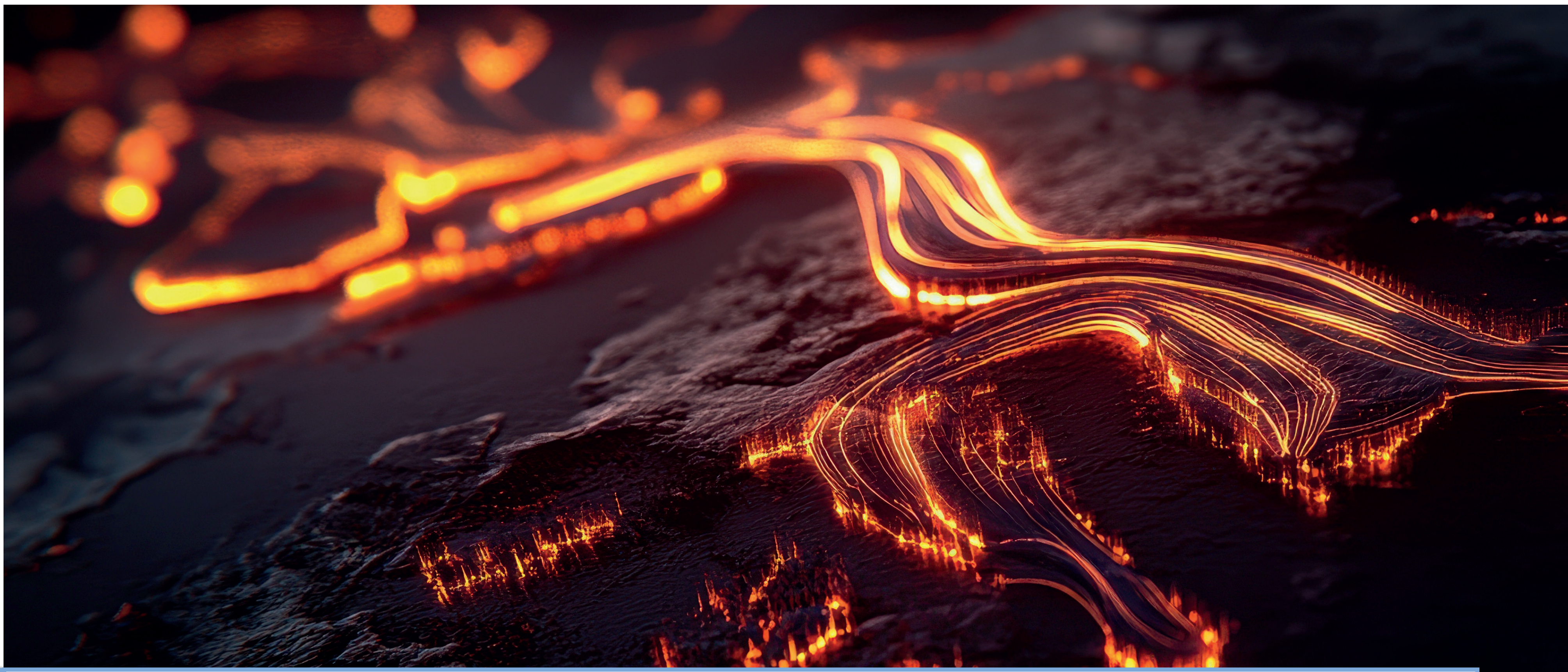


REVIEW OF ADVANCES IN GEOTHERMAL ENERGY

Dr Raj Shah and Mathew Roshan explore the advances and future potential of geothermal energy

As global attention moves increasingly towards renewable and sustainable energy sources, geothermal energy, energy produced by harnessing heat from under the Earth's surface, has gained prominence as an increasingly feasible form of energy production.

Geothermal energy production started in 1904 at Larderello, Italy with an experimental 10 kWe generator.

Since then, geothermal electricity production has spread to 29 countries, supplying an equivalent of 63 million individuals.

Geothermal energy production has grown 6.2% annually since the end of the Second World War. In 2020 production capacity stood at 95,098 GWh of electricity.

The trend of growth in recent years is seen in Figure 1 [1].

Furthermore, in 2020 geothermal plants produced an estimated 1,020,887 TJ of thermal energy. Of which 58% were utilised in the form of geothermal heat pumps. And the remainder in other heating applications such as water heating for swimming and bathing (18%), space heating (16%), greenhouses (3.5%) and industrial applications (1.6%) [1].

The expansion of geothermal energy has been complemented by innovation and advancements in the field, particularly focused on reducing the costs associated with creating new geothermal power plants and optimising their functioning and efficiency.

As demand for geothermal energy increases, the speed of technological progress increases as well.

Developments in the field are rapid and diverse in scope; to gain a better perspective on where the geothermal energy technology is headed, we can consider advances under the following categorised domains of focus:

- Development of deeper, more advanced and efficient geothermal systems
- Improved drilling technology for geothermal wells
- Applications of AI and ML for resource exploration and plant optimisation
- Development of hybrid facilities that combine geothermal plants with other renewable energy technologies.

We will consider select innovations from the last 3-4 years in each category.

Deep and advanced geothermal systems

Geothermal plants are structured around a well, dug into the earth in a region of identified high underground thermal activity.

The well bores directly into hot permeable rock containing groundwater. The plant then utilises this to produce energy, or inject water into permeable hot rock, in order to produce steam and then electricity via turbines.

This, however, represents the most standard type of geothermal plant.

Enhanced Geothermal Systems (EGS) bore into non permeable hot rock. They inject pressurised fluid to artificially create the needed permeability to access the latent geothermal energy.

The deeper the well is bored into the earth, the more thermal energy we can access.

Recently, focus has shifted towards the idea of "deep wells". These bore deep enough into the earth that the present fluids or injected fluids would exist in supercritical states due to the greater heat.

The supercritical fluids would, from a thermodynamics standpoint, be ideal for power generation efficiency. However, as the depth of the wells increase, costs and technical difficulties magnify greatly [2].

Many of the key challenges surrounding EGS are based on the usage of traditional heat extraction methods that involve extraction of hot water from underground.

These include environmental concerns such as groundwater contamination, induced seismic activity and operational and efficiency-based concerns such as loss of water due to leakage into surrounding formations.

Furthermore, at many sites, there are geographical limitations as to water injection capabilities.

Huang et al [3] proposed a novel Super Long Gravity Heat Pipe (SLGHP) geothermal system. This circumvents these issues with a closed system, heat pipe-based heat transmission method.

Furthermore, the proposed design is tailored to applications in deep geothermal wells. Though heat pipe technology is not recent, there have been little developments in adapting it for the purpose of deep earth geothermal energy.

Huang et al proposed an innovative stepped ladder structured gravity heat pipe featuring a pipe in pipe design, illustrated in Figure 2 [3].

Each unit module contains a single pipe step and a smaller condensate guiding pipe.

The working fluid (ammonia is proposed as it was shown that the temperature gradient in the pipe is less sensitive to diameter changes for ammonia than water) is pumped into the closed loop, gravity assists as it moves toward the thermal reservoir.

Due to the heat, vaporisation occurs and the fluid vapour rises up towards the turbines and power generation set up. After this stage it is condensed and the cycle repeats.

The condensate guiding pipes prevent accumulation of condensed fluid or non-vapourised fluid at the bottom of the loop.

This design was implemented at Xiong 'an New Area, Hebei Province, China at a 4,507m deep geothermal well in 2022.

The installed gravity heat pipe is the longest in the world. It produced more than 1 MW of heat continuously, demonstrating exceptional heat transfer capability at 40 MW/m2 through the radial cross section.

Furthermore, the pilot power generator produced 7 kW steadily for 72 hours upon the initial test.

The research group notes that while they expect the design to be implemented widely there is additional work for optimisation of

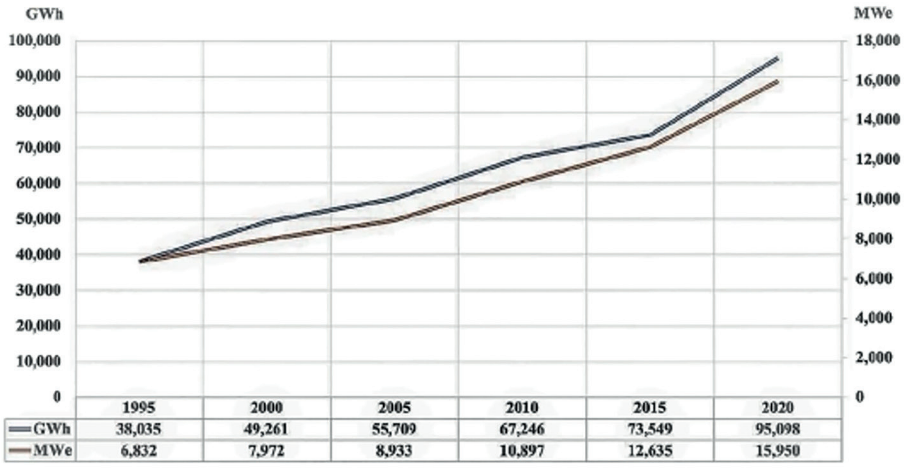
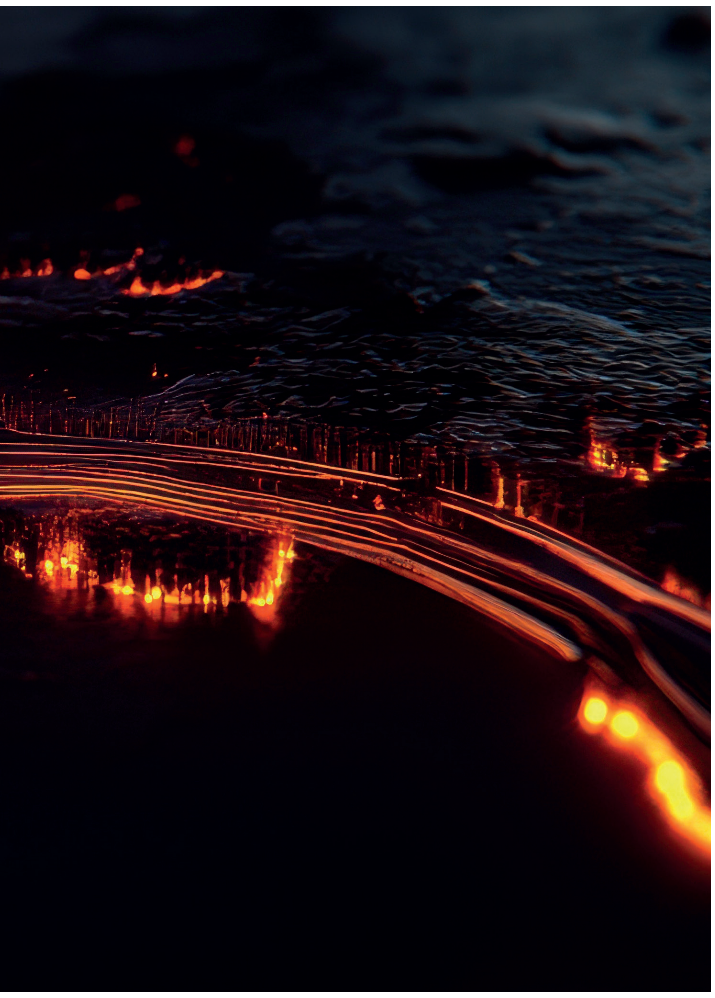


Figure 1: Geothermal energy production trends



the surface level installations and steam turbines for such a system [3].

The Utah FORGE (Frontier Observatory for Research in Geothermal Energy) geothermal project in the United States is also an interesting and very recent case study of cutting-edge geothermal systems.

The FORGE project is focused on developing advanced methods for EGS. It creates permeability in deep crystalline geothermal reservoirs, whilst optimising heat extraction, stimulated reservoir volume and reducing seismic activity and negative environmental impact [4].

Figure 3: Utah FORGE wells [5]

FORGE is pioneering many methodologies in EGS, such as multi-zone hydraulic fracturing to create extensive fracture networks between injection and production wells in deep granite.

In April 2022, for the first time, a deviated injection well was fractured in three stages.

Based on this, a commercial level multi-stage fracturing was performed in 2024 with eight fracturing intervals.

Multiple methods such as fibre optic distributed sensing of cracks, use of proppants and custom high temperature fracture plugs and varying the rheology of the fracture fluid were combined to produce a highly conductive and connected fracture network between the injection and production wells.

When performing closed loop controlled circulation tests on the created crack networks, 70% of the injected water was recovered and at temperatures of 139 C. This indicates substantial flow and heat output for an artificially created geothermal reservoir [5].

The FORGE project also pioneered the use of sophisticated 3D reservoir modelling. Full thermal-hydrologic-mechanical models of the reservoir were calibrated to data recorded from the wells in previous phases of the project.

The model was used to predict EGS behaviour upon stimulation and iterative modelling helped optimise the fracturing process and circulation tests [6].

The working fluid used in geothermal systems for power generation has been another key area of research. Particularly as the choice of working fluid can have a major impact on the efficiency of a geothermal plant and subsequently affect its economic viability.

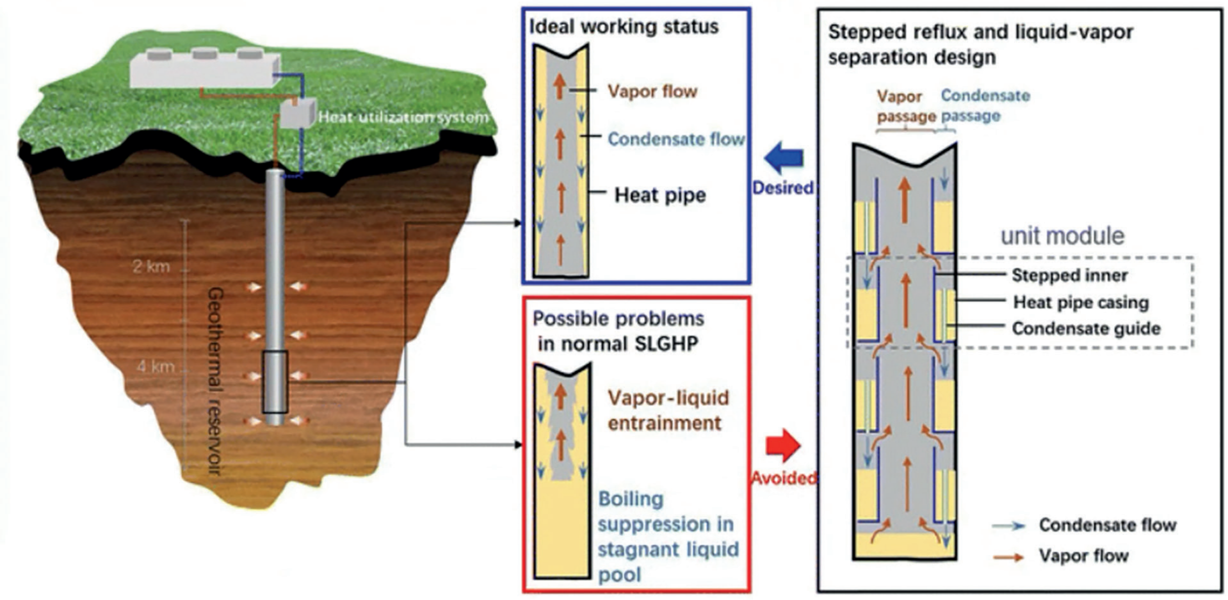


Figure 2: Proposed structure and working principle for SLGHP

Currently, almost all functioning plants use water as a working fluid; Huang et al [3] proposed using ammonia.

However, much work is being done on the viability of supercritical carbon dioxide as a working fluid.

The lower density and viscosity of CO_2 [MR2] allow for higher sustained flow rates, (3.7x faster than water as shown by simulations), lower friction losses and pumping requirements. The lower kinematic viscosity allows for better circulation in low permeability reservoirs.

Furthermore, CO_2 has a higher buoyancy, which would allow it to drive its own thermosiphon circulation, reducing the energy cost of sustaining long-term circulation.

The higher possible flow rates and higher thermal expansivity of CO_2 also allow for effective heat transfer.

An added benefit is that the solubility of minerals in CO_2 is very low. This lowers the risk of mineral precipitation in geothermal wells and fractures.

CO_2 has about half the heat capacity of water; this can be compensated through a higher flow rate. But geothermal systems must then accommodate these higher flow rates, which is more difficult and costly.

If water or brine is present in the geothermal well, a variety of complications can result. CO_2 can evaporate the water causing mineral precipitation, which can clog fractures, or it can produce carbonic acid that can cause well bore corrosion.

Furthermore, injection of cold CO_2 can produce thermal stresses. These may cause unwanted fractures affecting stability.

The cost of procuring large amounts of CO_2 is an economic barrier that makes practical implementation of such a system currently unfeasible.

However, a solution to this comes in the form of CO_2 Plume Geothermal.

CO_2 Plume Geothermal taps wells in natural regions of CO_2 accumulation, such as oil-gas fields or volcanic areas.

> *As demand for geothermal energy increases, the speed of technological progress increases as well.*

Liao et al conducted in 2020 a study on an EGS plant in Dikili, Turkey. They demonstrated that CO_2 achieved higher final production temperatures and lower driving pressures for heat extraction compared to water.

Song et al's simulation showed the pressure drop in production wells using CO_2 was 31-45% of that of water.

In a 2023 numerical study Zhao et al showed that for an EGS plant in the Gonghe basin, China, CO_2 as a working fluid maintained a high heat extraction rate with lower external pumping costs than those of water over a 30-year production period.

Even if CO_2 is not used directly as the working fluid in geothermal plants, there is demonstrated benefit in using it in secondary cycles for power generation.

Garapati et al showed that geothermal systems that utilise CO_2 as a secondary working fluid in a secondary power generation cycle connected to the main geothermal well via heat exchangers showed 20% higher output compared to standalone geothermal power generation systems [7].

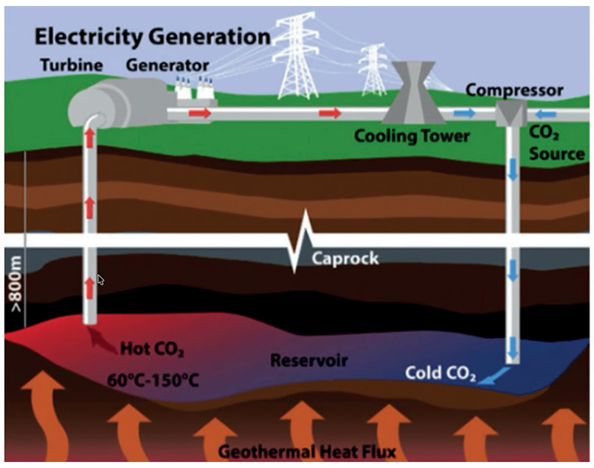


Figure 4: CO_2 as working fluid for geothermal cycle [7]

There are however several challenges to the direct use of CO_2 as a working fluid. That is why experimentally it has not been implemented.

The way forward is improved geothermal wells and system designs that can mitigate the issues associated with CO_2, so that we can capitalise upon the efficiency advantage [7].

Drilling and mining technology

The drilling of the borehole or geothermal well is arguably the most difficult and costly part of the process of establishing a geothermal plant. It accounts for up to 70% of the cost in some projects [4].

This is even more so the case with deep geothermal projects.

Historically, the geothermal industry has benefited from the innovation driven by the petroleum and natural gas drilling industry in terms of drilling methods and technologies.

However, it is important to note that much of the drilling technology from the petroleum and gas industries does not translate into use in the geothermal sector. This is because of the different nature of drilling required.

Drilling to create geothermal wells involves boring through rock layers that are at much higher temperatures (300+ Celsius compared to 150 Celsius) and also significantly harder.

Oil and gas reservoirs are typically found under sedimentary rock. While geothermal reservoirs are under crystalline and volcanic rock layers.

Hence, breakthroughs in drilling technologies capable of high rates of penetration under the harsh conditions outlined are pivotal in making the expansion of geothermal energy more feasible.

Millimeter Wave Drilling (MMW) recently developed at MIT and field tested for the first time in 2025 is an exciting new innovation in this space.

MMW drilling utilises high-frequency electromagnetic radiation generated by gyrotrons to melt or vaporise rock. It uses circulation of purge gas to remove vapourised debris, avoiding the mechanical wear and inefficiencies encountered in conventional drilling.

It is capable of penetration rates five to 10 times that of conventional methods. This allows for access to much deeper geothermal reservoirs [4].

Quaise Energy, which carried out the recent field tests estimates that MMW could achieve a rate of penetration (ROP) of 3-5 m/hr with a 1 MW gyrotron for an 8-10" borehole diameter, reaching 10 km in 100 days or less [8].

Furthermore, it produces a vitrified borehole lining, eliminating the need for traditional casing and enhancing borehole stability.

MMW drilling also heavily involves real time diagnostics, measurement and automated control systems to precisely monitor and adjust energy delivery in high-temperature, high-pressure environments [4].

In addition to the massive energy requirement, MMW drilling faces the technical challenge of deploying and retrieving the waveguide. This must also be kept vertical throughout the drilling process.

This makes drilling sections at angles or varied orientations difficult. If the orientation of the waveguide shifts from the vertical, it can get significantly heated by the beam. This leads to almost 10% in energy losses [8].

Access to SHR (super-hot rock) for field testing, is critical for the further development of this technology.

Figures 5 and 6: MMW drill bottom hole assembly (BHA) and rig set up from Quaise Energy site [14]

In addition to MMW drilling, which is the most recent, several other drilling methodologies exist and are being actively improved. Examples include plasma drilling, water jet drilling, particle drilling, percussive drilling and laser drilling. All focused on maximising penetration of hard rock.

However, most geothermal drilling is still carried out using conventional methods.

To better adapt conventional drilling methods for the harsher conditions of geothermal drilling, development of more wear resistant and harder drill bit materials and optimal drill cone designs such as polycrystalline diamond cutters (PDC), more thermal and corrosion resistant components, experimentation with different drilling fluids and insulated drilling pipes and automated surface control systems are primary areas of research [8].

Site identification and system optimisation-applications of AI

The artificial intelligence (AI) and machine learning (ML) boom in the last three to four years has affected virtually every industry; the geothermal energy industry is no exception.

AI and ML tools are used increasingly in almost every facet of the field; from site identification, optimisation in drilling and fracturing processes, thermodynamic modelling of geothermal systems and reservoirs, to optimisation of the functioning of geothermal plants by integrating ML tools with internet of things (IOT) sensory devices and control systems.

Site identification is conventionally carried out by identifying geophysical indicators in physical geographic surveys. More advanced remote sensing tools have been used over the years such as magnetotellurics.

Post 2020-2021, much work has gone into using ML models for site identification.

Models are trained to identify sites from surface features and thermodynamic, hydrological and geological data. Various model architectures have been developed to this effect.

In 2022 Moraga et al [9] used data from remote sensing methods, such as geo-spatial data from thermal satellite imaging, mineral markers from spectral analysis and surface deformation data. This helped to develop a supervised classification model, which could produce a potential map for geothermal sites on a pixel basis.

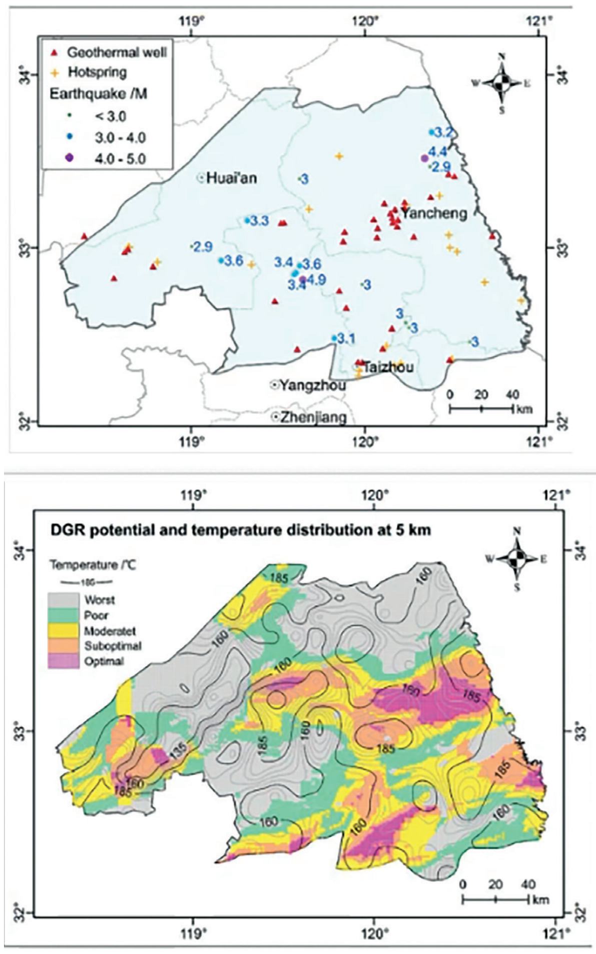
The model showed 92-95% accuracy when tested on the Brady and Desert Peak sites in the US (it was trained on data from these sites).

However, the research group noted the model's effectiveness was dependent on the availability of data. Its performance was also localised to an extent; the accuracy dropped to 72-76% on cross site testing.

A notable practical application was the development of an enhanced evaluation index system based on nine indicators split amongst geophysical features, tectonic indicators and hydrogeological indicators.

This system uses tree-based classification models by Luo et al in 2024 [10].

The model was able to identify high geothermal potential belts in the North Jiangsu Basin (results in Figures 7 and 8), China. This provides quantitative evidence for the exploration of specific locations in the region for deep geothermal resources.



Figures 7 and 8: Map of North Jiangsu Basin, with marked geothermal points and geothermal potential map generated by the ML model

Machine learning applications are being adopted into geothermal site operations at a similar rate to maximise efficiency and productivity and minimise risk of accidents.

The Geothermal Operational Optimization with Machine Learning (GOOML) system was developed as a digital twin environment for plant operators in steam fields in New Zealand and the United States.

It was first developed in 2020, with implementation across 2021-22 at the Wairakei and Kawerau plants in New Zealand and the McGinness Hills (Nevada) plant in the US.

The system includes a component-based approach. It uses regression and deep neural network models to perform specified tasks for various plant components; such as forecasting mass and enthalpy decline for wells, predicting the separation efficiency for the flash plants and predicting and power output for turbine-generators.

It matched historic data very well with 5-8% mean average error.

GOOML was also integrated with reinforcement learning (RL) models in order to test and develop autonomous control optimisation.

The RL agent was given control over plant settings such as well head and pipe target pressures. It was able to produce a 2-5% increase in annual power output.

GOOML was shown to work with imperfect sensor data and be highly transferable. It was implemented across different kinds of geothermal plants from flash plants to binary units.

Key areas for further improvement have been noted. These include the adding of constraints in the decision-making model to restrict its decisions within environmental, injection or plant capacity limits, developing full closed loop digital twins and scaling of the software for larger scale management [11].

Combination with other sustainable and renewable technologies

Geothermal energy has gained prominence due to the global shift towards more environmentally friendly energy solutions.

Hence a key area of geothermal development is focused on utilising geothermal power for environmentally beneficial applications. Particularly by combining it with other technologies to create systems dedicated to sustainable practices.

In 2025, Gillick et al proposed an economically feasible model for a geothermal plant to be utilised as a biogas reformation facility and a design for a wellbore methane reformation tool.

The facility would be multi-purpose, disposing greenhouse gas, performing carbon sequestration and producing renewable hydrogen fuel for green energy applications.

Biogas, primarily methane, would be pumped into the geothermal well. It would decompose to carbon dioxide and hydrogen under the high temperature and pressure.

The CO$_2$ would be stored in the geothermal reservoir and the hydrogen, which comes to the surface, would be filtered using electrochemical membranes. These utilise far less energy than electrolytic cells (3-5 kWh/kg vs 45-55 kWh/kg).

They estimate from their economic analysis that they could produce hydrogen at $3-4 USD/kg with the use of two shallow borehole wells.

The advantages of such a system are that it can be integrated into a geothermal power generation set up as well; the carbon removal does not require any additional system as the CO$_2$ would become stored in the reservoir. And the heated CO$_2$ could improve geothermal fluid efficiency by 15-50%.

Furthermore, this process can be performed in shallow wells (1,500-2,000 m) as well. This could lower installation costs of such a system by 50%.

Integrating such a system into an agricultural area, where large amounts of biogas are produced from organic waste and manure, would be highly economically and environmentally beneficial.

The facility would provide electricity, heating, renewable hydrogen fuel, and dispose of biogas contributing to the greenhouse effect [12].

Another interesting hybrid system was proposed by Fatih Yilmaz; a geothermal energy based multi-generation plant that combines a flash-binary geothermal cycle, with a secondary Rankine cycle using CO$_2$ as the working fluid, a PEM electrolyser for hydrogen production and a water desalination plant.

The geothermal fluid, water is injected into a flash chamber in the geothermal well.

As it is heated, the expanding vapours drive a steam turbine.

The residual heat from the fluid then drives a transcritical CO$_2$ Rankine cycle for further power generation.

The residual heat from the secondary cycle and primary cycle is then used to drive a desalination process.

The freshwater produced is electrolysed using a polymer electrolysing membrane (PEM), with electricity produced from the primary and secondary cycles.

Analysis of the system with realistic parameters and economic metrics yielded a power output of 1,639 kW, a hydrogen generation rate of 0.002081 kg/s and overall energetic efficiency of 52.01%.

The estimated cost of running the entire plant was £139.6USD/hr [13].

The multi-generation hybrid plant displays a much higher efficiency compared to a standard single generation plant.

Future directions

With geothermal systems, the trend is towards creating increased access for geothermal power extraction. Whether by improving methods for creation of artificial permeability (EGS) at thermally active sites or newer systems that are capable of reaching hotter geothermal reservoirs at greater depths.

Furthermore, increased efficiency of geothermal cycles remains a key objective as it is linked to economic feasibility.

To this end, different choices of working fluids like carbon dioxide and closed loop systems such as heat pipes are being explored.

With EGS, the application of more advanced sensory tools and control methods in addition to more precise fracturing methods is the key area of development. This will create reservoirs optimised for fluid circulation and heat extraction and minimise induced environmental effects like instability or seismicity.

The design of new geothermal systems such as heat pipes or other high efficiency closed systems, and their implementation and testing, are a second area of great potential.

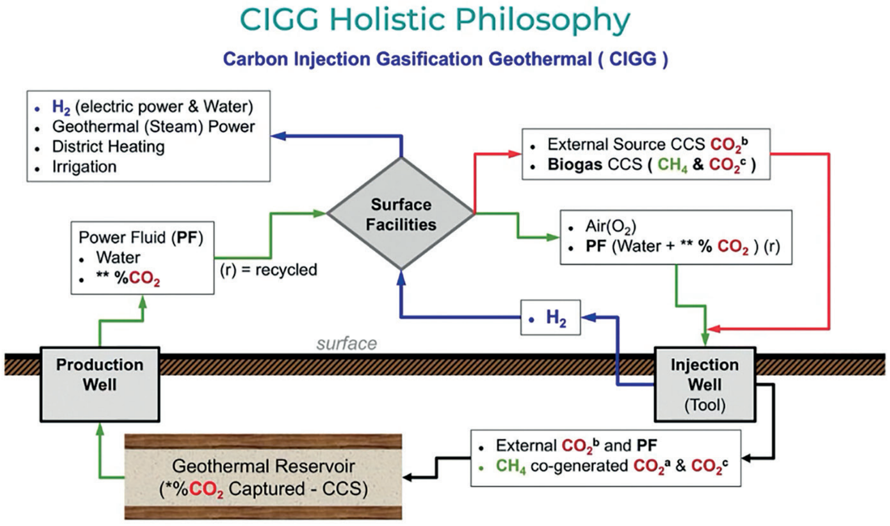


Figure 9: Flow diagram for proposed multi-purpose geothermal facility [12]

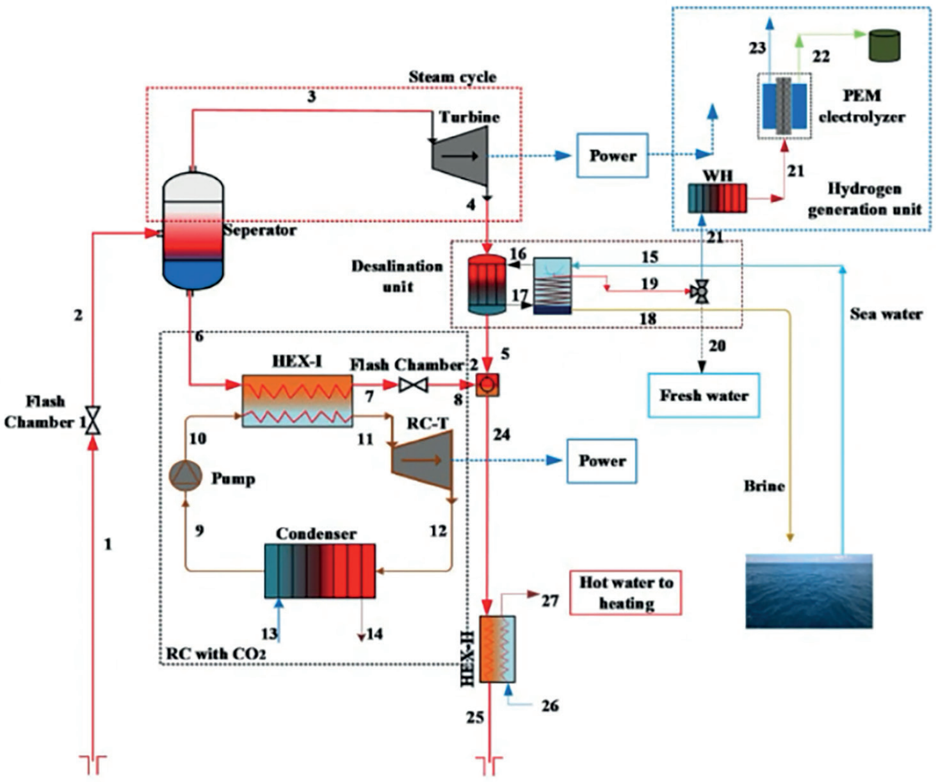


Figure 10: Cycle schematic for proposed multi-generation plant [13]

With the work on alternate working fluids, the current body of work is mostly computational. Experimental studies and practical implementation are the next step to develop the next generation of geothermal systems.

Though the mining industry for geothermal wells is currently dominated by conventional methods, the potential of alternate mining technologies, such as Millimeter Wave Drilling, specialised for the conditions of geothermal reservoir rock is recognised. Particularly as they become more economically viable.

Further field testing and access to resources for experimental validation are essential for MMW drilling and other methods to enter commercial use. Particularly as the high hardness, high heat drilling conditions for geothermal wells are difficult to simulate or substitute.

Implementation of AI and ML applications in the geothermal industry is at an upward trend.

For site identification, the advancement and increase in sophistication of ML models is the main area of focus.

As their predictive power increases, and their capabilities tested further, these models have the potential to substitute conventional surveying methods and reduce exploration costs.

For this, however, greater availability of geo-physical data and advancement of remote sensing methods is key.

As for plant operational systems like GOOML, as they become more accurate and reliable with further training and testing, they can phase out manual operation.

Integration with reinforcement learning based agents, as is being currently experimented with, opens the possibility of autonomous control systems. These can optimise a plant for productivity whilst being conscious of safety and environmental regulations.

Economic feasibility remains one of the main challenges to expansion of geothermal energy. Hybrid multi-functional systems that can maximise the productivity of a geothermal site emerge as a solution to make large scale implementation of geothermal energy more viable.

Geothermal systems that can perform functions like carbon capture, desalination and hydrogen production (which itself is a lucrative emerging industry) have increased economic value.

They can be integrated into economic zones, such as a bio-gas reformation-geothermal system constructed in an agricultural area, to make entire communities more sustainable and improving their access to resources such as heating and electricity.

The design of such systems, and studying their economic viability, is a key area for further research.

Conclusion

Though geothermal energy has seen steady growth over the past several decades, it is experiencing unprecedented prominence.

The expansion of geothermal energy is complemented and propelled by technological innovation and advancement in almost every facet of the industry, with a general focus towards more efficient, more environmentally friendly, and multi-functional systems.

Technological advancements, particularly in the last three to four years, can be observed as falling into four domains.

The geothermal systems themselves, where new technologies such as SLGHP, are proposed to increase efficiency. And a shift is seen towards enhanced geothermal systems, optimised for maximal heat extraction, even where the natural reservoirs are not present.

Overall, advancements in this domain are pushing for deeper wells and more scalability, overcoming geographical restrictions.

Geothermal drilling has benefited majorly from advancements in petroleum drilling, which is a much larger industry.

However, as a push is made towards deeper and hotter wells, the need for specialised drilling technology has emerged. This technology can allow for faster, deeper boring, and minimise the cost of geothermal well installation.

Amongst many other technologies, Millimeter Wave Drilling has emerged as a new prospect. It shows great promise but requires much additional field testing.

The application of AI and ML tools is another such domain that have garnered the focus of researchers in recent years.

The use of ML methods for site identification and mapping has moved from research studies to guiding geothermal installation projects. This is due to its ability to reduce surveying and exploration costs.

Furthermore, the development of systems like GOOML presents new avenues for the optimisation of geothermal energy production and maximisation of productivity through data analysis and creating pathways towards breakthroughs such as autonomous control systems.

The final domain is hybrid systems. These are the combination of geothermal power with other sustainable technologies such as geothermal plants integrated with biogas reformation systems for carbon capture and hydrogen production, or multi-generation, multi-cycle geothermal plants that perform desalination and hydrogen production synchronously.

Research is directed towards the development of these systems and making them economically feasible.

Geothermal energy is geared towards larger scale commercialisation. And the technology in the field is advancing to support this ambition.

The direction, and the goal of these advancements is summarised as such: reducing costs and increasing productivity and efficiency.

References

[1] J. W. Lund, G. W. Huttrer, and A. N. Toth, “Characteristics and trends in geothermal development and use, 1995 to 2020,” Geothermics, vol. 105, 2022, Art. no. 102522, doi: 10.1016/j.geothermics.2022.102522.

[2] R. DiPippo, Geothermal Power Plants, 5th ed. Amsterdam, Netherlands: Elsevier, 2015.

[3] W. Huang, J. Wang, Y. Liu, Y. Yang, and C. Chen, “Developing kilometers-long gravity heat pipe for geothermal energy exploitation,” Energy & Environmental Science, 2024.

[4] T. Elshehabi and M. Alfehaid, “Sustainable geothermal energy: A review of challenges and opportunities in deep wells and shallow heat pumps for transitioning professionals,” Energies, vol. 18, no. 4, pp. 811–832, 2025, doi: 10.3390/en18040811.

[5] Utah FORGE, “FORGE completes stimulation and circulation tests,” Univ. of Utah, May 2024.

[6] R. Podgorney et al., “A reference thermal-hydrologic-mechanical native state model of the Utah FORGE site,” Energies, vol. 14, no. 16, p. 4758, 2021.

[7] L. Cong, S. Lu, P. Jiang, T. Zheng, Z. Yu, and X. Lü, “Research progress on CO_2 as geothermal working fluid: A review,” Energies, vol. 17, no. 5415, pp. 1–32, 2024, doi: 10.3390/en17215415.

[8] R. Pearce and T. Pink, Drilling for Superhot Geothermal Energy: A Technology Gap Analysis, 2024.

[9] J. Moraga et al., “The Geothermal Artificial Intelligence (GEAI) for exploration,” Renewable Energy, vol. 192, pp. 134–149, 2022.

[10] J. Luo, J. Shen, X. Liu, and H. Shi, “Evaluating the potential distribution of deep geothermal resources in the North Jiangsu Basin, East China, using machine learning,” Sustainable Energy Technologies and Assessments, vol. 54, 2024, Art. no. 102851.

[11] M. Siratovich, H. Scott, W. Hagen, and T. Sewell, “GOOML: Machine learning optimization of geothermal power plants,” in Proc. 47th Workshop on Geothermal Reservoir Engineering, Stanford Univ., Stanford, CA, USA, Feb. 2022.

[12] S. Gillick and M. Babaei, “A geothermal energy techno-economic analysis for downhole wellbore hydrogen production from biogas with subsurface carbon retention,” Energy & Fuels, 2025.

[13] F. Yilmaz, “Development and modeling of the geothermal energy based multigeneration plant for beneficial outputs: Thermo-economic and environmental analysis approach,” Renewable Energy, 2022.

[14] J. Salas, “Quaise energy demos millimeter wave drilling for deep geothermal,” *New Atlas*May 29, 2025. Accessed: Dec. 19, 2025. [Online]. Available: https://newatlas.com/energy/quaise-energy-millimeter-wave-drill-demo-houston/

Biographies

Dr. Raj Shah is director at Koehler Instrument Company in New York, where he has worked for over 25 years. He is an elected Fellow or Chartered professional with numerous organisations, including ASTM, IChemE, STLE, NLGI, the Energy Institute, the Royal Society of Chemistry, and the Chartered Management Institute, among others, and is an ASTM Eagle Award recipient. He coedited the bestseller *Fuels and Lubricants Handbook* and holds a PhD in Chemical Engineering from Penn State. Dr Shah is an adjunct professor in materials science and chemical engineering at Stony Brook University, serves on multiple academic advisory boards, and has authored over 725 publications during more than three decades in the energy industry.

Mathew Roshan

Mr. Mathew Stephen Roshan is a chemical and molecular engineering undergraduate student at Stony Brook University and intern at Koehler Instrument Company, Holtsville, NY. He also serves as a research assistant at Stony Brook University where he studies vehicle design and tribology and is a member of his local AIChE Chapter and FSAE Team.

Author Contact Details

Dr. Raj Shah, Koehler Instrument Company
- Holtsville, NY11742 USA
- **Email: rshah@koehlerinstrument.com**
- **Web: www.koehlerinstrument.com**