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Opportunities for Geothermal Development Created by New Technologies

Geothermal Academy

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CSM MISSION

Colorado School of Mines' role and mission has remained constant and is written in the Colorado statute as:
The Colorado School of Mines shall be a specialized baccalaureate and graduate research institution with high admission standards. The Colorado School of Mines shall have a unique mission in ***energy, mineral, and materials*** *science and engineering and associated engineering and science fields. The school shall be the primary institution of higher education offering energy, mineral and materials science and mineral engineering degrees at both the graduate and undergraduate levels. (Colorado Revised Statutes, Section 23-41-105)*

Geothermal Education Office

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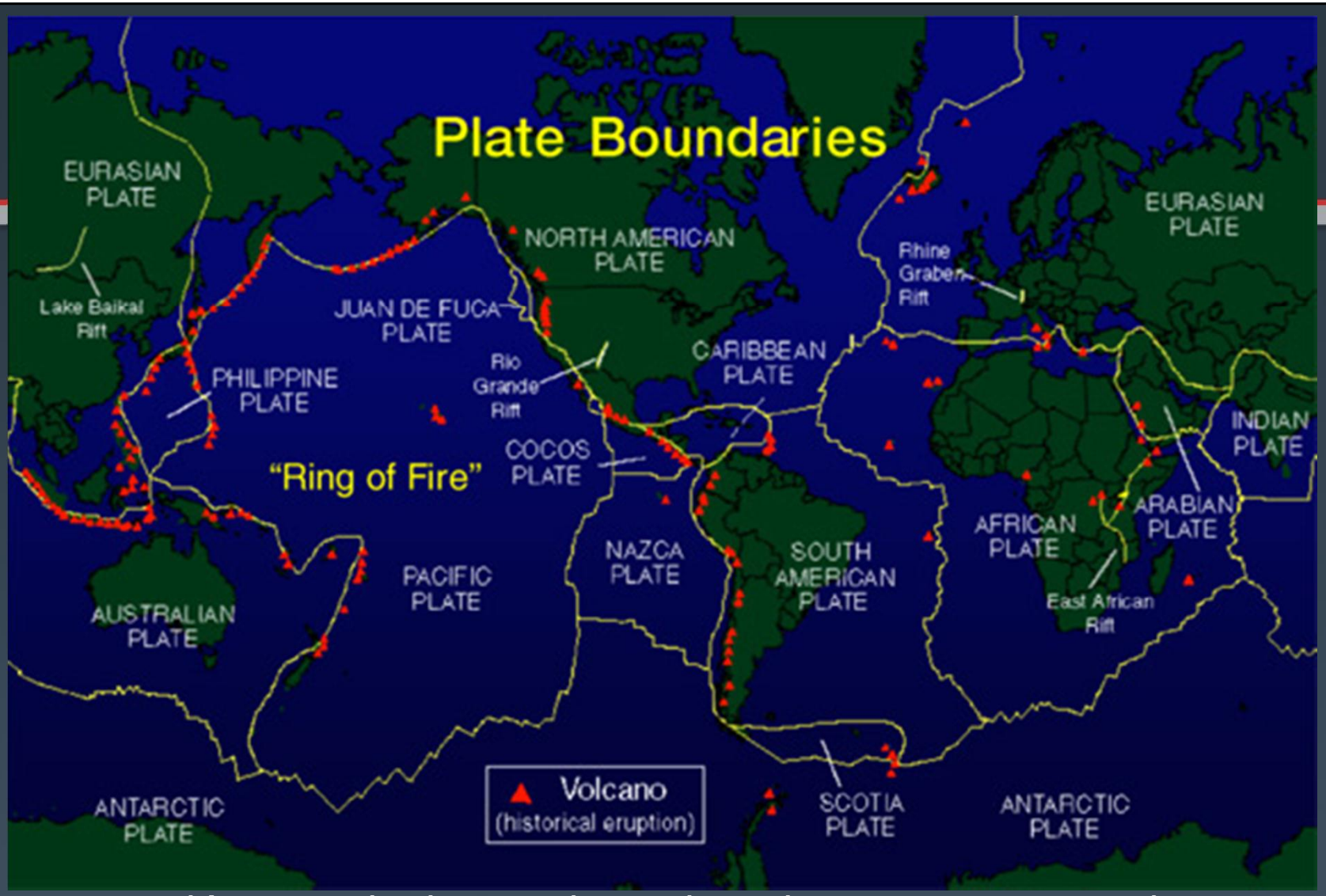
WHAT IS GEOTHERMAL ?

Geothermal energy draws sustainable power from the natural heat of the earth. It is the thermal energy contained in the rock and fluid (that fills the fractures and pores within the rock) in the earthôs crust. It is believed that the ultimate source of geothermal energy is radioactive decay occurring deep within the earth. The presence of volcanoes, hot springs, and other thermal phenomena are surface evidence of our planetôs heat resource.



Earth's crust is broken into huge plates that move apart or push together at about the rate our fingernails grow. Convection of semi–molten rock in the upper mantle helps drive plate tectonics.

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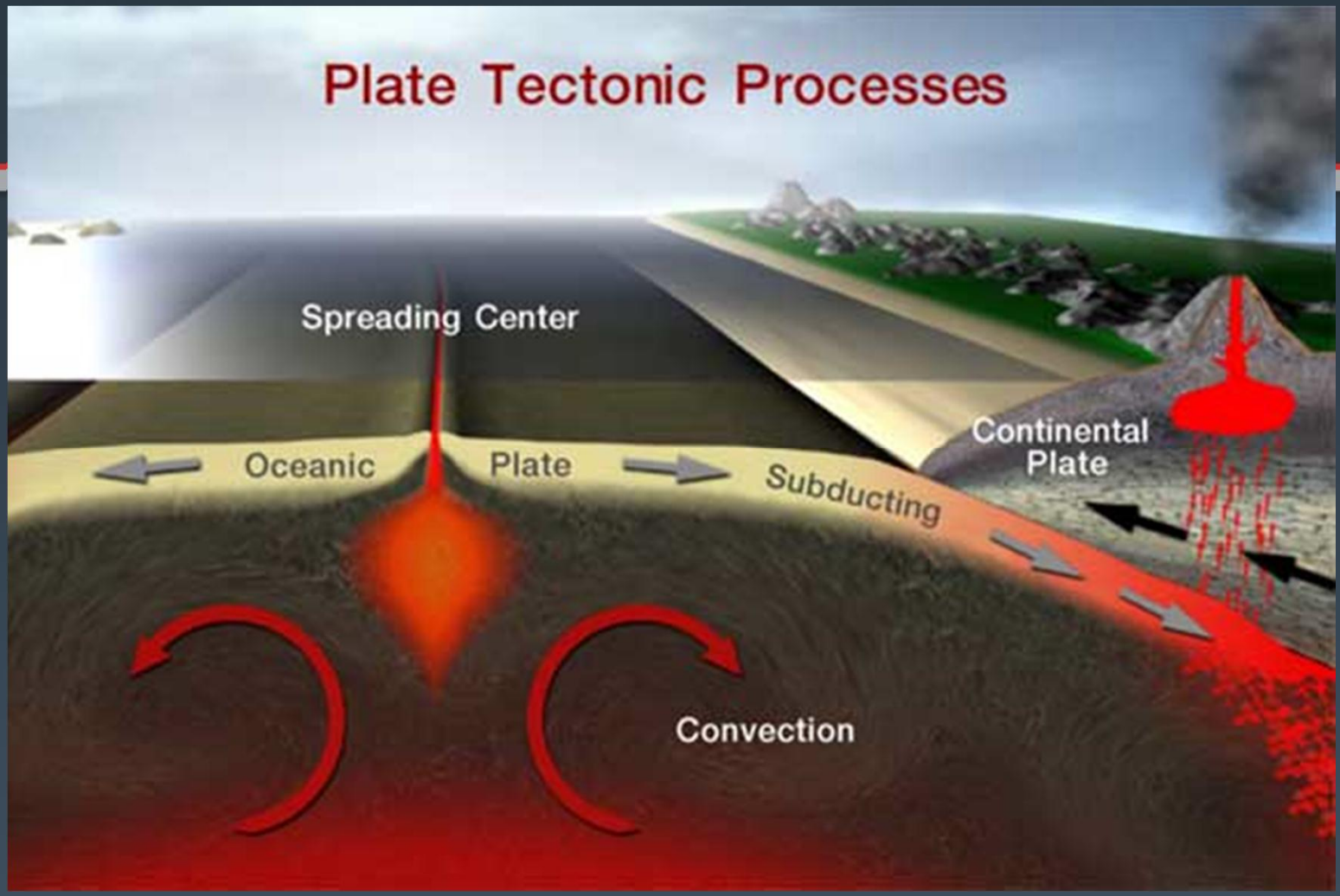
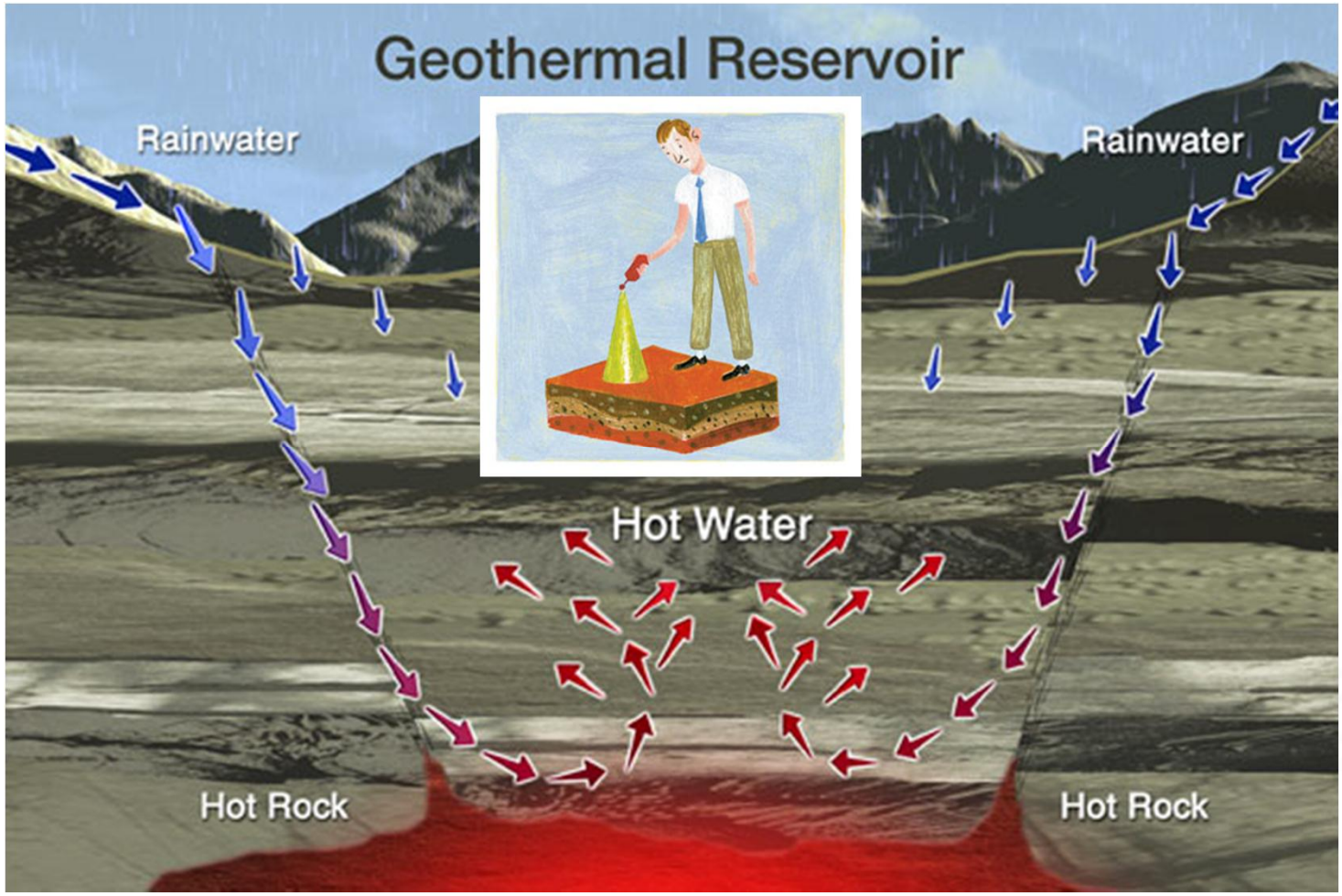
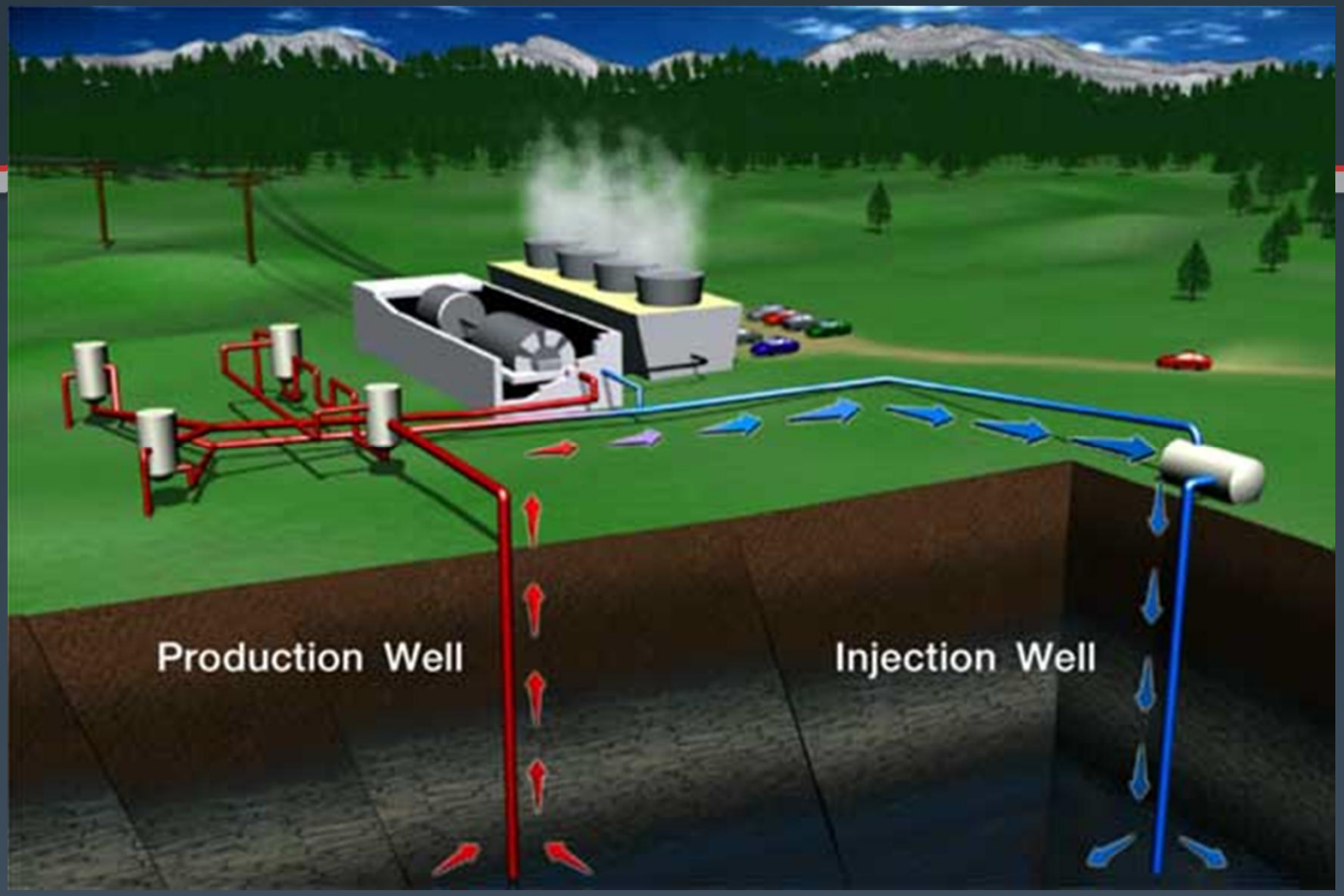


New crust forms along mid–ocean spreading centers and continental rift zones. When plates meet, one can slide beneath another. Plumes of magma rise from the edges of sinking plates.

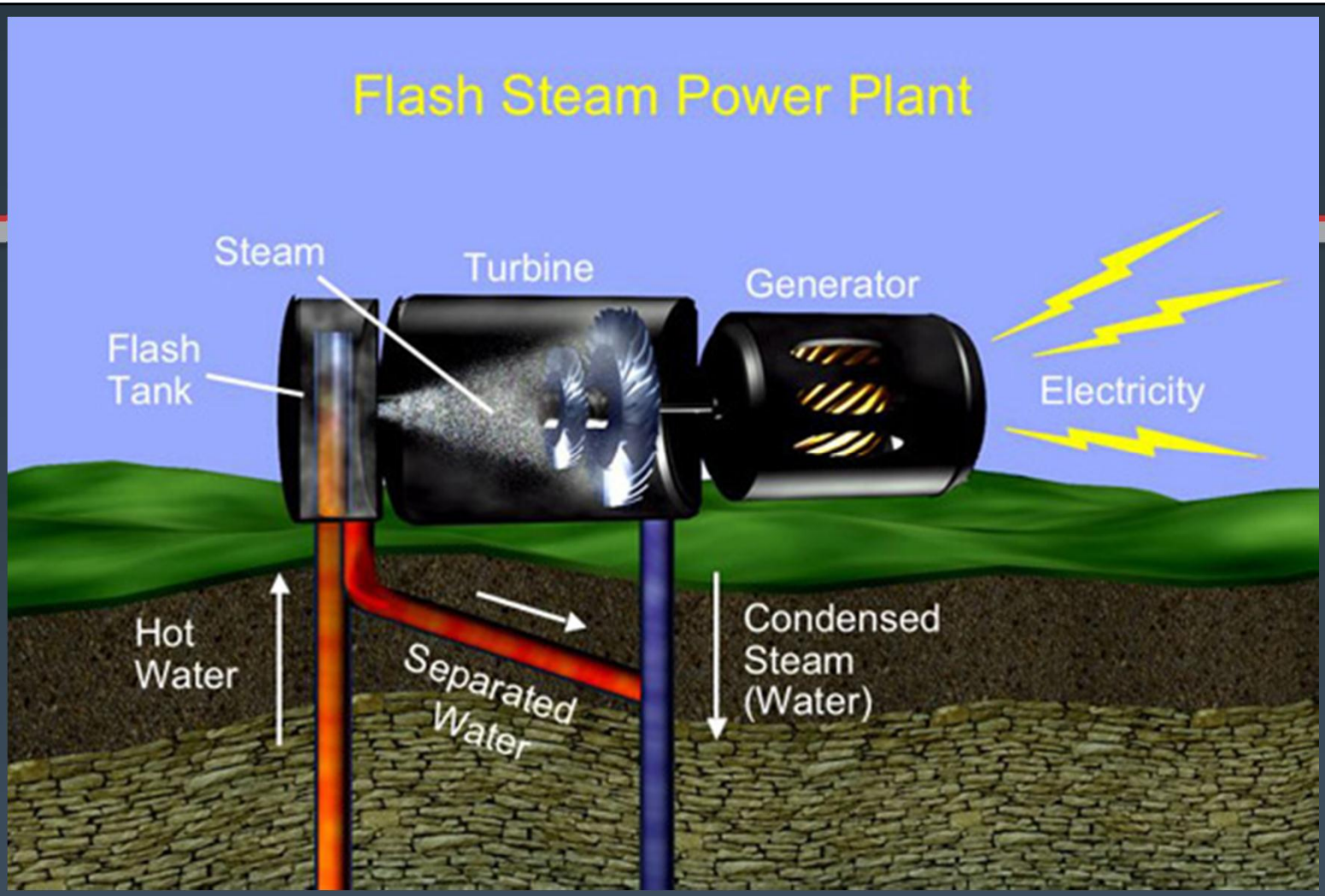
Hydrothermal Geothermal Resources



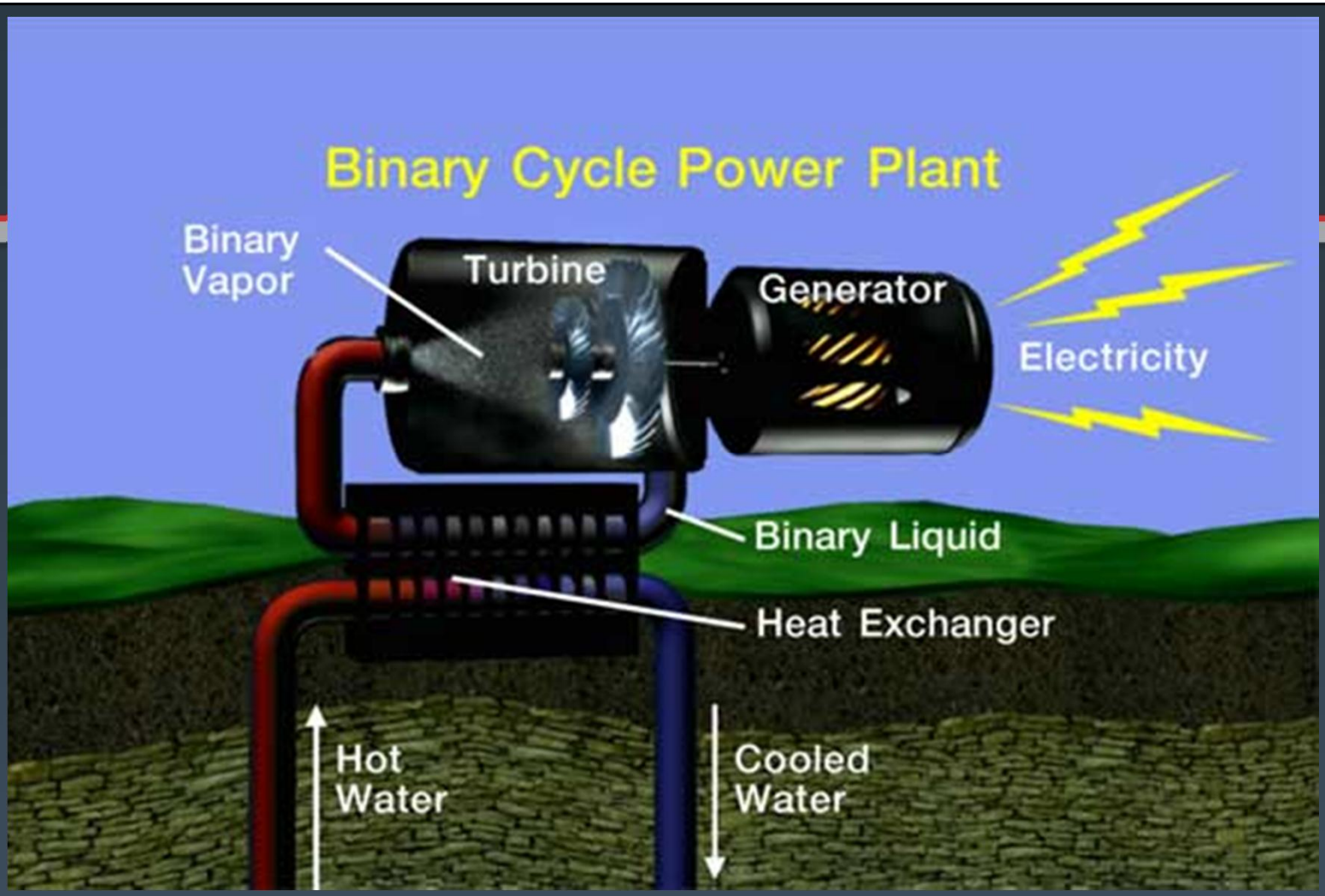
Drilling cost is the major challenge…



Natural steam from the production wells power the turbine generator. The steam is condensed by evaporation in the cooling tower and pumped down an injection well to sustain production.



Flash steam power plants use hot water reservoirs. In flash plants, as hot water is released from the pressure of the deep reservoir in a flash tank, some if it flashes to steam.



In a binary cycle power plant (binary means two), the heat from geothermal water is used to vaporize a "working fluid" in separate adjacent pipes. The vapor, like steam, powers the turbine generator.

US DOE Geothermal Technology Program

- EERE: Energy Efficiency and Renewable Energy

- Identify new geothermal opportunities
- Accelerate a commercial pathway to EGS
- Overcome development barriers
- Additive value
- Subsurface engineering crosscut

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Key Goals, Objectives, and Priorities

Identify New Geothermal Opportunities

- Lowered risk and cost
- New prospecting workflow/*"Play Fairway"*

Accelerate a Commercial Pathway to EGS

- Frontier Observatory for Research in Geothermal Energy (FORGE)
- Reservoir characterization/creation technologies

Overcome Deployment Barriers

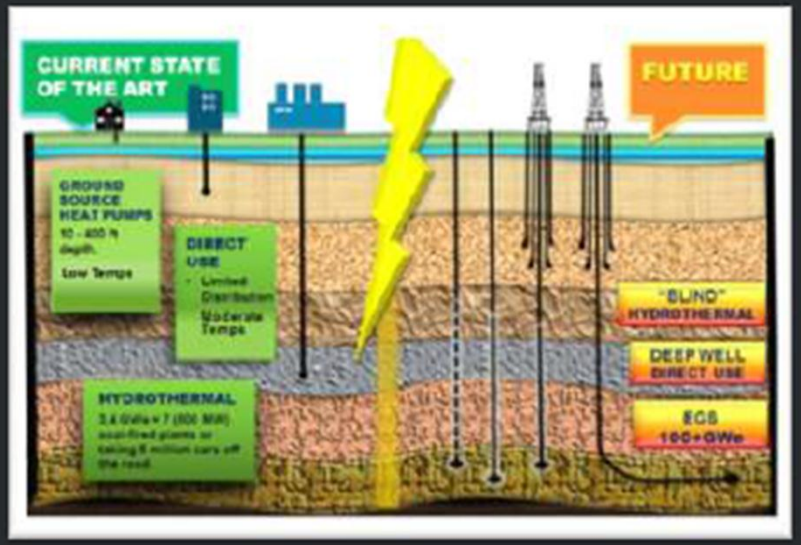
- Regulatory Roadmap: Streamlining
- National Geothermal Data System: Reducing upfront exploration cost

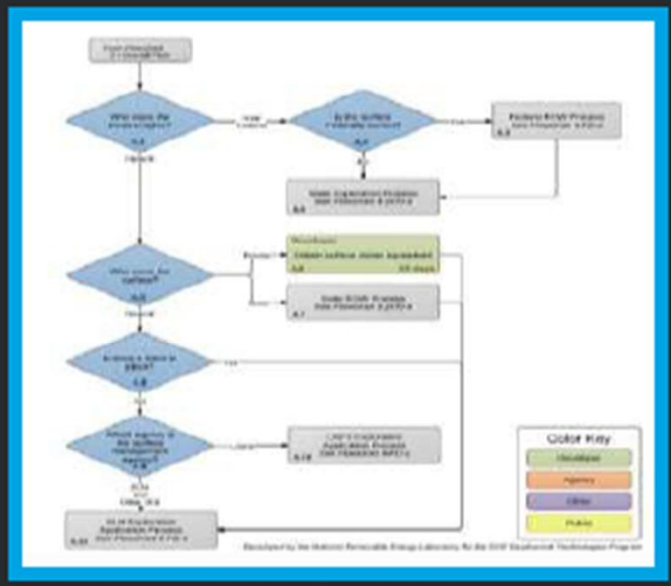
Additive Value

- Co-production and Distributed Power
- Strategic Materials

Subsurface Engineering Crosscut

- Intra- and inter-agency efforts to address common subsurface challenges and better leverage DOE funding





NGDS

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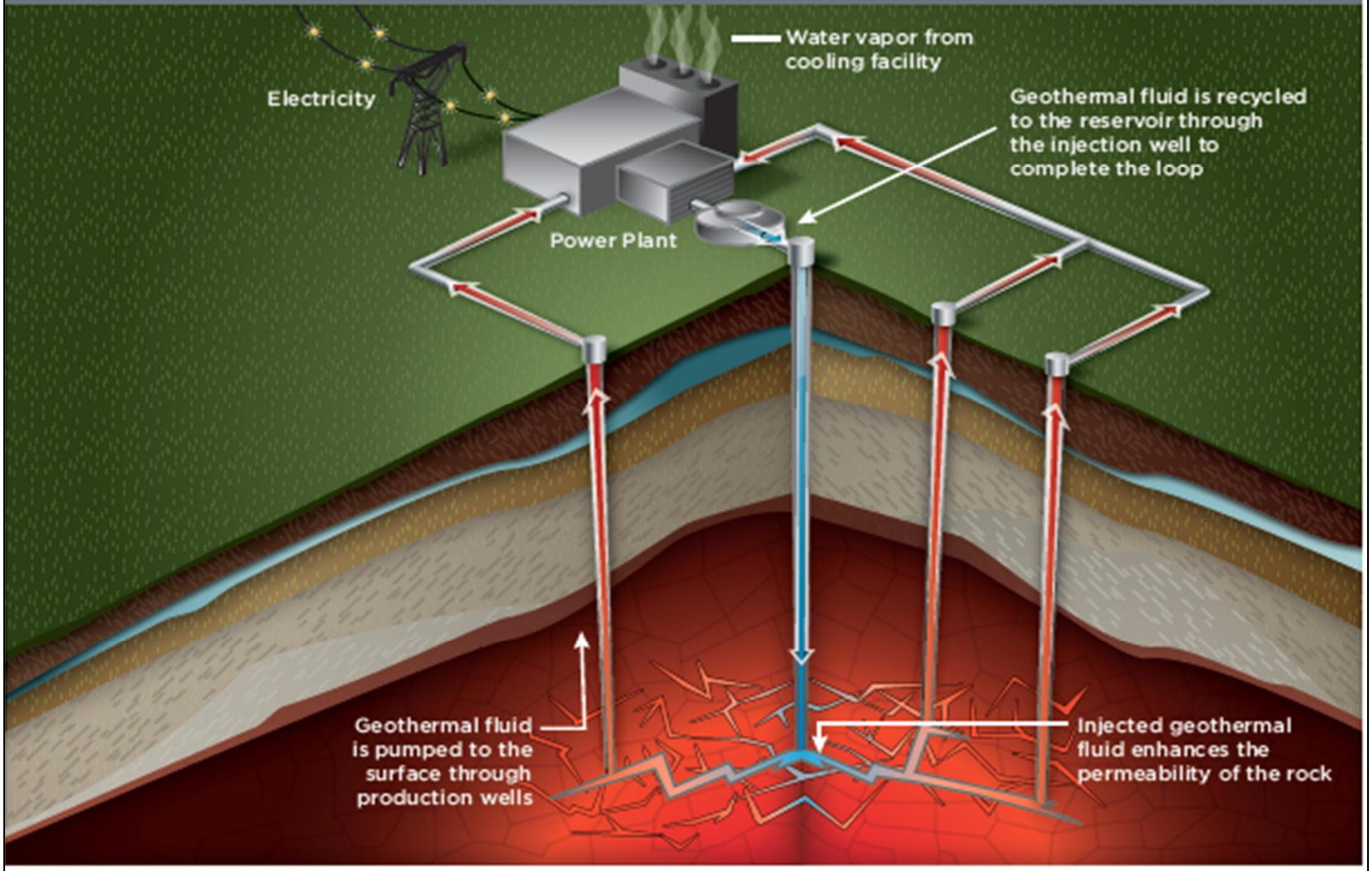
Enhanced Geothermal Systems

An Enhanced (or Engineered) Geothermal System (EGS) is a man-made reservoir, created where there is hot rock but insufficient or little natural permeability or fluid saturation.

A 2006 MIT study shows that in the US alone, 100GWe of cost-competitive capacity could be provided by EGS in the next 50 years.

As the illustration indicates, fluid injection enables hot rock to become a geothermal resource.



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Benefits of EGS

1. EGS has the potential to be an important contributor to the US energy portfolio as a source of clean, renewable energy.

2. EGS emits little to no greenhouse gases. Most geothermal power plants use a closed-loop binary cycle power plant and have no greenhouse gas emissions other than water vapor that may be used for cooling.

3. EGS could facilitate geothermal development outside of traditional hydrothermal areas in the western US, thereby extending geothermal energy production nationwide.

4. EGS can supply base load energy with limited to no intermittency, eliminating the need for energy storage technologies.

Induced Seismicity --- Public Concern

During EGS reservoir creation and stimulation, rocks may slip along pre-existing fractures and produce microseismic events. Researchers have found these microseismic events, also known as Induced seismicity, to be a very useful diagnostic tool for accurately pinpointing where fractures are re-opened or created, and characterizing the extent of a reservoir. In almost all cases, these events occur in deep reservoirs and are of such low magnitude that they are not felt at the surface.

DOE Induced Seismicity Protocol

Geothermal Technology Challenges: *Solvable or "Chasms"?*

Characterizing and Predicting

Efficiently and accurately locate target geophysical and geochemical responses, finding more viable and low-risk resource, and quantitatively infer their evolution under future engineered conditions

Accessing

Safe and cost-effective drilling, with reservoir integrity

Engineering

Create/construct desired subsurface conditions in challenging high-pressure/high-temperature environments

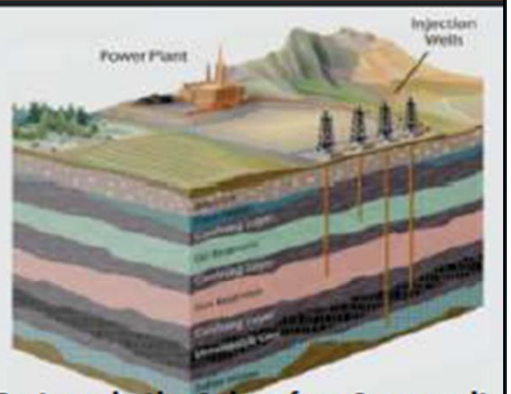
Sustaining

Maintain optimal subsurface conditions over multi-decadal or longer time frames through complex TMHC system evolution

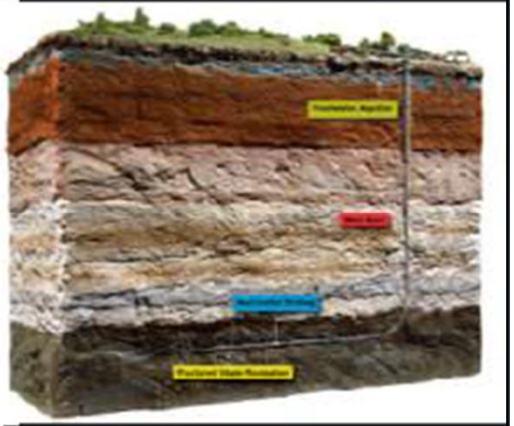
Monitoring

Improve observational methods and advance understanding of multi-scale complexities through system lifetimes

Strong thematic cross-cuts into other subsurface communities – oil and gas, CO2 sequestration, nuclear waste, storage etc.



Partners in the Subsurface Community



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Innovative Geothermal R&D with Translational Impacts

1. **Subsurface Characterization** – invented microseismic modeling for reservoir mapping, capitalized on by further investment through DOE's Unconventional Gas Research Programs. Now used by all subsurface communities.
2. **Drilling** –Developed polycrystalline diamond compact (PDC) drill bits, which are used in 60% of oil and gas well footage and are estimated to reduce oil and gas offshore costs by $56/foot drilled.
3. Electric Submersible Pumps (ESP) – Successful development of a high temperature/pressure ESP, through ARRA funding, led General Electric to create a new Artificial Lift business and acquire smaller lift companies to maintain market share .
4. Power Plant – Improved binary conversion cycles; for mid-level temperatures (150-190 C) resulting in a 15% increase in productivity over flash plants
5. **Reservoir Technology** – Developed geothermal reservoir models that are estimated to allow increased geothermal well productivity by 10% and oil and gas well productivity by up to 20% and (based on The Geysers)
6. **In-/Near-Field EGS** – Demonstrated and tested EGS technologies in a near and in-field environment that resulted in additional power of 2-5MW at $0.04/kWh.
7. **Data access** – the NGDS is reducing upfront exploration and development risk by making geothermal data public and interoperable. Earth magazine has referred to this effort as "digitizing the earth," offering leverage to other subsurface sectors.

INNOVATION ⇒ **FURTHER R&D** ⇒ **COMMERCIALIZATION**

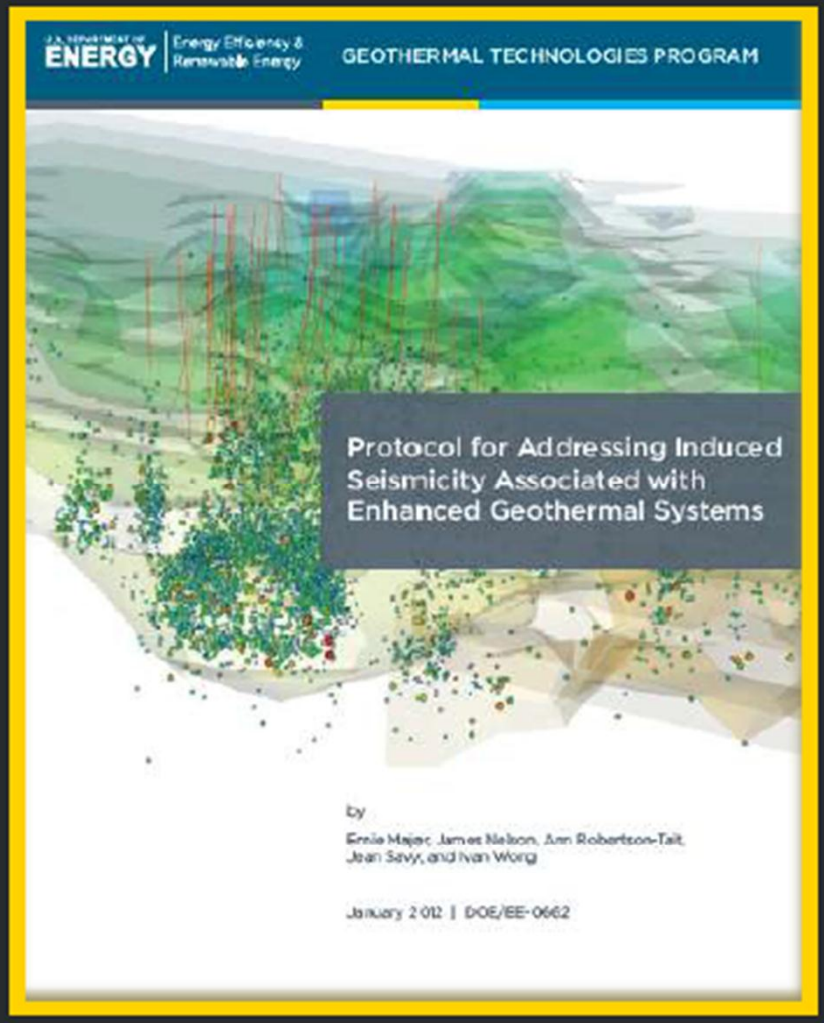
e.g., microseismic modeling | *DOE Fossil Energy refines seismic mapping techniques* | *Oil and gas community adopts technology as essential fracking tool*

"DOE's long-term support was critical in the development of commercial tools for microseismic monitoring of fracturing procedures."
NETL, 2007, DOE's Unconventional Gas Research Programs , An Archive of Important Results

Induced Seismicity Protocol and Best Practices

General guide for geothermal developers to address induced seismicity issues

- DOE commissioned a group of experts to develop an Induced Seismicity Protocol
- This effort engaged the United States and international scientific and industry communities to assess the impacts of induced seismic events.
- DOE released the Protocol in 2012 and adopted its safety guidelines for all DOE-funded EGS demonstration projects.
- The Protocol was well received by the National Research Council (NRC) and recommended as a "best practice" document for use by all other subsurface technologies.



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Cascading Use of Geothermal Resources