Advanced Technology Geothermal Energy Solution

Opportunity for Baseload Renewable Power Generation and Water Management at Colstrip, Montana

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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.

EGS: The Best Energy Solution:

Changing Times. The Changing Climate.

- The geothermal resource is enormous
- The geothermal resource is everywhere. *We know it's at Colstrip because a deep well was drilled for waste disposal.*
- The earth's heat is available 24/7
- Geothermal has no CO2 emissions, or any other emissions for that matter, with binary plants
- EGS has the cheapest LCOE of any renewable
- No fuel cost volatility because…..No fuel cost.
- Our environmental future and our financial future are tied to investment in the transition from fossil fuels to renewables

Geothermal: The only renewable that can replace coal.

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Geothermal Co-Located with Coal

- Advanced technology geothermal energy (EGS) can be located anywhere.
- LCOE is competitive when geothermal gradients are >50°C/km
- EGS can use waste water to fill reservoir & as make-up for water lost to rock.
- Natural gas is still a fossil fuel, constrained by pipelines & price volatility
- Drilling costs are low now with decreased gas drilling -> driller jobs
- EGS co-located with coal takes advantage of existing infrastructure, means zero emissions with very low cost to operate and keeps jobs

Manage waste water while generating clean,
emission free baseload energy

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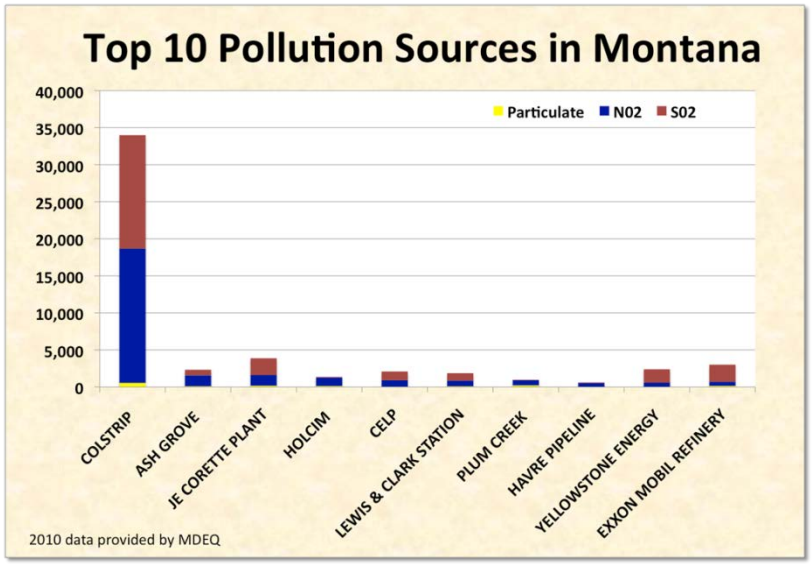
Benefits of Geothermal at Colstrip

- 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.

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		Unit 1	Unit 2	Unit 3	Unit 4	Ownership Total, MW	% of Total Plant
Puget Sound Energy	% MW	50% 153.5	50% 153.5	25% 185	25% 185	677	32.3%
Talen Montana		50% 153.5	50% 153.5	30% 222		529	25.3%
North Western Energy					30% 222	222	10.6%
Portland GE				20% 148	20% 148	296	14.1%
Avista				15% 111	15% 111	222	10.6%
PacifiCorp				10% 74	10% 74	148	7.1%
Total		307	307	740	740	2094	100.0%

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Table 1.1: The 2015 Preferred Resource Strategy

Resource	By the End of Year	ISO Conditions (MW)	Winter Peak (MW)	Energy (aMW)
Natural Gas Peaker	2020	96	102	89
Thermal Upgrades	2021-2025	38	38	35
Combined Cycle CT	2026	286	306	265
Natural Gas Peaker	2027	96	102	89
Thermal Upgrades	2033	3	3	3
Natural Gas Peaker	2034	47	47	43
Total		**565**	**597**	**524**
Efficiency Improvements	**Acquisition Range**		**Winter Peak Reduction (MW)**	**Energy (aMW)**
Energy Efficiency	2016-2035		193	132
Distribution Efficiencies			<1	<1
Total			**193**	**132**

No gas pipeline to Colstrip means that these gas plants couldn't be built at Colstrip. Jobs on these projects would move to locations with gas supply.

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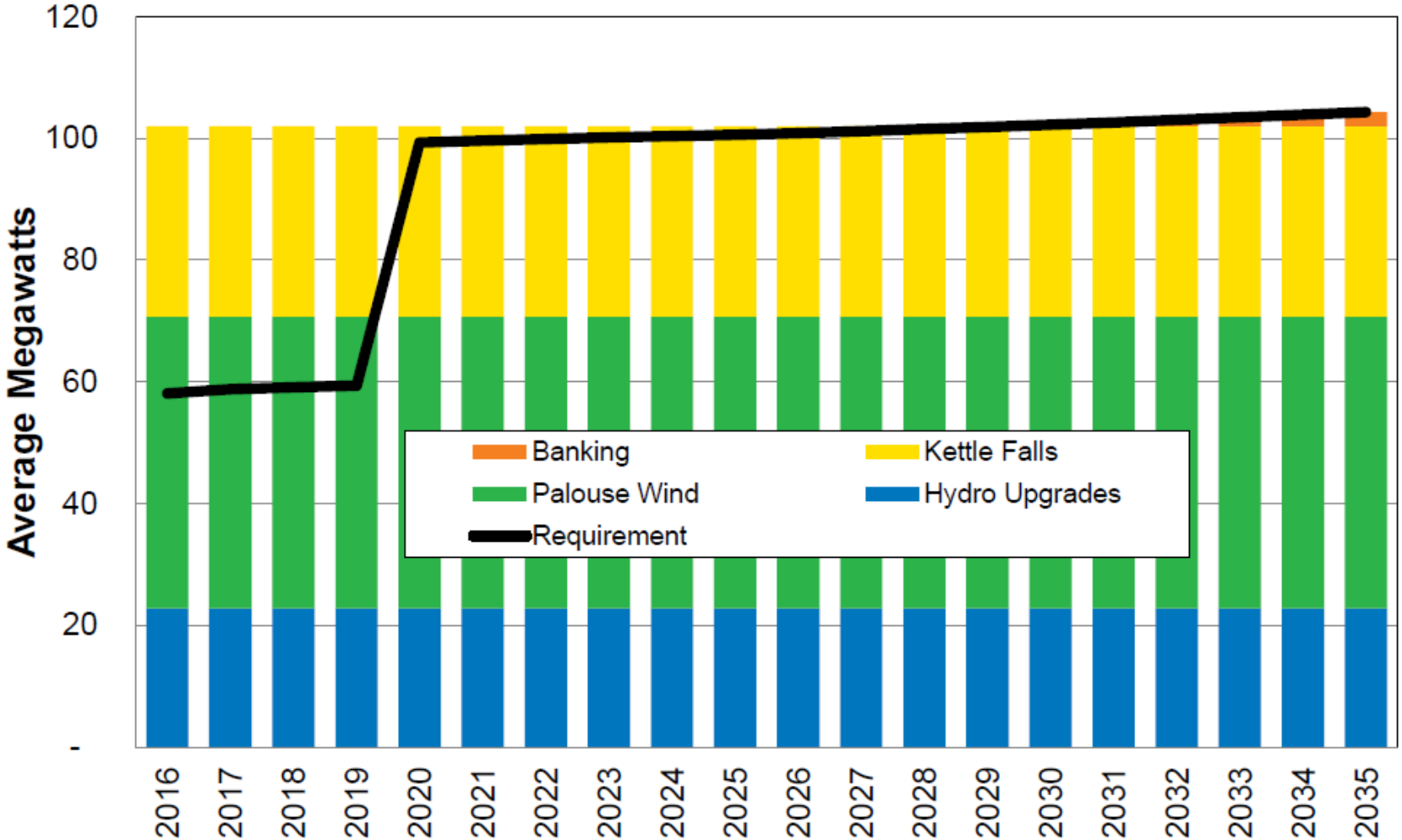
Figure 1.6: Avista's Qualifying Renewables for Washington State's EIA



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EGS Resource Potential at Selected Coal Plant Sites

Site	Coal Plant Capacity (MW)	Available Land Area (Acres)	Net Reservoir Thermal Potential (MW)	Recoverable Heat (MW)	Electricity Potential (MW)
Colstrip Power Plant	2094	56,000	2.69E+11	207,088	41,418
AEP Mountaineer Power Plant	1480	1700	1.02E+10	7,861	1,572
AES Cayuga Generating Station	306	1100	6.60E+09	5,086	1,017
Danskammer Point, Newburgh, NY	Converted to Natural Gas 2014	550	3.30E+09	2,543	509
NV Energy North Valmy Generating Station	522	10000	4.80E+10	36,980	7,396

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Issues for Geothermal Project Siting

Environmental Issues

- Small surface area used, but need geothermal rights to large subsurface area.
- Transmission access needed Not at Colstrip
- Potential visual impact of power plant and transmission line. Not at Colstrip
- Induced seismicity
- Noise
- Air emissions
  - Only an issue for flash plants with water cooling
  - No emissions with binary plants
- Solid waste disposal during drilling/cooling tower clean-out
- Wildlife impact? Not at Colstrip

Water Issues

- Water needed during drilling and stimulation Available from waste water
- Thermal features may be disturbed by hydrothermal projects Not at Colstrip
- Water quality concerns for injection wells Can be managed with well design and regulatory oversight.
- What about EGS?
  - Water needed for fill up of reservoir
  - Water lost to reservoir during operations can be managed to dispose of waste water or conserve water.
- Availability of cooling water
  - Cost of water vs efficiency improvement
  - Water rights needed if evaporative cooling used.
  - Dry cooling works well for binary plants to have no water consumption.

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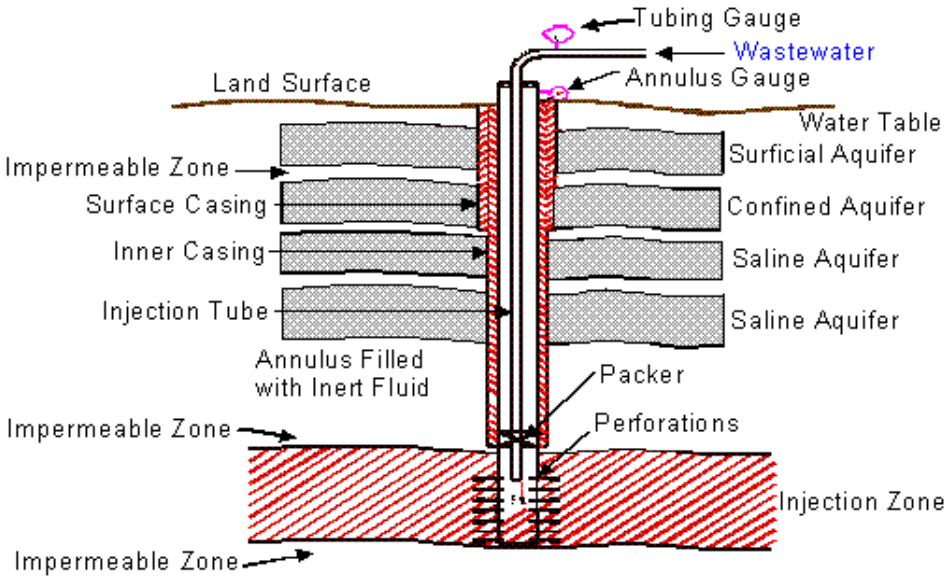
Deep Well Injection

- Deep injection well drilled at Colstrip to Madison Limestone. Not permeable.
- Injection wells to dispose of liquid waste in geologic formations in oil fields since 1930's
- EPA and states regulate through UIC (underground injection control)
- Geothermal injection wells regulated as **non-hazardous fluids**.



- Class V UIC permits - Injection of non-hazardous fluid:
  - 400,000-650,000 permitted wells, mostly shallow, some deep that inject below USDWs
  - Geothermal Electric Power – 234 documented injection wells in US
  - Brine Disposal - US Bureau of Recl. has operated a deep (~15,000') brine disposal well (TDS~250,000 mg/L) in the Paradox Basin of CO since 1986. Permit recently renewed.
- EGS injectors put cooled water into hot rock to recover heat. Then producers take it back out. No pressure build up
- Hot water produced from up to 3 wells per injector to make power

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Water Use

Reservoir stimulation/make-up water

- Water use is one of most important environmental issues for EGS
- Need about 215-370 acre-feet (70-120 million gallons) of water for initial stimulation per 6-18 MW
- Lose 1%-5% of water to rock in some systems.
- Can be designed to operate with no water loss with production and injection pressures.
- Can use waste water
- CO2 as circulating fluid possible for the future

Cooling water make-up

- Steam plants need wet cooling and ~400 gpm circulating water per MW
- Binary plants can use dry cooling with no water use
- Efficiency lost with dry cooling has impact on EGS costs
- Hybrid systems possible
- Innovative cooling systems under development

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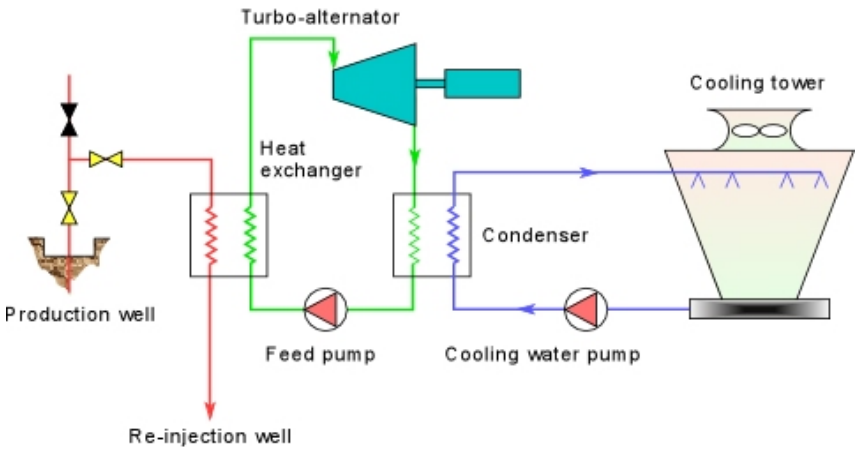
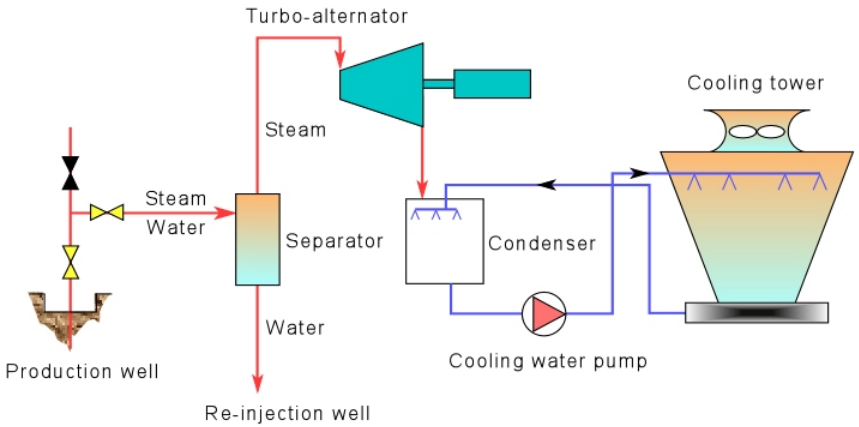
How Do We Generate Power With Geothermal?

Binary Plant



Flash Plant



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Feasibility of Managing Waste Water with EGS Power Generation at Colstrip

- Remaining questions:
  - Will regulators allow water injection from a power plant into Madison Limestone aquifer?
    - Many geothermal injection wells have been permitted in NV, CA, UT, NM & OR
    - Underground Injection Control regulations standardized for permitting of geothermal wells
    - Well completions with regular inspections ensure safety of groundwater
  - Can the value of water management be used to improve the economics of an EGS project?
  - Could corrosion & scale issues be mitigated economically & in environmentally friendly way?
  - Is induced seismicity likely to be an issue at an EGS project in eastern Montana?
  - If extended to other areas, could an eastern Montana project serve as a model for water management with power generation for coal power plants? Coal mines? Other industrial operations with waste water?

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Combining Deep Well Injection and EGS Power Generation

- Put surplus water in ash ponds to work generating electric power
- Creation of the EGS reservoir uses from 70M to 120M gallons of water (215-370 acre-feet)
- Water losses during operation
  - 2-20% in sedimentary rocks
  - 2-5% in crystalline basement rocks
- Treated waste water is used very effectively at the Geysers to recharge the natural steam reservoir
  - ~7000 gpm of treated sewage effluent
  - Injection year-round with seasonal fluctuations at the Geysers
- Water quality for EGS
  - Particulates must be low
  - Geothermal projects often operate with very high TDS natural water
  - Scale and corrosion managed through chemical treatment

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What Do We Know About the Geothermal Resources in Montana?

Temperature

- Wells drilled at or near Colstrip show an elevated temperature gradient of about 38ºC/km.
- Temperature in Madison Limestone at Colstrip is 97ºC
- Several other wells in Billings area in similar geology have similar temperatures
- Poplar oilfield to the northeast has 90º-130ºC temperatures in the Madison Limestone
- Wells at Rocky Mt. Oilfield Test Center in Wyoming in similar geology have similar gradient and 90º-110ºC 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

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How Would EGS Work at a Typical Site?

- Create EGS reservoirs through cold water stimulation using AltaRock TZIM technology 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
    - 5-9 MW per well for 1000 MW plant

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How Would EGS Work?

- Dispose of stored water from ponds during creation of EGS reservoirs
- Ongoing water disposal through water losses to rock
- Manage injection and production pressures to ensure appropriate amount of water loss to manage water produced by coal plants
- Manage risk of induced seismicity through low pressure injection and siting
- Two options:
  - 2.7 km (8500 ft) deep wells in Madison Limestone
    - Temperature known – 207ºF (97ºC)
    - Binary power plant with wet cooling
    - Water losses to rock higher due to natural permeability in limestone
    - 1.2 MW per well
    - ~$5.5M/MW installed for 25 MWg plant
  - 5 km (16,000 ft) deep wells in granitic basement rocks
    - Temperature (185ºC, 365ºF) projected from shallower wells
    - Better conversion efficiency means more power per well even with lower flow rates in granitic rock
    - Binary power plant with wet cooling
    - Water losses to rock low due to lack of natural permeability
    - 6.2 MW per well
    - ~$3.6M/MW installed for 185 MWg plant

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First Step: Feasibility Study

- Data review and analysis. Data gaps
- Project economics for two geologic scenarios
  - Drilling and stimulation costs
  - Pumping costs and power generation potential
  - Energy balance analysis
  - Water balance calculations
  - Total project cost and revenue generation threshholds
- Environmental and Regulatory Compliance
- Risk Analysis

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Feasibility Study
Cost Estimate

Task Description	
1. Phase 1 – Date review and analysis	$ 112,000
1.1. Collect existing geologic, geophysical, temperature, pressure, stress regime and fluid chemistry data from the Madison limestone and any available data from below the Madison into the Precambrian basement rocks.	
1.2. Determine heat flow and calculate temperature gradients and temperature at depth	
1.3. Evaluate stress field data to determine stress magnitude and direction of principal stresses	
1.4. Run proprietary stimulation predictive software, AltaStim, to generate the reservoir fluid volume requirements	
1.5. Evaluate rock/fluid interaction issues and determine if mitigation is needed for scale or corrosion	
1.6. Determine cooling water availability for wet cooling	
2. Phase II – Project economics	$ 84,700
2.1. Madison limestone EGS reservoir	
2.1.1. Estimate cost of drilling production and injection wells to Madison limestone for ~100C water.	
2.1.2. Estimate cost of stimulation in Madison – acid stimulation costs higher than water frac	
2.1.3. Estimate power production possible at a range of flow rates per producer for Madison limestone production.	
2.1.4. Evaluate parasitic pumping requirements for water injection and production from Madison	
2.1.5. Evaluate total project cost and revenue potential	
2.2. Basement rock EGS reservoir	
2.2.1. Estimate cost of drilling production and injection wells to Madison limestone for ~100C water.	
2.2.2. Estimate cost of stimulation in Madison – acid stimulation costs higher than water frac	
2.2.3. Estimate power production possible at a range of flow rates per producer for Madison limestone production.	
2.2.4. Evaluate parasitic pumping requirements for water injection and production from Madison	
2.2.5. Evaluate total project cost and revenue potential	
1. Risk Analysis and Regulatory Compliance	$ 75,020
1.1. Evaluate project risks: Cost risk, technology risk, operational risk	
1.2. Determine regulatory compliance framework and develop compliance plan.	
1.3. Present project to regulators and evaluate risk associated with permitting.	
Travel	$ 3,690
Total Estimated Cost	$ 275,410

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How Can We Work Together?

- HERO is a nonprofit founded to reach out to the public, utilities, communities and regulators to help increase understanding of the potential of geothermal energy
- HERO can do feasibility studies, testing and pilot projects
- HERO can seek funding for all or part of project costs from grants, philanthropy or socially responsible investment
- Pilot project could lead to utility scale project
  - SPV would build out geothermal project to meet utility needs
  - Build/operate/transfer or utility joint venture possible

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