

Techno-environmental evaluation of a river-source heat pump system using a hot gas bypass valve

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Master course

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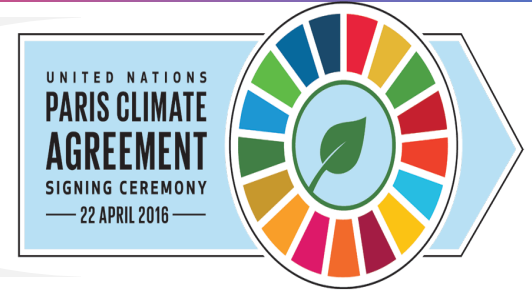
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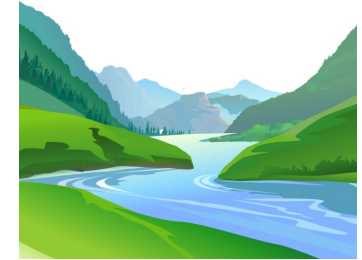
By 2030,

- Paris Climate Agreement adopted to suppress global temperature rise^[1]
- Korea aims to reduce GHGE by 40% compared to 2018^[1]
* Greenhouse gas emissions
- Using renewable energy sources is essential to achieve the goal



Utilization of river-water sources

- Seawater, lake water, etc. are included in renewable energy sources
- River-water sources incorporated as one of the water sources in Korea^[2]



	Heat pump (HP)	
	Water source heat pump (WSHP)	Air source heat pump (ASHP)
Annular temperature deviation	Low	High
Thermal property of heat source	Good	Poor
Efficiency of heat pump	High	Low
Heat exchanger freezing in winter	Occur	Occur

WSHPs show superior performance compared with the ASHPs^[3], but **freezing occurs in the evaporator** owing to the low source temperature in winter

Base

Conventional hybrid water source heat pump system (CHHPS) utilizes a gas boiler

- To overcome the freezing issue
- To ensure stable operation during winter

Purpose

However, **a lot of energy is consumed owing to the gas boiler** because the heat pump system cannot operate at a low water temperature in winter.

- In this study, **hybrid water source heat pump system using hot gas bypass valve (HBHPS)** is presented compared with **CHHPS**
 - An increase in the performance of the entire system is expected
 - An increase in WSHP operation time under low water temperature is expected

Background

- The use of renewable energy is essential to reduce GHGE by 2030
- WSHPs show better performance than conventional ASHPs
- However, WSHPs are limited to use in winter owing to freezing issues

Purpose

- In winter, by using WSHPs with the hot gas bypass valve,
- Increase the operation time of WSHPs
 - Improve the performance indicator (GHGE, Cost etc.)

Method

- Python is used for modeling hot gas bypass valve
- Transient simulation program ^{* TRNSYS} is used for comparing the systems
- Compare seasonal performance factor (SPF), greenhouse gas emissions(GHGE), and operation cost



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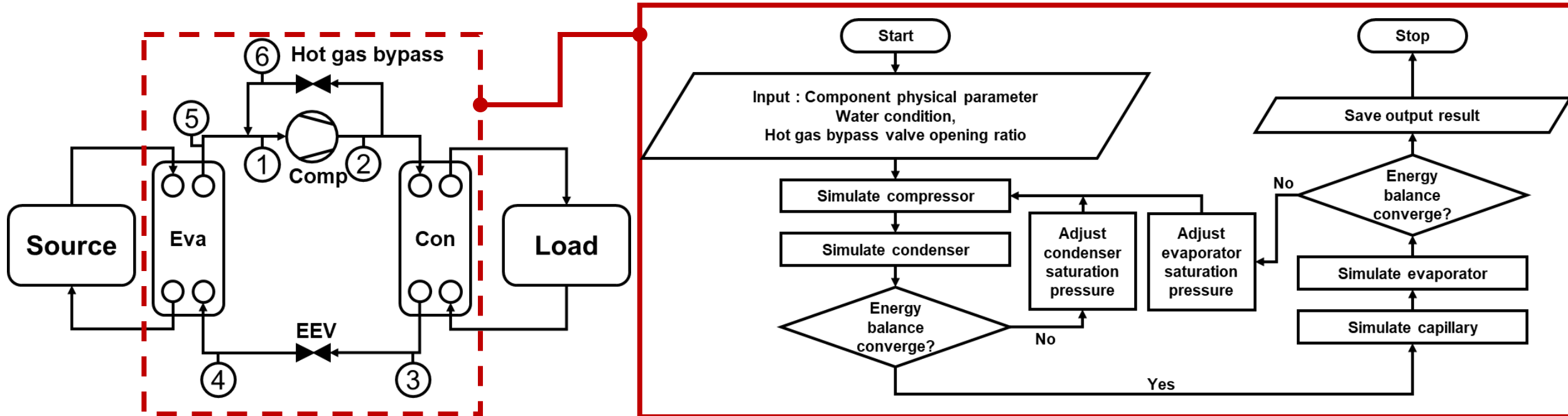
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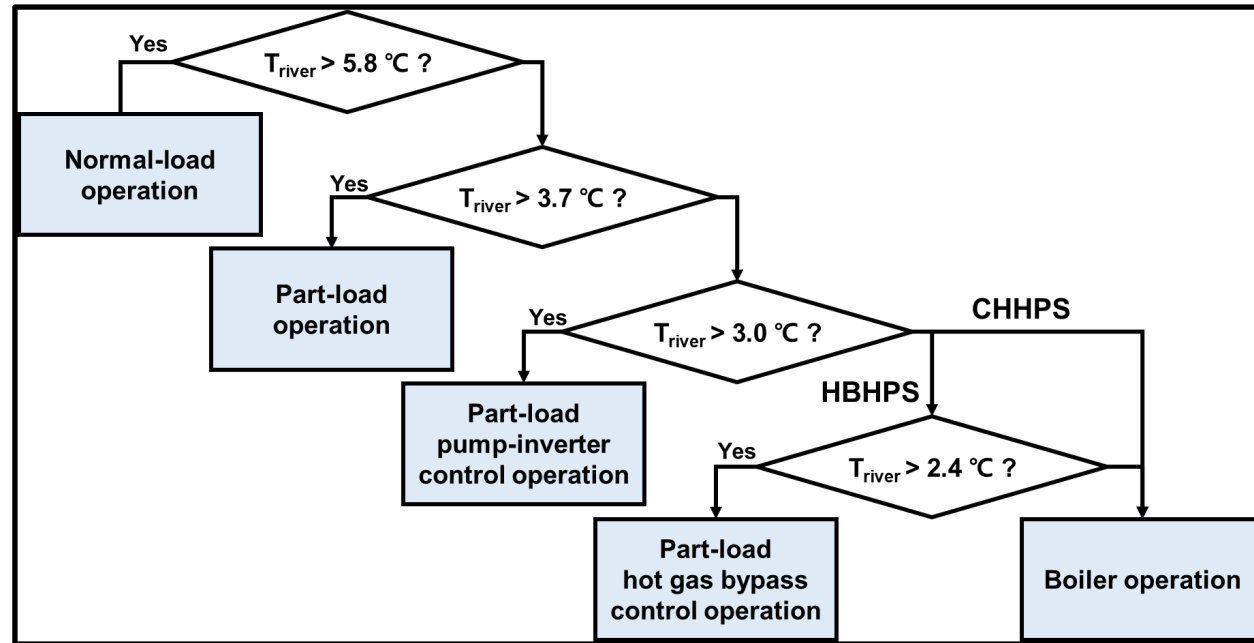
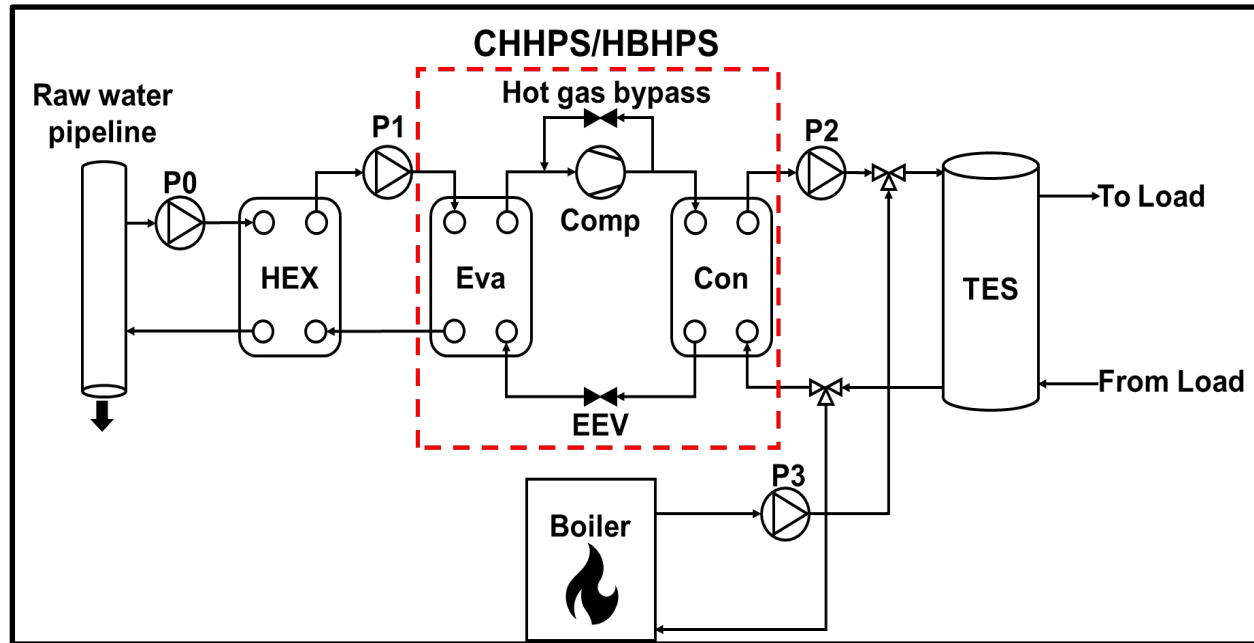
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Modeling WSHP in HBHPS by ORNL method^[4]

- ❑ Energy balance in the condenser and evaporator was iteratively calculated until converging
- ❑ Operating characteristics of hot gas bypass valve were obtained by previous research^[5-8]
- ❑ Bypass opening ratio (x) was determined by water source temperature



❑ Transient simulation by TRNSYS

- Boiler-Heat pump hybrid system is considered
- The boiler will operate in low water source temperature conditions

❑ Case study (CHHPS, HBHPS)

- Case 1 (CHHPS) : Only inverter control
- Case 2 (HBHPS) : Inverter + hot gas bypass control

Heat pump	
Rated capacity	500 RT
Evaporator design capacity	391 RT
Evaporator min. water outlet temp.	1 °C

Water temp.	
Paldang Dam water source	Measured data

Load	
Business building	Measured data

Heat exchanger	
Design capacity	1350kW

Pump	
Rated flow rate (P0, P1)	6533 LPM
Rated flow rate (P2, P3)	5040 LPM

TES	
Load side min. water outlet temp.	45 °C

Boiler	
Combustion efficiency	0.8

- Design each equipment based on the measured maximum heating load
- Average monthly water temperature : Nov : 11.4 °C / Dec : 4.7 °C / Jan : 2.1 °C / Feb : 1.8 °C / Mar : 6.4 °C

* Key Performance Data

- Seasonal performance factor (SPF)

$$SPF = \frac{E_{th,HP}}{E_{p,tot,P} + E_{p,tot,HP}}$$

- Greenhouse gas emission for lifecycle (GHGE)

$$GHGE = L * (AEC_e * EF_e + AEC_g * EF_g)$$

- Operation cost for lifecycle

$$Operation\ cost = \sum_n \left\{ \frac{1+i}{1+d} \right\}^{L-1} (AOC_e + AOC_g)$$

* Nomenclature

$E_{th,HP}$	Heat supplied by heat pump (MWh)
$E_{p,tot,P}$	Energy consumption by whole pump in system (kWh)
$E_{p,tot,HP}$	Energy consumption by heat pump in system (kWh)
L	Average lifetime of Equipment (y)
AEC_e	Annular energy consumption by electricity (kWh)
AEC_g	Annular energy consumption by gas (kWh)
EF_e	Emission factor of electricity (kg CO ₂ produced/kWh)
EF_g	Emission factor of gas (kg CO ₂ produced/kWh)
i	inflation rate (%)
d	discount rate (%)
AOC_e	Annular operation cost by electricity (\$)
AOC_g	Annular operation cost by gas (\$)

□ Emission factor, electricity and gas costs can be calculated on the South Korea bases^[9-12]



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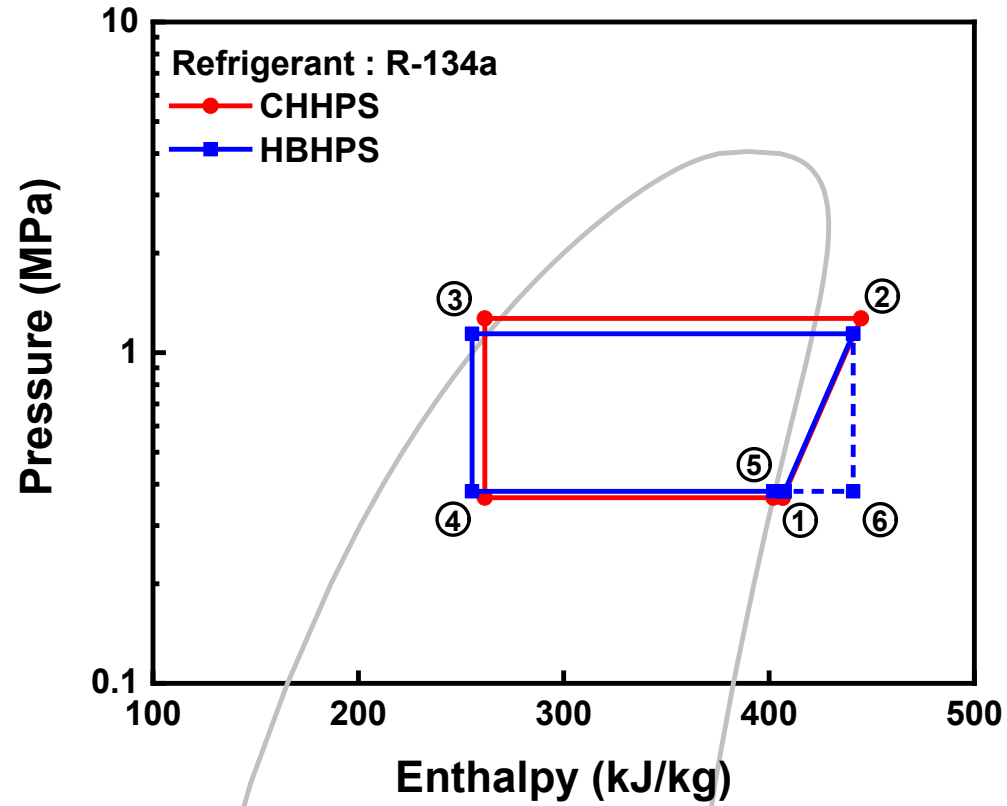
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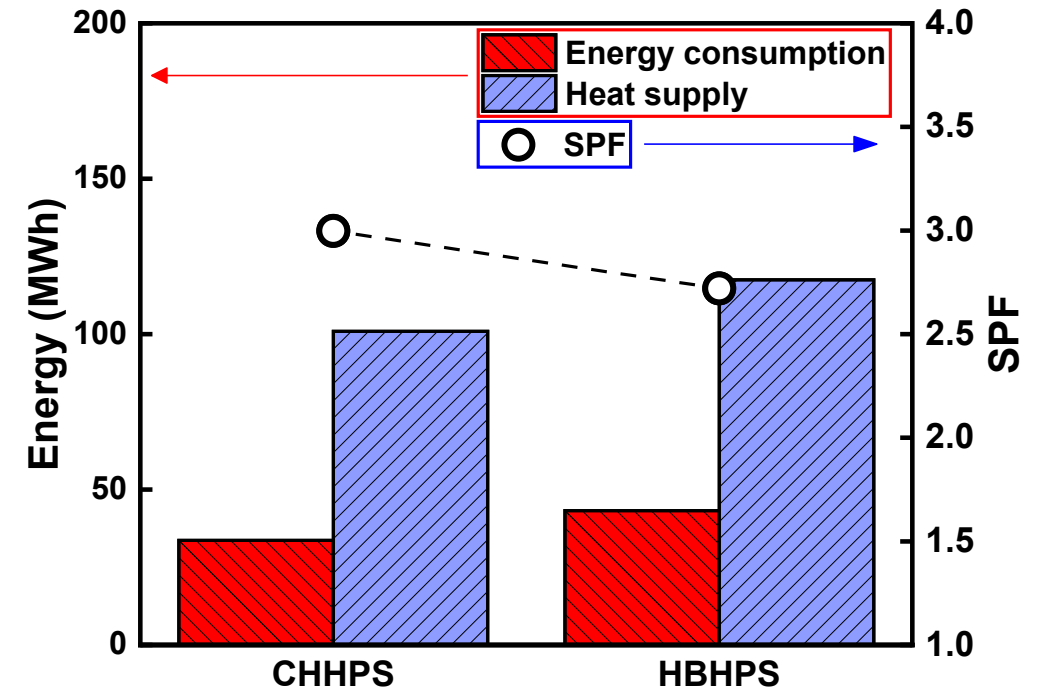
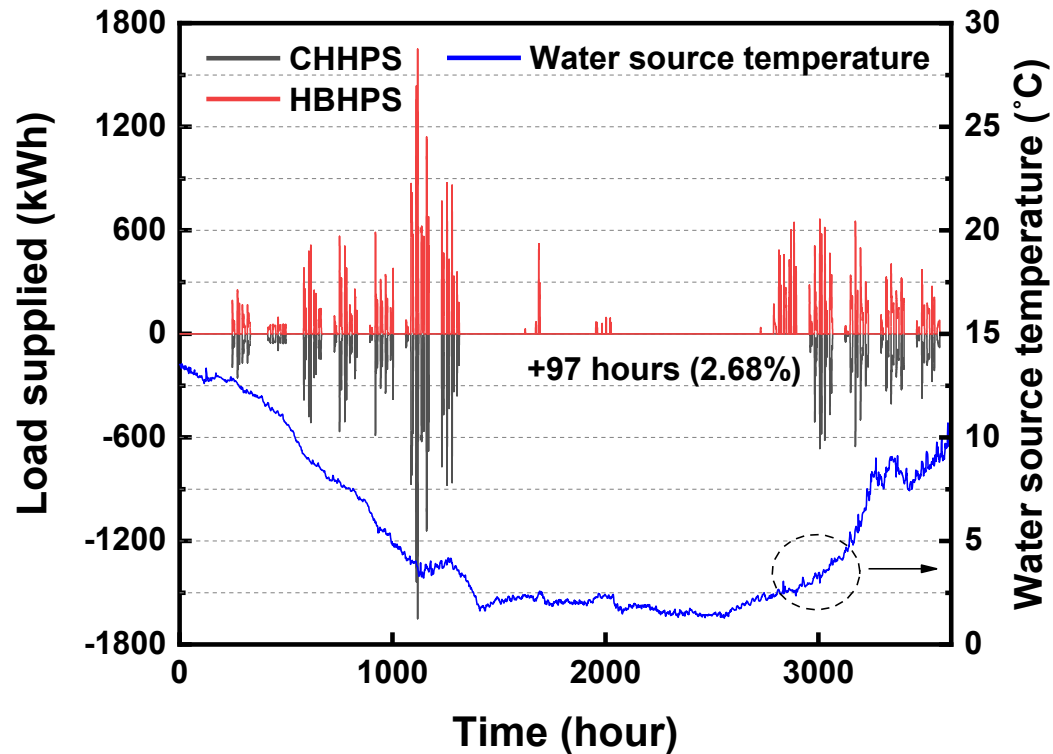
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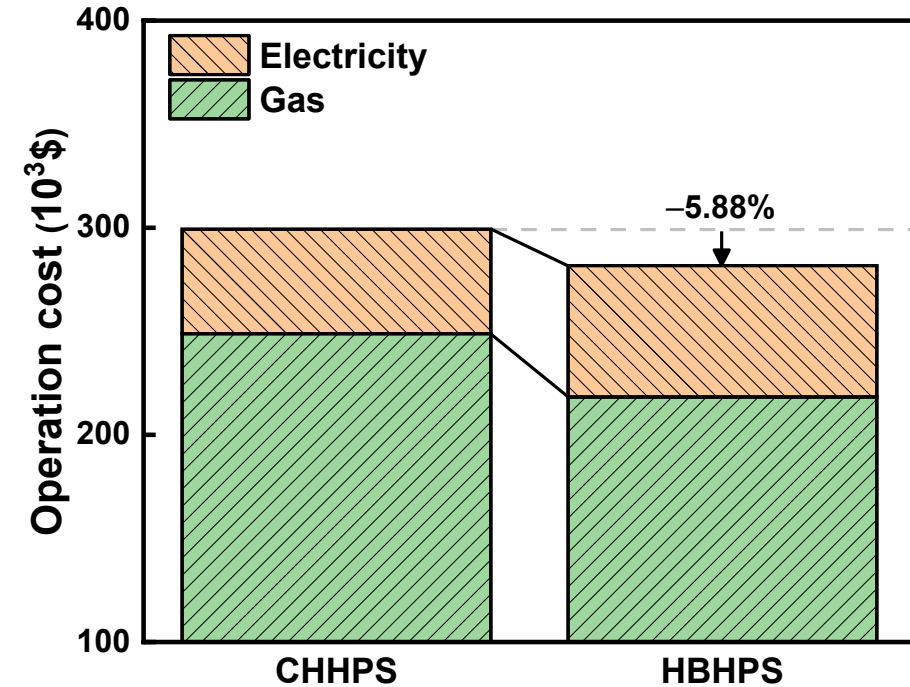
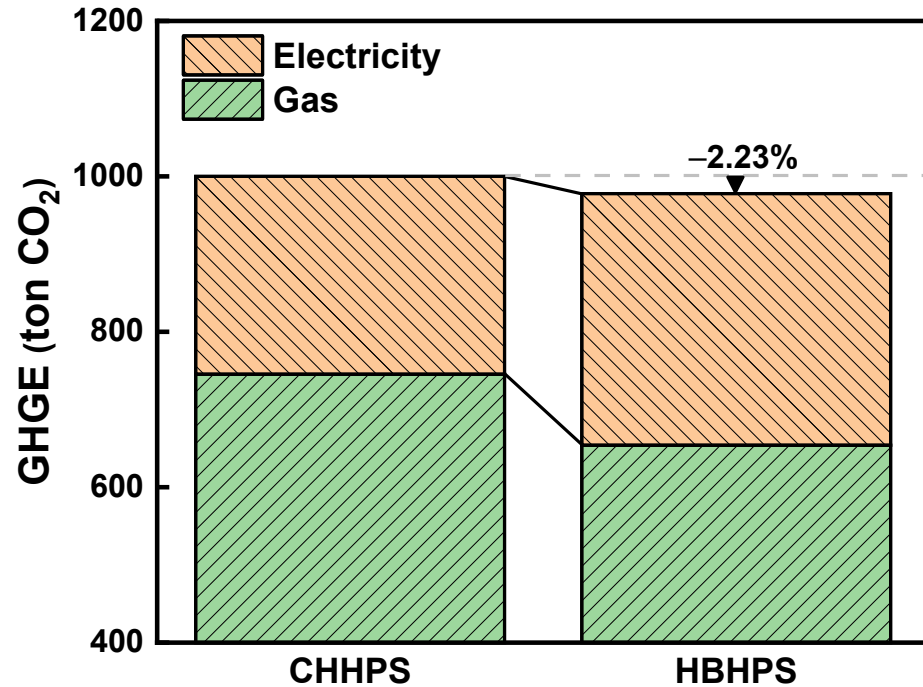


- Condenser water inlet temp. : 40 °C
- Evaporator water inlet temp. : 12 °C
- Bypass opening ratio (x) : 0.5

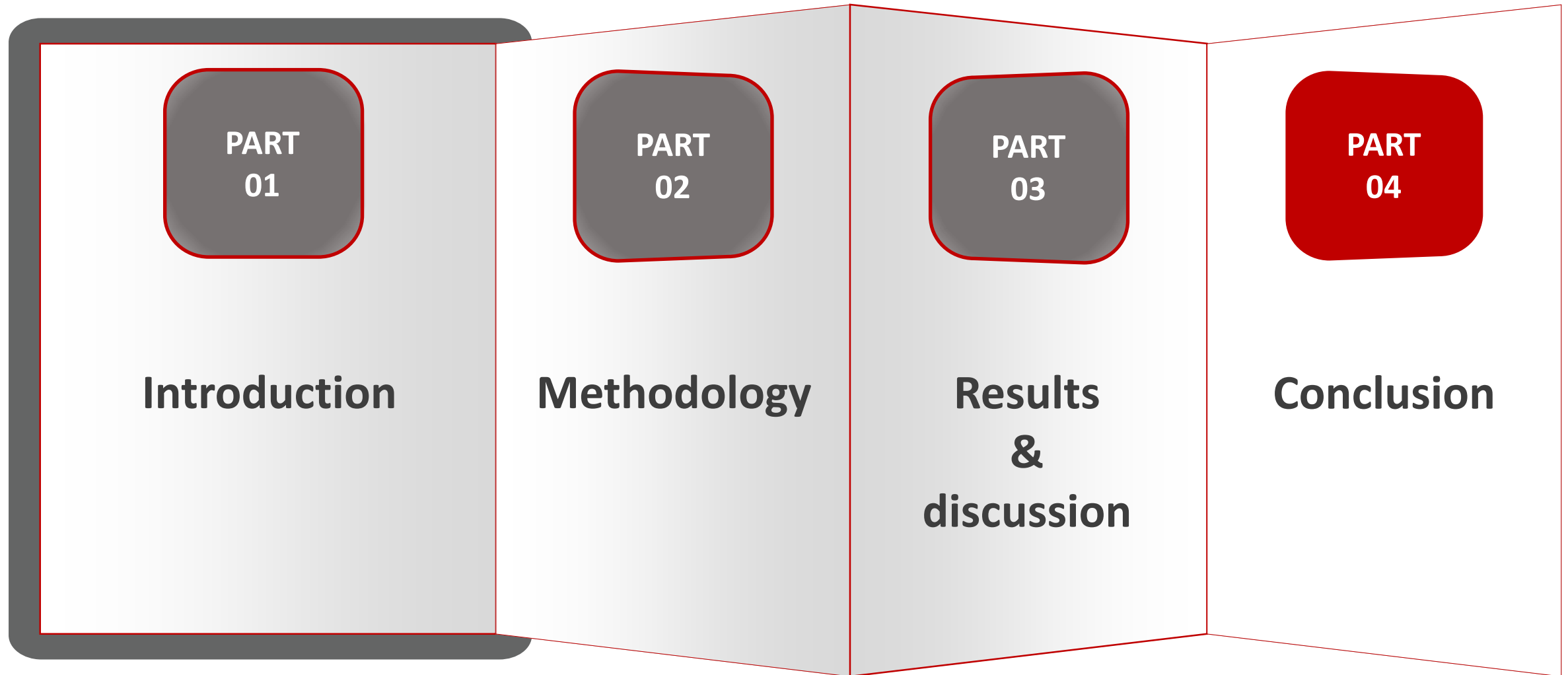
- The condensing pressure decreased owing to the bypassed gas on the compressor discharge side
- The evaporating pressure increased owing to the bypassed gas flowing into the outlet of the evaporator



- ❑ The heat pump in HBHPS operated until 2.38 °C while that in CHHPS operated until 3.03 °C
- ❑ Operation time : HBHPS > CHHPS 97 hours (2.68%) ↑
- ❑ Energy consumption : HBHPS > CHHPS 28.30% ↑
- ❑ Heat supply : HBHPS > CHHPS 16.43% ↑
- ❑ SPF : HBHPS < CHHPS 9.26% ↓



- Even though the EF of electricity was higher than that of gas, GHGE decreased by 2.23%
- As the heat pump operation time increased and boiler operation time decreased, operation cost was reduced by 5.88%



Compare with conventional hybrid heat pump system,
a hybrid heat pump system that applies a hot gas bypass heat pump,

- The operation time of the heat pump increased by 2.68% in winter
- Greenhouse gas emissions reduced 2.23% in winter
- Annular operation cost reduced 5.88% in winter
- Although the SPF has decreased 9.26%, it is still efficient



Although the water temperature conditions in winter are low, performance indicators are improved

➔ Greater performance improvement is **expected in areas with relatively higher water source temperature conditions in winter**

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Thank you!

Q&A