MITSUBISHI POWER

Geothermal

Power Plants

Mitsubishi Heavy Industries, Ltd.
Energy Systems

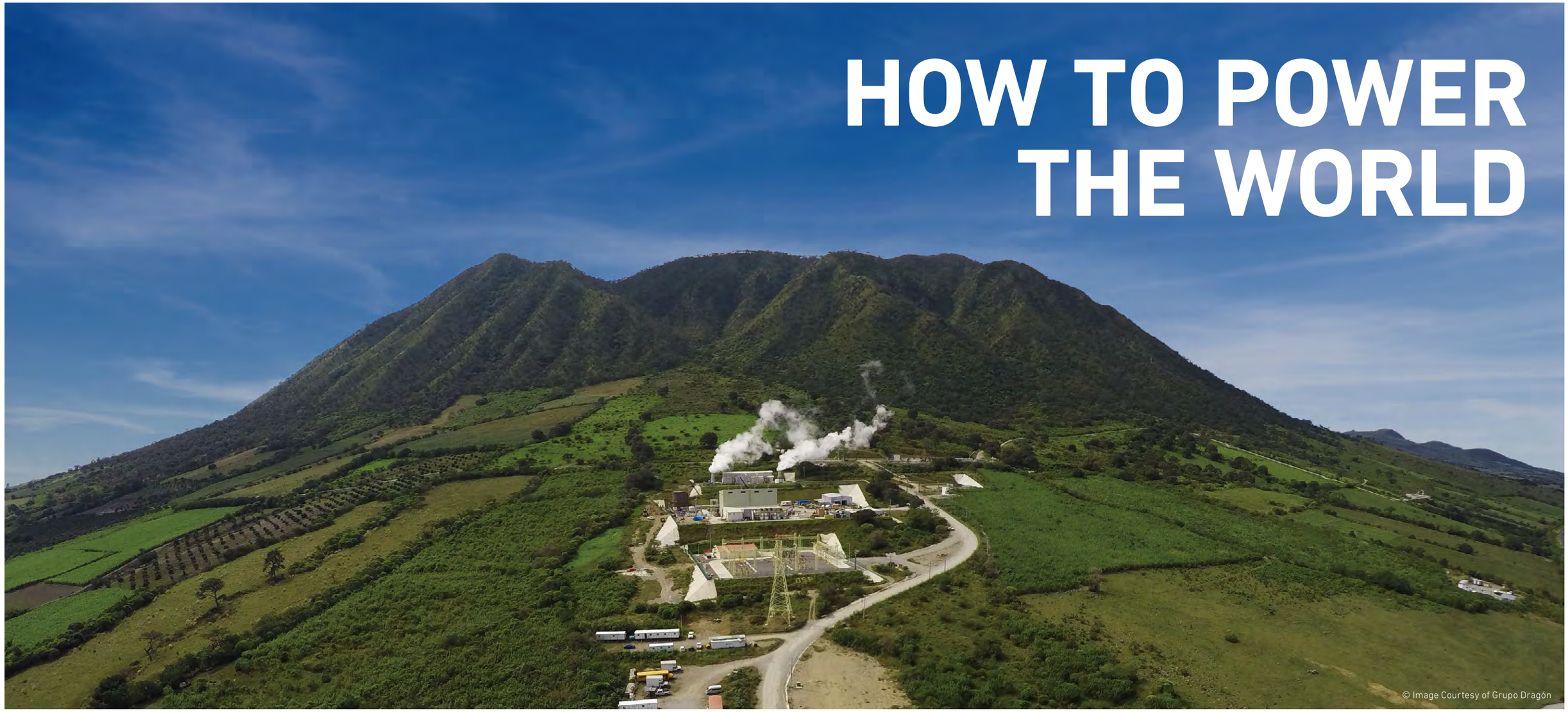
3-3-1, Minatomirai, Nishi-ku, Yokohama,
Kanagawa, 220-8401, Japan
power.mhi.com

METP-01GP01E1-A-0, (1.0)21-09, ZEG

Mitsubishi Power is a power solutions brand
of Mitsubishi Heavy Industries.

MOVE THE WORLD FORW>RD MITSUBISHI HEAVY INDUSTRIES GROUP

HOW TO POWER THE WORLD



© Image Courtesy of Grupo Dragón

OUR PLANET IS CALLING FOR AFFORDABLE, SUSTAINABLE, HIGHLY RELIABLE AND CLEAN POWER. TOGETHER WE CAN ACHIEVE IT.

Power grows when we all work together.

There is a strong demand for energy decarbonization in the world today. One in ten people is forced to live without reliable access to electricity, while global demand for power continues to grow. Mitsubishi Power addresses such needs by providing stable, highly reliable, and clean energy solutions.

Mitsubishi Power, a power solutions brand of Mitsubishi Heavy Industries based on a long history of product development and supply for more than a century, has been dedicated to designing, manufacturing, verifying, engineering, installing and providing services for a wide range of proprietary power generation systems.

One of our products is gas turbine combined cycle (GTCC) power plants, which provides incredibly efficient electric power while reducing CO_2 emissions.
We also provide next-generation power systems, such as integrated coal gasification combined cycle (IGCC) power plants, steam power plants, geothermal power plants, air quality control systems (AQCS) and intelligent solutions TOMONI™.

Mitsubishi Power combines cutting-edge technology with deep experience to deliver innovative, integrated solutions that help to realize a carbon neutral world, improve the quality of life and ensure a safer world.

Geothermal
Power Plants

Mitsubishi Power's geothermal power plants extract heat energy from the ground to produce environmentally-friendly electric power of high efficiency with the latest power generation technology.

High Performance and Reliability

Environmentally-Friendly

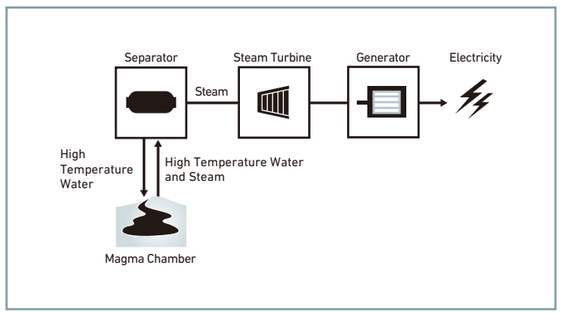
Engineering, Procurement and Construction (EPC) Services

Wide Output Range from
100 kW to 160 MW

What is geothermal power?

Geothermal power comes from the Earth. Deep inside the planet, arteries flowing with molten-hot magma create extremely hot water and highly pressurized steam. The steam and hot water are extracted from the ground through production wells. The steam separated by the separator rotates a turbine that activates a generator, which produces electricity. The hot water separated by the separator is re-injected into the underground, providing a sustainable resource.

Geothermal power plants are a highly capable and reliable supply of permanent electricity. Otake Geothermal Power Plant, Japan's first water-dominated geothermal power plant, was commissioned in 1967 and has been delivering reliable power for over 50 years.



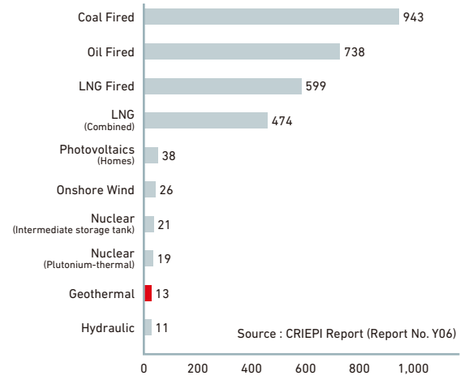
High performance and reliability

Mitsubishi Power became the first in the world to introduce the two-phase flow transportation system and the double flash cycle as technologies for geothermal power generation. We have been striving to develop new geothermal power generation technologies. Based on research findings accumulated over a long period of time, our geothermal power plants have been verified to produce high performance and high availability all over the world. For example, the Los Azufres III phase I geothermal power plant in Mexico, which came into operation in 2015, achieved an availability of 99.6% during the one-year from the commencement of operation. Mitsubishi Power will continue to supply reliable electric power on the basis of our superior geothermal power generation technologies.

Environmentally-friendly

Geothermal power generation involves no combustion on the ground because it uses magma heat energy from inside the earth. Therefore, it emits very little carbon dioxide to the atmosphere and is effective against global warming. While it is a natural energy source, heat energy that exists in large quantities inside the earth is not affected by weather conditions. This gives geothermal power generation the advantage of a high availability, comparable with that of thermal power generation.

Life cycle CO_2 emissions (g-CO_2/kWh) from power generation technologies



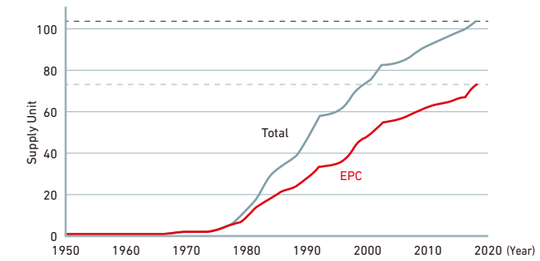
Engineering, procurement and construction (EPC) services

Mitsubishi Power is not merely a manufacturer that designs and manufactures the equipment and devices required for geothermal power plants. We also provide EPC services, including plant construction, in a consistent manner.

We delivered over 100 geothermal power plants since 1950 and we supplied EPC service for more than 70% of them. Accordingly we have offered engineering, procurement and construction services.

Our strength is the optimization and integration of power plants, including design, manufacturing and construction to ensure maximum output from limited geothermal energy and atmospheric properties which vary from region to region.

Supply units for geothermal power plant



Contribution to Kenya's expansion of environmentally-friendly energy sources

KenGen's 105MW Olkaria II Geothermal Power Plant.
Source: Kenya Electricity Generating Company (KenGen) PLC

Olkaria I-II & V Specification

Scope of Delivery	EPC
Commercial Operation	I-#1: 1981, #2: 1982, #3: 1985 II-#1,2: 2003, #3: 2010 V-#1,2: 2019
Type	Single Flash Cycle, Down Exhaust
Output	I-#1-3: 15 MW II-#1,2: 34.83 MW, #3: 35.14 MW V-#1,2: 86.16MW
Speed	3,000 rpm
Main Steam Temprerature	I-II: 152℃, V: 184℃
Exhaust Pressure	I-II: 0.13 bara, V: 0.074 bara

In Kenya, hydroelectric power has been the mainstay of the country's power generation industry for several decades. However, in recent years, poor rainfall has limited hydropower production, resulting in serious power shortages and a growing reliance on thermal energy sources to make up the shortfall.

To stabilize the electricity supply and meet projections for a sharp increase in energy demand, the government's Kenya Vision 2030 national development policy set targets to significantly expand energy generation capacity by 2030. As part of the policy, it has made increasing geothermal power generation, harnessing the country's ample geothermal resources, a top priority.

Executing every phase of the geothermal power generation process

Mitsubishi Power has been involved in geothermal development by the national electric utility, Kenya Electricity Generating Company Ltd. (KenGen), in the Olkaria steam field in the Great Rift Valley, since the early 1980s. Beginning with the installation of a 15 MW power plant at Olkaria I-#1 1981, it was followed by two additional 15 MW power plants at I-#2, 3. In 2003, at Olkaria II- #1, 2 combined to provide 70 MW (35 MW x 2). Then in 2010, Olkaria II-#3 provided an additional 35 MW of power capacity.

Subsequently, the 170MW Olkaria V-#1,2 geothermal power plant was constructed under a full turnkey contract and started operations in 2019. Mitsubishi Power designed the plant's geothermal facility and supplied the steam turbines, generators, condensers, and other auxiliary equipment. Making use of our extensive expertise and experience in EPC (engineering, procurement, construction), we also dispatched our technical advisors on-site to assist with installation and commissioning trial runs.

Mitsubishi Power's superior reliability and technology

Mitsubishi Power's performance on this project was highly evaluated for its excellent record of equipment delivery, technological strength and EPC execution capabilities. Today, the project is helping to achieve Kenyan government energy generation targets, while at the same time reducing greenhouse gas emissions and preserving our environment. Thanks to this investment, in recent years geothermal power is positioned to overtake hydropower as the country's main source of power generation.

Geothermal energy is not only securing Kenya's energy future, it is also an important source of employment. By contributing to this sector, which is indispensable for stimulating industrial development and improving living standards, Mitsubishi Power aims to stimulate economic growth and environmental sustainability, while providing reliable and cost-effective electricity to the people of Kenya with our highly efficient and environmentally friendly technologies.

Mitsubishi Power has supplied more than 100 units supplying more than 3,000 MW of geothermal steam turbines to 13 countries worldwide.

Reykjavik Energy
(Hellisheidi)

Country	Iceland
Owner	Reykjavik Energy
Plant	Hellisheidi Geothermal Power Plant #1-6
Mitsubishi Power Scope	EPC
Output	#1-4: 40 MW, #5,6: 45 MW
Commercial Operation	#1,2: 2006, #3,4: 2008, #5,6: 2011

GEODESA
(Domo de San Pedro)

Country	Mexico
Owner	Geotermica para el Desarrollo S.A.P.I. de C.V.
Plant	Domo de San Pedro Geothermal Power Plant
Mitsubishi Power Scope	EPC
Output	25.5 MW
Commercial Operation	2016

Kyushu Electric Power
(Hatchobaru)

Country	Japan
Owner	Kyushu Electric Power Co., Inc.
Plant	Hatchobaru #1,2
Mitsubishi Power Scope	EPC
Output	#1,2: 55 MW x 2
Commercial Operation	#1: 1977, #2: 1990

GÜRMAT
(Germencik)

Country	Turkey
Owner	GÜRMAT ELECTRICITY GENERATION CO. INC.
Plant	Germencik Geothermal Power Plant #I,II
Mitsubishi Power Scope	STG
Output	47.4 MW × 2
Commercial Operation	#I: 2009, #II: 2015

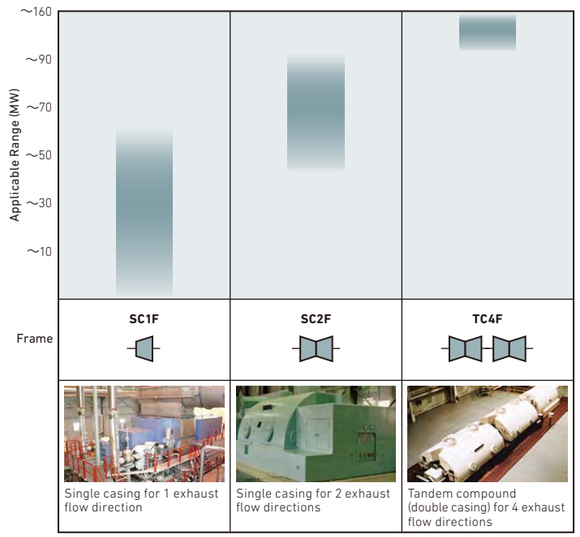
Star Energy
(Darajat)

Country	Indonesia
Owner	Star Energy
Plant	Darajat #2,3
Mitsubishi Power Scope	ST
Output	#2: 81.3 MW, #3: 110 MW
Commercial Operation	#2: 1998, #3: 2007

Steam Turbines

Over the years Mitsubishi Power has supplied more than 100 steam turbines for geothermal plants generating more than 3,000 MW of electricity and satisfying a wide range of output levels to meet various operational requirements.

Wide Output Range: 100 kW to 160 MW

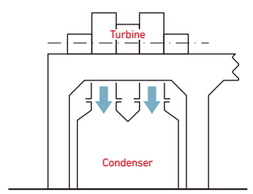


Providing a flexible range of exhaust directions and characteristics

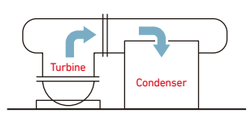
Mitsubishi Power offers a lineup of steam turbines with upward, downward and axial exhaust designs to suit different turbine-generator (TG) building and condenser layouts. The different exhaust directions and turbine building layouts are shown below.

Exhaust direction	Downward exhaust	Upward exhaust	Axial exhaust	
			Surface-cooling condenser	Direct-contact condenser
TG building height	High	Medium	Low	Low
Turbine frame	SC1F SC2F TC4F	SC1F SC2F	SC1F	SC1F
Output	~160 MW	~90 MW	~60 MW	~60 MW

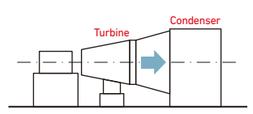
• Output shown above is a guideline



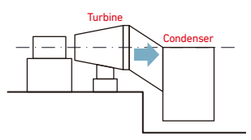
Downward exhaust



Upward exhaust



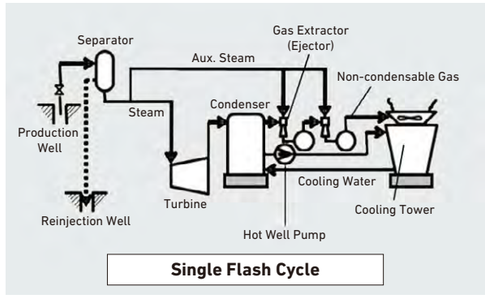
Axial exhaust
(Surface-cooling condenser)



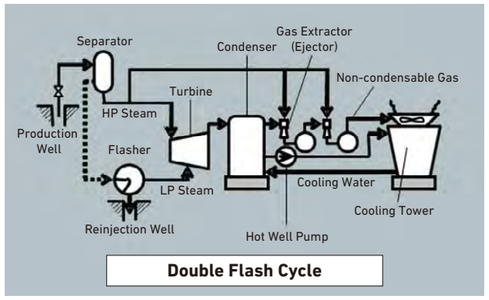
Axial exhaust
(Direct-contact condenser)

Meeting demand for various steam conditions

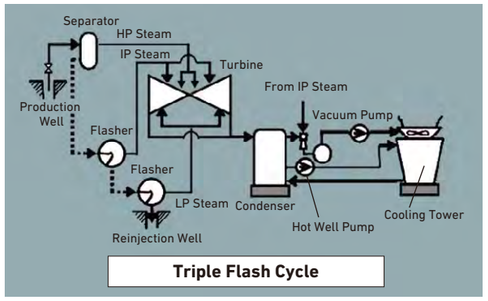
Mitsubishi Power can offer single, double and triple flash cycle to meet the varied demands of different geothermal steam conditions.



Single Flash Cycle



Double Flash Cycle



Triple Flash Cycle

Mitsubishi Power technologies in turbines for geothermal power plants

As geothermal steam contains corrosive gases and impurities such as silica, salt, and solid particles, steam turbine design for geothermal plants has to be not only highly efficient, but also highly corrosive-resistant. Hence, the following technologies are applied in all our turbines for geothermal power plants.

Extra-low sulfur CrMoV rotor material
Compared to low-pressure rotors used in conventional thermal power plants, this rotor material has higher corrosion resistance, resistance against stress corrosion cracking, and higher corrosion fatigue strength. This is achieved by reducing the amount of sulfur and nickel composition and adjusting the rotor quenching temperatures.

12Cr/17-4PH material for blades
Usually 12% Cr stainless steel is used for the blades, but for long blades where stresses are higher, and for first-stage blades where scaling easily occurs, 17-4PH is used. Compared to 12% Cr stainless steel, 17-4PH steel has better corrosion resistance against elements, such as H2S in geothermal steam, better resistance against stress corrosion cracking, and higher corrosion fatigue strength and durability.

3D blades/nozzles
Full 3-dimensional design is used to optimize blade profile so as to minimize secondary losses and frictional losses, thus increasing efficiency.

ISB blades/last stage blades
Integral Shroud Blades (ISB) are designed such that the root section, profile section and shroud form a single body. This eliminates the need for high accuracy assembly required for blades with sections manufactured separately. During operation, the ISB also connects with each other to increase vibration damping and reduce tip leakages, thus increasing reliability and efficiency.

Drain catchers
To reduce water droplet erosion, drain catchers are applied to remove condensed water droplets.

Mitsubishi Power also applies the following technologies, especially designed for corrosive steam conditions.

12Cr rotor material
The amount of Cr is increased to improve resistance against stress corrosion cracking and corrosion resistance.

Titanium blades
Used for first-stage blades when chlorine (Cl) concentration is high in the geothermal steam.

Inconel thermal spraying/overlaying
Applied at the gland sections susceptible to corrosion, so as to increase corrosion resistance.

Casing/diaphragm horizontal flange surface stainless steel overlaying
Stainless steel overlaying is applied on the surface to increase corrosion resistance.

Services

We provide tailored solutions with our technology and system optimization integrated ICT services with TOMONI™ for improved efficiency, reliability, and lifespan.

Maximizing Customer Asset Value

Given that production wells change periodically, understanding these conditions is a key for success. As a world leader in geothermal plants, Mitsubishi Power diagnoses and precisely predicts plant conditions to propose tailored solutions from the extensive list of services available, including inspections, maintenance, repairs and upgrades depending on diverse customer needs and budget.

- Maintaining original design conditions is not always the optimal solution.
- It is important to optimize accordingly with ongoing changes in geothermal resources.

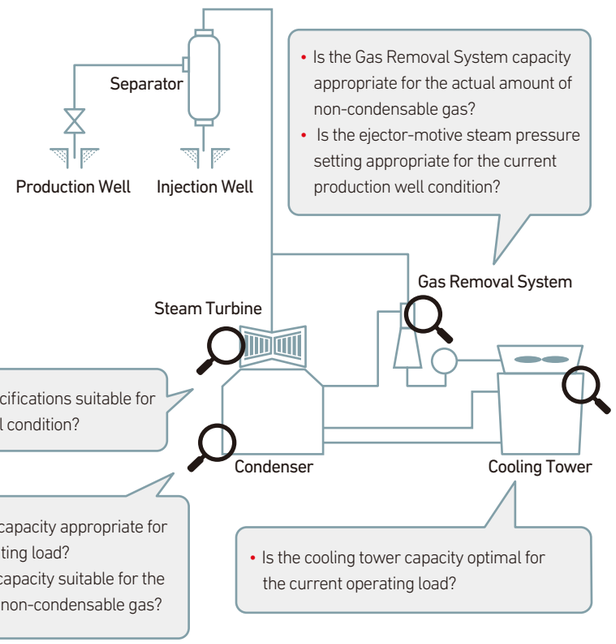
Plant Assessment Services for Diverse Customer Needs

Mitsubishi Power assesses plant operation data and production well characteristics to provide optimum solutions that improves plant performance and reliability, including ones manufactured by other power equipment manufacturers.

Our solutions:

- Main steam pressure optimization
- Brine heat resource utilization
- Auxiliary steam flow reduction
- Auxiliary power consumption reduction
- Condenser vacuum improvement
- Scale deposition countermeasures
- Corrosion countermeasures
- Plant operation troubleshooting

...and more.



Geothermal Steam Turbine Retrofits and Repairs

Aged steam turbines suffer from performance degradation and other various problems due to erosion, corrosion and fatigue damage over decades of operation.

Backed by our experience serving thousands of customers worldwide, Mitsubishi Power offers large-scale retrofitting with the latest technology from whole unit replacement to parts and supplies, as well as repair and restoration depending on plant conditions and customer needs.

We provide comprehensive solutions and long-term services. Integrating TOMONI with these can further increase the value of your assets.

Intelligent Solutions TOMONI™

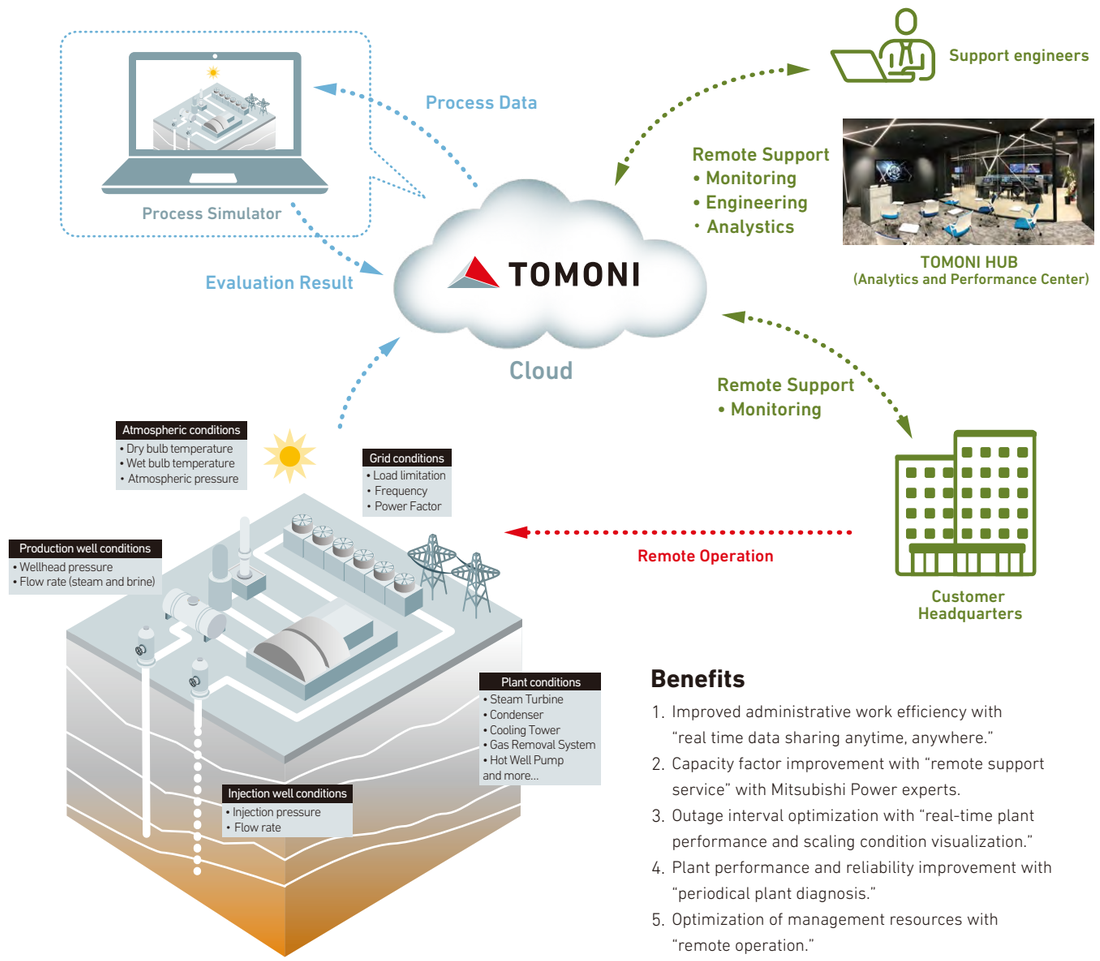
Mitsubishi Power is leading the development of the smart power plant of the future with TOMONI™, a suite of intelligent solutions enabled by decades of O&M and plant expertise. Our solutions utilize advanced analytics and are driven by customer collaboration to deliver powerful financial and environmental advantages.

Features

Our unmatched experience in geothermal plants and TOMONI enable us to provide O&M solutions, including maintenance interval optimization, by visualizing performance degradation status from scale accumulation.

Advanced Operation and Maintenance of Geothermal Power Plants

In order to achieve safe and highly reliable "Advanced Operation and Maintenance" of geothermal power plants, it is necessary to monitor real-time operation conditions and have the engineering ability for proper utilization.
TOMONI provides "real-time plant condition visualization to utilize it correctly," "anomaly detection to prevent unplanned outage," and "quick countermeasure planning and guidance to shorten unplanned outage" via secure TOMONI cloud storage. Customers enjoy our extensive experience, knowledge and engineering ability of geothermal power plants through TOMONI for "advanced operation and maintenance such as remote operation."



Benefits

1. Improved administrative work efficiency with "real time data sharing anytime, anywhere."
2. Capacity factor improvement with "remote support service" with Mitsubishi Power experts.
3. Outage interval optimization with "real-time plant performance and scaling condition visualization."
4. Plant performance and reliability improvement with "periodical plant diagnosis."
5. Optimization of management resources with "remote operation."