Enhanced Geothermal Systems (EGS)

Emerging Technologies

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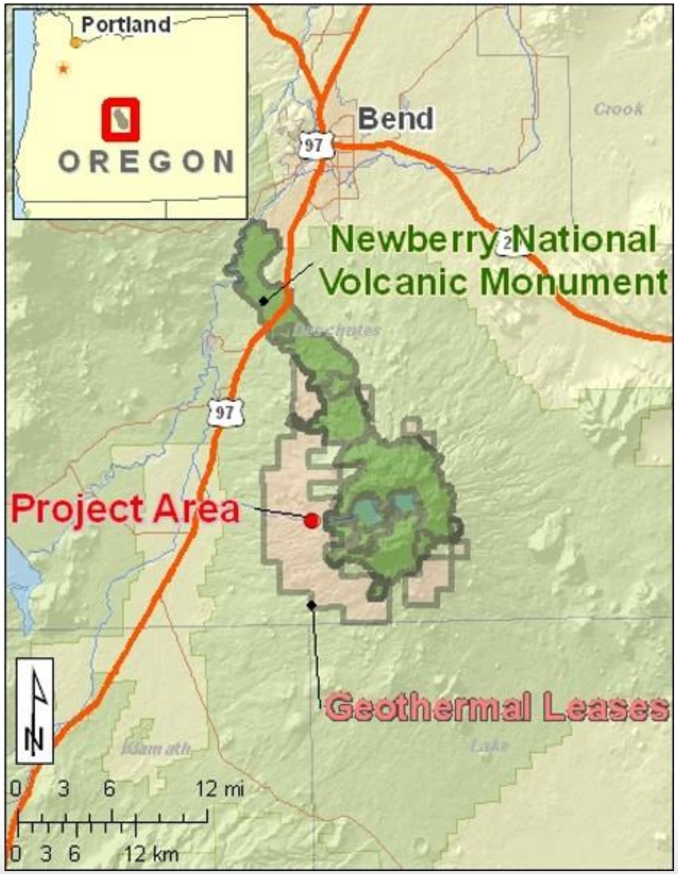


Oregon's Newberry EGS Site

Today's Discussion on EGS

1. What is EGS?
2. Why is EGS important as an emerging technology?
3. How is EGS handled in the Power Plan?
4. Technology Basics
5. Cost
6. History
7. Newberry Field Project
8. Environmental Issues
9. EGS Future
10. Terminology and a few Resources

1) What is EGS

EGS involves "harvesting energy from earth's crust by passing fluid through a zone of enhanced permeability in rock at depth"*

Conventional Geothermal "depends on naturally occurring waters bringing heat from earth's interior to the surface"*

* JASON/MITRE Corp Dec. 2013 study

1) What is EGS

EGS can refer to two types of projects

#1 Stimulation and expansion of an existing hydrothermal field

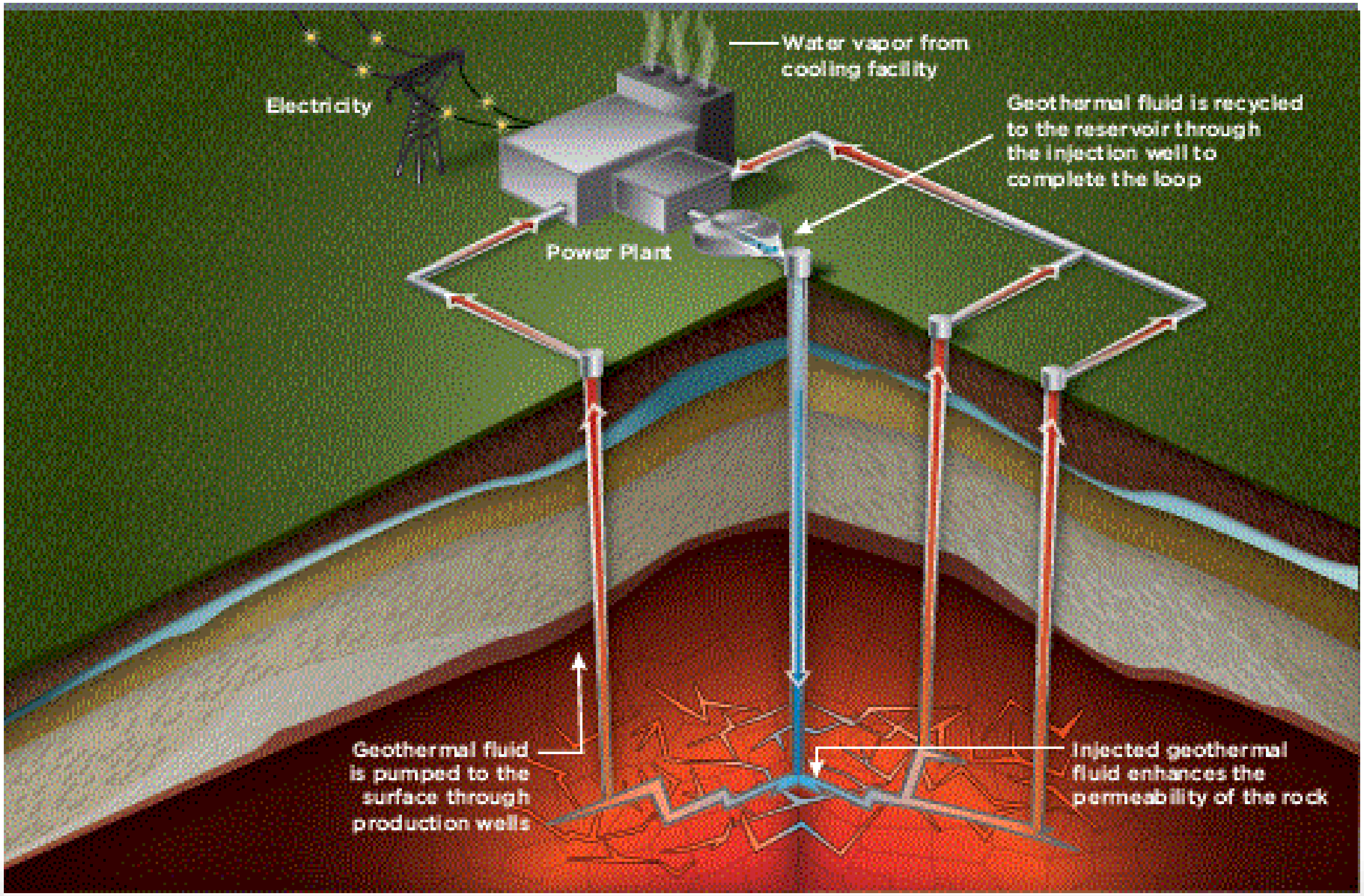
#2 Mining earth's heat to depths of 1km to 5km – hot dry rock (HDR)

We are focusing on #2

1) What is EGS

1. Conditions for conventional geothermal are limited (mostly volcanic regions with abundant groundwater)
2. However, hot dry rock is widely available – as long as you can drill deeply enough and create sufficient permeability
3. “Enhancements” include
   a) Drilling to depth and high temperatures through hard rock
   b) Stimulating or fracturing rock to get fluid flow and heat transfer

1) What is EGS



Water vapor from cooling facility
Electricity
Geothermal fluid is recycled to the reservoir through the injection well to complete the loop
Power Plant
Geothermal fluid is pumped to the surface through production wells
Injected geothermal fluid enhances the permeability of the rock

2) Why is EGS important?

1. Electricity generation from EGS
   a) Can produce baseload renewable power
   b) Small environmental footprint, emits little to no greenhouse gas
2. 90% of the overall geothermal potential in the US resides in EGS (100 GW overall)
3. According to an MIT study – "with a reasonable investment in R&D and a proactive level of development, EGS could supply 10% of the US baseload electricity by 2050"
4. The Northwest could play a big role – 2 high grade EGS resources are within the region

2) Why is EGS important?

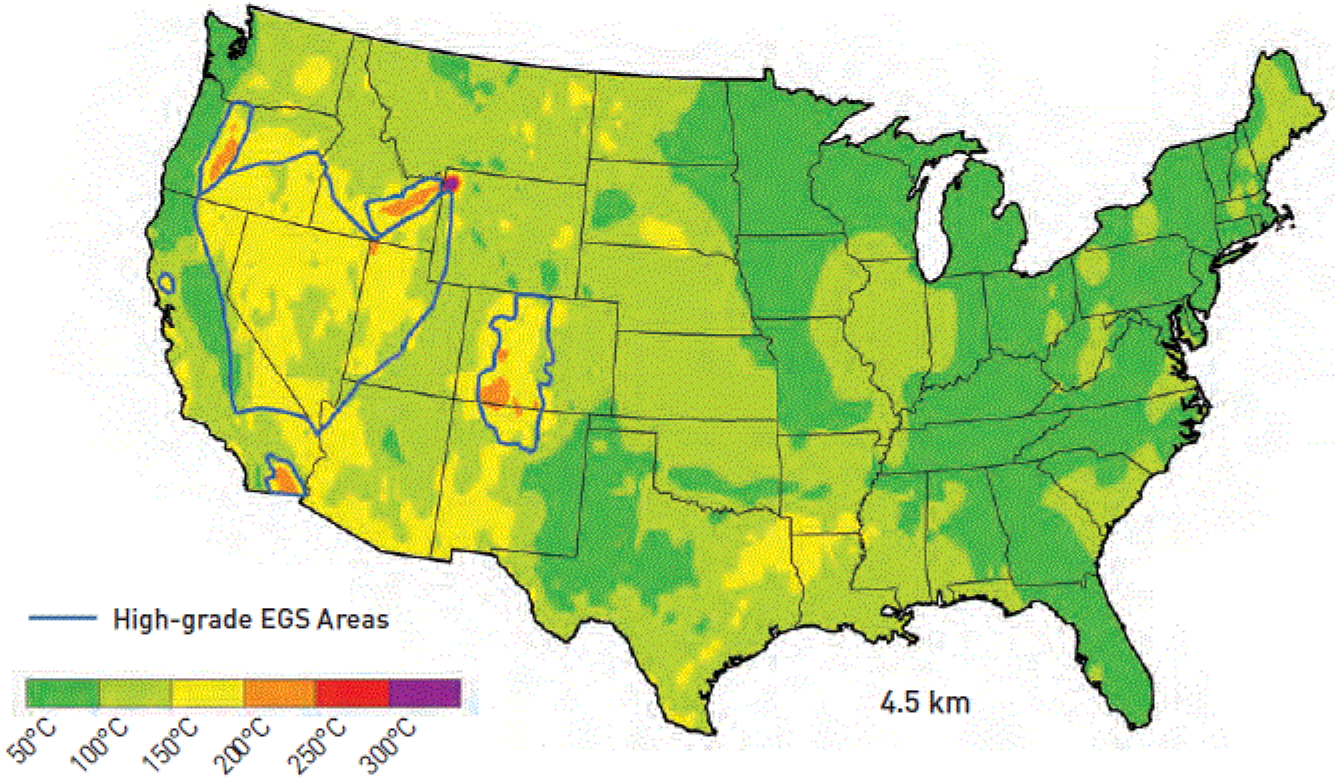


Figure 2.7b Average temperature at 4.5 km. Includes areas of special EGS interest outlined in blue and identified in Table 2.2.

From MIT report

2) Why is EGS Important?

1. Snake River Plain
   a) 75km x 500 km region
   b) 75% of the region is at temps >200 deg C
   c) Somewhat unknown geological features as 3km to 10 km depths – existing fractures may be limited
2. Oregon Cascades Range
   a) 50km x 200 km region
   b) 25% of region is at uniform, high temps
   c) Uniform geology – mostly volcanic

3) EGS and the Power Plan

1. 6th Power Plan
   a) Not considered as commercially proven
   b) Not included in modeling, no cost or operational estimates were developed
   c) The potential in the NW was recognized
2. 7th Draft Power Plan
   a) Not considered commercially proven
   b) Still significant risk and uncertainty around the technology
   c) Will continue to monitor progress – in particular the demonstration project at Newberry Volcano in Oregon

4) EGS Technology Basics

Steps to developing a project

1. Identify a site and characterize
2. Create a reservoir – drill injection well into HDR, inject water at high pressure, fracture – creating flow rate at temp and volume with sustainability. EGS resources are at 150 to 300 deg C
3. Drill projection wells to close the loop
4. Generate electricity – using a steam turbine or binary plant power system

4) EGS Technology Basics

- Hydraulic fracturing produces tiny crack-like networks which combines with existing fractures and faults in the rock to create a network
- Difficulty creating the optimal flow – if cracks are too large, fluid flows through without reaching high enough temps, too small requires a higher pressure drop between wells

4) EGS Technology Basics

How does EGS stimulation compare to hydro-fracking methods so effectively used in the Oil and Natural gas industry?

1. EGS involves deep vertical drilling only, no horizontal drilling
2. EGS fractures at lower pressures than for Natural Gas
3. EGS uses water, not a chemical/water slurry – no wastewater is produced

4) EGS Technology Basics

Major technological challenges:

1. Ability to identify well sites with adequate subsurface features to allow the creation of flow networks with proper heat and flow volume
2. Ability to design, drill and operate wells at depth
3. Ability to design and execute stimulation that optimizes water exposure to hot rock
4. Water scarcity
5. Induced seismicity

4) EGS Technology Basics

6. Extracting energy from flowing cold water through hot rock – temperature of the rock gradually approaches the temp of the water – a fracture zone may last only 5 to 6 years – and drilling is expensive

5) EGS Costs

- Rough cost estimates now – 245 $/MWh LCOE
  - 20 MW plant
  - 175 deg C at 3km depth
- Target cost by 2030 – 59 $/MWh
- Largest cost component is well field development (drilling) and reservoir creation
- Prime cost determinants for EGS success:
  - Recovery factors for thermal energy
  - Lifetime of a producing region – how often do you need to re-drill or re-stimulate

6) EGS History

- First EGS field project was Fenton Hill New Mexico – 1977
- No projects have been validated on a commercial scale
- Well failures, equipment failures, unpredictable fracture patterns, funding shortfalls are just some of the problems encountered
- Each field project has informed the next
- Currently 6 DOE funded projects underway

7) Oregon's Newberry EGS Project

- DOE Geothermal Technologies Program (as part of American Recovery & Re-Investment Act) awarded largest grant - around 21.5 million $ to the Newberry site, additional 40 million $ from private investors
- Considered a critical project for EGS in the Northwest – the NW is estimated to have 5 GW of potential
- Why the Newberry site?
    1. Very hot rock, and relatively easy to stimulate a reservoir
    2. Utilizing several abandoned wells in the area

7) Oregon's Newberry EGS Project

- Alta Rock is working on a novel multi-zone stimulation process utilizing diverters – bio degradable plastic that temporarily fills in fractured slips – so new fracture zones can be created using the same deep well bore
- Alta Rock expects to drill down as far as 3km, close for winter, and in spring 2015 drill production wells
- Goal is around 5 to 10 MW

8) EGS Environmental Issues

1. Water consumption and water quality – need to drill below water table
2. Micro-seismicity – stimulation of fractures causes small earthquakes

9) EGS Future

- R&D is continuing in 3 main categories
  1. Reservoir characterization
  2. Reservoir creation
  3. Operation
- Reservoirs are expected to have lifetimes of only 6 years, after which re-drilling or re-stimulation would be required – which is expensive

9) EGS Future

- The right mixture of technique and technology came together for the shale gas industry (horizontal wells and slurry injection) – this balance has eluded EGS thus far – but it could come together rapidly
- EGS may benefit from advances in both geophysical imaging and drilling technologies from the Oil and Gas industry – which would be fitting since the PDC (poly crystalline diamond compact) drill bits used by the Oil and Gas Industry was originally developed 30 years ago by geothermal drillers

10) Terminology & Resources

1. EGS: Enhanced Geothermal System
2. HDR: hot dry rock- typically at a depth of 1km to 5 km
3. Permeability: a measure of the ability of a material's pores or openings to allow liquids or gases to flow through them under a pressure gradient

10) Terminology & Resources

1. *The Future of Geothermal Energy*, MIT, 2006
2. *A Technology Roadmap for Strategic Development of Enhanced Geothermal Systems, Geothermal Technologies Office*, Feb 2013
3. *Enhanced Geothermal Systems*, JASON/The Mitre Corp, Dec 2013