Energy Proceedings
Vol 55, 2025
ISSN 2004-2965

Development of Hydrogeological Information for Strategic Dissemination of GSHP System: Example of the Inawashiro Plain, Fukushima Prefecture, Japan#

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ABSTRACT

Shallow geothermal utilization systems (especially GSHP systems) are used for heating and cooling, hot water supply, snow melting, and other applications. They are an energy-saving technology with the potential to decarbonize and reduce utility costs. However, GSHP systems have been slower to spread in Japan than in the other countries due to the high cost of GSHP system installation, lack of awareness, and lack of hydrogeological information. Therefore, the Shallow Geothermal and Hydrogeology Team of AIST is engaged in research on social implementation to popularize shallow geothermal utilization system, and this report introduces an example of such research.

Keywords: Ground Source Heat Pump system, renewable energy, hydrogeology, Inawashiro Plain

NONMENCLATURE

Abbreviations	
GSHP	Ground Source Heat Pump
AIST	National Institute of Advanced Industrial Science and Technology
GSI	Geospatial Information Authority of Japan

1. INTRODUCTION

Shallow geothermal utilization systems use low-temperature thermal energy, which exists up to a depth of approximately 200 m below the ground surface, for heating and cooling, hot water supply, snow melting, and other purposes. In particular, the system combined with heat pumps (called GSHP systems) is widely used. In Japan, the temperature of the ground 15 m below the surface remains almost constant throughout a year, although it varies from region to region (Fig. 1).

Air conditioning systems used in residential and office buildings are often air source heat pump systems. In air source heat pump systems, the greater the difference between the controlled indoor temperature and the outdoor temperature, the lower the operating efficiency of heat pumps. Therefore, electricity consumption increases especially during the hottest and coldest months of the year [1]. In contrast, GSHP systems improve the operating efficiency of the heat pump because of the temperature characteristics of the ground, which is lower in summer and higher in winter compared to air temperature (Fig. 2). As a result, energy savings can be realized, leading to a decarbonization effect and reduced operating expense for users of GSHP systems [2].

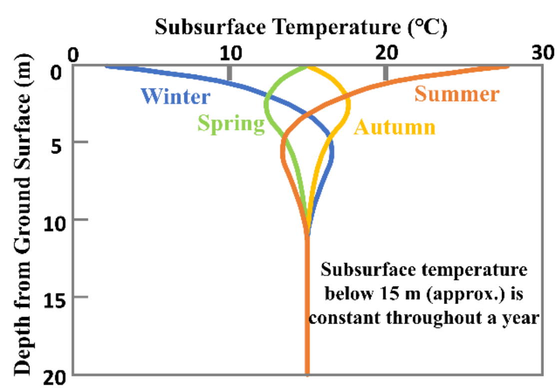

Fig. 1 Typical vertical temperature profile in Japan

This is a paper for the 16th International Conference on Applied Energy (ICAE2024), Sep. 1-5, 2024, Niigata, Japan.

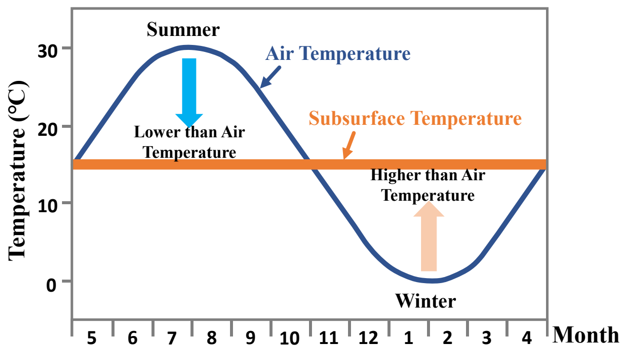

Fig. 2 Annual temperature change

2. CURRENT STATUS OF GSHP SYSTEM UTILIZATION IN JAPAN AND FACTORS HINDERING DISSEMINATION

Although GSHP systems have many advantages, their utilization in Japan is not as widespread as it is in Europe, the United States, China, and South Korea. Factors hindering the dissemination of GSHP systems in Japan include (1) the high cost of GSHP system installation, (2) lack of awareness, and (3) lack of hydrogeological information.

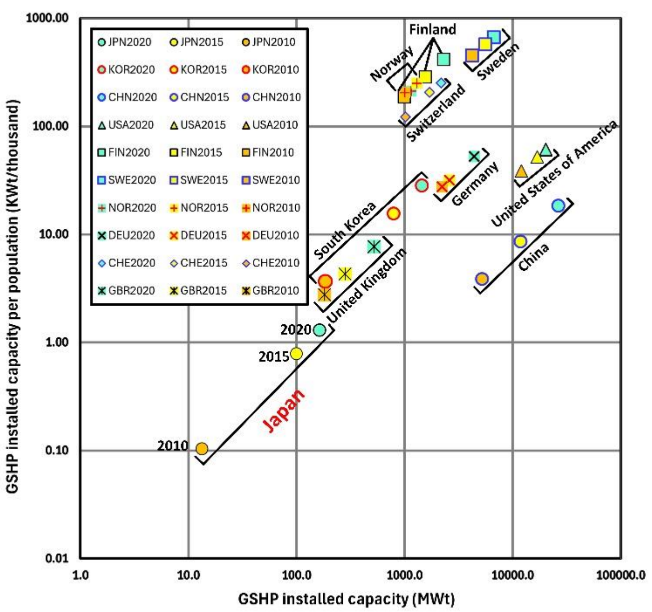

Fig. 3 GSHP installed capacity in different countries around the world [2-5].

The utilization of GSHP systems in Japan and major countries in the world in 2010, 2015, and 2020 is shown in Fig. 3 [2-5]. The horizontal axis represents the GSHP installed capacity in each country, and the vertical axis represents the GSHP installed capacity per thousand population in each country. It is clear that installation capacity of GSHP systems in Japan as of 2020 is equivalent to that in South Korea and the United Kingdom (UK) as of 2010, and is far behind that of other developed countries. On the other hand, a comparison between South Korea and the UK shows that while both countries had similar levels in 2010, South Korea is well ahead of the UK in 2020. Since the 2000s, South Korea has encouraged its national renewable energy deployment policy and subsidy system [6], and has developed a geothermal database with information on the physical and thermal properties of rocks and wells [7]. These efforts are considered to have contributed to the dissemination of GSHP systems in South Korea. By contrast, in the UK, GSHP systems have been slow to spread due to lack of awareness and uncertainty of hydrogeological information, and the development of one was in the developing phase [8]. As Japan aims to expand the use of GSHP systems in the future, it is considered important to improve the support system for installation and to develop ground information.

3. AIM OF THIS STUDY

In many cases, the geological structures are different between Europe / United States, and Japan [9]. While most of the underground geology in Europe and the United States consists of bedrock with high thermal conductivity, the underground geology of urban areas in Japan has a complex geological structure with heterogeneous deposits of gravel, sand, and mud (Quaternary System), which have low thermal conductivity. Therefore, the heat exchanger is longer and the drilling cost is higher if the same amount of heat is to be extracted [9]. On the other hand, in Japan's Quaternary System, groundwater is actively flowing, resulting in efficient heat exchange due to the heat advection effect, and reducing the installation cost. Therefore, the development of hydrogeological information is one of the key factors for the appropriate design and dissemination of GSHP systems in Japan, which is positioned as an issue to be addressed by AIST as national geological survey institute.

The Shallow Geothermal and Hydrogeology Team of AIST is engaged in three researches on social implementation of shallow geothermal utilization systems: (1) “Research on GSHP Dissemination Methodology,” (2) “Collection and Management of Hydrogeological and Thermophysical Data,” and (3) “Development of Technology for Optimization of GSHP Systems". In this study, as part of (1) and (2), hydrogeological information system has been developed and analyzed for potential assessment of the GSHP system in the Inawashiro Plain, Fukushima Prefecture, Japan (Fig. 4). In the Aizu Basin, which is adjacent to the western part of the Inawashiro Plain, suitability maps of shallow geothermal have already been established [10]. Therefore, the purpose of this study is to clarify the similarities and differences in the effects of hydrogeological structures on geothermal potentials. Fukushima Prefectural government has set a goal of generating energy equivalent to 100% of the prefecture's energy demand from renewable energy sources by around FY2040. The results of this study are expected to support the installation of GSHP systems and ultimately contribute to the above goal.

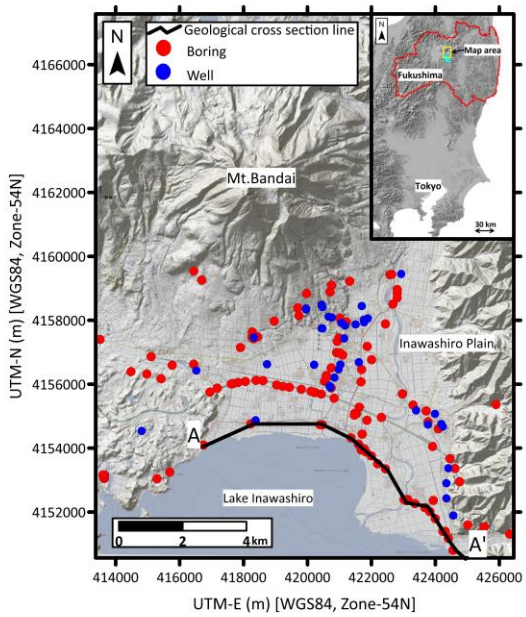

Fig.4 Location map of geological cross section in the Inawashiro Plain, Fukushima Prefecture, Japan (Topographic maps and Digital Elevation Models (GSI) are used for background maps.)

4. RESULTS AND DISCUSSION

Fig. 5 shows a cross section of the subsurface geology of the Inawashiro Plain, based on geological boring and well columnar section data. Unit 1 (fluvial sediment) is found in the plain area with a thickness of about 50 m, but the thickness gradually decreases toward the western part of the plain. Unit 2-a (lacustrine sediment) is deposited below Unit 1 with a thickness of 20-30 m. Unit 2-b (Okinajima debris avalanche deposit) and Unit 4 (volcanic product) are also found below Unit 2-a in the borehole core data. Based on the formation process of Lake Inawashiro, Unit 2-c (fluvial sediment) is subordinate to Unit 2-a. Unit 1 and Unit 2-c are composed mainly of gravel and sand that could be aquifers. On the other hand, Unit 2-a is composed mainly of silt and clay, which is distributed not only at the bottom of Lake Inawashiro but also in the subsurface of the Inawashiro Plain. Unit 1 and Unit 2-c are considered to be aquifers in the Inawashiro Plain, and Unit 2-a is considered to be an aquiclude.

5. CONCLUSION

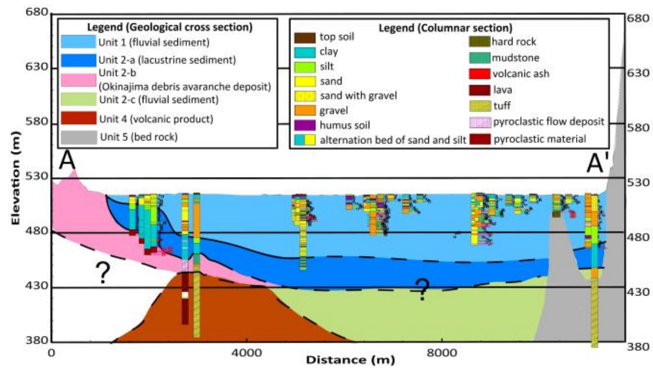

Fig.5 Geological cross section of the Inawashiro Plain, Fukushima Prefecture

Unit 2-a is distributed not only at the bottom of Lake Inawashiro but also in the surrounding plains. Therefore, considering the regional groundwater flow in the groundwater basin of the Inawashiro area, it is possible that the aquifers are separated by Unit2-a. On the other hand, there is not distributed in the Aizu Basin. In the future, groundwater flow analysis will be conducted to compare the effects of groundwater conditions on the suitability of GSHP systems in the Aizu Basin and Inawashiro Plain.

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