Unlocking Hidden Geothermal Potential: Leveraging Artificial Intelligence for Subsurface Exploration

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February 2024

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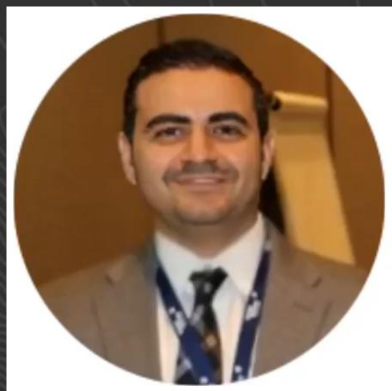


Geothermal Energy

Geothermal energy is extracted from the Earth's subsurface layers and is derived from the heat generated during rock formation and the decay of radioactive materials. The main advantages of geothermal energy are its low operating costs, stable supply and the ability to operate at high-capacity factors all year round.

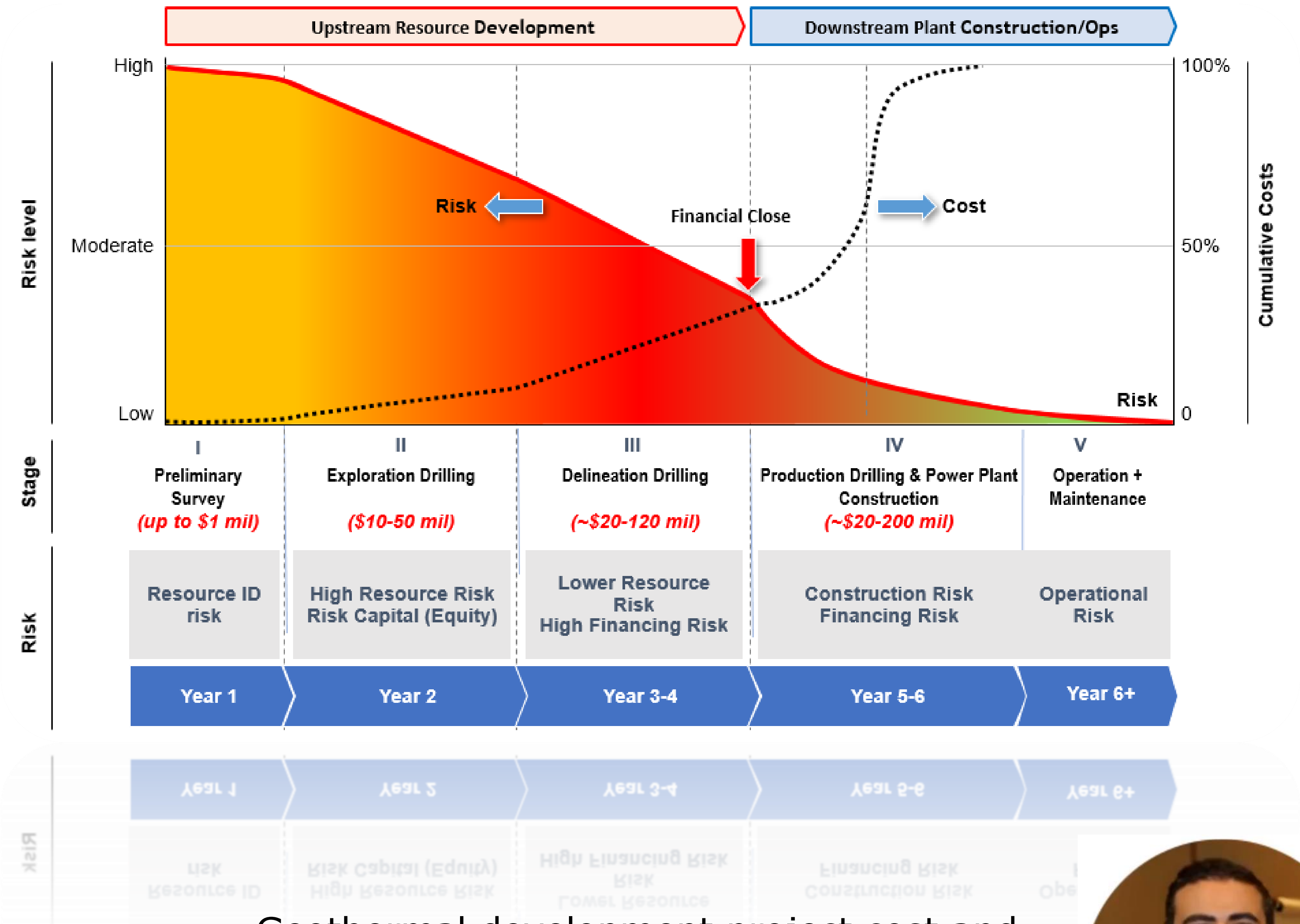
Recent Activities in Geothermal Energy

Many countries are investigating the feasibility of commercializing untapped geothermal resources. This requires information on the hydrological, geophysical, geological, geochemical, and thermal characteristics of the hydrothermal reservoirs to determine whether the geothermal resource has sufficient potential to recover exploration and development costs.

Geothermal Exploration Challenges

Geothermal exploration is challenging and costly due to the subsurface complexities involved in locating potential reservoirs.

Geothermal resource evaluation plans are often hindered by the significant investment and high financial risks associated with preliminary surveys, exploration and delineation drilling for data collection and interpretation. As a result, many geothermal reserves remain unexplored due to the ineffectiveness or high cost of existing detection methods.



Geothermal development project cost and risk profile throughout various project stages (The World Bank, 2019)

Role of Artificial Intelligence in Geothermal Exploration

Raw Data Analysis

Machine learning algorithms can analyze large, multidimensional datasets, including geophysical, geological, geochemical, thermal, and geospatial datasets, to identify complex patterns that guide the exploration of hidden geothermal resources.

Imagery Data Analysis

The analysis of raw geophysical imagery and seismic survey data to identify key subsurface features and stratification can be automated by deep neural networks.

Data Management

Unsupervised learning techniques, such as clustering analysis, can identify outliers and reveal distinct sets of characteristics associated with hidden geothermal potential.

Summary of Different AI Approaches in Geothermal Exploration

Research Area	AI Algorithm Used	References
Play Fairway Analysis Application	LR, ANN, PCA, K-means, Bayesian NN, NMF k, DT, XGB	Faulds et al. (2015); Faulds et al. (2020); Smith et al. (2021); Brown et al. (2020); Brown et al. (2022); Vesselinov et al. (2021); Holmes and Fournier (2022)
Combined Geological, Geophysical, Geochemical, and Thermal Data Application	NMF k, RF, ANN	Vesselinov et al. (2022); Ahmed and Vesselinov (2022); Siler et al. (2021); Ahmed, Vesselinov, and Middleton (2020); Ahmed et al. (2020); Ahmed and Vesselinov (2021); Mudunuru, Ahmed and Vesselinov (2022); Meshalkin et al. (2020); Shakirov et al. (2021)
Geochemical Data Application	ANN, MLP, SVM, KNN, DNN, NMF k, K-means, Gaussian mixture model	Bayram (2001); Can (2002); Diaz-Gonzalez et al. (2008); Serpen et al. (2009); Bayram and Gultekin (2010); Perez-Zarate et al. (2019); Acevedo-Anicasio et al. (2021); Yang et al. (2022); Tut Haklidir and Mehmet Haklidir (2019, 2021); Ahmed et al. (2021); Kazuya Ishitsuka et al. (2021)
Geophysical Data Application	ANN, NK, DT, Adaptive Booster Regression, RF, SVR, FNN, Bayesian NN, DBNN, CNN, K-means, ICA, DL, fuzzy logic	Spichak (2006); Ishitsuka et al. (2018); Namaswa et al. (2021); Akpan (2013); Maryadia and Mizunaga (2021); Trainor-Guitton et al. (2014); Sutarmin and Yunus Daud (2020); Yadav et al. (2021); Ishitsuka et al. (2021); Hokstad and Tanavsuu-Milkeviciene (2017); Zheng et al. (2021); Gao et al. (2021); Perozzi et al. (2021); Matzel et al. (2021); Abubakar et al. (2019); Moraga et al. (2022); Sadeghi and Khalajmasoumi (2014)
Thermal Data Application	NK, MNN, ANN, DL, ridge regression model, DT, XGB, RF, linear and polynomial regression	Koike et al. (2001); Spichak (2006); Shahdi et al. (2021); Bassam et al. (2010); Espinoza-Ojeda and Santo
Other Data Application	ANN, DL, (SVM), DT, KNN	Porkhial et al. (2015); Xiong et al. (2022)

Artificial Intelligence Limitations in Geothermal Exploration

Data Availability and Quality

The accuracy and reliability of AI models used in geothermal exploration heavily depend on the availability and quality of data. Limited datasets or data with inaccuracies can hinder their success.

Complexity of Subsurface Features

Geothermal exploration can be challenging for AI algorithms to accurately interpret due to the complexity of subsurface features.

Generalization to New Geological Environments

AI models trained on existing geological environments may struggle to apply their findings to new and unfamiliar geological settings. The limited availability of data from specific regions can restrict the applicability of AI in new regions.

Conclusions

- The use of AI in geothermal exploration is a recent development that has the potential to significantly enhance efficiency, effectiveness, and productivity compared to simple physics-based and statistical approaches.
- The growing use of AI in geothermal exploration indicates that its application will continue to expand. However, acquiring meaningful geothermal data remains a significant challenge that must be addressed for AI to have a transformative impact on geothermal exploration.
- To make multiple datasets and insights accessible to scientists, shared initiatives across the industry are necessary.
- Partnerships between academic and professional organizations can be particularly influential in accelerating the development and improvement of AI approaches on a larger scale.

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