Geomechanics for carbon neutrality

The Hong Kong Polytechnic University 香港理工大學

RESEARCH CENTRE FOR RESOURCES ENGINEERING TOWARDS CARBON NEUTRALITY 碳中和資源工程研究中心

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Background

- Global warming facts: ice sheet melting, ocean current slowdown, sea level rise, permafrost disintegrate, etc.
- Worldwide disastrous climatic events: unprecedented typhon, drought, flood, wildfire, etc. These catastrophic events are becoming more severe and frequent[1].
- Carbon neutrality – We need to act NOW!

Challenges

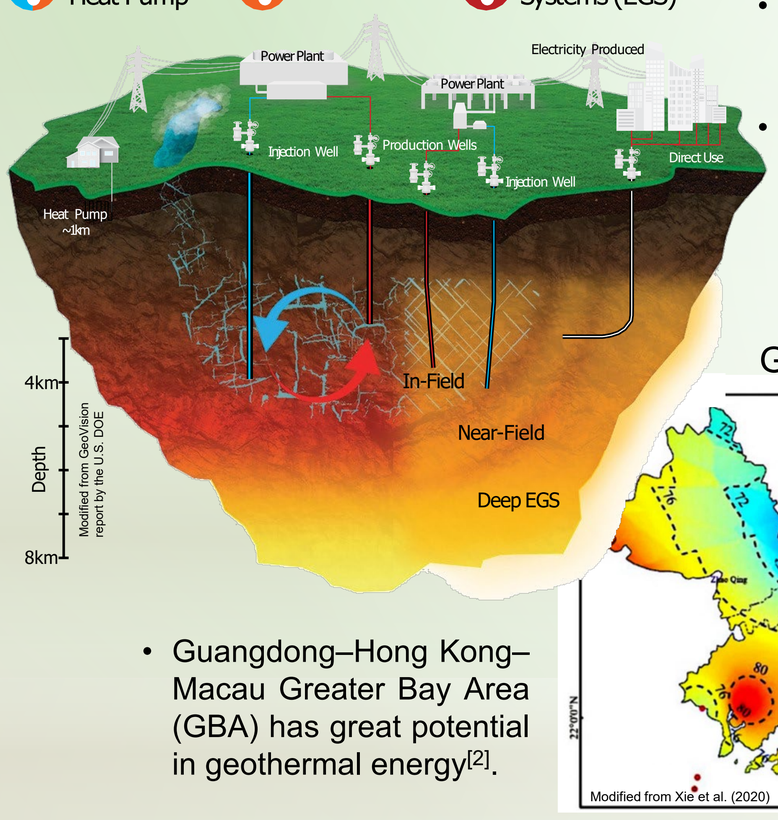
- Our societies still rely on fossil fuel, much more renewable energy is required.
- Wind and solar energy have fluctuations, other renewable energy resources and large-scale energy storage are needed to compensate the fluctuations.
- Large amount of unavoidable carbon will still be released, CO_2 sequestration and permeant storage is needed.
- Geomechanics challenges: difficulties in understanding the thermal-hydraulic-mechanical coupled rock behaviour at depth, injection of fluids underground may induce earthquakes, etc.

Alternative Energy Solutions

Geothermal energy

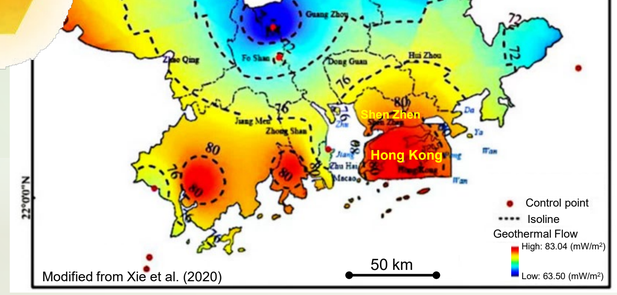
Beneath our feet lies enough energy to potentially meet all of humanity's requirements.

Geothermal Heat Pump | Hydrothermal | Enhanced Geothermal Systems (EGS)



- The deeper, the hotter, thus, the more energy can be extracted.
- EGS requires stimulation (e.g., hydraulic fracturing) and the cost of the required engineering is high.

Geothermal Flow in GBA



- Guangdong–Hong Kong–Macau Greater Bay Area (GBA) has great potential in geothermal energy[2].

Carbon capture, utilisation and storage (CCUS)

CCUS refers to a suite of technologies that that contributes both to reducing emissions directly and to removing CO_2 to balance unavoidable emissions.

- Reducing emission is not enough, we need to reverse the emission process by capturing and storing CO_2 permanently.
- Geological CO_2 sequestration is one of the most promising storage methods. It has two main mechanisms: (1) physical trapping and (2) geochemical trapping.

Underground energy storage

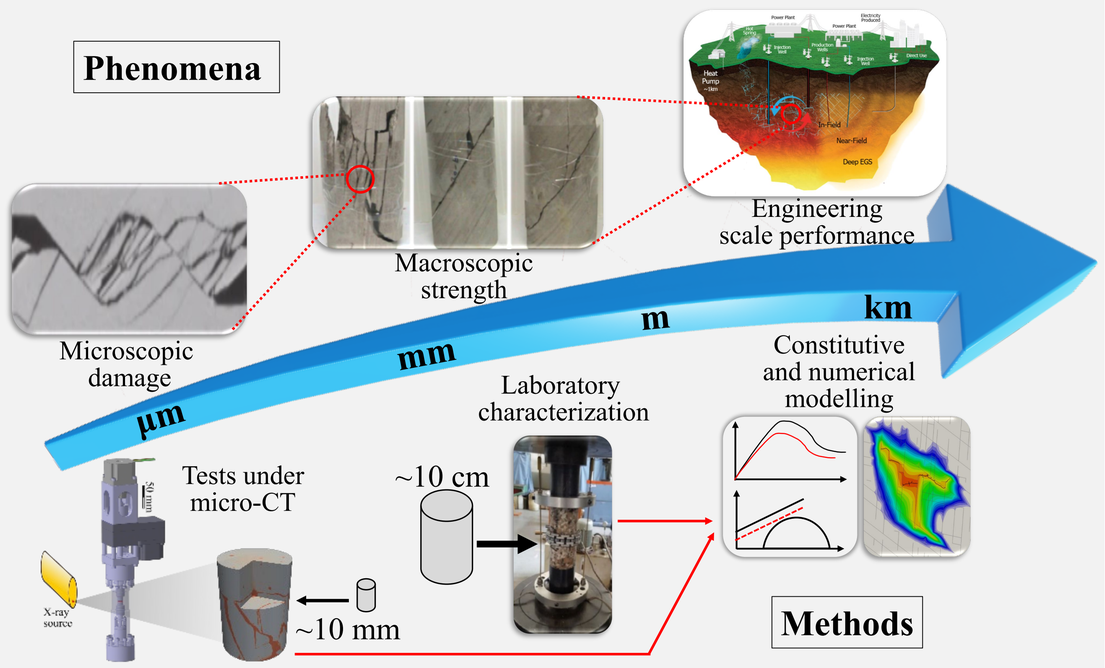
Energy storage is required to balance demand and supply when generating power with wind and solar.

- Large-scale, long-term energy storage that is not battery-based is vital for electrifying our society.
- Underground energy storage is one of the good alternatives.
- Examples:
  Compressed Air Energy Storage (CAES)
  Underground Pumped Hydro Storage (UPHS)
  Underground Thermal Energy Storage (UTES)

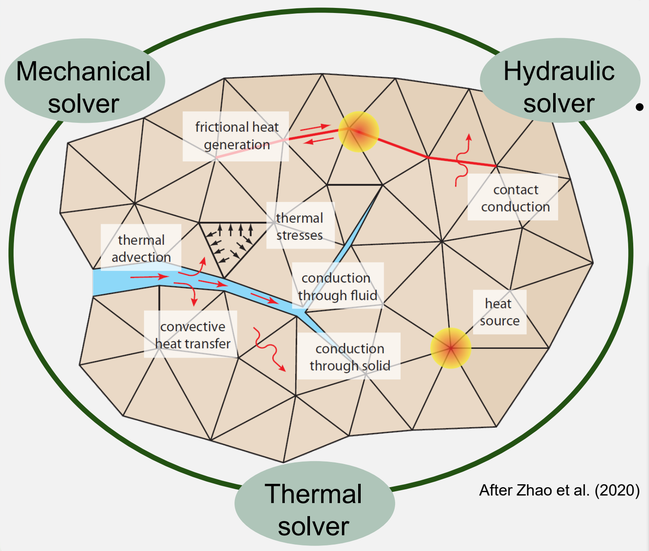
Geomechanics for carbon neutrality

- **Geomechanics**: the study of how subsurface rocks behaviour in response to changes of stress, pressure, and temperature.
- We use geomechanics studies to
  (1) Optimize the design of renewable energy projects in rocks,
  (2) Forecast their long-term performance,
  (3) Mitigate potential hazards, and
  (4) Improve the interpretation of geophysical monitoring data.

- **Multiscale characterization and modelling**

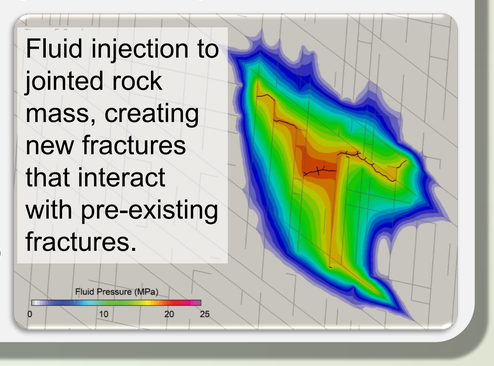


- **Thermal-hydro-mechanical (THM) coupled hybrid finite-discrete element method (FDEM)**



After Zhao et al. (2020)

- FDEM combines the advantages of finite element method and discrete element method.
- It is an excellent tool for studying rock discontinuities, e.g., hydraulic fracturing for enhanced geothermal systems[3].



References: **[1]** Thiery, B.W. et al. (2021). Intergenerational inequities in exposure to climate extremes. *Science*, **374**(6564), 1158-160. **[2]** Xie H., Yang, Z, & Deng J. (2019) Assessment of Geothermal Resource Potential in the Guangdong−Hong Kong−Macao Greater Bay Area. *Advanced Engineering Sciences*, **51**(1): 1-8. **[3]** Zhao, Q.; Glaser, S.; Lisjak, A.; and Grasselli, G. (2020) Numerical simulation of fault slip during geothermal energy extraction. In 54th U.S. Rock Mechanics/Geomechanics Symposium, 2020.

Dr Zhao's webpage
https://qzucb.github.io/

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https://www.polyu.edu.hk/rcre/