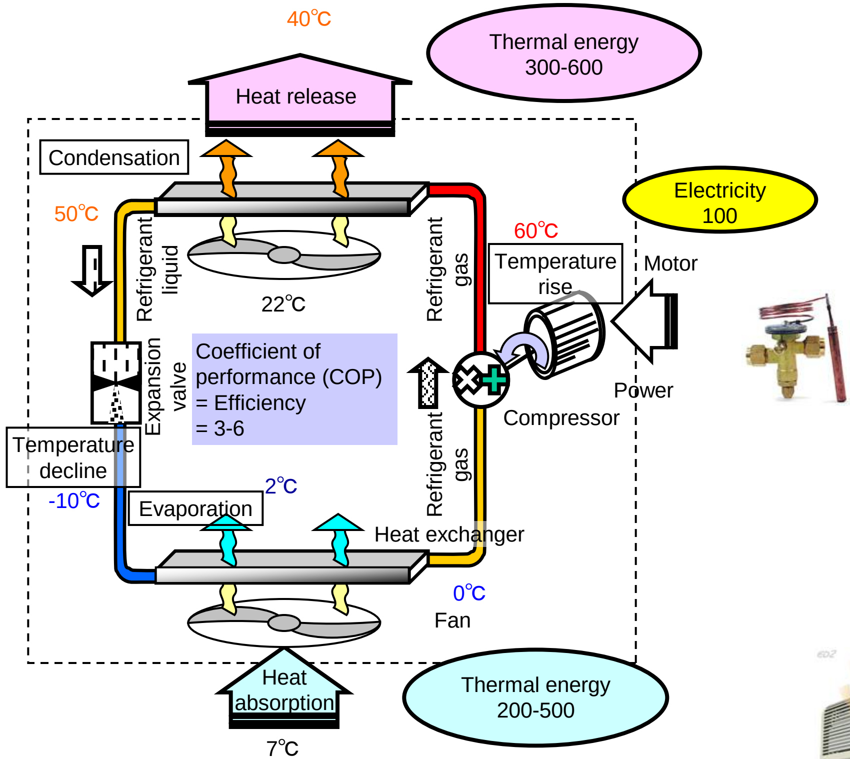
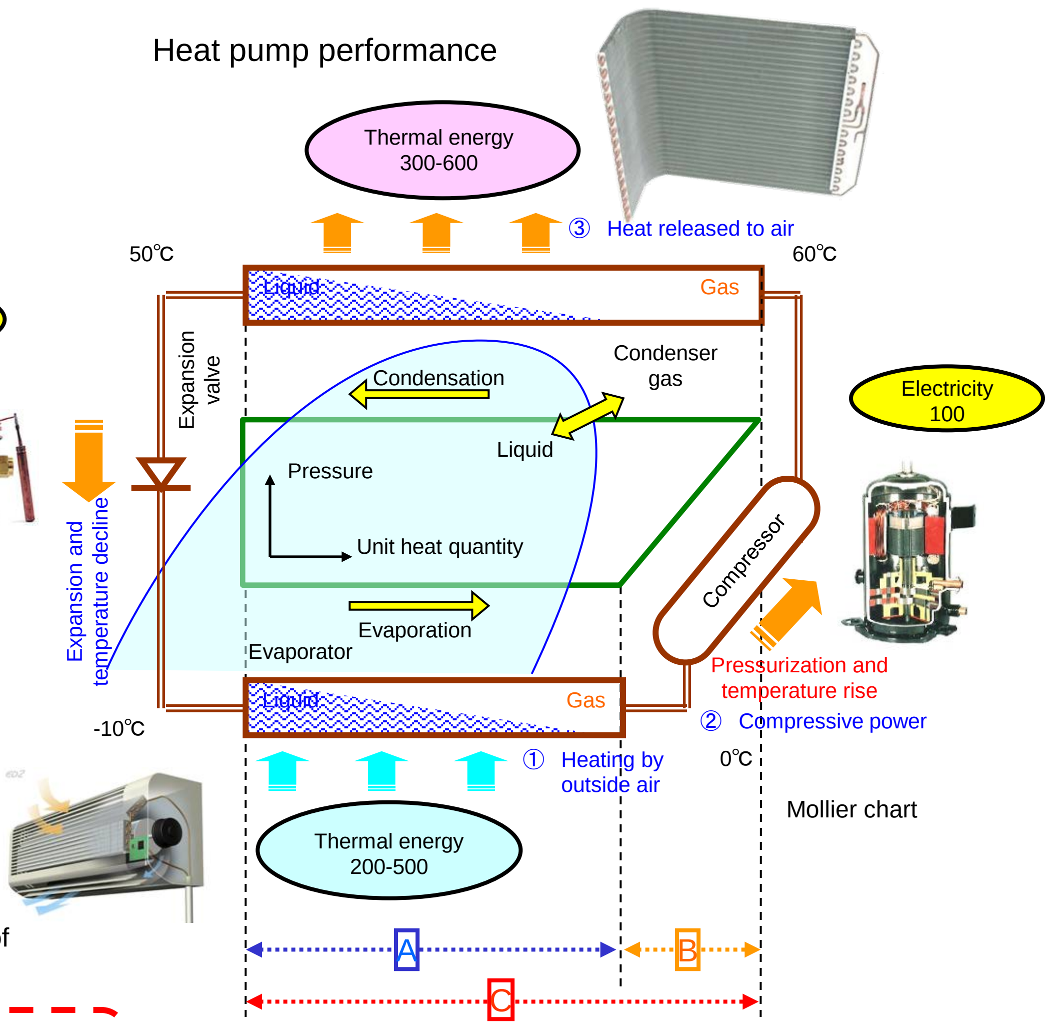
Figure 1: Heat pump and refrigeration cycle





In case of heating: Temperature of each part shows an example and varies depending on operating conditions (volume of refrigerant circulated, air flow).

COP_h = C/B for heating ← Refrigeration cycle efficiency

COP_c = A/B for cooling

For efficiency improvement of heat pumps

① Bring condensation temperature close to evaporation temperature.
② Expand the range of supercooling and superheat degree as much as possible.
③ Improve compressor efficiency.
④ Improve motor and inverter efficiency.
⑤ Control output changes and achieve sophisticated control.
⑥ Reduce auxiliary power and power loss.

Heat pump efficiency = Refrigeration cycle efficiency x compressor efficiency (insulation efficiency, volume efficiency) x motor efficiency

* Consideration also given to auxiliary power

Figure 2: Merits of unused heat sources

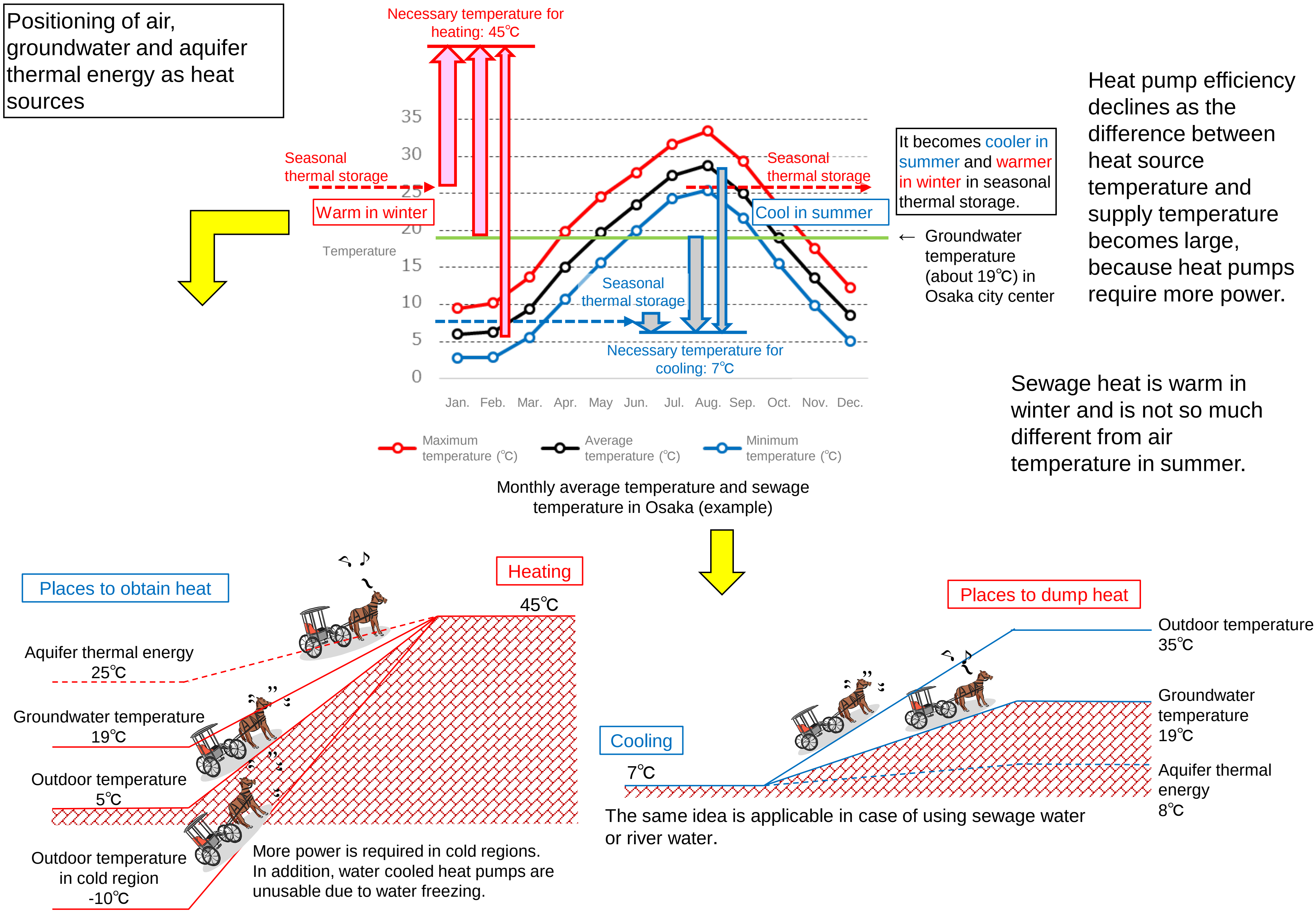
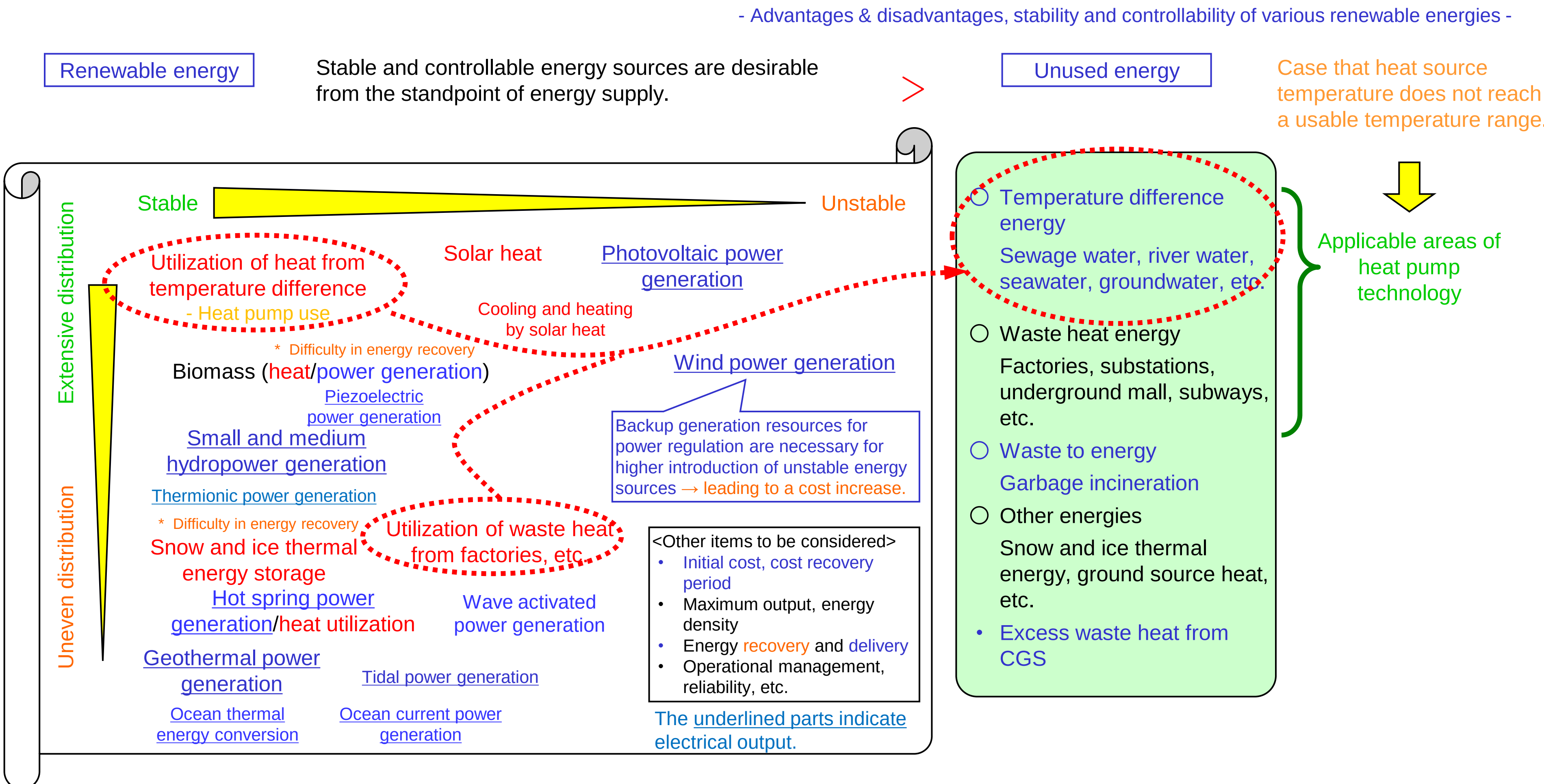


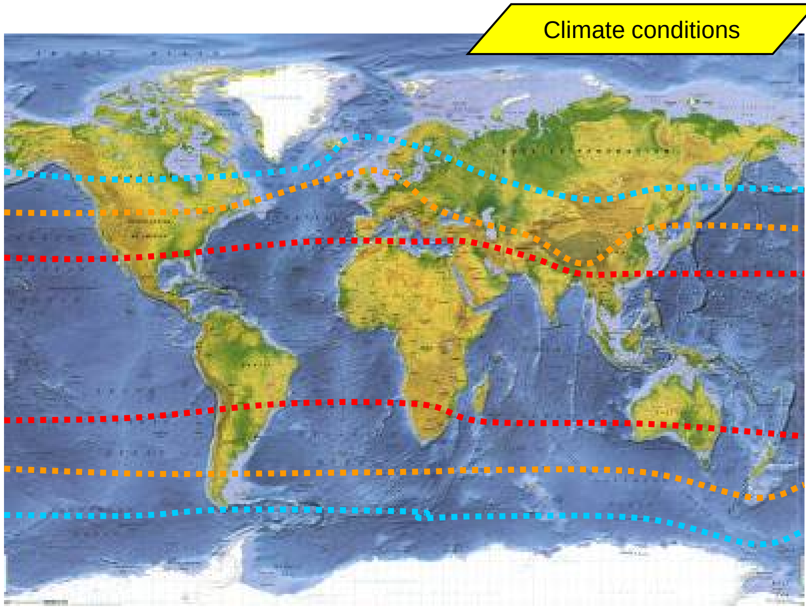
Figure 3: Types of renewable energy and positioning of unused energy



- Outputs of photovoltaic power generation (national average utilization rate: 12%) and wind power generation (national average utilization rate: 20%) change significantly.
  → These technologies cannot flexibly respond to changes in electricity demand.
  → They should be combined with an appropriate energy storage technology, in order to respond to output changes of renewable energy sources that are beyond regulation capacity on power system side.
  Electricity storage technology: Pumped storage power generation has a large capacity and its overall efficiency is about 70%, NaS battery efficiency is more than 80%, and Li-ION batteries have higher costs.
  Thermal storage technology: Overall efficiency of thermal storage tanks is more than 90% in case that the final demand is for heat utilization. Aquifer thermal energy should be used for long-term utilization.
  ↑ Heat pump technology and thermal storage technology are compatible with each other.

Figure 4: Worldwide deployment and efficient use of heat pumps

- Firstly, consideration should be given to climate conditions and differences in use in respective regions-



- World's climatic division and heat pump (HP) technology

Regional division	Regional characteristics	Applicable technology
Cold region (low humidity)	Mainly for heating	Ground source HPs, seawater source HPs, etc. Air source HPs for cold region
Mild weather region (high humidity in summer)	It has four seasons and requires cooling and heating.	Air source inverter HPs HP thermal storage system for day and night
Tropical region (high humidity/low humidity)	Mainly for cooling	HP thermal storage system for day and night Air source (air cooled/water cooled) HPs

\+ Highly efficient humidification during heating and dehumidification during cooling according to the region

→ Reinforcement of building insulation and a better ventilation system are needed.

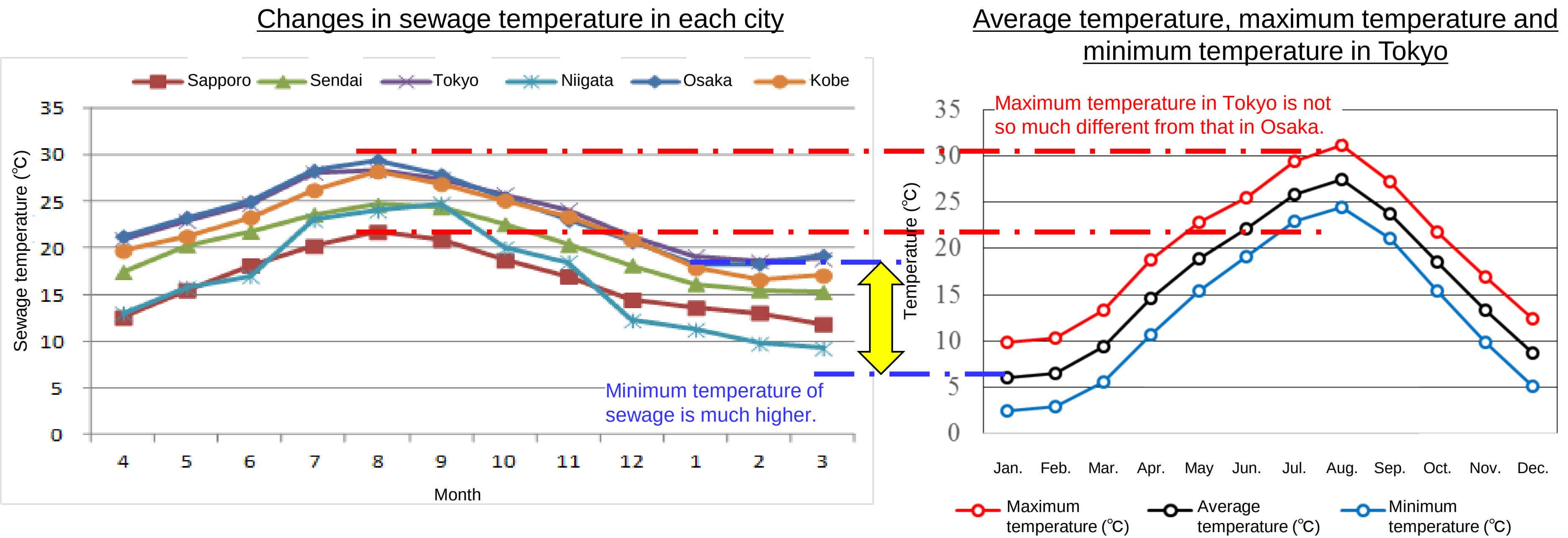
Clarification of requirements and appropriate system configurations are necessary for use in each country.

Outline of respective HP and thermal storage technologies

	Industrial use	Commercial use	Residential use
Heating	Air cooled HP chiller (two-stage compression, etc.) Ground source heat brine chiller	Air cooled multiple (two-stage compression, etc.) Ground source heat brine chiller	Air cooled air conditioner (two-stage compression, etc.) Ground source heat air conditioner, HP heater for panel floor heating
Cooling and heating	Air cooled inverter HP chiller Heat recovery type turbo refrigerator	Air cooled inverter HP chiller Air cooled package multiple air conditioner	Air cooled inverter air conditioner
Cooling	Inverter HP (air cooled/water cooled) chiller High-efficiency turbo refrigerator (efficiency improvement by employing water cooled type) + thermal storage (effective use of lower temperature in nighttime)	Inverter HP (air cooled/water cooled) chiller Package multiple (air cooled/water cooled) air conditioner	HP (air cooled/water cooled) chiller Package multiple (air cooled/water cooled) air conditioner
Hot water supply Hot heat	CO_2 refrigerant HP for commercial use HP for high temperature applications (heat medium, hot air)	CO_2 refrigerant HP for commercial use Commercial use HP (hot water circulation type)	CO_2 refrigerant HP for residential use HP water heater

Effective in tropical region

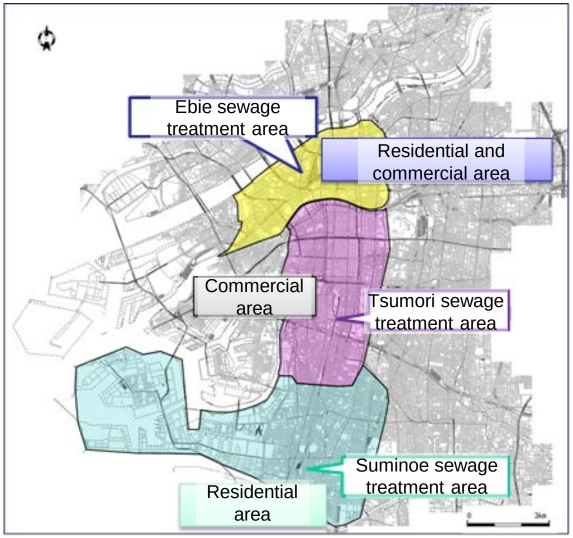
Figure 5: Monthly average temperature and sewage temperature in each major city of Japan



Sewage temperature in Sapporo is advantageous to obtain heat for heating and hot water supply in winter as well as heat for cooling in summer.

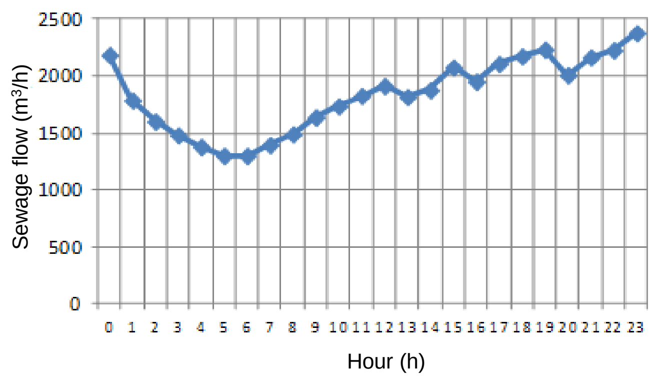
Figure 6: Characteristics of sewage heat, hourly sewage flow and trend of monthly sewage temperature

Measurement areas in Osaka-shi



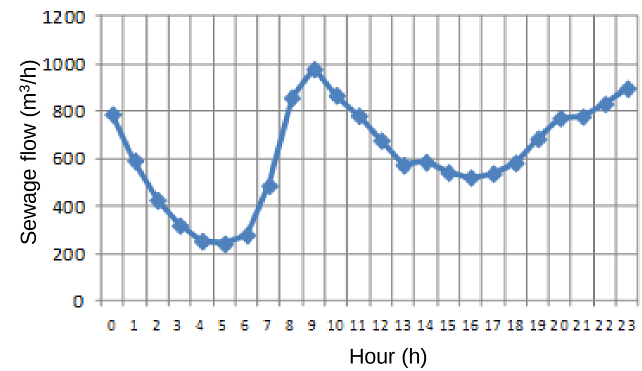
Example of sewage conduit flow measurement in business and commercial areas (total floor area of houses occupies 10%)

- Changes in a day are smaller compared to residential areas.
- Sewage flow peaks around 11:00 P.M.



Example of sewage conduit flow measurement in residential areas (total floor area of houses occupies 72%)

- Sewage flow significantly decreases in early morning.
- Sewage flow peaks around 9:00 A.M.

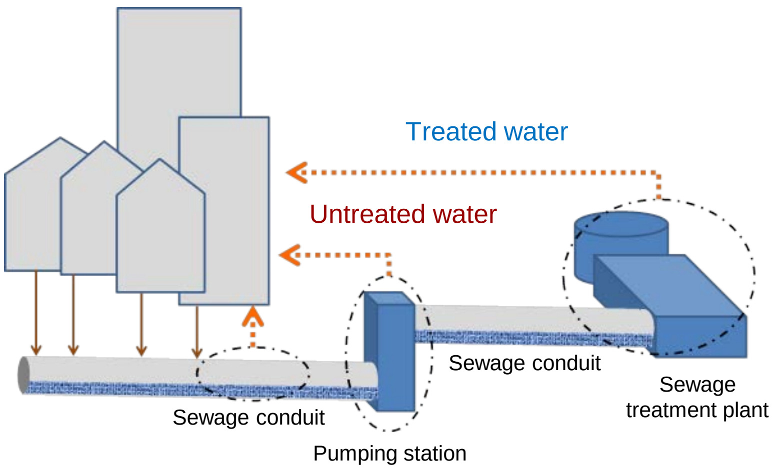


Heat utilization potential in Osaka-shi

This shows an estimated value.

Sewage conduits in Osaka-shi with a heat utilization potential of 5 GJ/h (more than 1,400 kW)

Figure 7: Various methods for sewage heat utilization

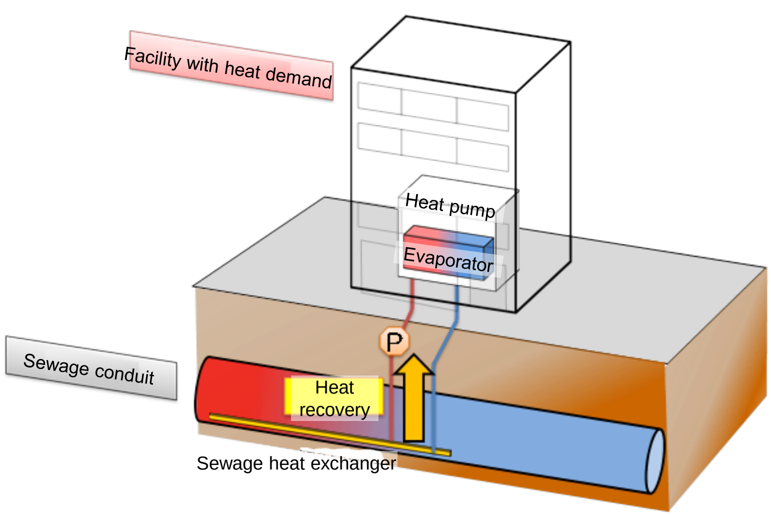


Places for sewage heat recovery

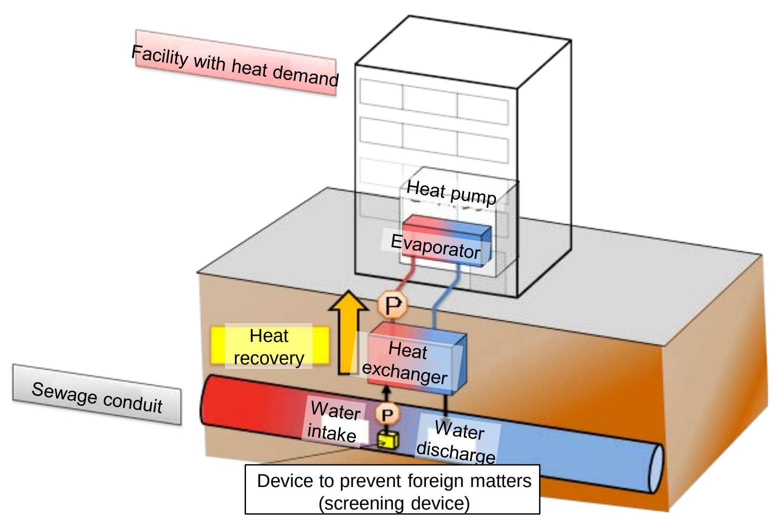
Various methods for sewage heat utilization

Heat source	Heat exchange	Heat exchanger	Heat utilization method
Treated water Untreated water	Existing heat exchanger	Plate type Spiral type Shell & tube type	Individual use (1:1)
	Inside-of-conduit type heat exchanger	Response to contaminated water (contamination by biological slime)	District heat supply (1:n)
	Outside-of-conduit type heat exchanger	Response to contaminated water	Heat source water (1:n)

Water screen + heat exchanger



Inside-of-conduit type heat exchange method for heat from untreated water



Outside-of-conduit type heat exchange method for heat from untreated water

Figure 8: Cases of sewage heat utilization in Japan

- Sewage heat utilization in Japan is limited only to sewage treatment plants, pumping stations and surrounding areas -

Utilization of treated water as heat source

Large plant

Makuhari Shintoshin area, Shinagawa Sony City, etc.

Makuhari Shintoshin area

Business approval: March 31, 1987
Start of supply: April 1, 1990
Service district: 1-chome, Nakase, Mihama-ku, Chiba-shi, Chiba prefecture and surrounding areas
Area of the district: 48.9 ha as of March 31, 2008
Total floor area: 919,681 m^2 as of March 31, 2008
Buildings receiving heat : Office buildings, hotels

Shibaura → Sony Shinagawa at present

Project for effective use of the area above Shibaura Water Reclamation Center with its reconstruction
Construction of a 32-story building with a height of about 153 m

Small plant

Bureau of Sewage, Tokyo Metropolitan Government (11 plants)

Water reclamation centers in Tokyo

Facility	Start of operation	Air conditioning floor area
Ochiai	Jan. 1987	2,270 m^2
Shingashi	Apr. 1990	2,680 m^2
Morigasaki	Apr. 1991	2,490 m^2
Kosuge	Apr. 1993	5,910 m^2
Kitatama	Apr. 1994	450 m^2
Nakano	Jul. 1995	5,600 m^2
Ariake	Sep. 1995	4,410 m^2
Shibaura	Apr. 1997	2,705 m^2
Nakagawa	Feb. 2000	4,106 m^2
Ukima	Apr. 2001	4,066 m^2
Miyagi	Apr. 2005	2,421 m^2

Ochiai

Nagoya City Sewage Bureau (6 plants)

Horidome

Meijo

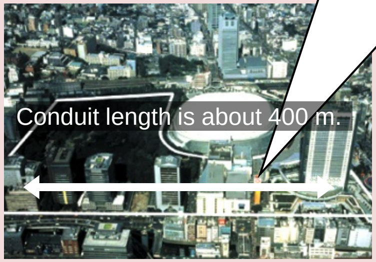
Heat exchanger is a general plate type that does not incorporate any new technological elements of heat exchanger systems.

Utilization of untreated water as heat source

Only two large plants: They are forced to use untreated water because no treated water is available from relay pumping stations.

Installation cost of heat supply conduits is almost similar to that of heat source equipment.

Koraku 1-chome district

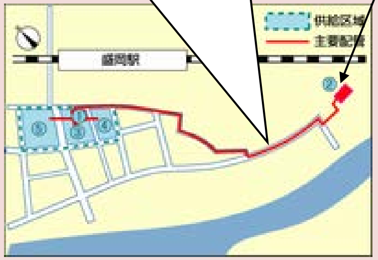


Start of supply: July 1, 1994
Area of the district: 21.6 ha as of March 31, 2008
Total floor area: 294,800 m^2 as of March 31, 2008
Sewage water volume: About 50,000 m^3/day

The heat exchanger is made of titanium and a strainer filtrates untreated water in conduit.

The water treatment plant and heat source plant are connected by the heat source water conduit with a length of about 1 km.

West exit area of Morioka station



Nakagawa Pumping Station

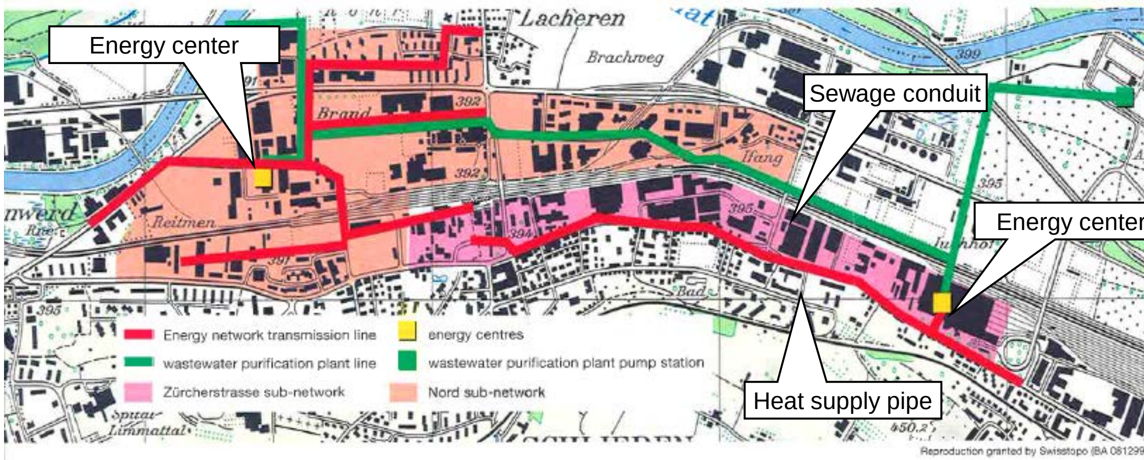
Start of supply: November 25, 1997
Area of the district: 2.4 ha as of November 30, 2008
Total floor area: 101,900 m^2 as of November 30, 2008

The heat exchanger is made of stainless steel and a strainer filtrates untreated water in conduit.
The heat exchanger is washed inside by sponge ball.

Figure 9: Large-scale district heating and cooling (DHC) with using treated sewage water as heat source in Schlieren, Zurich

- 30% of the total heat demand in Schlieren district, Zurich are met by using cold heat directly from sewage water and 55% are supplied by heat pumps using sewage water heat. As a result, fossil fuels are used for meeting only 15% of the total heat demand in this district.
- Limmat river in Zurich also serves as a heat source for district heating and cooling.

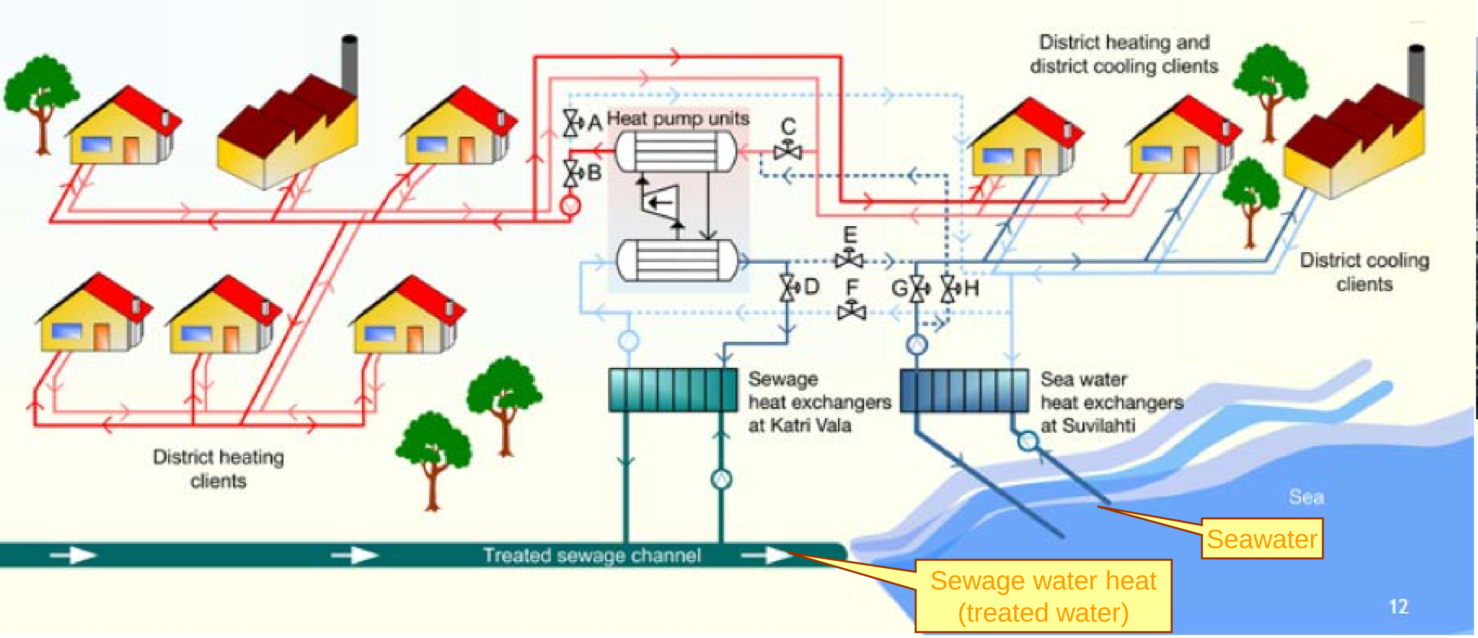
Schlieren district in Zurich: DHC with using sewage water heat



Equipment capacity
Heating by heat pumps: 11,100 kW, cooling by heat pumps: 9,000 kW
Gas boiler: 17,000 kW

Figure 10: District heat supply with hybrid heat source of sewage water and seawater in Helsinki

- By switching heat source water from treated sewage water to seawater between winter and summer, the heat pumps aim at ensuring their heat source capacity and improving their efficiency.



Fernwärme - Kälte Produktions- Anlage "Katri Vala", Helsinki, Finnland

Fernwärme - Kälte Produktions- Anlage "Katri Vala", Helsinki, Finnland

5 x UNITOP® 50 FY

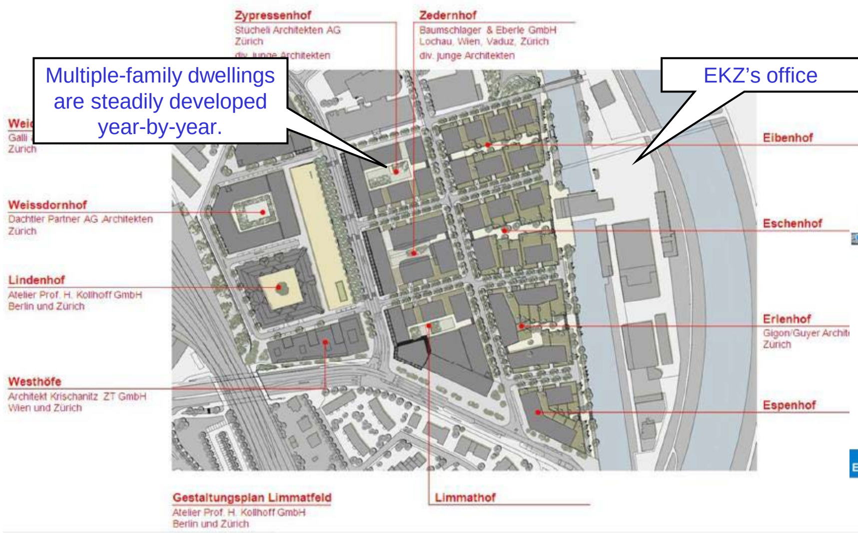
Technical data:
5 units of heat pumps (Friotherm's Unitop® 50FY)

Operation in winter
- Heating capacity: 16,770 kW
- Supply water volume: 1,221 m^3/h
- Return temperature/feed temperature: 50/62℃
- Electricity usage: 4,770 kW
- Electric motor capacity: 6,500 kW
- Cooling capacity: 12,000 kW
- Inlet temperature and outlet temperature of sewage water: 10/4℃

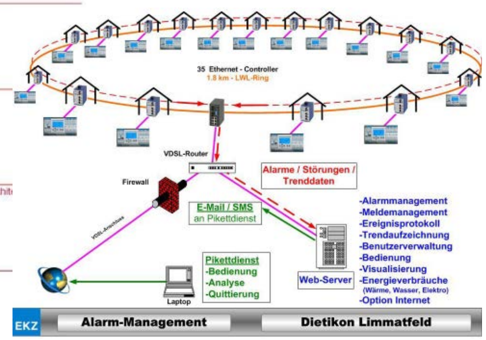
Operation in summer
- Heating capacity: 18,113 kW
- Supply water volume: 370 m^3/h
- Return temperature/feed temperature: 45/88℃
- Electricity usage: 6,113 kW
- Cooling capacity: 12,000 kW
- Inlet temperature and outlet temperature for DHC: 20/4℃

Figure 11: System for variable temperature district heat supply in winter/heat source water supply in summer in Limmatfeld, Zurich

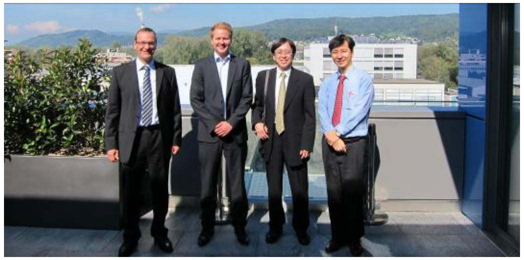
- Though this district heat supply system was built with expecting that heat loss during conveyance would be smaller as the heat source is relatively close to the place of heat demand, it is a highly advanced system that significantly improves the performance of buildings and secondary side air conditioning equipment and changes supply temperature according to outdoor temperature (air-conditioning load).
- It is said that dissemination of district heat supply systems remains low and one possible reason is that inflexible system operation leads to loss of opportunities to save energy.



New housing development project is planned near EKZ's office.



System control and charging are entirely conducted online.

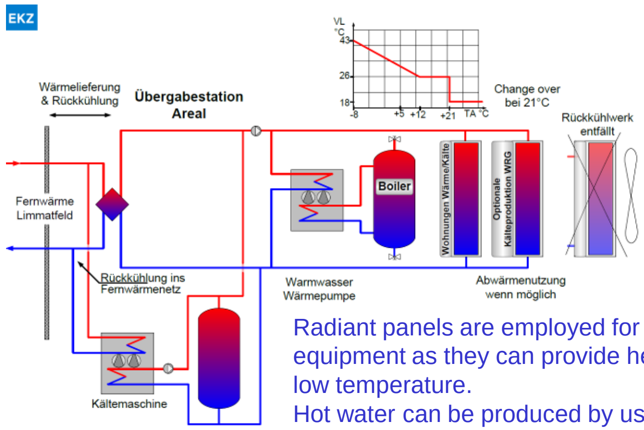


Heat source pipes are directly buried.

Heat source equipment room

Significant energy savings are expected as supply temperature is variable.

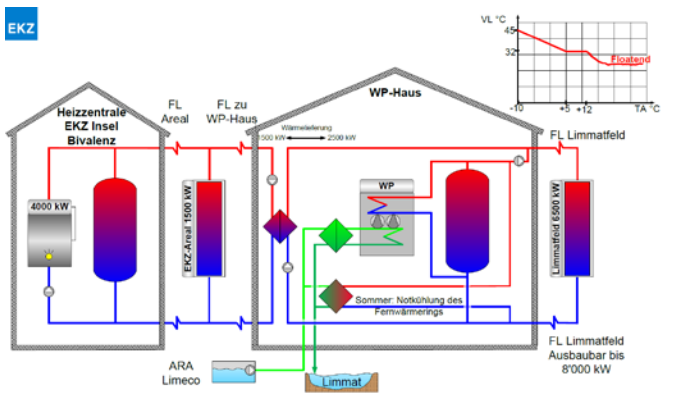
Systems on housing side



Radiant panels are employed for terminal equipment as they can provide heating at a low temperature.
Hot water can be produced by using water for heating in winter.
Hot water can be produced while providing radiation cooling in summer.

4 units of heat source HP with a capacity of 1,000 kW

Heat source system

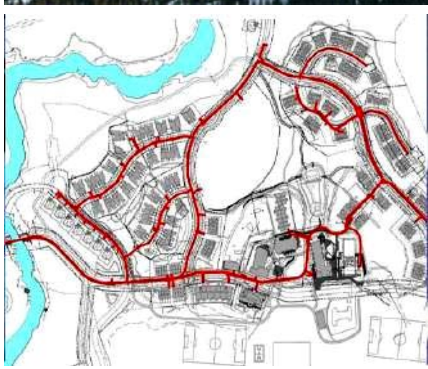


Conventional heat source

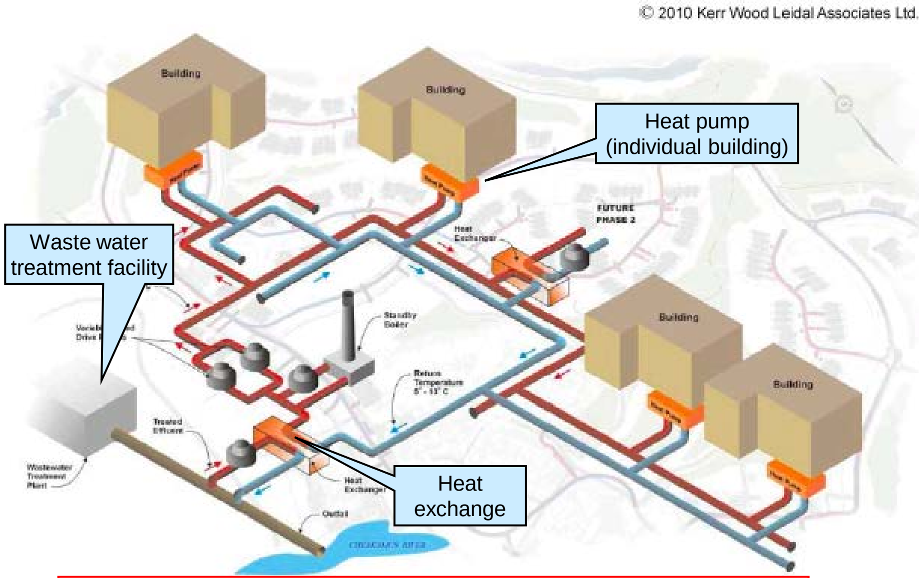
HP heat source from sewage water heat (during heating)
Bypass operation in summer

Figure 12: Athletes' village in Whistler - network to supply treated sewage water as heat source

- The network recovers sewage water heat to supply heat source water with a temperature of 10 to 15℃ which is used as heat source for heat pumps. The temperature of the returned water from the heat pumps ranges from 6 to 10℃. 300 units of heat pumps in the first phase and 600 units in the second phase will be connected with low temperature heat supply pipes.
- If energy density in the supply area drops, the loss of heat would become large in case of high temperature heat supply. In this example, efficiency is improved by using a relatively low temperature heat source. The network consists of sewage heat utilization systems with a total capacity of 2.5 MW and heat conduits with a length of 2 km.



- 10.5°C DES Supply Temperature:
  - **>90% displacement of natural gas**
  - **Annual saving of ~ $300K from BAU (@2010 NG prices)**
- 12°C DES Supply Temperature:
  - **~50% displacement of natural gas**
  - **Annual saving of ~ $170K from BAU (@2010 NG prices)**



It is not always appropriate to supply a high-temperature heat.

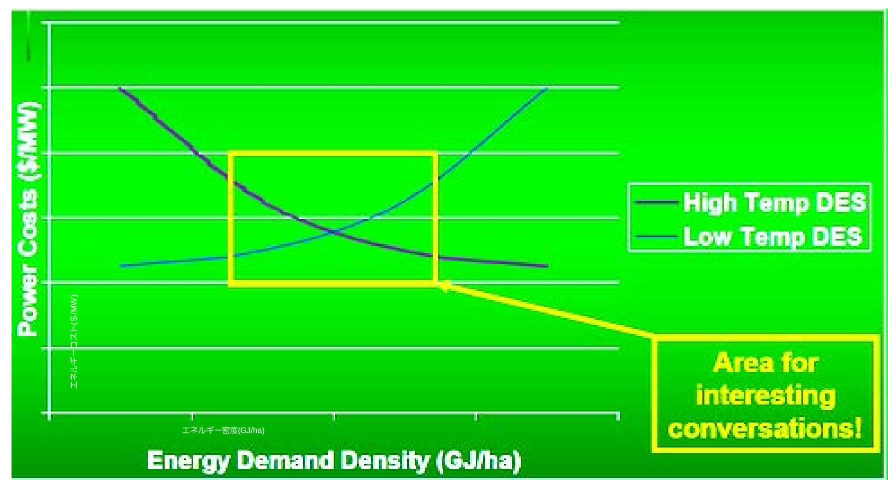
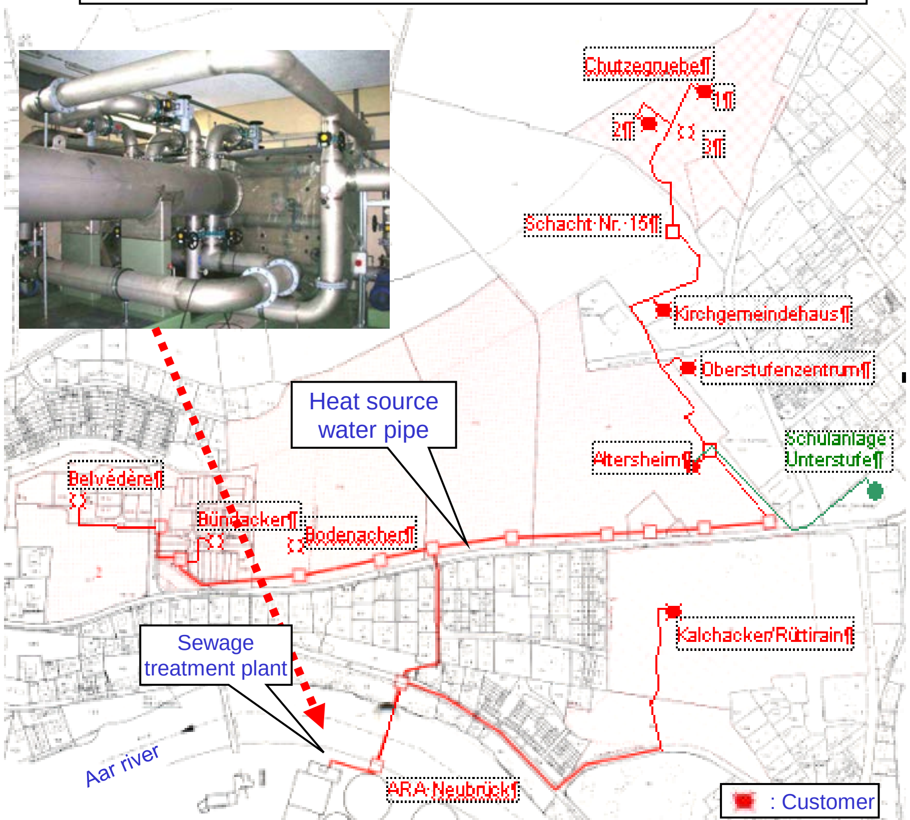


Figure 13: Heat source water network system and untreated sewage water heat system in Bern

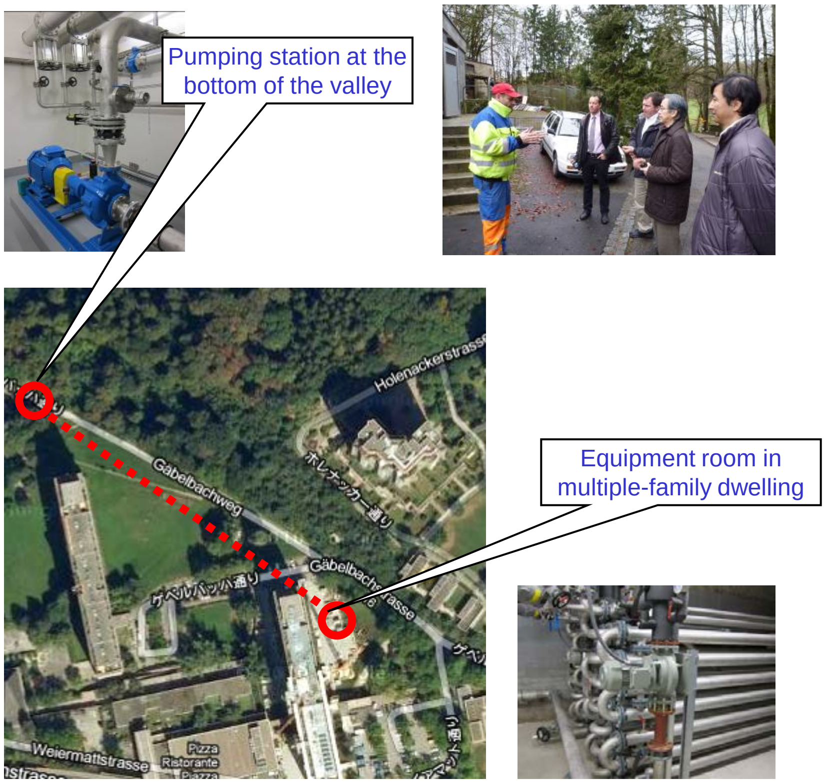
- The needs for heat supply is large even in an area with low energy density. Though we usually use air cooled heat pumps that are operable even in below zero conditions in Japan, it seems that such heat pumps are not an option in Europe.
- Generally, water cooled heat pumps cannot be used in below zero conditions. In Europe, there exist systems that use clear water with a temperature of 7-15℃ as heat source.
- The left figure in this slide shows a low temperature heat supply line which conducts heat exchange with the treated water from a sewage treatment plant (called “ARA” in Germany and Switzerland). This temperature range allows to bury pipes directly in the ground and no insulation is necessary. Cost reduction is also achieved.
- On the other hand, the system in Gäbelbach conducts heat exchange in the middle of pumping sewage water to main sewage conduits on the hill from the pumping station at the bottom of the valley.

Bremgarten district in Bern: Low temperature heat source water line



This line consists of low temperature heat source water line to conduct heat exchange with the effluent from ARA (sewage treatment plant). Nearby houses and offices have their own heat pumps.
2 units of heat exchangers with a capacity of 700 kW, 13℃/9℃ for feed temperature and 11℃/7℃ for return temperature
Conduit length: 3,750 m + 800 m, 477 m + 550 m +73 m

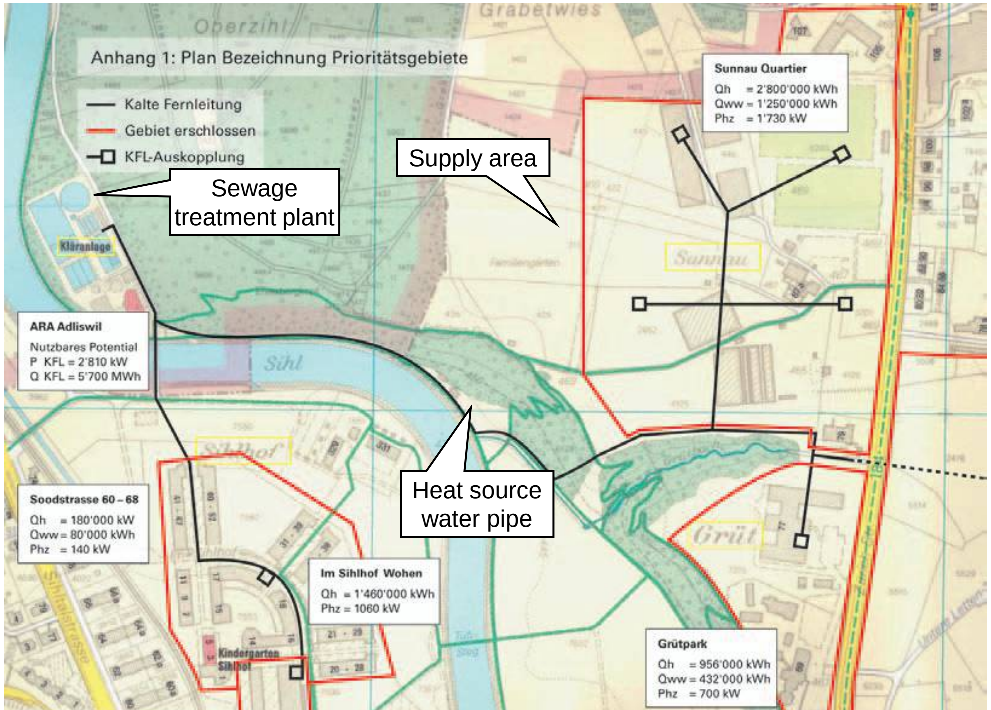
Gäbelbach district in Bern: Heat recovery from sewage supply pipes



Double pipe sewage heat exchangers and heat pumps are installed in the equipment room of the multiple-family dwelling. The pipes for heat exchangers have the same diameter of water supply pipes. After heat exchange, garbage flows with sewage.

Figure 14: Advanced heat source water network system in Adliswil, Zurich

- This slide shows the advanced heat source water network type sewage heat utilization system operated by EKZ in central Switzerland.
- The heat source water network was employed with consideration given to the distance to the load center in this case.



- They said that the heat exchanger is cleaned by circulating hydrogen peroxide once a week.
- If operation of a plate type heat exchanger is realized, high efficiency can be achieved with lower cost.

- The plate type heat exchanger responds to the load of about 1,000 kW at present.
- They said that if the load increases, additional heat exchanger will be installed.

This network system consists of low temperature heat source water line to conduct heat exchange with the effluent from ARA (sewage treatment plant).
Capacity of heat exchanger on sewage treatment plant side: 2,800 kW
Capacity of heat pumps in each district: 140 kW + 1,060 kW + 1,730 kW + 700 kW

☐ : Customer

Heat pumps for heating on housing side

Figure 15: Outline of overseas survey as part of NEDO Sewage Heat Research

In starting the NEDO research, the situation of sewage heat utilization is researched on the Internet.

→ We found the existence of a heat recovery system with using heat exchangers directly installed in sewage conduit.

→ We made contact with professor Thielen of University of Applied Sciences Giessen-Friedberg, who is a leading expert in Germany.
In September 2010, we participated in the 4th Conference of Sewage Heat Utilization in Bochum, Germany (Nakaso and Mike of Sogo Setsubi Consulting Co., Ltd.)

→ We visited the sewage heat utilization system in Bochum and found the existence of the association InfraWatt in Switzerland.

→ In January 2011, we visited professor Thielen at the university.

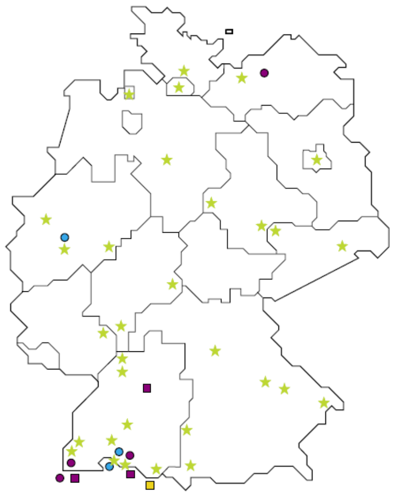
→ We visited the association InfraWatt (Raiser Technical Office) in Bern, ARA Bern and others.

→ We visited Picatech Huber AG in Luzern (professor Nakao and Nakaso).

→ In September 2011, we visited the association InfraWatt (national organization) and EKZ (electric utility) in Zurich (Professor Nakao and Nakaso), together with officials of MLIT.

→ We presented our activities (the government and NEDO) at the 5th Conference of Sewage Heat Utilization in Berlin.

→ We visited IKEA shopping center and other three facilities in Berlin, Berlin City Waterworks and Sewage Bureau and the Federal Ministry for Environment, Nature Protection and Nuclear Safety.

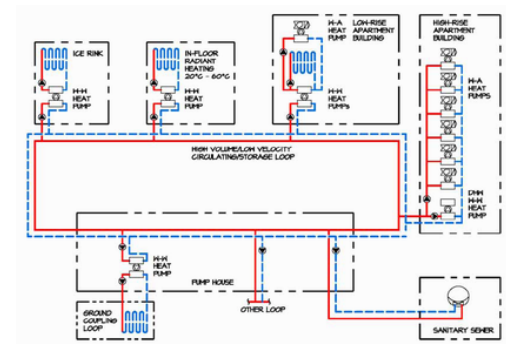


Cases in Germany: More than 30 cases of treated water/untreated water utilization

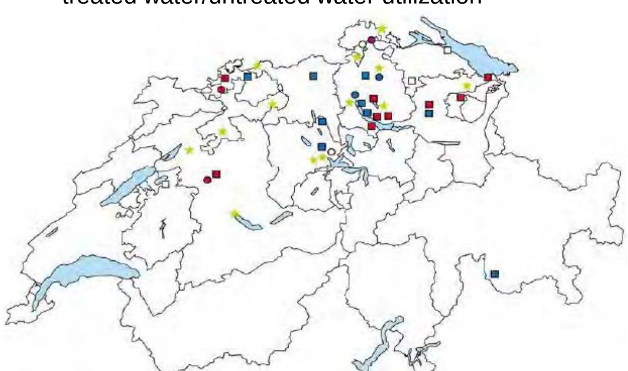
Inside-of-conduit type

New-pipe-installation type

Installation-in-the-existing-pipe type



Example of heat source system



Cases in Switzerland: More than 80 cases of treated water/untreated water utilization

Legend: Energy source
- ○ Untreated water (conduit)
- □ Treated water

Energy utilization form
- ■ Heating
- ■ Heating and hot water supply
- ■ Cooling, heating and hot water supply

Sites under consideration
- ★ Field survey and project in progress

Outside-of-conduit type

Various types are available.

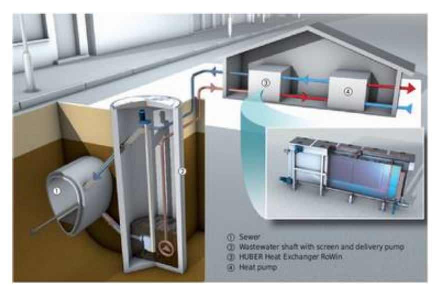
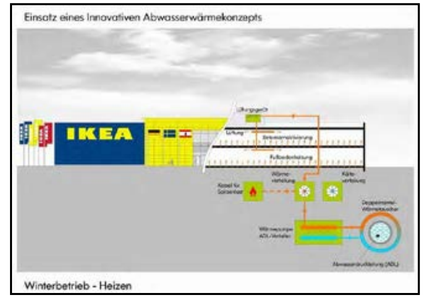
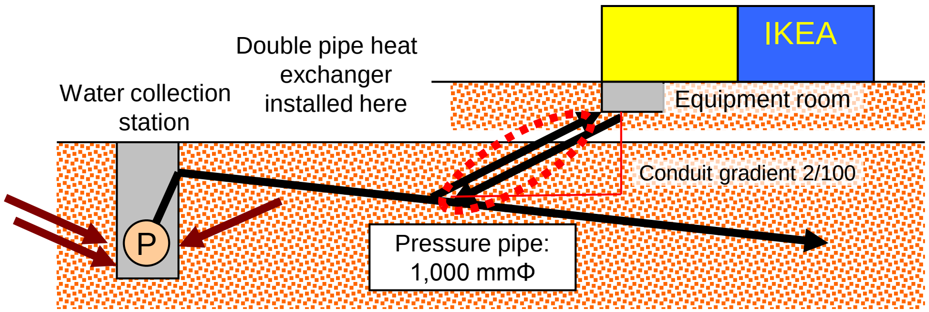


Figure 16: Study tour at various facilities during the Conference of Sewage Heat Utilization in Berlin

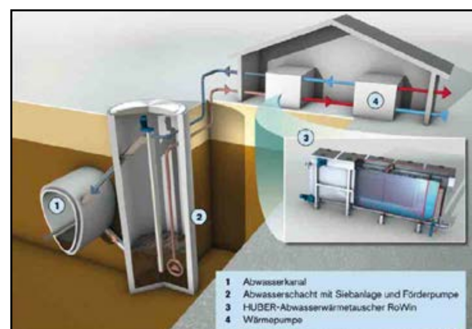
- Case of IKEA shopping center in Lichtenberg, Berlin

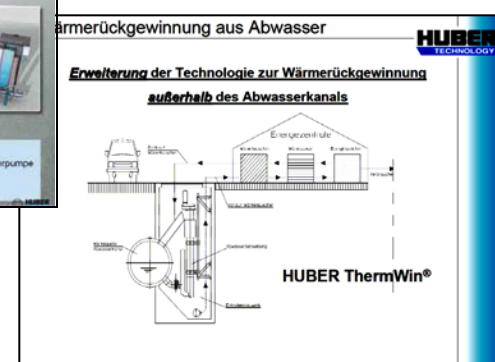




- The type of the system is similar to that of our system in Koraku. However, this type has very simple heat exchangers and there is no need to dispose of garbage in sewage.
- According to Berlin city sewage authority, there are many similar water collection stations in Berlin as the city has many flatlands. They said that they accept the increased power for water supply pumps at present.

- Case of fitness center in Friedrichshain-Kreuzberg, Berlin





- High efficiency heat exchange system made by Huber
- Equipment room on the right figure was replaced with the container.

Figure 17: Forms of sewage heat utilization

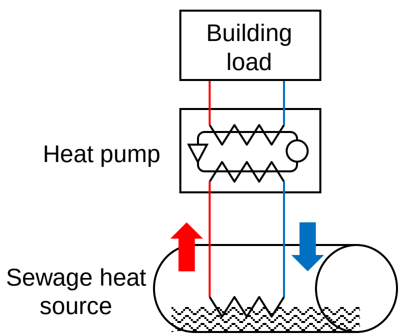
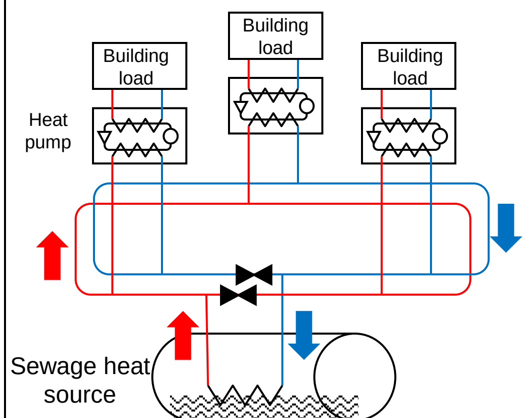
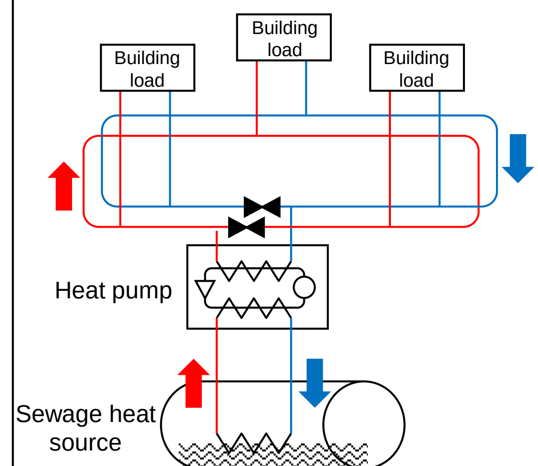
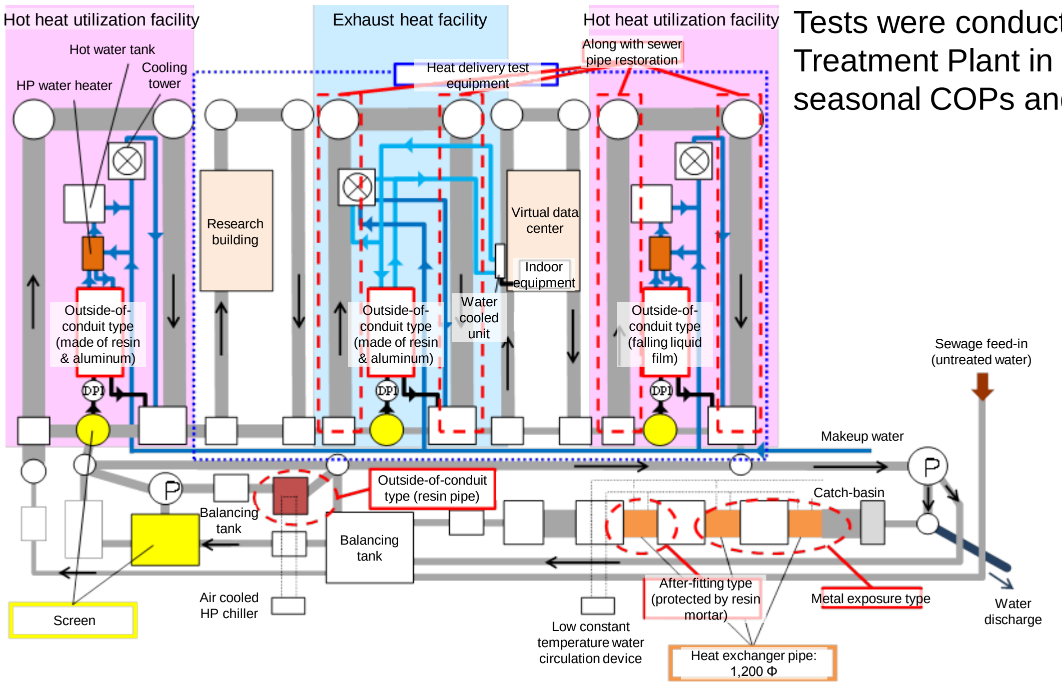
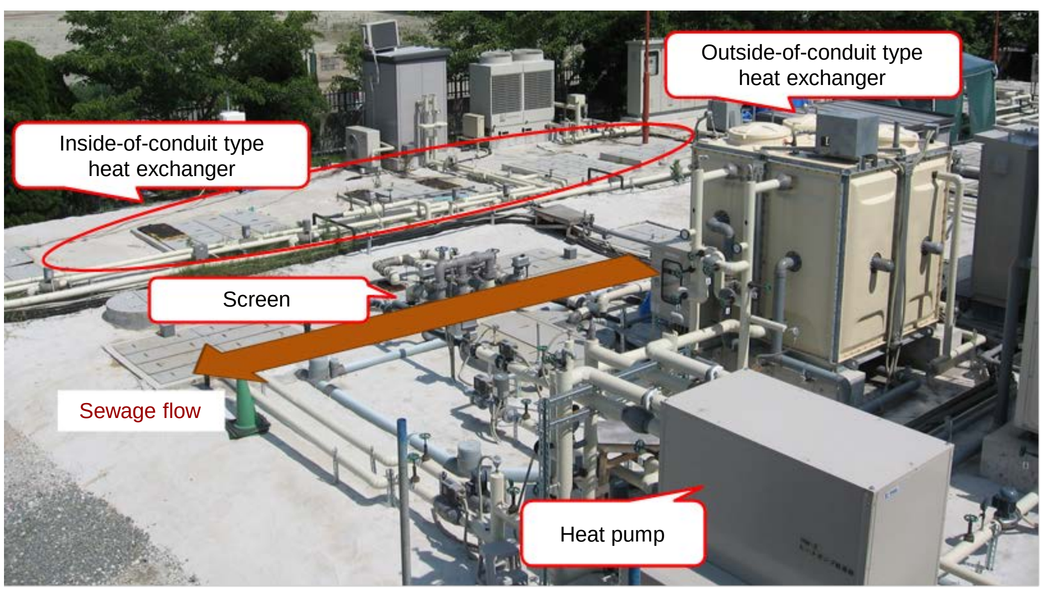
	Individual heat source	Heat source water NW	District heat supply
Treated water Easy to handle Close to sewage treatment plant	Tokyo: In sewage treatment plant Tokyo: Shinagawa Sony City Nagoya: In sewage treatment plant	Switzerland: Bremgarten in Bern, Adliswil in Zurich Finland: Helsinki Canada: Athletes' village in Whistler	Chiba: Makuhari Shintoshin area Switzerland: Schlieren and ☆ Limmatfeld in Zurich
Raw sewage Difficult to handle Available anywhere + Installation of inside-of-conduit type heat exchanger Or Installation of outside-of-conduit type heat exchanger	Germany: Bochum heated pool Leverkusen Berlin IKEA SC Berlin Friedrichshain Federal Ministry for Environment, Nature Protection and Nuclear Safety in Berlin Switzerland: Gäbelbach  Produce heat individually for use.	 Share one heat source.	Tokyo: Koraku 1-chome district Iwate: West exit area of Morioka station  Produce heat in bulk for distribution.
Feature	One-to-one basis First-come-first-served basis Minimum loss Highly flexible Small aggregation effect Less economic efficiency if the number of heat users is large	One-to-N basis Equal opportunity Small loss if supply area is extensive Highly expandable	One-to-N basis Equal opportunity Large loss if supply area is extensive Large-scale Large aggregation effect Less flexible

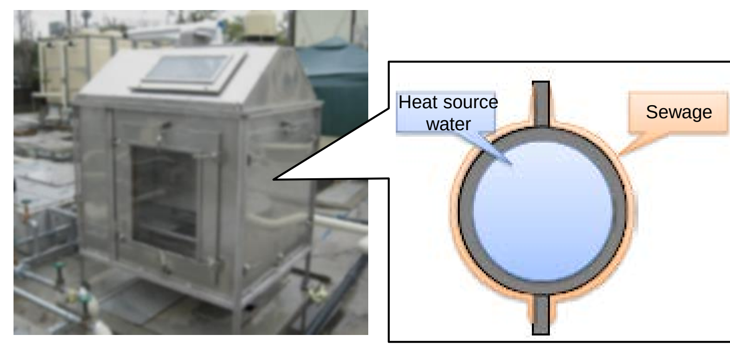
Figure 18: Outline of NEDO’s demonstration test equipment



Tests were conducted at Chishima Sewage Treatment Plant in Taisho-ku, Osaka-shi to measure seasonal COPs and SCOPs.



Appearance of falling liquid film heat exchanger that delivered the best performance among the developed products and changes in heat transfer property



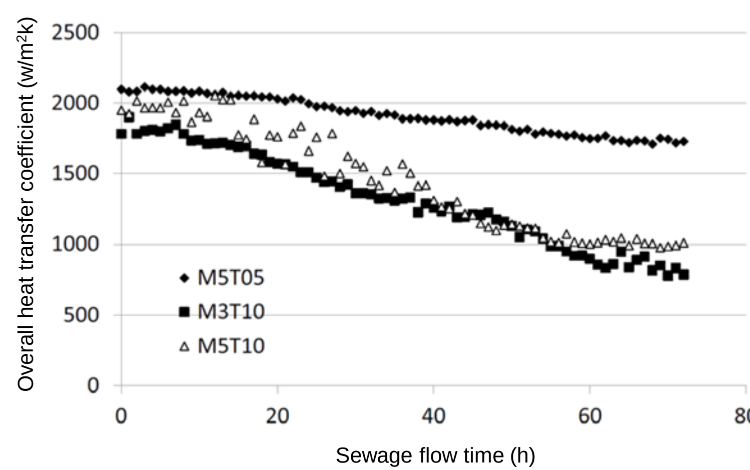


Figure 19: Newly developed heat exchangers

- Newly developed heat exchangers are as follows. As for outside-of-conduit type, falling liquid film heat exchangers have higher initial performance, reduce performance deterioration caused by biofilm, and become more excellent in performance recovery by washing.
- As for inside-of-conduit type, installation-at-conduit-bottom type (parallel type) equipment have a higher overall heat transfer coefficient and serial type equipment require no header pipe, leading to a cost advantage if their configuration is small.

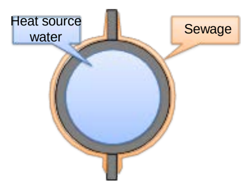
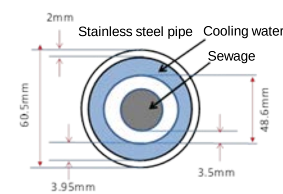
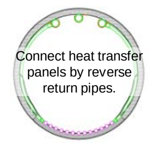
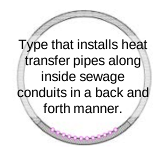
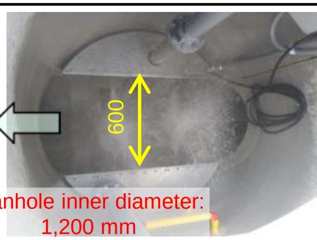
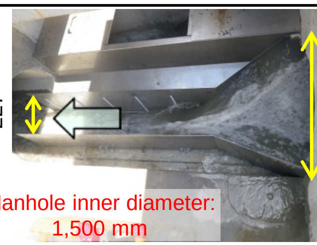
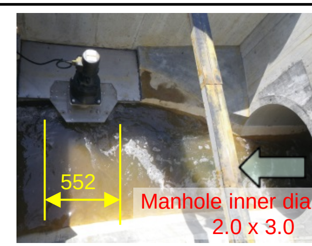
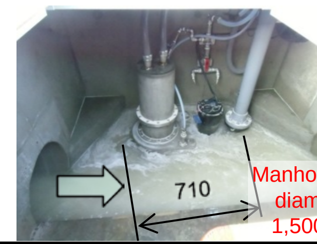
Category		Outside-of-conduit type			Inside-of-conduit type		
Heat exchanger type		Resin + aluminum	Falling liquid film type	Double pipe type	Installation-at-conduit-bottom type		Integrated-with-conduit type (resin)
Photo of appearance							
Flow velocity		Heat source water side: 0.25 m/s Sewage side: 0.10 m/s	Heat source water side: 2.7 m/s Sewage side: 0.52 kg (m/s) 	Heat source water side: 0.75 m/s Sewage side: 1.0 m/s 	Sewage flow velocity: 0.3 m/s Heat source water flow velocity: 2.8 m/s for parallel type 	1.4 m/s for serial type 	Heat source water side: 0.24 m/s Sewage side: 0.13 m/s
Overall heat transfer coefficient (W/m²・k) ① Initial performance ② After biofilm growth ③ After washing	①	180	2,000	800	Parallel type 850	Serial type 800	120
	②	120	1,300 (after 120 h)	350 (after 120 h)	350	280	100
	③	180	1,700	650	600	400	—
Washing method		Water spray flow rate: 0.52 (L/min・m) per unit pipe length	Washing by sewage water at a flow rate of 1.0 kg/(m・s) for three minutes.	Washing by industrial water at a flow rate of 1.5 kg/(m・s) for five minutes.	Increase the flow rate to 0.9 m/s for about one minute.		No washing
Definition of heat transfer area for heat transfer coefficient		Standard for outer diameter of heat exchanger coil (contact surface with sewage)	Standard for outer diameter of heat transfer pipe for heat source water (contact surface with sewage)	Standard for inner diameter of sewage pipe (contact surface with sewage)	Contact surface of heat exchanger with sewage (upper half of outer diameter)		Contact surface with sewage at rib where heat source water flows

Figure 20: Newly developed pumping screen

- The screening device in combination with an outside-of-conduit type heat exchanger has achieved a significant cost reduction compared to the existing devices made in other countries, by capturing and releasing foreign matters in conduit, as shown below.
- Mobile type hydraulic spray shows the highest performance. However, comparison of the installation cost of rotary rake type and others is necessary depending on the volume of water recovered and manhole shape at design stage.

Washing method	Mobile type hydraulic spray	Scraping by electric motor rotary rake	Scraping by electric motor rotary rake	Scraping by electric motor rotary rake
Water intake screen	Perforated metal with 3 mm diameter holes at the bottom	Vertical slit with 2.5 mm diameter holes at the bottom	Horizontal slit with 2.5 mm diameter holes on the lateral side	Horizontal slit with 2.5 mm diameter holes on the lateral side
Application	・Water intake capacity = 14 L/s (water depth: 14 cm) ・Minimum manhole width = 600 mm for pump and pipe space (depending on main pipe diameter) + main pipe diameter	・Water intake capacity = 50 L/s (manhole water depth: 19 cm, length: 55 cm) ・Minimum manhole width = 600 mm for speed reducer space (depending on main pipe diameter) + main pipe diameter + margin on one side	・Water intake capacity = 14 L/s (water depth: 11 cm) ・Minimum manhole width = 500 mm for screen installation width + main sewage pipe diameter + margin on one side ・Installation height = pipe elevation	・Water intake capacity = 10 L/s (water depth: 9 cm) ・Minimum manhole width = 500 mm for equipment installation width + main sewage pipe diameter + margin on one side ・Screen installation height = pipe elevation (integrated pump height = pipe elevation - 50 mm)
Hot water supply load*	500 households	More than 1,900 households	500 households	350 households
Equipment appearance				
Structure description	Spray water from nozzle moving to the direction of pipe axis blows foreign matters in perforated metal holes to flow with sewage.	Rakes at the pipe bottom remove foreign matters during water recovery.	Horizontally rotating rakes remove foreign matters from the fixed screen plate slit during water recovery.	Horizontally rotating rakes remove foreign matters from the fixed screen plate slit and the pumps integrated with main equipment recover water.
Installability and maintainability	・Installation in a dried condition (one day installation) ・There exists a risk of corrosion and shortening life of submerged hydraulic cylinders ・Washer spray should not be used during the inspection in manhole.	・Installation in a dried condition (one day installation) ・The fluid flows right above the rakes, resulting in a large risk of damaging rake tine or slit. ・Inspection work can be conducted during water recovery.	・Installation and inspection work can be conducted while allowing the water to flow on one side (one day installation). ・If the captured foreign matters are dried, they cause the damage of rotary rakes.	・Installation and inspection work can be conducted while allowing the water to flow on one side (one day installation). ・As the removed foreign matters are accumulated, it prevents rake tine from moving or causes deformation.
Evaluation	◎: Highly effective to remove foreign matter and possible to recover the water stably.	△: Applicable to a system that allows foreign matters to flow into heat exchangers.	△: Low failure risk as it is an applied form of ready-made products. Foreign matters including fibers, etc. are easy to pass through.	△: Compared to other equipment, a larger space for installation is required to recover an equivalent amount of water.

* This is the case that heat pumps operate for eight hours in midnight in a multiple-family dwelling (temperature difference of sewage water is 5 K). The figures in the table become 2.5 times larger in case of 20 hour operation per day.