Ultra-high Temperature Underground Thermal Energy Storage (UHT-UTES) for Large-scale, Inter-seasonal Electricity Storage

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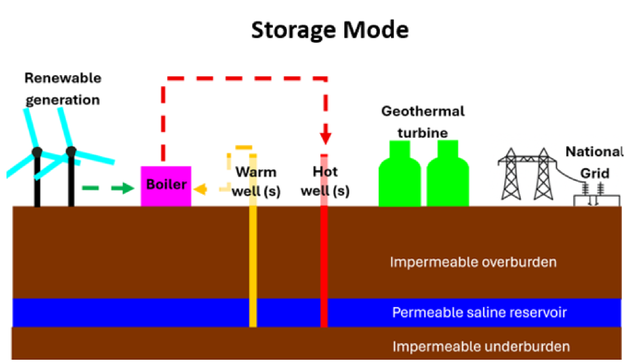
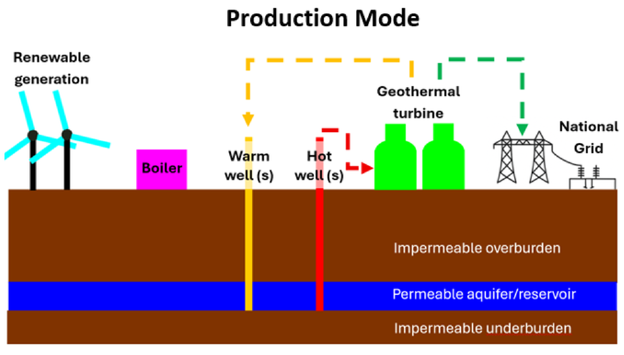
1, Introduction

- Energy storage is vital for tackling variable renewable energy (VRE) intermittency by providing flexibility to energy withdrawal.
- Here, we investigate the potential for ultra-high temperature (UHT-) UTES which operates **storage mode** to collect curtailed VRE:



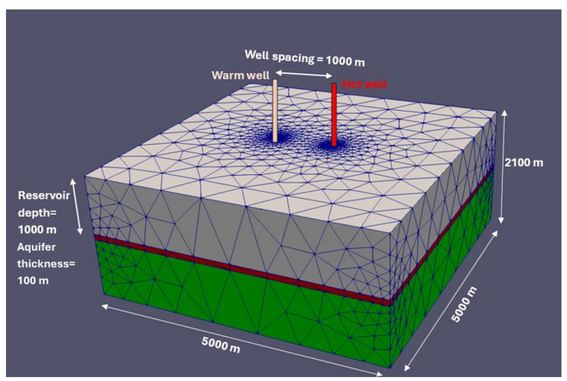
- During excess demand, **production mode** operates:



- Storage temperature for hot well $\geq$ 150 °C to enable efficient electricity generation, aquifer depth $\geq$ 500 m to maintain storage water in liquid phase.

2, Methodologies

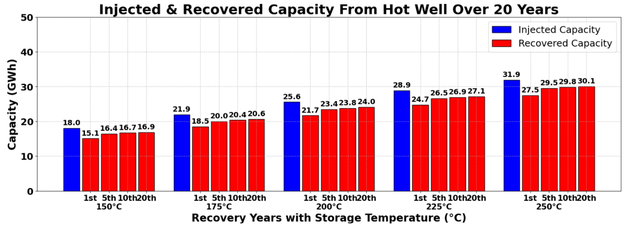
- We use Imperial College Finite Element Reservoir SimulaTor (IC-FERST, available at: https://multifluids.github.io) to simulate UHT-UTES model:



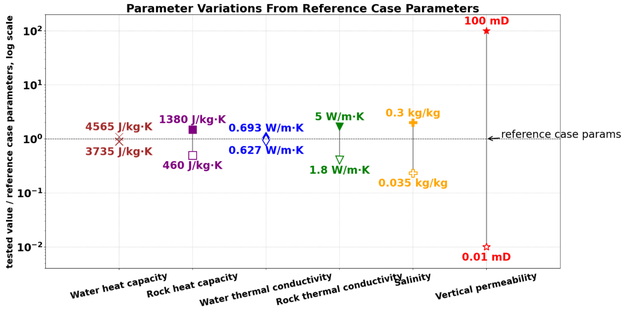
3, Results

3.1, Reference Case Hot Well Performance

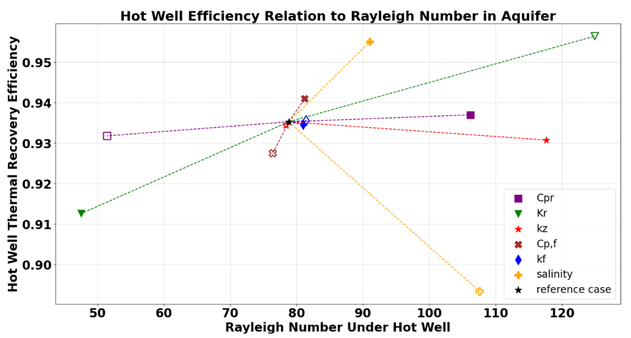
- Five different storage temperatures between 150 °C and 250 °C are experimented for the hot well.

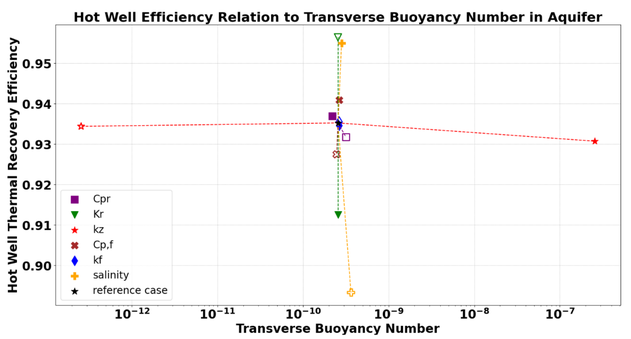


3.2, Sensitivity of Hot Well Performance



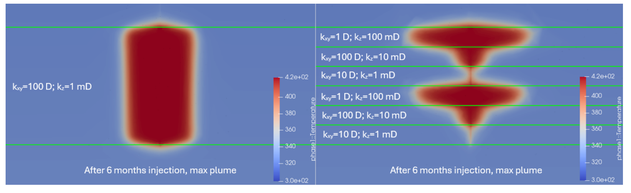
- Sensitivity of thermal recovery efficiency of the hot well is controlled by both conduction and buoyancy effect.

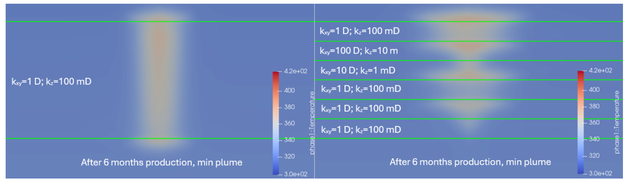


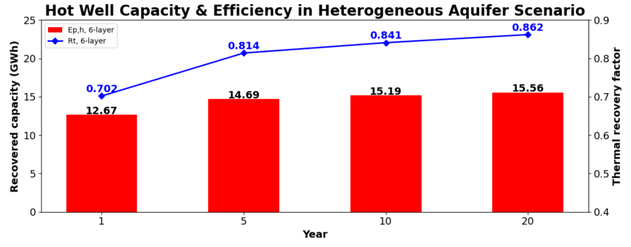


3.3, Impact From Aquifer Heterogeneity

- Heterogeneity invokes more conductive and advective loss from the hot well.

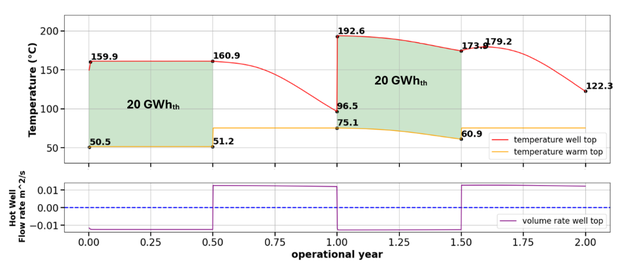




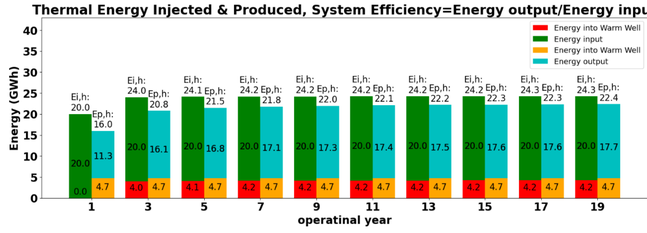


3.4, System Efficiency in Real World Operation

- Considering 20 GWh_e is uniformly supplied to UHT-UTES over 6 months,
- Hot well injection temperature is dynamically adjusted to meet a fixed power input from VRE.



- If the steam turbine operates an outlet temperature of 75 °C, the net thermal energy available for electricity generation also reaches ca. 90% after 20 years of operation.



4, Conclusion

- UHT-UTES can store 10's GWh_{th} with thermal recovery efficiency of ca. 90% for the hot well.
- Sensitivity of hot well performance is $\leq$ 2% and governed by both conductive and buoyancy loss.
- Aquifer heterogeneity causes about 7% of addtional thermal loss from the hot well.
- UHT-UTES operation can be based on energy input instead of temperature, which can also achieve ca. 90% system efficiency for electricity generation.
- Future work in UHT-UTES will involve constraining round-trip efficiency for electricity generation, system optimisation and suppressing operational obstacles.