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Eyes Inside Geothermal Plants with Internet of Things

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INTRODUCTION

The wide adoption of Internet of Things (IoT) technology has enabled the physical world to be digitally monitored and controlled. In geothermal power generation, plant efficiency depends on: **maintaining thermal balance, managing steam flow, water pressure, and temperature**. **Sensors** such as thermistors measure extreme subsurface temperatures, while **actuators** automatically adjust valves and motors to optimize performance remotely. Integrating IoT into daily operations enables real-time data acquisition and anomaly detection, hence minimizing downtime and maintenance costs. This capability is increasingly germane in today's digital era of rising energy demand. Despite its capital-intensive requirement, geothermal energy remains one of the most reliable baseload power sources, and innovations such as **wellhead generation** continue to accelerate its deployment. To keep pace with that trajectory, the integration of IoT could positively shift how geothermal systems are managed and overhauled. As stated in Huawei's 2030 Digitalization Report: "In the fight for a greener future, energy is the main battlefield, electric power is the main force, and digitization is the key."

METHODS

- Adopted a desktop-based research approach to explore the application of IoT in geothermal systems.
- Reviewed reputable technology sources such as IBM blogs and McKinsey Insights for general IoT trends and benefits.
- Conducted an online literature review to identify three leading geothermal companies which are integrating IoT into their operations.
- Analyzed how these integrations have influenced monitoring efficiency, predictive maintenance, overall plant performance, and cost savings.

RESULTS

CONCEPTUAL FRAMEWORK

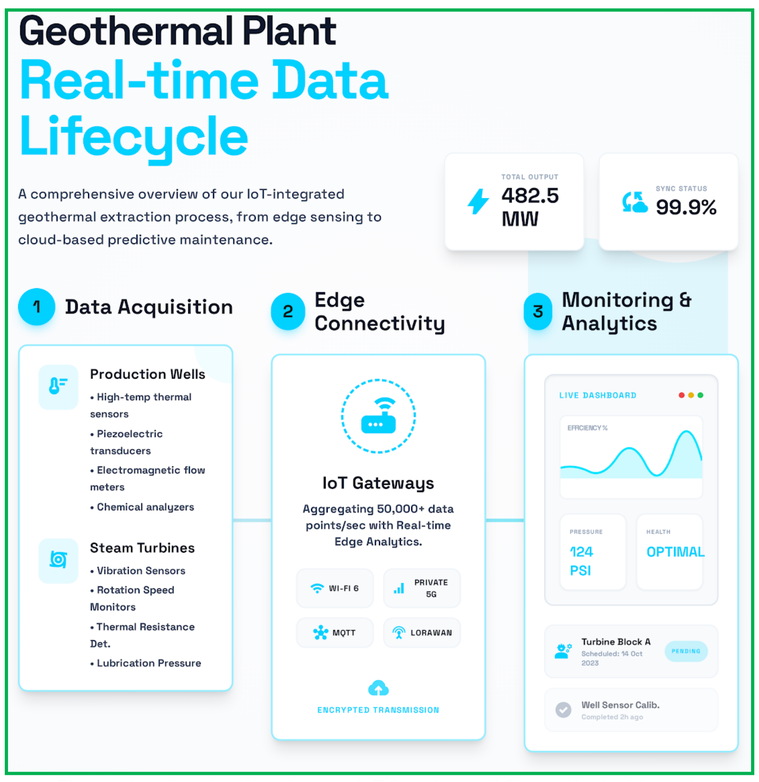
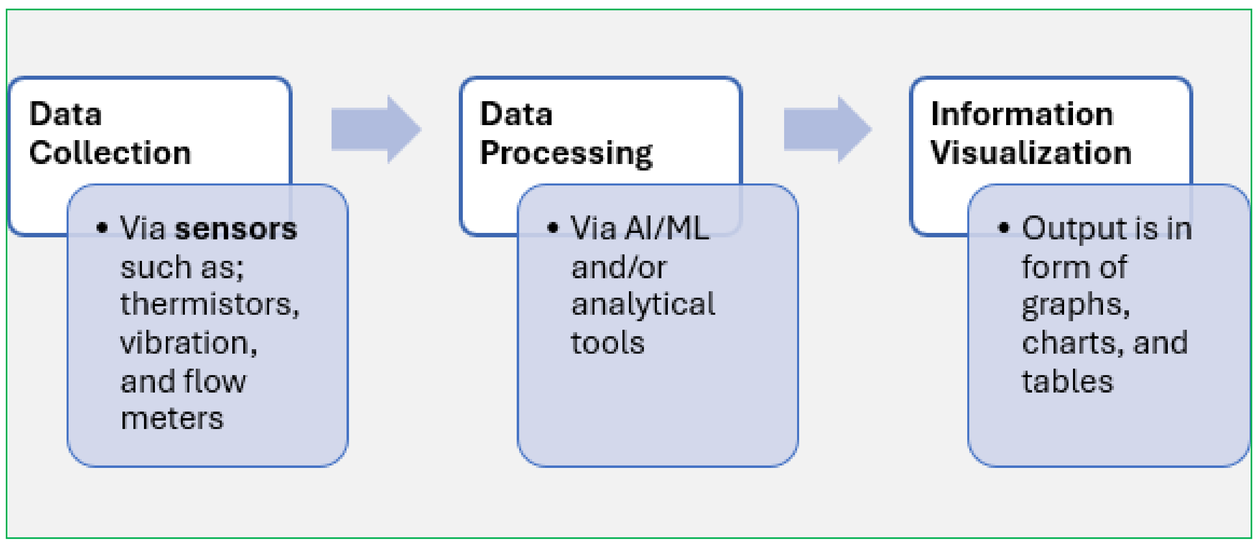


Figure showing simulated smart IoT Geothermal System's dashboard.

(1) Data Collection from sensors all across the plant, from the deep wells to the spinning turbines. The actuators put in place enable automatic opening and closing of valves which saves time and removes the need for a professional on site especially since most plants are located in remote areas away from the main control room.

(2) Real-Time Processing as the system receives big data from the sensors, It is run by analytical and visualization tools to extract insights and flag any real-time error or predict near failures.

(3) Visual Output: It transforms those complex calculations into simple charts and alerts, giving operators a clear and live picture of the entire plant's operation.



DISCUSSION (USE CASES)

Various geothermal companies which integrated Internet of things into their operations have reported added benefits that include:

- KenGen (Kenya): Deployed Yokogawa's ExaPilot and ExaQuantum to centralize operational data and automate root cause analysis, equipment monitoring, and performance optimization. This in turn improved maintenance, operational efficiency, and sustainability, earning KenGen the Best Public Sector Digital Innovation Award.
- Patuha Geothermal Plant (Indonesia): Toshiba's EtaPRO monitoring software reduced system faults by 20% through real-time detection of geothermal-specific anomalies such as **thermal inversions** and **surging wells** by enabling faster corrective response and equipment protection.
- Enel Green Power (North America): Implemented IoT-based predictive monitoring across its 25 MW Cove Fort, 13.4 MW Salt Wells, and 33.1 MW Stillwater geothermal plants. The system provided real-time diagnostics for Electrical Submersible Pumps (ESPs), enabling early fault detection, reduction of downtime, and improvement of plant reliability.

CONCLUSION

Low-carbon, electrified, digital, and intelligent systems will define the next phase of global energy stability. Geothermal energy stands out as a sustainable baseload option capable of operating continuously, regardless of weather or time. When integrated with Energy 4.0 technologies such as the Internet of things (IoT), geothermal systems can achieve higher efficiency and reliability through continuous data collection, real-time control, and predictive analytics.

These digital integrations reduce unplanned outages, extend equipment lifespan, safeguard the health and well-being of professionals, as well as optimizing energy output. They also protect the staff from continuous exposure to hazardous gas leaks since some anomalies can be corrected remotely via the use of actuators.

Ultimately, IoT-enabled geothermal plants represent a shift toward smarter and cleaner energy production, from the above use cases, it is clear that IoT is reducing maintenance costs, thereby creating a pool of resources that can be allocated to further development or upgrade in the sector.

Acknowledgements

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