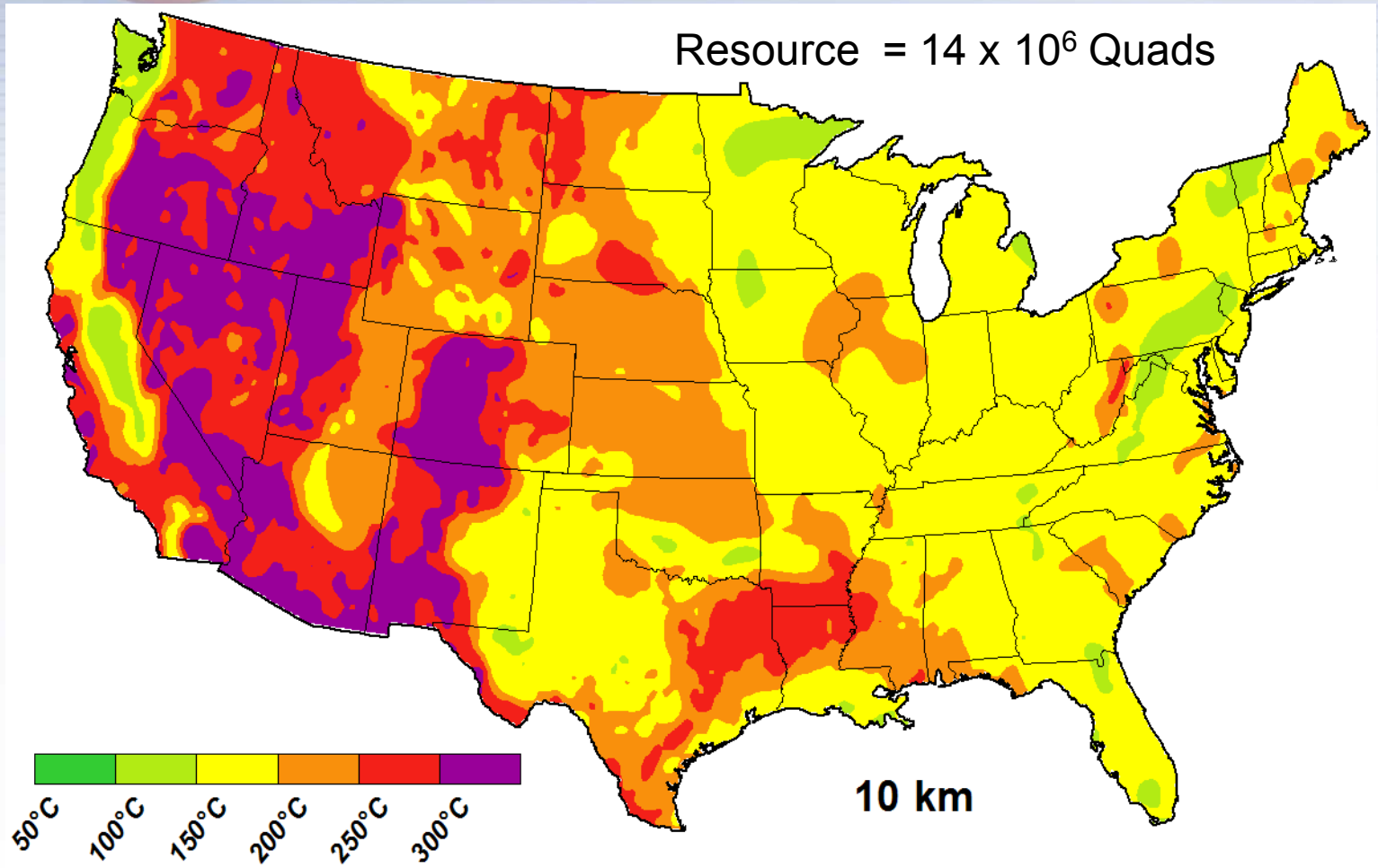
Geothermal Resource in the United States



The Future of Geothermal Energy, MIT

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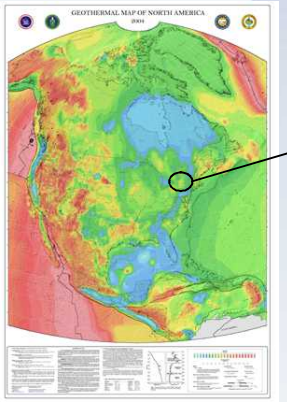
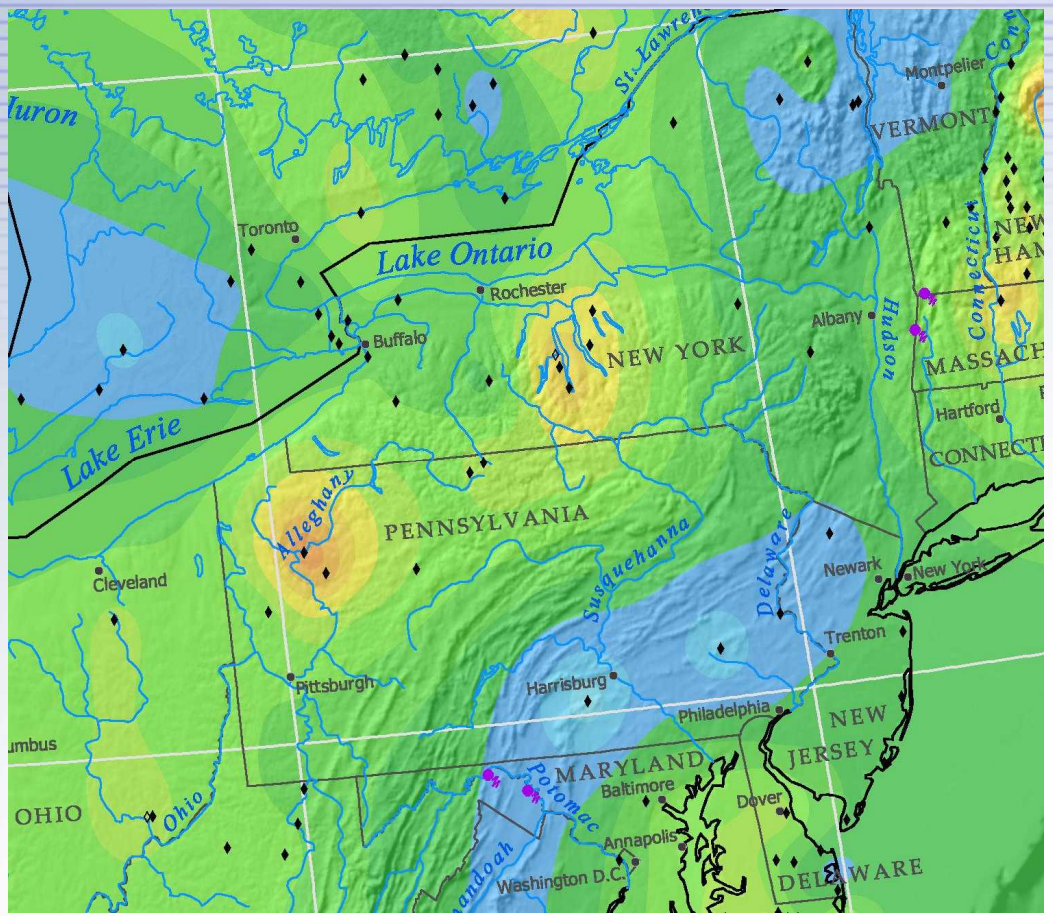
Heat Flow in New York





Subset of the Geothermal Map of North America, 2004

Courtesy: Maria Richards, SMU Geothermal Laboratory

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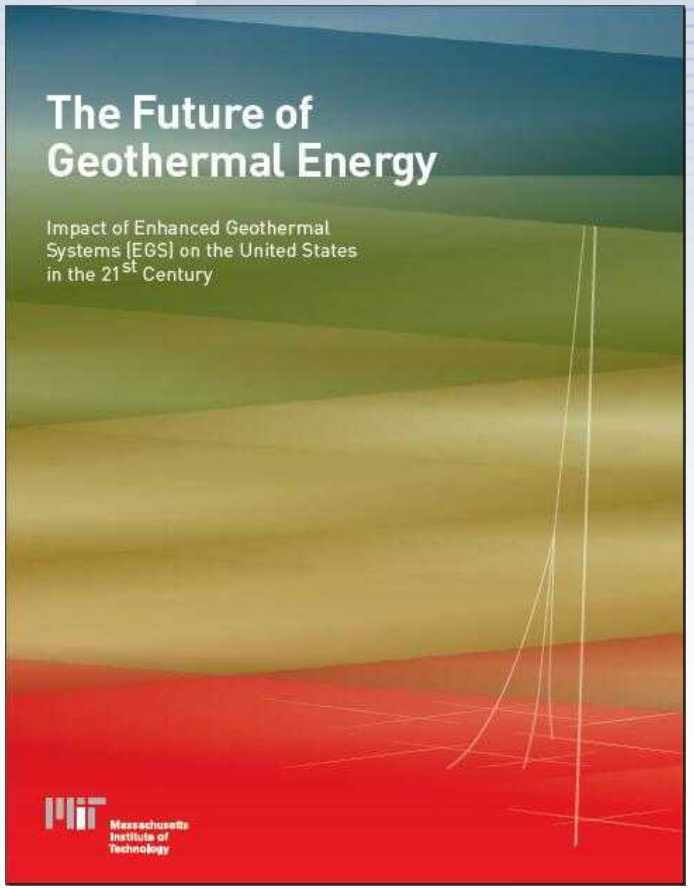
Study of Enhanced Geothermal Systems (EGS) by MIT-Led Panel of Experts



Key Findings/Recommendations

- Extractable geothermal resource exceeds 2000 times the annual energy consumption of the United States
- EGS are versatile, modular, and scalable from 1 to 50 MWe unit sizes
- Technical issues are surmountable – no showstoppers
- Cumulative EGS capacity of 100,000 MWe can be achieved in the United States within 50 years
- Public/private investment of $800 million to $1 billion over 15 years would produce 100,000 MWe by 2050

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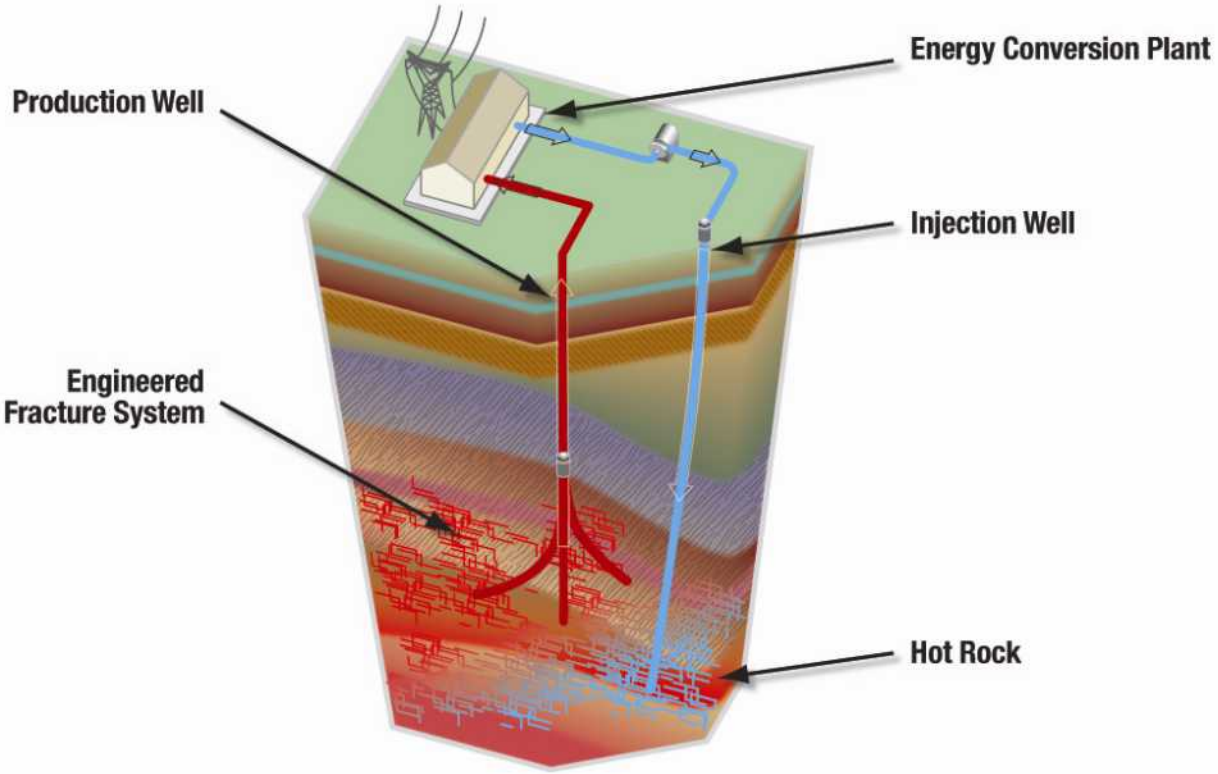
EGS System Components



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Sandia's Focus
Drilling, Monitoring, and Analysis

- **Geothermal well construction**
  - **"Most" difficult on a per-foot basis**
  - **Can be 50% of capital costs**
  - **Broad technology areas**
    - **High-temperature electronics**
    - **Diagnostics**
    - **Rock reduction technologies**
    - **Wellbore integrity and lost circulation**
    - **Drilling dynamics mod/sim**
    - **Vibration mitigation**
    - **Downhole telemetry**
  - **Key to future EGS**
- **Applying capability and technology to other industries and agencies**
  - **Frontier O&G, unconventionals, environmental, DOD, others**

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Polycrystalline Diamond Compact (PDC) Bits

- Fundamental work
  - FEM analyses
  - Bonding
  - Cutter tests
  - Bit design / analysis
  - Lab / field testing
  - CRADAs
- Catalyzed a major industry
- PDC bits now a ~ $1.5 billion industry
- PDC bits save industry $ billions annually
- Over 60% of world footage today

DOE Energy 100 Award for *Synthetic Diamond Drill Bits*

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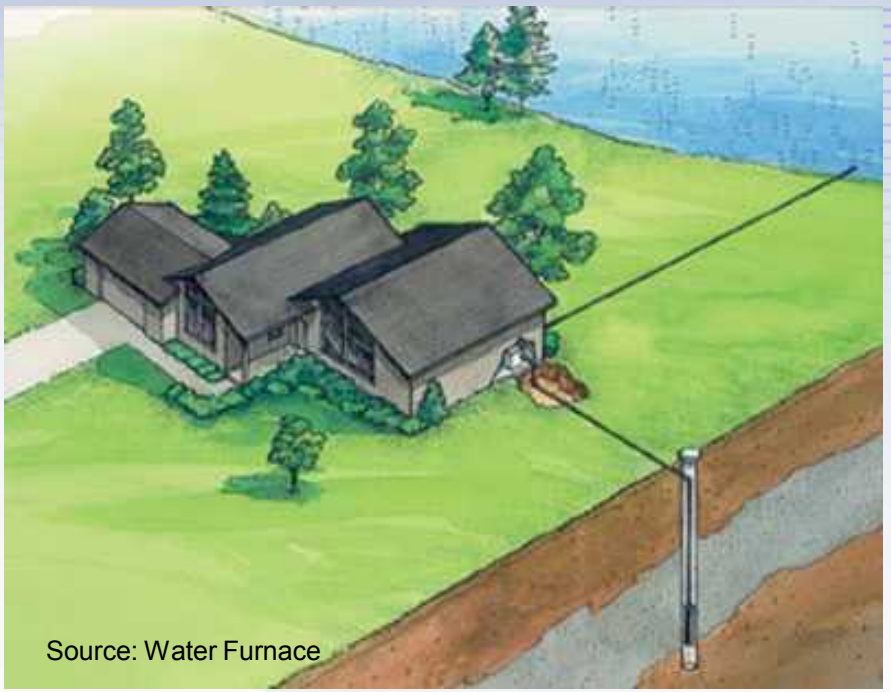
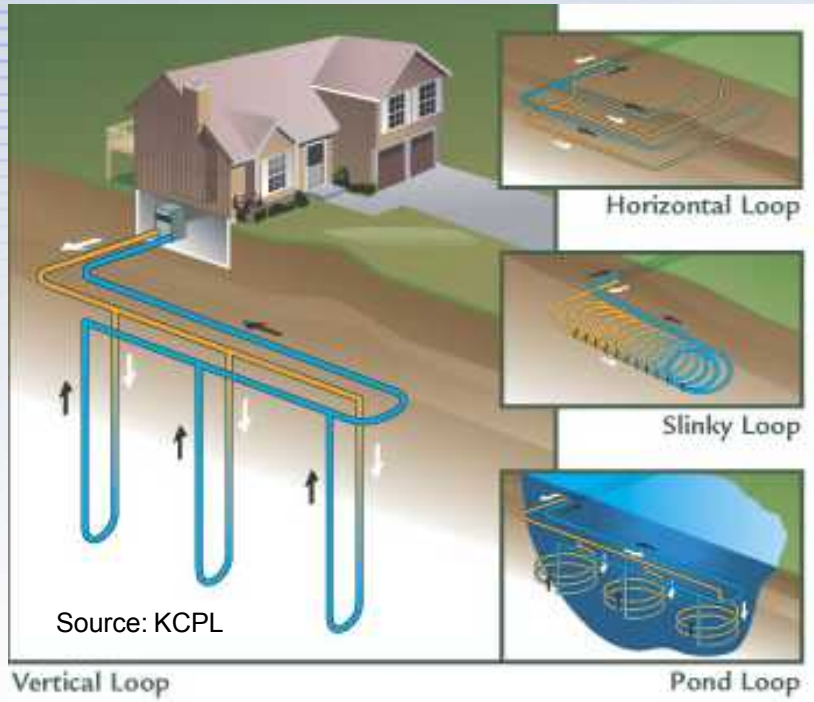
Geothermal Heat Pumps





Geothermal heat pumps are established technology that use the constant temperature of the earth as a heat exchange medium – they provide cooling in the summer and heat in the winter and are among the most efficient heating cooling systems available.

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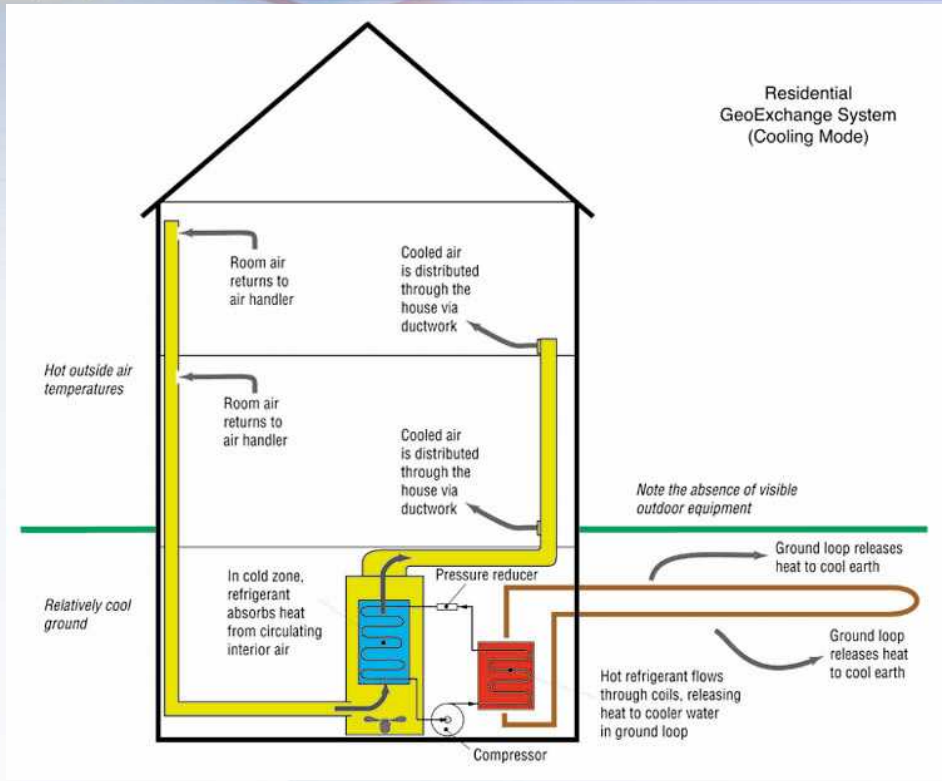
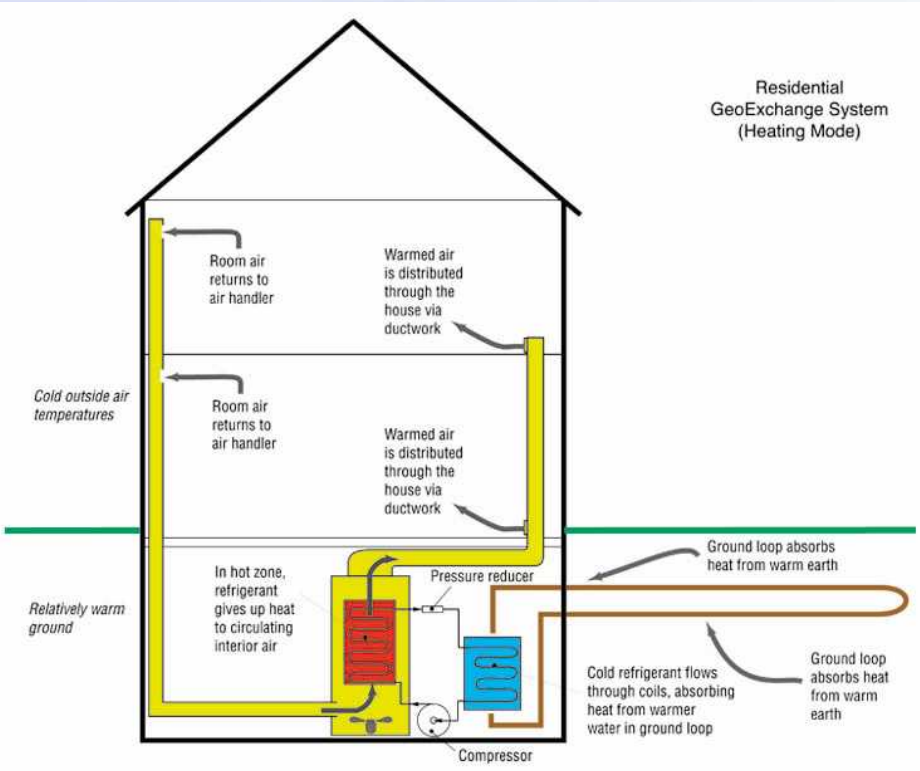
How Geothermal Heat Pumps Work



Summer

Winter



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Geothermal Heat Pumps

- **US has largest installed base, but rates of installation higher in Europe and Asia**
- **Aggressive installation could potentially save ~ 4 quads by 2030 (nearly 100, GW scale coal plants)**
- **Proven technology but barriers exist**
  - **Higher installation costs**
  - **Market immaturity and consumer awareness – marketing largely "word of mouth"**
  - **Market delivery infrastructure – lack of qualified drillers, loop designers / installers**
  - **Designs more complex (you are dealing with the earth)**
  - **Economy of scale not yet achieved**
- **Appears a renewed federal interest exist via tax credits**

Geothermal heat pumps work, they make sense, and can make a difference today

Sources: Jonathan Cross and from *Geothermal (Ground-Source) Heat Pumps: Market Status, Barriers to Adoption, and Actions to Overcome Barriers,* ORNL

Sandia National Laboratories

Thank You