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Development and Application of New Heat Supplying Systems Utilizing Hot Spring Water in the Northern Island of Japan

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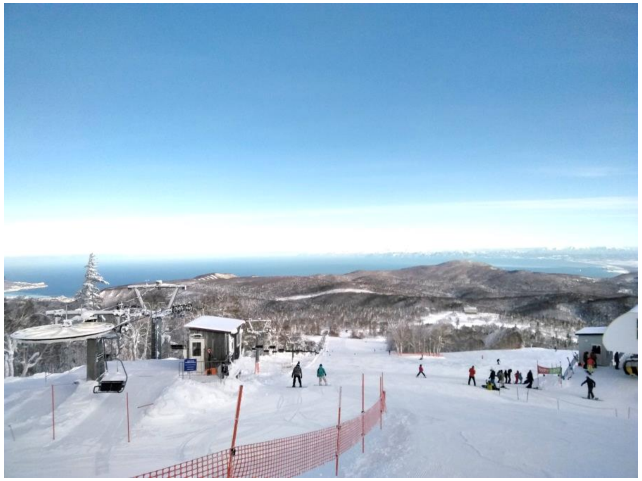
Outline

- Introduction Hokkaido, the Northern Island of Japan and the motivation of this research (Energy self-sufficiency and CO_2 emission in Hokkaido)
- Evaluation of utilizable energy of hot spring water in Hokkaido as a heat source for 4GDH
- A Newly developed palisaded heat exchanger combined with plastic pipes to collect heat from hot spring water
- A heat energy network system among several facilities using hot spring water and the heat exchanger

Where is Hokkaido? The Northern Island of Japan

Location of Hokkaido

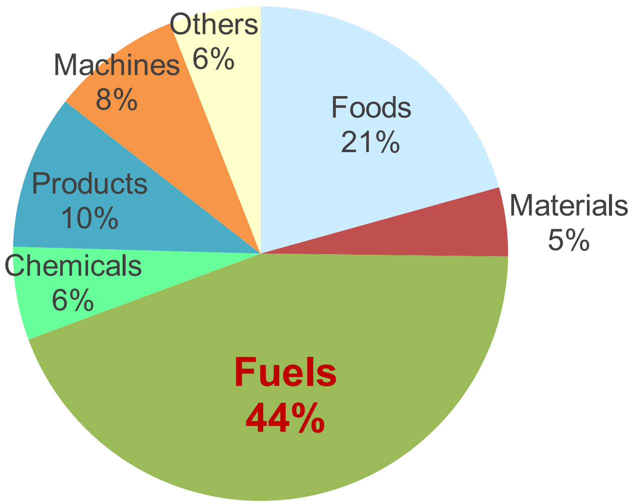


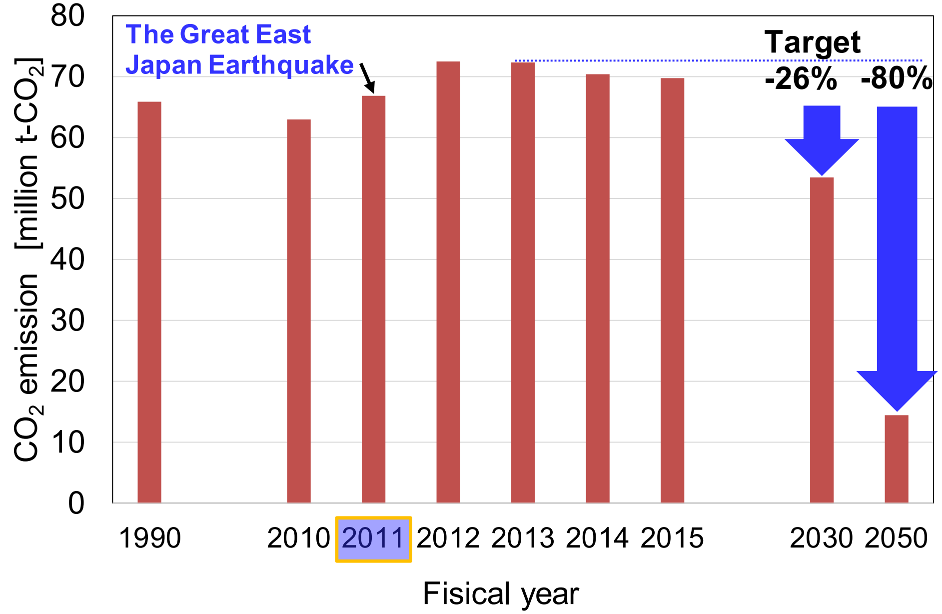
Ski resort in Hokkaido

Radiation panels for heating
Heat source: usually oil, gas

- About 8000km away from CPH
- Annual average temp. of prefectural capital (Sapporo):8.9℃（CPH:8.4℃）, snowy and cold climate

Motivation of this research





Import rate in Hokkaido

※ (Total amounts:906 billion yen, Exports:371)
Source: Hakodate Customs (2017)

CO_2 emission in Hokkaido

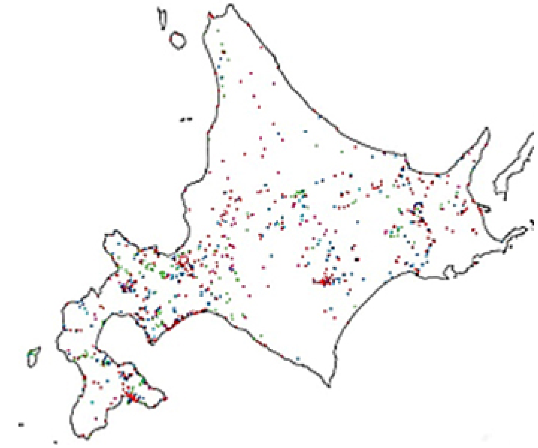
※ 13.0 t-CO_2/person (10.4 t-CO_2 in Japan)
Source: Hokkaido local government (2018)

- Low energy self-sufficiency rate :only 7%
- Renewable energy sources and their suitable systems are required.

Hot springs in Hokkaido

- Sites:245, Number 2225
- The total emission amount: 2,110 m^3/min
- About 59% more than 315K (42℃)

Source: Environment ministry of Japan（2015）



Map of hot Spring sites in Hokkaido

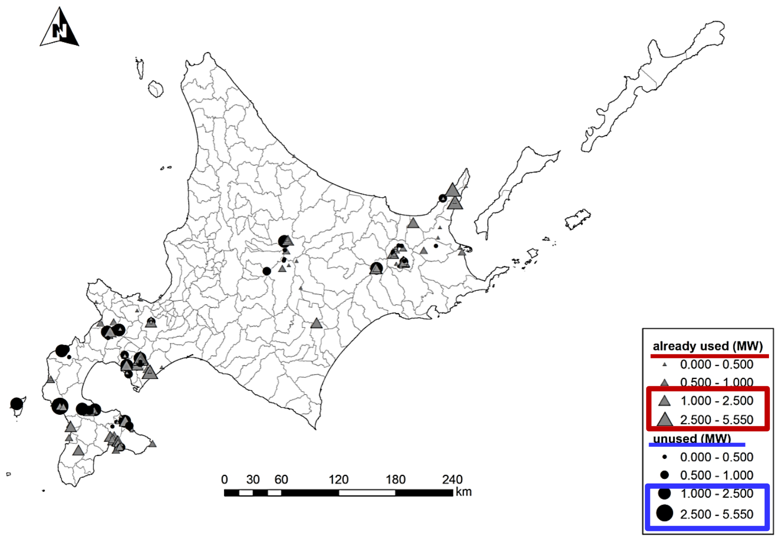
Hot springs as heat sources

Hot springs like lakes

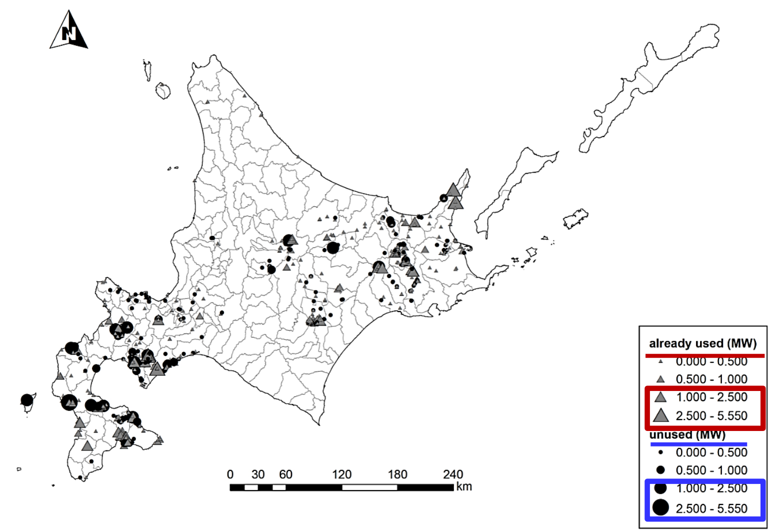
Unutilized hot springs

Waste hot water from spa facilities

Utilizable energy of hot spring water as a heat source for 4GDH



Calculated from more than 333K(60℃)



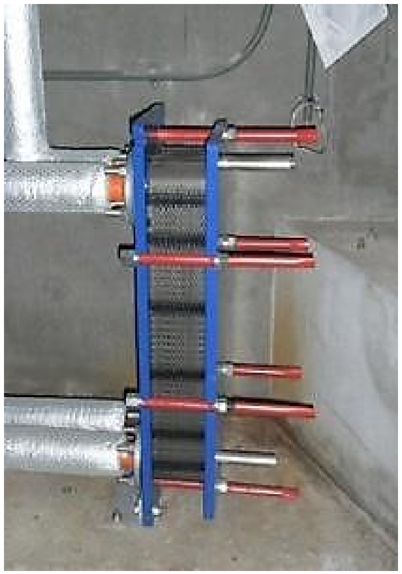
Calculated from more than 313K(40℃)

Maps of the utilizable energy of hot springs in Hokkaido

Estimated more than 1MW

- 40 already used sites, 11 unused sites (more than 60℃)
- 6 added for already used, 1 added for unused (more than 40℃)
- Concentrated in the eastern area or the western area

Problems of metal heat exchangers for heat collected from hot spring water

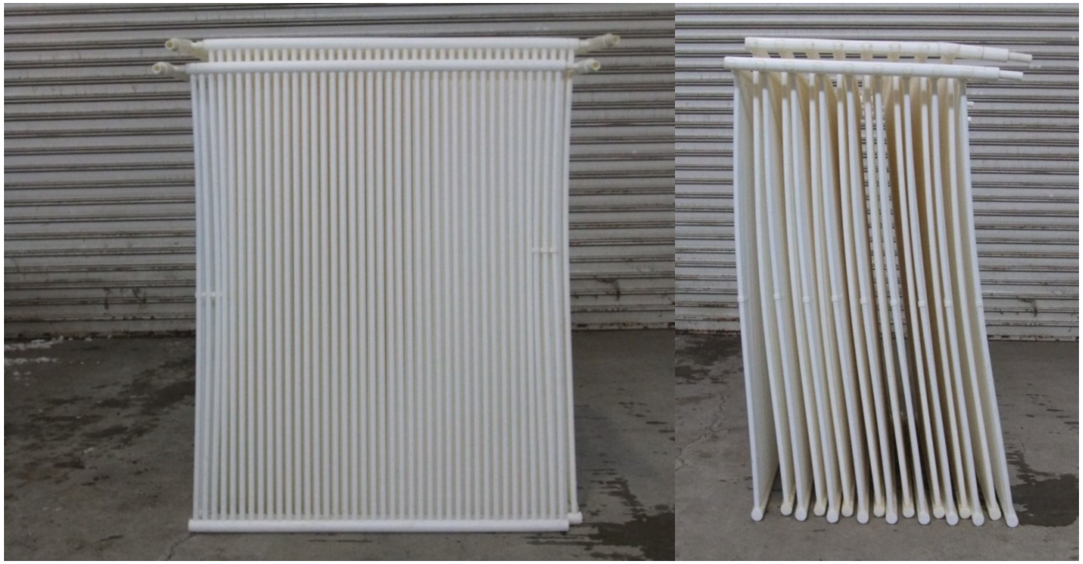


Metal plate heat exchanger

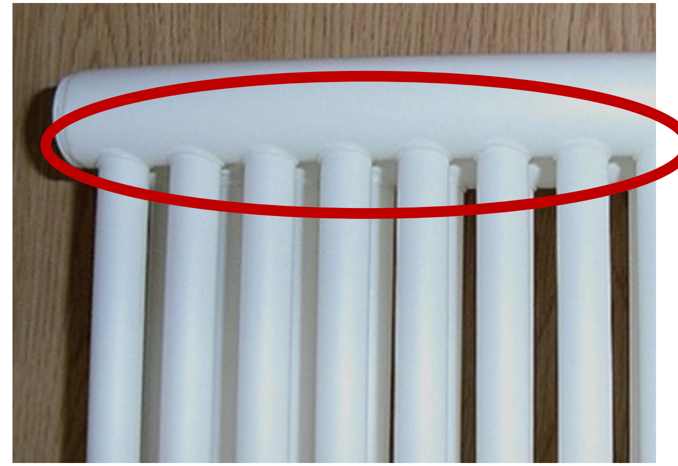
× Make an effort of dividing each plate and cleaning

× Corrosion

A new type of palisaded heat exchanger for hot spring water



Appearance of palisaded heat exchanger
(prototype:893 × 1023 × 560 mm)



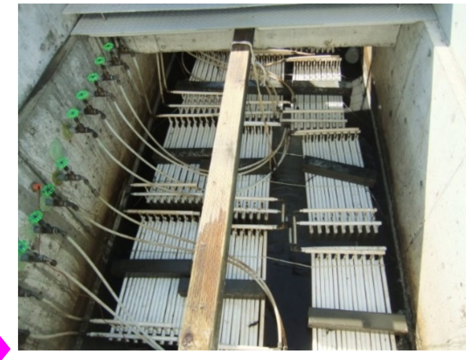
Sites of thermal fusion bonding

- A palisaded heat exchanger combined with pipes formed by thermal fusion bonding
- Corrosion resistance
- Ease of cleaning

Cleaning of heat exchangers


Before cleaning

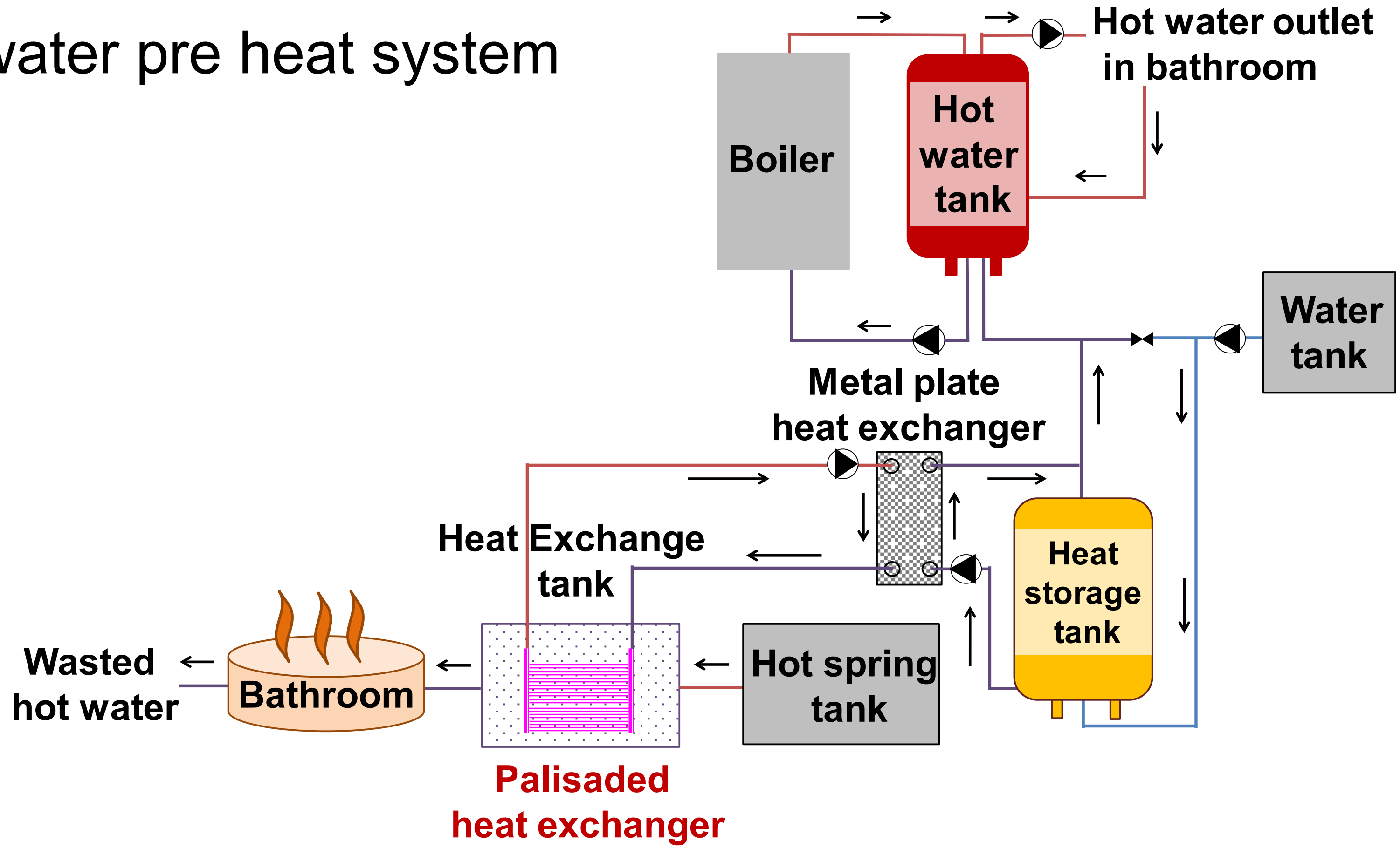

Cleaning



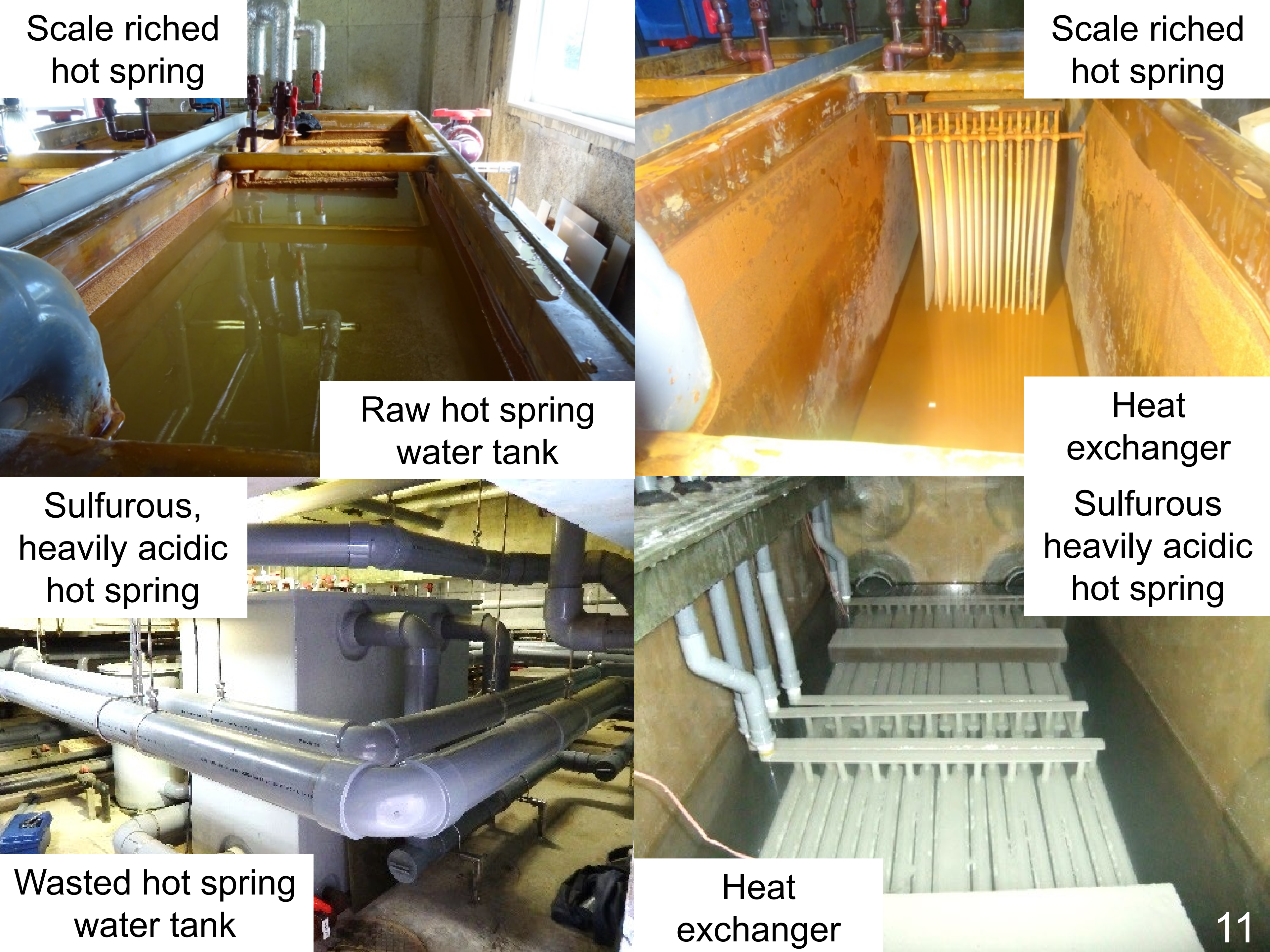

After cleaning

Cleaning of heat exchanger using water or dissolution of scale by hydrochloric

Hot water pre heat system



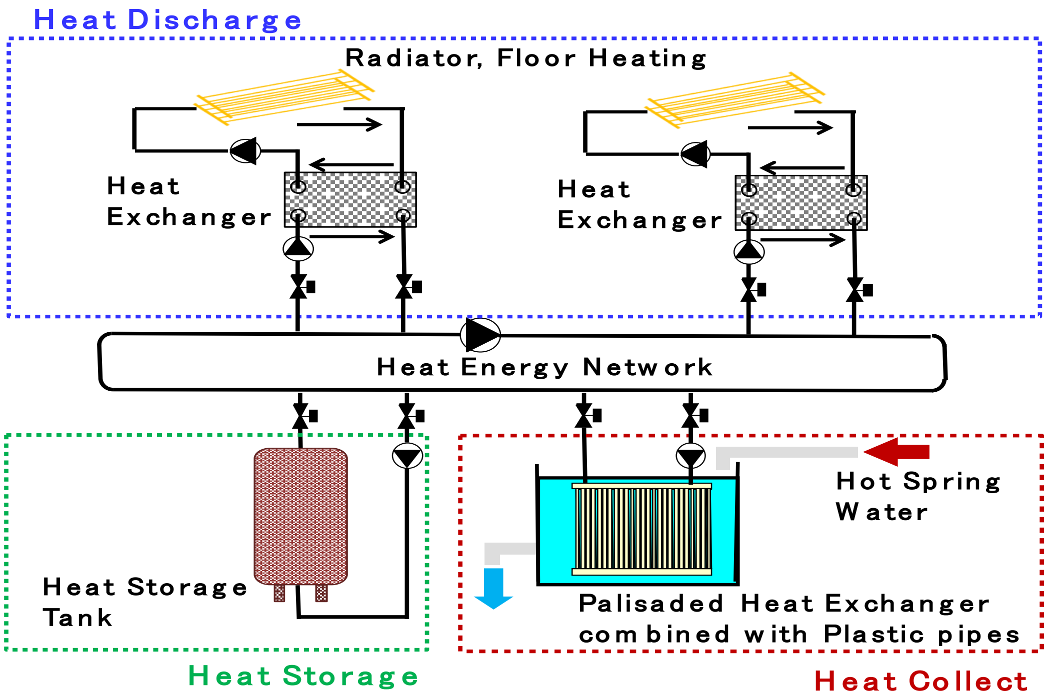
Outline of hot water pre heat system (indirect heat exchange method)


Scale riched hot spring
Raw hot spring water tank
Scale riched hot spring
Heat exchanger
Sulfurous, heavily acidic hot spring
Wasted hot spring water tank
Sulfurous heavily acidic hot spring
Heat exchanger

Energy conservation and cost at system-installed facilities

Entry	A	B	C	D
Location of facilities	Kamoenai village	Ishikari city	Noboribetsu city	Sapporo city
Characteristics of hot spring	Scale rich	mild	Sulfurous, heavily acidic	mild
Heat source	Raw hot spring	Wasted hot spring	Wasted hot spring	Wasted hot spring
Number of prototype heat exchanger	2 sets	2 sets	2 sets	6 sets
Amounts of average heat collect [kWh/day]	**576.9**	**110.2**	**314.9**	**1099.8**
Energy contribution of the system [%]（boiler efficiency 90%）	**49.8**	**33.9**	**44.0**	**26.8**
Temperature of the hot water tank[℃]	**65**	**70**	**41**	**60**
Payback time [year]	**5.6**	**5.6**	**7.6**	**2.3**

Heat energy network systems among several facilities using hot spring water



A schematic diagram of the system

Conclusion

- Already used in 46 sites, and Not used in 12 sites of the hot springs in Hokkaido, (the northern most island of Japan,) were shown as the sites that more than 1MW of the utilizable energy existed.

- A palisaded heat exchanger combined with plastic pipes for preventing corrosion and clogging was newly developed and applied for heat recovery systems from the hot springs.

- We are trying to design an energy network system to install hot spring water. The heat exchanger is one of the solutions to deal with hot spring problems such as corrosion and clogging.

Appendix

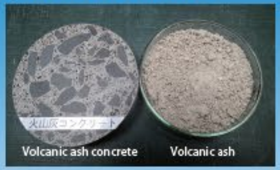
Research achievements by the HRO in support of Hokkaido

~ The following wide range of achievements ~

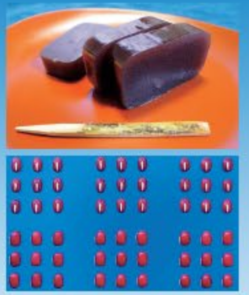
We have predicted the resource volume of artificial forests for up to the next 50 years and estimated the yield and the diameter distribution of logs for each region.

We conduct surveys of the geology and terrains of collapsed slopes to formulate measures against slope disasters.

To improve the usage rate of Hokkaido-grown timber, we have recommended the use of Japanese larches for structural and interior materials, and verified its quality with demonstration tests using an actual house.



We have developed the method to product long-life concrete using volcanic ash in Hokkaido.



We have developed Erimo 167, a new adzuki bean variety that has quality attributes similar to Erimoshozu, a popular Hokkaido adzuki bean variety. Erimo 167 is also resistant to brown stem rot.

We have developed Kitahonami, a wheat cultivar with a good flour color and good quality for udon noodles, accounting for approximately 80% of the total amount of wheat produced in Hokkaido.

We have studied how to collect woody residue (forest biomass) produced by logging, how to utilize it as fuel and evaluated its value as fuel.

Rare plant protection can lead proper conservation at unique ecosystem surrounding its habitat.

We have conducted various studies to put the new wood material CLT (cross laminated timber) made of Hokkaido timber to practical use and achieved CLT construction using domestic larch for the first time in Japan.

In collaboration with a Hokkaido company, we have developed an easily cleaned plastic heat exchanger that can recover heat from strongly acidic hot spring water or dirty hot waste water with many suspended solids. It is applied to a preheating hot-water supply system.

Kentaro　　Yukirara, a new variety

Yukirara, a new spring strawberry variety, is larger and higher-yield but less frequently harvested than the well-regarded Kentaro variety, resulting in reduced harvesting work.

We have developed Katsu-haya-zakura 5, a superior seed bull of Japanese Black Cattle; the bull has excellent meat quality and quantity characteristics. Its calves are well grown, and its daughters are excellent in body shape.

We explore the possibilities of geothermal/hot spring resource development and evaluate the effect of such development on the surrounding hot springs, contributing to regional promotion through the use of geothermal resources.

We have examined mutual interactions between organisms, including leaf litter, aquatic insects and fish to identify the importance of the connections between these organisms in the natural world.

In collaboration with a Hokkaido company, we have developed a super-thin wooden blind with a slat thickness of 0.8 mm or less. The slat has a sandwich structure comprised of veneer and Japanese paper.

We have suggested approaches to the eco-renovation of existing buildings like schools mainly using passive methods that have been adopted in their designs.

As a result of snow wind tunnel and other tests, we have suggested a shape and layout for buildings to help prevent snow cornices, snow accretion and drifts, reflecting them in the design of buildings.

We have succeeded in the mass propagation of rare, useful trees (*Myrica gale*) using tissue culture technologies, and developed cosmetics and cheese using these trees in collaboration with companies.

The third Hokushin-maru scientific research vessel was completed in November 2014. Using the cutting-edge devices (a pelagic and/or mid water trawl net, multipath ultrasonic flowmeter, etc.) in this vessel, surveys are conducted on the distribution densities of Pacific saury and other migrating fish, water temperature and flow, and the results are released as migrating fish news. Such information is used to increase the operational efficiency of fishery operators and marine product companies.

The development of a technique to automatically discriminate/count scallops in seabed footage taken from a sleigh drawn by a fishing boat has made it possible to accurately estimate the quantity of these resources. Through fisheries management and appropriate density management, we contribute to the quality improvement of scallops.

We work on improving the accuracy of salmon resource predictions and offer the predicted value to those concerned with the fishing industry before the fishing season every year. This information is used to secure parent fish necessary for the salmon breeding project in Hokkaido.

Health-conscious consumers increasingly use kelp for salads and other dishes. We have developed a technique to make culled kelp (which is rarely utilized) into a paste. It is used for a sauce for seafood bowls and dressings.

To promote the utilization of primary products in Hokkaido, we have developed processed food with high-added value leveraging the health functionality of their ingredients.

The HRO uses trial product testing facilities that meet facility standards based on the Food Sanitation Act at the Food Processing Research Center, contributing to the development of the food industry in Hokkaido by stepping up food-related research and providing more technical support.

Evaluation of utilizable energy of hot spring water as a heat source for 4DH

$$Q=1/1000\times Cp\times \rho \times F/60\times (T_{out}-313) \cdots \quad (1)$$

Q: Amount of the utilizable energy [MW]

Cp: Specific heat of hot spring water≒4.2[kJ/kg・K]

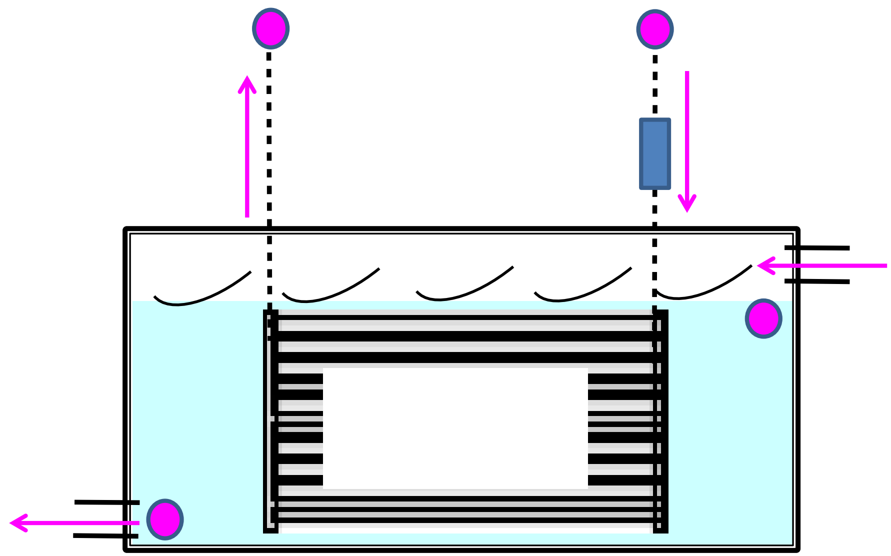
ρ: Density of hot spring water≒1.0[kJ/kg・K]

F: Flow rate of hot spring water [L/min]

T_{out}: Discharge temperature of hot spring water[K]

313: Temperature for heating[K] (40℃)

Heat exchange capability

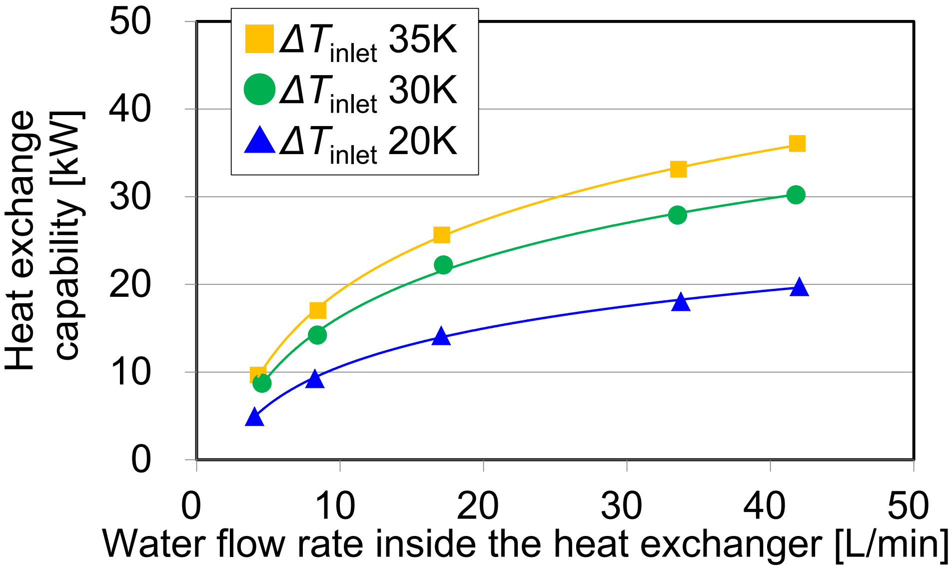


Test apparatus

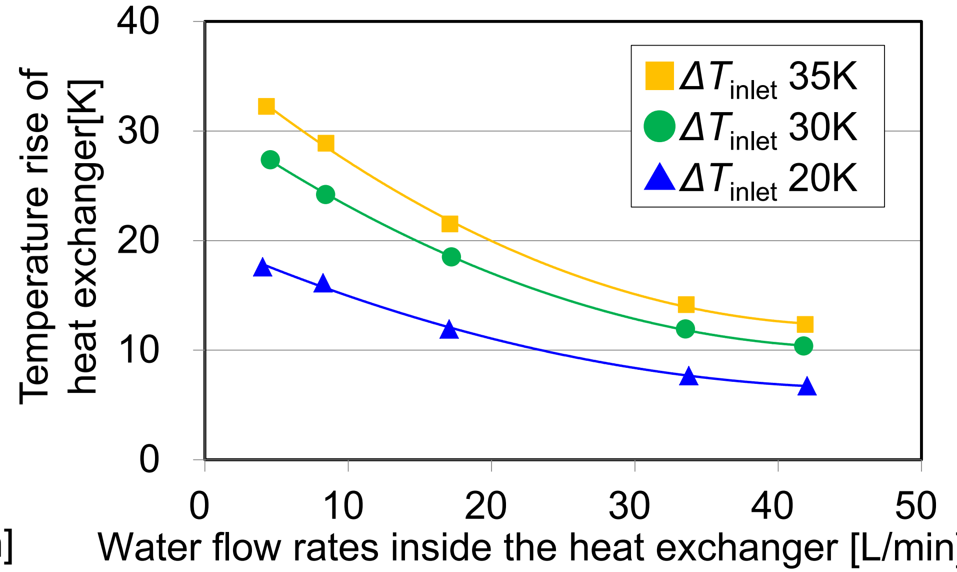
$Q = Cp \times \rho \times F \times (T_2 - T_1)$ [W] (1) $Q = K \times A \times \Delta T_m$ [W] (2)

Q: Heat exchange capability [W], Cp: specific heat of water[J/(g·K)], ρ: density of water [g/L], F: flow rate inside heat exchanger [L/s] , K:the overall heat transmission coefficient of the heat exchanger [W/(m²·K)], A: heat transfer area of the heat exchanger [m²], $\Delta T_m = (\Delta T_{inlet} - \Delta T_{outlet}) / \ln(\Delta T_{inlet} / \Delta T_{outlet})$

Heat exchange capability test apparatus



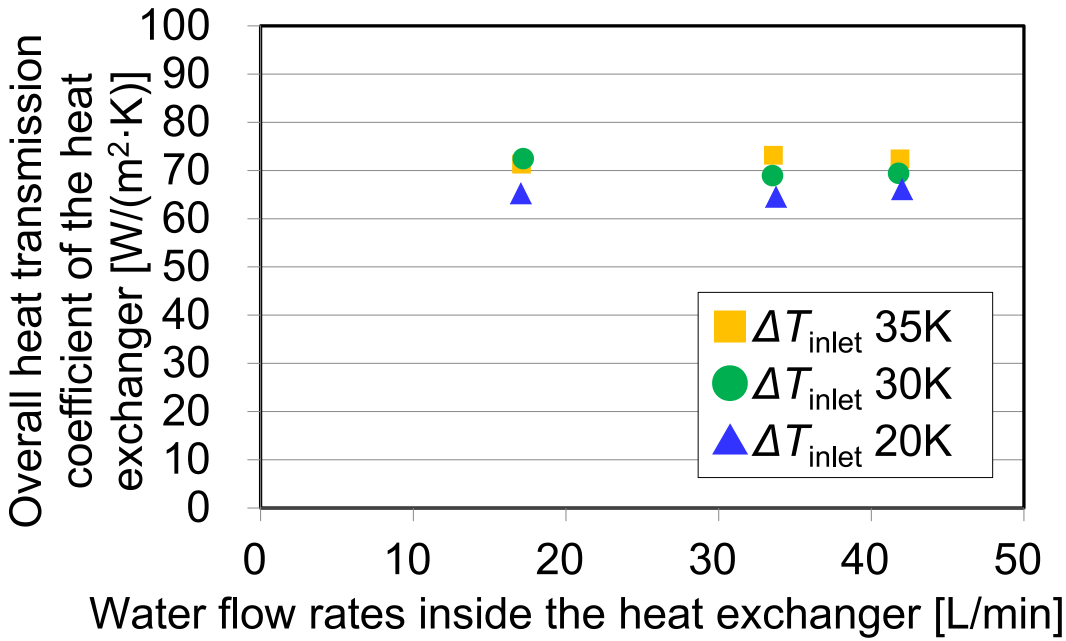
Heat exchange capability of the heat exchanger to flow rate of the water



Temperature rise of the heat exchanger to flow rate of the water

- Temperature difference of the inlet：20K→the maximum heat recovery：about 20kW
- The maximum temperature rise：18K

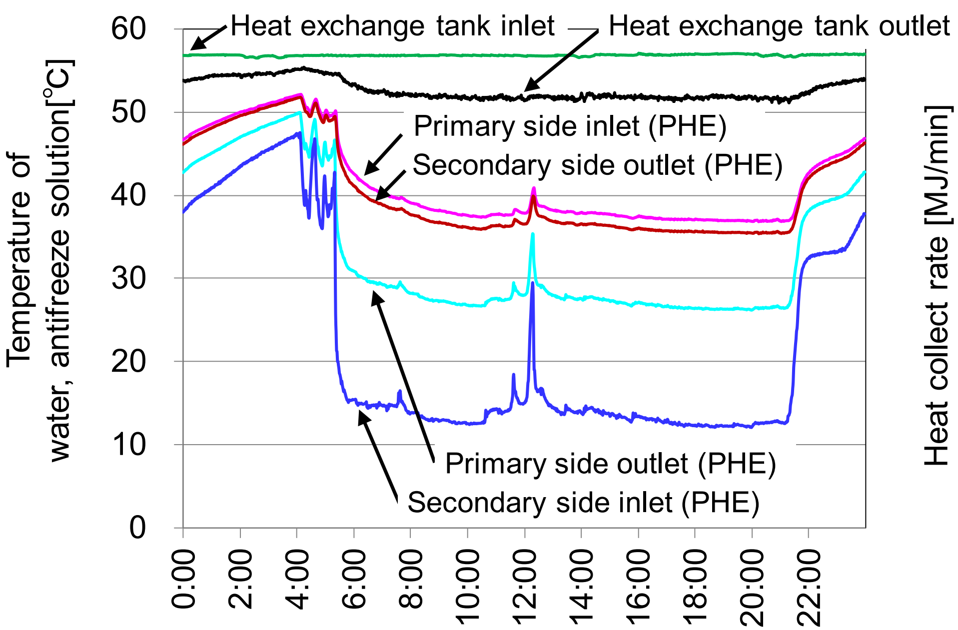
Overall heat transmission coefficient

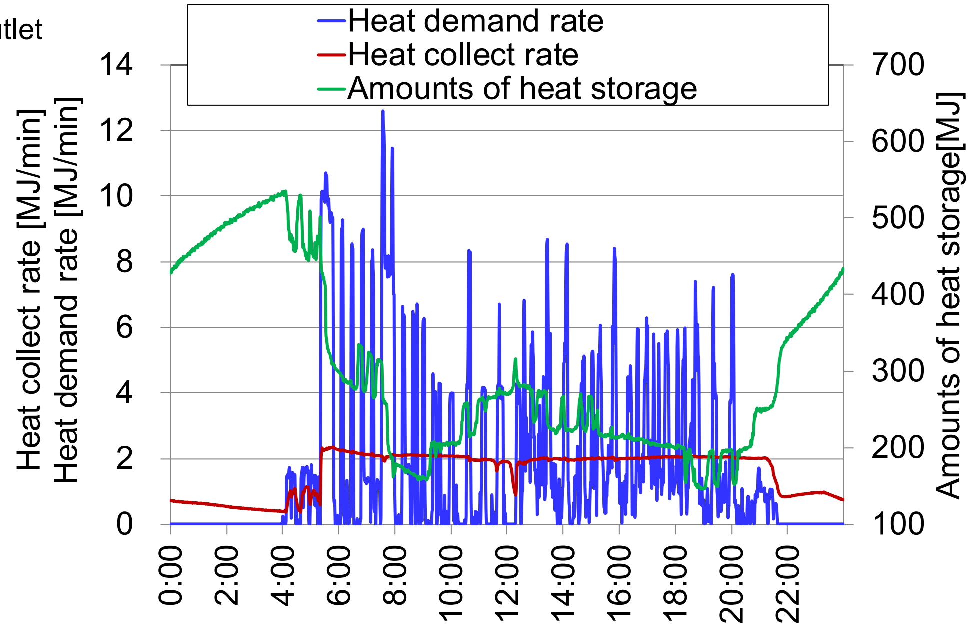


Overall heat transmission coefficient of the heat exchanger

- Low overall heat transmission coefficient
- Enough to deal with the hot spring and wasted water that are corrosive or have a lot of suspended solids

Example of operation data





Heat collect data of the scale riched hot spring
(December 23 2018, Indirect heat exchange method)

■ Cold water is warmed from 12～15℃ to about 35℃.

Material endurance

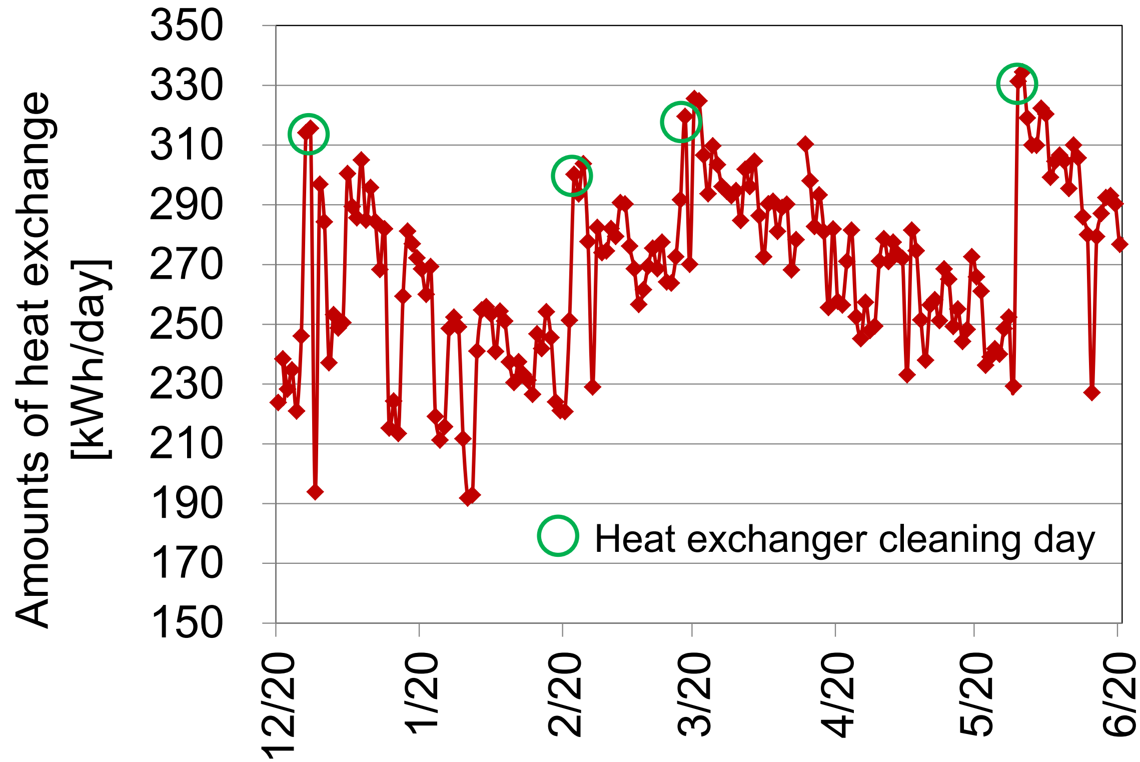
Test pieces
set in the hot springs

Tensile yield strength of test pieces of the heat exchanger

Location	A	B	C
Water temperature [℃]	60.2	58.8	72.5
Quality	Sulfurous spring pH=2.3	Sulfurous spring pH=1.6	High temperature spring
Before soaking [MPa]	22.5	22.5	22.5
1 time [MPa]	23.4	23.1	23.1
2 times[MPa]	23.5	23.5	23.6
3 times[MPa]	23.2	23.6	22.3
4 times[MPa]	23.6	23.6	22.6

- Test pieces had endurance in the early periods.
- The heat exchangers installed at location A has worked well for more than 4 years.

Effect of cleaning for heat collect



Effect of cleaning for heat collect

(Sulfurous, heavily acidic hot spring 2015)

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