



Environmental Thermal Engineering

Lecture Note #7

Professor Min Soo KIM





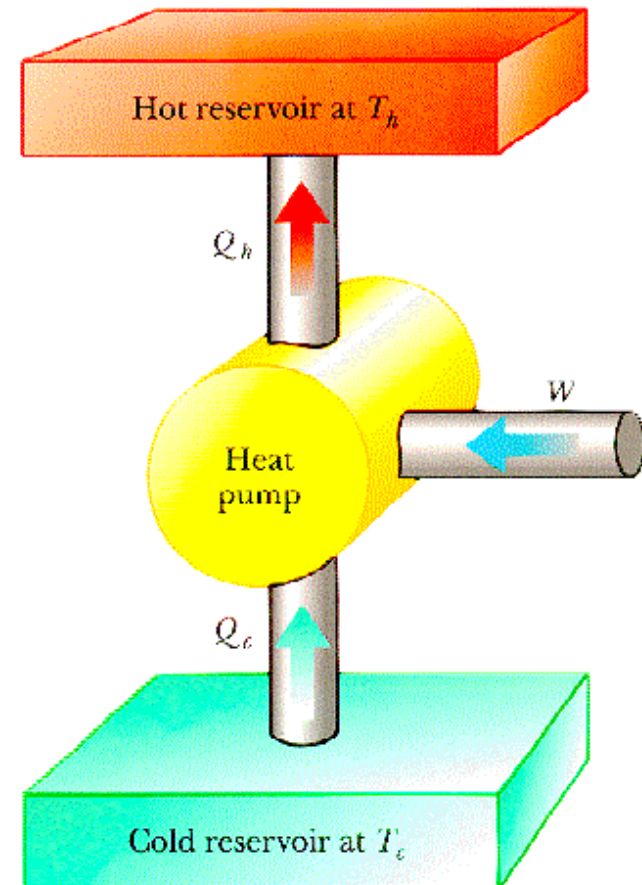
Heat Pump



Heat Pump

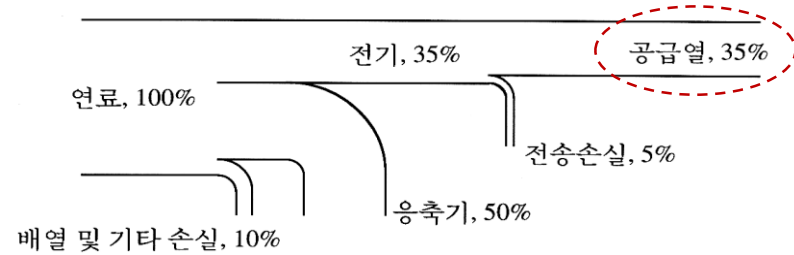
Heat Pump Cycle

- ❑ Absorbs heat from a low-temperature heat source and transports heat to a high-temperature part
- ❑ The composition of the existing refrigeration cycle is the same
- ❑ It is also widely used as a combined heating and cooling device.
- ❑ Very economical in terms of initial installation cost and installation space
- ❑ Change the flow direction of refrigerant according to the purpose of operation (cooling, heating)
- ❑ Changing the role of indoor and outdoor heat exchangers
- ❑ The flow path conversion uses a four way valve

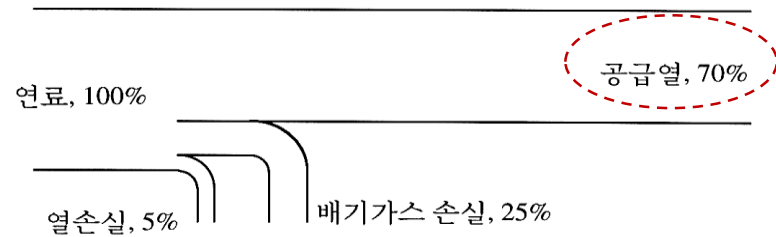


Compare Energy Flow Diagram

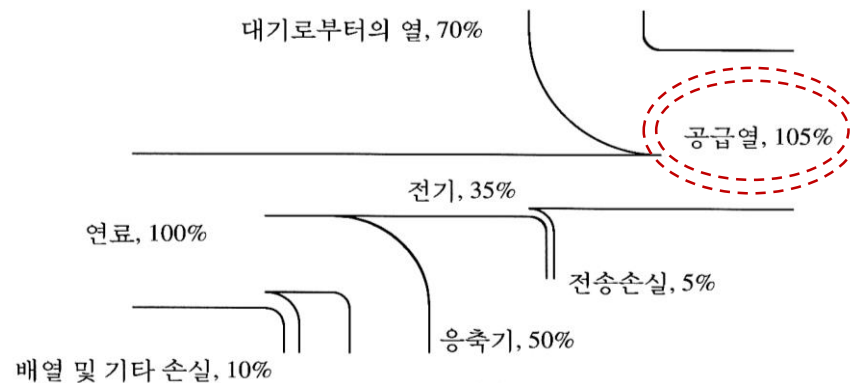
Electric
Heating
instrument



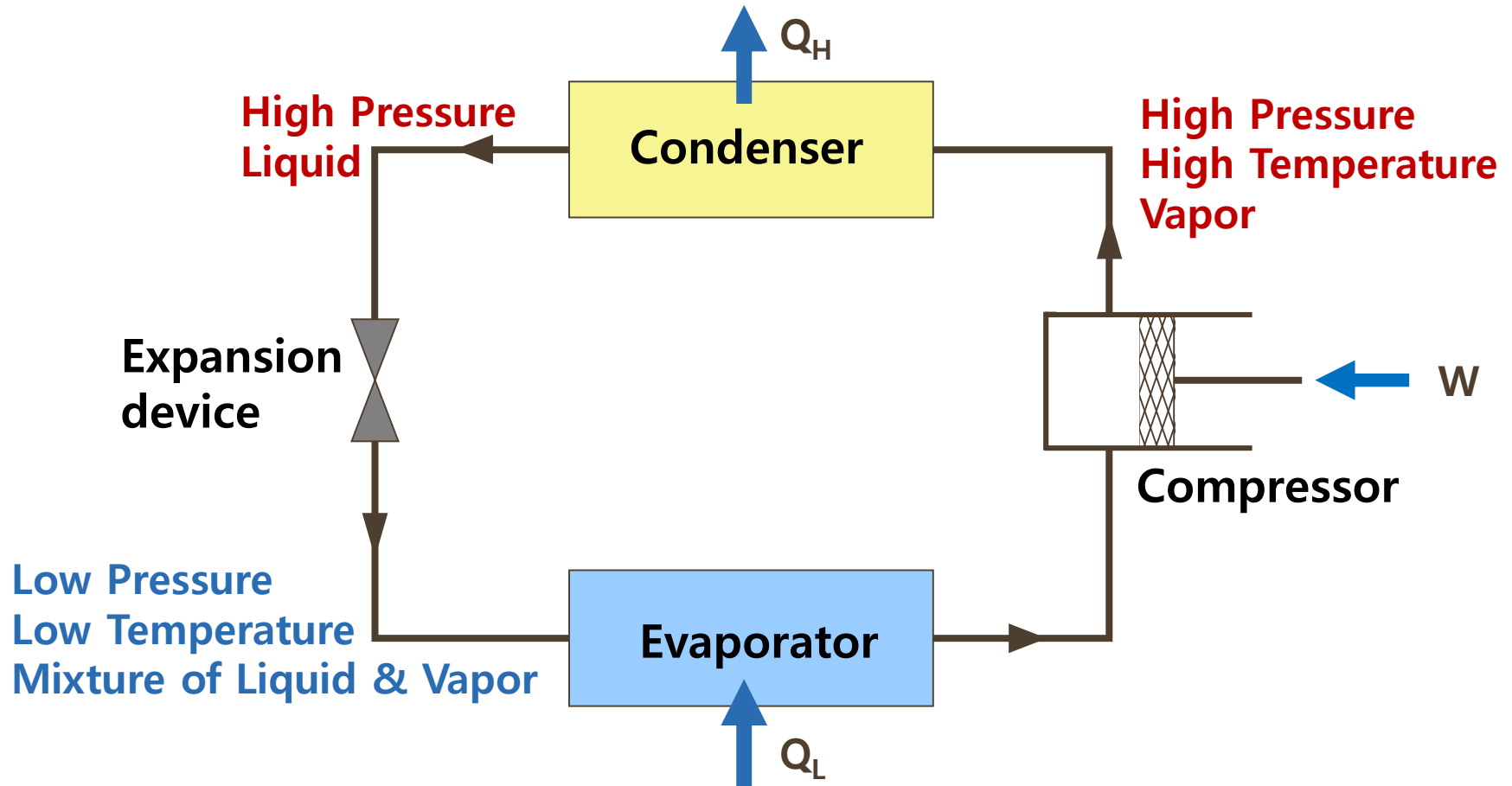
Boiler



Heat Pump



General Vapor Compression Heat Pump



Heat Pump Operating Characteristics

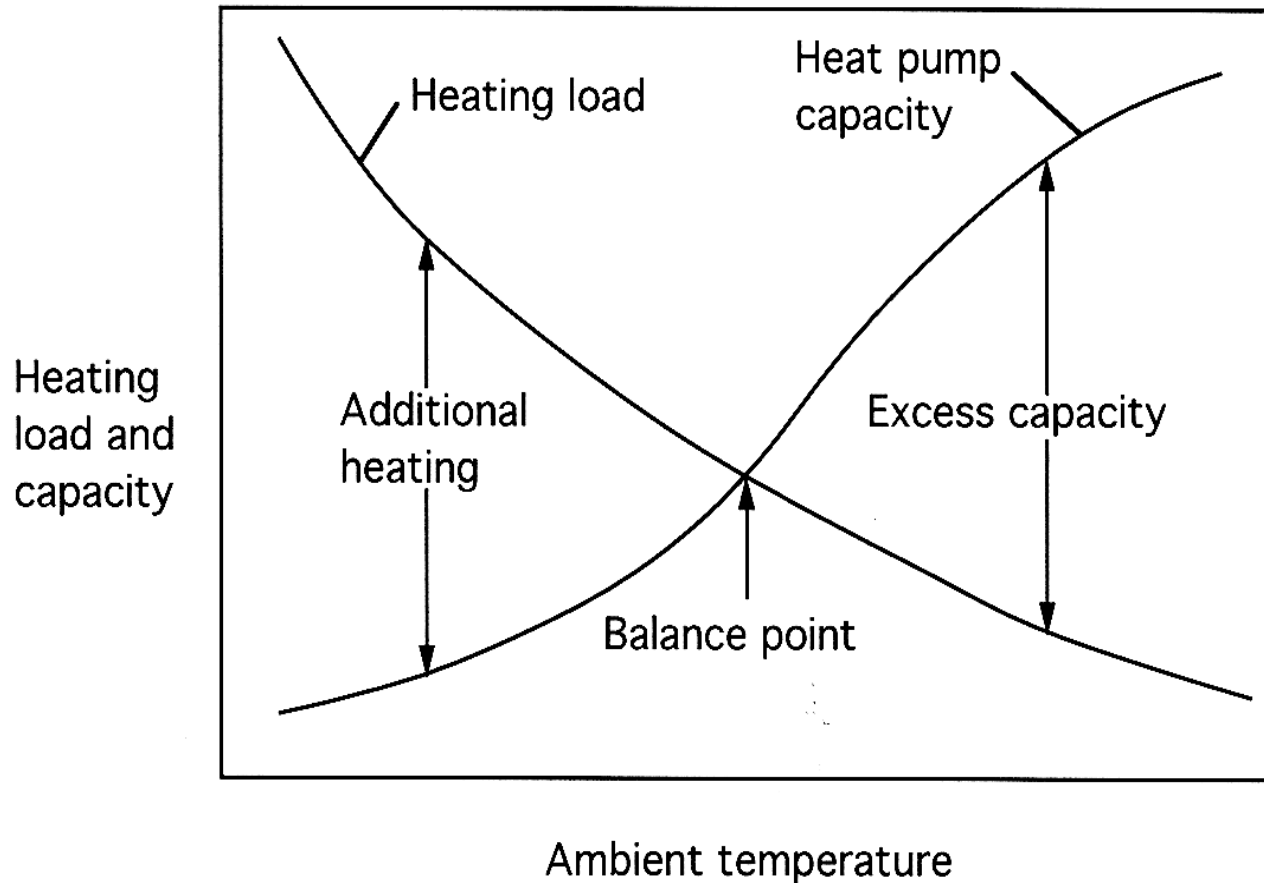


FIGURE Heating capacity and load of heat pump depending on the change of outdoor temperature

Thermodynamics in Heat Pump

- Indoor supply heat = Outdoor heat + Compressor electrical work

$$q_L + w_{comp} = q_H$$

- COP of heating mode = Heat effect and input power proportions

$$\text{COP}_h = \frac{q_H}{w_{comp}}$$

- COP of heating mode = Heat effect and overall electrical input power proportions

$$\text{COP}_h = \frac{q_H}{w_{comp} + w_{elec}}$$

- COP of cooling mode

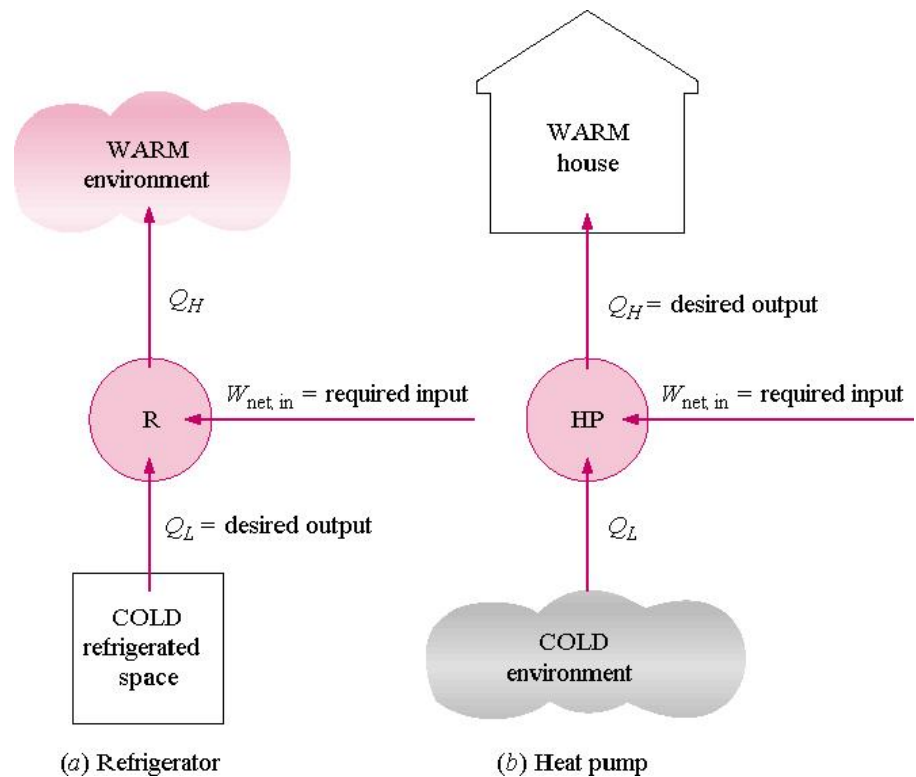
$$\text{COP}_c = \frac{q_L}{w_{comp}}$$

COP of Heat Pump System

Capacity & COP Operation mode	Heat absorbed by evaporator	Work input to compressor	Heat rejected by condenser	COP
Heating	1	0.3	1.3	4.3
Cooling	1	0.3	1.3	3.3

Heat Pump Cycle

- ❑ Heat absorption from cold reservoir and heat transport to the hot reservoir
- ❑ Same organization with existing refrigerating cycle
- ❑ Used for both heating and cooling
- ❑ Highly economical in initial installation cost and space

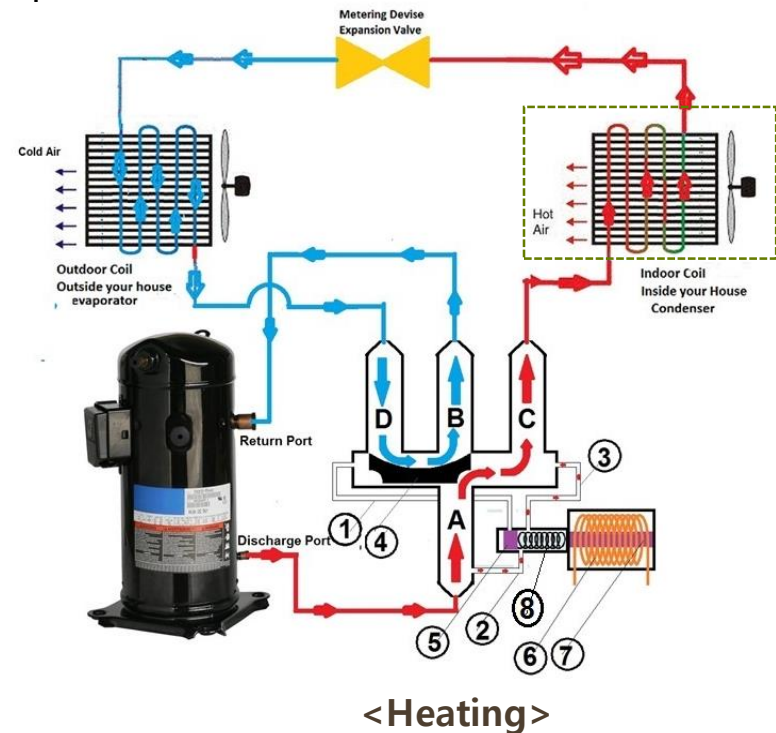
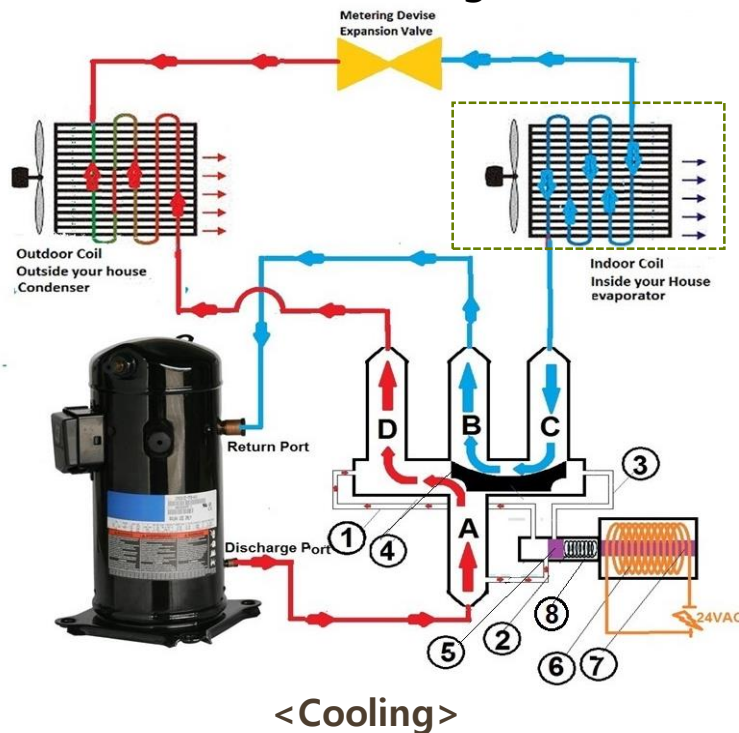


Heat Pump

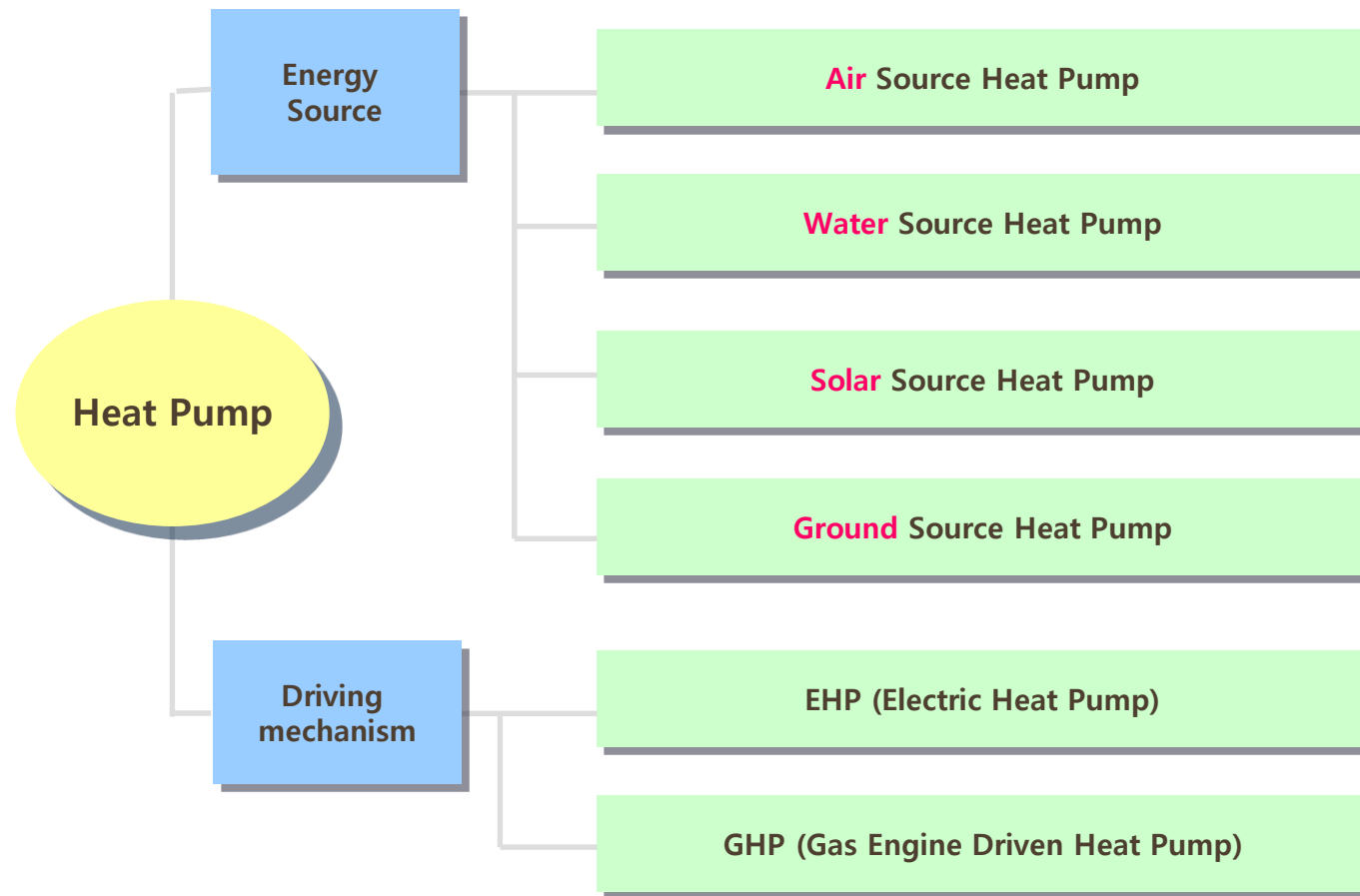
Basic Heat Pump System

❑ Heat pump heating/cooling operation conversion

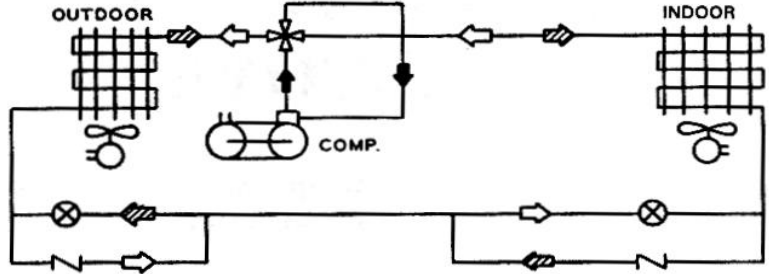
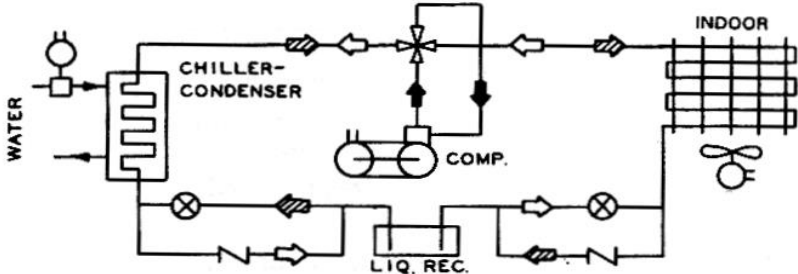
- Refrigerant flow can be changed with a 4 way-valve to switch between heating and cooling operation
- During cooling operation, the indoor heat exchanger acts as an evaporator and the outdoor heat exchanger acts as a condenser.
- During heating operation, the indoor heat exchanger acts as a condenser and the outdoor heat exchanger acts as an evaporator.



Classification of Heat Pump



Classification of Heat Pump

Heat Source & Sink	Distribution Fluid	Thermal Cycle	Schematics
Air	Air	Refrigerant changeover	
Water	Air	Refrigerant changeover	

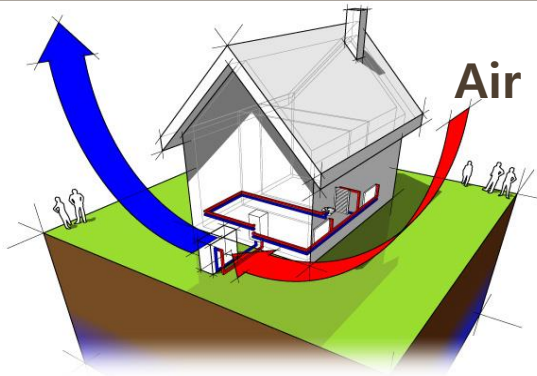
Classification of Heat Pump

Heat Source & Sink	Distribution Fluid	Thermal Cycle	Schematics
Water	Water	Water changeover	
Ground-coupled	Air	Refrigerant changeover	
Ground-source, Direct-expansion	Air	Refrigerant changeover	

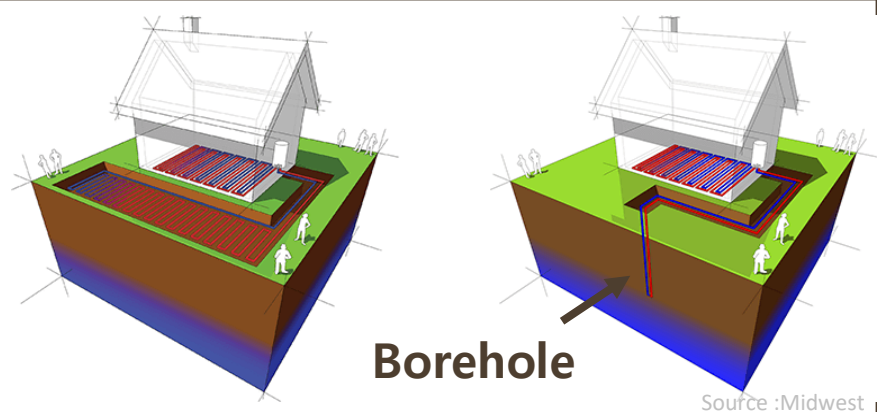
Utilization of Heat Pump

❑ Classification by Heat Pump Heat Source

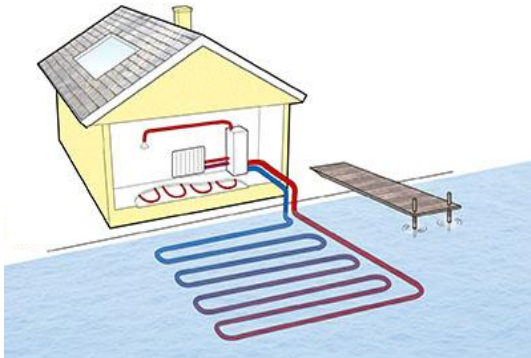
Air source heat pump (ASHP)



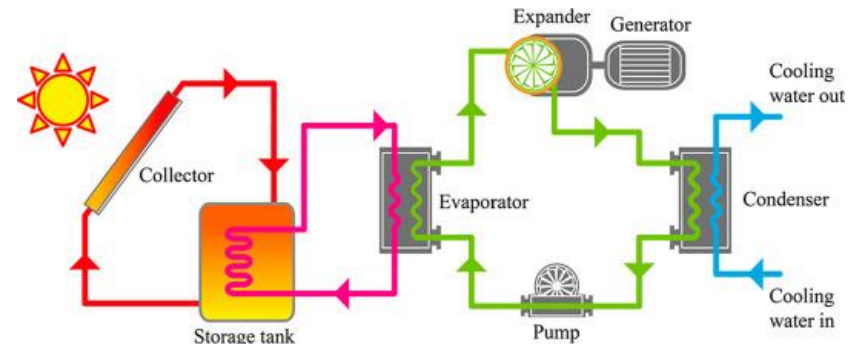
Geothermal heat pump (GSHP)



Water source heat pump (WSHP)



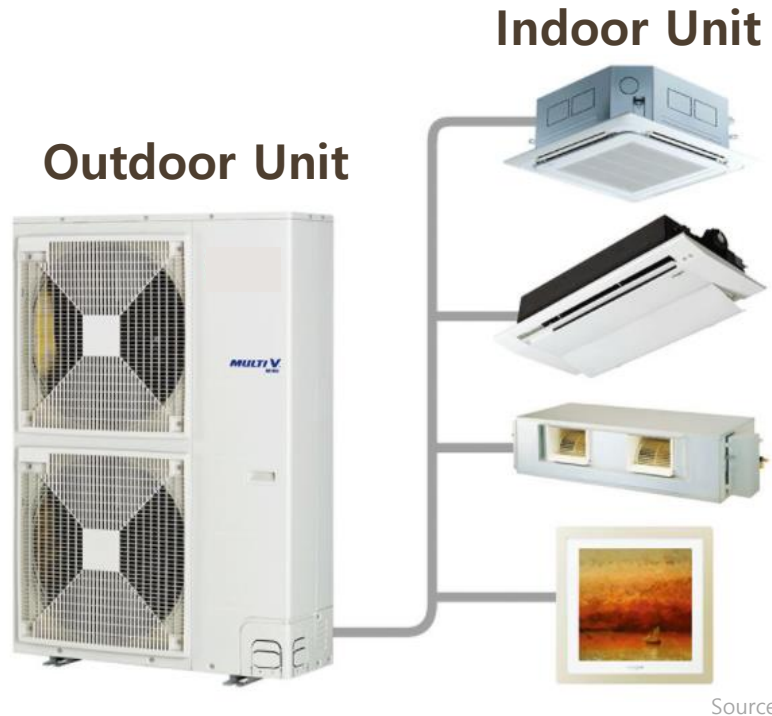
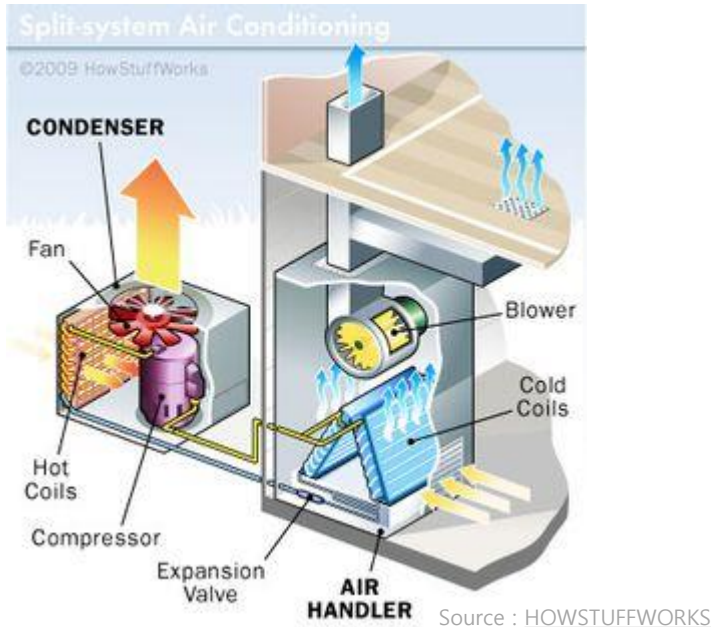
Solar assisted heat pump (SAHP)



Heat Pump

Utilization of Heat Pump

❑ Air Source Heat Pump (ASHP)



- The outdoor unit heats the room by absorbing heat from the indoor air in summer and releasing it to the outdoors through heat exchange with the outside air.
- Occupies most of the heat pump market due to freedom of choice of heat source
- High-efficiency technology for heating supply in low-temperature outdoor conditions, low-GWP refrigerant-applied heat pump development, etc. are required

Heat Pump Operating Characteristics

❑ Outdoor Temperature Drop

1. Less heat pump capacity than required heating load

(1) Use additional heating device

→ Reduction in the overall efficiency of heat pump

(2) Use a large heat pump or apply inverter control

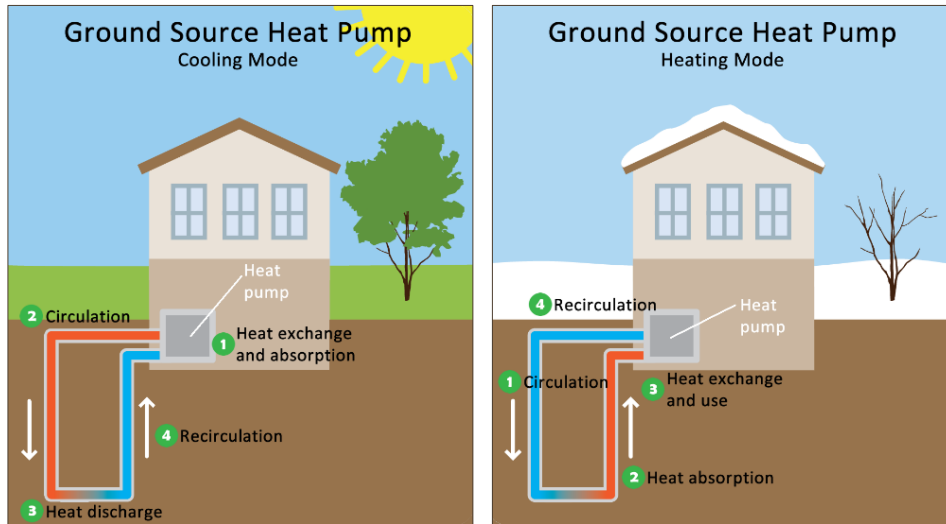
2. Frost formation on the surface of the outdoor coil

→ **Decrease in heating capacity, causing the liquid refrigerant to the compressor**

(1) Prevention of reduction in efficiency and heating capacity by increasing the temperature of evaporator using waste heat, river water, well water, etc.

Utilization of Heat Pump

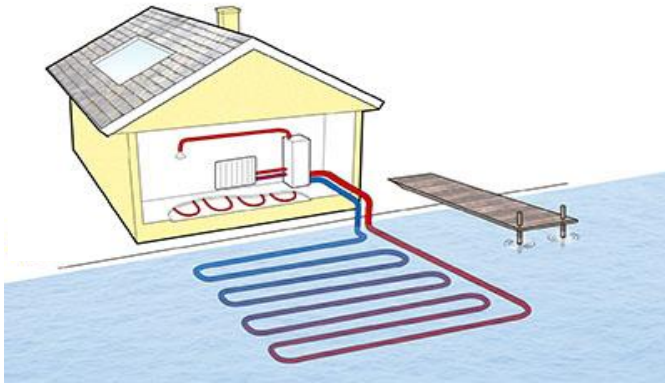
❑ Ground Source Heat Pump (GSHP)



- As the cave is cool in summer and warm in winter, the underground temperature does not vary greatly depending on the season.
- Cooling in summer and heating in winter using these characteristics
- Recognized as a new and renewable energy technology, the market growth rate is high (Geothermal REC 1.0~2.5, the older the installation year, the lower the REC)

Utilization of Heat Pump

❑ Water Source heat Pump (WSHP)



- Seawater and river water, which have better temperature conditions than geothermal sources, are used as heat sources to drive a heat pump to supply heating and cooling.
- In 2019, river water heat sources were recognized as renewable energy, and the government's mandatory ratio of new and renewable energy installations increased (30% in 2020 → 40% in 2030)
- The development of antifouling technology for seawater heat exchangers and the development of corrosion-resistant heat exchangers are required.

Heat Pump

Solar Heat Driven Heat Pump

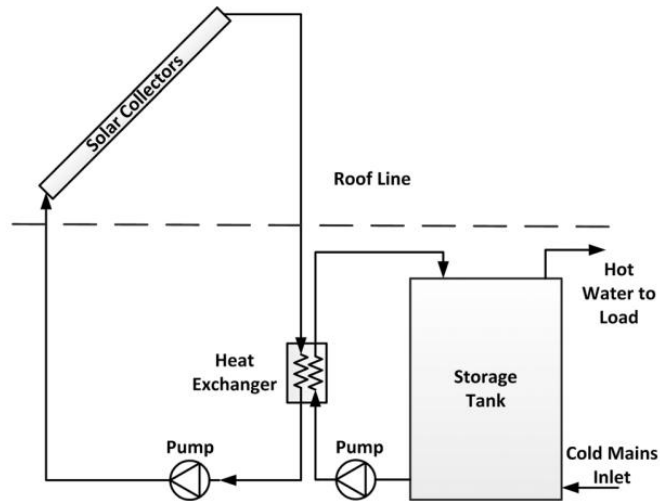


FIGURE Typical indirect solar DHW system (without heat pump)

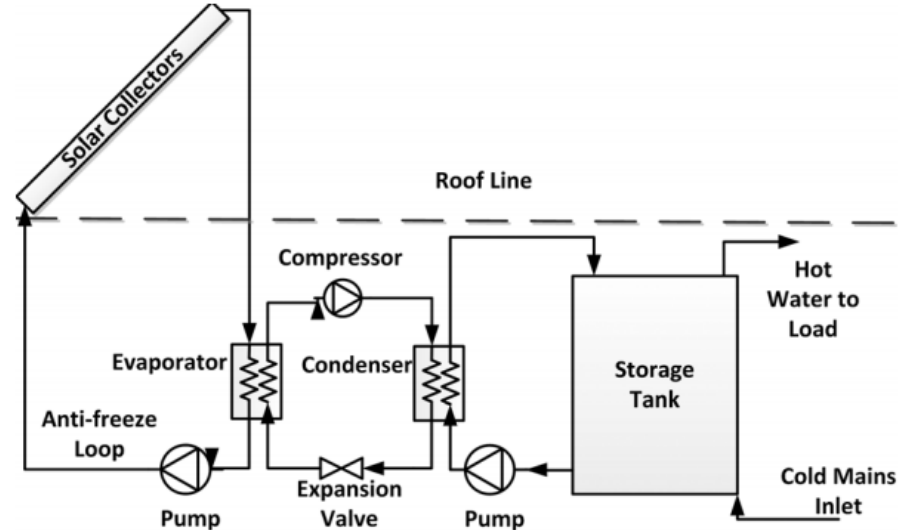


FIGURE Schematic of indirect series SAHP (Solar associated heat pump)

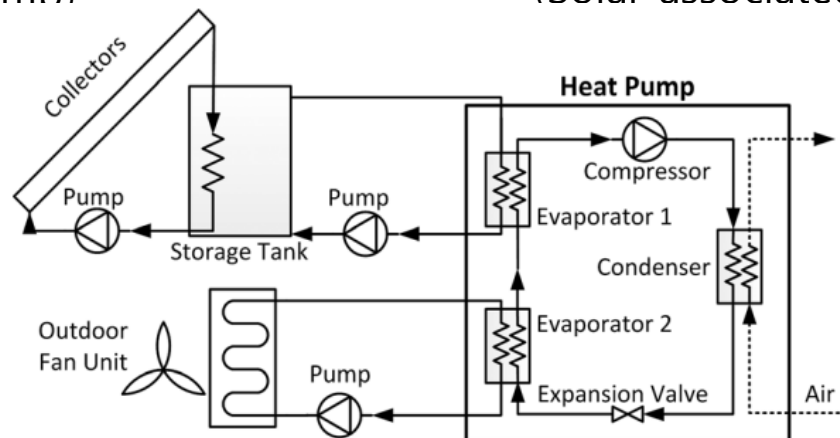


FIGURE Schematic of a dual source SAHP space-heating system

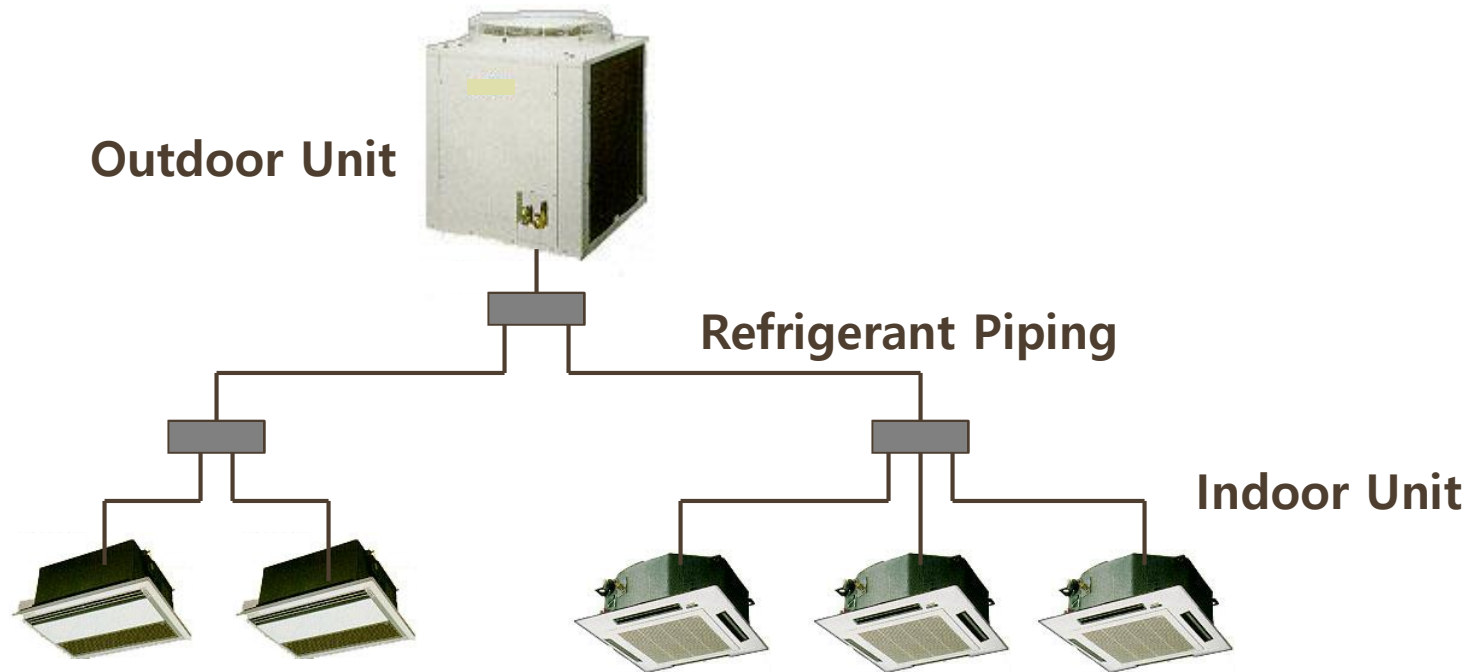
Multi-type heat pump system

- Growing demand for home air conditioning equipment
- Multi-type air conditioning system
 - 1 Outdoor Unit + Multiple Indoor Unit
- Multi-type heat pump system
 - Summer season : Air conditioner
 - Winter season : Heating equipment
- System complexity and capacity control issues



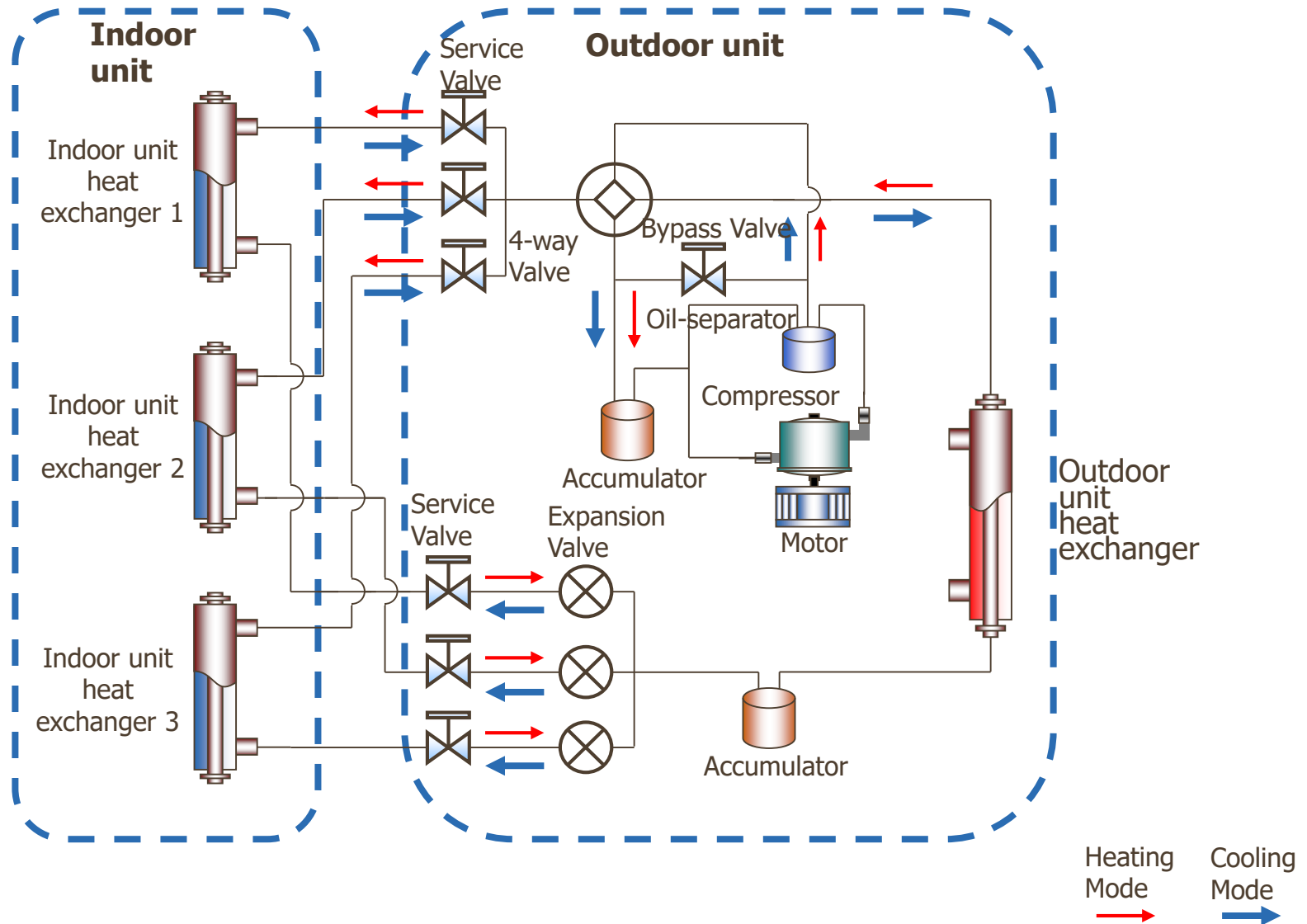
Cost and space savings

Multi-type air conditioner for buildings



Heat Pump

Schematics of Heat Pump System



Gas Engine Driven Heat Pump

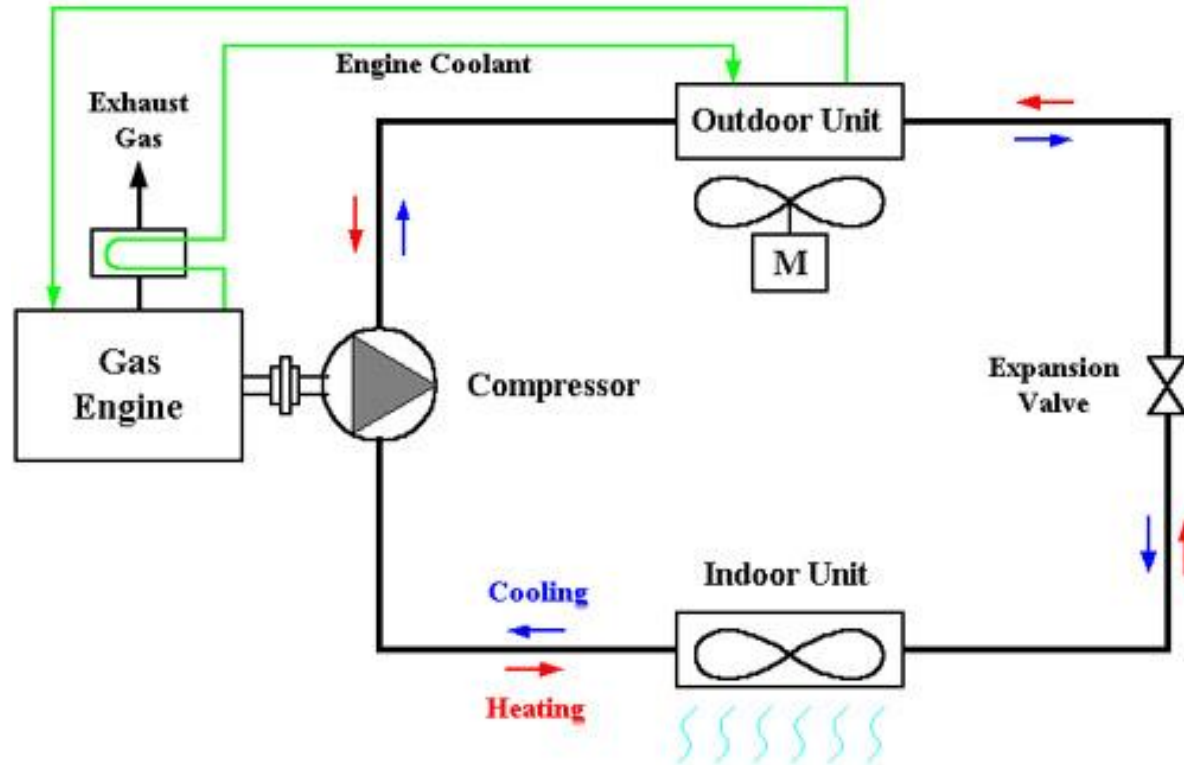


FIGURE Cooling and Heating Cycle of Air-preheating GHP system

Gas Engine Driven Heat Pump

□ Background of Development

- Promote the use of alternative energy
- Efficient use of energy
- Suppress the power consumption in summer
- Averaging annual load of gas and electricity

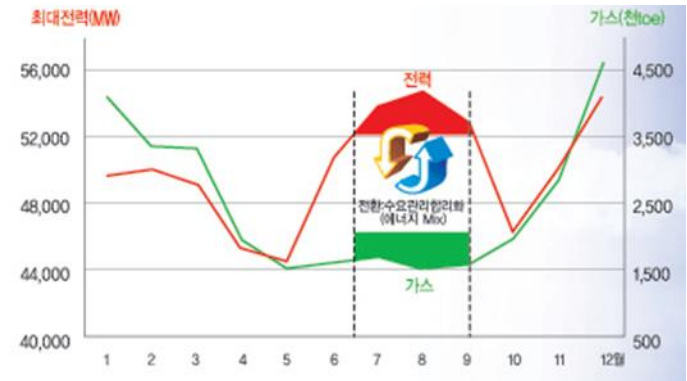


FIGURE Patterns of consumption of gases & electricity

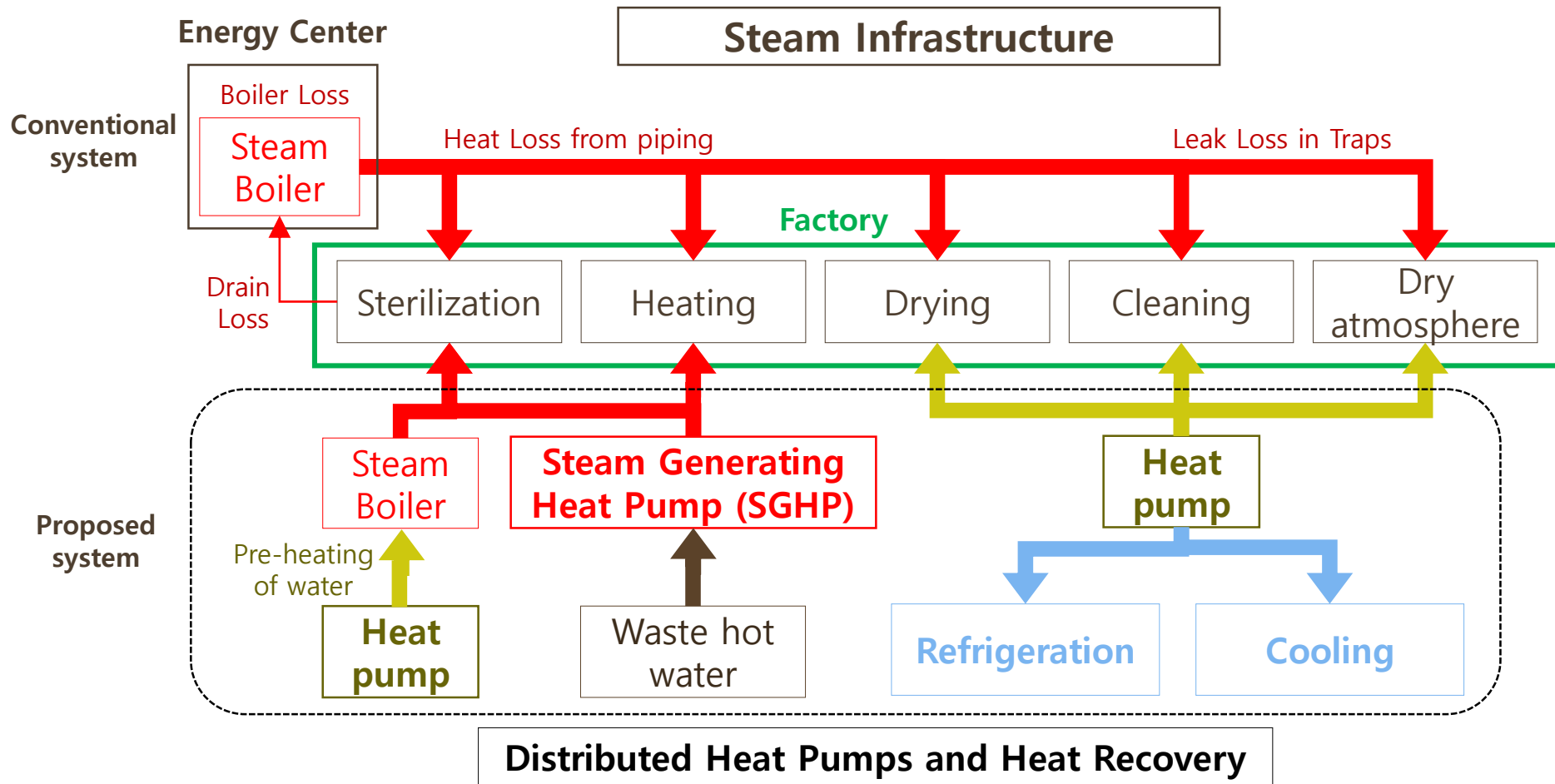
□ Gas Engine Driven Heat Pump

- Drive compressor using a gas engine
- Increase system efficiency by waste heat recovery
- Supplement the heating capacity decreases using waste heat depending on outdoor temperature decrease
- Defrost operation is not required, and start-up characteristic is fast in heating mode
- Fuel diversification, low NOx Tue, small size, low noise, etc., is required.

Heat Pump

Steam Generating Heat Pump (SGHP)

❑ Necessity of Steam Heat Pump

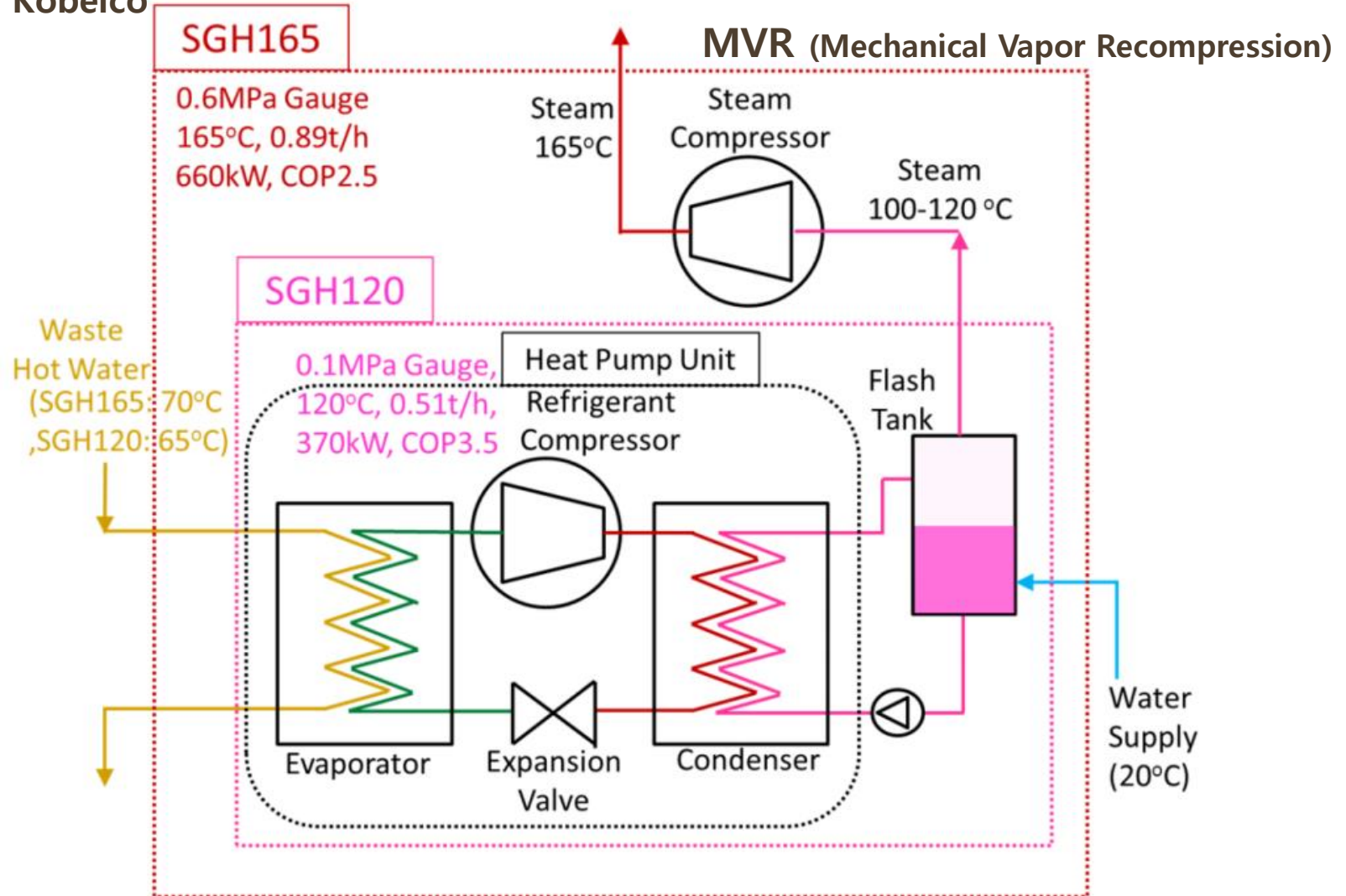


[1] Australian Alliance for Energy Productivity (A2EP), HIGH TEMPERATURE HEAT PUMPS for the Australian food industry: Opportunities assessment, August 2017

Heat Pump

Examples of Steam Generating Heat Pump

JaPan, Kobelco

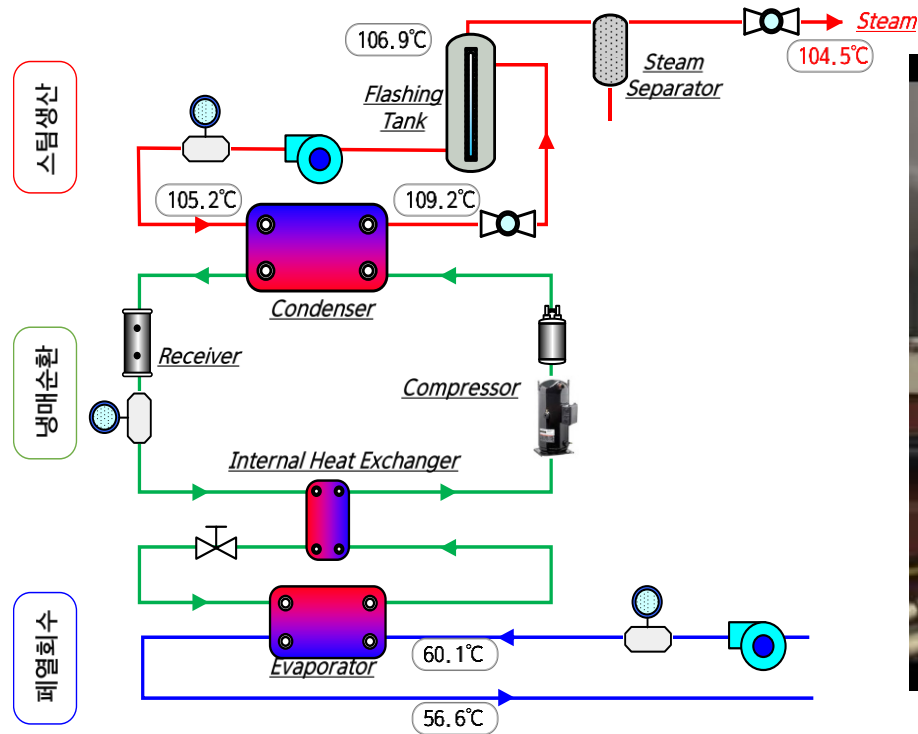


Source: IEA HPP Annex 35 2013, Application of Industrial Heat Pumps, Task 3

Heat Pump

Examples of Steam Generating Heat Pump

❑ Industrial low pressure steam production steam heat pump



- **Organized by :** Korea Energy Research Institute
- **Participating Institutions :** Joint research with Seoul National University and 8 other institutions

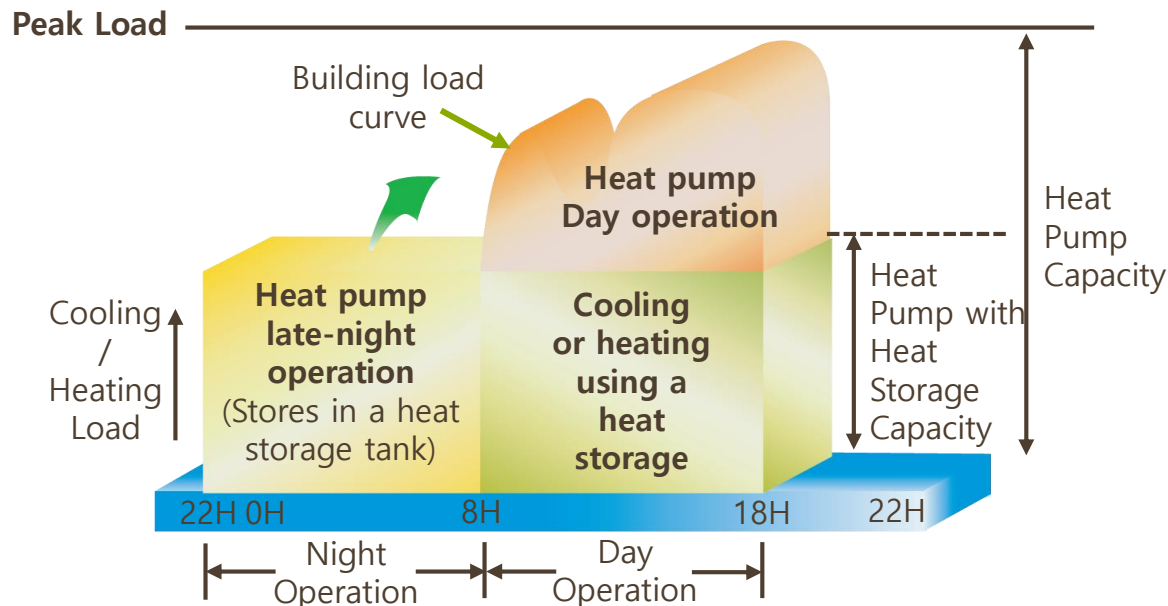


Source : Korea Energy Research Institute

Heat Pump

Heat Pump Using Heat Storage

- A system that operate a heat pump with late-night power to generate and store hot or cold water to use them during the day
- Cold/hot water can be stored for heating and cooling
- Eco-friendly because it does not use a separate low-temperature solution (brine)
- By adding a heat storage tank to an existing refrigerator, the cooling capacity increases
- The cooling efficiency of a heat storage tank is better than ice heat storage



Heat Pump

Heat Pump Using Heat Storage

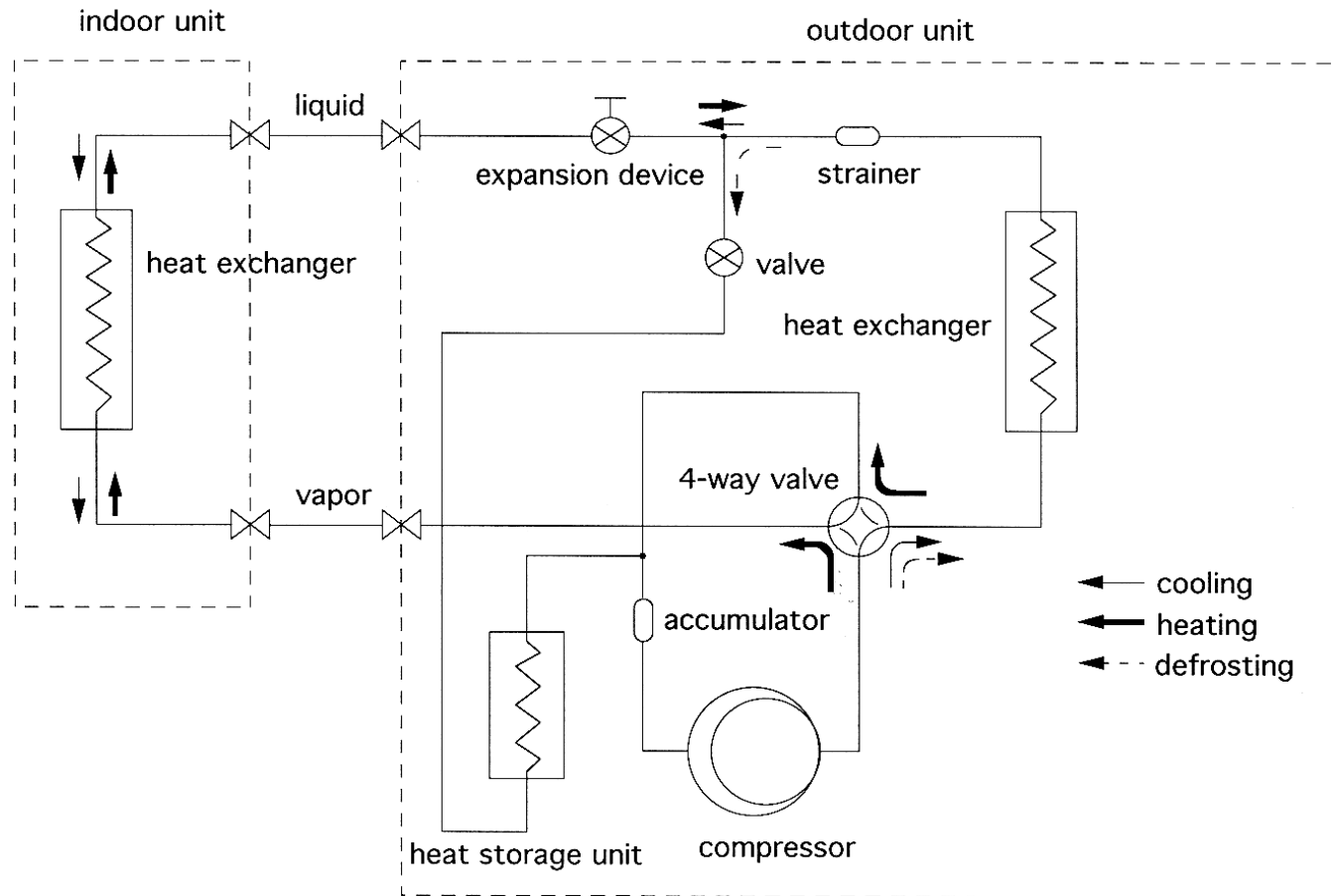


FIGURE Heating and cooling heat pump using heat storage

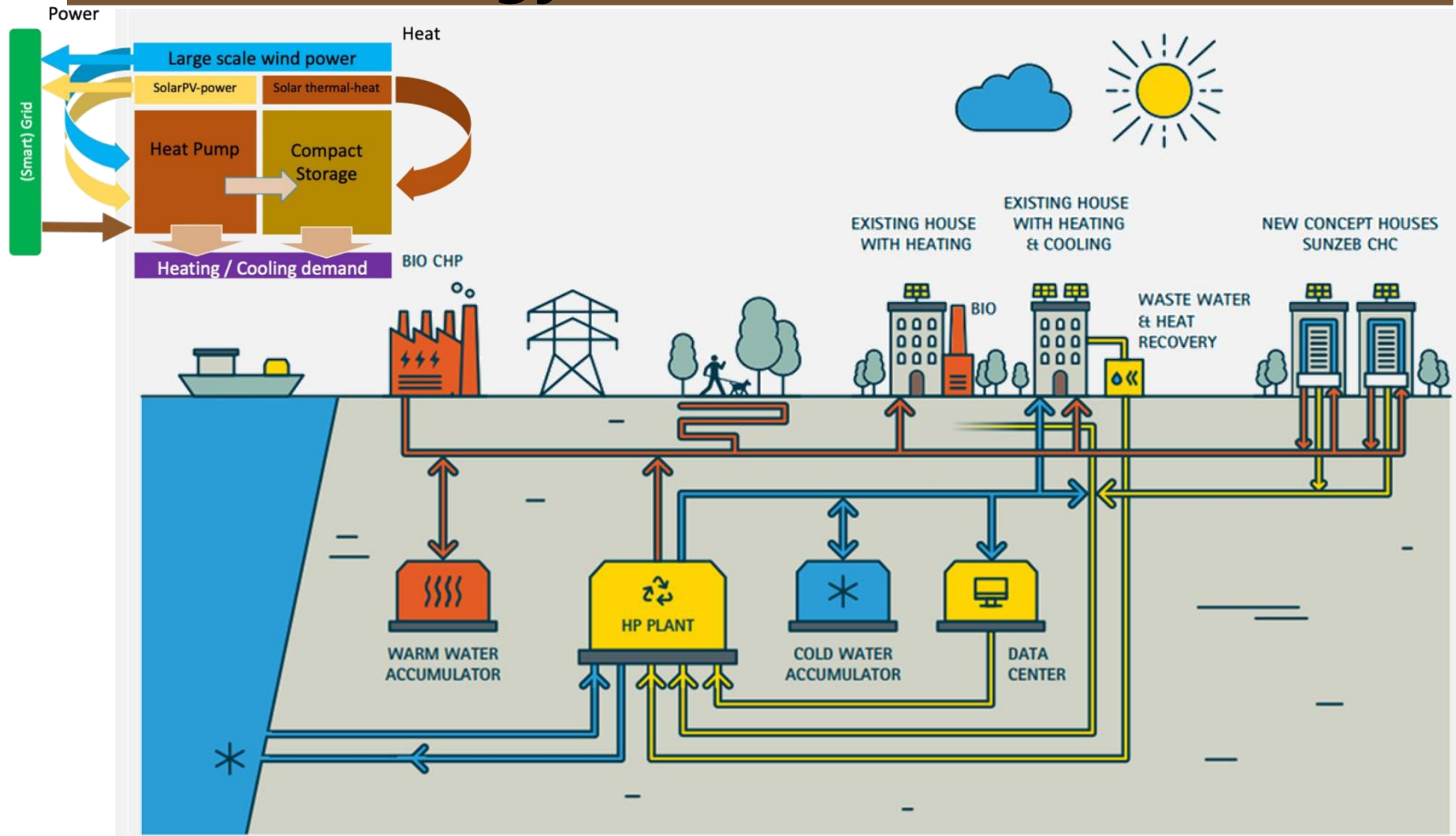
Heat Pump Thermal Energy Network



Source : Korea Energy Research Institute

Heat Pump

Thermal Energy Network



Source: HELEN

FIGURE schematics of District Heating and Cooling

Q&A

Question and Answer Session

