



北海道大学

DIT seminar  
February 24<sup>th</sup>, 2015

# Heat Recovery Ground Source Heat Pump System in Smart Community

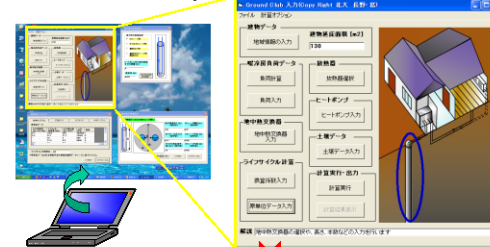
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## Research topics related to the GSHP system

### (1) Development of the simulation tool for the GSHP system

- 1) Heat transfer analysis in the ground surrounding the ground heat exchanger
- 2) Development of simulation model for the ground heat exchanger, heat pump unit, subsystem, etc.
- 3) Application of the simulation tool such as development of design method and evaluation method

Window while input

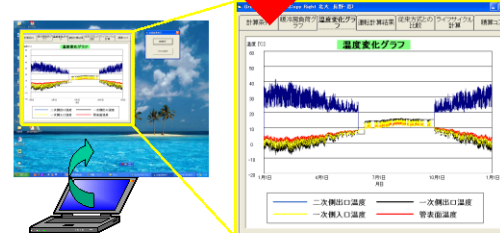


#### Input items

- Building data
- Region and climate
- Radiator
- Spec of heat pump unit
- Spec of ground heat exchangers
- Number of ground heat exchangers
- Soil condition
- LCA data etc

Calculation

Window while output



#### Output items

- Temperature variation of each part
- Performance of the GHP system
- Annual electric power consumption
- Annual energy consumption and CO<sub>2</sub> emission
- Running cost
- Result of LCA

### (2) Development of low cost & high efficient GSHP system

- 1) Minimization of installing cost of ground heat exchangers
- 2) Development of low cost & high efficient GSHP unit

### (3) Heat recovery ground source heat pump system

## (1) Outlines of Heat Recovery Ground Source Heat Pump System

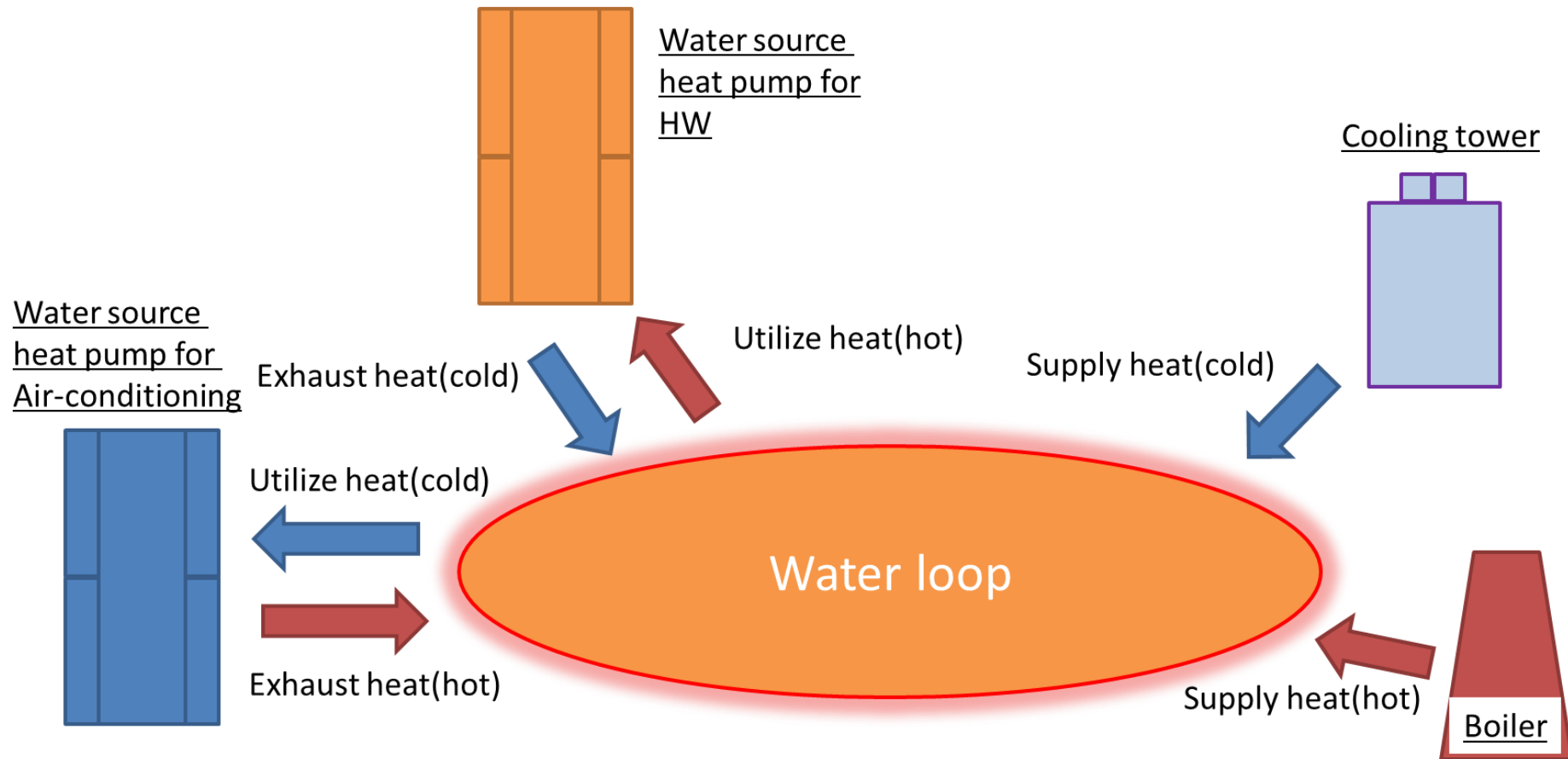
- 1) Outlines of the heat recovery ground source heat pump(HR-GSHP) system
- 2) Advantage and issue of the HR-GSHP system

## (2) Experimental Proof of HR-GSHP System Installed in the Dormitory in Smart Community (in Kitakyushu City)

- 1) Outlines of the building (Dormitory) and HR-GSHP system
- 2) Optimized control method of the HR-GSHP system by using the simulation tool
- 3) Measurement result of HR-GSHP system with the optimized control
- 4) Energy saving effect of the HR-GSHP system compared with the conventional air source heat pump (ASHP) system
- 5) Application of HR-GSHP system in Smart Community in Future

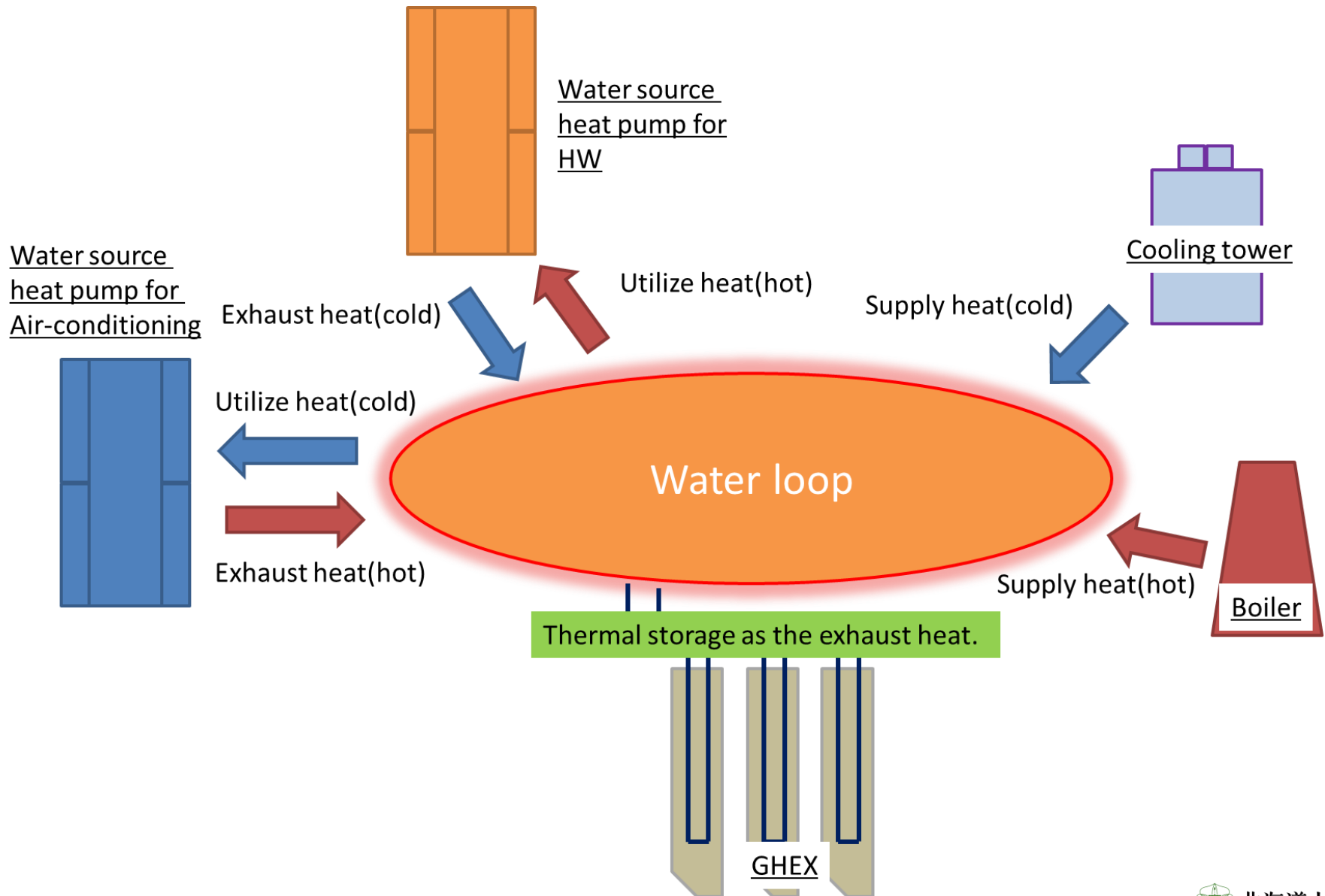
# Outlines of heat recovery ground source heat pump system<sup>3</sup>

## Concept diagram of conventional heat recovery heat pump system



# Outlines of heat recovery ground source heat pump system<sup>4</sup>

## Concept diagram of HR-GSHP system



## Advantage of HR-GSHP system

The HR-GSHP can utilize the thermal storage effect in the ground.



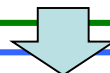
The exhaust heat can be absorbed in the ground and utilized more effectively even if the heating and cooling load are generated at the different time each other.



The HR-GSHP system yields higher energy efficiency and contributes energy saving for the air-conditioning and hot water supply

## Issue of HR-GSHP system

It is difficult to operate the HR-GSHP system for obtaining the energy saving effect because the system consists a lot of equipment



We installed the HR-GSHP system to the dormitory in Kitakyushu City and investigated the optimizing control method which can obtain the maximum energy saving effect



## R&D Project of HR-GSHP system in dormitory of Nippon Steel & Sumikin Engineering



- Location, Higashida area in Kitakyushu city
- Classification by use, Dormitory
- Structure, floor SRC, 7 floors



- Lot area  
7,774m<sup>2</sup>
- Building area  
2,066m<sup>2</sup>
- Floor area  
9,374m<sup>2</sup>
- Height  
22.52m

# Heat recovery ground source heat pump system<sup>7</sup>

## HR-GSHP system installed in dormitory

Appearance of GSHP outdoor unit



Ground (water) source HP units for AC

Ground (water) source HP unit for HW

Appearance of Solar collector



Solar collector

Air conditioned area by GSHP



Appearance of ground heat exchanger



Air conditioning

Cooling tower

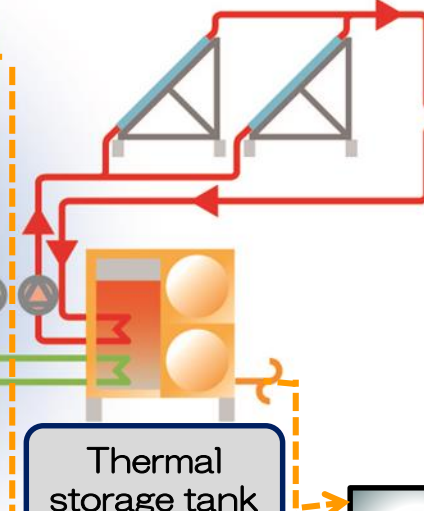
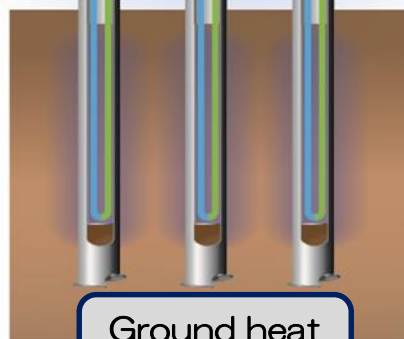
Thermal storage tank

Hot water

ASHPs for hot water

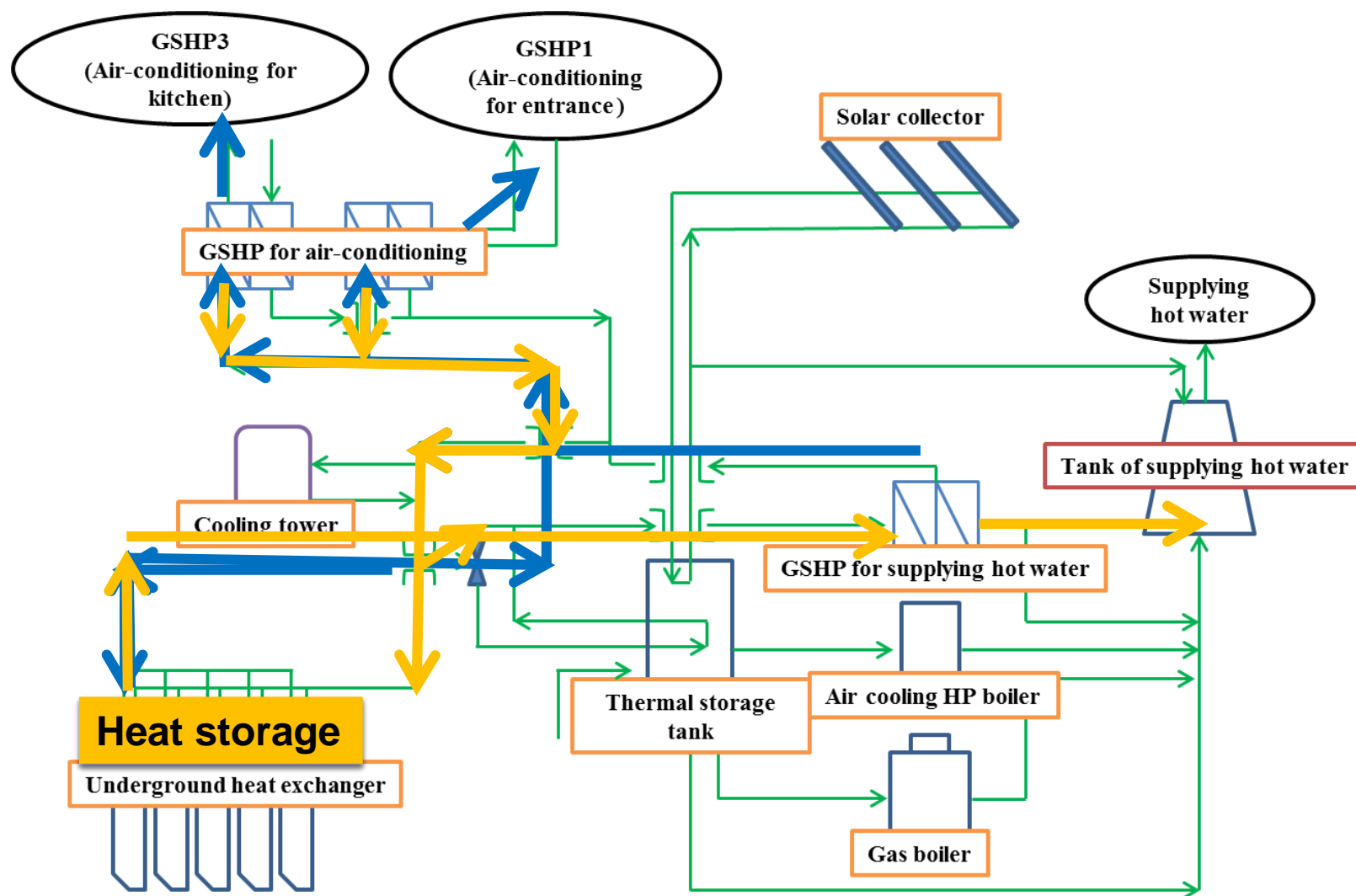
Hot water storage tank

Ground heat exchangers



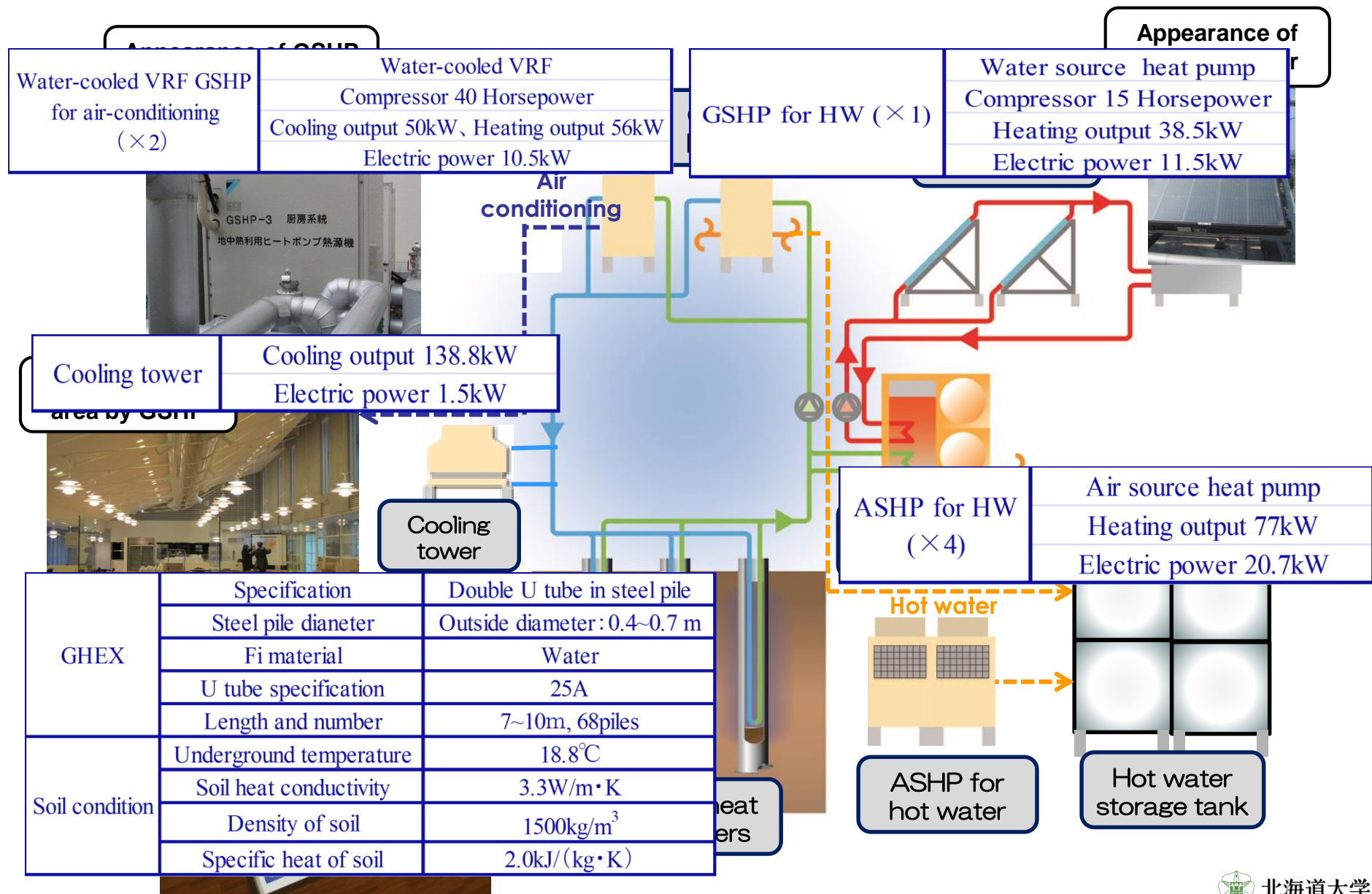


## Mechanism of 'Heat recovery' effect in HR-GSHP system in dormitory

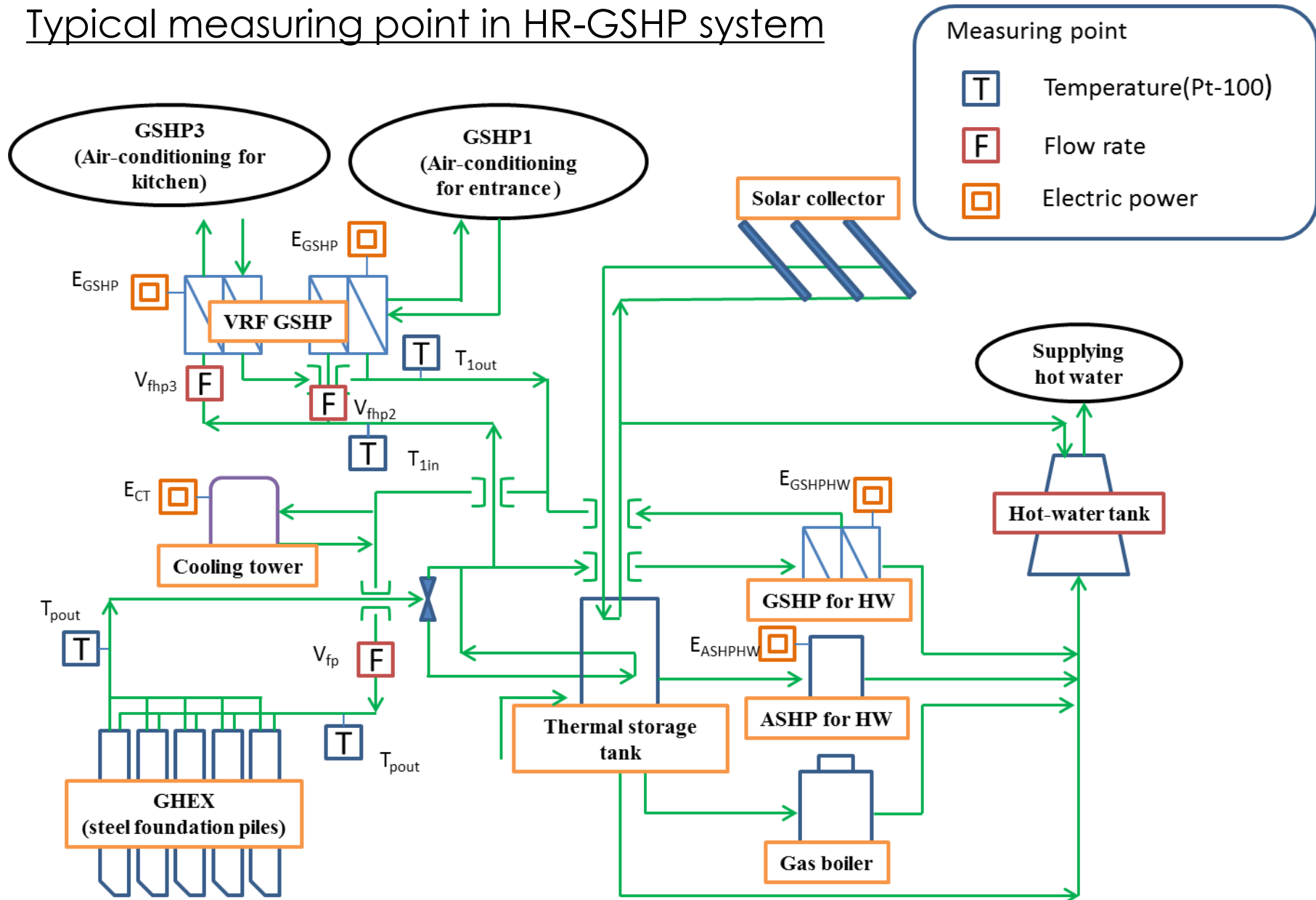


# Heat recovery ground source heat pump system

## Specification of the equipment in HR-GSHP system

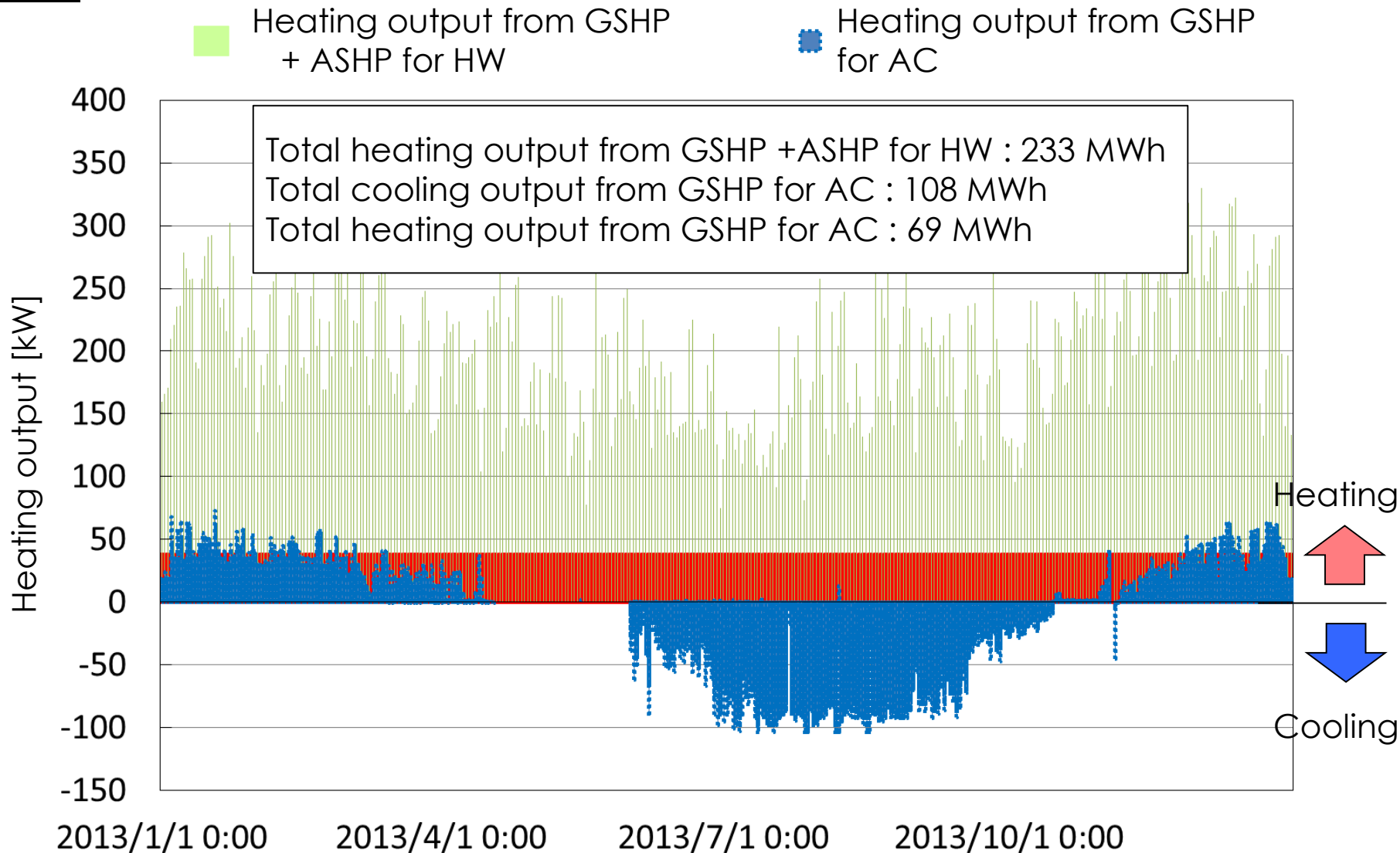


## Typical measuring point in HR-GSHP system



# Heating and cooling output of HR-GSHP system<sup>11</sup>

## Hourly heating and cooling output of HR-GSHP system measured in 2013



# Optimizing control method for HR-GSHP system<sup>12</sup>

## Optimizing control method for HR-GSHP system by using simulation tool

### Flow of optimizing control method

#### 1. Monitoring HR-GSHP system

##### Measurement data

- Inlet and outlet temperature of GHEXs
- Flow rate in the GHEXs
- Heating and cooling output of heat pumps
- Energy consumption of equipment

#### 2. Modifying simulation tool

#### 3. Optimizing the control method by using the simulation tool

#### 4. Operating the HR-GSHP system basis on the optimized control method

Back to 1

In this control method, the optimized control which minimizes annual energy consumption of whole the system is determined by using the simulation tool.

$$\min E_{system}$$

For example, the energy consumption of whole the system in the dormitory is expressed by the following equation

$$E_{system} = E_{GSHPc} + E_{GSHPH} + E_{GSHPHW} + E_{ASHPHW} + E_{CT} + E_{th}$$

$E_{GSHPc}$ : Energy consumption of GSHP for AC (cooling) [kWh]、 $E_{GSHPH}$ : Energy consumption of GSHP for AC (heating) [kWh]、 $E_{GSHPHW}$ : Energy consumption of GSHP for hot water [kWh]  
 $E_{ASHPHW}$ : Energy consumption of ASHP for hot water [kWh]、 $E_{CT}$ : Energy consumption of cooling tower[kWh]  
 $E_{th}$ : Energy consumption for heating the thermal storage tank [kWh]

Optimizing control method of HR-GSHP system by using simulation tool

Changing the operating period of GSHP for HW and determining the operating period that can minimize the total energy consumption



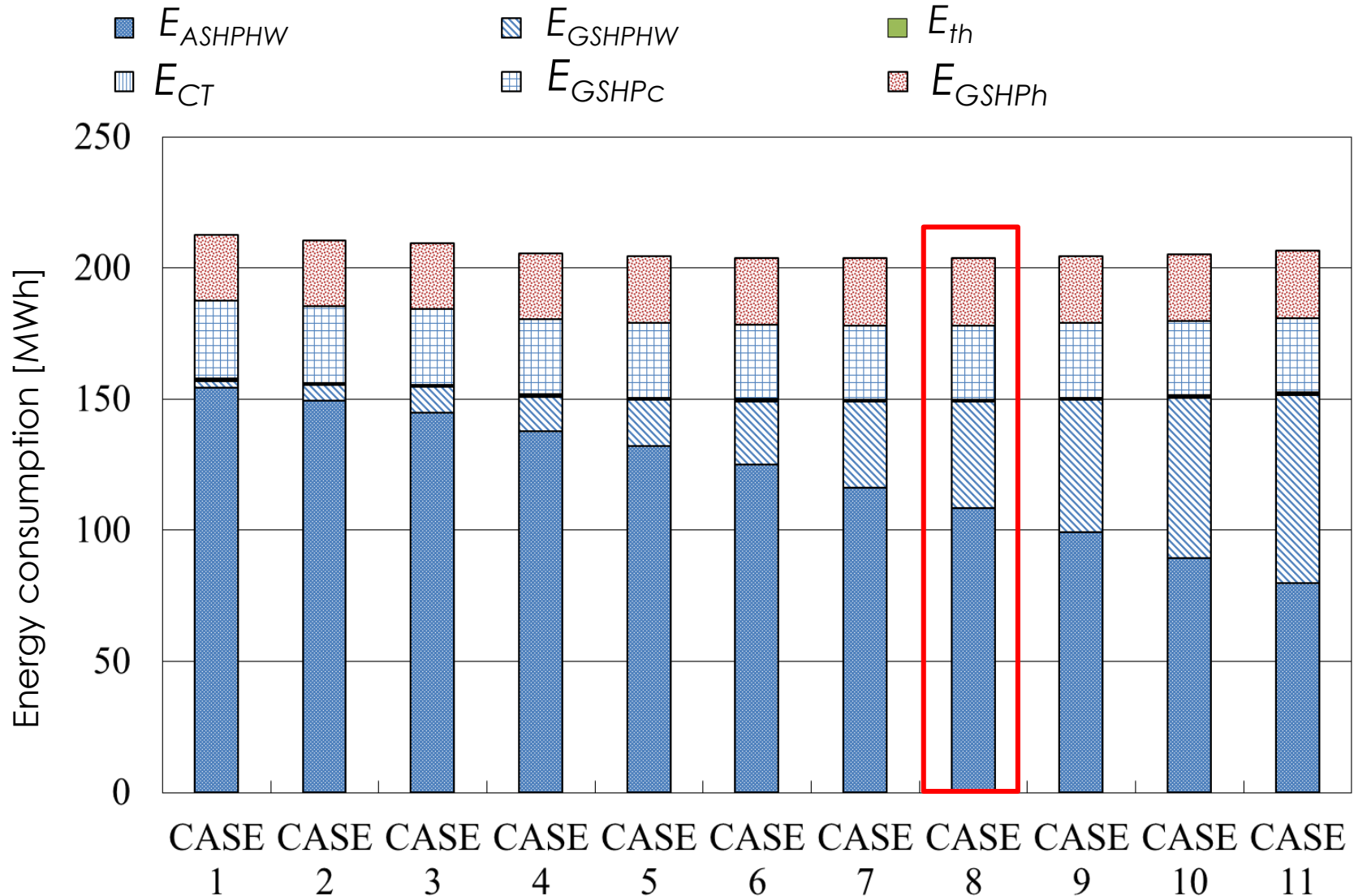
The HR-GSHP system that operates the GSHP for HW for the determined period is the system with optimized control

Condition of operating period of GSHP for hot water

	Operating period of GSHP for HW		Operating period of GSHP for HW
CASE1	August (1month)	CASE7	May~November (7month)
CASE2	July~August (2month)	CASE8	April~November (8month)
CASE3	July~September (3month)	CASE9	April~December (9month)
CASE4	June~September (4month)	CASE10	March~December (10month)
CASE5	June~October (5month)	CASE11	March~January (11month)
CASE6	May~October (6month)	CASE12	All though the year (12month)

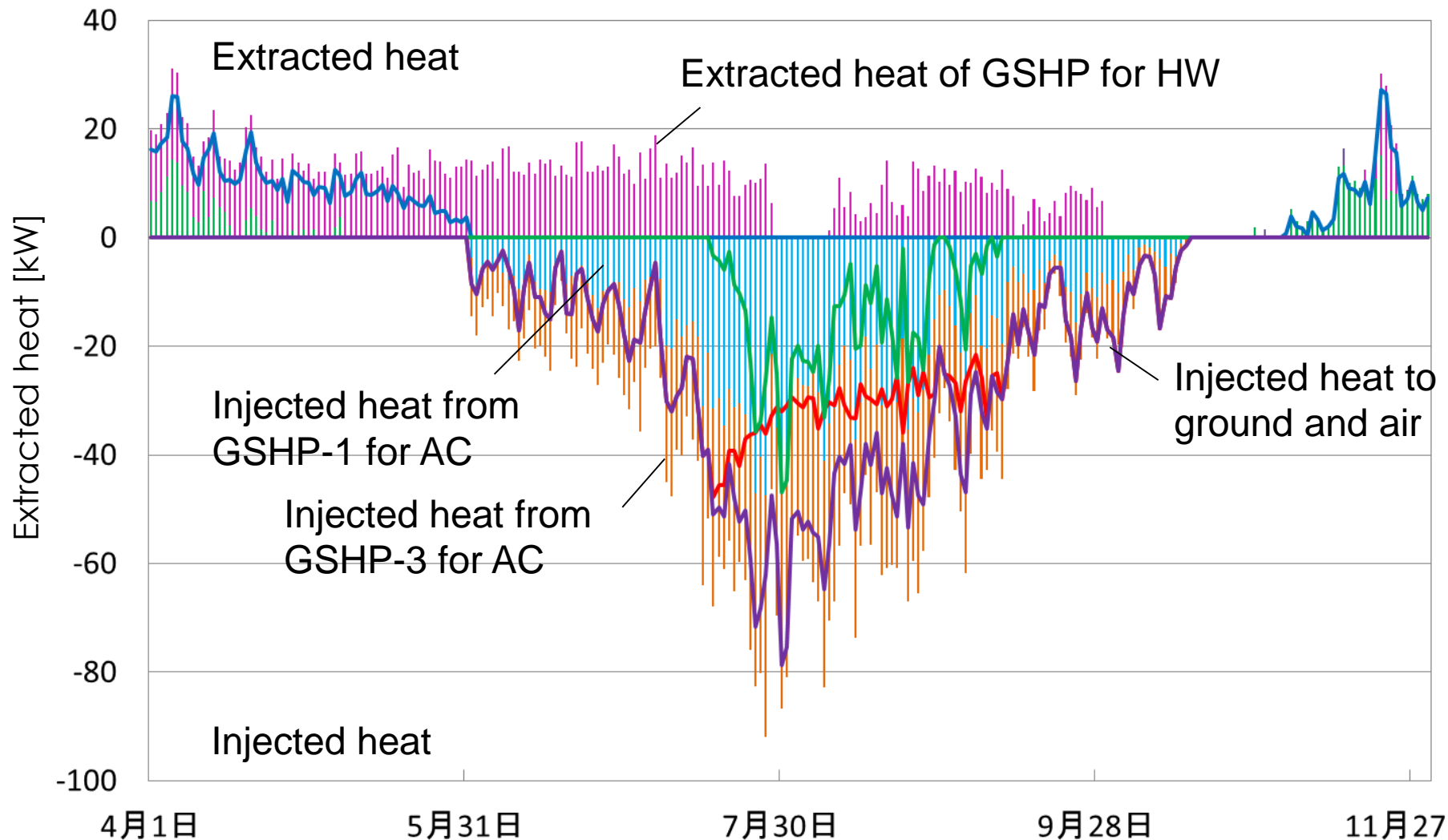


Total energy consumption of HR-GSHP system according to the condition of operating period of GSHP for HW



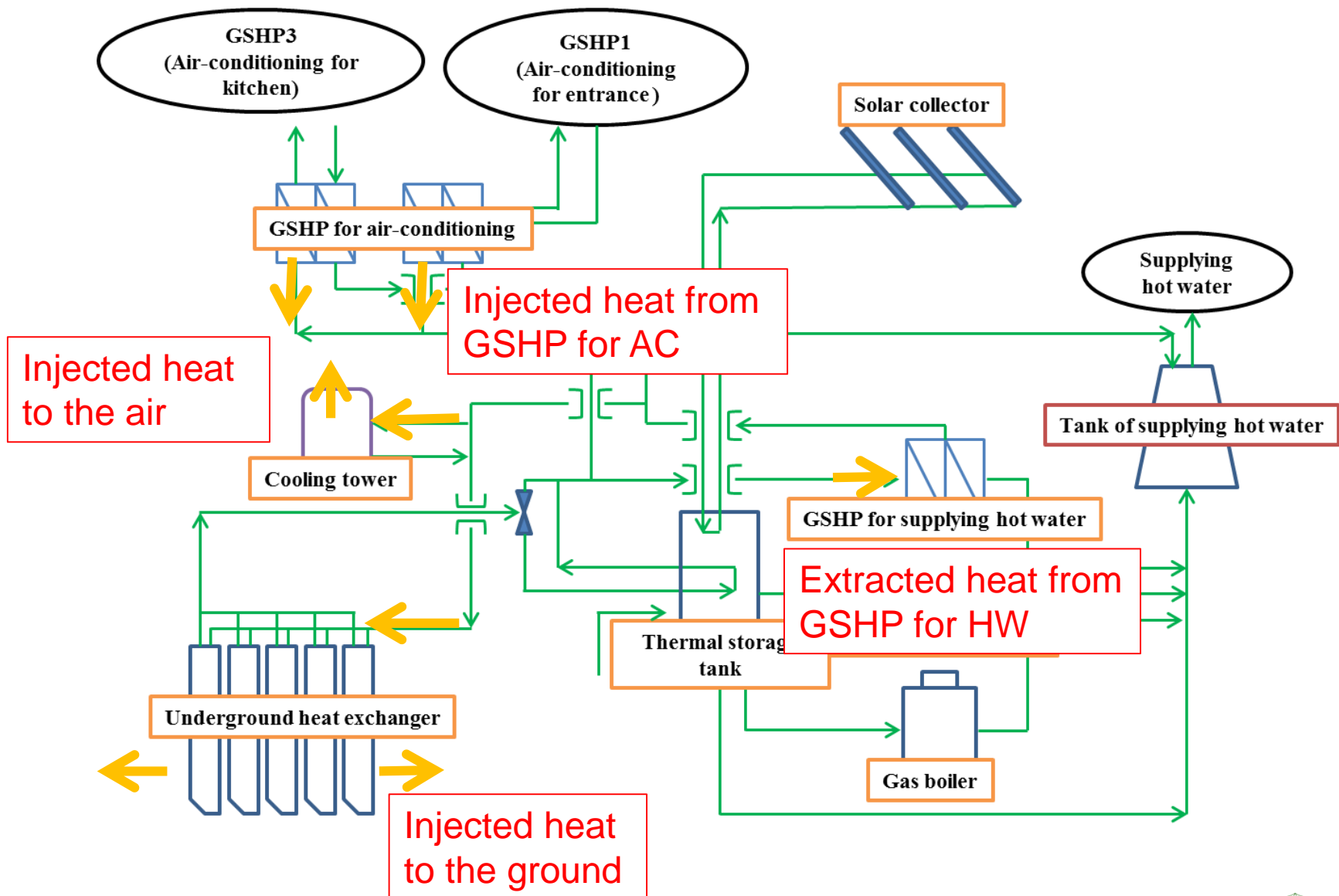
# Measurement result of HR-GSHP system in 2014<sup>15</sup>

Variation of heat extraction or injection from or to equipment in the HR-GSHP system (Apr. 1<sup>st</sup> ~ Nov. 30<sup>th</sup>)



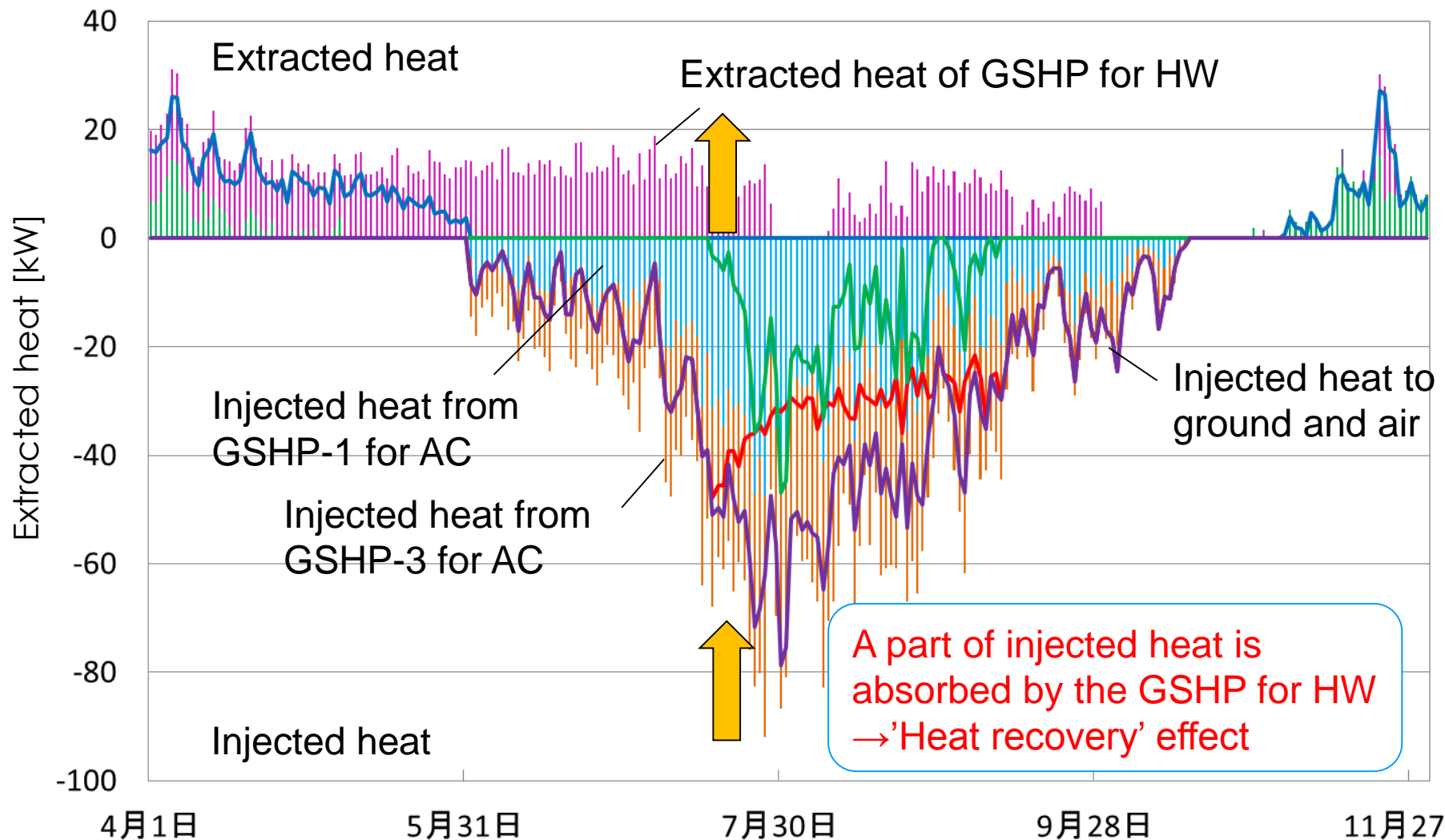
# Measurement result of HR-GSHP system in 2014<sup>16</sup>

## Diagram of HR-GSHP system



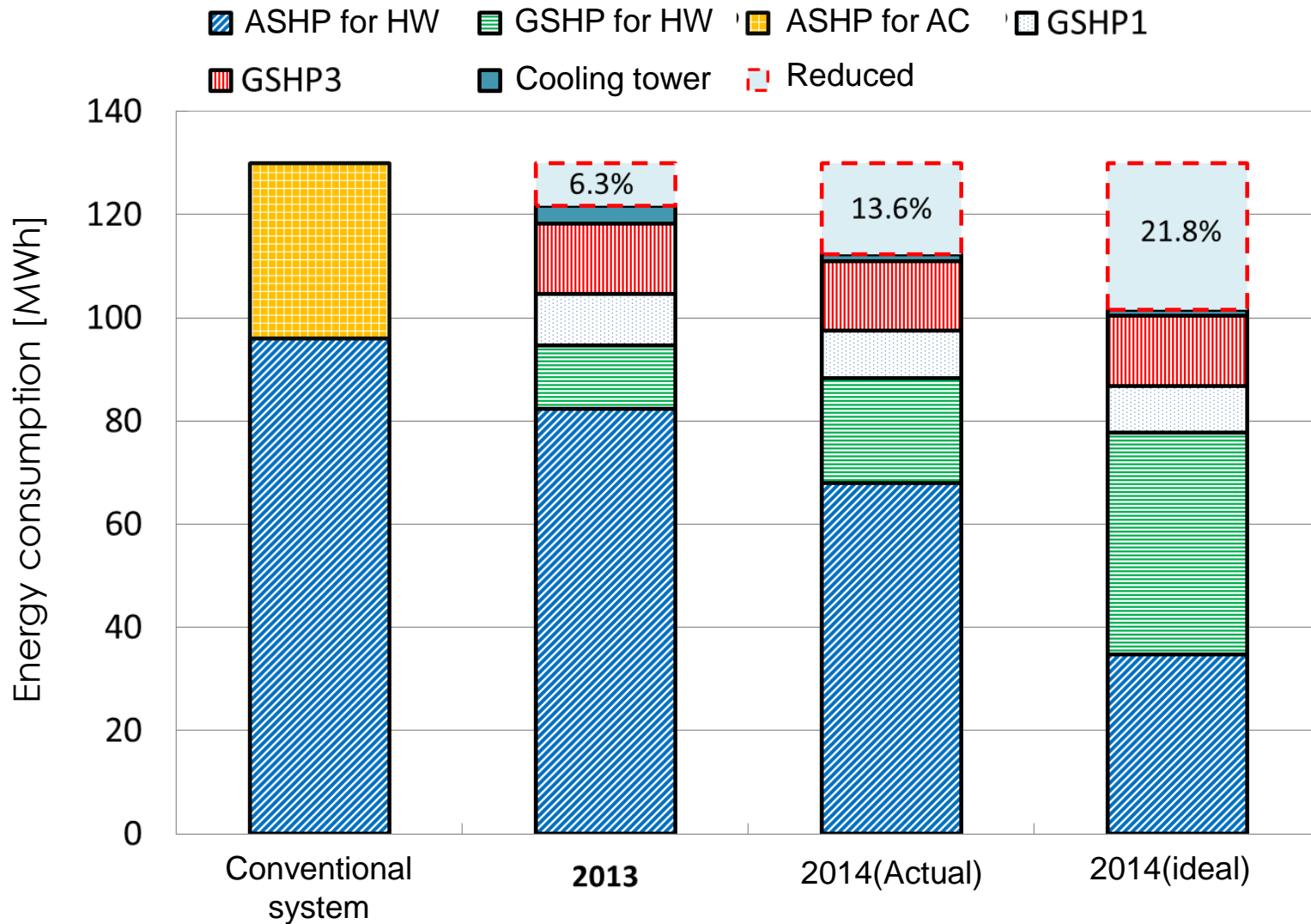
# Measurement result of HR-GSHP system in 2014<sup>17</sup>

Variation of heat extraction or injection from or to equipment in the HR-GSHP system (Apr. 1<sup>st</sup> ~ Nov. 30<sup>th</sup>)



# Measurement result of HR-GSHP system in 2014<sup>18</sup>

Total energy consumption in HR-GSHP system and comparison with conventional system (From Apr. 1<sup>st</sup> to Nov. 30<sup>th</sup>)





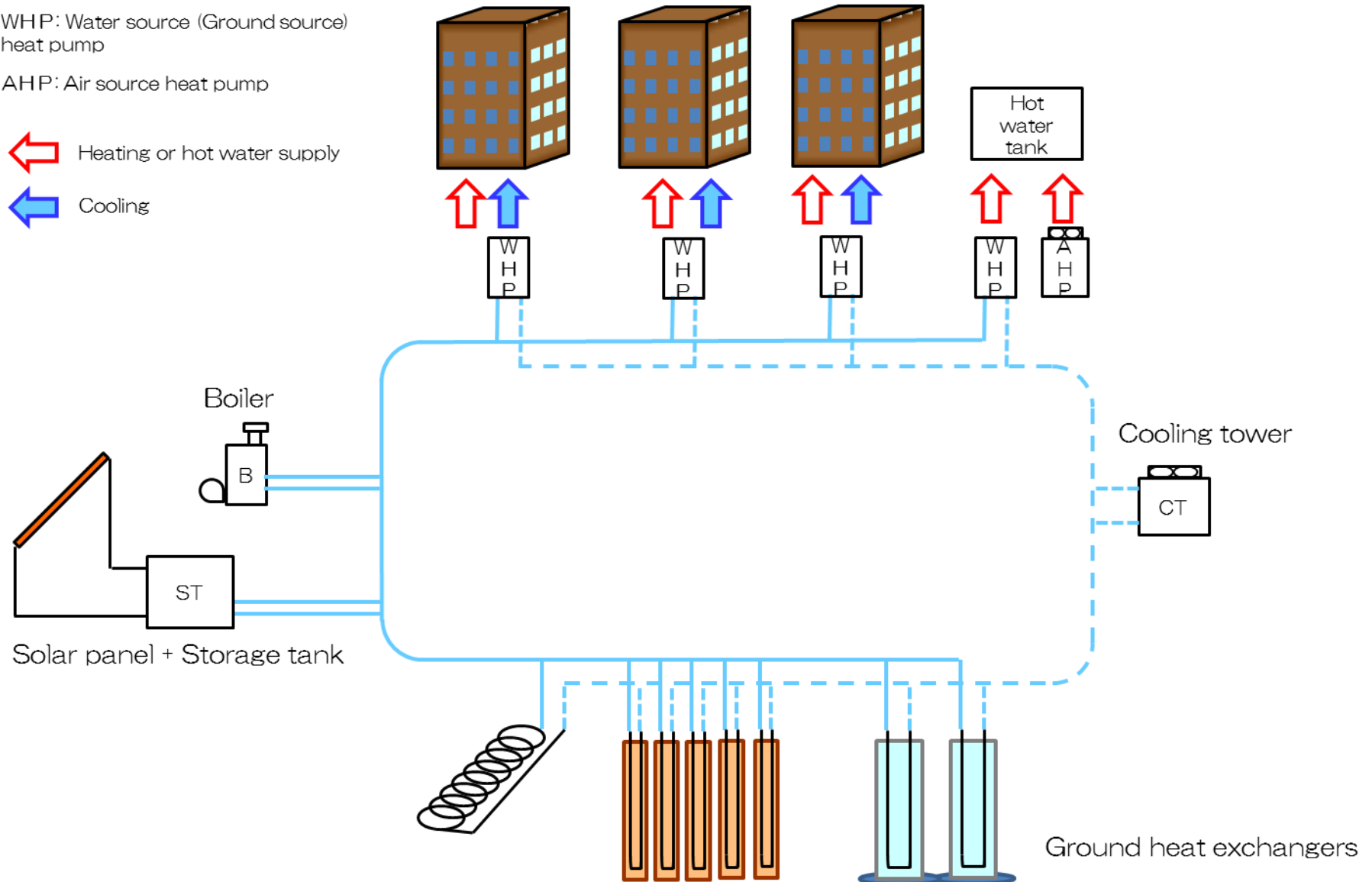
# Application of HR-GSHP system in Smart Community in Future

## Application concept of HR-GSHP system in Smart Community

WHP: Water source (Ground source) heat pump

AHP: Air source heat pump

 Heating or hot water supply  
 Cooling





(1) Outlines of Heat Recovery Ground Source Heat Pump System was explained

(2) Experimental Proof of HR-GSHP System Installed in the dormitory in Smart Community was introduced

- 1) The optimized control method of the HR-GSHP system by using the simulation tool was described
- 2) It is confirmed that 'Heat recovery' effect was obtained by measuring the HR-GSHP system with optimized control
- 3) It is possible to reduce 21.8 % of the energy consumption compared to the conventional ASHP system when the HR-GSHP system is operated with optimized control
- 4) Application of the HR-GSHP system in Smart Community in Future