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An investigation of geothermal energy applications and assisted air-conditioning system for energy conservation analysis

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ABSTRACT

This study used the Sea Gaia Spring Hotel in Wanli, Jinshan District, where geothermal water at 90–100 °C is used as a hot spring, as a case study to analyze the effect of geothermally assisted air-conditioning systems. The results of analysis showed that the total electric energy consumption in the building was reduced by 26%, the electric energy consumed by the air-conditioned heating system of the building was reduced by 54%, and the electric energy consumed by the air-host was reduced by 66.5%.

1. Introduction

Taiwan's geothermal energy reserves has been estimated to exceed 500 MW. However, geothermal energy (Ozgener et al., 2005) is not tapped as an electricity power source for buildings (Srinivasan et al., 2012) and is merely used for hot springs. Taiwan's geographical environment is an island with a humid subtropical climate. However, the global climate change in recent years has turned the climate on the island into a dry, hot summer and a wet, cold winter, during which snow is expected in high-elevated mountain areas and the cold temperature brought by the northeastern monsoon can be lower than 10 °C. All of these factors contribute to longer hours of using air-conditioned heating systems, thus greatly increasing energy consumption (Kalz et al., 2005). The hotel building used as a case study is a business establishment that requires comfortable 24-h operated indoor temperature and humidity control. If the source of heating is fully provided by electricity, then the operation costs would be too high and so would the installation expenses of the electrical system in the building. To reduce costs, early deployment of heating is based on diesel-fuelled boilers, but this approach has adversely caused environmental pollution because of the emission of SO_x, heavy metals, CO_2, and waste heat.

The hotel building used in this study is located in the Jinshan District, Taiwan, geographically in the area of the Tatun Volcano distribution. The geothermal layer in this area is near the land surface and the sea; hence, the water source of this building is provided by a mixture of underground water and sea water. Therefore, the geothermally assisted air-conditioned heating system was adopted to replace the early boiler heating system.

2. Site environment and equipment

2.1. The site's climate analysis

According to Central Weather Bureau (CWB) (Table 1), three meteorological observation stations are near the Wanli/Chatou area: Anbu, Zutsuhu, and Keelung. The Anbu and Zutsuhu stations are near, but they vary significantly in elevation; therefore, only the data collected from the Keelung station were used in this study.

2.2. Equipment

As shown in Fig. 1, the spring hotel is a four-story RC structured building, in which the total area served by indoor air-conditioning is 1100 M^2, and the heating system and equipment for storing hot water and maintaining its temperature are installed on the rooftop. The business of this spring hotel comes mainly from its restaurants, hot spring pools, and guest rooms for accommodations, and the electric energy is mostly consumed by air-conditioners, indoor/outdoor lighting, elevators, small-scale water pumps, and heating devices for cooking.

As shown in Fig. 2, the geothermal storage tank must be installed 3 m above the ground to acquire a high-temperature heat source and pressure difference needed to feed the high steam temperature geothermal water through the CPVC4120 pipe to the machine

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Table 1
Statistics of average monthly temperature and precipitation in Keelung, 1981–2010.

Months	Average monthly temperature (°C)	Average monthly precipitation (mm)
January	16.0	331.6
February	16.2	397.0
March	17.9	321.0
April	21.3	242.0
May	24.5	285.1
June	27.3	301.6
July	29.3	148.4
August	28.9	210.1
September	27.0	423.5
October	24.1	400.3
November	21.2	399.6
December	7.7	311.8
Mean	22.6	3772

Fig. 1. Photos of Sea Gaia Spring Hotel.

equipment room of the building for heat energy exchange with the geothermal exchange system. Limited daily peak usage and the confined site boundaries have limited the dimensions of the geothermal storage tank. If geothermal water exceeds the capacity of the tank, then the geothermal water, which is as high as 100 °C,

Fig. 2. Geothermal drainage by drilling to the rock mass 1000 m underground and the plate heat exchange system.

Table 2
Water-consumption levels and CO_2 emissions based on geothermally assisted air-conditioned heating system at the Sea Gaia Hotel.

Months	Periods	Consumptions (M^3)	Expenses (NT$)	CO_2 emissions (kg)
2011.01	2011/01–2011/02	6119	73,532	602.1096
2011.03	2011/03–2011/04	4857	60,528	477.9288
2011.05	2011/05–2011/06	2779	35,437	273.4536
2011.07	2011/07–2011/08	3404	43,563	334.9536
2011.09	2011/09–2011/10	3927	49,298	386.4168
2011.11	2011/11–2011/12	3503	44,179	344.6952
Total			365,181	2419.5576

must be drained from the tank. The daily drainage of the geothermal water is approximately 200 M^3.

3. Analysis of geothermally assisted air-conditioning system

3.1. Research objective

The data for this study were collected within a six-month period, from October 2011 to March 2012. This study first analyzed the energy consumption from the device combining geothermal energy and the plate heat exchanger, as shown in Fig. 3, and then recorded the annual electricity and water consumption expenses. The data were compared to the expenses of energy consumption based on the early boiler heating system to evaluate quantitatively the performance of the geothermally assisted air-conditioning system.

3.2. Geothermally assisted air-conditioning system equipment

The heat source combined with geothermal energy raises the evaporated temperature in the air-host of the air-conditioning system and partially improves the work environment of the air compressor. This geothermally assisted approach not only solves the problem of the air compressor being unable to operate properly under outdoor low temperature conditions but effectively extends the lifetime of the air-conditioning unit.

3.3. Quantitative analysis of energy consumption expenses

3.3.1. Water utility bill data record description

The record of water expense was based on the combined water bills charged to the Sea Gaia Spring Hotel (at No. 150-5 and No. 16-6, Cha-Tou Rd, Wanli Dist.) in 2011, when the geothermally assisted air-conditioned heating system was used.

According to Table 2, it was estimated that every NT$126.7 produces 1 kg of CO_2 emissions. This number was used quantitatively in computing the water consumption and CO_2 emissions produced by the boiler system (Table 3).

Fig. 4 shows a comparison of the water expenses between the boiler system and the geothermally assisted air-conditioned heat-

Table 3
Water expense based on boiler system.

Months	Periods	Expenses (NT$)	CO_2 emissions (kg)
99.01	99/01–99/02	202,960	1602
99.03	99/03–99/04	144,976	1144
99.05	99/05–99/06	131,819	1040
99.07	99/07–99/08	124,721	984
99.09	99/09–99/10	154,107	1216
99.11	99/11–99/12	217,418	1716
Total	976,001	7702	