Hoshinoya Karuizawa, Japanese Style Onsen Hotel - The Largest Geothermal Heat Pump System in Japan

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Introduction

"Hoshinoya Karuizawa" is a hot spring ("onsen" in Japanese) hotel in Karuizawa, a town on the border of Nagano prefecture where the winter Olympics were held in 1998. The Hoshino Onsen Hotel, which boasts a 100-year history, was fully refurbished prior to its reopening in 2005. The town of Karuizawa lies amidst highlands at an altitude of about 1,000 meters near the foot of Mt. Asama – an active volcano. Surrounded by a rich natural environment, it is one of the best-known resort areas in Japan.

In essence, resort facilities situated in such rich natural environments should strive to impose the minimum environmental impact. On the other hand, the operation of resort facilities depends to a large extent on fossil fuels due to their high thermal demand. Deep down, we have been feeling a growing sense of crisis about our continued use of fossil fuels from the perspective of global environmental issues, fuel costs and stability.
Furthermore, safeguarding the fresh water, air, natural sound of the water and wind, and abundant flora and fauna is of crucial importance to guests who visit resort facilities. We believe that providing these environmental factors is both valuable and meaningful.

Under the above concept, the "Hoshinoya Karuizawa" project was launched in the 1990s, and we originally considered the use of natural energy. We have been operating an in-house hydropower plant since 1904, but we planned to establish a facility that does not depend on fossil fuel by adopting a geothermal heat pump heating system.
As a result, about 75% of the power used for the facility is self-supplied.

Figure 1 Exterior of Hoshinoya Karuizawa

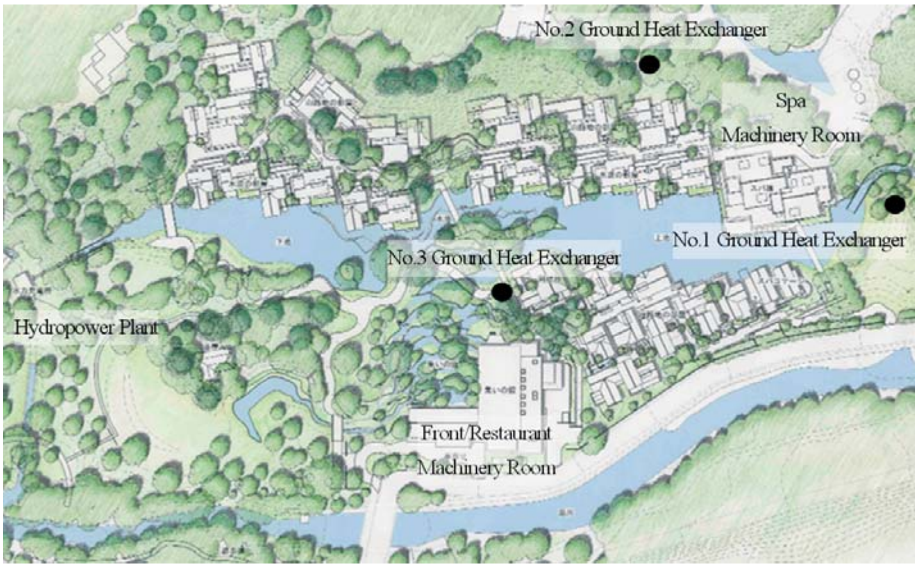

Figure 2 Architecture Of Hoshinoya Karuizawa

Fossil fuels are not used at all except for the liquefied petroleum gas (LPG) used in the kitchens and the fuel used for our vehicles. There are neither chimneys nor flue gas emissions anywhere in our facility.

Overview of the architecture and facilities

1) Architecture

Building name: Hoshinoya Karuizawa
Address: Hoshino, Karuizawa, Kitasaku-gun, Nagano Prefecture
Site area: 42,055.10 m2
Building area: 6,303.16 m2
Total floor space: 8,507.92 m2
Structure: Reinforced concrete (partially, steel-reinforced concrete), steel-framed, wooden construction
Storeys: 1 basement, 2 storeys above ground (77 guest rooms)

2) Heat source facilities

Ground heat exchangers: 400 m x 3 / 600 kW
Hot-spring exhaust heat recovery facility: 418 kW
Water-to-water heat pumps: 25 HP x 16 modules
Hot water storage tanks: 42 t x 1; 28 t x 1
Hot spring tank: 26 t x 1
Ice thermal storage tank: 20 t x 1 (static)
Central monitoring facility

Geothermal utilization

Heat drawn from the ground heat exchanger and through heat exchange from the hot spring runoff is pooled, and termed geothermal utilization in the wide sense. The main advantage is that a high temperature heat source is readily available throughout the year. This represents the heat source for the heat pump.

Ground heat exchangers

Steel pipes of 200-mm (almost 8-inch) diameter and a fiberglass pipe are stored concentrically for the ground heat exchanger. Water circulates within the ground heat exchanger, with the heat absorbed from the ground, and then extracted above ground. The ground heat exchangers, which feature the coaxial double-pipe method, are sunk to a depth of 400 m, and there are three such wells within the site.

Terrestrial heat exchange is dependent on the passage of a fluid, such as groundwater, which is mainly heated through advective flow. Using this method, about ten times more thermal output (500 W/m) is possible per unit length compared to the heat collection method through thermal conduction that is generally popular in Europe and America.

The average ambient temperature near to the heat exchanger is about 30 °C. Fluid circulates around a closed loop between the ground surface and deep underground. Flowing at a rate of about 300 liters per minute, it is inverter-controlled in accordance with the load demanded by the terrestrial facilities. An extraction temperature of 25 °C can be achieved when the input temperature is 15 °C, allowing about 200 kW of heat energy to be collected.

Use of hot spring run-off heat

300 liters per minute of hot spring water flows continuously through the hot spring facility attached to the accommodation. Since the temperature of the run-off water is about 35 °C, a plate-type heat exchanger is used to extract the heat, which is then used as a heat source for the heat pump, before the water is allowed to drain away after being cooled to ambient temperature.

Water-to-water heat pumps

Water-to-water heat pumps made by Zeneral Heat Pump Industry are used by our facility. Geothermal energy and heat from the hot spring run-off are used as its heat sources. 25 HPs constitute one module. Multiple modules are linked together to form one unit, with operation performed by controlling the number of modules used.

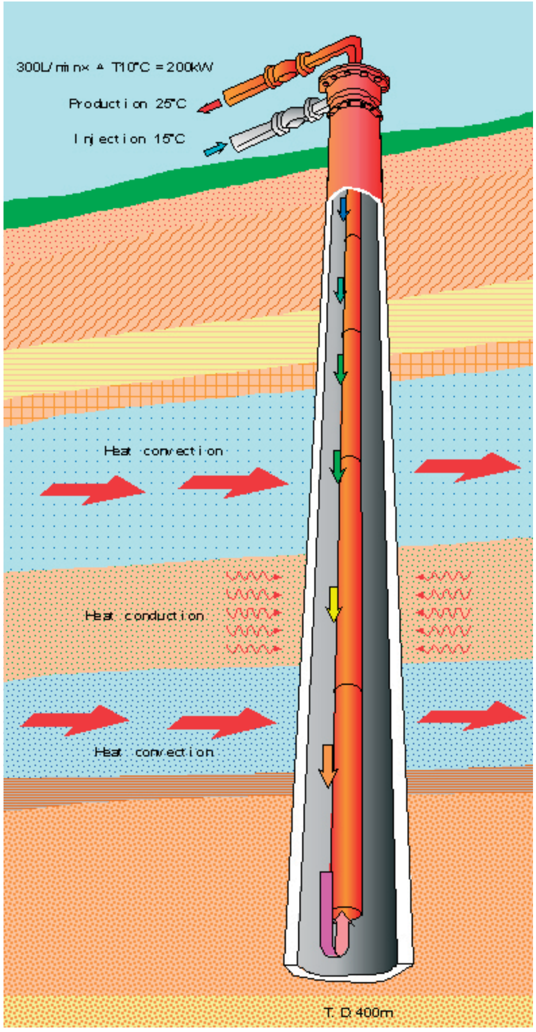

Figure 3 Structure of Ground Heat Exchanger

Figure 4 Water-to-Water Heat Pumps

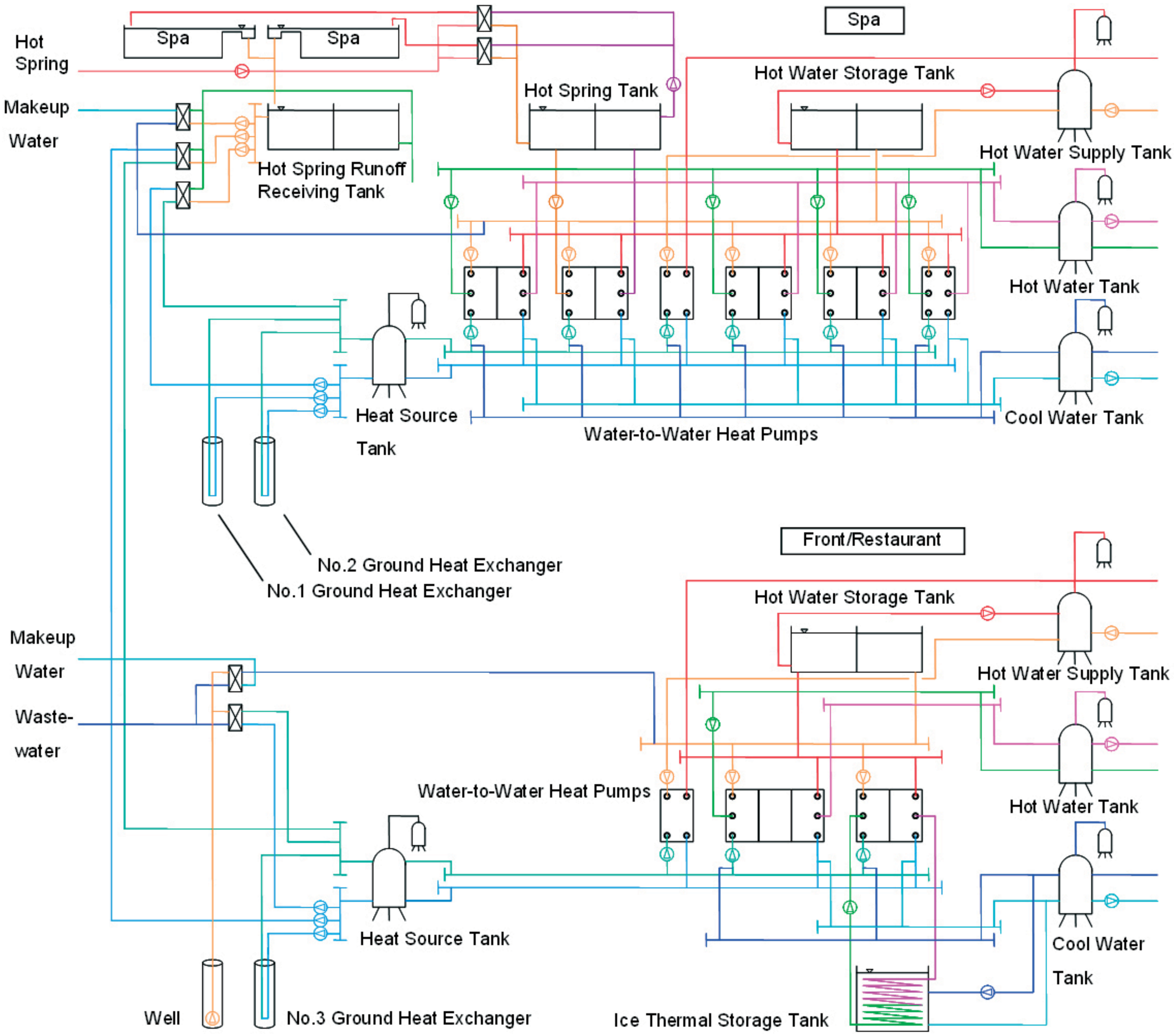

Figure 5 Diagram of Geothermal Heat Pump System

By using plate-type heat exchangers which significantly improve their surface areas, and using liquid-gas heat exchangers, etc, the heat pumps are more efficient than conventional types. This heat pump unit is multi-functional and supports high temperature usage. Simultaneous cooling and heating is possible through heat recovery in addition to the hot water supply circuit, heating circuit, and cooling circuit.

This is used separately, depending on the time and season, in an effort to optimize the facilities' capacity. They are automatically operated using an

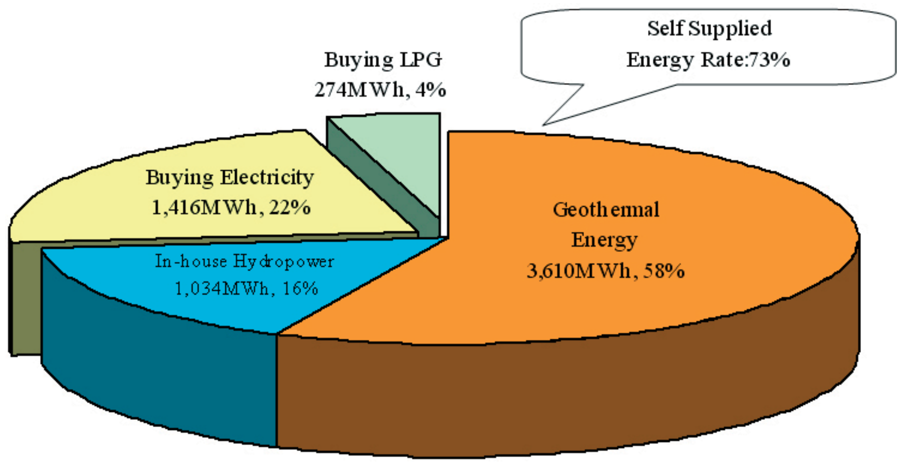

Figure 6 Self Supplied Energy Rate of Hoshinoya Karuizawa

optimization control system via a central monitoring panel integrated into the heat source system, together with remote monitoring and operation via a telephone line.

Load leveling through thermal storage

Heat pumps that use geothermal energy as their heat source produce hot and cold water for hot water supplies and air conditioning. These are supplied centrally to facilities, with the underground machine room defined as the energy center.

Energy-saving measures, such as the adoption of triple glazing and low-E glass are thoroughly implemented for secondary equipment. Floor heating has been fully adopted. The temperature of the hot water supply to the floor heating system is set low in accordance with its load. Highly efficient operation of the heat pumps is sought, as well as improving users' comfort and safety.

An ice thermal storage tank and hot water tank are combined for the heat source facility. The load factor reaches 56 % in the evenings or later due to load leveling operation using late night service. In summer, heat discharged from the cooler can be recovered for the hot water supply using these thermal storage tanks, thus boosting operational efficiency. Automated operation and optimization control are also conducted using the central monitoring facility, achieving an average system COP of 3.7.

Assessment of economic efficiency and environmental performance

73 % of our energy needs can be self-supplied by combining our entire existing hydropower generation (rated 225 kW) and geothermal utilization. The total reduction in carbon dioxide emissions is estimated to be 1,581 t CO_2/year.

The unit price for energy is ¥1.4 per kWh. This is about 20 % of existing systems, which is equivalent to an 80 % cost reduction. Installation of geothermal facilities is more expensive than existing systems, but the difference in equipment investment costs could be recovered in two years due to its low running costs.

Conclusion

Bear in mind that the need to match facilities and secondary equipment is very important when adopting natural energy. One of the reasons is the reduced consistency in energy quality in comparison with fossil fuels, etc. Different methods and timing may be needed from existing designs.

Economic viability must not be ignored with environmental investment: rather, cost-effectiveness should be the motive for equipment investment. We focused on customer satisfaction as the most important factor. We selected and introduced natural energy usage as a means to this end. As a result, significant environmental benefits and cost performance have been achieved, and we are certain that our customers approve.

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