01. Introduction
Energy Production and Consumption

- How we consume and produce energy is not sustainable
- Renewables are becoming more ubiquitous but still a lot unknown and underutilized
- As of 2017 Geothermal Accounted for only .0022% of US consumption

Geothermal Energy

- Cold water injected into well
- Runs over hot rock – heats up
- Exits well as steam
- Spins turbines – runs generator
- Water cooled and pumped back to injection well
- Cycles
- Similar system can be used as a heat pump
  - Residential heating
  - Mid temperature rock acts as consistent reservoir

[Image of Geothermal Power Plant]

Fractures

- Discontinuities in rock
- Vary in size, shape, permeability, etc..
- Change overall properties of a reservoir
- Very difficult to measure in total
- New fractures can open up or existing ones can shift with loading

https://fi.pinterest.com/pin/385480049329088083/?nic_v2=1a5FZS0Eh
02. Research Question:

*How do fractures affect the production of geothermal energy?*
03. Background Research
Numerical Heat Transfer and Fluid Flow

- Textbook by Suhas V. Patankar
- Math and physics behind what the program does
- Discretization
- Heat Conduction
- Convection and Diffusion
- It is important to understand the physics behind the phenomena you are trying to study
The Importance of Numerical Models

- Numerical Model: mathematical models of a system that use numerical time stepping to obtain the behavior
- Low Cost
- Fast
- Complete in Information
- Simulate Realistic and Ideal Conditions
04. Methodology
The Process

- Learn TOUGH2
  - Program to analyze heat and fluid transfer in geologic settings
  - Tricky to learn virtually
- Learn toughio
  - Program for visualizing TOUGH outputs and writing mesh files
  - Also tricky to learn virtually
- Create a base mesh – just rock and basic well
- Create meshes with varying fracture geometry
- Run simulation for each geometry
- Adjust parameters as needed and repeat
- Compare results for different meshes
05. Discoveries
Research is Hard

- Learning new math, physics, and programs mostly independently is a slow and tiring process
- I faced many setbacks because of this
- My host and others who helped were very helpful when I was stuck, but could not always immediately assist due to virtual
- I would often find myself stuck for hours on something
- On-going project – no concrete results currently
Fractures

- More adjustments and iterations required for substantial results
- Appears where fractures exist, fluid flow is slowed
- Longer tail of warm in fractured mesh
  - Faster heat transfer?
- Lower pressures where fracture exist
  - Less likely for more fractures to open up?
06. Conclusion
Conclusion

- This summer was a great learning experience
  - Gave me insight into research as a whole as well as the topics of interest
  - Important skills in working independently and virtually
  - Where I have time, I will continue my work and hopefully produce some more concrete results
References

*Numerical Heat Transfer and Fluid Flow*, Suhas V. Pantakar

*Thermal Drawdown-Induced Flow Channeling in Fractured Geothermal Reservoirs*, Pengcheng Fu, Yue Hao, Stuart DC Walsh, Charles R Carrigan

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