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Introduction

Context & Importance

- Rising energy demand & sustainability challenges → need for **energy-efficient foundations**.
- Net zero Agenda
- **Energy piles**: foundation elements that exchange heat with the ground.

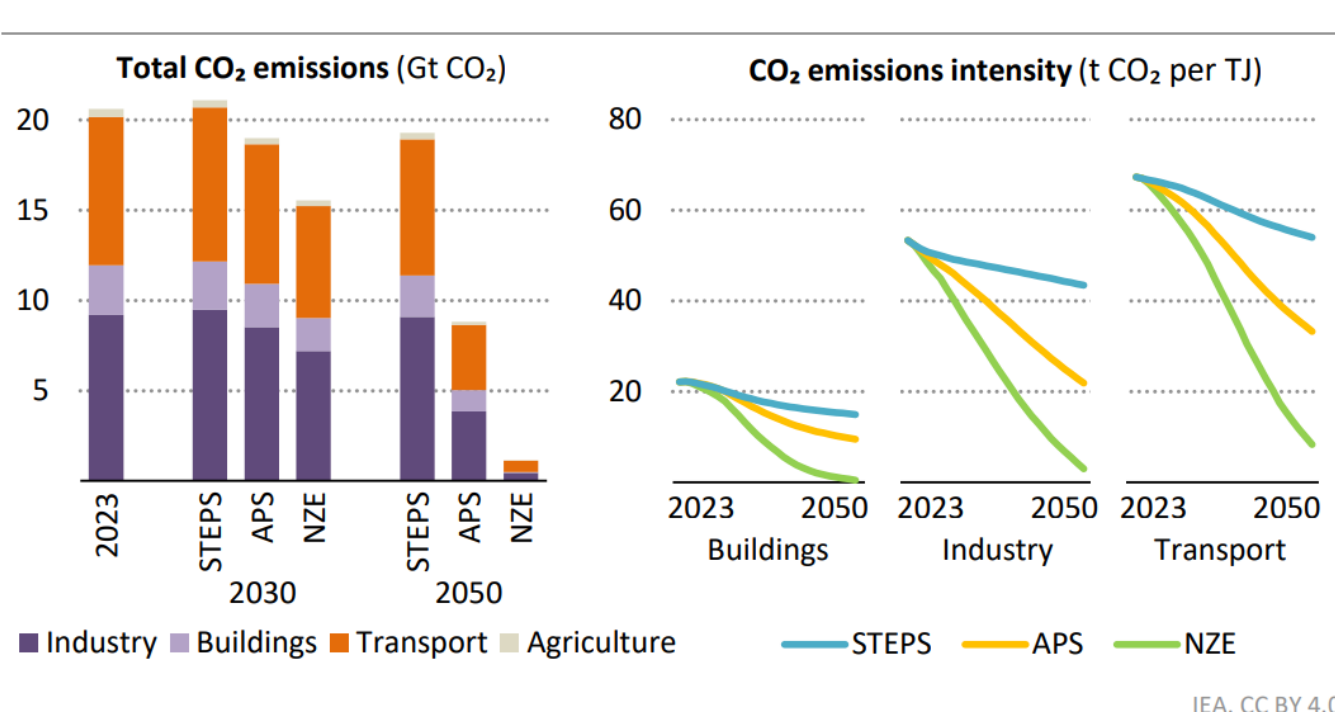


Figure 1 CO² emissions and emissions intensity by end-use sector and scenario, 2023, 2030 and 2050 (from IEA, 2024)

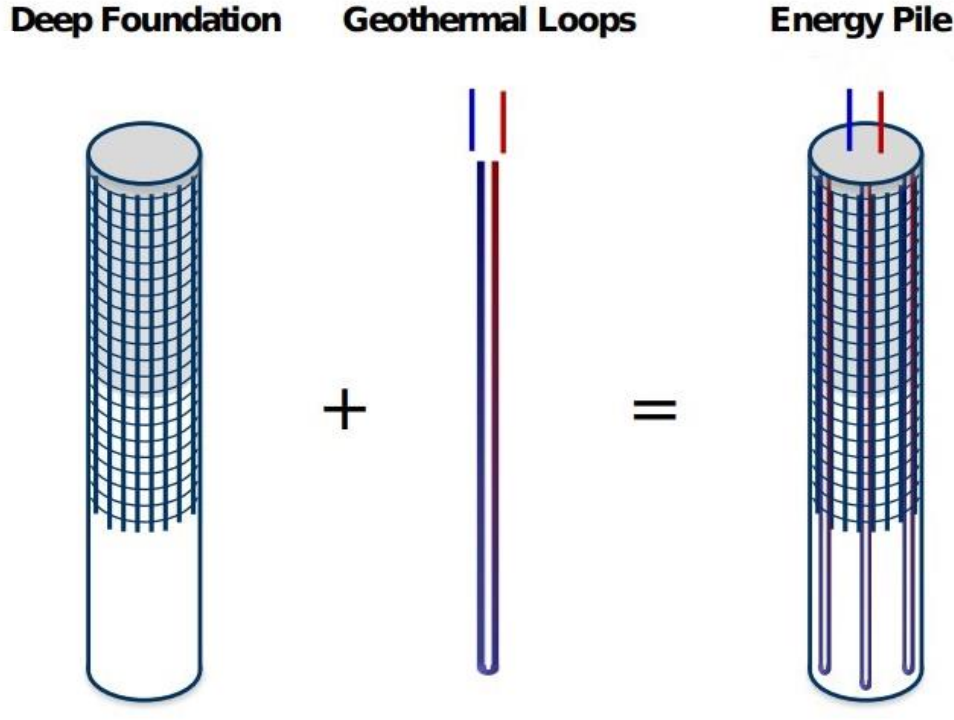


Figure 2 Energy piles - dual purpose structure (after Olgun & McCartney, 2014)

Research Questions

- How do heat transfer and moisture movement affect energy pile performance in unsaturated soil?
- How do cyclic loading and variations in soil suction influence energy pile's long-term behaviour?
- What are the best numerical modelling techniques for THM analysis?

Why unsaturated soils?

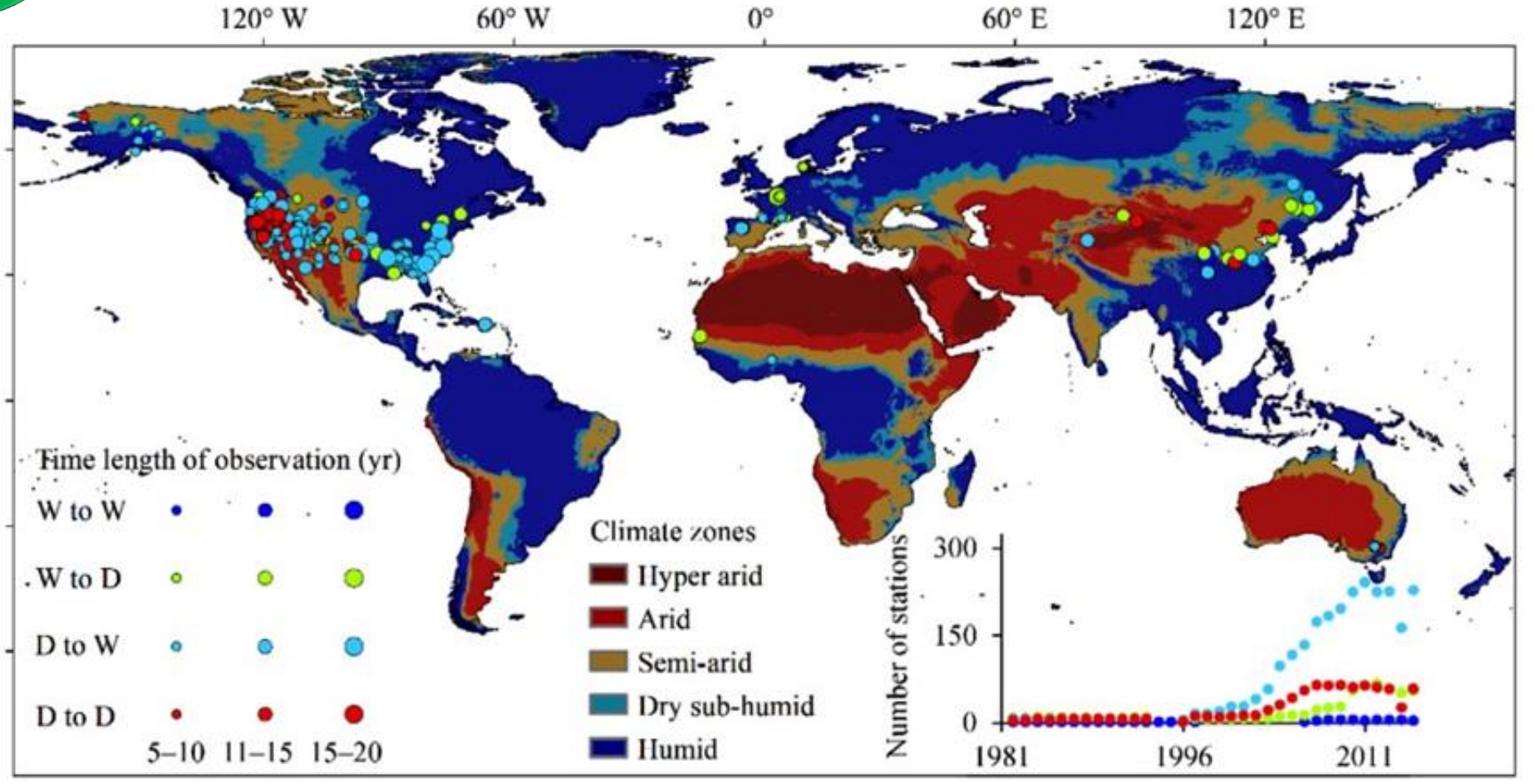


Figure 3 Classification of global climate zones and spatial distribution (from Deng et al., 2020)

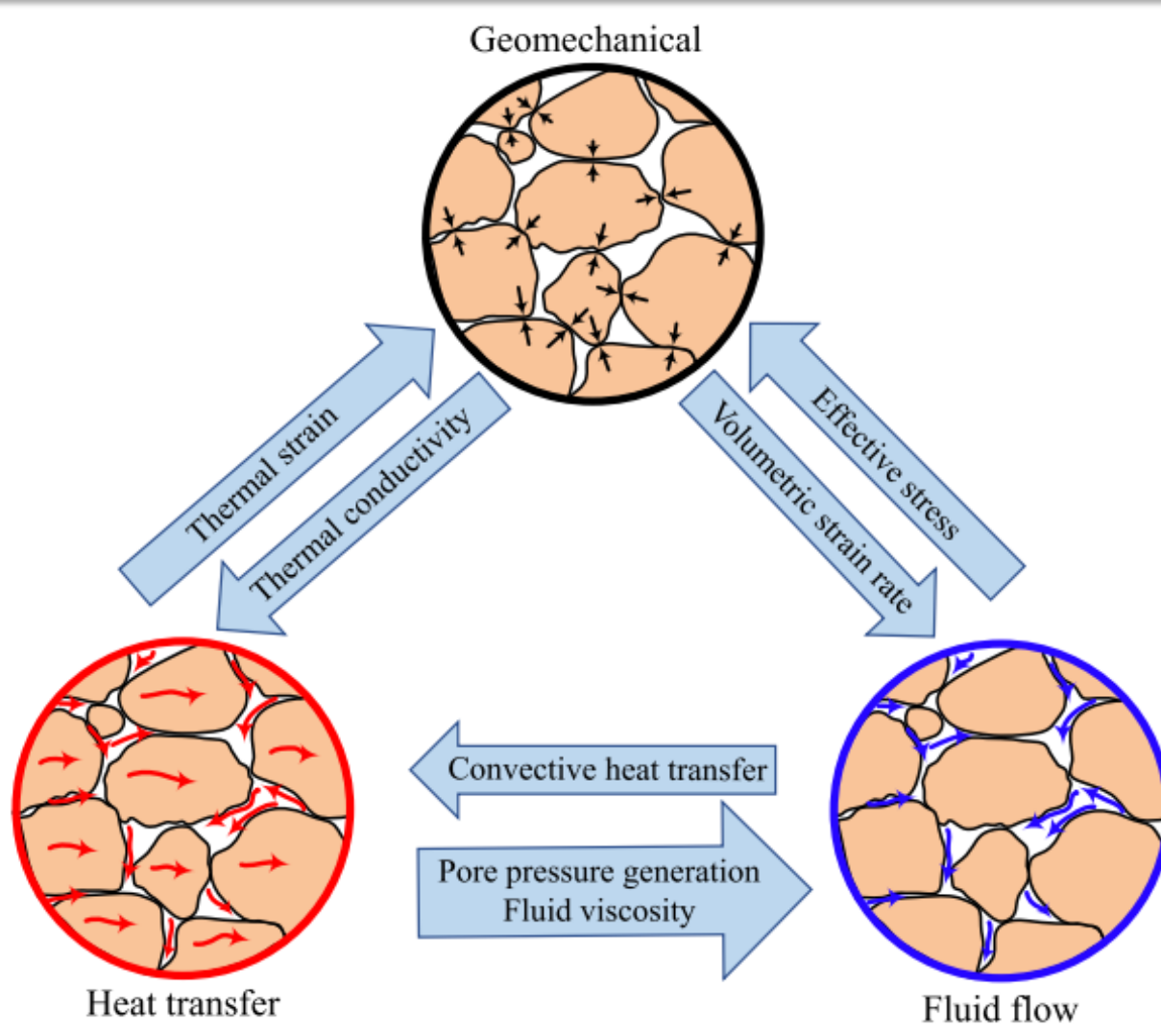


Figure 4 Thermo-hydro-mechanical coupling flowchart (Jafari et al, 2023)

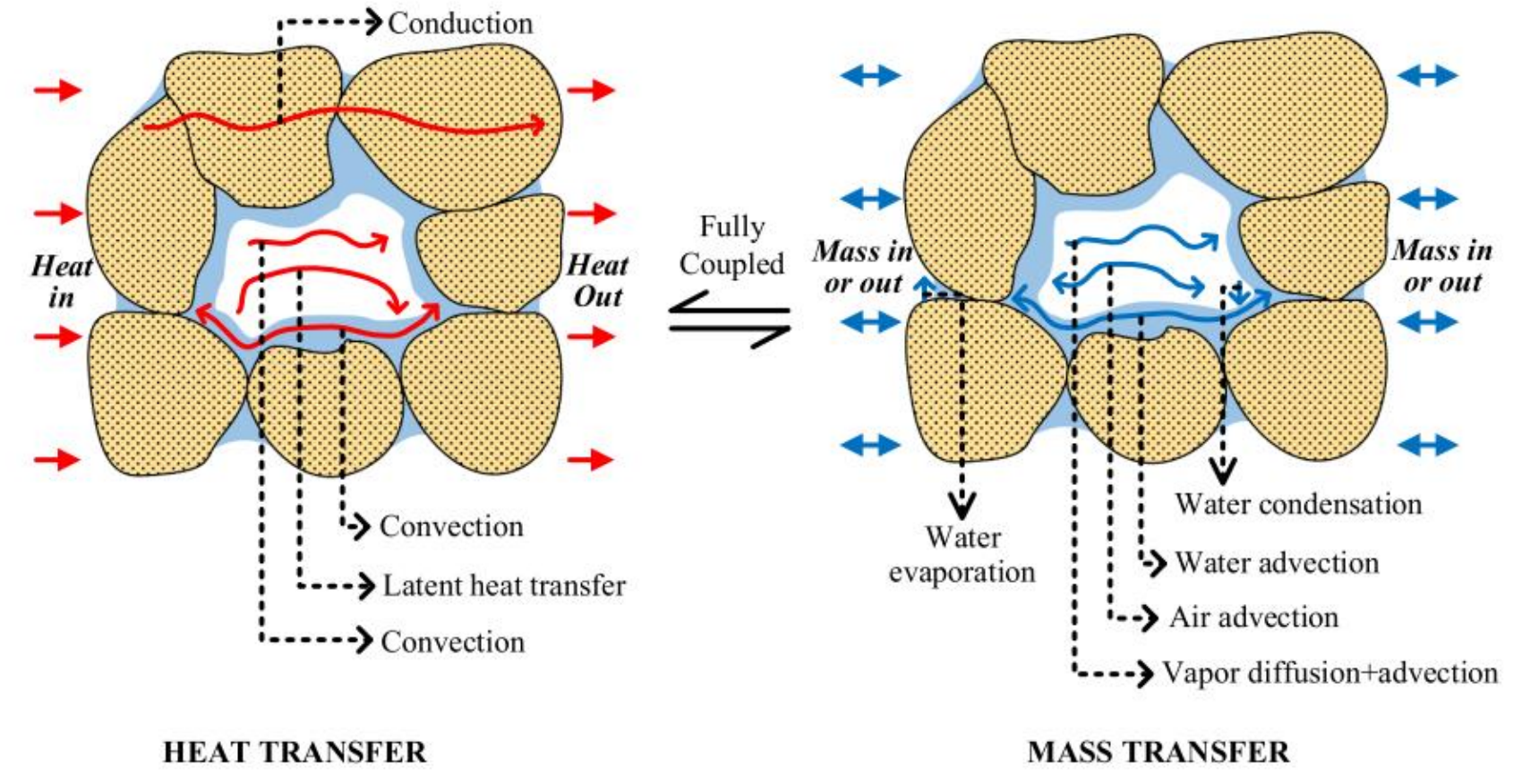
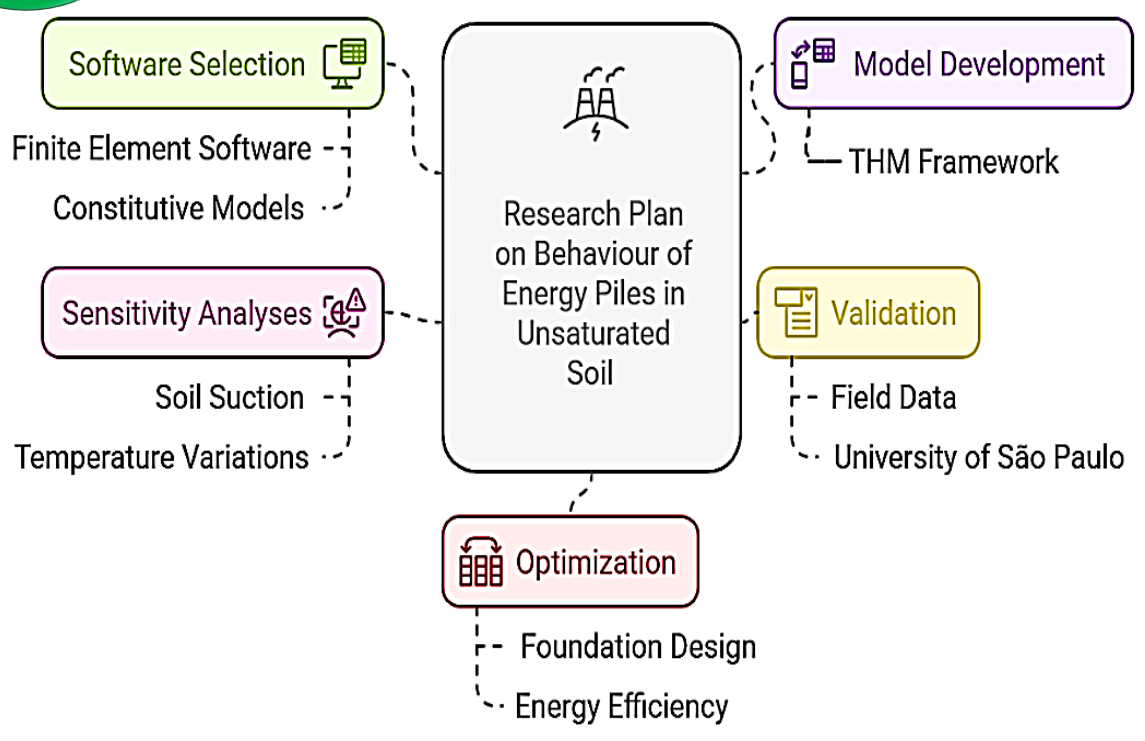


Figure 5 HT multiphysics processes in unsaturated soils (Kumar et al, 2025)

Methodology



Conclusion and Key Insights

- Understanding THM coupling is crucial for optimizing energy pile design.
 - Soil properties & suction play a major role in long-term pile stability.
- Next Steps
- Validation with field data from the São Paulo test site.
 - Optimization strategies for real-world application.

Acknowledgments

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References

➤ Deng, Y., Wang, S., Bai, X., Luo, G., Wu, L., Chen, F., Wang, J., Li, C., Yang, Y., Hu, Z., Tian, S., & Lu, Q. (2020). Agricultural and Forest Meteorology, 292–293. ➤ Jafari, A., Vahab, M., Broumand, P., & Khalili, N. (2023). Computers and Geotechnics, 159, 105458. ➤ Kumar, A., Bidarmaghz, A., Khoshghalb, A., & Soga, K. (2025). Computers and Geotechnics, 177, 106893. ➤ International Energy Agency (IEA) (2024) World Energy Outlook. Available at: <https://www.iea.org/reports/world-energy-outlook-2024>. ➤ Olgun, C. G., & McCartney, J. S. (2014). DFI Journal - The Journal of the Deep Foundations Institute, 8(2), 59–73.