WHITE PAPER:

INCREASING CARBON-FREE ENERGY WITH INTELLIGENT DIGITAL SOLUTIONS

Geothermal resources to support electric power generation are available worldwide. New and existing plants can be more productive using the latest digital technologies.

Domo de San Pedro Geothermal Power Station in Nayarit, Mexico © Image courtesy of Geotérmica para el Desarrollo

GEOTHERMAL: A SOURCE FOR DISPATCHABLE RENEWABLE ENERGY

The world is hungry for more energy, while climate change requires lower emissions from power plants. Power-generation companies must supply more energy and lower emissions at the same time. One type of power plant that has an edge when it comes to supplying carbon-free energy is geothermal. Geothermal power generation involves no fossil fuel combustion because it uses magma heat energy inside the earth. Therefore, it emits little carbon dioxide to the atmosphere during operation and is very effective against global warming.

Geothermal power plants can run all the time, given that their fuel source is constant. Thus increasing energy generation with geothermal offers decarbonization with fully dispatchable renewable and carbon-free energy. It is a valuable baseload source of renewable power that is not susceptible to external factors like the availability of wind and sun, neither of which can be considered to be reliably dispatchable.

Geothermal plants even have some advantages over existing hydro plants in times when there is low rainfall or drought threatens, and perhaps longer term if climate change continues to redistribute rainfall. Geothermal is the only renewable energy resource that truly is reliably available 24/7/365.

Thus anything that can sustain the long-term power output, reliability or availability of a geothermal power plant is very valuable.

USA

Turkey

Philippines

Iceland

GLOBAL OPPORTUNITIES FOR NEW AND EXISTING GEOTHERMAL POWER

There are hundreds of geothermal power plants in operation in 30 countries around the world that are already capable of generating nearly 16 GW (Source: Proceedings of the World Geothermal Congress 2021+1), and there is opportunity to build additional plants in many areas.
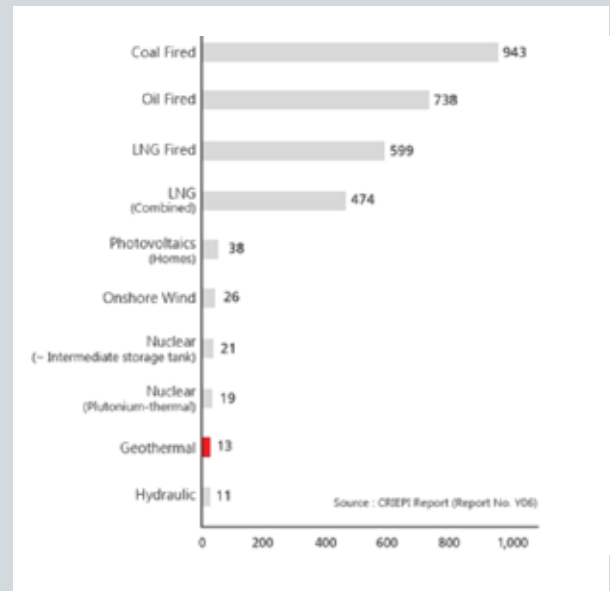
A significant challenge for operators of geothermal power plants is that sources of geothermal energy gradually change their characteristics over time, so regular optimization of O&M practices and thermal cycle equipment are needed to maximize the productivity of geothermal plants.

Another challenge is that the steam generated from geothermal sources can contain impurities that require special attention to sustain the maximum potential electrical output from the geothermal heat source.

The growing opportunities for application of new digital technologies based on extensive geothermal plant construction, operation and maintenance experience, combined with experience developing advanced technology for gas and steam turbine applications, provide a firm foundation for tailoring intelligent solutions that help geothermal plant operators manage the unique conditions of their plants for improved efficiency and reliability.

The latest monitoring, plant process simulation and advanced analytics provide the data for early identification of anomalies,

LIFE CYCLE CO_2 EMISSIONS (g-CO_2/kWh) FROM POWER-GENERATION TECHNOLOGIES

Technology	Emissions
Coal Fired	943
Oil Fired	738
LNG Fired	599
LNG (Combined)	474
Photovoltaics (Homes)	38
Onshore Wind	26
Nuclear (~ Intermediate storage tank)	21
Nuclear (Plutonium-thermal)	19
Geothermal	13
Hydraulic	11

Source : CRIEPI Report (Report No. Y06)

performance degradation trends and optimization opportunities. Once identified and classified by root cause, corrective actions to offset the changes can restore the plant to optimum performance in the most cost-effective manner.

TECHNOLOGY ADVANCEMENTS FOR GEOTHERMAL POWER PLANTS

In recent years, there have been many advancements in geothermal power plant technology that improve their efficiency, reliability and profitability. A real-world example of advancements in technology that increases reliability and efficiency is at the Domo de San Pedro Geothermal Power Station in Nayarit, Mexico.

The Domo de San Pedro Geothermal Power Station is the first geothermal power plant in the world to add Mitsubishi Power's TOMONI® intelligent digital solutions to improve efficiency and reliability. TOMONI solutions were applied to the Domo de San Pedro Power Station to sustain its long-term competitiveness through asset optimization, analytics for operator and maintenance support, and artificial intelligence.

Mitsubishi Power built the 25-MW Domo de San Pedro plant under a turnkey engineering, procurement and construction contract completed in 2016. Because geothermal production wells change over time and steam conditions diverge from optimal design, geothermal plants should be optimized periodically to compensate for these changes.

The intelligent digital solutions applied at Domo de San Pedro include remote monitoring and real-time data analysis of the total power plant systems. Mitsubishi Power combines its experience in plant design and operation with actual operating data to develop real-time models that identify opportunities to optimize plant operation and maintenance.

For example, equipment is monitored online for degradation of thermodynamic performance, an indicator of scale accumulation caused by naturally occurring minerals in the steam and hot water, so optimal outage plans can be developed based on the plant's actual condition rather than on standardized remedial schedules. Remote monitoring and support services can also shorten or even prevent unplanned outages by detecting anomalies and providing early countermeasure planning and operational guidance.

Domo de San Pedro now has the tools to diagnose and predict changing operating conditions and to develop optimal solutions that allow the plant to continuously adapt to maximize plant performance and reliability. Those tools have been supporting detailed simulation and analysis of current geothermal resource conditions and have identified plant modifications that will increase net plant output of

KEY PLANT AND WELL PARAMETERS

AUTOMATED TRACKING AND REPORTING
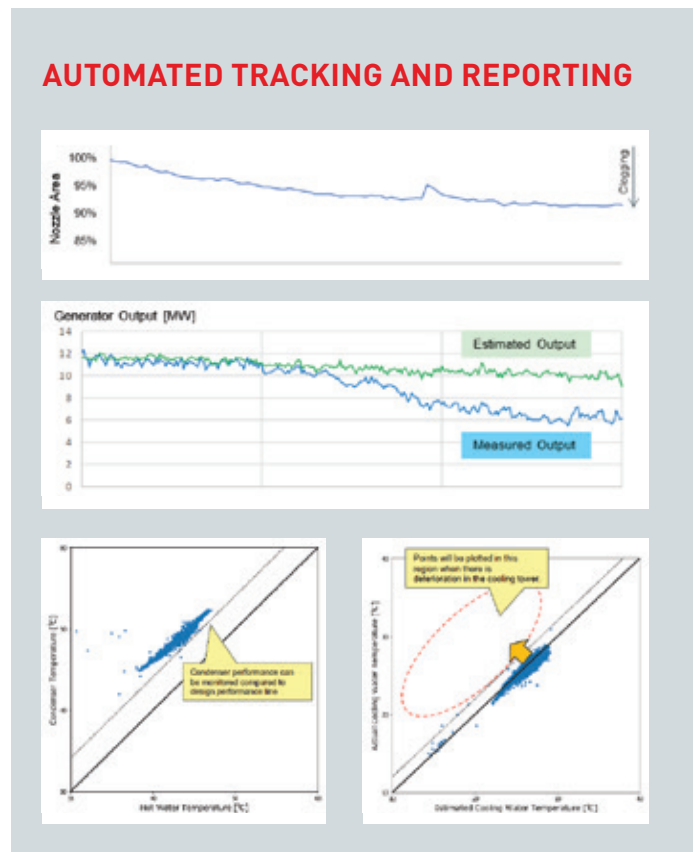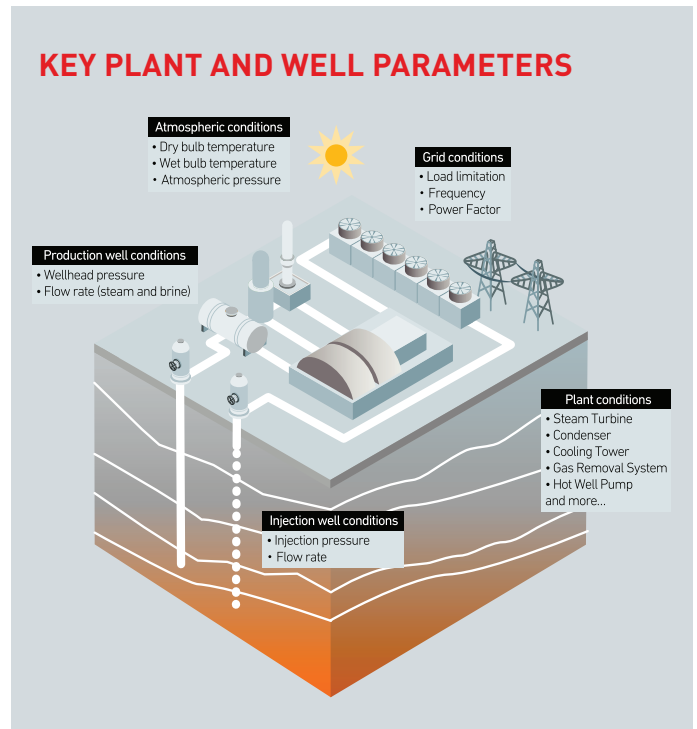
the existing generating unit by nearly 10%. They have also identified several opportunities for the existing equipment to operate more efficiently and reliably, thereby increasing the long-term cumulative generation from the plant (results on other plants may vary based on plant configuaration and well condition).

Nagasaki, Japan TOMONI HUB that supports geothermal power plants

REAL-TIME INTERACTIVE SUPPORT OF GEOTHERMAL PLANTS

The TOMONI HUB Analytics and Performance Center in the Mitsubishi Power Nagasaki Shipyard and Machinery Works in Nagasaki, Japan, remotely supports operations and maintenance (O&M) for various types of power-generating equipment, including geothermal power systems, with the full expertise of plant and equipment designers.

For geothermal power plants, O&M support includes a focus on scale precipitation within the steam processing equipment and steam turbines of geothermal generators, as these are routinely placed in harsh environments that are highly susceptible to corrosion. It tracks and trends changes in geothermal well characteristics such as pressure, flow and impurity composition to compare to the equipment design basis and allows identification of the most effective and economic cycle optimization over time. It also applies analytics proven on fired boiler and other steam turbine–based thermal cycles, electric generator and BOP systems to maximize the performance of the total plant.

For over 20 years, Mitsubishi Power has been steadily expanding the capabilities of its TOMONI HUB network and has been successfully providing remote monitoring and increasing the use of advanced analytics to make power plants more reliable and profitable.

TOMONI HUB provides connected software and services that monitor and provide early warning of impending issues or needed corrective action to avoid unit trips or load reductions while reducing energy-efficiency losses and avoiding unnecessary maintenance.

TOMONI HUBs are centralized resources that can support all types of energy systems, long-term and short-term energy-storage systems. Proven benefits show plants connected to TOMONI HUB have on average two to four fewer days of unplanned downtime per year and three to four fewer days of planned downtime per year than similar unconnected plants, providing millions of dollars of annual value for their owners.

Increasing the energy generated by geothermal plants significantly contributes to decarbonization goals to cut emissions and supply carbon-free energy. Combined with new technology advancements such as artificial intelligence, analytics and remote monitoring, geothermal power plants will improve their efficiency, reliability and profitability to create more energy from existing and future geothermal power plants.

TOMONI intelligent digital solutions for geothermal power plants monitor, analyze and model data to:
- Simulate expected performance versus actual performance
- Optimize the thermodynamic cycle
- Mitigate scale accumulation effects
- Reduce maintenance intervals and costs
- Identify opportunities to optimize and improve performance

TOMONI® is a suite of intelligent solutions that accelerates decarbonization with power plant design, O&M and system knowledge, together with strong customer and partner collaborations. TOMONI leverages advanced controls, artificial intelligence and machine learning with multi-layered cybersecurity to make energy systems smarter, more profitable and ultimately more autonomous on the road to a sustainable future.

TOMONI®

■ **Data Foundation & Enablers**
■ **O&M Optimization**
■ **Performance Improvement**
■ **Flexible Operations**