Baseload Renewable Power with No CO2

The Energy Under Our Feet

The Resource is Enormous

- Enormous resource stored as heat in rock
- Natural heat flow recharges stored heat
- Areas with high heat flow
  - ¾ Across the US
  - ¾ Around the world
- We can generate power and use the heat with today's technology
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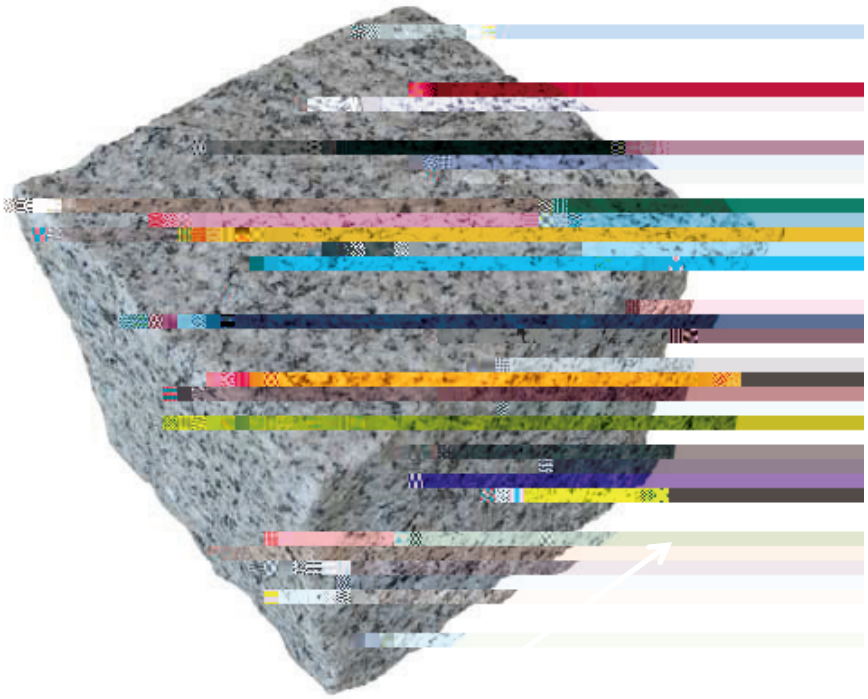
Heat Stored in Rock



50,000 MW Aging Coal Fired Power Plants

- Plants more than 50 years old
- Currently can't be relicensed because they don't meet emissions standards for mercury, CO2, NOX, SOX, particulates.
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Coal Plants Ready for Retirement

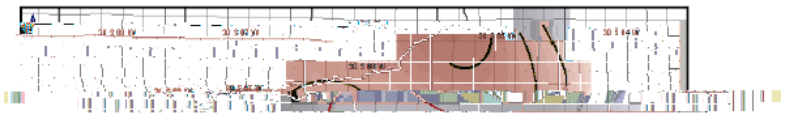
- Clean power plan has accelerated the timing for coal retirement in the U.S.
- COP21 commitments will extend this worldwide
- Air quality issues are impacting coal plant new development even in China.
- Replacement with EGS allows

Old Coal Plants: Waste Water

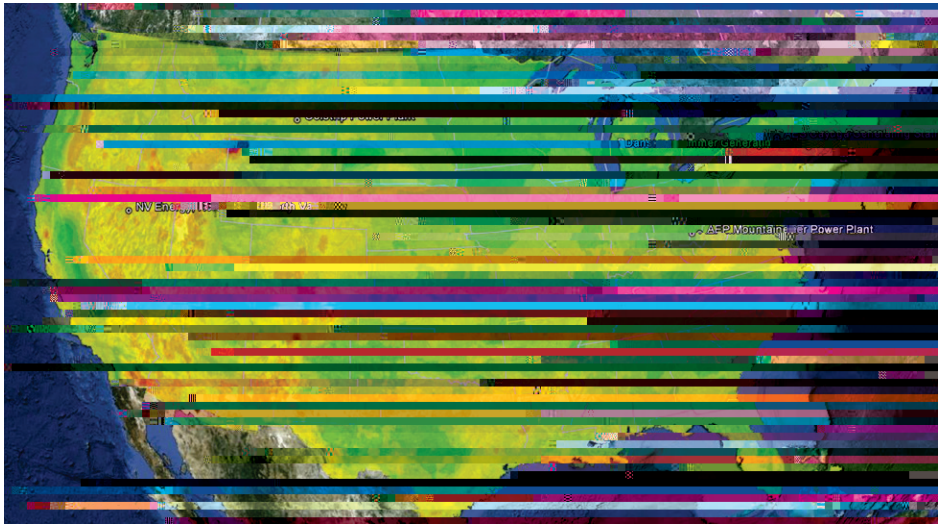
- Waste coal, liquid coal waste, coal ash and scrubber sludge can't be discharged without treatment
- Holding untreated wastewater in ponds at plants
  - Overflow to rivers and lakes in Maryland, West Virginia, Alabama
  - Groundwater contamination in North Carolina, Maryland, Tennessee
- Disposal to treatment plants not set up to handle these contaminants
- Fines for disposal into inland waters
- Public concern over environmental risk

Combining Waste Water Injection and EGS Power Generation

- Phased development of geothermal resource uses up waste water while coal plant continues to operate
- Put surplus water to work generating electric power
  - Use water to develop EGS reservoir
  - Lose water to the reservoir during power project operation
  - Lose water to evaporation for wet cooling
- Reduce cost of managing waste water
- Use generated power to gradually replace coal fired generation
- Take advantage of higher than normal temperature gradients
  - Option 1: Drill into sedimentary basin to develop EGS reservoir in basal sandstone
  - Option 2: Drill deeper to get higher temperatures in crystalline basement



Case Studies



Western States Coal Plants

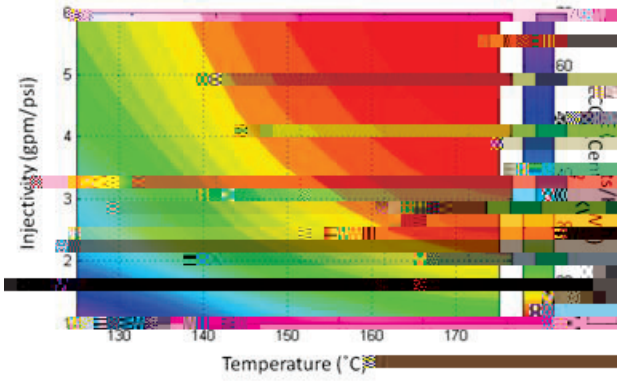
Example: NV Energy North Valmy Generating station.

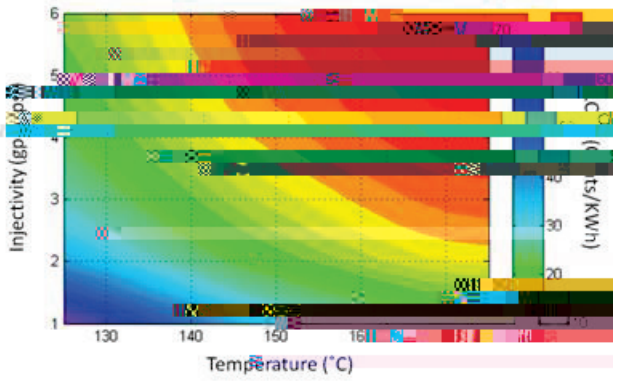
Valmy plant slated to close between 2019-2025
High geothermal gradient with ample data.
Potential for conventional geothermal project as first phase
Holding residual waste water in holding/evaporation ponds.

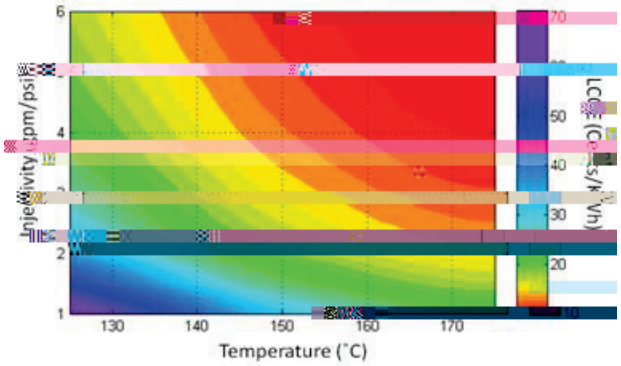
Eastern States Coal Plants

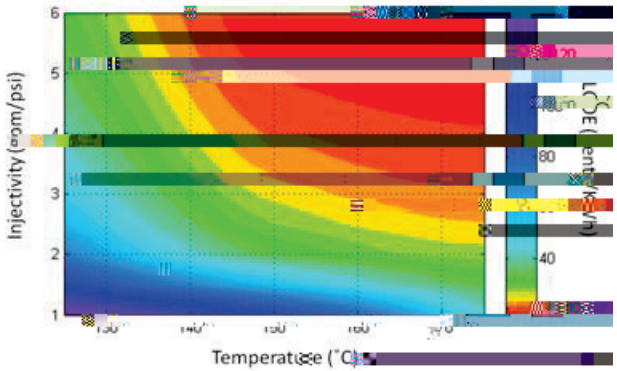
Example: Cayuga Power Plant near Lansing, New York.

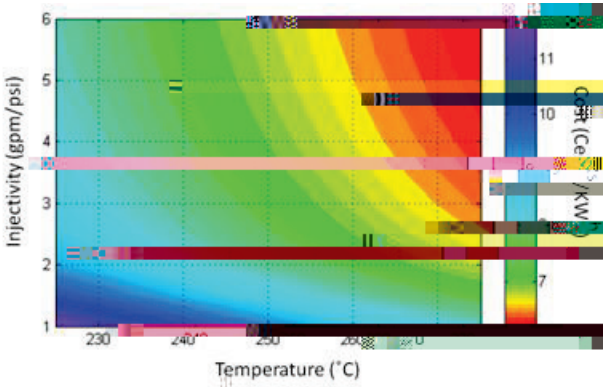
- Plant is located in one of the best areas for geothermal energy in the east.
- Slated to close in Feb., 2015 but governor stopped closure to preserve jobs/property taxes
- Gas repower would need expensive pipeline the public doesn't want





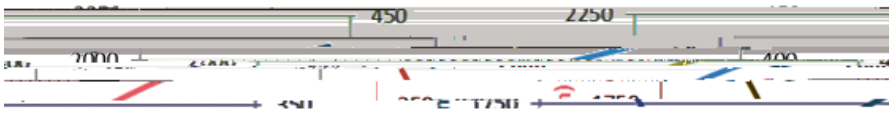






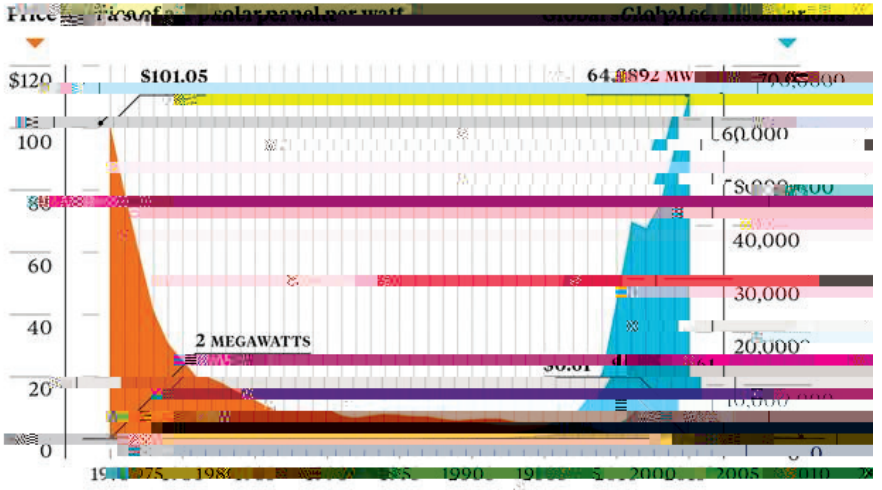
Increased inje

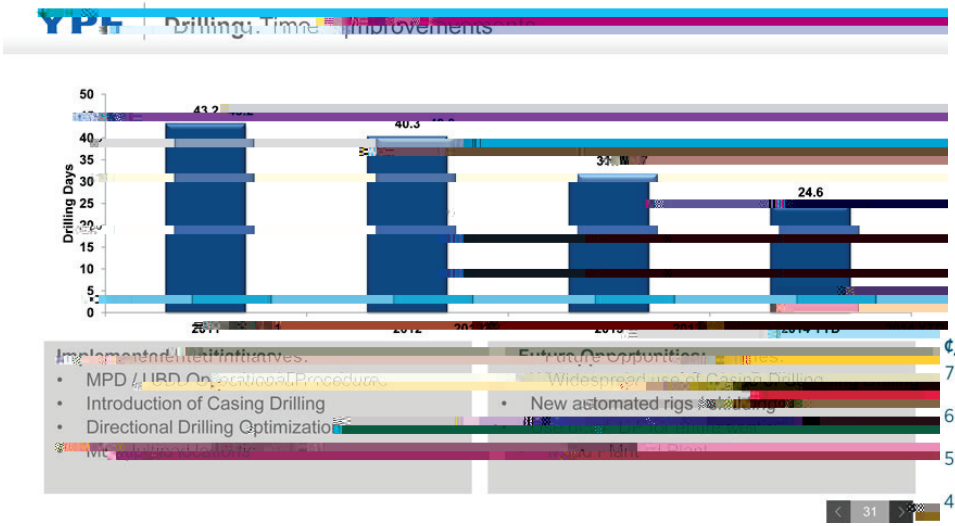
Sensitivity of LCOE to Cost Factors: 2013 EPRI Study



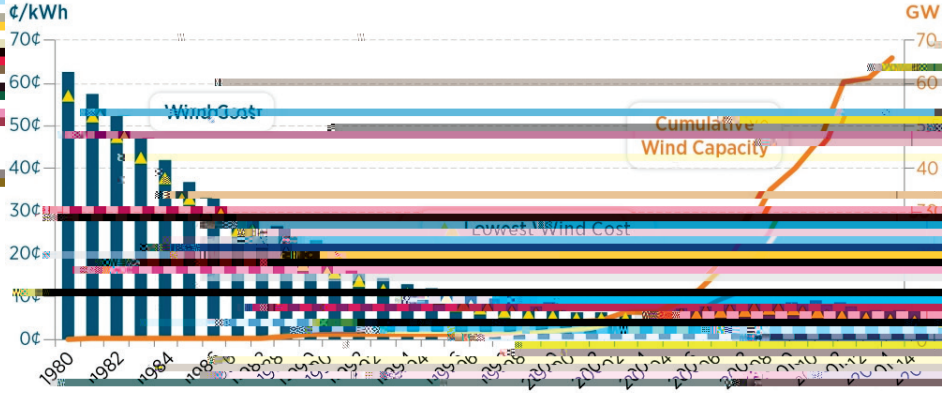
Learning By Doing Reduces Costs

- Dramatic drop in solar costs with number of installations





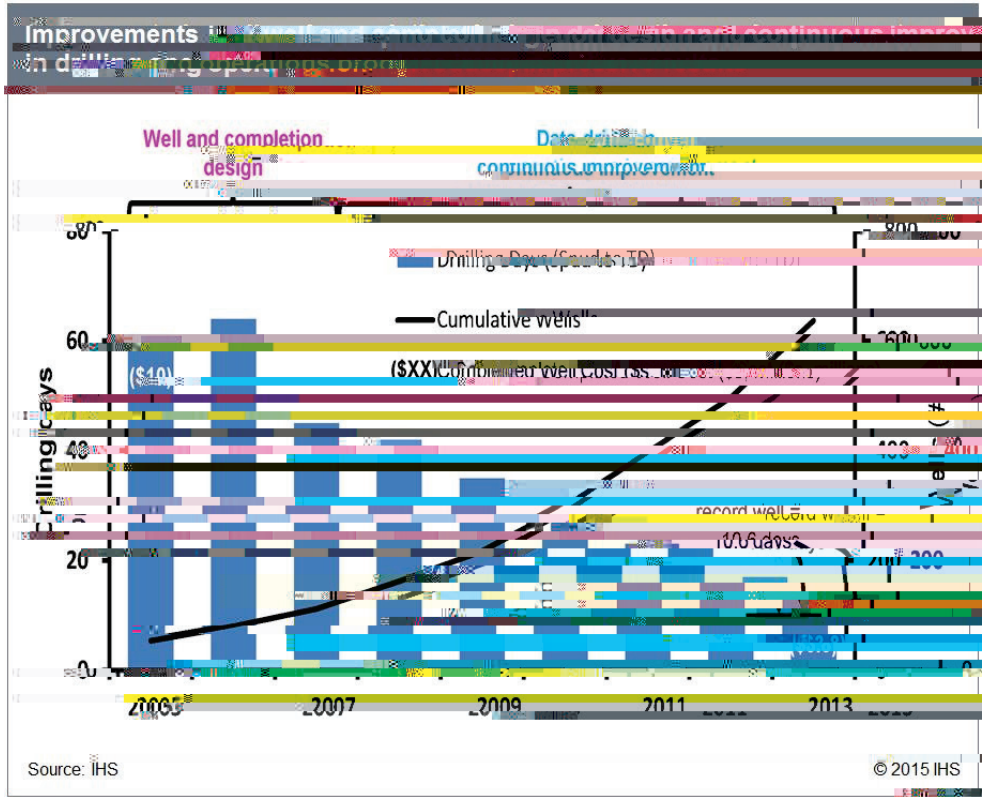
- Drilling time improvements in oil and gas with number of wells



- Wind energy costs drop as installations increase

Learning By Doing Reduces Costs For Oil And Gas Drilling: *Can Geothermal Drilling Costs Do The Same?*

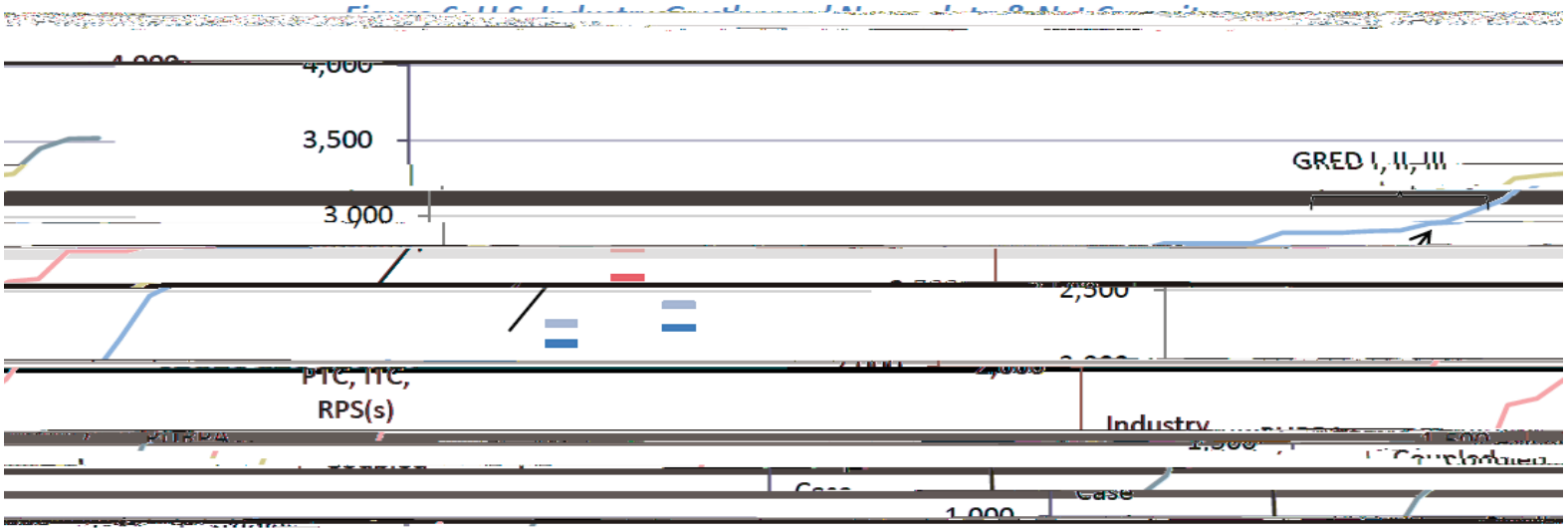
- Oil and gas drilling costs drop as large numbers of wells are installed in the same geologic setting
- Decrease in drilling time for geothermal wells at Awibengkok from 55 days to 20 days 2006-2008 93 new wells



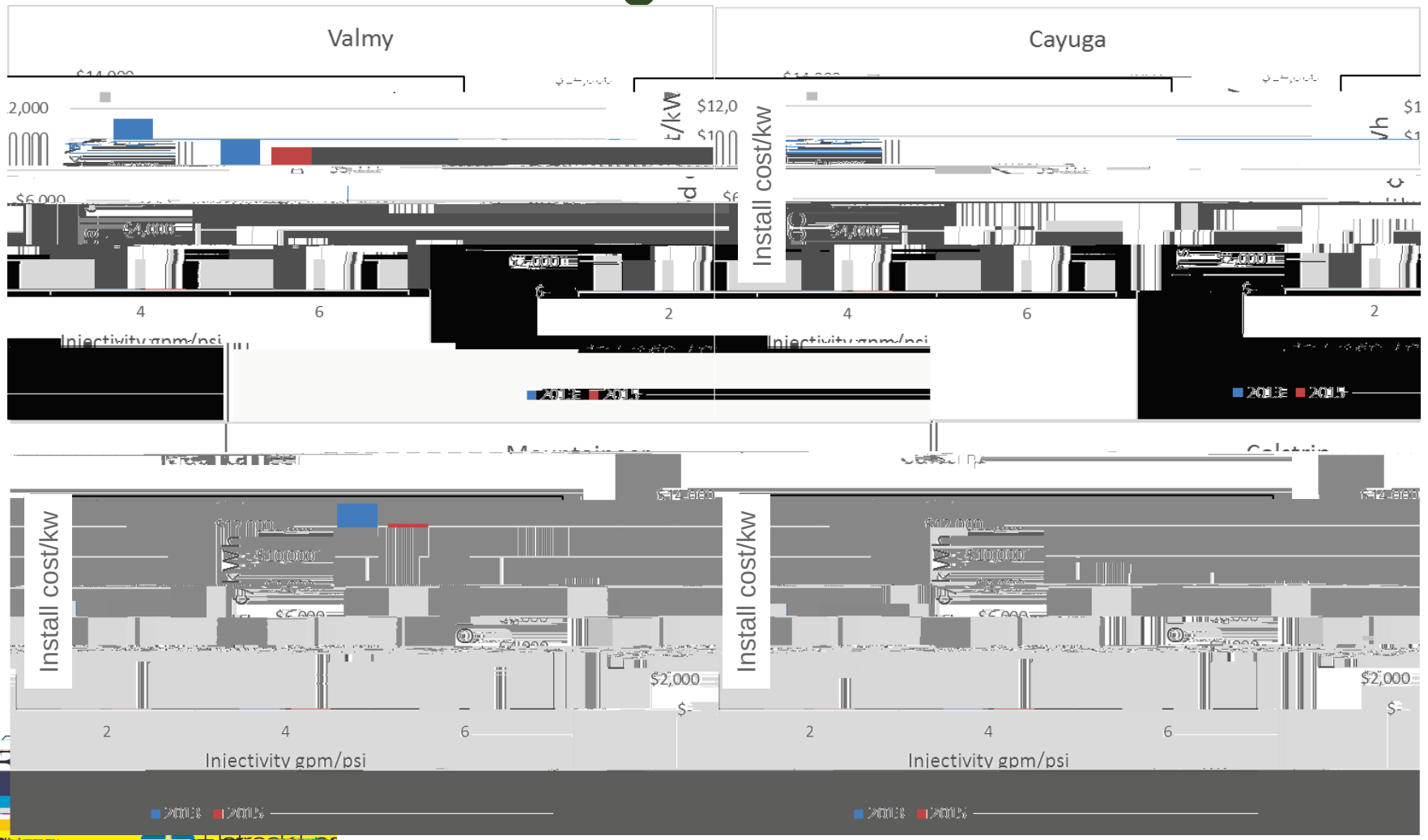
Utility scale EGS requires 100s of wells drilled and stimulated in the same geology: Costs will come down!!

Geothermal Capacity Growth In the US

- Large fields discovered early
- Number of new wells currently low
- Tax incentives intermittent



Updated Capital Cost with Current Drilling Costs



Reservoir stimulation/make-up water

- Water use is one of the most important environmental issues for EGS
- Need about 215-370 acre-feet (70-120 million gallons) of water for initial hydroshearing stimulation per 5-18 MW
- Lose 1-10% of water to rock during operation of field. Pressure controls magnitude of losses
- Can be managed to lose more or less water

Cooling water make-up

Example 1:

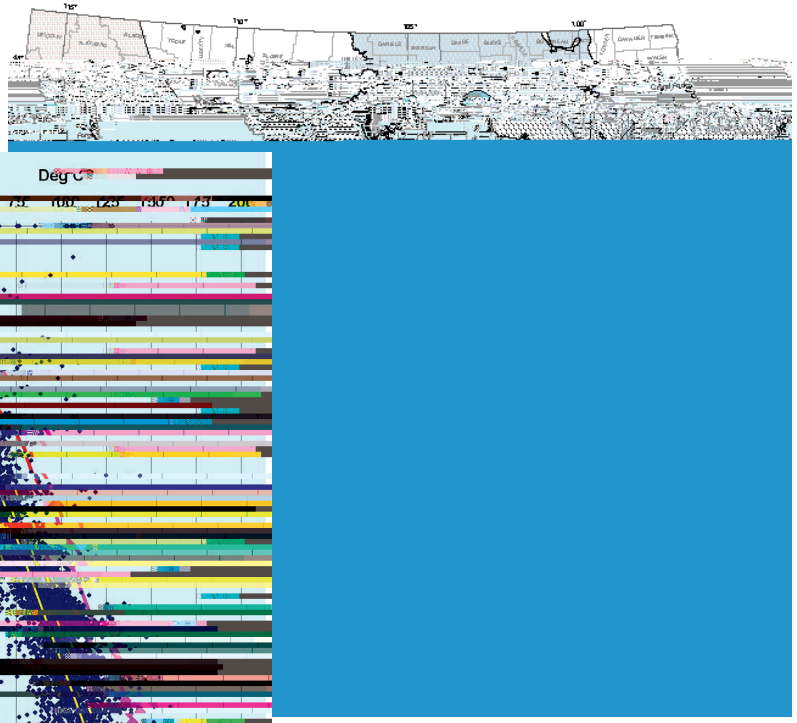
Central New York

- Wells drilled for oil and gas exploration in the Finger Lakes region of New York show an elevated temperature gradient of 32-38°C/km.
- Areas with high heat flow observed.
- Ample well data available with depth ranging from 1,125 m to 4400 m.

Example 2:

Central Montana: High Temperature Gradients

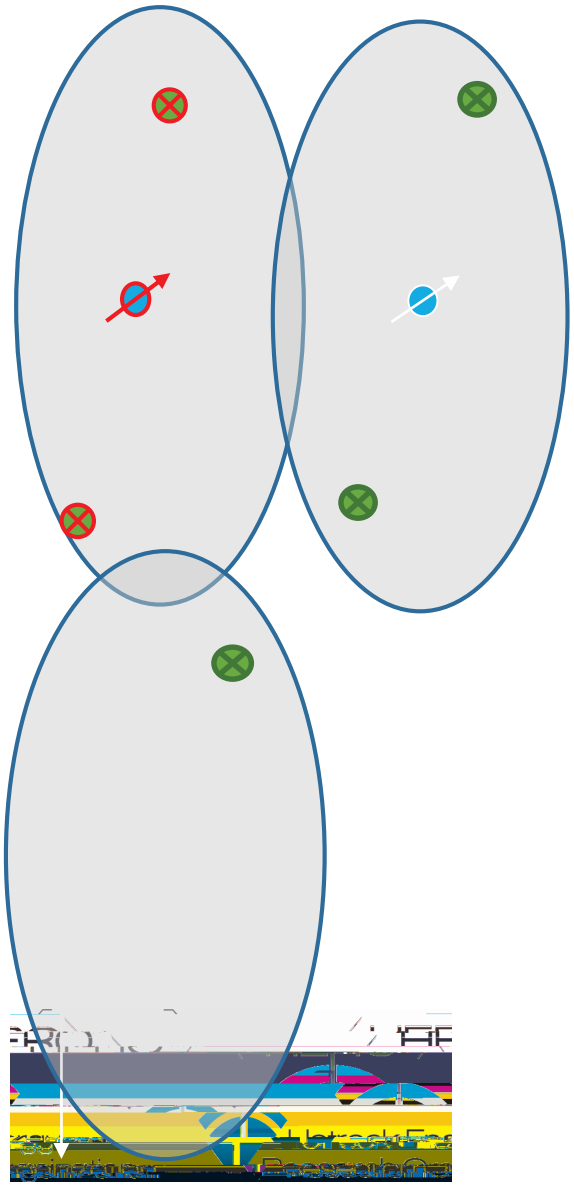
- Deep sedimentary basins with ample data from oil wells
- Williston Basin oil wells have demonstrated elevated temperatures with depth
- Best sites for deep hot water
- Coal fired power plants across the area
- Temperature gradients above 45ºC/km
- Deep disposal well drilled for Colstrip plant found good temperatures for EGS geothermal



How Would EGS Work at a Typical Site?

- Create EGS reservoirs with cool waste water using multizone stimulation to fill reservoir with stored waste water
- Once EGS reservoir is operating, water loss to rock managed to dispose of all waste water from coal plant
- Reduce coal fired generation as geothermal project expands
- Two options:
  - 2-5 km (8000-16,000 ft) deep wells in Sedimentary Basin
    - Temperature known – 302ºF (150ºC)
    - Binary power plant with wet cooling
    - Water losses to rock higher due to natural permeability in sediments
    - 3-5 MW per well so for 1000 MW plant 200-300 wells
  - 3-7.5 km (10,000-25,000 ft) deep wells in crystalline basement rocks
    - Temperature (>225ºC, 440ºF) projected from shallower wells
    - Better conversion efficiency means more power per well even with lower flow rates
    - Flash plant with evaporative cooling or hybrid flash/binary plant with air cooling
    - Water losses: evaporation in cooling tower and loss to reservoir rock
    - 5-10 MW per well for 1000 MW plant

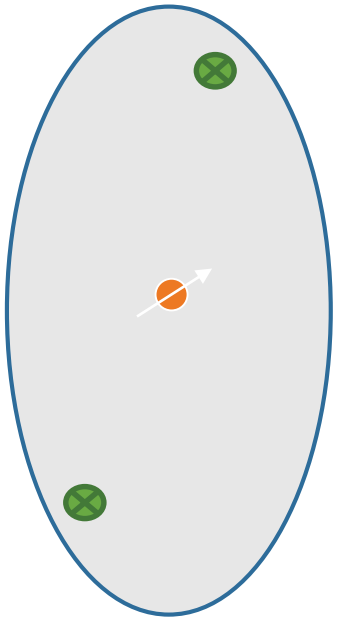
EGS Project: Moderate Temperature



Year	New Wells	Annual Water Loss from Operations (Mgal)	Annual Water Loss from Stimulation (Mgal)
1	13	344	518
2	12	661	478
3	10	926	398
4	8	1,138	319
5	8	1,349	319
6	6	1,508	239
7	6	1,667	239

15,000 ft wells
320ºF resource temperature
Average 3.5-5 MW per producer using TZIM stimulation
740 acres can yield 50 MW with little surface disturbance

EGS project – High Temperature



11,150-16,000 ft wells in basement
480º

Development Potential for Geothermal

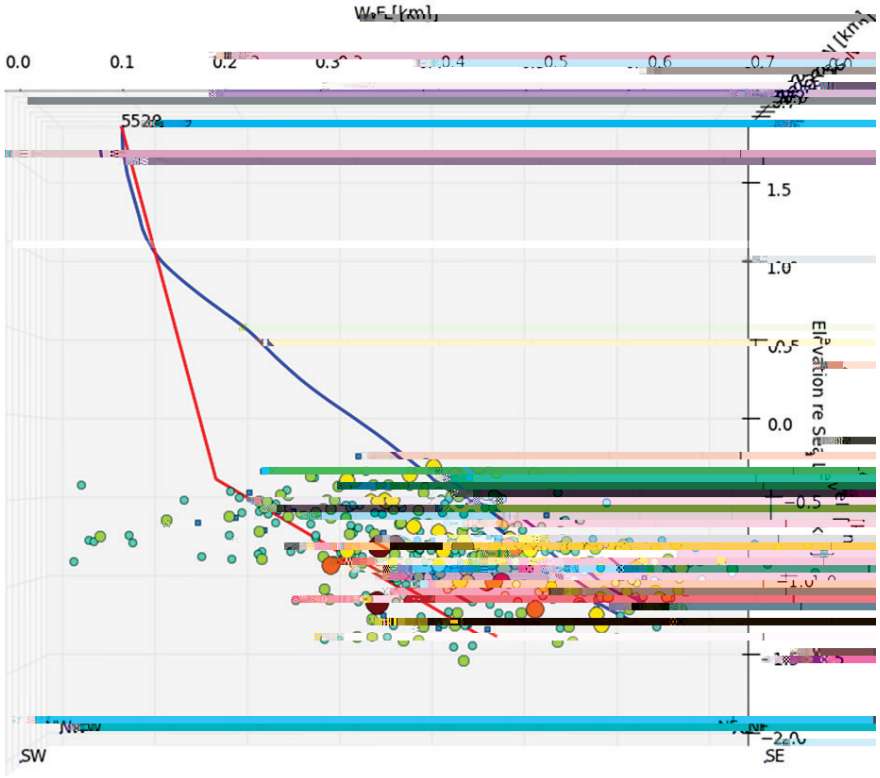
- Geothermal now makes up a small fraction of total energy consumption
- Opening up the EGS resource to development can move geothermal from small to large scale

Figure 6: U.S. Industry Geothermal Nameplate & Net Capacity

What Research is Needed to Move the Technology Forward

- Better stimulation methods to increase ouput of each well
- Improved understanding of resource characteristics
- Improved drilling technology to reduce drilling costs
- Better reservoir management for long term use

AltaRock has proven stimulation technology for multizone stimulation in high temperature wells

How Will We DO It?

- Feasibility studies
- Pilot projects at coal plants
  - Variety of geologic settings
  - Different geothermal gradients
  - Different water management needs
- Scale to reduce cost/risk
- Now is the time to start:
  - Drilling is on sale
  - 30% or more reduction in drilling costs