INTRODUCTION TO GEOTHERMAL POWER STATION OF KYUDEN MIRAI ENERGY CO., INC.


2239

Hatchobaru	／	110,000kW
Otake	／	14,500kW
Yamagawa	／	30,000kW
Ogiri	／	30,000kW
Takigami	／	27,500kW
Hatchobaru Binary	／	2,000kW
Sugawara Binary	／	5,000kW
Yamagawa Binary	／	4,990kW

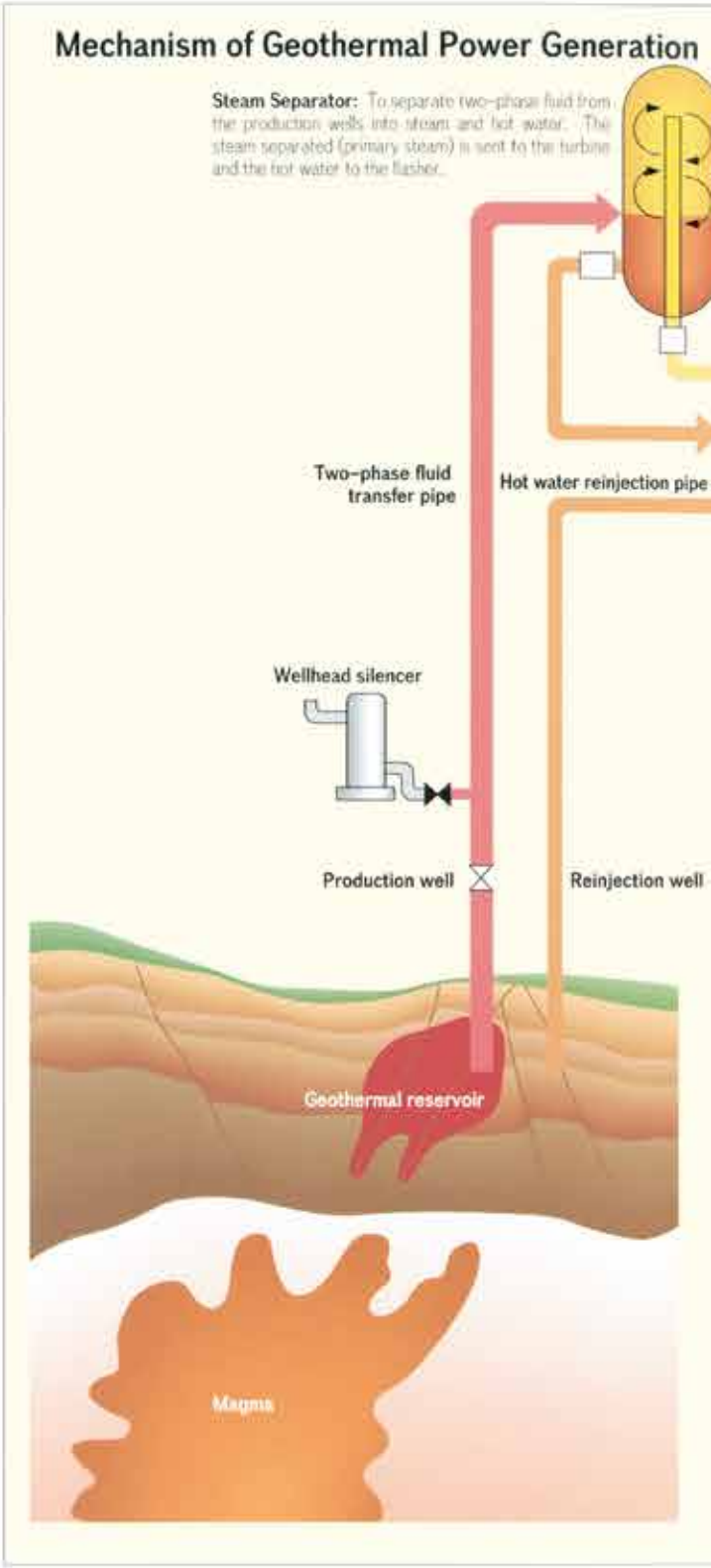
HISTORY OF GEOTHERMAL POWER DEVELOPMENT OF KYUDEN GROUP

The history of Kyushu Electric Power Group (Kyuden Group) 's geothermal development has begun in 1949, when Kyushu Electric Power started survey and development in Otake and Hatchobaru areas.
After overcoming numerous difficulties, Otake Power Station (12,500kW) started to operate in August 1967 as the first hot water dominated and single-flash type geothermal power plant in Japan.
Furthermore, based on the achievements of Otake Power Station, Hatchobaru Power Station No. 1 Unit (55,000kW) was built in June 1977 as the first two-phase flow transportation pipeline system, the first double-flash type geothermal power plant in the world. Hatchobaru No.2 Unit (55,000kW) started to operate in June 1990, and has become one of the world's leading geothermal power plants with total output of 110,000kW.
Yamagawa Power Station started commercial operation in March 1995, Ogiri Power Station in March 1996, and Takigami Power Station in November 1996.
Subsequently a 2,000kW binary cycle power facility was built at Hatchobaru. After pilot testing, commercial operation began in April 2006 as Hatchobaru Binary Power Station.
In June 2010, the rated output of Takigami Power Station was changed to 27,500kW.
In October 2020, we updated the power plant facility at Otake and increased the rated output to 14,500kW. Herewith, Kyushu Electric Power's geothermal power generation facilities have capacity of 214,000kW.
On the other hand, Kyuden Mirai Energy Co., Inc. started to operate Sugawara Binary Power Station (5,000kW) in June 2015 as one of the largest binary power plants in Japan, which effectively utilize low temperature geothermal fluid that cannot be used with conventional geothermal power plants.
Yamagawa Binary Power Station (4,990kW) started commercial operation in February 2018.
Then Kyuden Mirai Energy took over Kyushu Electric Power's geothermal business in April 2024 as result of integration of the Kyuden Group's renewable energy business.
Kyuden Group is promoting the development and installation of geothermal power generation in order to effectively utilize domestic energy and achieve carbon neutrality in 2050.

GEOTHERMAL POWER GENERATION?

Geothermal power generation is to produce electricity by rotating a turbine directly with the steam taken out of the deep underground. While in the thermal power generation the steam is generated by the combustion heat of coal, oil, or LNG, it can be said that in the geothermal power generation, the earth itself plays a role of a boiler. Generally the deeper in the earth, the higher gets the temperature. It is assumed to be about 1,000℃ at the depth of 30 to 50 km, where it can be regarded as a large thermal storage. It would be impossible, however, to utilize this heat source with the current technology because of too much depth in the earth. It happens, though, that in the so called "geothermal zone" where there exist volcanoes, natural fumaroles, solfataras, spas, or altered rocks, the magma of about 1, 000℃ is located at a comparatively shallow level of several km in depth.

The magma may heat the meteoric water infiltrating into the underground and form the geothermal fluid reservoir. The method to utilize the underground heat at such a place as a direct energy source is called the geothermal power generation.

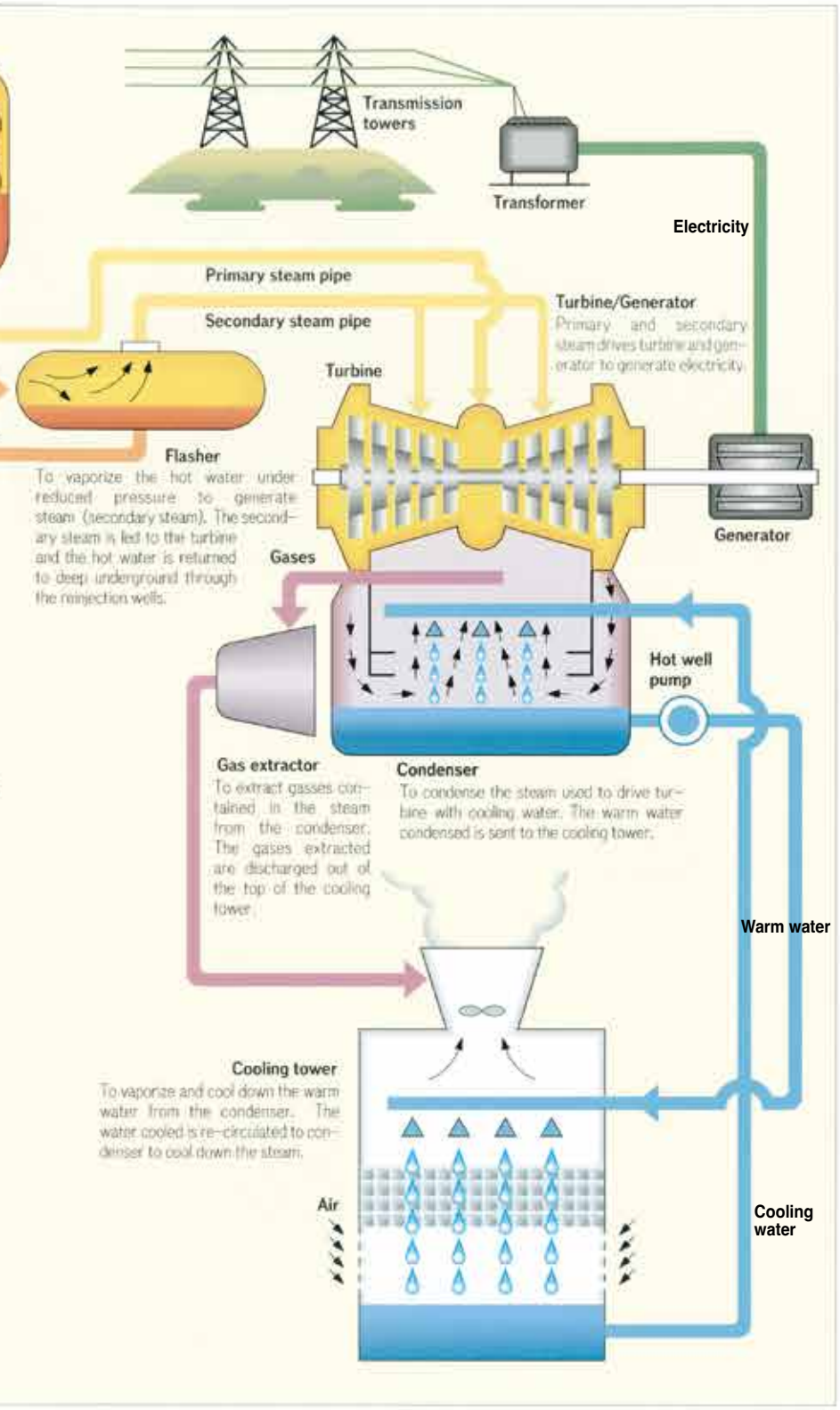


SPECIALTIES OF GEOTHERMAL POWER GENERATION

Advantages in:
- Effective use of indigenous energy resource
- No necessity of fuel
- Semipermanent, stable use as renewable energy
- Clean energy, highly effective in controlling CO_2 emissions
- Power can be generated stably regardless of weather or time of day or night

Disadvantages in:
- Difficulties of construction of a large capacity power station
- Necessity to pay much attention to the harmony with natural surroundings, because the site for geothermal power generation is often situated in natural beauties.

Panoramic View of Hatchobaru Geothermal Power Station



We carried out integrated development at Otake and Hatchobaru Power Stations: geothermal resource survey, exploration, drilling, engineering, construction, operation and maintenance of power plants. On the other hand, Ogiri and Takigami Power Stations were developed together with steam supply developers: The developers developed resources and supply steam to us while we purchase steam for power generation.
Yamagawa Power Station initially started jointly development in the same way as Ogiri and Takigami, but we took over the steam supply facility in February 2005 to run integrately from underground to aboveground.

HISTORY OF GEOTHERMAL POWER DEVELOPMENT

1904	Succeeded in power generation of 3/4 horsepower utilizing natural steam at Larderello, Italy. (The world's first geothermal utilization for power generation)
1913	Geothermal power generation of 250 kW at Larderello. (The world's first geothermal power station)
1919	Vice Admiral, Masuji Yamauchi succeeded in drilling a steam well at Beppu, Oita Pref., Japan.
1925	Dr. Heiji Tachikawa succeeded in power generation of 1.12 kW at Beppu. (Japan's first geothermal power generation)
1927	Dr. Tachikawa drilled a steam well at Otake, Oita Pref., Japan.
1949	Kyushu Haiden (Kyushu EPC, presently) started investigation and research of geothermal regions in Oita Prefecture.
1951	Kyushu EPC carried out experimental power generation of 30 kW at Beppu in cooperation with Industrial Technology Institute.
1953	Kyushu EPC started investigation and research at Otake district.
1958	A 6,500 kW power station started operation in Wairakei, New Zealand. (The world's first hydrothermal separation type geothermal power station)
1960	The Geysers No. 1 Unit in California, U.S.A. started operation. (11,000 kW)
1966	Matsukawa Power Station in Iwate Pref. started operation (23,500 kW). (Japan's first full-scale geothermal power station)
1967	Kyushu EPC commissioned Otake Power Station (12,500 kW). (The first geothermal power station by public utility, in Japan)
1977	Kyushu EPC commissioned Hatchobaru No. 1 Unit (55,000 kW)
1990	Kyushu EPC commissioned Hatchobaru No. 2 Unit (55,000 kW)
1995	Kyushu EPC commissioned Yamagawa (30,000 kW)
1996	Kyushu EPC commissioned Ogiri (30,000 kW) and Takigami (25,000 kW)
2006	Hatchobaru Binary Power Station (2,000 kW) started operation.
2010	Takigami Power Station output rating changed. (25,000 kW to 27,500 kW)
2020	Otake Power Station renovated. (12,500 kW to 14,500 kW)
2024	Renewable Energy Business integration (Kyushu Electric Power → Kyuden Mirai Energy)

Otake Geothermal Power Station

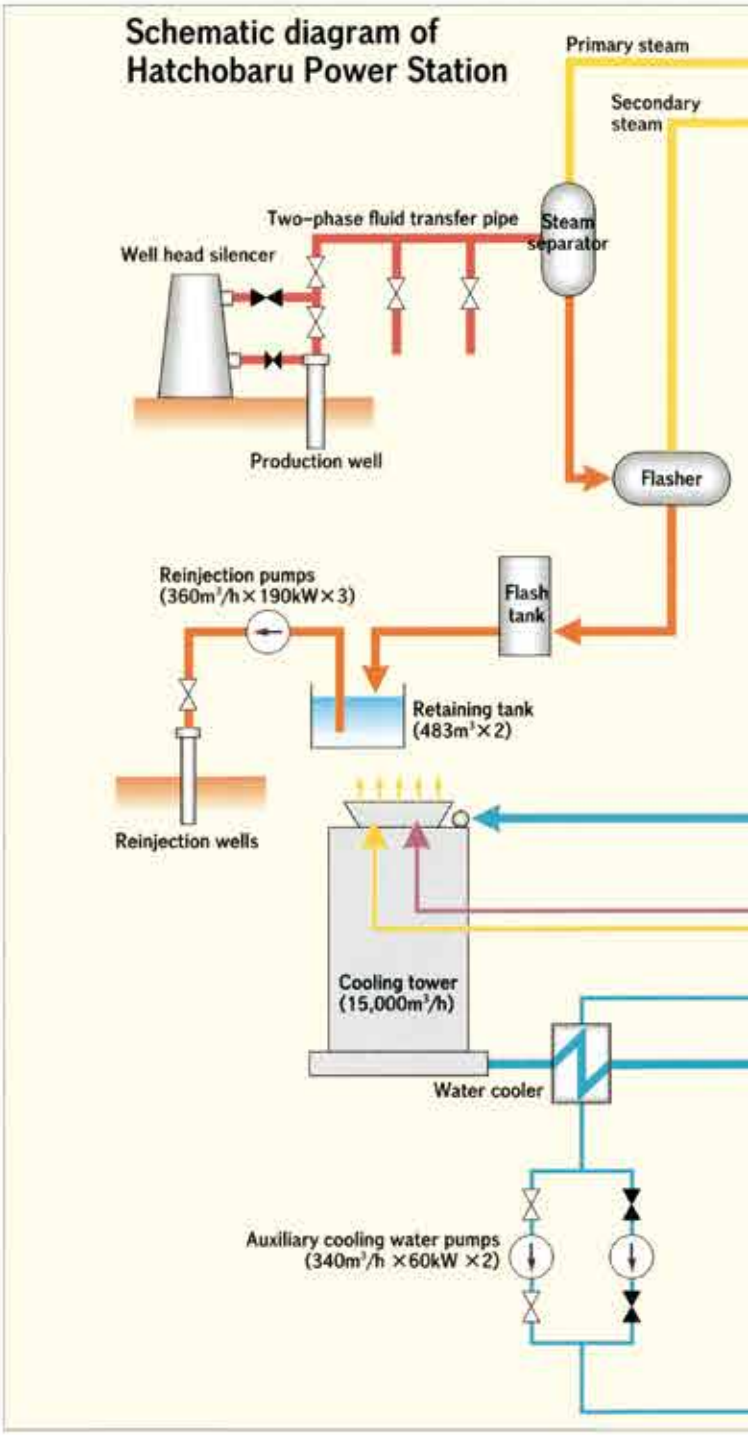
Hatchobaru Binary Power Station

GEOTHERMAL POWER GENERATING SYSTEM

Production Wells

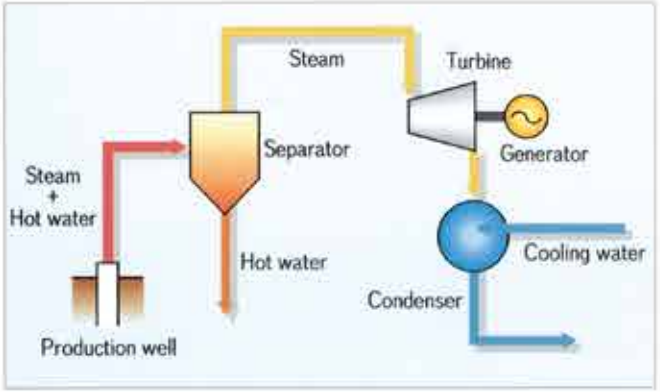
Wellhead Silencer
Equipment that reduces the noise of steam being blown out from the production well and released into the atmosphere when the steam turbine is stopped, for example.

To use geothermal energy taken to the ground surface from production wells for power generation, there are some generation systems depending on characteristics of geothermal fluid (pressure, temperature, flow rate, etc.)



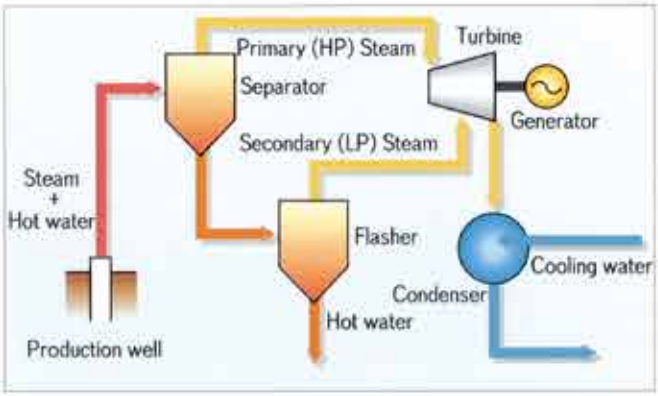
(1) Single Flash System

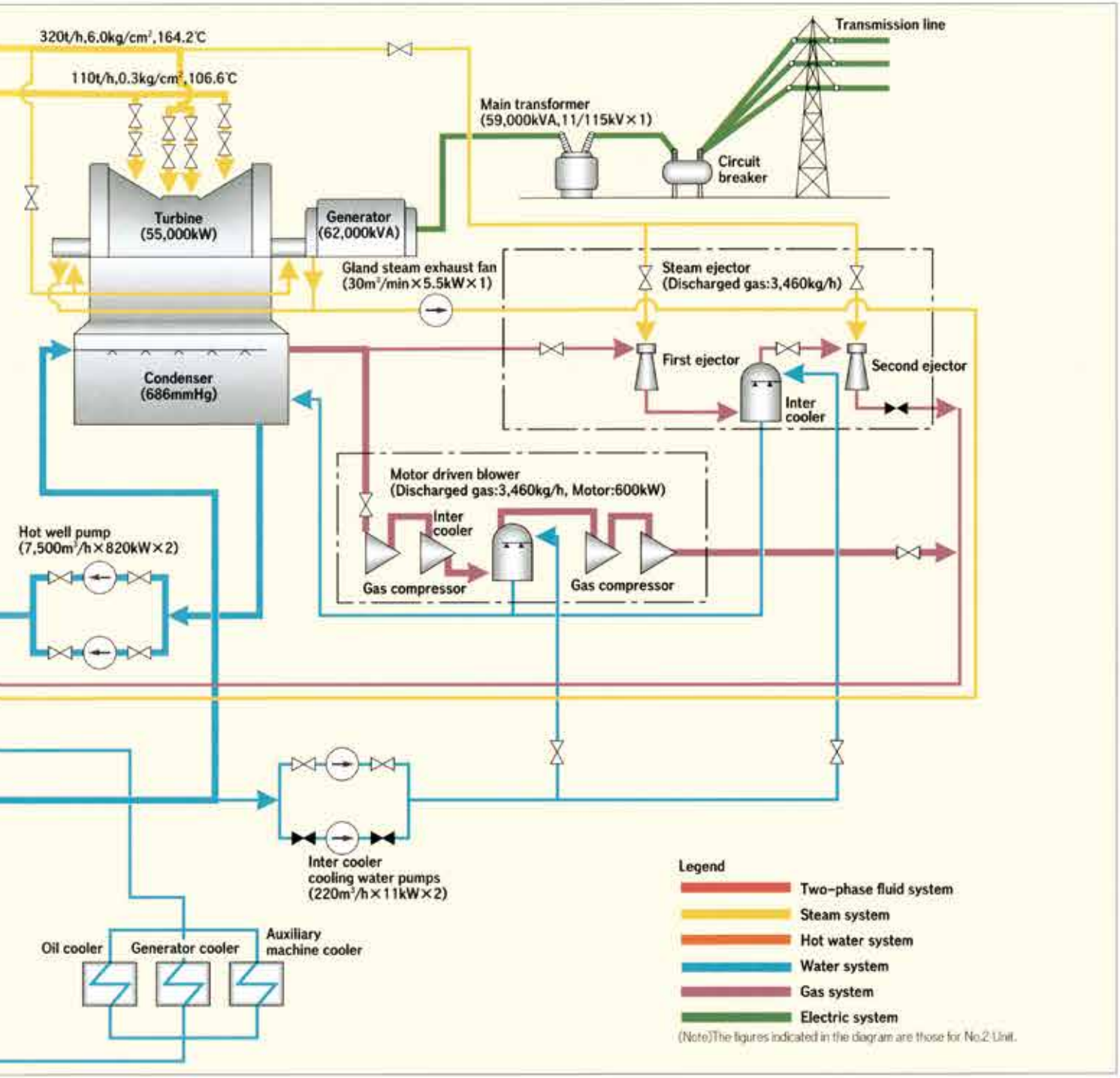
Where the geothermal fluid forms a steam and hot water mixture, the fluid is led to a separator to separate the steam from the hot water. Then, the steam is used to rotate the turbine for power generation. This system was applied for Yamagawa, and Ogiri power stations.



(2) Double Flash System

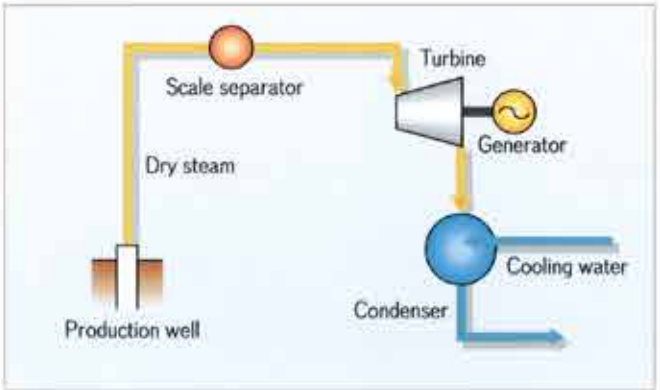
Where a temperature of hot water separated by the single flash system is still high enough, this system can be applied. Application of this system increases the output by 15% to 25% though it increases the investment to additional facilities compared with the Single Flash System. This system was applied for Hatchobaru, and Otake power stations.





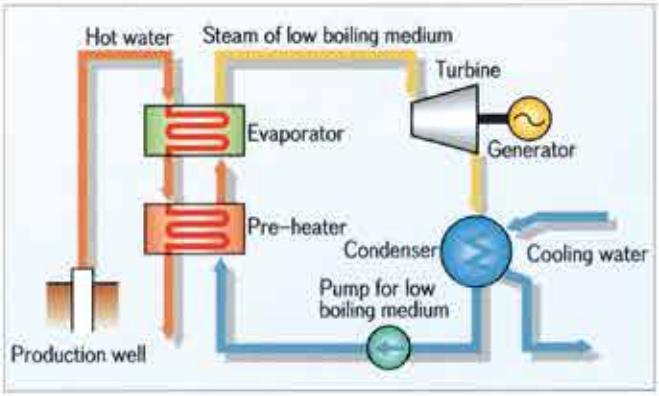
(3) Dry Steam System

This is a system to rotate directly with dry steam for power generation. This system is applied at Larderello in Italy, The Geysers in the US, and Matsukawa in Japan.



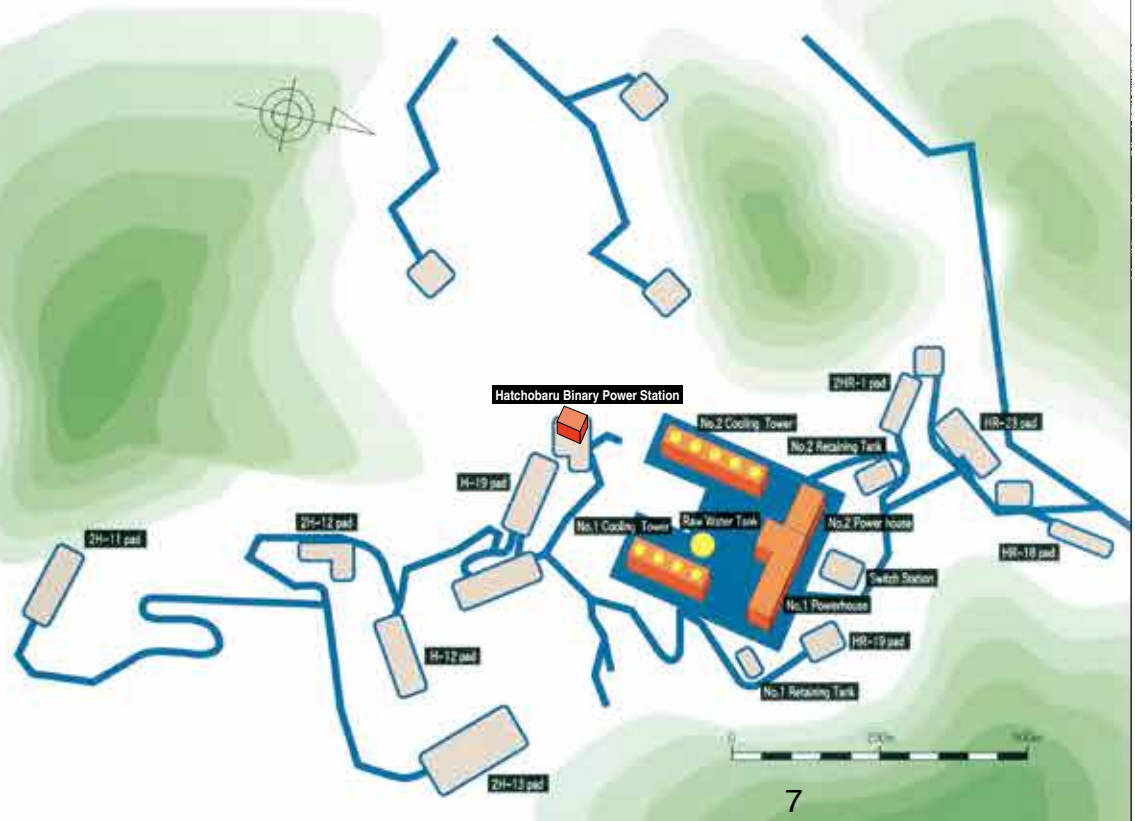
(4) Binary Cycle System

Where the temperature of geothermal fluid is lower and no steam is available, low boiling medium is heated with hot water to produce the steam for power generation. This system is applied at Hatchobaru Binary, Sugawara Binary and Yamagawa Binary Power Stations.



HATCHOBARU GEOTHERMAL POWER STATION

Hatchobaru Geothermal Power Station has a total capacity of 110,000 kW, which is the largest rated capacity of the geothermal power station in Japan.
This power station adopts a two-phase fluid transfer system where the steam and hot water from production wells are led in a mixed form to a steam separator installed near the power station facilities. The mixed fluid is separated here into primary (high pressure) steam and hot water, and the hot water is then expanded under a reduced pressure in a flasher to generate secondary (low pressure) steam. The primary and secondary steam taken out this way drives the turbine generator. This system is called a double flash system.
The system was jointly developed and put into commercial use as a pioneer in the world with Mitsubishi Heavy Industries, Ltd. This research and development was awarded with The Prize of Japan Society for the Promotion of Machine Industry in 1980.
Hatchobaru is an unattended geothermal power station and controlled by the operators stationed in Otake, about 2 km away from Hatchobaru. The operating conditions including generator outputs, turbine revolutions, condenser vacuum, etc. are supervised and controlled with a tale-control system and data logger.

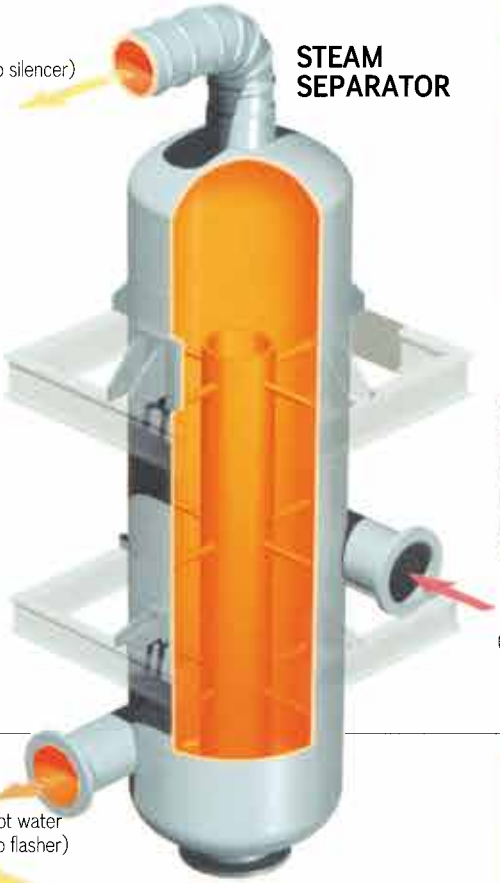


DEVELOPMENT HISTORY

1964-66	Drilled 2 exploration wells between Otake and Hatchobaru
1968	Started production well drilling
July 1973	No.1 Unit development approved by the Government's Power Resource Development and Coordination Committee
July 1975	No.1 construction commenced
June 1977	No.1 commissioned
July 1980	Applied permission of the exploration to the Government for development of No.2 Unit
Dec. 1981	Started drilling of exploration wells for No.2 Unit
Dec. 1981	No.2 Unit development approved by the Government's Power Resource Development and Coordination Committee
Dec. 1986	No.2 Unit construction commened
June 1990	No. 2 Unit commissioned
Apr. 2006	Hatchobaru Binary Power Station started operation
Apr. 2024	Renewable Energy Business Integration (Kyushu Electric Power → Kyuden Mirai Energy)

FEATURES

- The double-flash system increases generated power by about 20% and attains more effective heat utilization than the single flash system using only steam from the production well. Also, less number of production wells required and the reinjection volume decreases.
- Because the system can transport both steam and hot water in the same piping, the compact piping can be applied and the construction cost is reduced.




Two-phase Fluid Transfer Pipes

●OUTLINE OF STEAM SEPARATOR

	No. 1 Unit	No. 2 Unit
Type	Vertical, cyclone type (w/bottom outlet)	
Steam Separated Flow Capacity	206.5 t/h	197 t/h
Hot water Separated Flow Capacity	455 t/h	591 t/h
No. of Unit	2 units	2 units


Steam Separator


Flasher

●OUTLINE OF FLASHER

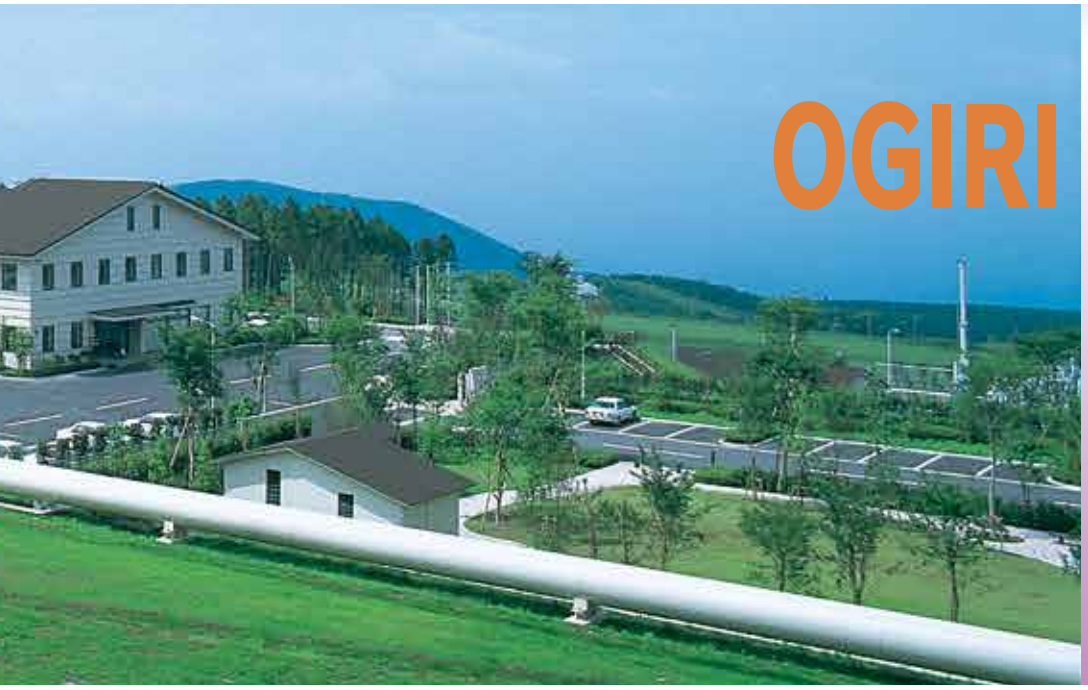
	No. 1 Unit	No. 2 Unit
Type	Horizontal, drum-type, separation, tray type	
Separated Steam Flow Capacity	107 t/h	132 t/h
Separated Hot water Flow Capacity	803 t/h	1,183 t/h
No. of Unit	1 unit	1 unit

●OUTLINE OF OTAKE AND HATCHOBARU GEOTHERMAL POWER STATIONS (Current as of August 2016)

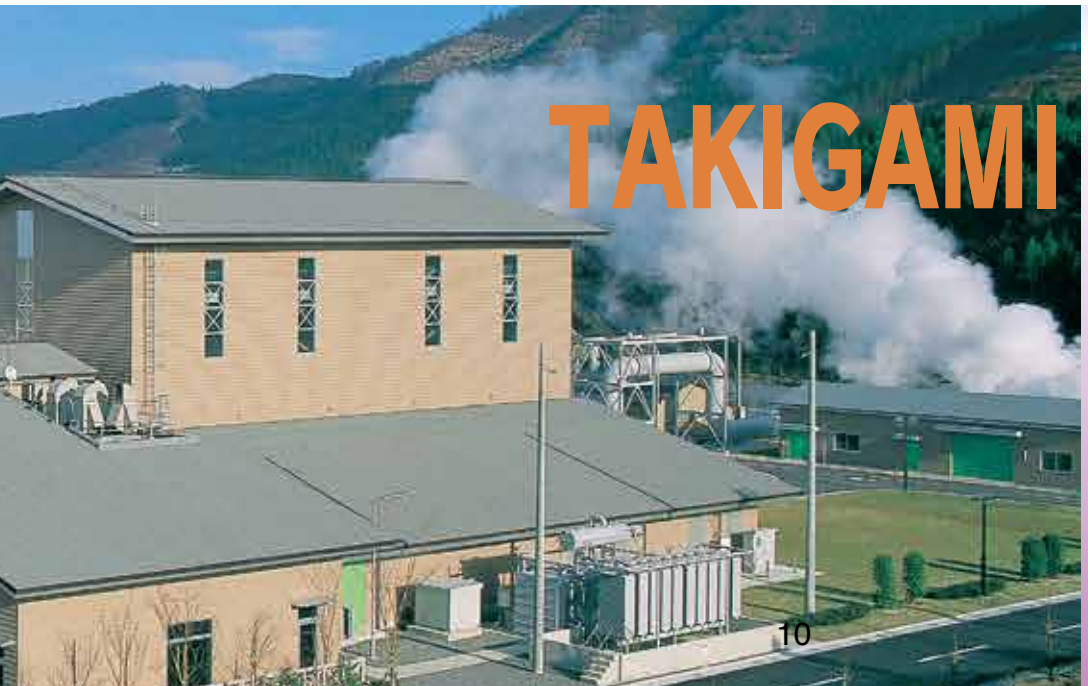
			Otake	Hatchobaru No. 1	Hatchobaru No. 2
Location			Oh-aza Yutsubo, Kokonoe-machi, Kusu-gun, Oita Pref.		
Output			14,500 kW	55,000 kW	55,000 kW
Commissioned Date			August 11, 1967	June 24, 1977	June 22, 1990
Land area			159,167 m²	1,948,109 m²	
POWER STATION FACILITIES	Turbine	Steam Pres.	0.235 MPa (2.4 kg/cm²)	0.49 MPa(52 kPa (5.0 kg/cm²)/0.53 kg/cm²)	0.59 MPa/29 kPa (6.0/0.3 kg/cm²)
		Steam Temp.	136℃	158.1/111.4℃	164.2/106.4℃
		Approx. Steam Flow Rate	120 t/h	372/91 t/h	320/110 t/h
		Type	Single cylinder, impulse, condensing type	Single cylinder, double flow, impulse, mixed pressure condensing type	
	Generator	Capacity	15,000 kVA	62,000 kVA	62,000 kVA
		Voltage	6,600 V	11,000 V	11,000 V
		Type	Horizontal, cylindrical revolving field type		
		Cooling Method	Air cooled	Hydrogen cooled	Air cooled
	Cooling Tower	No. of cells	3	4	5
		Capacity	4,200 m³/h	13,140 m³/h	15,000 m³/h
		Type	Mechanical draft, counter flow double suction type		
	Condenser	Vacuum	91.6 kPa (687 mmHg)	91.6 kPa (687 mmHg)	91.5 kPa (686 mmHg)
		Type	Barometric jet type	Foundation unified, jet (direct contact) type	
	Gas Extractor	Capacity	1,570 kg/h	2,320 kg/h	3,460 kg/h
		Type	Vacuum Pump	Ejector + Motor driven blower	
STEAM PRODUCTION FACILITIES	Separator	Capacity	Diff. by well	413 t/h*	394 t/h*
		No. of unit	4	2	2
		Type	Vertical, cylindrical cyclone separator		

*: Total processing steam flow

YAMAGAWA GEOTHERMAL POWER STATION



OGIRI GEOTHERMAL POWER STATION



TAKIGAMI GEOTHERMAL POWER STATION

YAMAGAWA
GEOTHERMAL POWER STATION

Development History and Features

1977 Japan Petroleum Exploration Co. (JAPEX) started the geothermal resource exploration.
Oct. 1988 Kyushu EPC and JAPEX concluded a basic agreement for geothermal power generation undertaking.
Dec. 1988 JAPEX founded Japex Geothermal Kyushu Co. (JGK) and JGK succeeded geothermal resource development.
Dec. 1992 The government approved the development.
Sep. 1993 Kyushu EPC started construction.
Mar. 1995 Commissioned.
Feb. 2005 Kyushu EPC takes over steam production facilities
Apr. 2024 Renewable Energy Business Integration (Kyushu Electric Power → Kyuden Mirai Energy)

YAMAGAWA is characterized by its location at the plain land area surrounded by agricultural fields as compared with the other geothermal power stations in Japan mostly located in mountainous area. In Yamagawa, the turbine inlet pressure is set as high as 0.98 Mpa because the reservoir temperature is high.

OGIRI
GEOTHERMAL POWER STATION

Development History and Features

1973 Nippon Steel Mining Co. (NSM) started geothermal resource exploration.
1979 Nippon Steel Corp. (NSC) joined the geothermal development undertaking.
1989 Kyushu EPC, NSM and NSC concluded a basic agreement for geothermal power generation undertaking.
Feb. 1990 NSC and NSM co-financed to establish Nittetsu Kagosima Geothermal Co. and the company succeeded the geothermal development.
Dec. 1993 The government approved the development.
Nov. 1994 Kyushu EPC started construction.
Mar. 1996 Commissioned.
Apr. 2013 Nittetsu Mining Co., Ltd. takes over the business of Nittetsu Kagoshima Geothermal Co., Ltd. through an absorption-type merger.
Apr. 2024 Renewable Energy Business Integration (Kyushu Electric Power → Kyuden Mirai Energy)

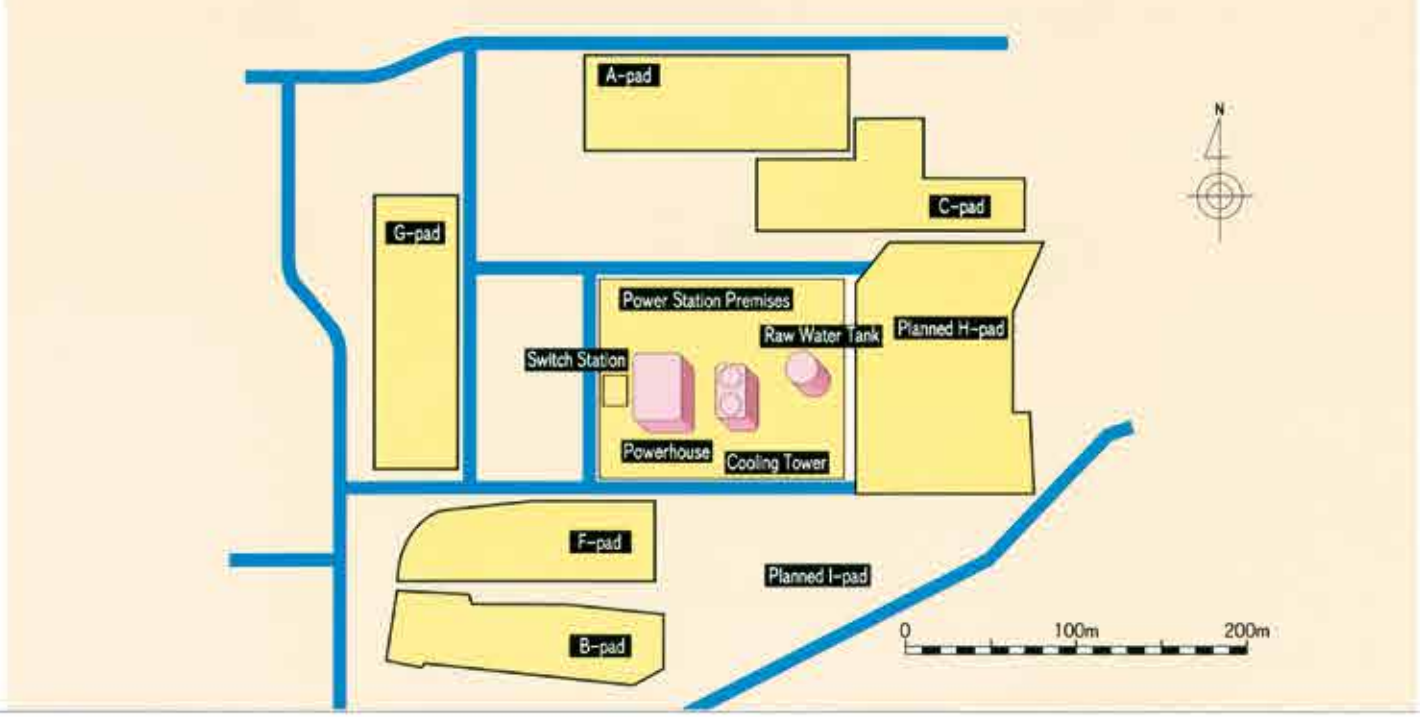
OGIRI is located at the west of Kirishima Mountain Range in Kyushu, and has its well bases along the gentle slope from NE to SW. As it is surrounded by stock farming grass and woods, greening was made inside the power station premises and the power station buildings are standardized in creamy color to harmonize with the surroundings.

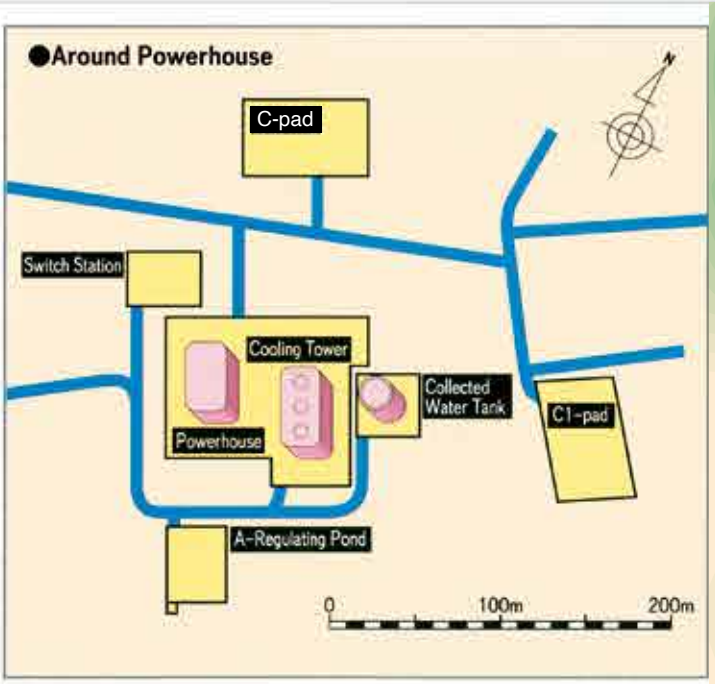
TAKIGAMI
GEOTHERMAL POWER STATION

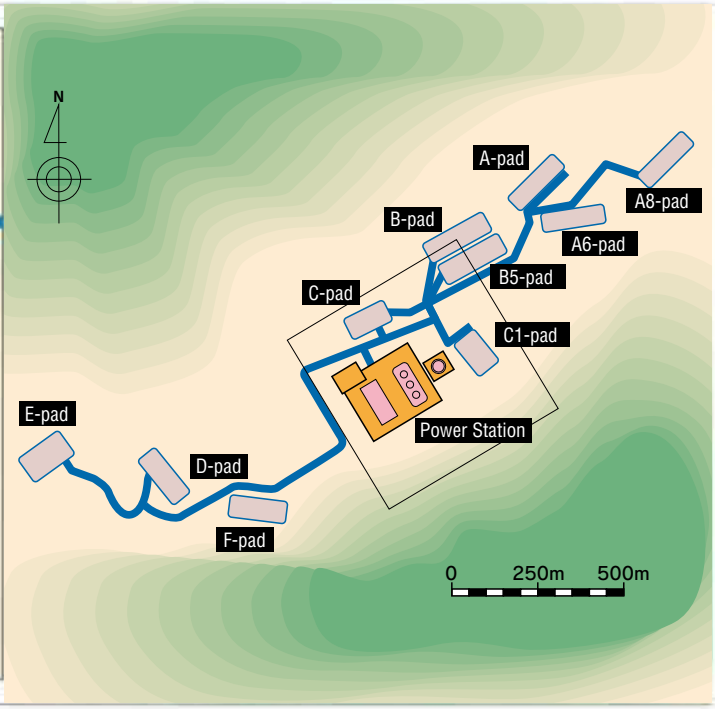
Development History and Features

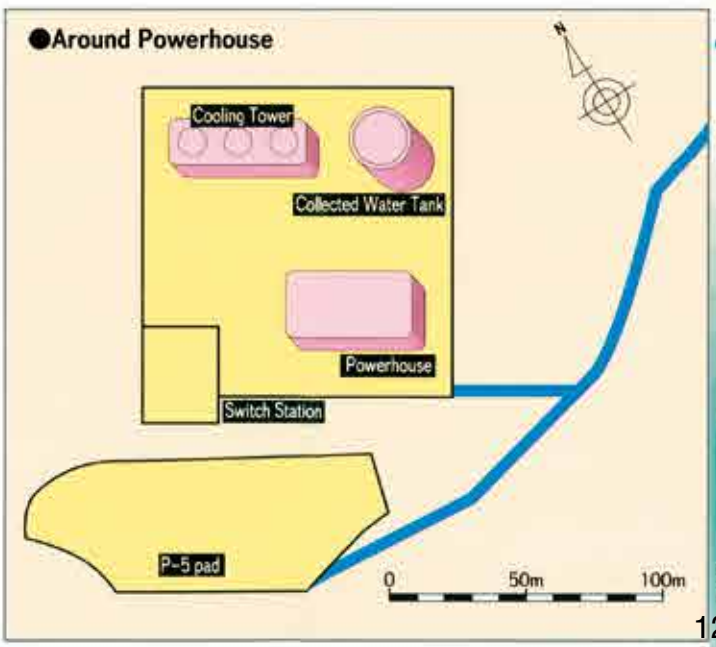
1979 Idemitsu Geothermal Co. (IGC) started the geothermal resource exploration.
Aug. 1991 Kyushu EPC and IGC concluded a basic agreement for geothermal power development.
Oct. 1993 Idemitsu Kosan Co., Ltd. established Idemitsu Oita Geothermal Co. and the company succeeded the resource development.
Jul. 1994 The government approved the development.
Sep. 1995 Kyushu EPC started construction.
Nov. 1996 Commissioned.
Jun. 2010 Output rating changed (25,000 kW to 27,500 kW)
Apr. 2024 Renewable Energy Business Integration (Kyushu Electric Power → Kyuden Mirai Energy)

TAKIGAMI is located on a plateau with gentle slope in an elevation range from 700 to 800m above sea level at the north slope of the Kuju Mountain Range, Kyushu. There are 5 production well bases and the steam separated at each base is led to the power station.


A-pad
C-pad
G-pad
Power Station Premises
Raw Water Tank
Planned H-pad
Switch Station
Powerhouse
Cooling Tower
F-pad
Planned I-pad
B-pad
N
0
100m
200m


●Around Powerhouse
C-pad
Switch Station
Cooling Tower
Powerhouse
Collected Water Tank
C1-pad
A-Regulating Pond
N
0
100m
200m


N
A-pad
A8-pad
B-pad
A6-pad
B5-pad
C-pad
C1-pad
E-pad
Power Station
D-pad
F-pad
0
250m
500m


●Around Powerhouse
Cooling Tower
Collected Water Tank
Powerhouse
Switch Station
P-5 pad
N
0
50m
100m


R-2 pad
R-1 pad
P-1 pad
P-3 pad
Power Station
P-2 pad
P-5 pad
P-4 pad
N
0
500m
1000m

Condenser

Steam distribution pipe

CONDENSER

To minimize the powerhouse size, the condenser is installed outside and a spray jet type, required less cooling water than surface type and hardly affected by non-condensable gases, is adopted. Taking into account the corrosive gases contained in geothermal fluid in particular and condensate, stainless-clad steel plate is used for fabrication of the condenser.

●OUTLINE OF POWER STATION

(Current as of August 2016)

Name			YAMAGAWA	OGIRI	TAKIGAMI
Location			Yamagawa, Ibusuki City Kagoshima Pref.	Makizono-cho Kirishima City and Yusui-cho, Aira-gun, Kagoshima Pref.	Kokonoe-machi, Kusu-gun, Oita Pref.
Output			30,000 kW	30,000 kW	27,500 kW
Commissioned Date			March 1, 1995	March 1, 1996	November 1, 1996
Land area			157,800 m^2	297,600 m^2	418,400 m^2
Steam Supplier (Developer)			Kyuden Mirai Energy Co., Inc.	Nittetsu Mining Co., Ltd.	Idemitsu Oita Geothermal Co.
POWER STATION FACILITIES	Turbine	Steam Pres.	0.98 MPa (10.0 kg/cm^2)	0.196 MPa (2.0 kg/cm^2)	0.147 MPa (1.5 kg/cm^2)
		Steam Temp.	183.2℃	132.9℃	126.8℃
		Approx. Steam Flow Rate	225 t/h	290 t/h	260 t/h
		Type	Single cylinder, single flow, impulse, reaction condensing type		
	Generator	Capacity	34,000 kVA	34,000 kVA	28,000 kVA
		Voltage	11 kV	11 kV	11 kV
		Type	Horizontal, cylindrical, revolving field type (air cooled)		
	Cooling Tower	No. of cells	2	3	3
		Capacity	7,000 m^3/h	9,800 m^3/h	10,500 m^3/h
		Type	Mechanical draft, counter flow double suction type		
	Condenser	Vacuum	88.1 kPa (661 mmHg)	90.5 kPa (679 mmHg)	90.5 kPa (679 mmHg)
		Type	Spray jet type + Tray type gas cooler (direct contact type)		
	Gas Extractor	Capacity	1,650 kg/h	798 kg/h	1,605 kg/h
		Type	1 series-2 stage Ejector	Ejector + Motor driven blower	
STEAM PRODUCTION FACILITIES	Separator	Capacity*	275 t/h** × 2 series	440 t/h**	325 t/h**
		No. of unit	2 × 2 series	4	6
		Type	Vertical, cylindrical cyclone separator		

*: As of end of March 2010

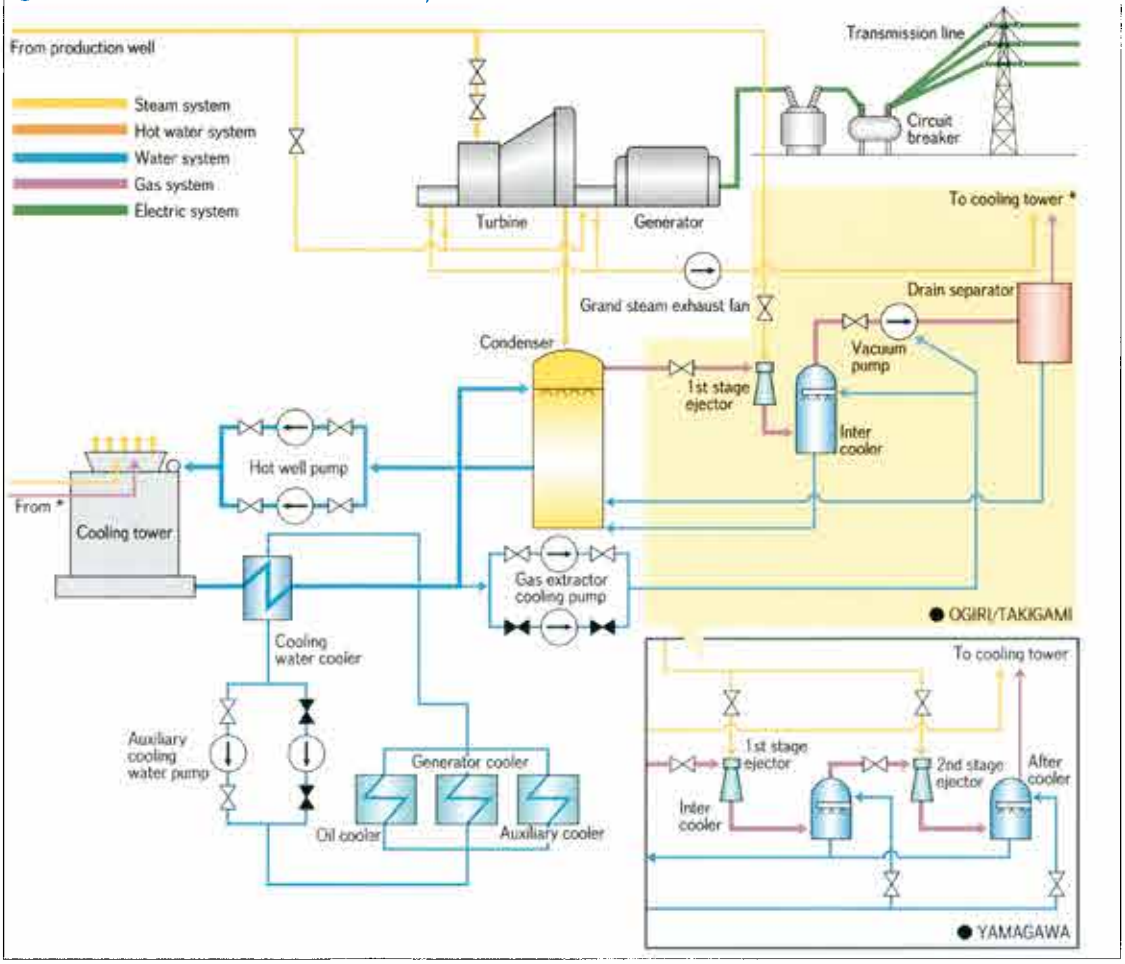
COOLING TOWER

A cooling tower has a function to exhaust and disperse the extracted gasses into air in addition to the circulating water cooling function. The layout and number of cells are determined in due consideration of the dispersion conditions simulated with meteorological data such as wind directions and velocity as well as economic cost of construction.

Cooling Tower

Turbine and Generator

SYSTEM DIAGRAM OF YAMAGAWA, OGIRI AND TAKIGAMI GEOTHERMAL POWER STATIONS



STEAM TURBINE

A single cylinder, single flow, module turbine, which is widely used and proven, is adopted. By design of the turbine exhaust at the upward position, the turbine could be installed right on the ground floor and this avoided the high-floor turbine foundation.

GENERATOR

A generator of air cooling system, standardized to this class, was adopted. It equips with an internal pressurized device which makes the internal pressure higher than the outside to prevent H_2S gas from entering. The exciter is of a blushless exciting type advantageous in maintenance as well as space.

Gas Extractor

GAS EXTRACTOR

To downsize the powerhouse, the gas extractor is installed outside. YAMAGAWA adopted a highly reliable 1-series, 2-stage steam ejector, and OGIRI and TAKIGAMI a hybrid system of a steam ejector and a vacuum pump installed in a series.

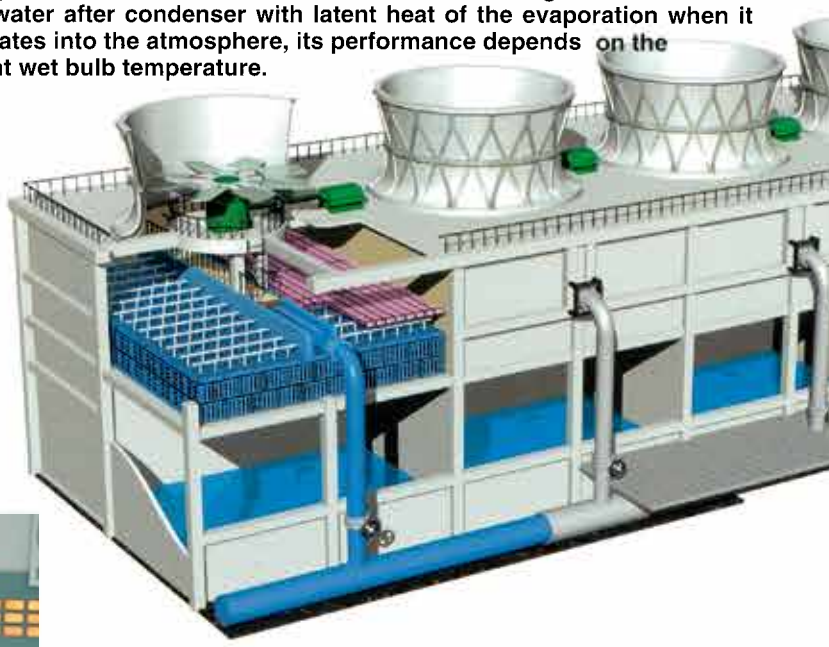
HOT WELL PUMP

In selection of a hot well pump, the operating record of that installed in HATCHOBARU is considered and a vertical, canned-pit type pump is adopted.

SPECIALTIES OF FACILITIES

■COOLING TOWER

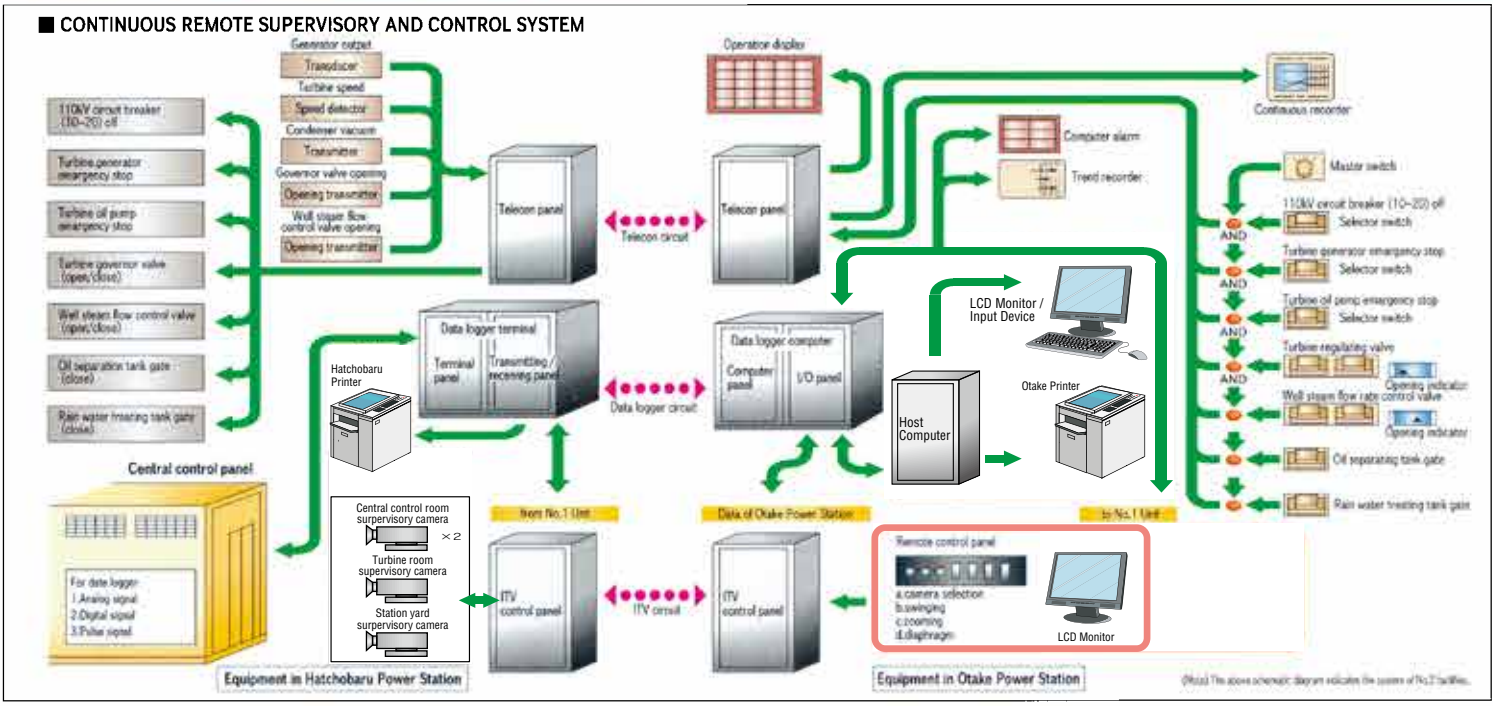
Generally, a geothermal power station is located in the mountainous area. This makes it difficult to get a large volume of cooling water. The hot water after passing through the condenser is cooled down at the cooling tower and recirculated. Because the cooling tower cools the warm water after condenser with latent heat of the evaporation when it evaporates into the atmosphere, its performance depends on the ambient wet bulb temperature.



■ Continuous monitoring control system

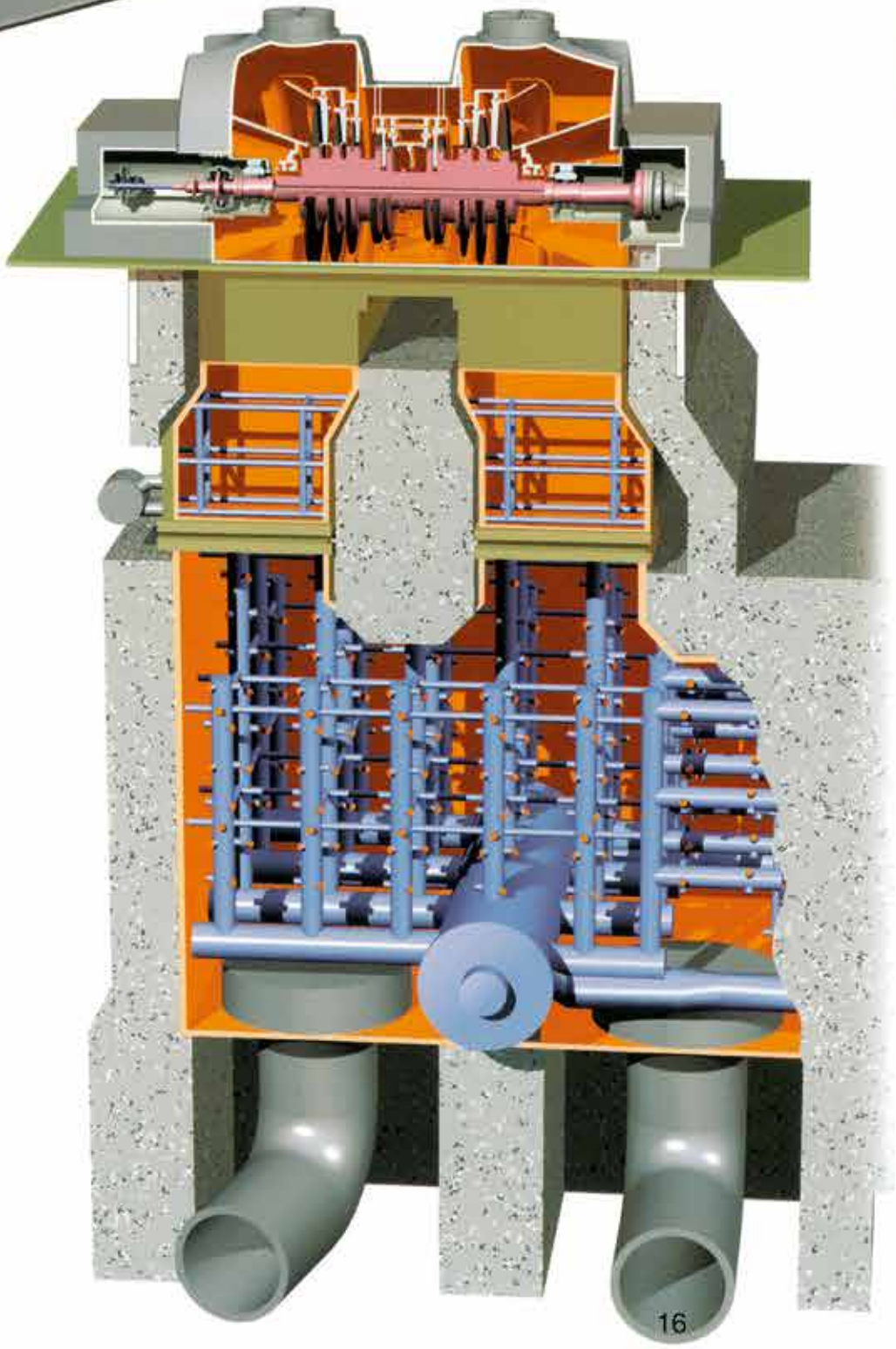
Our geothermal power stations operate at a stable output and there is no need frequently operation by human operators. The geothermal power stations generates with autonomous unmanned during night-time and on holidays. The operators operate them as needed.

■ CONTINUOUS REMOTE SUPERVISORY AND CONTROL SYSTEM



Cooling Tower

Turbine and Generator



TURBINE

As the geothermal turbine is driven by low pressure steam, its bulk and flow rate become larger for the small output. Therefore, it is engineered so that this steam could expand and pass through efficiently. The size of a turbine adopted at Hatchobaru is equivalent to a low pressure turbine of a 156,000kW class conventional steam turbine.

SPECIALTIES

· Because the geothermal steam contains gasses and impurities, the turbine uses anti-corrosive materials and has a configuration with an anti-scaling measures.

· Because of higher wetness of the exhaust steam than the conventional steam turbine, the turbine features drain removal and anti-erosion measures.


5

Sugawara

Binary Power Station

Yamagawa

Binary Power Station

Sugawara Binary Power Station

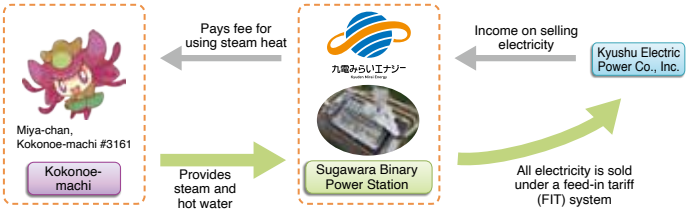
FEATURES

Sugawara Binary Power Station is the first 5,000kW-class geothermal binary cycle power plant in Japan. We work together with local government, Kokonoe Town to conduct this geothermal power generation project.

Kokonoe Town provides us with steam and hot water from their own geothermal wells while we purchase the geothermal fluids and generate electricity by using the geothermal binary cycle power plant.

We sell generated electricity to Kyushu Electric Power Co., Inc., with Feed-in Tariff system. Both we and Kokonoe Town can make steady income while simultaneously contributing to effective use of purely domestic energy and promotion of global warming prevention.

Furthermore, with the cooperation of Kokonoe Town, we are also working on co-existence with the local communities by implementing hot spring monitoring as well as providing explanations to the locals etc.



DEVELOPMENT HISTORY

- 1988 NEDO drilled the geothermal wells in Kokonoe Town for research
- 2003 NEDO transferred the wells to Kokonoe Town free of charge
- 2010 Kokonoe Town conferred with Kyushu Electric Power Co., Inc. regarding geothermal development in order to effectively utilize of the wells
- 2012 Well test and assessment for hot springs carried out
- 2013 We agreed with Kokonoe Town regarding geothermal power generation project in this area (Nov. 22)
- 2014 Geothermal resources development debt guarantee adopted by JOGMEC※2 (Apr. 10)
  Construction work started (Apr. 21)
- 2015 Test run started (Apr. 1)
  Commercial operation started (Jun. 29)

※1 : New Energy and Industrial Technology Development Organization

※2 : Japan Organization for Metals and Energy Security

Yamagawa Binary Power Station

FEATURES

Yamagawa Binary Power Station is one of the largest binary power plants in Japan. Until the time when it started to operate, some of hot water could not be used for power generation and was returned to underground at Yamagawa. The binary system can effectively utilize the unused energy of hot water.

We received "New Energy Award" in 2019 for recognition of our efforts to solve technical issues such as corrosion and scaling caused by high temperature and high concentration of hot water, and for the expected expansion of installation of geothermal power generation in the future.

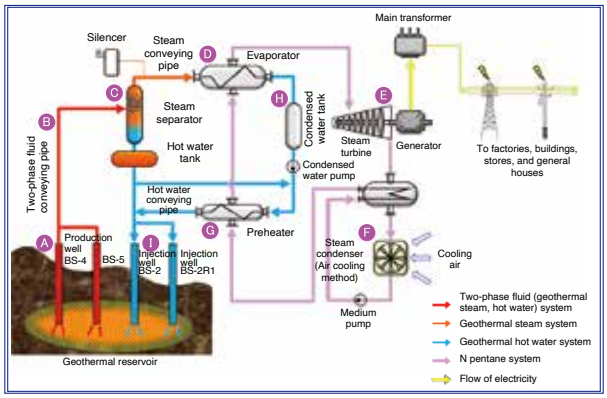
DEVELOPMENT HISTORY

- Aug. 2016 Civil engineering work started
- May 2017 Construction work of power generation facility started
- Oct. 2017 Test run started
- Feb. 2018 Operation started

OUTLINE OF SUGAWARA BINARY POWER STATION

Location		554-13 Sugawara, Kokonoe Town, Oita Prefecture
Rated output		5,000kW
Commercial operation started in		Jun.29, 2015
Owner of power station / Owner of geothermal well		Kyuden Mirai Energy Co., Inc. / Kokonoe Town (2 Production wells and 2 Injection wells)
Manufacturer of main machine		Turboden, a Mitsubishi Heavy Industries group, Italy
Geothermal fluid (outlet of separator)	Pressure / Temperature	0.286MPaG / 142.4°C
	Steam flow rate	40.1t/h
	Hot water flow rate	261.8t/h
Working fluid (inlet of turbine)	Pressure / Temperature	0.953MPaG / 137.5°C
	Flow rate	298t/h
	Working fluid type	N pentane (boiling point: 36°C)
Generator	Type	Horizontal cylindrical rotating field type synchronous generator
	Rotation speed	1,800min^{-1}
Separator	Type	Vertical cylinder cyclone separator
	Maximum pressure / Temperature	0.55MPaG / 162°C
Condenser	Type	Mechanical-draft air cooling
	Number of fans	27 units (3 units x 9 rows)
	Inlet temperature of air / Inlet temperature of working fluid / Outlet temperature of working fluid	20°C / 58.8°C / 37°C
Heat exchanger	Evaporator	Horizontal straight tube type (1 unit)
	Preheater	Horizontal straight tube type (1 unit)
	Feed liquid heater	Horizontal U-shaped tube type (1 unit)
Production well	Temperature / Flow rate / Depth of well	BS-4 : 142°C / 18.7t/h / 811m BS-5 : 159°C / 28.5t/h / 870m
Injection well		BS-2 : 552m BS-2R1 : 589m
Power generation facility size		Approx. 47 m x 74 m
Length of Power line		Approx. 20 km
Plant control		Monitoring as needed

SYSTEM DIAGRAM OF SUGAWARA BINARY POWER STATION

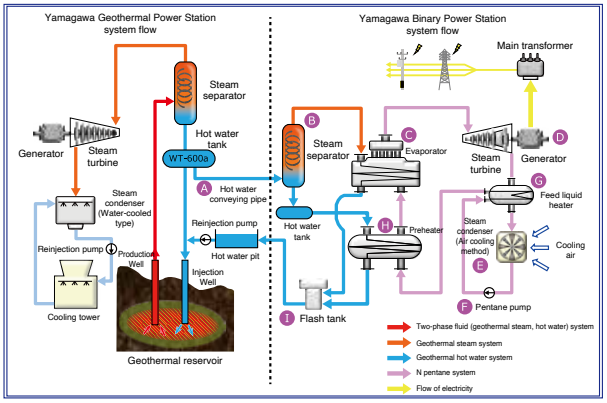


We adopt “binary cycle” system in which n-pentane (lower boiling point than water) is heated and evaporated by the geothermal fluid supplied from production wells, and the turbine is rotated by n-pentane steam. Also, the geothermal fluid, which is the heat source, is supplied from the well owned by Kokonoe Town. The air cooling system is adopted for cooling and liquefaction of n-pentane.

OUTLINE OF YAMAGAWA BINARY POWER STATION

Location		2303 Yamagawa Ogawa, Ibusuki City, Kagoshima Prefecture
Rated output		4,990kW
Commercial operation started in		Feb.23, 2018
Owner of power station		Kyuden Mirai Energy Co., Inc.
Manufacturer of main machine		Fuji Electric Co., Ltd.
Geothermal fluid (inlet of separator)	Pressure / Temperature / Flow rate	0.97MPaA / 178.6°C / 584.7t/h
Steam of geothermal fluid (inlet of evaporator)		0.38MPaA / 142.8°C / 41.7t/h
Hot water of geothermal fluid (outlet of hot water tank)		0.40MPaA / 143.6°C / 543.0t/h
Working fluid (inlet of turbine)	Pressure / Temperature / Flow rate	0.92MPaA / 122.1°C / 330t/h
	Working fluid type	N pentane (boiling point: 36.1°C)
Generator	Type	Three-phase AC synchronous generator
	Rotation speed	1,800min^{-1}
Separator	Type	Vertical cylinder cyclone separator
	Maximum pressure / Temperature	0.48MPaA/160°C
Condenser	Type	Mechanical-draft air cooling
	Number of fans	24 units (3 units x 8 rows)
	Inlet temperature / Outlet temperature of working fluid	60.6°C / 44.5°C
Heat exchangers	Evaporator	Horizontal kettle type (1 unit)
	Preheater	Horizontal shell and tube type (1 unit)
	Feed liquid heater	Horizontal shell and tube type (1 unit)
Power generation facility size		Approx. 63 m x 88 m
Power line		Connected to line on the premises of Yamagawa Power Station
Plant control		Monitoring as needed

SYSTEM DIAGRAM OF YAMAGAWA BINARY POWER STATION



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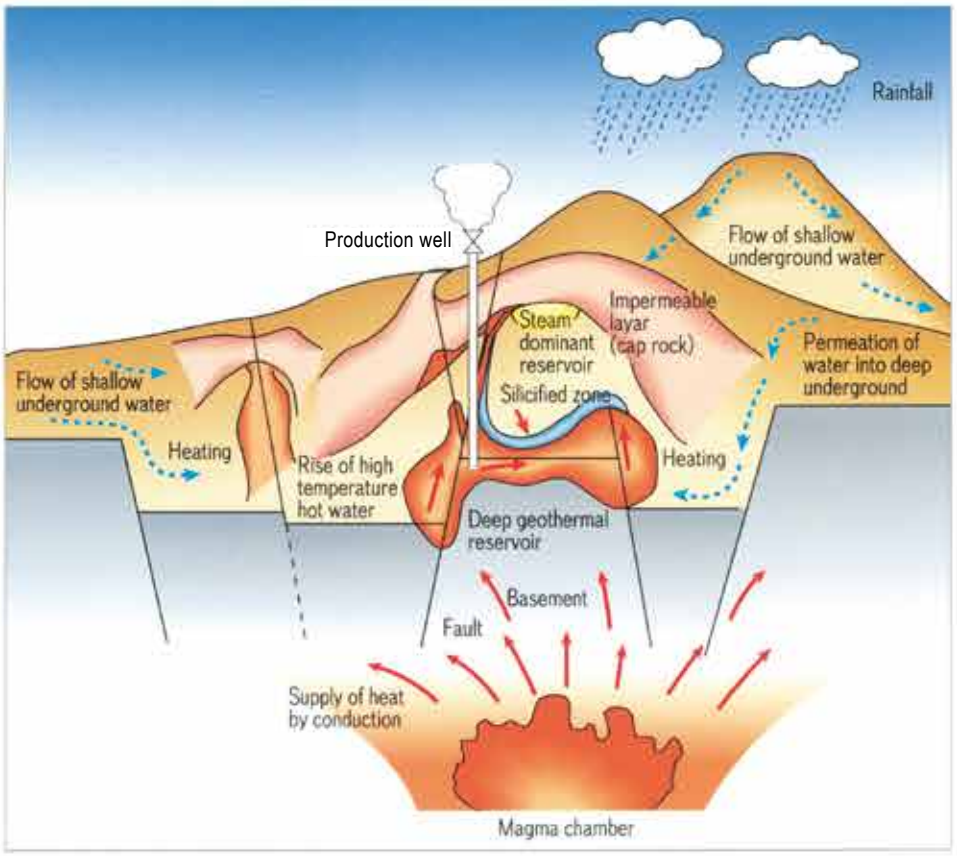
GEOLOGICAL STRUCTURE

The heat source of the geothermal energy is the magma which was generated by friction heat caused by plate movements. It is reported that in Hatchobaru district, volcanic activities by the magma began about 200,000 years ago and that the heat source has formed the present geothermal reservoir. The meteoric water infiltrating deep into the underground is heated up to 230 to 280℃ by the heat from the magma chamber, and forms the geothermal reservoir.

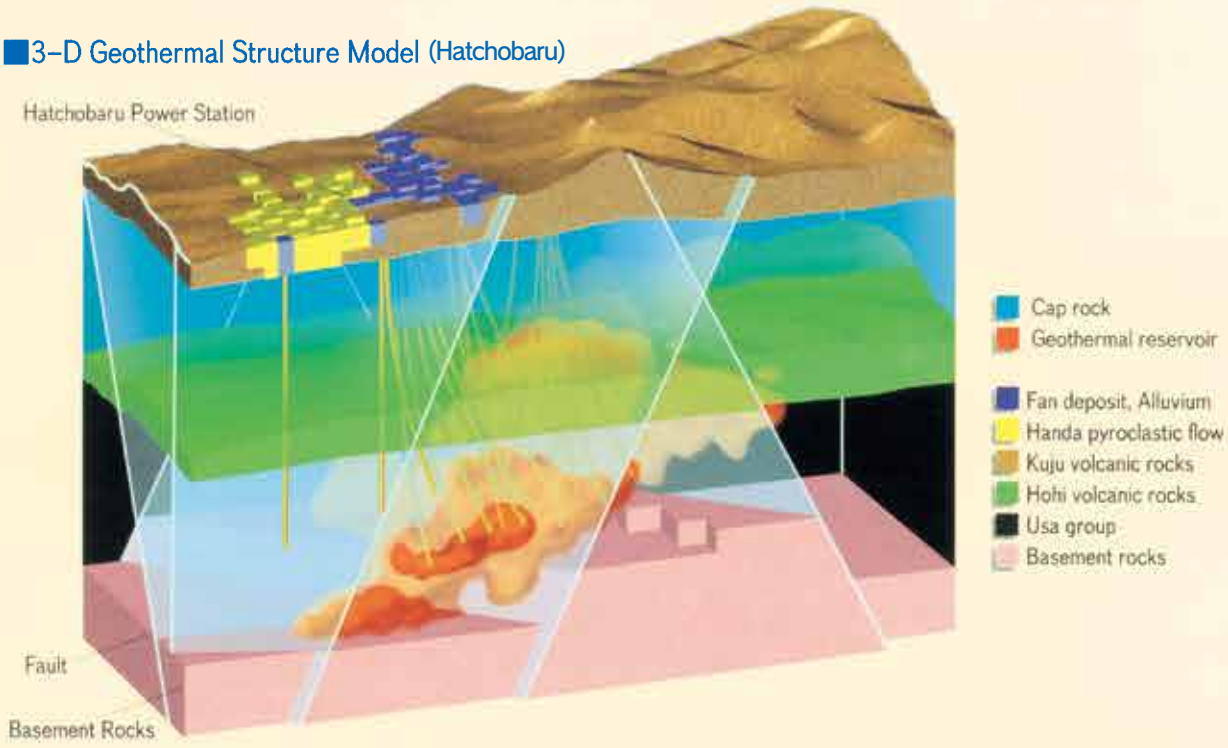
As a condition to form the reservoir, the cap rock of argillized zone (by acidic alteration) is necessary at the shallower level. This also had been made by geothermal activities in many years. The cap rock is a layer of impermeable substance which hardly passes liquids or gases through, and so plays a role of a cop or a cover of the reservoir. Hot water or steam from the deep prevented from ascending further by the cap rock, stays below the cap rock and forms a geothermal reservoir. The cap rock plays another role to prevent the hot water or steam from being mixed with low temperature ground water or hot spring water near the surface.

In Hatchobaru district, this reservoir is confirmed by the surface survey and investigation, exploratory well drilling, etc., and the steam taken out from the well is utilized for power generation.

Conceptual Geothermal Structure



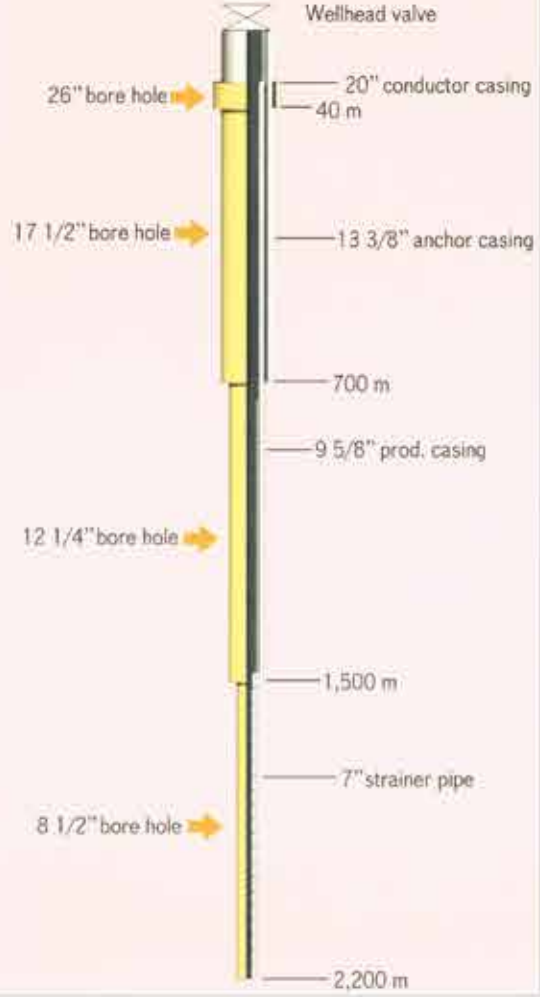
3-D Geothermal Structure Model (Hatchobaru)

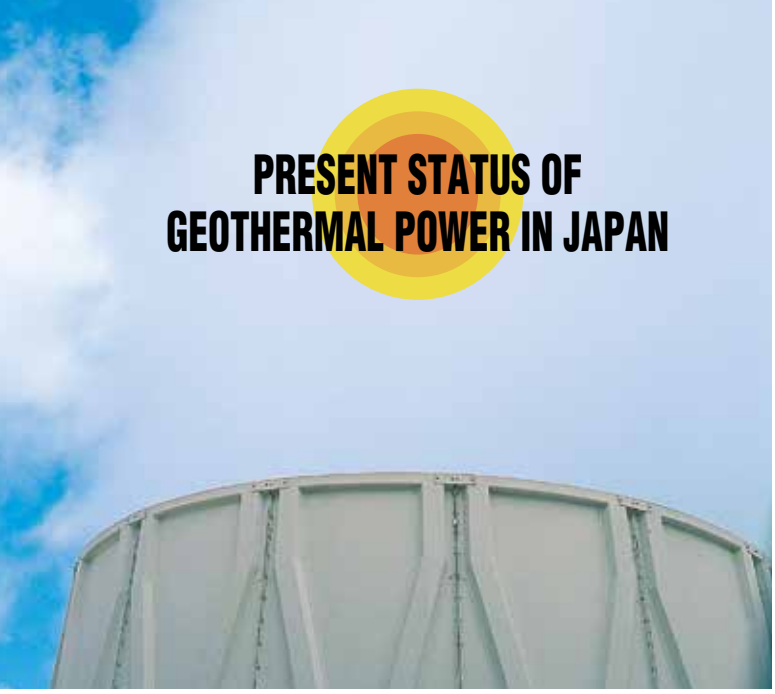


Drilling of Production Wells (Hatchobaru)

Conceptual Drawing of Drilling Bit End

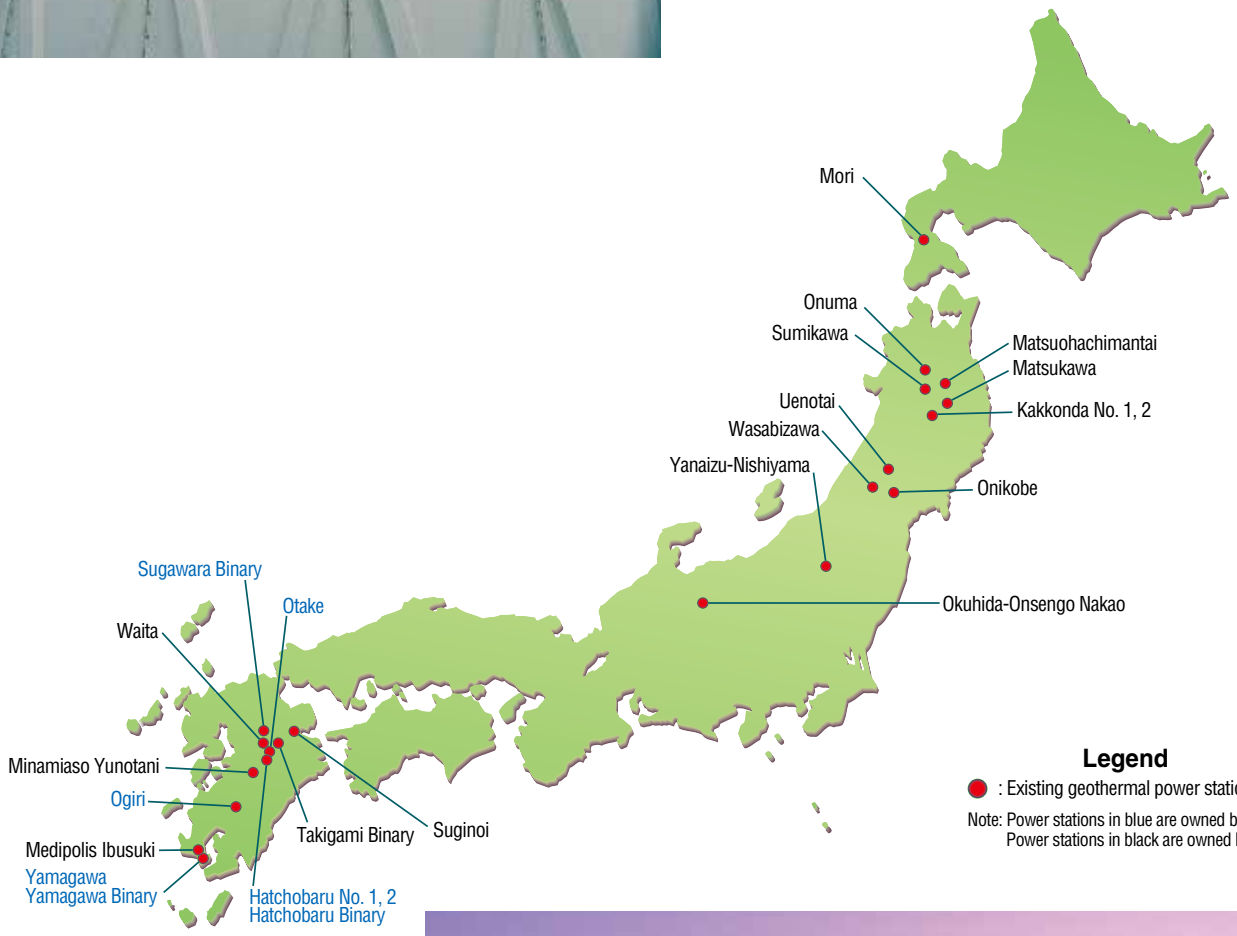
Well Cross Section (Production Well Standard Drawing)





PRESENT STATUS OF GEOTHERMAL POWER IN JAPAN

As of February 2020, the total capacity of geothermal power stations operating in Japan is about 540 MW. Of these, Kyuden Mirai Energy has 9 units in 6 stations for 224 MW, or about 41% of the capacity.
Though the geothermal power, to be said the 4th power followed by Nuclear power, occupies a small share in the energy mix in Japan, it has been playing an important role as highly stable power supply source by attaining a high capacity factor without anxiety of energy storage or supply.
Also, from the perspective of global warming prevention, it is a natural energy source that is highly effective in controlling CO_2 emissions, and for this reason there are high expectations for the development of geothermal power.



Ogiri Geothermal Power Station

Geothermal Power Stations in Japan

(As of February 2020)

Name	Location	Company name (Upper line:Power Station Owner / Lower line:Steam Suppller)	Rated Output (kW)	Commissioned in
Mori	Mori, Hokkaido	Hokkaido EPC	25,000	Nov.26,1982
Matsukawa	Hachimantai, Iwate Pref.	Tohoku Sustainable & Renewable Energy Co., Inc.	23,500	Oct.8,1966
Matsuohachimantai	Hachimantai, Iwate Pref.	Iwate Geothermal Power Co., Ltd	7,499	Jan.29,2019
Kakkonda	Shizukuishi, Iwate Pref.	Tohoku EPC Tohoku Sustainable & Renewable Energy Co., Inc.	30,000	Mar.1,1996
Onuma	Kazuno,Akita pref.	Mitsubishi Materials Corp.	10,000	Jun.17,1974
Sumikawa	Kazuno,Akita pref.	Tohoku EPC Mitsubishi Materials Corp.	50,000	Mar.2,1995
Uenotai	Yuzawa, Akita Pref.	Tohoku EPC Tohoku Sustainable & Renewable Energy Co., Inc.	28,800	Mar.4,1994
Wasabizawa	Yuzawa, Akita Pref.	Yuzawa Geothermal	46,199	May.20,2019
Onikobe	Osaki, Miyagi Pref.	Electric Power Development Co., Ltd.	14,900	Apr.2,2023
Yanaizu-Nishiyama	Yanaizu, Fukushima Pref.	Tohoku EPC Okuaizu Geothermal Co., Ltd.	30,000	May.25,1995
Okuhida-Onsengo Nakao	Takayama, Gifu Pref.	Nakao Geothermal Power	1,998	Dec.1,2022
Waita	Oguni, Kumamoto Pref.	Waitakai LLC	1,995	Jun.16,2015
Minamiaso Yunotani	Minamiaso, Kumamoto Pref.	Minamiaso Yunotani Chinetsu Co., Ltd.	2,168	Mar.3,2023
Suginoi	Beppu, Oita Pref.	Suginoi Hotel	1,900	Apr.1,2006
Takigami	Kokonoe, Oita Pref.	Kyuden Mirai Energy Co., Inc. Idemitsu Oita Geothermal Co., Ltd.	27,500	Nov.1,1996
Takigami Binary	Kokonoe, Oita Pref.	Idemitsu Oita Geothermal Co., Ltd.	5,050	Mar.1,2017
Otake	Kokonoe, Oita Pref.	Kyuden Mirai Energy Co., Inc.	13,700	Oct.5,2020
Hatchobaru	Kokonoe, Oita Pref.	Kyuden Mirai Energy Co., Inc.	55,000 55,000 2,000	Jun.24,1977 Jun.22,1990 Apr.1,2006
Sugawara Binary	Kokonoe, Oita Pref.	Kyuden Mirai Energy Co., Inc. Kokonoe Town	5,000	Jun.29,2015
Ogiri	Kirishima, Kagoshima Pref.	Kyuden Mirai Energy Co., Inc. Nittetsu Mining Co., Ltd.	30,000	Mar.1,1996
Yamagawa	Ibusuki, Kagoshima Pref.	Kyuden Mirai Energy Co., Inc.	30,000 4,990	Mar.1,1995 Feb.23,2018
Medipolis Ibusuki	Ibusuki, Kagoshima Pref.	Medipolis Energy Co., Ltd.	1,580	Feb.18,2015

Source: "The Current State of and Trends in Geothermal Power 2020" by Thermal and Nuclear Power Engineering Society The geothermal power plants with rated output of 1,000kW or more are listed.

World Geothermal Power Facilities (in MW)

Country	Output
USA	3,450.0
Philippines	1,870.0
Indonesia	1,340.0
Mexico	1,017.0
New Zealand	1,005.0
Italy	916.0
Iceland	665.0
Kenya	594.0
Japan	519.0
Turkey	397.0
Costa Rica	207.0
El Salvador	204.0
Nicaragua	159.0
Russia	82.0
Guatemala	52.0
Papua New Guinea	50.0
Portugal	28.0
China	27.0
Germany	27.0
France	16.0
Ethiopia	7.3
Austria	1.2
Australia	1.1
Thailand	0.3
Romania	0.1
Taiwan	0.1
Total	12,635.1

Source: "The Current State of and Trends in Geothermal Power 2015" by the Thermal and Nuclear Power Engineering Society

ENVIRONMENTAL FRIENDLY GEOTHERMAL POWER STATIONS

As it uses the underground heat resource, the geothermal power dose not require fuel and is a clean energy source not polluting the air. Geothermal power stations are built surrounded by abundant natural environment but we transformed the land area for development as small as possible by adopting the centralized power generation and steam supply facilities.
It is said, in this view point, that the geothermal power is an environmental friendly power source. To make best use of the favorable specialty of geothermal power, Kyuden Group has been trying to downsize the ground facilities as small as possible, and paying special attentions to coloring of the facilities. It has taken positive steps in coordination with the surroundings by promoting the greening in the premises of the power stations.

View of Kuju Mountain Range from Handa Plateau, Kokonoe-machi, Oita Pref.

Cuckoo

■ KUJU

In kokonoe-cho, there are 4 geothermal power stations : HATCHOBARU, OTAKE, TAKIGAMI and SUGAWARA BINARY. Kuju area nearby is one of the best scenery spots in Kyushu where the 1,700m class volcanoes are renowned their beauty in shape. Yamanami Highway, crossing these areas on a plateau, is also known as a comfortable driving course surrounded by natural beauty and scenery. Whenever you visit Handa and Kuju Plateaus , beautiful flowers and birds welcome and refresh you gently. Here also available many well-known hot spas like Sujiyu, Makinoto, Chojabaru and many more.

Kirisima-azalea and Mt. Takachiho

■ KIRISHIMA

Mt. Karakuni-Dake, rising at the north-east of Kagoshima Pref. and the surroundings are called "Kirishima" generally and included in "Kirishima-Yaku National Park". This region has a lot of hot spas called "Kirishima Spa Villages" and there are about 130 hot spa resources used for bathing and drinking. OGIRI is located in between Makizono-cho and Kurino-cho of this region.
You can enjoy different beauties of scenery in each season; fresh greens in spring, Kirisima-azalea in early summer, red-and-yellow leaves in autumn, and silver thaws in winter. This area forms its own world in Kyushu displaying the magnificent scenery. In the surroundings, there are many tourist spots including Mt. Takachiho famous for a Japanese mythology.

Sand Spa in Yamagawa and Mt. Kaimon

■ IBUSUKI

The Yamagawa Power Station is located in the area known as Ibusuki, facing Kagoshima Bay at the southern tip of the Satsuma Peninsula. The greater part of this area is covered by Kirishima-Yaku National Park and is a beautiful coastline and hot spring location.
The most famous Ibusuki Hot Spa and the others in this region provide unique hot spa bathing; to have your body buried in the hot sand. Fresh seafood also raised this region's reputation.

INTRODUCTION TO
GEOTHRMAL POWER STATION OF KYUDEN MIRAI ENERGY CO., INC.

KYUDEN MIRAI ENERGY CO.,INC.

2024.04