APPLICATION PRATIQUE DU SYSTEME DE FONTE DES NEIGES UTILISANT DES RESSOURCES NATURELLES AU JAPON

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Résumé

Une grande partie du Japon est soumise à un hiver rigoureux. Actuellement, 22% de la population (environ 28 millions de personnes) vit dans ces régions, qui ont une superficie totale de 230000 ㎢. Cela représente environ 60% de la superficie du Japon.
En 1961, un nouveau système de fonte de neige a été mis en place qui utilise les eaux souterraines avec des tuyaux installés sur les routes directement sur la neige pour aider à la faire fondre. Ce système est devenu le principal système de technologie de fonte de neige. Mais à cause de ce système , on a constaté de grandes quantités d'eau souterraine, un abaissement du niveau des nappes phréatiques ainsi que des affaissements de terrain. Cependant, une nouvelle meilleure solution a été développée avec le système de fonte de neige sans aspersion des eaux souterraines.
Le système fait fondre la neige et empêche les routes de geler. Comme cela ne vaporise directement les eaux souterraines, cela crée une circulation plus souple,pratique et moins de dommages sont causés à la chaussée. Après la sortie de l'énergie thermique, l'eau souterraine est ramenée dans l'aquifère, de sorte qu'elle n'affecte ni l'approvisionnement en eau ni cause un affaissement des terrains. Ce système est devenu la nouvelle tendance d'utilisation des ressources naturelles (énergie renouvelable) afin de résoudre les problèmes de circulation en hiver.
Je tiens à vous présenter l'application pratique du système de fonte de neige en utilisant non seulement les eaux souterraines, mais aussi une autre ressource naturelle au Japon.

1. SNOWY REGIONS IN THE WORLD

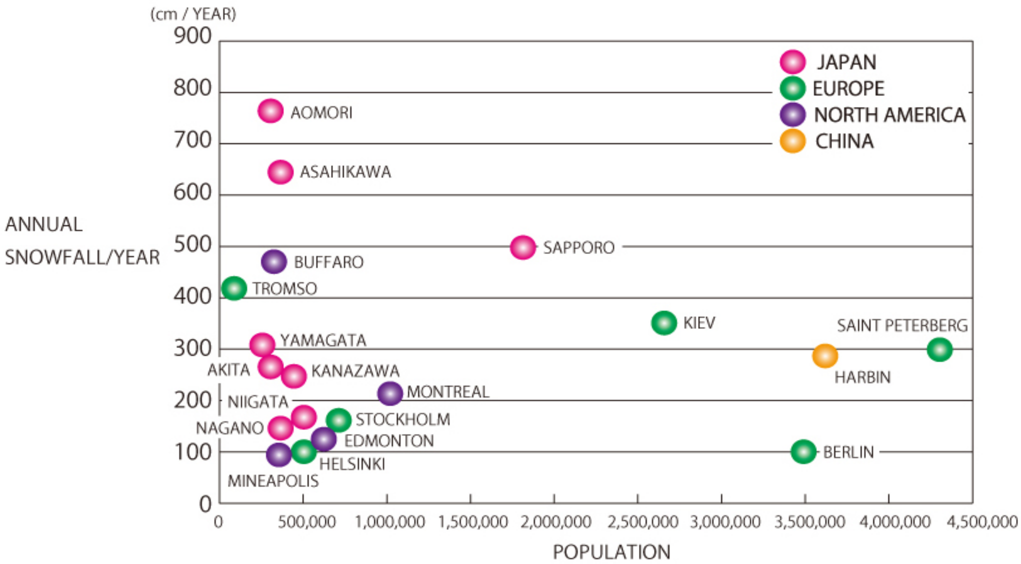

Figure 1 - Comparison of Snowy cities in the world[1]

Figure 1 shows that the comparison of snowy cities in the world. It shows that many people live in snowy and cold regions of Japan, where several meters of snow fall. It is rare to see such a large population in such snowy regions, anywhere in the world.

2. HISTORY OF SNOW MELTING SYSTEM IN JAPAN

A large part of Japan is subject to severe winter weather. Currently, 22% of the population (approximately 28 million people) live in such regions, which have a total 230,000 ㎢. This is about 60% of the area of Japan. (Figure 2)

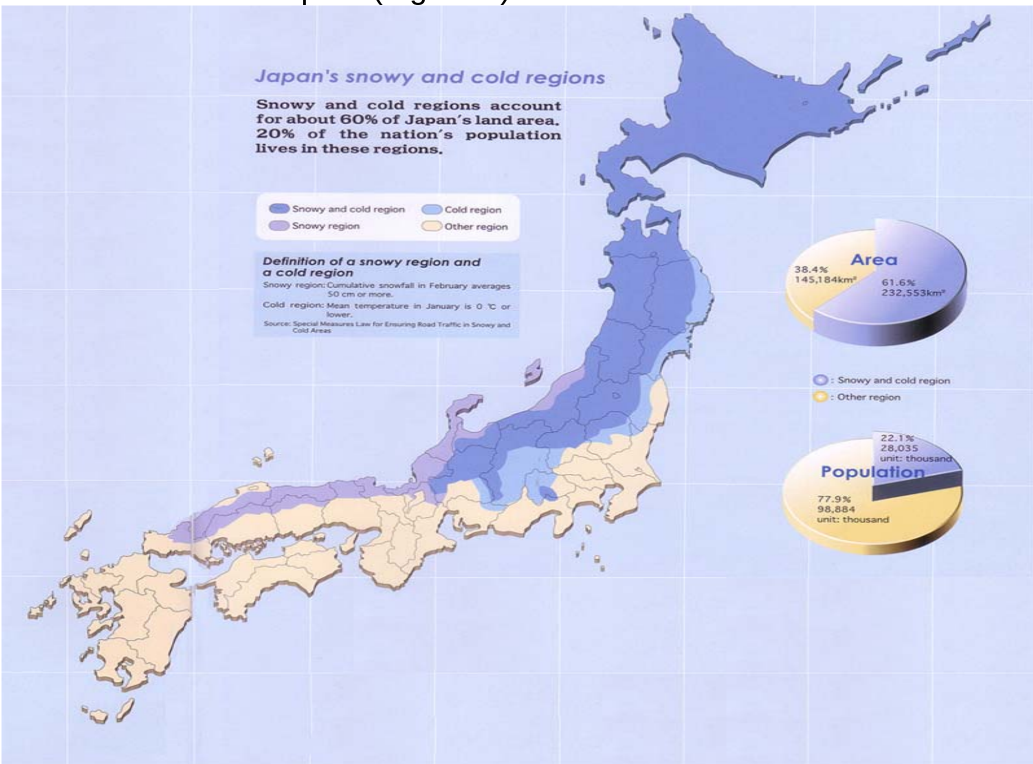

Figure 2 - Snowy and cold regions in Japan[2]

In 1957, the Act on Special Measures concerning Maintenance of Road Traffic in Specified Snow Coverage and Cold Districts was introduced in Japan, which made possible to allocate means to solve snow-related problems in these regions. However, traffic accidents and the isolation of cities due to heavy snow fall and icy roads still continue to be serious problems here.

In 1961, a new Snow Melting System was introduced which used groundwater sprinkled from pipes installed on the roads directly over the snow to help melt it. This system became main snow melting technology system. (Photo 1)

Photo 1 - Snow Melting System with groundwater sprinkling

But because of this system used amounts of groundwater, lowered groundwater level and ground subsidence happened. However, a new, better solution was developed which was the Snow Melting System without groundwater sprinkling.
The system melts snow and prevents roads from freezing. Since it does not directly spray groundwater, it provides for smoother, more convenient traffic, and less damage to the pavement. After releasing heat energy, groundwater is led back into the aquifer, so that it neither affects the water supply nor cause land subsidence. This system became new trend to use natural resource (renewable energy) to solve the problem of winter traffic.
I would like to introduce the practical application of Snow Melting System using groundwater in Japan.
This system became main snow melting technology system. But because of this system used amounts of groundwater, lowered groundwater level and ground subsidence happened. However, a new, better solution was developed which was the Snow Melting System without sprinkling groundwater. This system became new trend to use natural resource (renewable energy) to solve the problem of winter traffic.

3. SNOW MELTING SYSTEM WITHOUT SPRINKLING GROUNDWATER

The system melts snow and prevents roads from freezing by using heat radiation pipes installed under the pavement, with groundwater as the heat source (Photo 2).

Photo 2 - Snow Melting System without groundwater sprinkling in Yamagata

Since it does not directly spray water, it provides for smoother more convenient traffic, and less damage to the pavement. After releasing heat energy, groundwater is led back into the aquifer, so that it neither affects the water supply nor causes land subsidence.
This system consists of a pumping well, a heat radiation area, and an injection well (Figure 3). The pumping well extracts groundwater and pipes it to the heat radiation areas. Heat radiation areas have pipes under the pavement that transfer heat energy from groundwater. They melt snow and prevent roads from freezing. The injection well is used lead the groundwater back into the aquifer without make contact with the atmosphere.

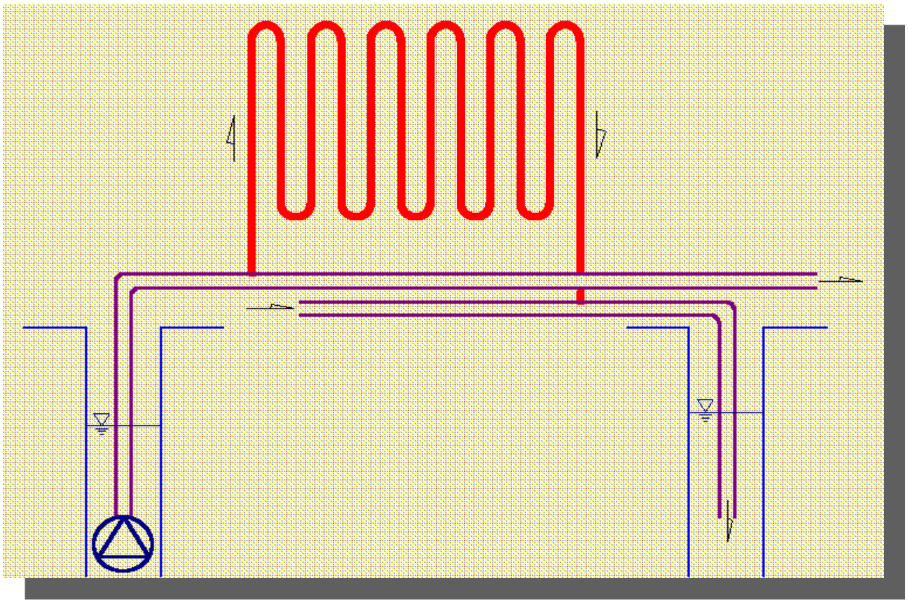

Figure 3 - Basic component of the SMS without groundwater sprinkling

3-1. Advantages of this system

- Energy saving and low running costs because of heat source of groundwater
- Convenient for pedestrians because of no water sprinkled and no splashed.
- No land subsidence because of it does not waste groundwater.

3-2. Design of this system

When we design this system, we need to collect information of the climatic conditions above data for more than 5 years, which are ambient temperature, strength of snow fall, temperature of snow, wind velocity, etc.

Then we calculate how much heat required for snow melting and deicing.

Depth and pitch of heat radiation pipes are designed according to how much heat required, and have to check about groundwater temperature and pavement materials.

In Yamagata City, we drill wells to a depth of 100m where the groundwater temperature is between 14℃ to 15℃, which is almost equal to the average of annual air temperature. Moreover, as we do not use fossil fuels for this system, running costs are very economical and the system emits less carbon dioxide than boiler and electrical snow melting system. (Table 1)

Table 1 - Cost estimate list of the Snow Melting System

Snow Melting System	HEAT SOURCE	INITIAL COST	RUNNING COST
Using groundwater without sprinkling	Ground source	50～70	0.4～0.6
Using groundwater with sprinkling	Ground source	12～30	0.2～0.5
Using electricity	Electricity	40～70	2.0～3.0
Using hot spring	Waste hot spring	30～40	0
Using hot boiler	Kerosene	45～70	1.0～1.7

* The design heat capacity：200W/㎡
* Initial cost : YEN1,000/㎡ (US$10/㎡)
* Running cost：YEN1,000/㎡/YEAR (US$10/㎡)

Because of heat source is natural energy which is groundwater, very low CO2 emissions compared with using kerosene (hot boiler) and using electricity. (Table 2)

Table 2 - Compare the CO2 Emission

Heat Source	Heat Capacity (W/㎡)	Area (㎡)	Operation Time (H)	Power consumption (kWh)	Fuel consumption (L)	CO2 emission (Kg)	Ratio
Groundwater	135	1,500	1,000	15,000	－	7,020	1
Hot Boiker(Kerosene)	135	1,500	700	9,450	20,300	54,970	7.83
Electricity	135	1,500	700	178,500	－	82,538	11.9

Reviewing Conditions
* Planning Part : Pedestrian walkway
* Planning area : A=1,500 ㎡(L=300m, W=2.5m, Both side pedestrian walkway)
* Heat capacity to melt snow : qt=135W/㎡
* Snowfall assumption : h=1.6cm/h, Temp=-3.1℃

4. SNOW MELTING SYSTEM USING GROUND SOURCE

We proved that low temperature energy like groundwater can melt snow in Japan.
Request for the snow melting system in the snowy regions in Japan is changing for more convenient and comfortable because of the aged society will be arriving.
We have experienced we could not get groundwater to build snow melting facility. At that time, we have to find another heat source like air-source, solar heat, wind, and biomass. But when we use these renewable energy, because of the energy densities is small, we have to make very large scale of heat source facilities.
Then, we are trying to use Snow Melting System using ground source. (Figure 4)

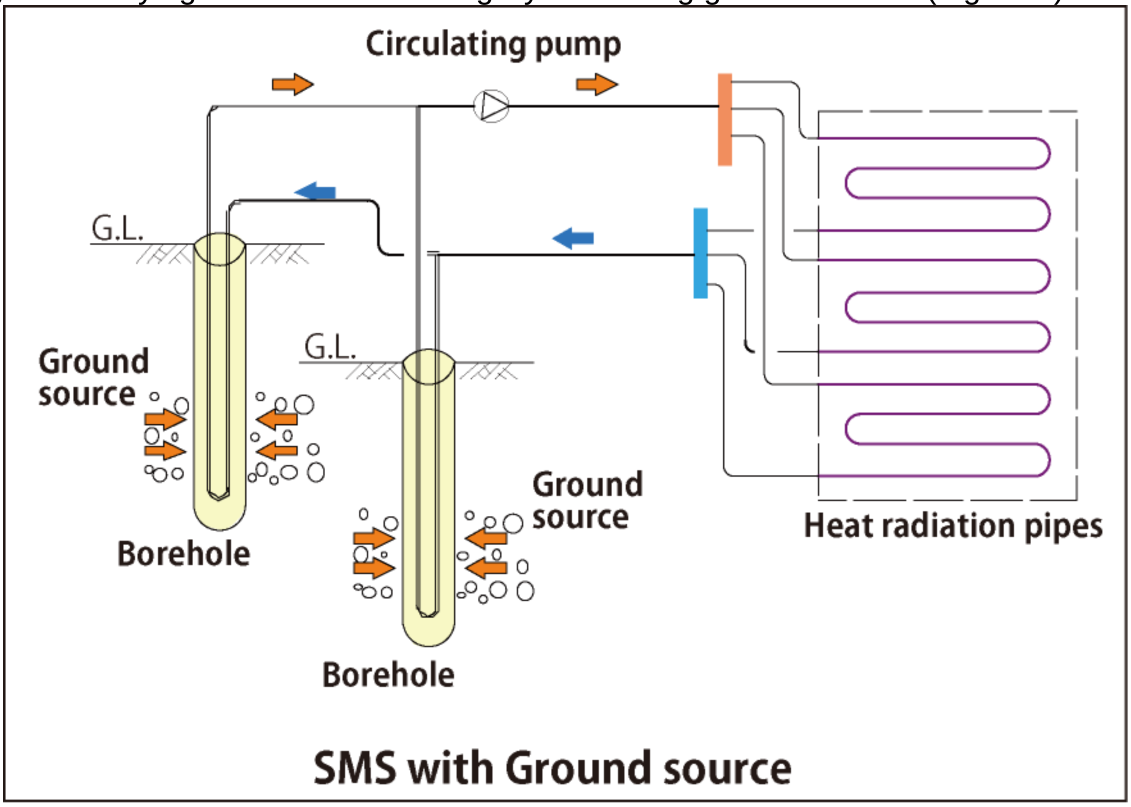

Figure 4 - Basic component of the SMS using ground source

This system is using circulation liquid instead of groundwater. As circulation liquid transport the heat energy of ground source. Temperature of the circulation liquid must lower than groundwater. And ability of snow melt must have the limit depend on the load for melting. That's why, when we make design of this system, we have to think about condition of the heat source, and the purpose and place to melt snow.
Whenever we need more temperature in heavy snow regions, we can use heat pump to improve the ability of snow melting. (Figure 5 & Photo 3)

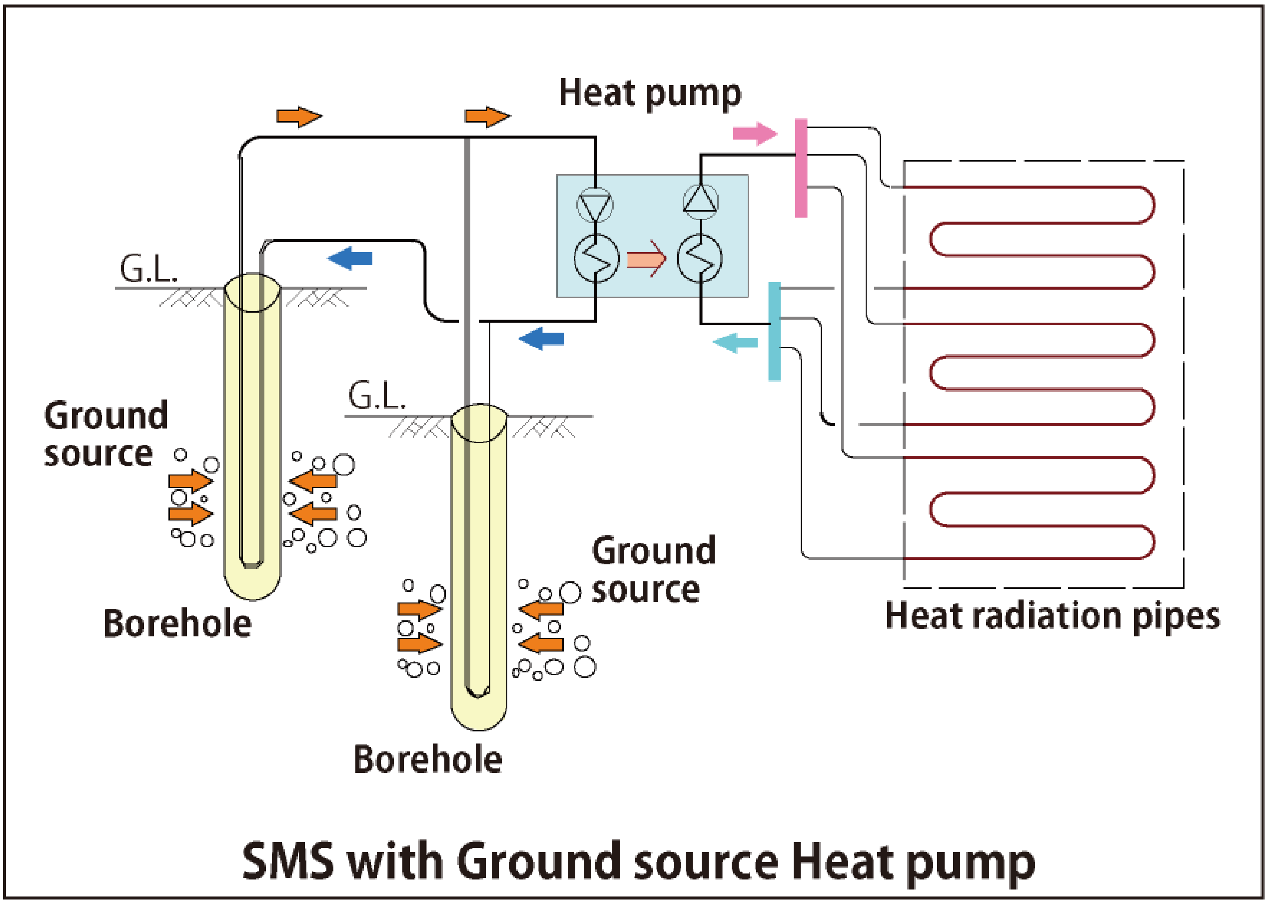

Figure 5 - Basic component of the SMS using ground source heat pump

Photo 3 - SMS using ground source heat pump in Aomori-city

Snow Melting system with ground source heat pump can make hotter liquid than groundwater by performance of heat pump. Therefore, effect of snow melting becomes to be improved.
When we design this system, it is necessary to anticipate how much heat energy can get from the ground by simulation analysis. We have to do the thermal response test (TRT) after drill the borehole, and find out to determine the amount of heat adopted from the thermal conductivity of the ground. Then we determine the proper number of bore hole. Because of the percentage of construction cost of bore hole is expensive, it is necessary to examine how many bore hole we need to drill.
Not only ground source, but also to use natural resource like energy density is limited, we have to decide the level of snow melting. Because of the level of snow melting will be the influence for initial and running cost.

5. HEAT PUMP AIR-CONDITIONING SYSTEM USING AQUIFER THERMAL ENERGY STORAGE (ATES)

The following serves as an example of the snow melting system combined with indoor climate control[3],[4].
Our company, JGD, is in Yamagata City, Yamagata Prefecture, Japan, located in the north eastern part of Japan. (Figure 6)

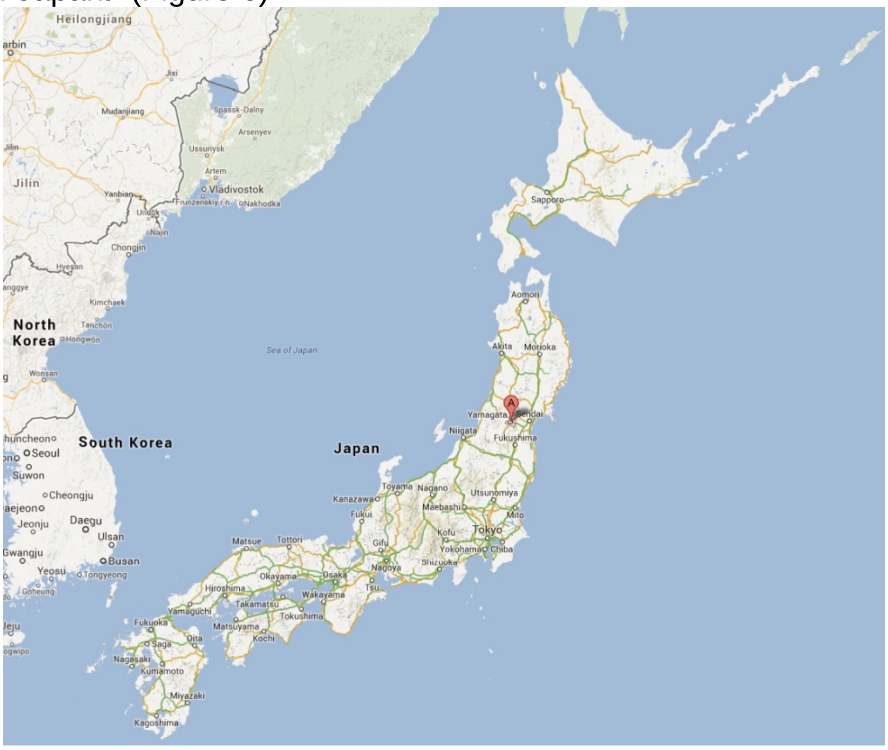

Figure 6 - The company location, Yamagata City, Japan

Air temperature between July to August is 23.9℃, and -3.5℃ between January to February (average for 1971 to 2000). The groundwater temperature from the observation well in the company is 15℃, and it is almost constant year around. As will be seen, it is higher than the atmospheric temperature in winter and lower in summer.
In 1983, JGD began to looking at the possibility of utilizing ATES not only for snow melting but also for air-conditioning for company building. (Figure 7)

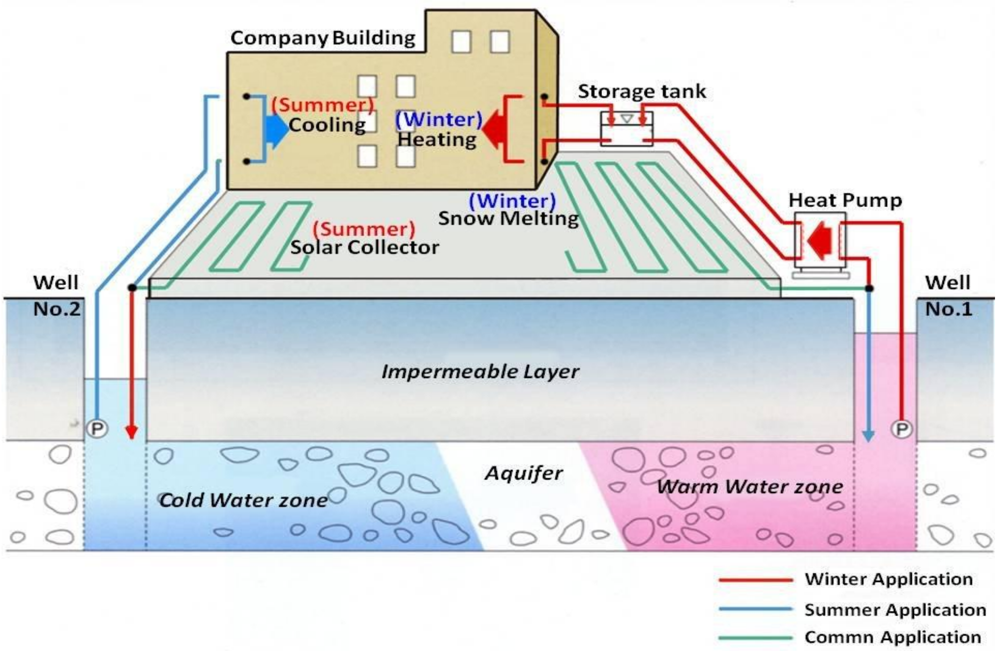

Figure 7 - System Overview of ATES

Total floor area of company building is 800 ㎡.

Heat radiation pipe area (solar collector) is 840 ㎡.

Output capacity of heat pump is 30KW (509.4 MJ of heating capacity, 491.4 MJ of cooling capacity).

In winter, groundwater is pumped from well NO.1, and fed into a heat pump to produce hot water at 50℃. This hot water circulates throughout the office building for heating. After the groundwater has transferred its heat to heat pump, it is led through the pipes under the parking zone to melt snow. The water temperature drops to approximately 8℃ during the process, and it is injected back into the aquifer through well NO.2 to form cold water zone. By the end of winter, the cold groundwater zone temperature become 12℃.

In summer, groundwater is pumped from well NO.2 (cold groundwater zone) and piped to the office building to cooling and to the parking zone to correct solar heat from the pavement, which functions as a solar collector. Groundwater heated by the solar collector is then injected into the aquifer again at well NO.1, which forms the warm groundwater zone, where the temperature is around 30℃. At the end of summer, the temperature of warm groundwater zone become 20℃.

ATES system effectively utilizes groundwater heat. Although the ATES system is still not widely known in Japan, it is obvious that energy of groundwater and ground source is more stable than other natural energy sources such as solar and wind.

It cuts carbon dioxide emissions and reduces the heat island effect by limiting the release of waste heat from air conditioners to the atmosphere.

ATES has a large potential and is not yet fully exploited.

From 2011, the JGD ATES system was adopted by the Low Carbon Technology Research and Development Program by the Ministry of the Environment, Japan. We are committed to collecting more data and carrying out further studies to show how well the ATES system can contribute the prevention of the global warming.

Technical improvements are expected to further reduce costs and enhance the system's performance, and to make the system popular in Japan.

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