Geothermal
Power Plants
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, Ltd. addresses such needs by providing stable, highly reliable, and clean energy solutions.

Mitsubishi Power, a core subsidiary of Mitsubishi Heavy Industries Group 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 CO₂ 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 is creating a future that works for people and the planet by developing innovative power generation technology and solutions to enable the decarbonization of energy and deliver reliable power everywhere.
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.

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.

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

Life cycle CO₂ emissions (g-CO₂/kWh) from power generation technologies

Engineering, procurement and construction (EPC) services

Wide Output Range from 100 kW to 160 MW
**CASE STUDY**

**Contribution to Kenya’s expansion of environmentally-friendly energy sources**

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 trials.

**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.**

**Reykjavík Energy**

<table>
<thead>
<tr>
<th>Plant</th>
<th>Owner</th>
<th>Country</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hellisheiði Geothermal Power Plant #1-6</td>
<td>Reykjavík Energy</td>
<td>Iceland</td>
</tr>
</tbody>
</table>

**Kyushu Electric Power**

<table>
<thead>
<tr>
<th>Plant</th>
<th>Owner</th>
<th>Country</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hatchobaru #1, 2</td>
<td>Kyushu Electric Power Co., Inc.</td>
<td>Japan</td>
</tr>
</tbody>
</table>

**GÜRÜMAT**

<table>
<thead>
<tr>
<th>Plant</th>
<th>Owner</th>
<th>Country</th>
</tr>
</thead>
<tbody>
<tr>
<td>Darajat #2, 3</td>
<td>Star Energy</td>
<td>Indonesia</td>
</tr>
</tbody>
</table>

---

**Olkaria I-#1-3 Specification**

<table>
<thead>
<tr>
<th>Scope of Delivery</th>
<th>Commercial Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>EPC</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Type</th>
<th>Speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single Flash Cycle, Steam Driven</td>
<td>3,000 rpm</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Main Steam Temperature</th>
<th>Exhaust Pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>117.3°C</td>
<td>0.19 bara</td>
</tr>
</tbody>
</table>

---

**Geothermal Power Plant Delivery Results**

<table>
<thead>
<tr>
<th>Country</th>
<th>Owner</th>
<th>Plant</th>
<th>Power Scope</th>
<th>Output</th>
<th>Commercial Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iceland</td>
<td>Reykjavík Energy</td>
<td>Hellisheiði Geothermal Power Plant #1-6</td>
<td>EPC</td>
<td>#1-6: 60 MW, #5-6: 45 MW</td>
<td>#1: 2016, #2-3: 2008, #4-5: 2011</td>
</tr>
</tbody>
</table>

---

**Scope of Delivery**

<table>
<thead>
<tr>
<th>I-I#:</th>
<th>15 MW</th>
</tr>
</thead>
<tbody>
<tr>
<td>I-II:</td>
<td>0.13 bara, 152°C, 3,000 rpm</td>
</tr>
<tr>
<td>V-#1, 2:</td>
<td>0.074 bara, 184°C, 3,000 rpm</td>
</tr>
</tbody>
</table>

---

**Kosair Electric Power Plant**

<table>
<thead>
<tr>
<th>Country</th>
<th>Owner</th>
<th>Plant</th>
<th>Power Scope</th>
<th>Output</th>
<th>Commercial Operation</th>
</tr>
</thead>
</table>

---

**REGEN**

<table>
<thead>
<tr>
<th>Country</th>
<th>Owner</th>
<th>Plant</th>
<th>Power Scope</th>
<th>Output</th>
<th>Commercial Operation</th>
</tr>
</thead>
</table>
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**

<table>
<thead>
<tr>
<th>Exhaust direction</th>
<th>Downward exhaust</th>
<th>Upward exhaust</th>
<th>Axial exhaust</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frame</td>
<td>SC1F</td>
<td>SC2F</td>
<td>TC4F</td>
</tr>
</tbody>
</table>

| Output           | ~7.5 MW         | ~15.5 MW       | ~25 MW       |

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.

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.
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.

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 OEMs.

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

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 OEM 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.”