Transitioning Fossil Fuels To Geothermal

Adding Value Through Hybridization

The Energy Under Our Feet
What if...

...we had a power source that had zero emissions, was cheap to operate and was available everywhere, anytime?

We do.  Geothermal Energy.  The energy beneath our feet.
The Geothermal Resource is Enormous

- Enormous resource stored as heat in rock
- Natural heat flow recharges stored heat
- Areas with high heat flow
  - Across the US
  - Around the world
- We can generate power and use the heat with today’s technology
- We can make it cheaper with tomorrow’s
- USGS: 500,000 MW of recoverable heat resource in the Western US
**Benefits of Geothermal at Colstrip**

- Units 1&2 Planned for retirement
- Colstrip has been cited as the largest single source of particulate, NOX and SO2 emissions in Montana
- Issues have arisen in the past with waste water management at the Colstrip project.

A geothermal project at Colstrip could both manage waste water and reduce emissions at Colstrip saving jobs and supporting the local economy.
Current Status of EGS Technology

- We can:
  - Drill wells to temperatures suitable for power generation
  - Fracture large volumes of rock > 2.5 km³
  - Map the fractures we make
  - Drill into the fractured volume
  - Circulate cold water into the injector and retrieve it hot from producers
  - Generate power at economic rates in some areas
  - Several projects operating in Europe
What Do We Know About the Geothermal Resources in Montana?

**Temperature**

- Wells drilled at or near Colstrip show an elevated temperature gradient of about 38°C/km.
- Temperature in Madison Limestone at Colstrip is 97°C
- Several other wells in Billings area in similar geology have similar temperatures
- Poplar oilfield to the northeast has 90°-130°C temperatures in the Madison Limestone
- Wells at Rocky Mt. Oilfield Test Center in Wyoming in similar geology have similar gradient and 90°-110°C temperatures
- We don’t know if the gradient continues to the basement rocks.

**Geology**

- Paleozoic sedimentary rocks to around 3 km
- Madison Limestone at a depth of 2.7 km produces oil and gas in many areas in eastern Montana
- Madison is known as a large scale source of low temperature geothermal water with low to moderate permeability
- No Quaternary faulting in the area.

Western Energy Well, Powder River Basin

**Location:**  N 45.8863
W 106.6194

**Nearest town:** 2 miles N of Colstrip

**County:** ROSEBUD

**Depth:** 9336 ft

**Temperature:** 205°F

**Flow:** 4.91 gpm

**TDS:** 1395 (mg/L)

**Site ID:** MGEOT092
<table>
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<tr>
<th>Well Name (# on map)</th>
<th>Total Depth</th>
<th>Interval Sampled</th>
<th>TDS</th>
<th>Ca</th>
<th>Mg</th>
<th>Na</th>
<th>K</th>
<th>Cl</th>
<th>SO4</th>
<th>Water-yielding Unit</th>
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<td>1395</td>
<td>213</td>
<td>25</td>
<td>131</td>
<td>65.8</td>
<td>79</td>
<td>737</td>
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<td>530</td>
<td>71</td>
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<td>Busby et al. (1991)</td>
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<td>49</td>
<td>21</td>
<td>960</td>
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<td>Moore (22)</td>
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<td>130</td>
<td>2400</td>
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<td>Busby et al. (1991)</td>
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<td>61</td>
<td>1400</td>
<td>110</td>
<td>1900</td>
<td>1300</td>
<td>Mission Canyon LS</td>
<td>Busby et al. (1991)</td>
</tr>
</tbody>
</table>

*NR = value not reported
Updated LCOE with Current Drilling Costs

- **Valmy**
  - LCOE ($/kWh$)
  - Injectivity gpm/psi: 2, 4, 6
  - 2013 vs. 2015

- **Cayuga**
  - LCOE ($/kWh$)
  - Injectivity gpm/psi: 2, 4, 6
  - 2013 vs. 2015

- **Colstrip**
  - LCOE ($/kWh$)
  - Injectivity gpm/psi: 2, 4, 6
  - 2013 vs. 2015

- **Mountaineer**
  - LCOE ($/kWh$)
  - Injectivity gpm/psi: 2, 4, 6
  - 2013 vs. 2015
Options for Transitioning Coal to Geothermal

• Build out geothermal starting with a pilot project at the site of coal plant
• Use geothermal heat during development to preheat boiler feed, dry biomass, dry coal
• Develop other renewables such as wind, PV, solar thermal and biomass at the site
• Flexible generation with thermal energy storage
Geothermal Combined with Solar

- ENEL operates a combined geothermal/solar plant at Stillwater in Nevada
  - Project uses PV to offset parasitic pumping power
  - Concentrating solar used to heat a low temperature well
- Solar heat in off-peak daylight hours could be stored in the geothermal reservoir to be recovered at peak.
Greenleaf Honey Lake Plant: Biomass/Geothermal Hybrid

- HLP burns between 150,000 and 200,000 tons of woody biomass
  - Forest derived fuel
  - Urban wood waste
  - Sawmill byproducts
- Biomass dried to improve energy density
- Uses geothermal water to preheat its boiler feed water, reducing the plants consumption of biomass
Combining Geothermal and Storage:

**Thermal Storage: Molten Salt**
- CSP at low demand when solar availability inject hot water into closed area of geothermal reservoir

**Thermal Storage with CSP**
- CSP at low demand when solar availability inject hot water into closed area of geothermal reservoir
- Discharge by pumping hot water back out and adding flow to binary system
- CSP can also be used to boost temperature into binary plant
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.

Utility scale EGS requires 100s of wells drilled and stimulated in the same geology: Costs will come down!!
How Do We DO It?

• Feasibility study for Colstrip
• Pilot project
  – Verify Geology and geothermal gradient
  – Determine water management needs
  – Site specific economics
• Build out to scale to reduce cost/risk
• Now is the time to start:
  – Drilling is on sale
  – 30% or more reduction in drilling costs