Present status of promotion of underground thermal utilization in Japan

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Abstract

Utilization of low-enthalpy geothermal energy in Japan has been far behind the other industrial countries. In 1998, people concerned in Japan conducted a feasibility study on promotion of low enthalpy geothermal resources utilization. In 2000, Geothermal Heat Pump Association was settled by the interested persons from universities and private companies. The activity has been succeeded by present Geo-Heat Promotion Association of Japan (GeoHPJ) since 2001 with an objective of 140 thousand installations for private houses by 2010. Geothermal Research Society of Japan also started new activities on this topic. Research groups in universities and national institutes have started geo-scientific research for its utilization in Japan. Thus, private, academic and governmental sectors have just started working on promotion of geothermal heat pump utilization.

Keywords: country update, underground thermal utilization, heat pump, Japan

1. Introduction

In Japan, utilization of geothermal heat pump has not been emphasized till recent years, while that has been rapidly increased in several European countries and in the USA since 1980s. While direct use of geothermal water in Japan amounts to 5,139 TJ per year (exclude bathing, compiled in March 2001) [1], the heat pump utilization is almost zero. The energy extracted from the ground with heat pumps in Switzerland in 1999 amounts to 1,562 TJ (434 GWh) and it would amount to 28,800 TJ (8 TWh) per year if the same level of utilization occurred in Japan [2]. Technically it can be applied everywhere and it has a thermal merit both for space heating and cooling, as shown in Fig. 1. The difference between surface (atmospheric) and underground (20m or deeper) temperatures gives the merit of geothermal heat pump compared to air source heat pump.

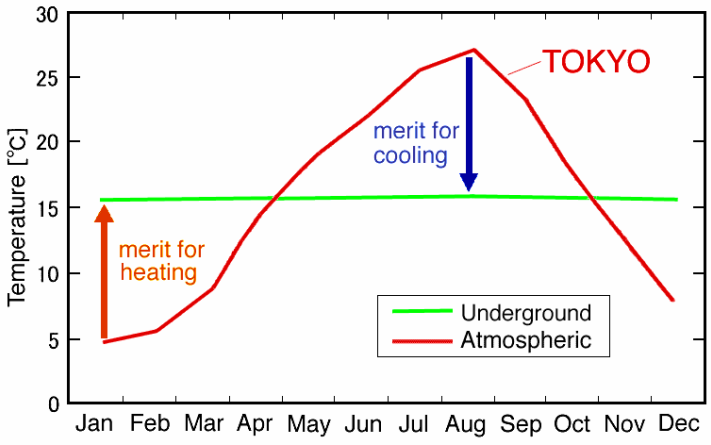

Fig. 1 Thermal merit of geothermal heat pump utilization in Tokyo

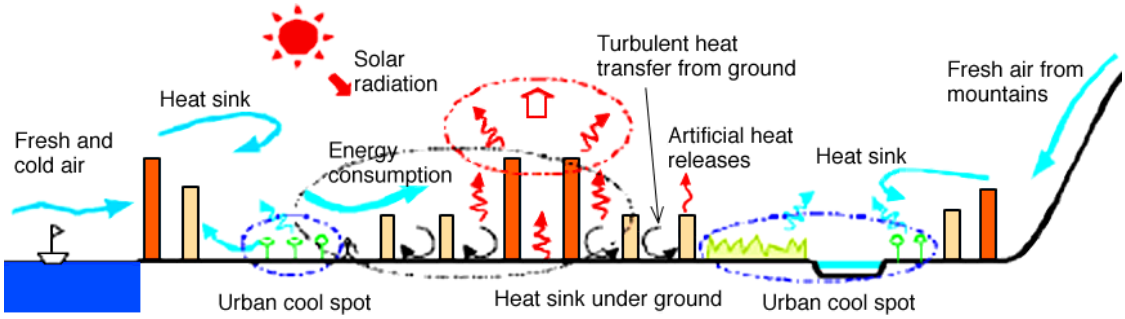

Fig. 2 Mechanism of heat generation from city center in urban scale [3]

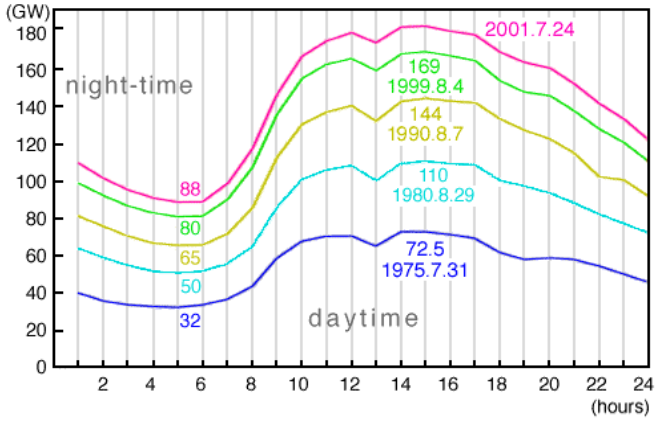

Fig. 3 Change of daily electricity demand in Japan [6]

An intensive underground thermal utilization in Japan may cause positive effects as:

a. Save energy and reduce CO_2 emission
b. Reduce urban heat-island phenomenon (ref. Fig. 2)
c. Reduce the required total capacity of the power plants

a. This effect is clear and common for all over the world. By geothermal heat pumps, consumption of both fossil fuels and electricity will be reduced and CO_2 emission will decrease. Fifty-two million tons of CO_2 emission, which is 4.3 % of CO_2 emission in 1995 over Japan, would be avoided if all the houses in Japan use the geothermal heat pump system [4]. By combination with the effect of b (reducing urban heat-island phenomenon), total electricity saving in the central part of Tokyo will amount to 10 % with the maximum installation of geothermal heat pump [5].

b. This is a peculiar phenomenon in the urban area in Japan. Besides global warming, heat-island phenomenon (local warming) is a severe problem in big cities such as Tokyo and Osaka. Fig.2 shows the mechanism of heat island phenomenon. By utilization of geothermal heat pumps, artificial heat release from the surface will be reduced and heat energy of solar radiation can be stored in the ground. An estimation shows that the average maximum temperature of a summer day in central Tokyo would be reduced for 1.2K if all air conditioners in the area are connected to geothermal heat pump systems [5].

c. In Japan, electricity consumption is considerably higher in daytime: especially in summer, electricity consumption for air conditioning is significant in addition to industrial uses (Fig. 3

[6]). Total capacity of power plants is thus designed to cover the peak load in a summer day, which is still increasing, and excess of electricity occurs at nighttime. Therefore electric power companies offer half price for nighttime, urging customers to use more at night and save at daytime. Geothermal heat pump utilization may contribute to decrease peak load by its high coefficient of performance (COP) and by combination with ice storage air-conditioning systems, using low price night electricity. It may normalize electricity consumption through a day/year and reduce the required capacity of the power plants.

In spite of these advantages, geothermal heat pump is not used in Japan till recent years except for few applications to snow melting on roads. Therefore a feasibility study on promotion of low enthalpy geothermal resources utilization was conducted in 1998 [4] sponsored by New Energy and Industrial Technology Development Organization (NEDO), an affiliate of the Ministry of Economy, Trade and Industry (METI). In 2000, interested persons from universities and private companies in Japan settled Geothermal Heat Pump Association. The activity has been succeeded by present Geo-Heat Promotion Association of Japan (GeoHPAJ), which mainly consists of private companies, since 2001 with a prospect of 140 thousand installations for private houses by 2010 (Fig. 4) [7]. Geothermal Research Society of Japan has also started activities for underground thermal utilization since 2001 with a strong collaboration with GeoHPAJ. A research group in the National Institute of Advanced Industrial Science and Technology (AIST) has started geo-scientific research on this topic since 2001. Thus, each sector in Japan has just started working on promotion of geothermal heat pump utilization.

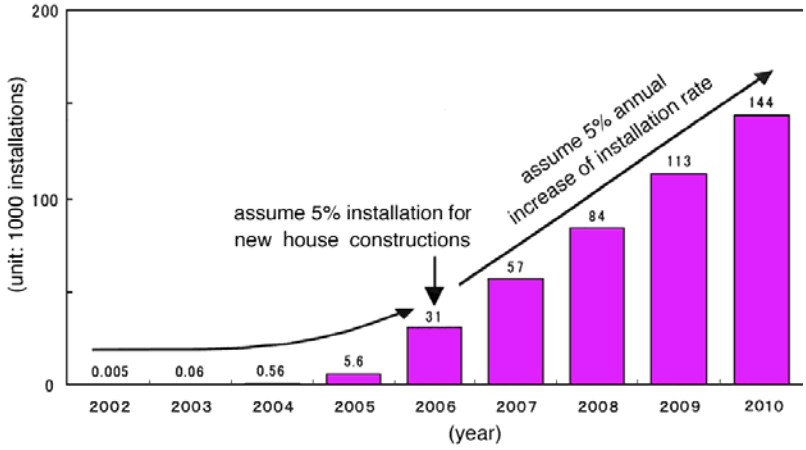

Fig. 4 Prospects of geothermal heat pump installation for houses in Japan [7].

2. Current status of shallow geothermal heat utilization in Japan

Fig. 5 shows the types and the numbers of geothermal heat pump applications installed for houses and buildings in Japan, 2002 [7]. Each symbol expresses one facility. Though the total number is quite small, it is clear that both space cooling and heating are necessary for most part of Japan while only heating is important in Hokkaido. Combination of space cooling and hot water supply is common to keep the yearly balance of heat release and extraction against the intensive space cooling in summer season. Since groundwater extraction is forbidden by regulations in prefectures that had faced severe ground subsidence, borehole heat exchanger is dominant to groundwater heat exchanger. The facility in Niigata uses ground water directly.

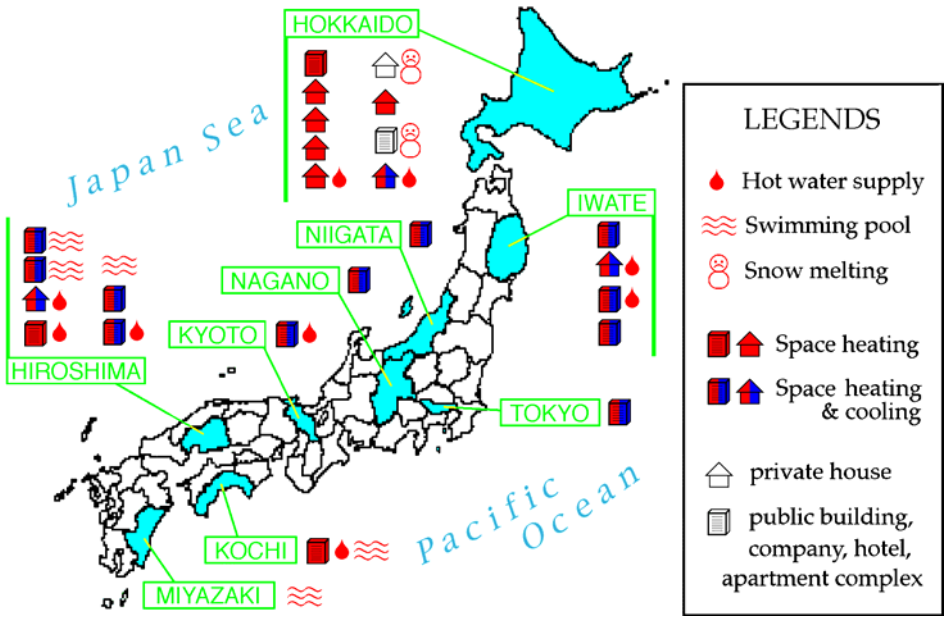

Fig. 5 Geothermal heat pump installation for houses and buildings in Japan, 2002

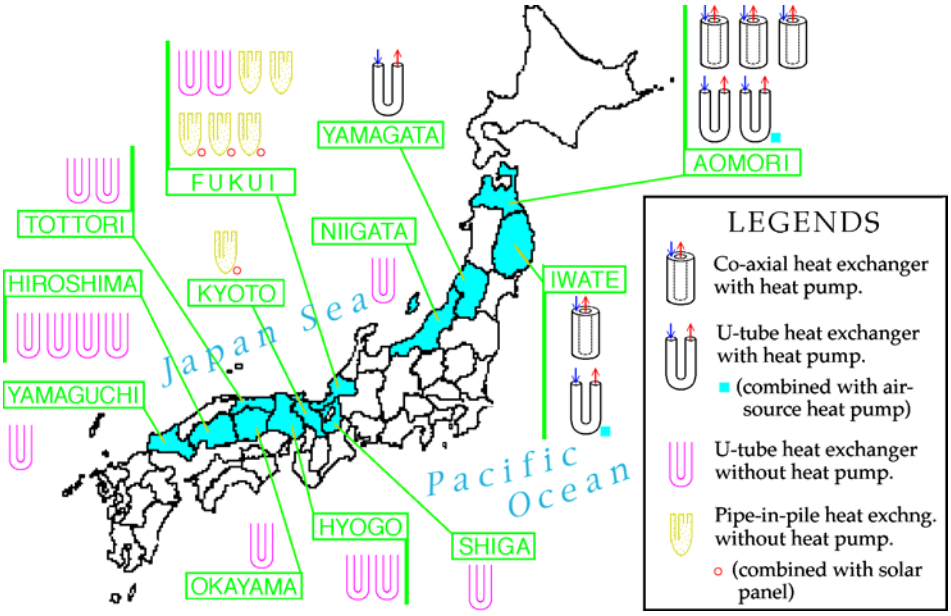

Fig. 6 Geothermal related snow-melting systems for roads, tunnels, etc., in Japan, 2002

Fig. 6 shows the types and numbers of geothermal-related snow melting systems installed for roads, bridges, tunnels and other open places. Most of them are installed in the prefectures facing the Japan Sea due to the fact that the major snowing area is located along the coast of Japan Sea. Heat pump is not used in the southwestern parts while it is used in the northeastern part because the near surface ground temperature is higher in the southwest.

3. Actions by various sectors

3.1. Private companies

GeoHPAJ was established in April 2001, based on the members of former Geothermal Heat Pump Association settled in 2000. Currently GeoHPAJ consists of 76 company members

(including geo-technical consultants, electric power company, drilling, construction and civil engineering companies, heat-pump manufactures, facility owners, etc) and several individual members from research institutes and universities. Four working groups, public information, planning, drilling technology, and regulation and strategy, perform activities on voluntary basis. Beside regular information exchange, services for the members and public information are emphasized. Experimental evaluation of a recently installed system is now conducted. Publication of articles, exhibitions at trade shows, and lecture at seminars are the major activities as public information. Panel discussion on promotion of geothermal heat pump was held with Geothermal Research Society of Japan (GRSJ).

3.2 Academic groups

In December 2001, Technical Division of Underground Thermal Utilization has settled under GRSJ. Collaborating with GeoHPAJ, the number of technical presentation related to geothermal heat pump in annual conference drastically increased since 2001. At the panel discussion, planned by the technical division and held by cooperation with GeoHPAJ in April 2002, current problems and desirable strategies for promotion were pointed out. Special issue of GRSJ journal was also edited. Four technical sub-groups, geo-science, drilling, total system and environmental effect, are planning to write a guidebook for public and/or technicians.

Understanding the action of GRSJ, several studies on geothermal heat pump system are in progress in Akita University [8][9][10], etc. A working group led by Prof. Niitsuma from Tohoku University compiled a proposal report "Development strategy of geothermal energy in conformity with the earth environment"[11]. This report introduces new concept of EIMY (Energy in My Yard, see Fig. 7) showing economical utilization of local natural energies. Utilization of low-enthalpy geothermal energy plays one of the important roles in EIMY concept.

3.3 Research institutes

Institute for energy utilization of AIST has been working on Downhole Coaxial Heat Exchanger (DCHE) system for 20 years [12]. The first application of DCHE for snow melting, which is the earliest geothermal snow melting system in Japan known as "Gaia system," has been in operation since 1995 [13]. Structurally DCHE has higher efficiency than U-tube type.

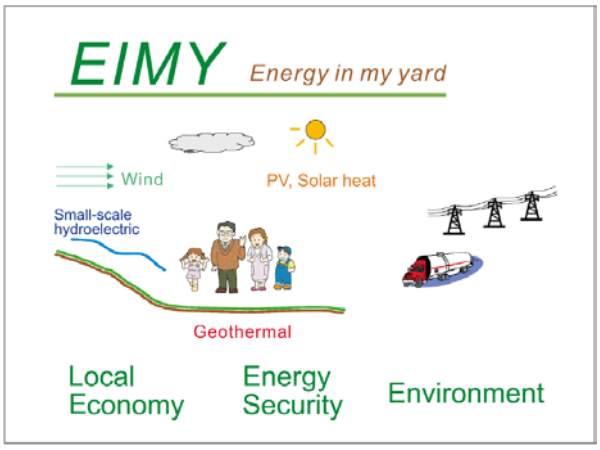

Fig. 7 Concept of EIMY [11]
People should utilize as much local renewable energy as available on demand and only when natural and economical conditions don't permit enough supply by renewables, they may use the national grid system.

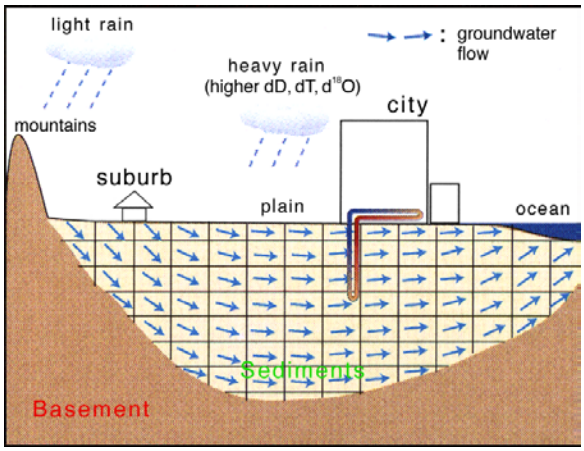

Fig. 8 Geological Research for utilization of low-temperature geothermal resources
Construct numerical model of subsurface hydro-geological structure to estimate available resources and estimate the environmental influence.

Promotion of geothermal heat pump may largely depend on its cost performance and cost competitiveness at each installation point. Institute for geo-resources and environment of AIST started “Geological Research for utilization of low-temperature geothermal resources” in 2001, sponsored by NEDO (Fig. 8). It aims at realizing shallow geological and hydrological structures to categorize economical applicability of geothermal heat pump system to any local area.

3.4 Public agencies

NEDO has financially supported several projects on installation of facilities that utilize low-enthalpy geothermal energy. It covers utilities by local governments (4 cases since 2000), international projects (2 cases, see section **3.5**), technical research projects (2 cases), and practical installation for private houses and buildings (9 cases). NEDO also give efforts on enlightenment and information exchange with other sectors.

Heat Pump & Thermal Storage Technology Center of Japan (HPTCJ), an affiliate of METI, settled a study party for utilization of geothermal heat pump in July 2002 for information exchange and technical improvement. HPTCJ is the Japanese agency for International Energy Agency (IEA) tasks on heat pump system and thermal storage (Annex-17 and Annex-14). Since domestic activities and members of HPTCJ for geothermal heat pump is quite similar to GeoHPAJ, stronger collaboration is requested.

3.5 International and cross-sectional activities

JMC Geothermal Engineering Co. LTD conducted two international projects in Changchun, Chana [14] and Petropavrovsk-Kamchatsky, Russia [15], respectively, both supported by NEDO (Fig. 9) in collaboration with international counterparts. Their results show the high efficiency of geothermal heat pump for ultra cold areas where air source heat pump is not applicable. For the system in Changchun, where average surface temperature in January is below –15°C, COP (coefficient of performance) of 3.1 was obtained. Environmental aspect is also highlighted because geothermal heat pump utilization may largely reduce So_x and CO_2 gas emissions from ordinary coal boilers, which are serious problems in this area [14].

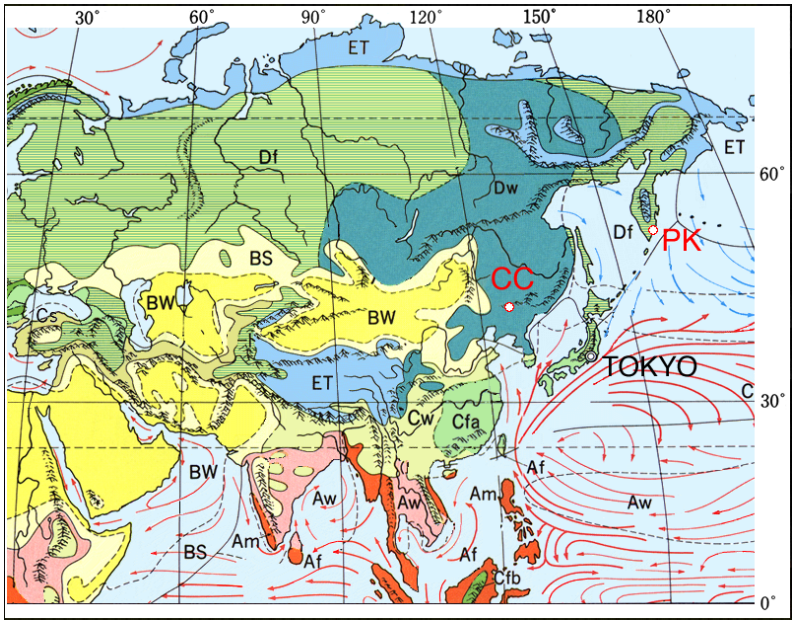

Fig. 9 Locations of Changchun (CC), Chana and Petropavrovsk-Kamchatsky (PK), Russia with Koeppen’s climate classification [16]

GeoHPAJ, NEDO, New Energy Foundation (NEF), AIST and GRSJ hold bimonthly meeting for information exchange. Such a meeting with different sectors is essential for strategy making for geothermal heat pump promotion.

3.6 Government

Probably because of promotion activities in each sectors in Japan, in January 2003, the Environment Ministry declared to introduce an experimental program to use a geothermal heat pump system for public facilities to begin in April 2003. Using geothermal heat pumps for hot water and air conditioning at public facilities including hospitals, libraries and city halls in 60 locations across the nation, an energy saving of 40% is expected. The government and local authorities will pay two-thirds of the construction cost, estimated at 10 million yen for each installation. The ministry hopes that the system will bring geothermal heat pumps to households in the future. Besides saving energy, the pumps address the "heat island" phenomenon of excessive warming of urban areas.

4. Conclusions

Utilization of low-enthalpy geothermal energy has just started in Japan recently. For its promotion, serious efforts are made by every sector. The new policy by the Environment Ministry is one of the fruits of these activities. To achieve the objective of 140 thousand installations for private houses by 2010 proposed by GeoHPAJ, further strategy making from political, technical and economical aspects are essential. International cooperation is also important.

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