CRIEPI
Central Research Institute of Electric Power Industry

Industrial Heat Pump Applications in Japan

Chillventa CONGRESS 2018
Nuremberg, Germany
October 15, 2018

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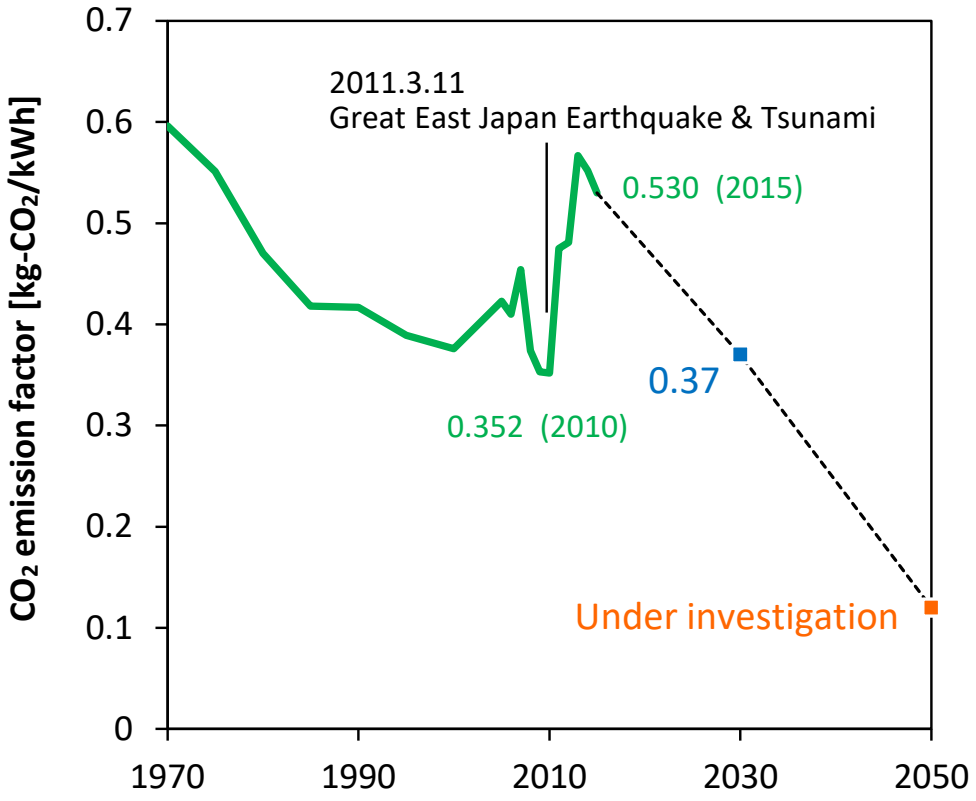
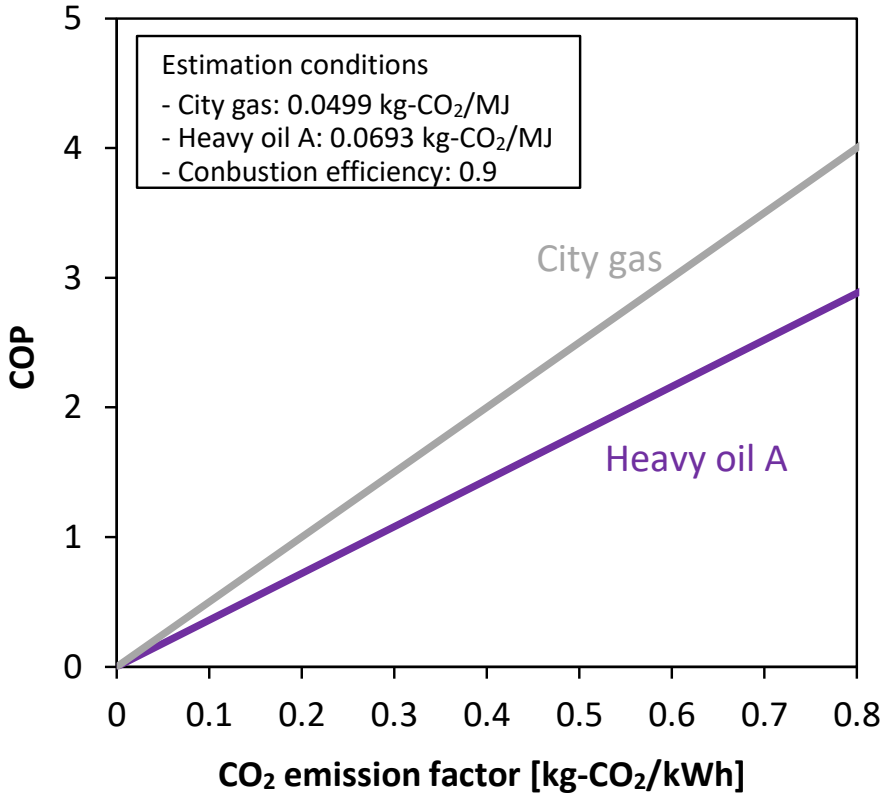
CO_2 Emissions Reduction by Electrification

- Key points for significant reduction of CO_2 emissions
  - Low carbonization of electricity
  - Higher efficiency electricity usage

Transition and target of CO_2 emission factor for electricity in Japan

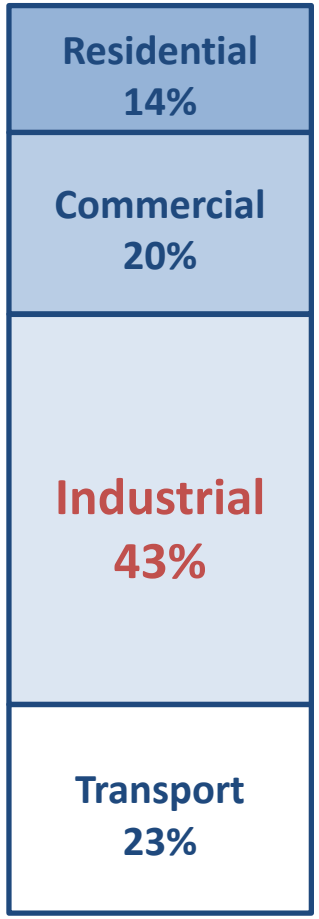


Heat Pump (EHP) vs. Boiler regarding CO_2 emissions under the condition that the heat load is equal

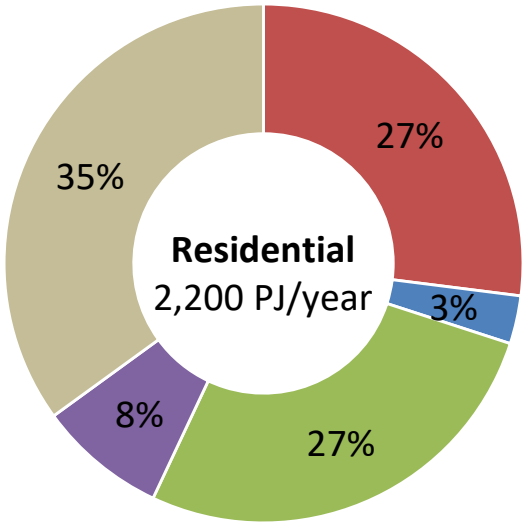


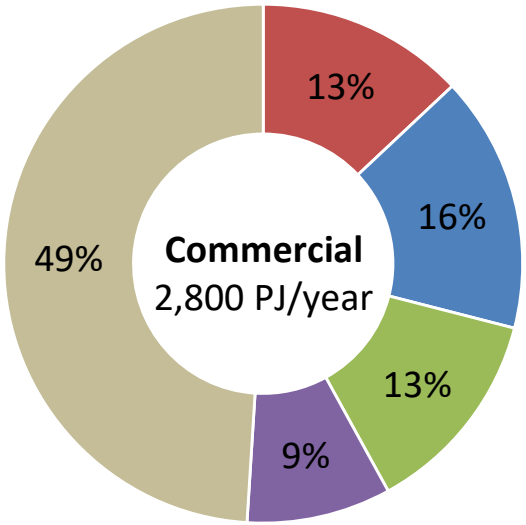
Final Energy Consumption in Japan

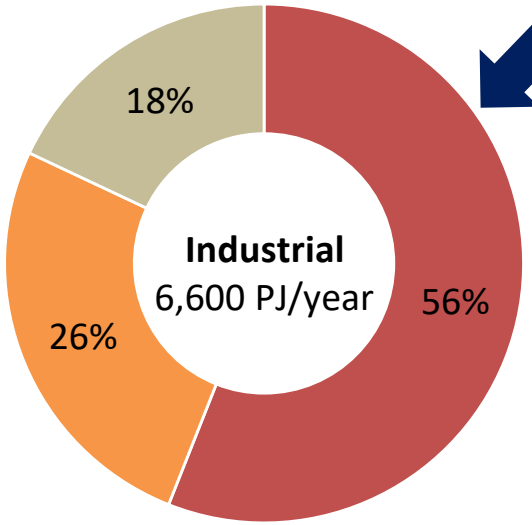
- Approximately 40% of the final energy consumption is “heat.”
- Industrial sector has the largest amount of energy consumption.



Total Final Energy Consumption in Japan: 13,548 PJ (FY2015)







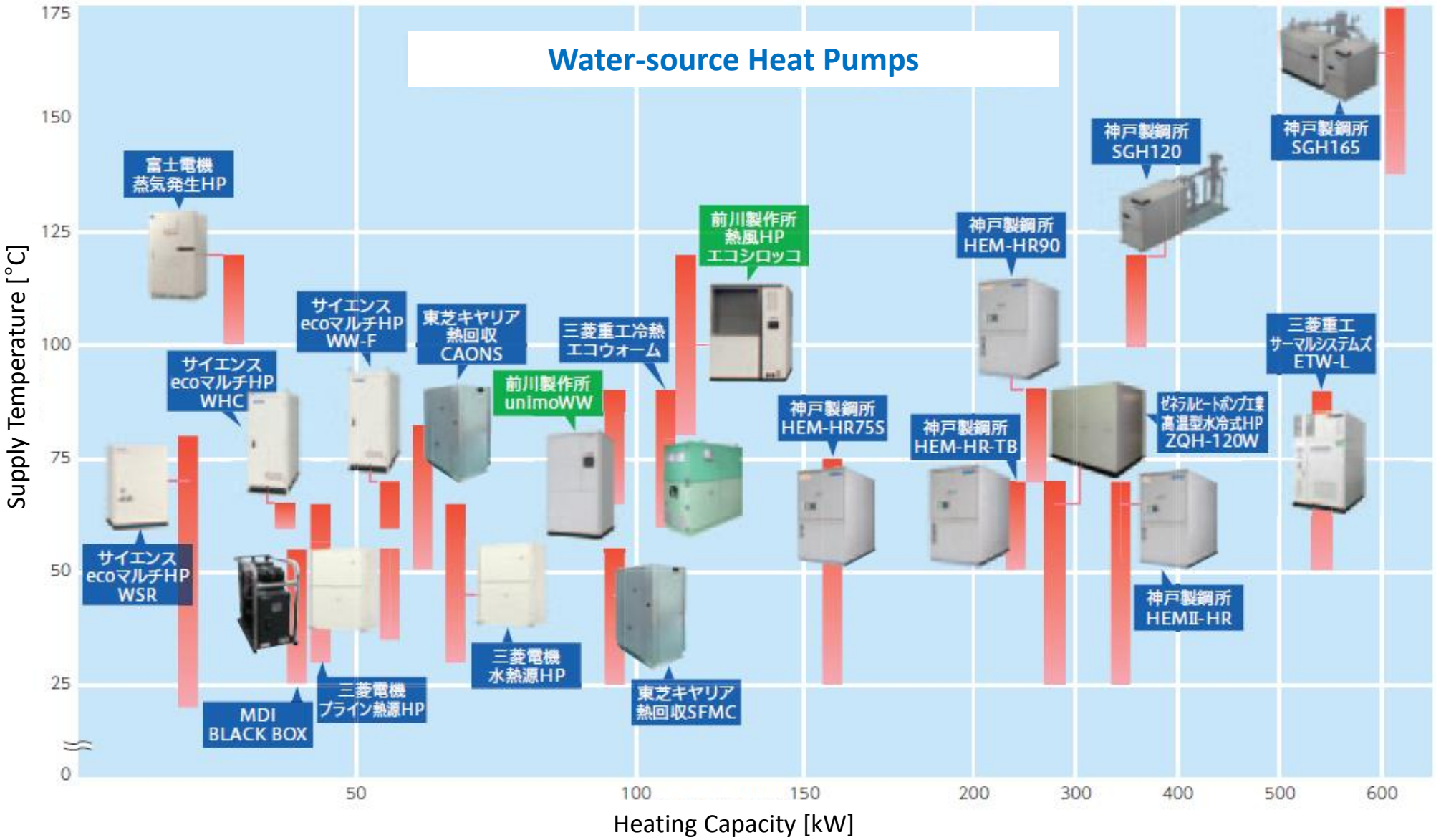
Industrial Heating

- Space Heating
- Space Cooling
- Hot Water Heater
- Kitchen
- Lighting & Power

- Space Heating
- Space Cooling
- Hot Water Heater
- Kitchen
- Lighting & Power

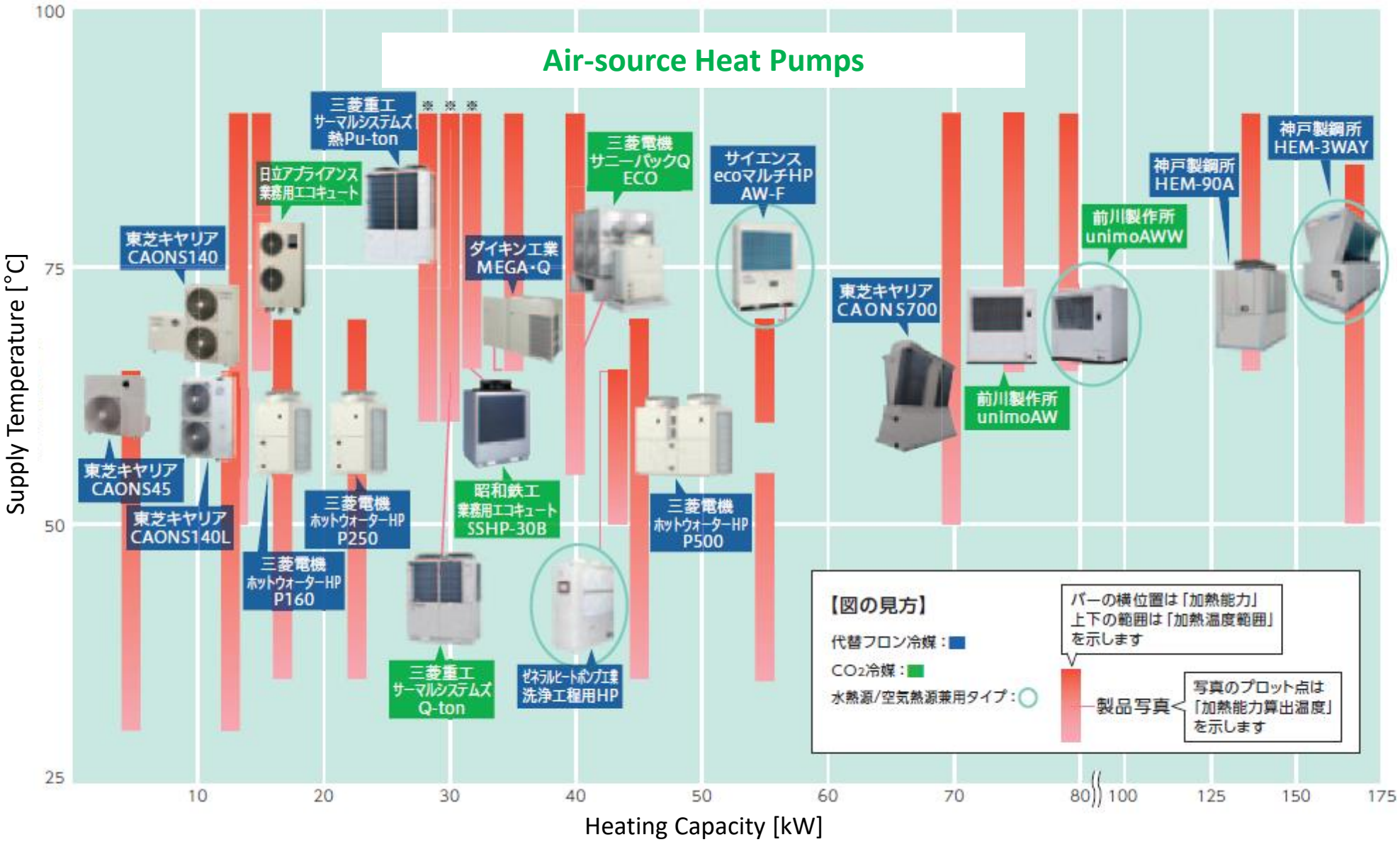
- Heating
- Material
- Lighting & Power

Commercialized IHPs in Japan



Source: JEHC (Japan Electro-Heat Center), “Guideline for using industrial heat pump,” 2017 [in Japanese]

Commercialized IHPs in Japan

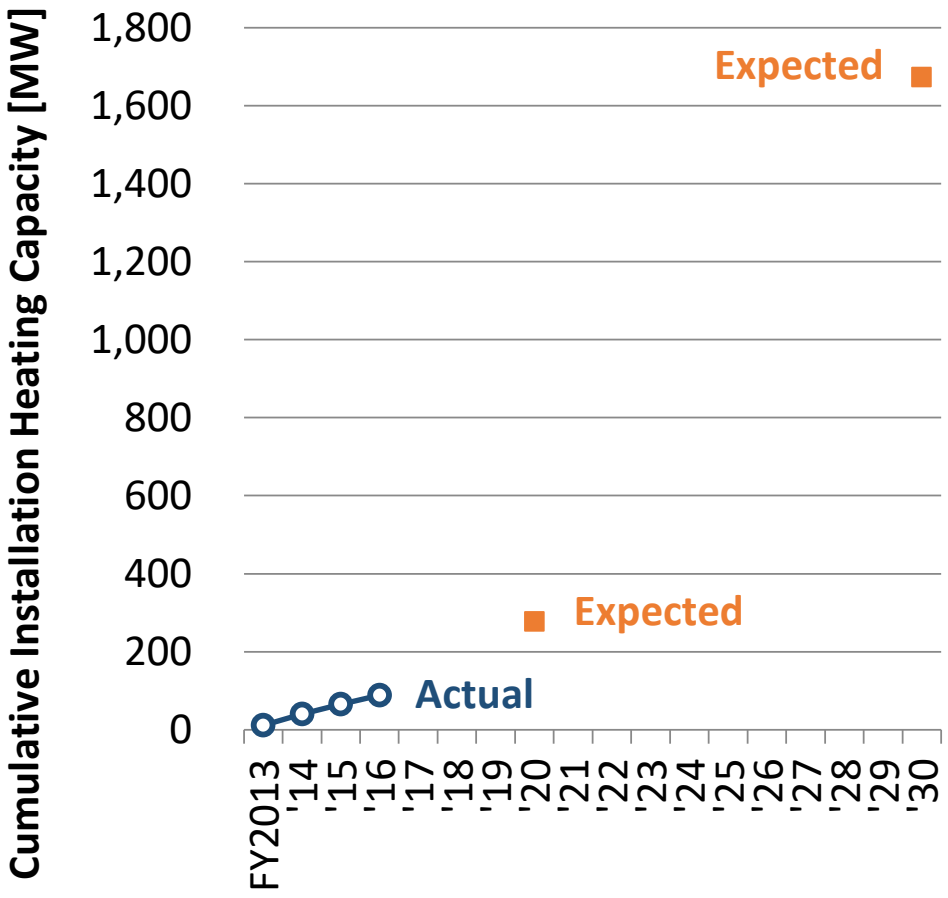


Source: JEHC (Japan Electro-Heat Center), “Guideline for using industrial heat pump,” 2017 [in Japanese]

Installation Target of IHPs by the Government

- "The Plan for Global Warming Countermeasures"
  - Decided by the Cabinet on May 13, 2016
  - **26%** reduction of GHG emissions by FY2030 compared to FY2013 (= **367 million ton-CO_2** reduction)

- The role of industrial heat pumps (IHPs)
  - Over 150 times spread (11 MW in FY2013 to 1,673 MW in FY2030)
  - **1.35 million ton-CO_2** reduction (= about 0.4% of total GHG emissions reduction)



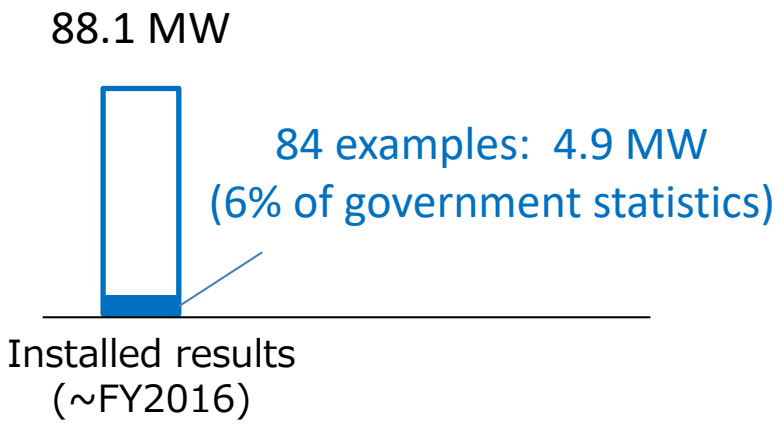
Source: METI (Ministry of Economy, Trade and Industry) & MOE (Ministry of the Environment) Joint Meeting, Feb. 28, 2018 [in Japanese]

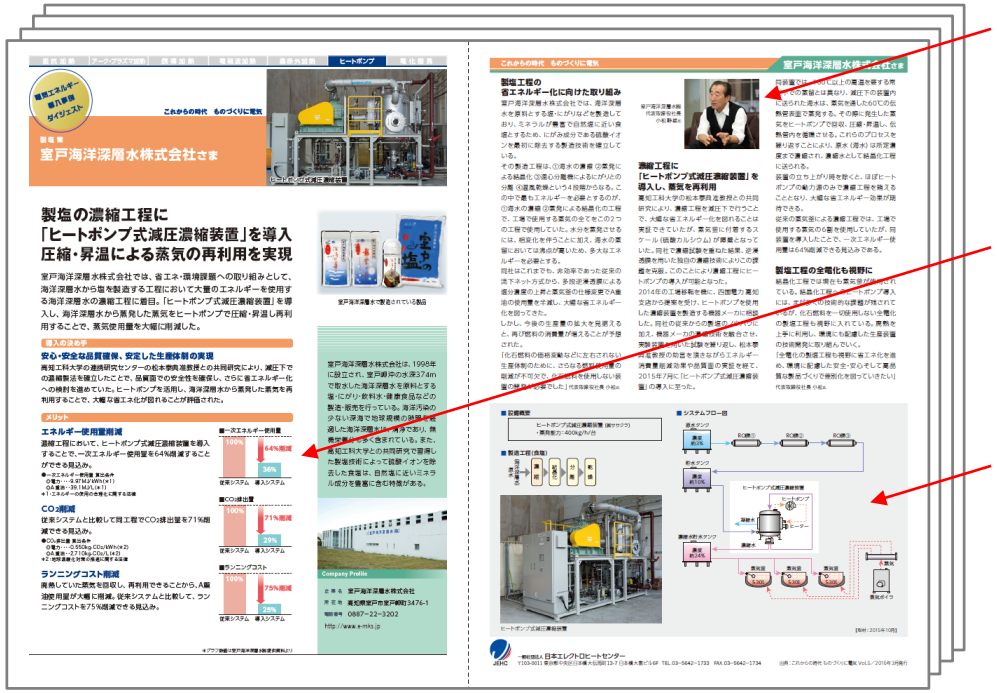
Installation Situation

Collection of Installation Cases

- Collection from published information
  - Japan Electro-Heat Center (JEHC)
  - Heat Pump & Thermal Storage Technology Center of Japan (HPTCJ)
  - The Energy Conservation Center, Japan (ECCJ)
  - Japan Society of Refrigerating Air Conditioning Engineers (JSRAE)

- Collected examples
  - 84 examples





Voice of customer

Effects of energy, CO_2 and cost reductions

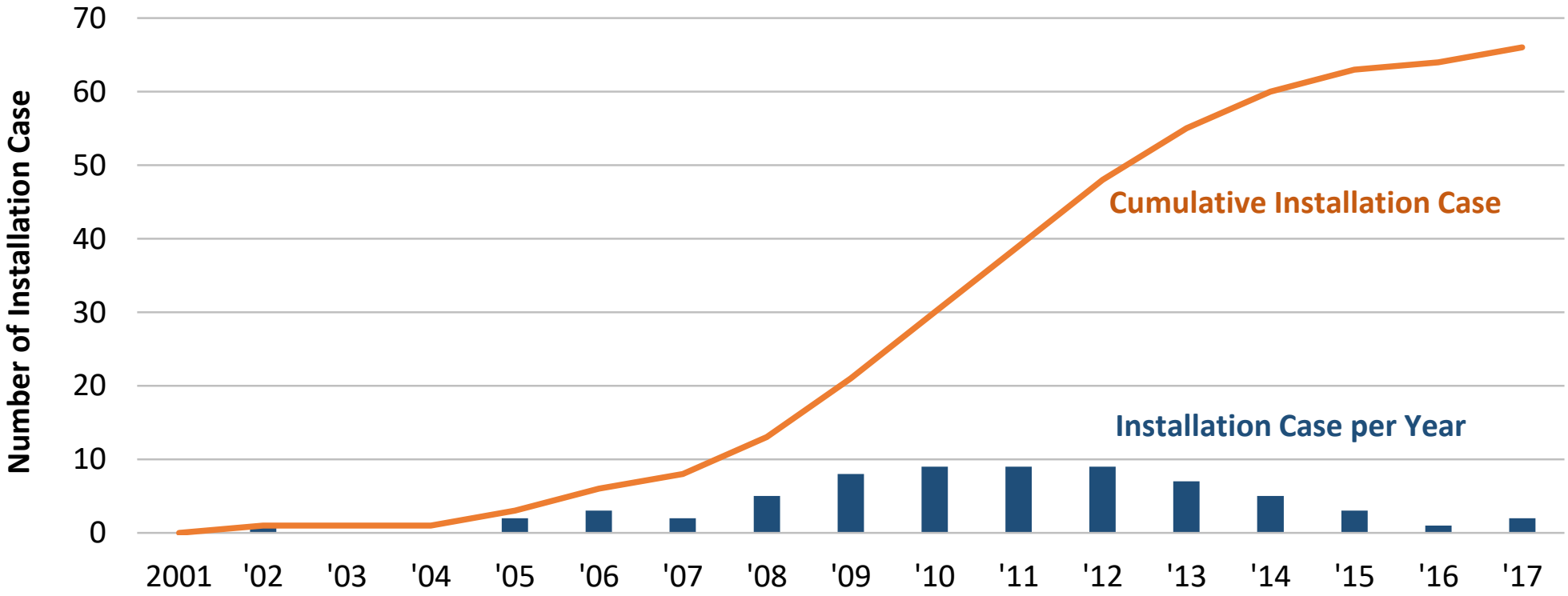
System flow

Installation cases of industrial heat pumps, published by Japan Electro-Heat Center (JEHC)

Installation Situation | Installation Year

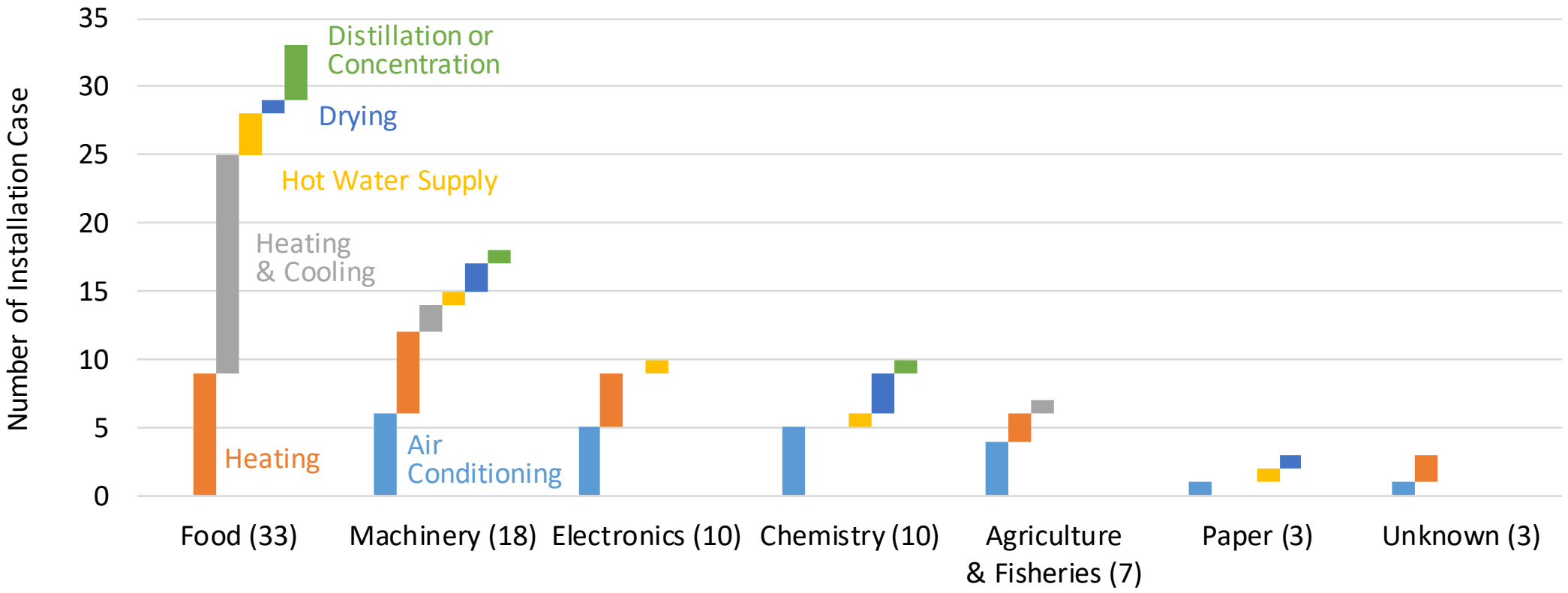
- After the mid-2000's
  - 2005- Steam-less air-conditioning system (by HP chiller & Evaporative Humidifier) [up to 50°C]
  - 2008- High temperature hot water supply HP [up to 90°C]
  - 2009- Hot air supply HP [up to 120°C]
  - 2012- Steam supply HP [up to 165°C]

* 66 example cases which installation years have been published among the total number 84 of installation cases collected



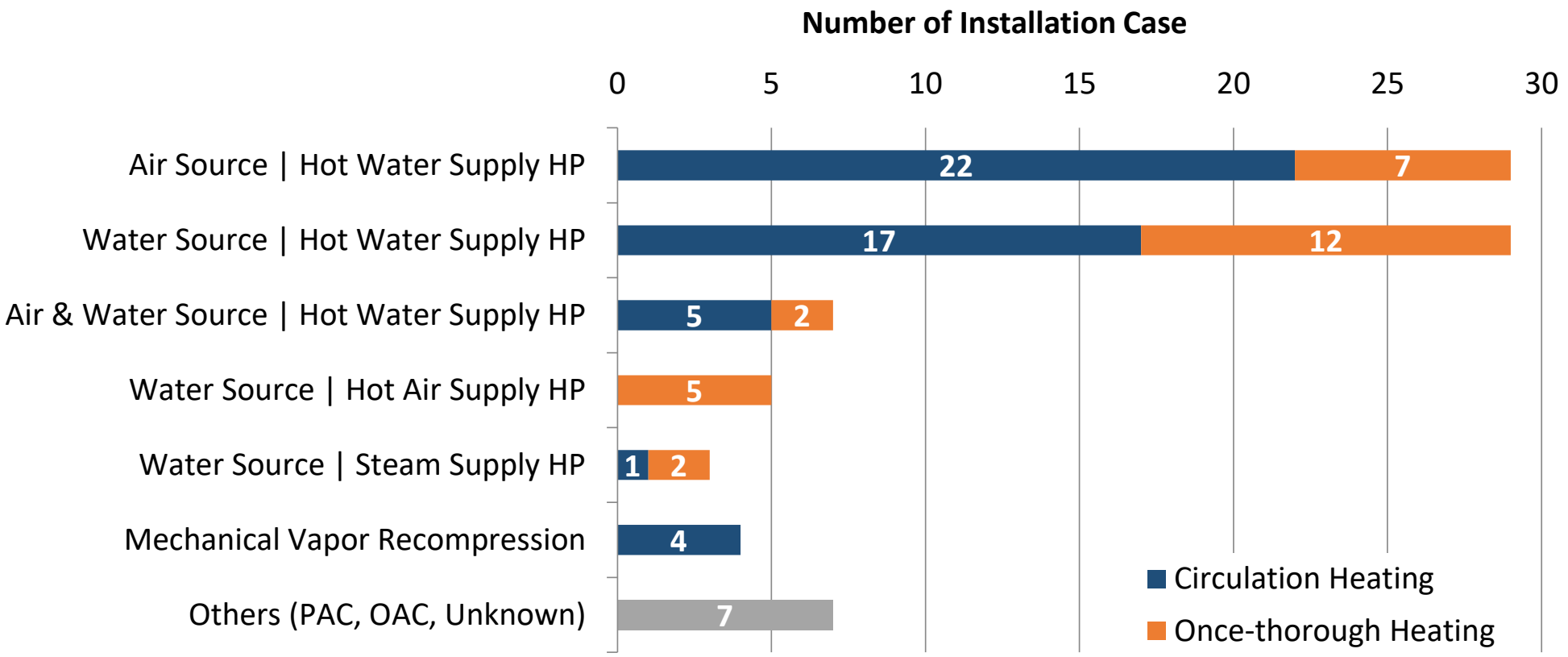
Installation Situation | Industry and Process

- Food industry: the most, various process, simultaneous heating & cooling
- Machinery, Electronics and Chemistry: steam-less AC for clean room
- Agriculture: AC for greenhouse
- Paper industry: large potential but small application



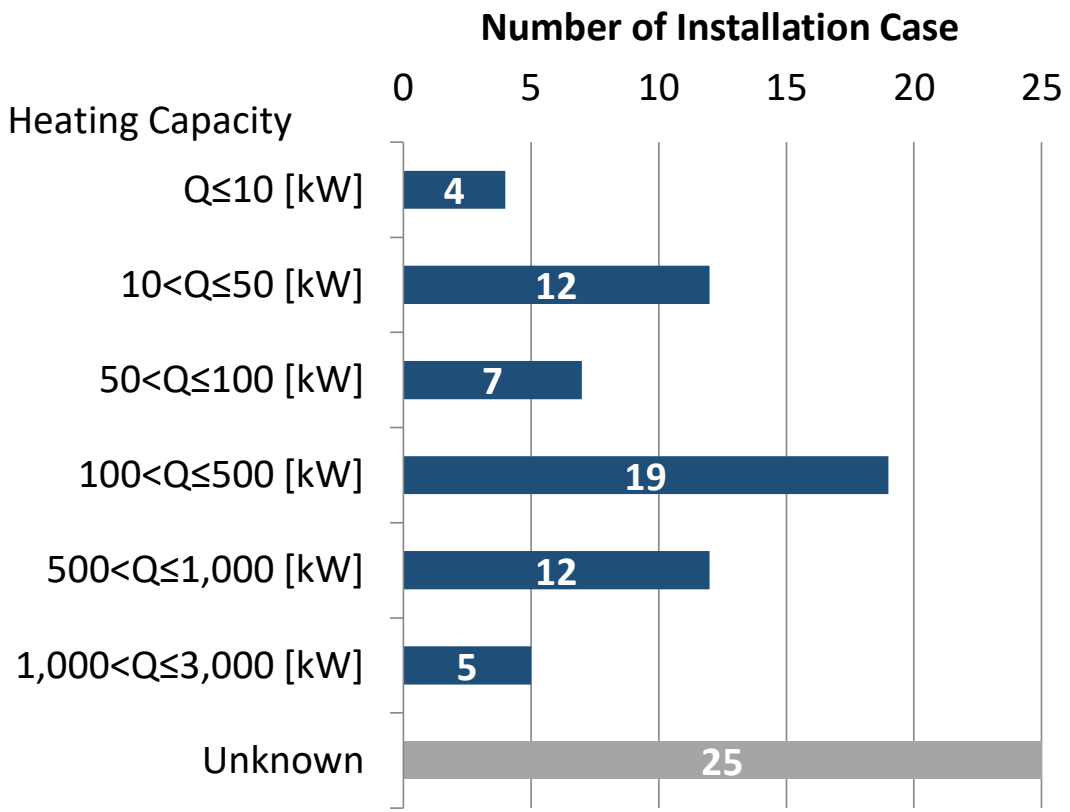
Installation Situation | Type of Heat Pump

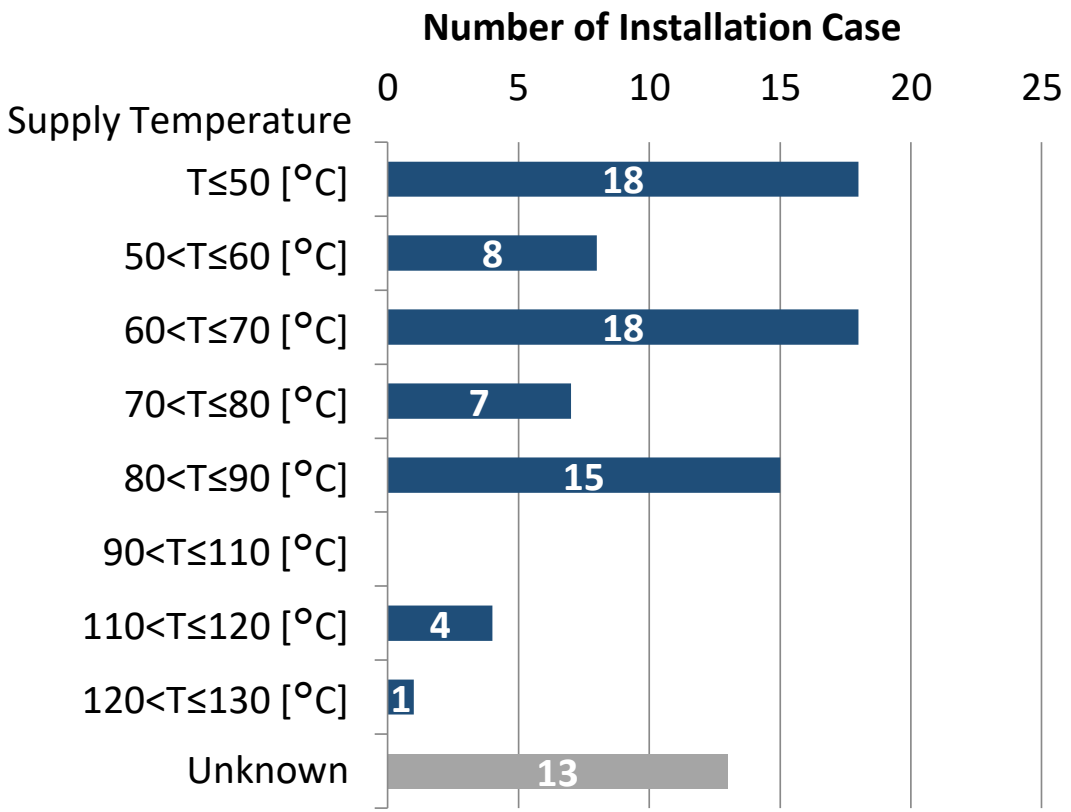
- Hot water supply type is used most often.
- Circulation heating > Once-through heating



Installation Situation | Heating Capacity & Supply Temperature

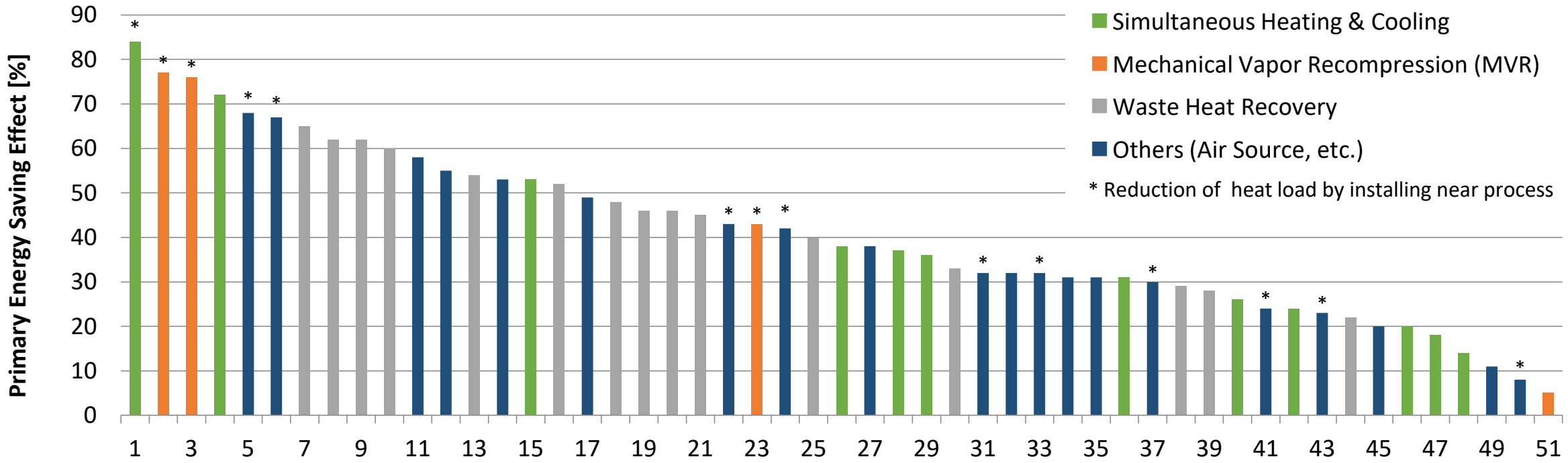
- The required heating capacity and temperature depend on the process.
- Many installations in the hundreds of kW class (700kW ≃ 1 ton/h steam boiler)
- Many installations of 65°C or 90°C hot water supply





Installation Situation | Energy-saving Effects

- Reduction of heat load by installation near process
- Reduction of cooling load by simultaneous heating & cooling
- Self heat recovery and high COP operation by MVR (Mechanical Vapor Recompression)



* 51 example cases which primary energy consumption reduction effects have been published among the total number 84 of installation cases collected

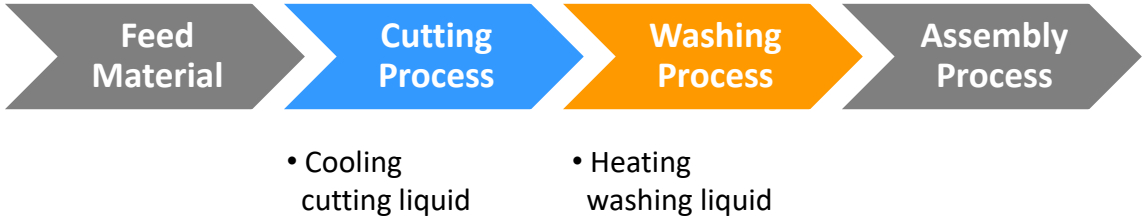
Case Study 1
-Simultaneous Heating & Cooling-

Case 1 | Washing Process in Automobile Parts Production

Outline of Installation

Industry	Machinery
Production	Automobile parts (Differential case)
User company	AISIN AW Co., Ltd.
Installed year	2010
Process	Cutting (Cooling), Washing (Heating)
Application	Hot Water (65°C) & Cold Water (15°C)
HP manufacturer	Zeneral Heat Pump Industry Co., Ltd.
HP System	AWW Heat Pumps Refrigerant: R134a Heating capacity: 476 kW (22 kW/unit × 6 units) (43 kW/unit × 8 units)
Effects	CO_2 reduction: 80% Primary energy reduction: 84% Energy cost reduction: 79% Payback period: 3.5 years

Process and Application

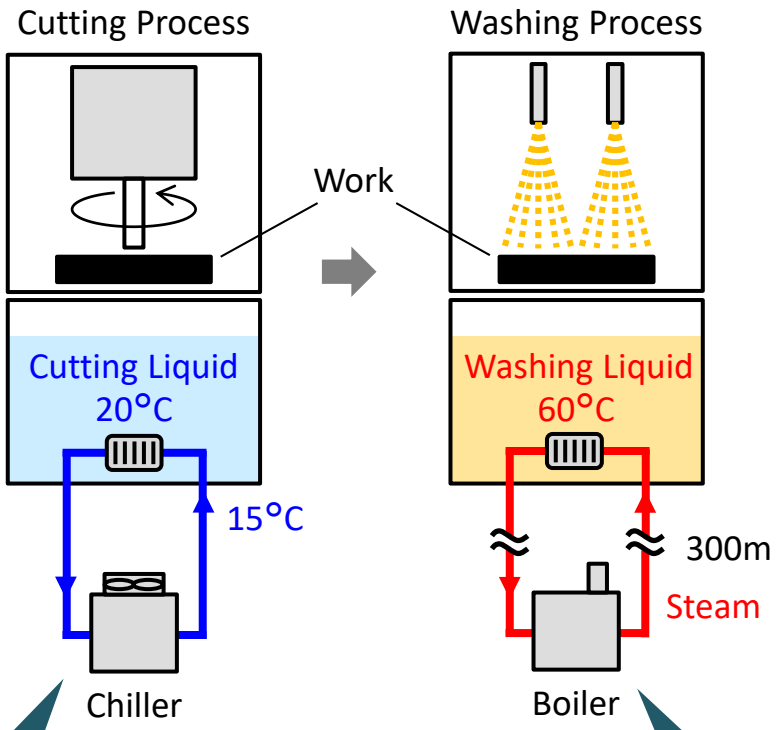


AWW Heat Pump
(Air to Water & Water to Water)

Product (Differential Case)

Case 1 | Washing Process in Automobile Parts Production

Before

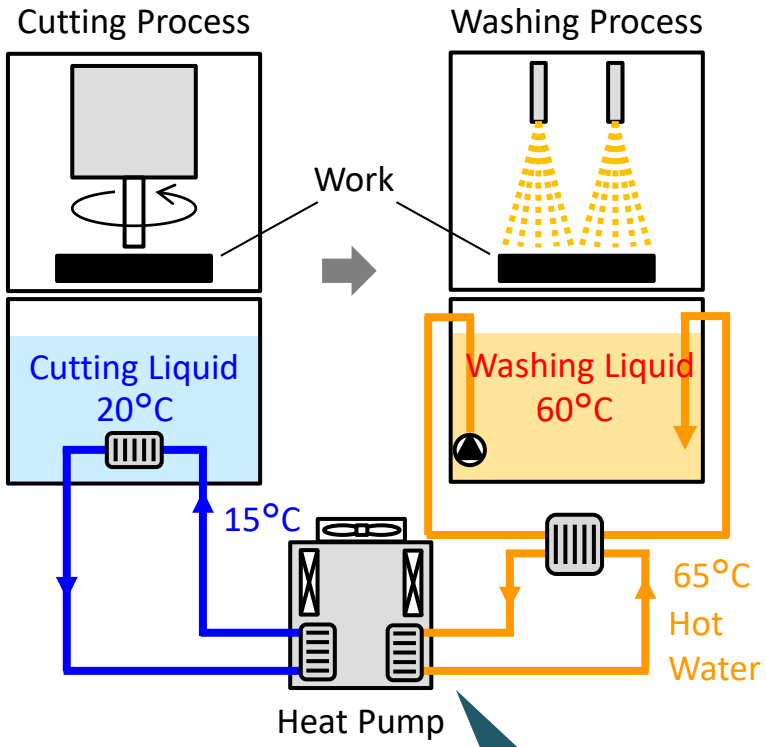


Issue 2 | Individual equipment installed in heating and cooling process
Chiller was used for cooling process. This caused hot waste heat dissipation to ambient air. Cooling COP of the chiller was 2.

Issue 1 | Low effective use of steam
Steam was supplied from boiler to 300 m away washing machines. This caused large heat loss from piping. Total thermal efficiency of steam supply system was 0.2.

Application of Heat Pump

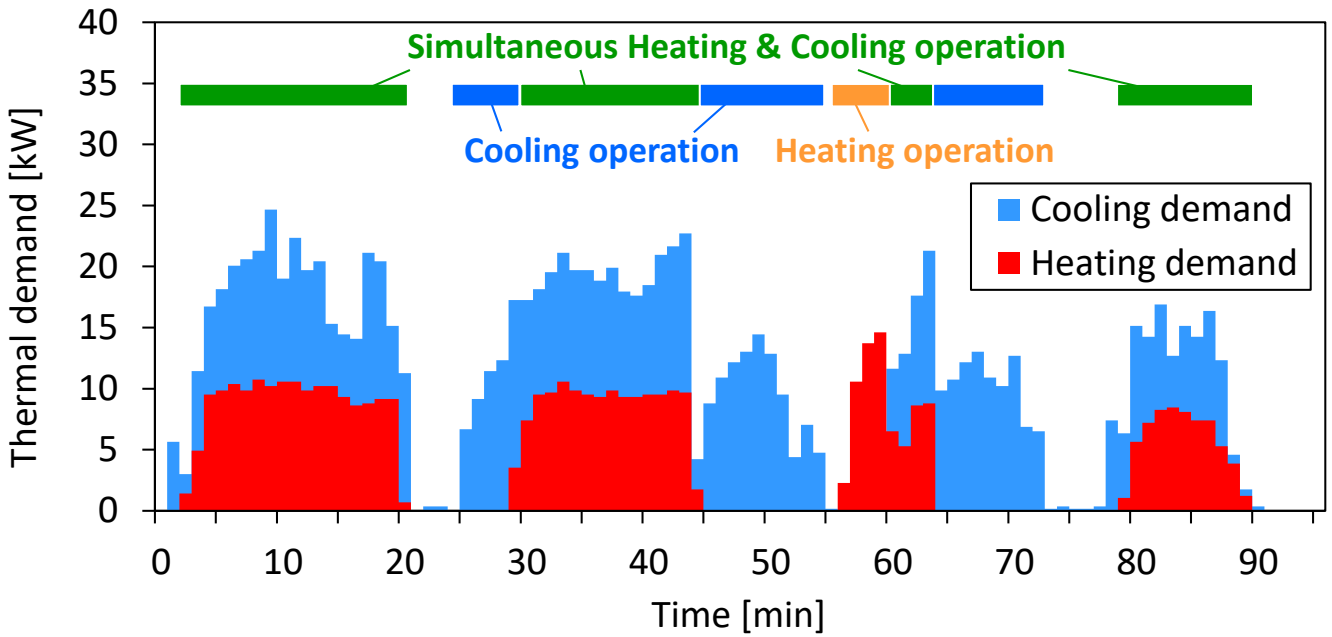
After

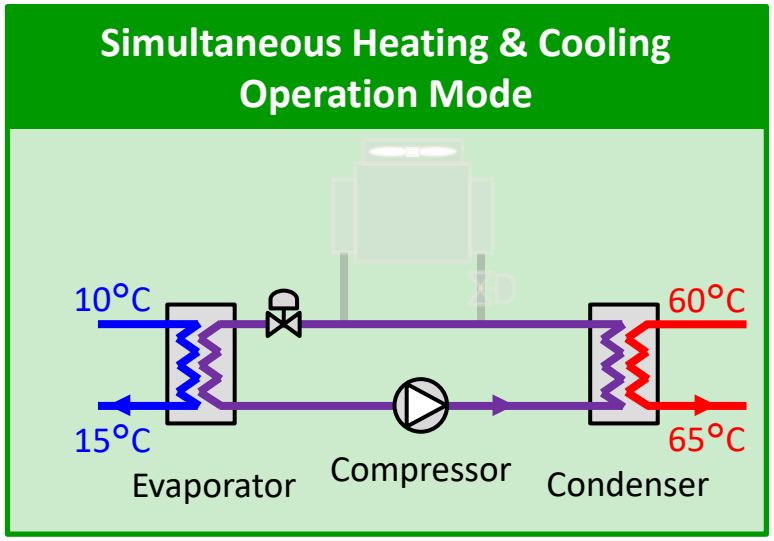


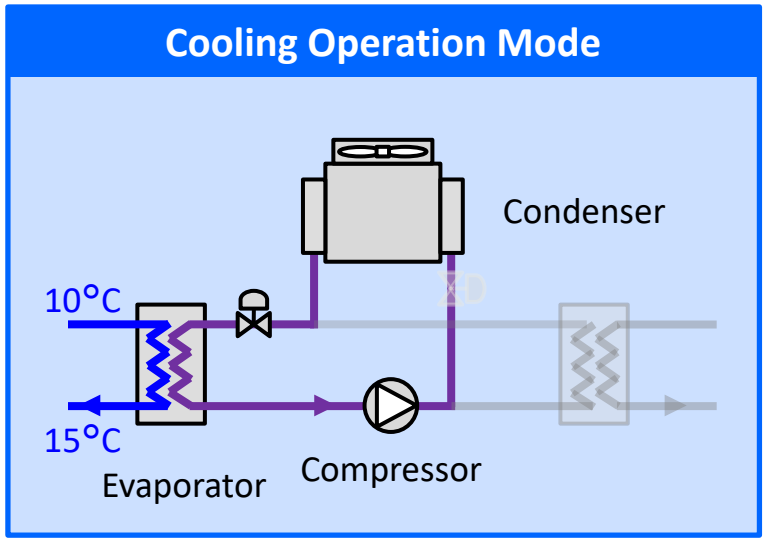
Resolution | Installation of simultaneous heating & cooling heat pump near process
By installing heat pump near process, heat loss was reduced and supply temperature was decreased. And by simultaneous heating and cooling use, this heat pump could achieve total COP of 5.

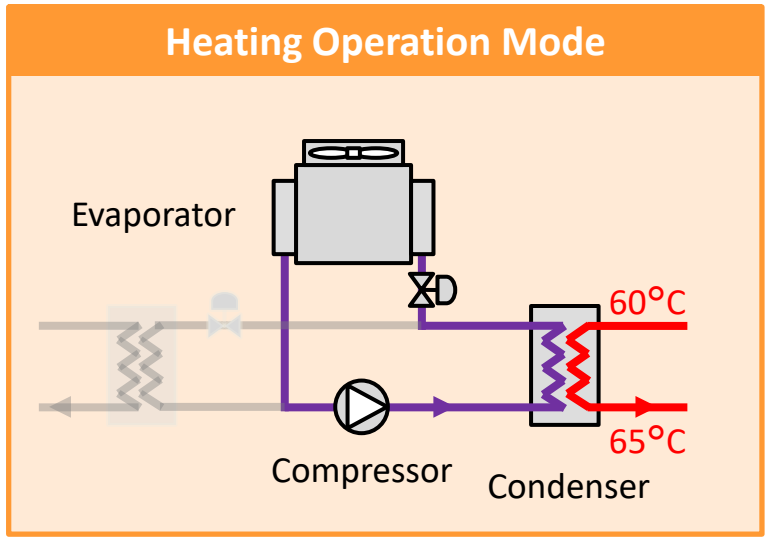
Case 1 | Washing Process in Automobile Parts Production

- Operation
  - 3 operation modes
  - Switching operation modes and unit control can cope with unbalance between heating and cooling demand
  - No back-up boiler and chiller









Case 1 | Washing Process in Automobile Parts Production

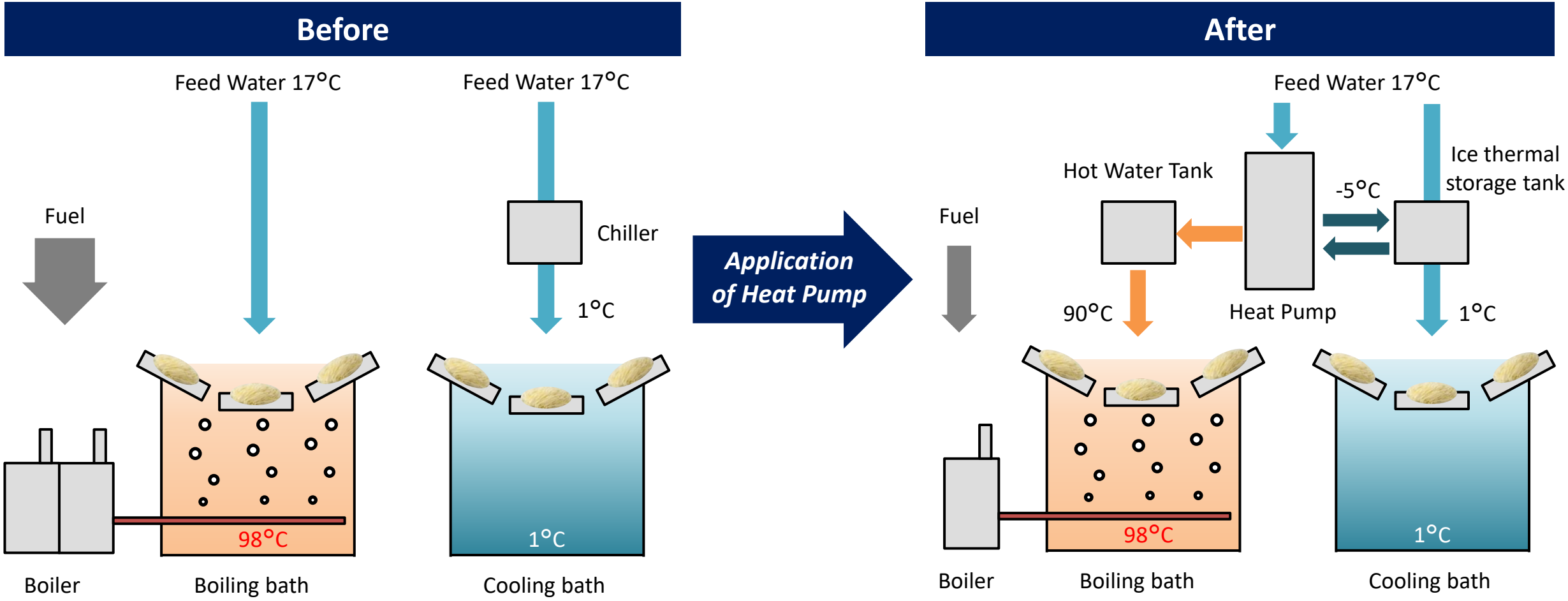
- Effects
  - CO_2 emissions
    - 80% reduction
    - 1,094 ton-CO_2/year reduction
  - Water consumption (Steam line)
    - 100% reduction
    - 6,953 kL-Water/year reduction
  - Primary energy consumption
    - 84% reduction
    - 437 kL-Oil/year reduction
  - Running cost
    - 79% reduction
    - 26 million JPY/year reduction
  - Payback period
    - 3.5 years

One of Top 10 BATs to Improve Energy Efficiency

ipeec
International Partnership for **Energy Efficiency** Cooperation

Other Simultaneous Heating & Cooling Application

- Noodle production
  - Application of brine source heat pump hot water heater
  - Primary energy consumption: 35% reduction



Summary | Simultaneous Heating & Cooling

- Application Examples
  - 16 examples in food industry
  - 2 examples in machinery

- Key points
  - Close distance of heating process and cooling process
  - Coping with unbalance between heating and cooling demand
    - Resolution 1: Switching operation mode with AWW heat pump
    - Resolution 2: Thermal storage

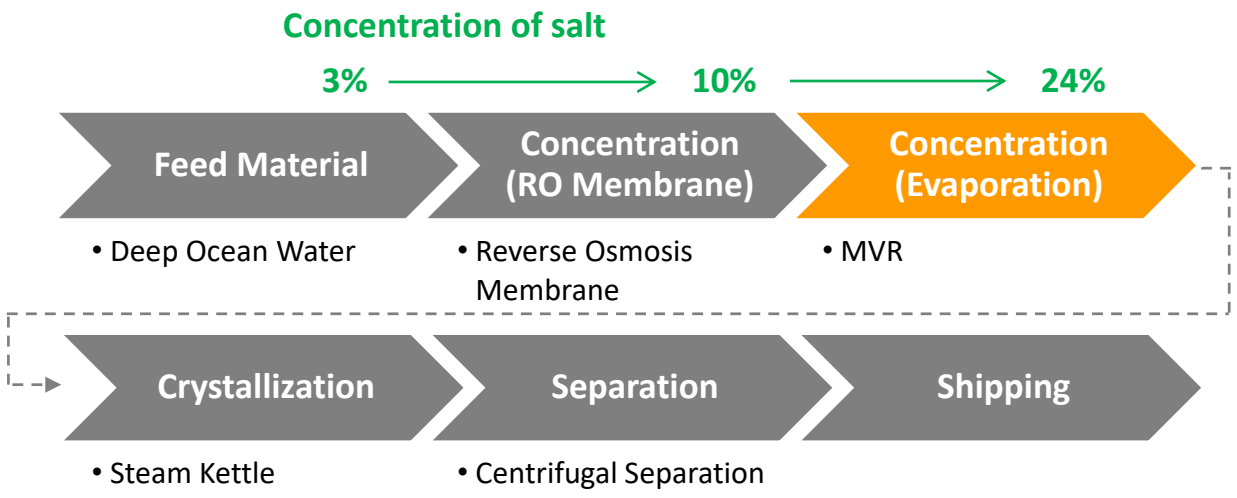
Case Study 2
-MVR-

Case 2 | Concentration Process in Salt Production

Outline of Installation

Industry	Food
Production	Salt (from deep ocean water)
User company	Muroto Kaiyoshinsosui Co., Ltd.
Installed year	2015
Process	Concentration
Application	Steam (70°C)
HP manufacturer	Sasakura Engineering Co., Ltd.
HP System	Mechanical Vapor Recompression (MVR) Steam temperature: 70°C (-0.07MPaG) Steam flow: 400 kg/h
Effects	Primary energy reduction: 79% Energy cost reduction: 78% Payback period: 2 years (with subsidy)

Process and Application

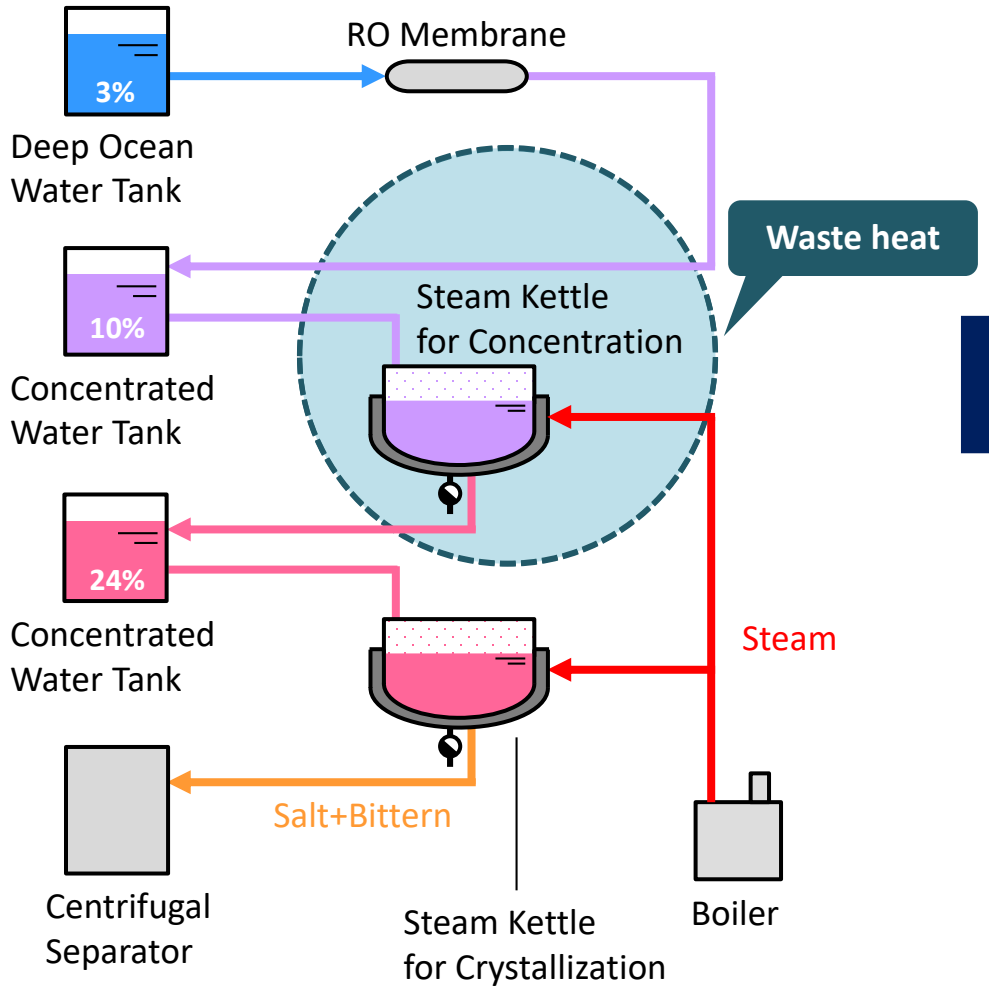


Mechanical Vapor Recompression

Product (Salt)

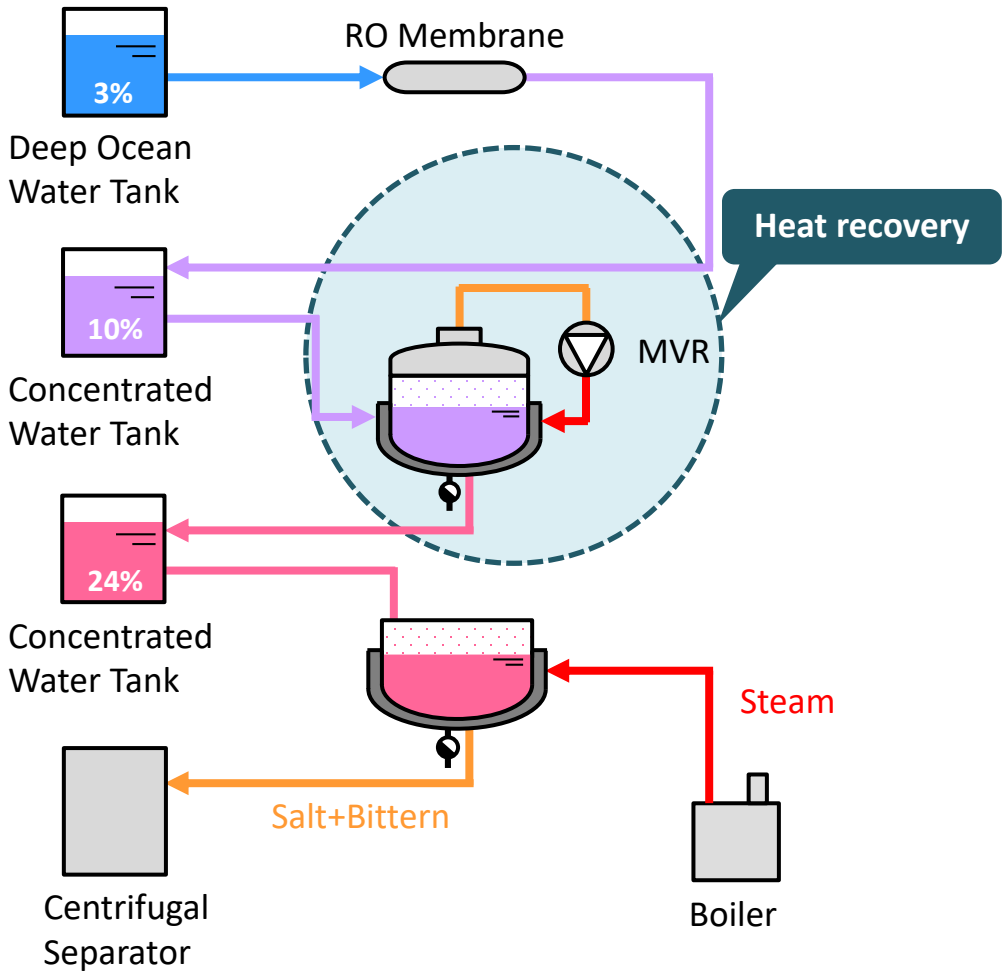
Case 2 | Concentration Process in Salt Production

Before



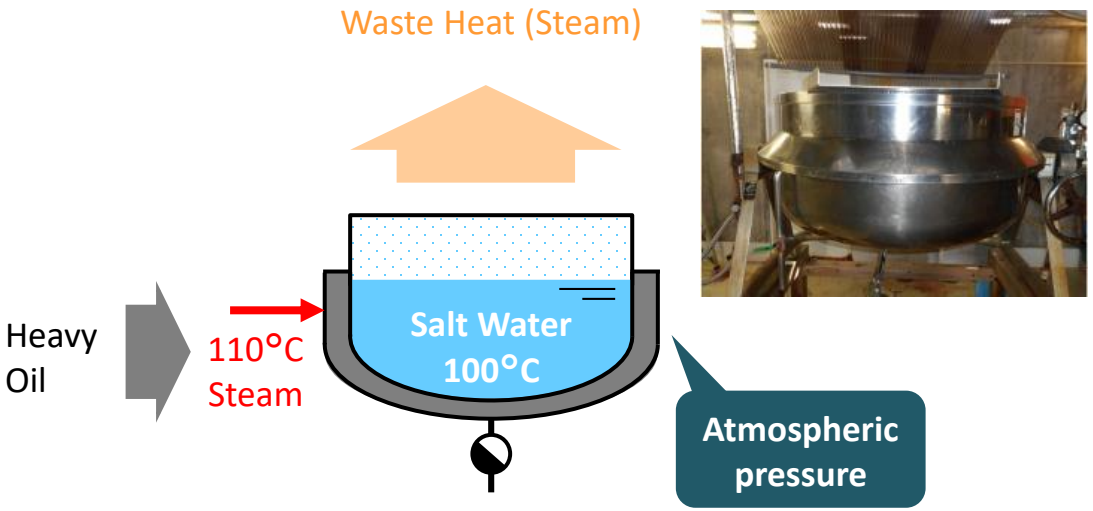
Application of Heat Pump

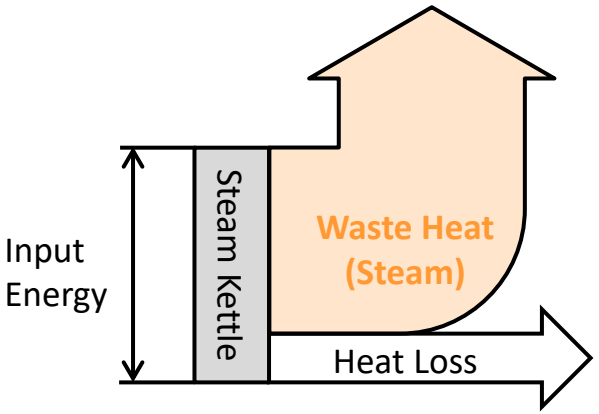
After



Case 2 | Concentration Process in Salt Production

Before





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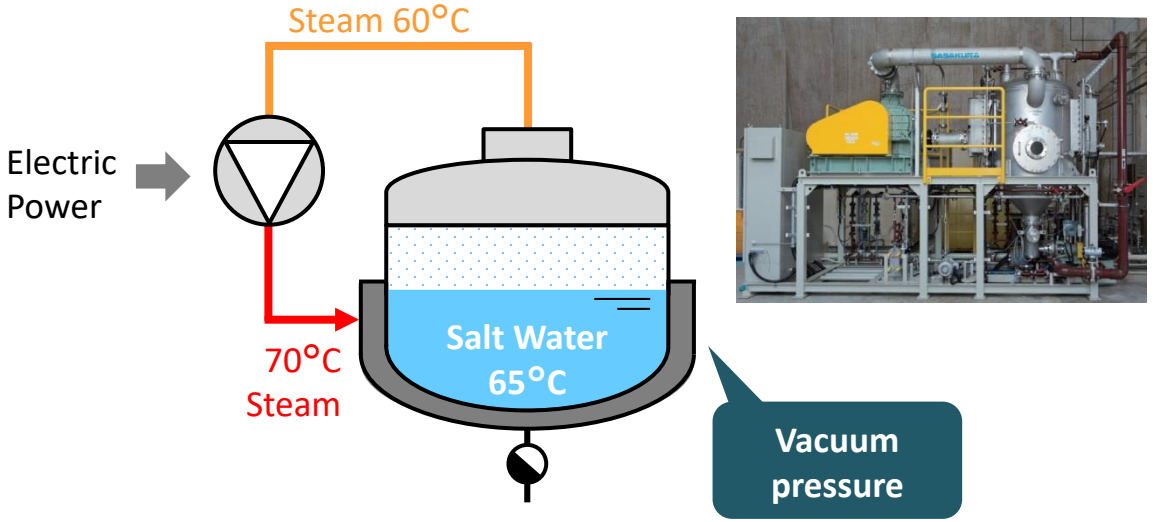
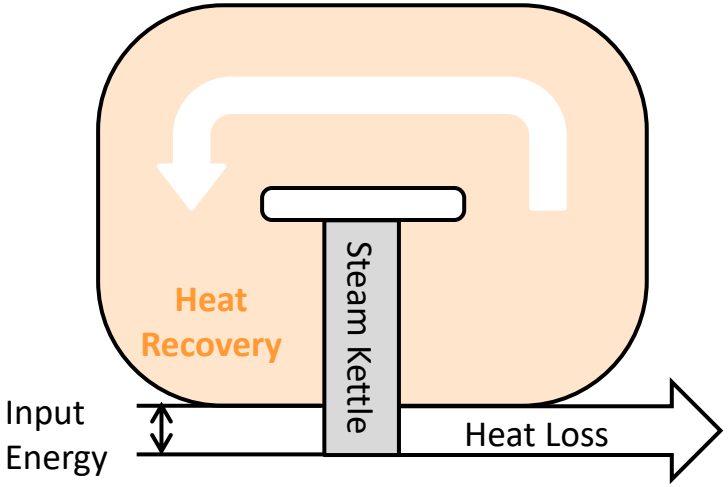
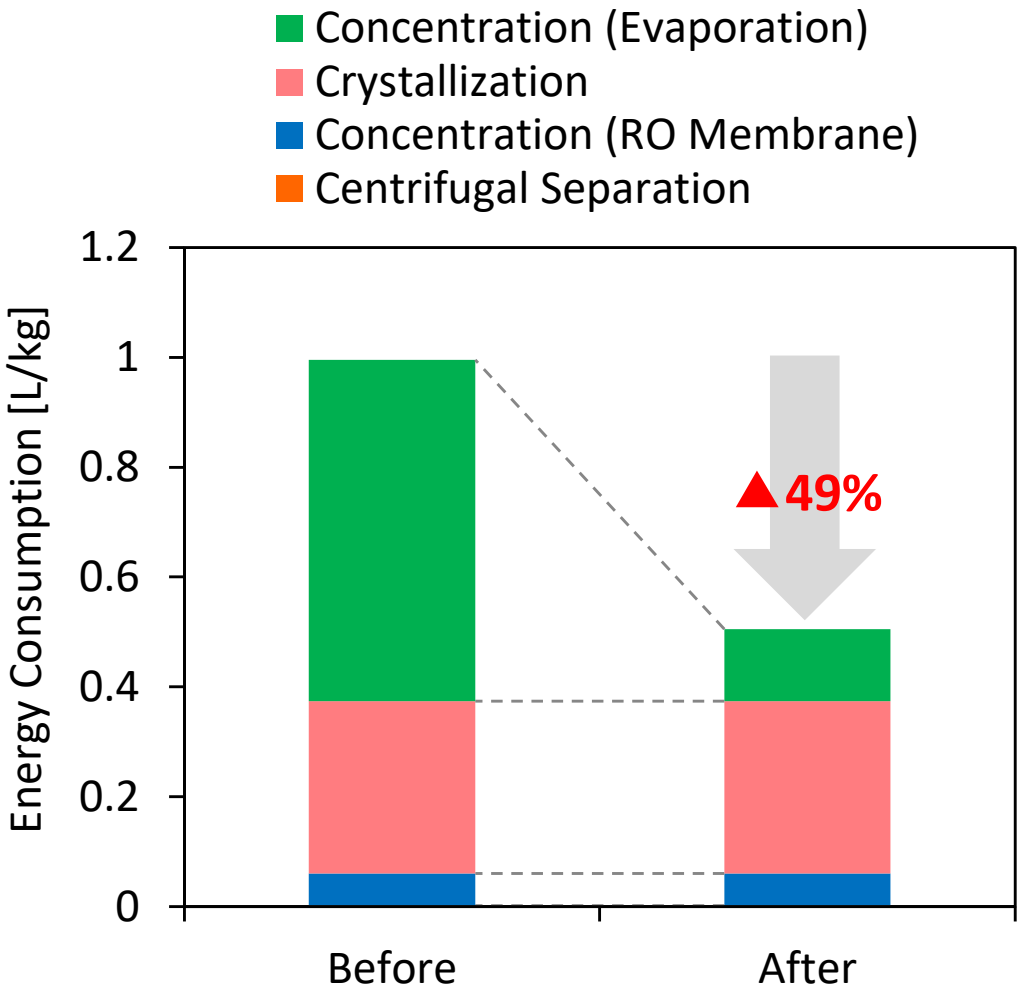




Case 2 | Concentration Process in Salt Production

- Effects
  - Primary energy consumption
    - 79% reduction (Evaporative concentration process)
    - 49% reduction (Total salt production processes)
  - Energy cost
    - 10 million JPY/year reduction
  - Payback period
    - 2.0 years (with subsidy)
    - 3.5 years (without subsidy)



Summary | MVR

- Application Examples
  - 2 examples in concentration process (Salt production, Drainage treatment)
  - 1 example in distillation process (Alcohol production)
  - 2 examples in drying process (Tissue production, Sewage treatment)

- Key points
  - Long time continuous process
  - Low BPR (Boiling Point Rising) for distillation process
  - Attention to corrosion or scale deposition because of direct compression

Described later
(Case studies 3 & 4)

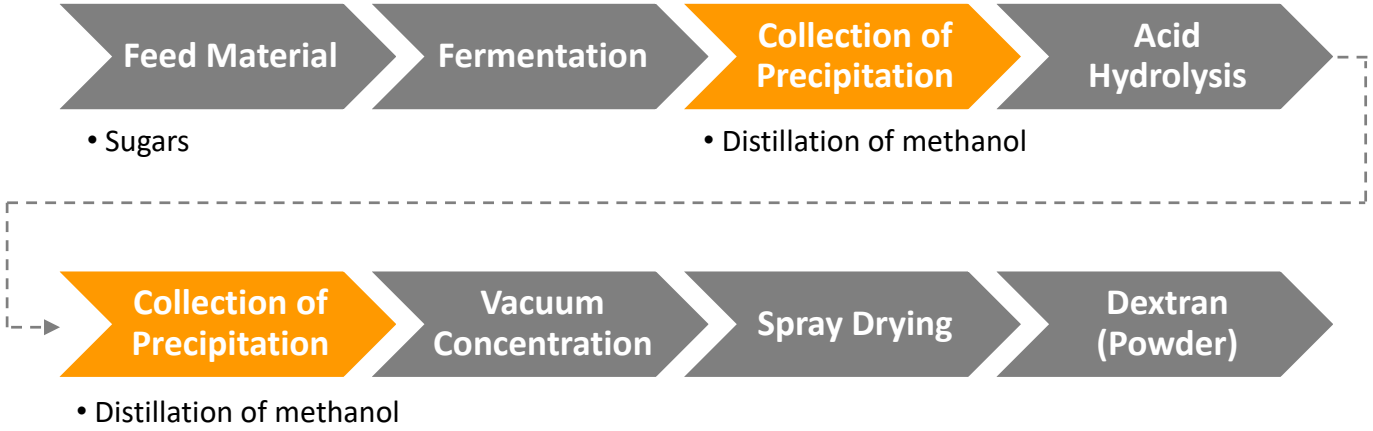
Case Studies 3 & 4
-Indirect Self Heat Recovery-

Case 3 | Distillation Process in Dextran Production

Outline of Installation

Industry	Chemistry
Production	Dextran (Polysaccharides)
User company	Meito Sangyo Co., Ltd.
Installed year	2017
Process	Distillation of methanol
Application	Hot water (90°C)
Contractor	Kimura Chemical Plants Co., Ltd.
HP manufacturer	Kobe Steel, Ltd. (KOBELCO)
HP System	HEM-HR90 (× 2 units) Refrigerant: R134a+R245fa Heating capacity: 800 kW
Effects	CO_2 reduction: 60% Primary energy reduction: 60% Energy cost reduction: 63%

Process and Application



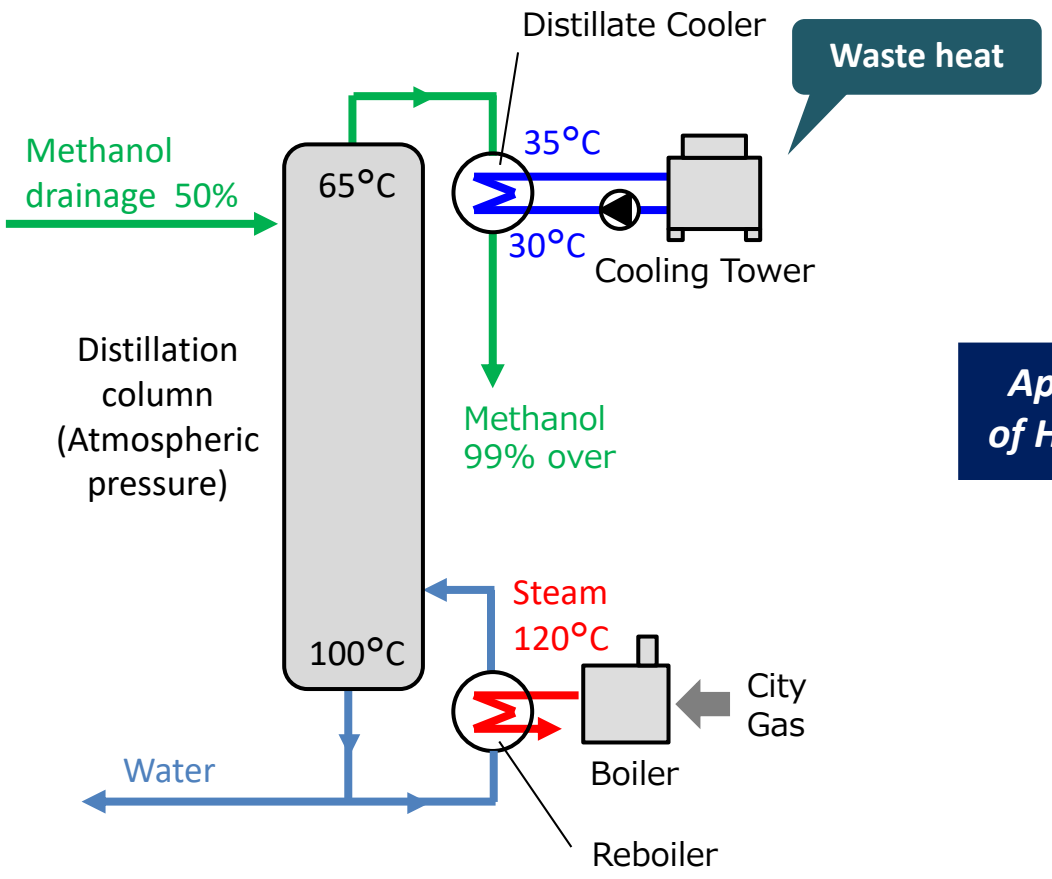
Heat Pump

Distillation Column

Product (Dextran)

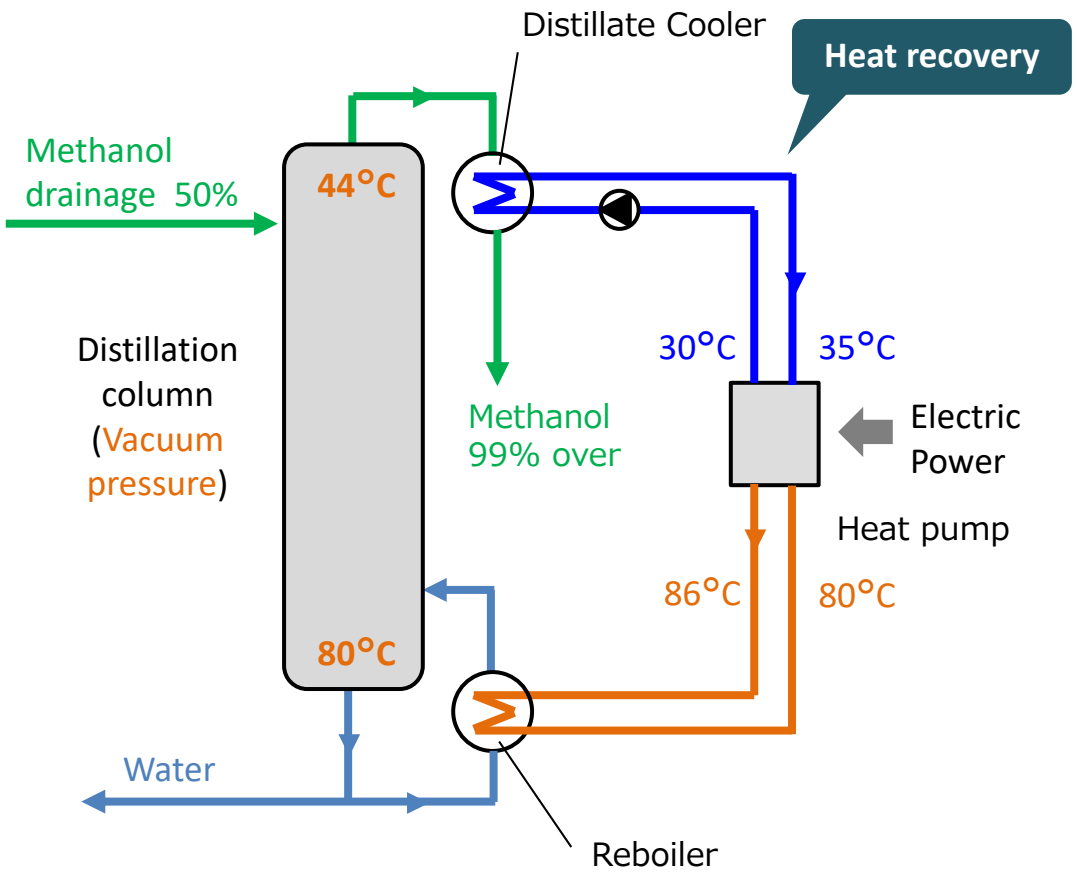
Case 3 | Distillation Process in Dextran Production

Before



Application of Heat Pump

After



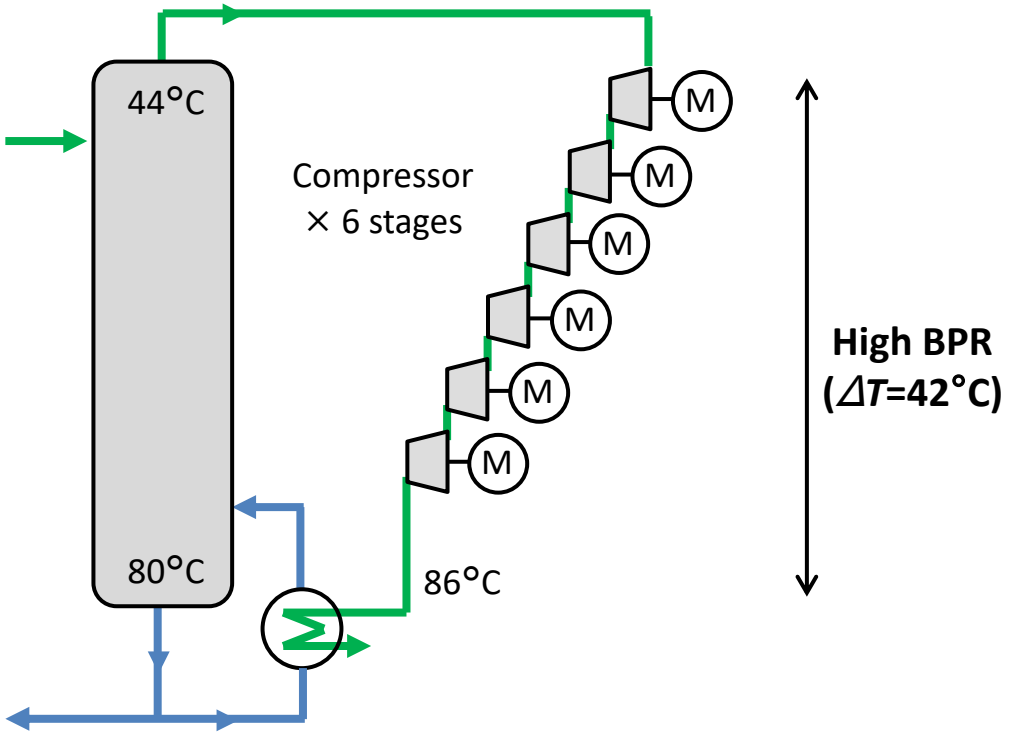
Hot water supply HP can be used when distillation column is decompressed.

Case 3 | Distillation Process in Dextran Production

Why MVR was not selected?

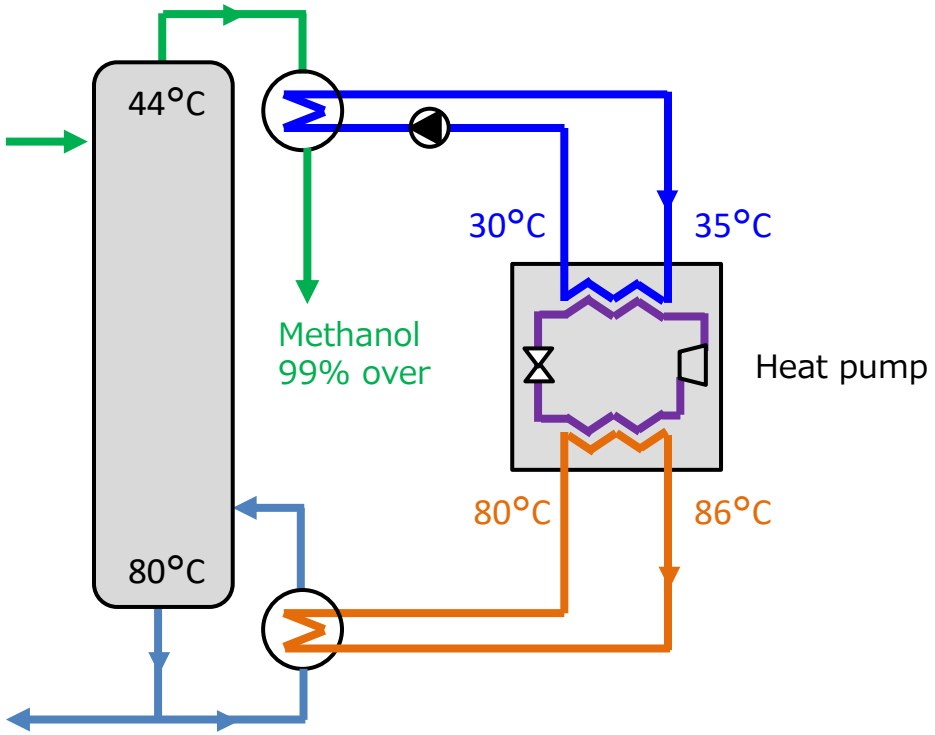
MVR

- Require a special specification compressor because of methanol vapor compression
- Require 6 stage compressors because of high BPR
  → high cost and complicated operation



Heat Pump

- Lower risk of methanol flammability
- Use a general-purpose heat pump
  → lower cost and better operability

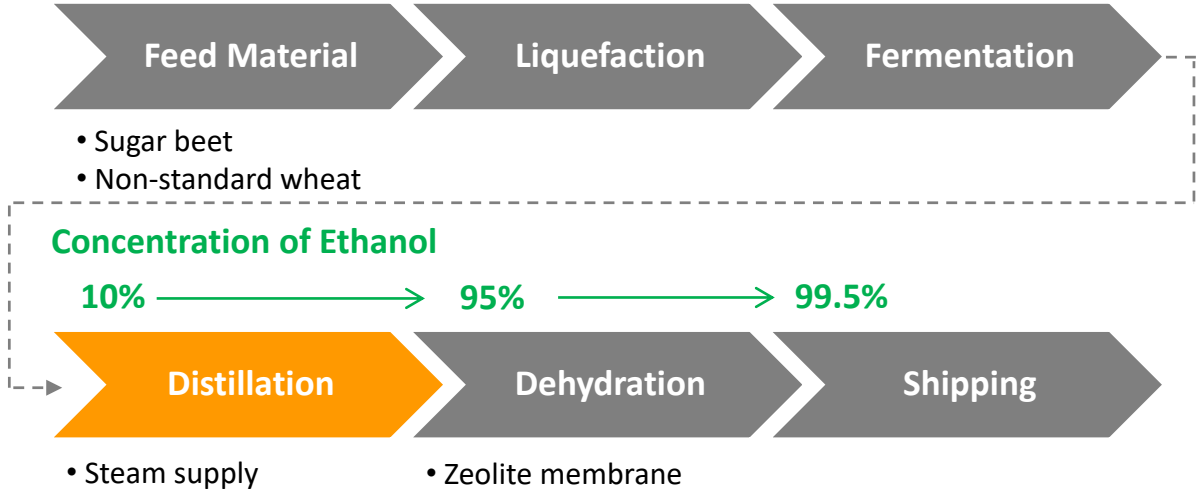


Case 4 | Distillation Process in Bio-ethanol Production

Outline of Installation

Industry	Chemistry
Production	Bio-ethanol
User company	Hokkaido Bioethanol Co., Ltd.
Installed year	2012
Process	Distillation of ethanol
Application	Steam (120°C)
Contractor	Japan Chemical Engineering & Machinery Co., Ltd.
HP manufacturer	Kobe Steel, Ltd. (KOBELCO)
HP System	SGH120 (× 5 units) Refrigerant: R245fa Steam flow: 2 ton/h
Effects	CO_2 reduction: 43% Energy cost reduction: 54% Payback period: 3.5 years

Process and Application

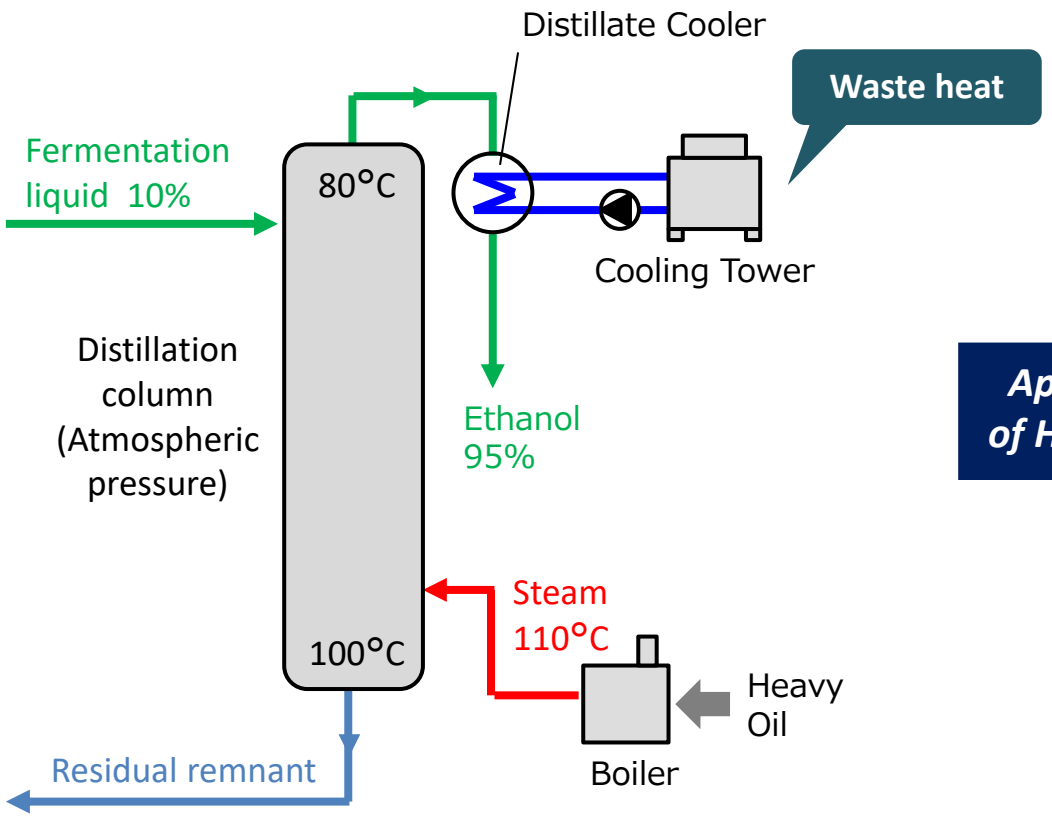


Heat Pump

Distillation Column

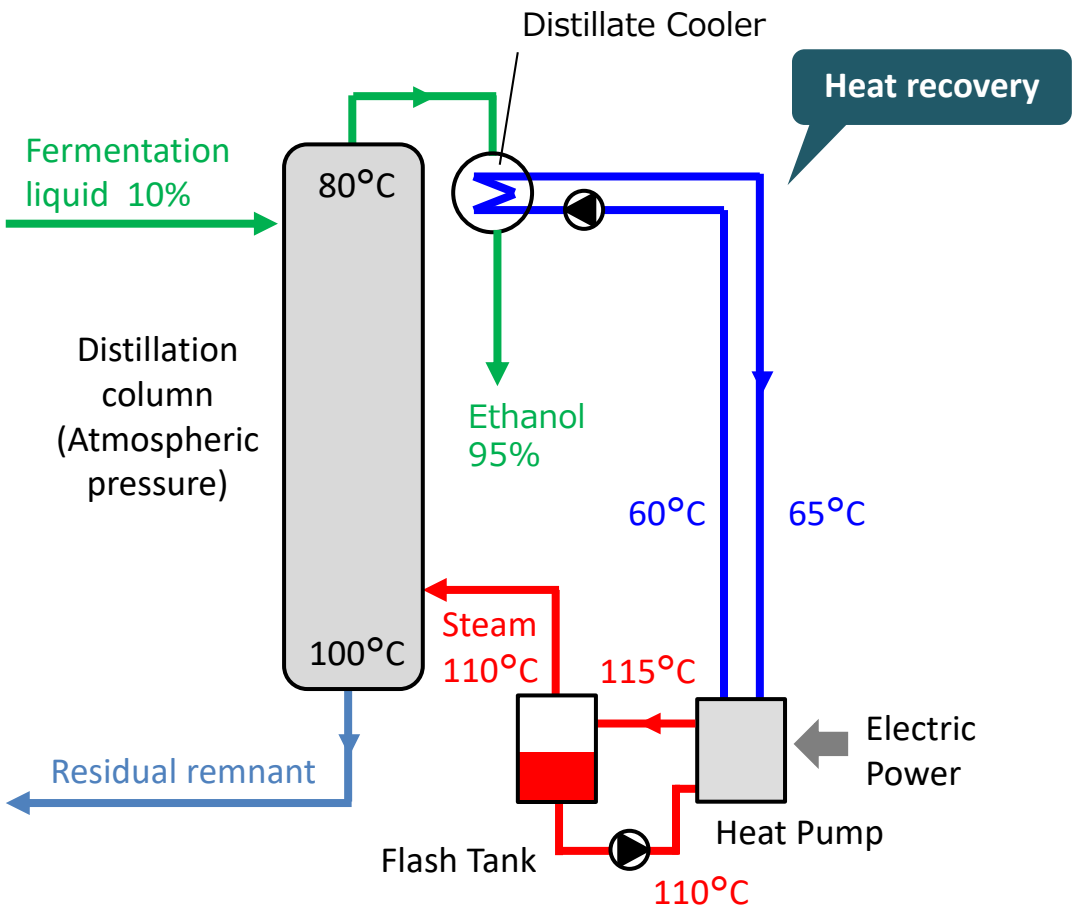
Case 4 | Distillation Process in Bio-ethanol Production

Before



Application of Heat Pump

After



Steam supply HP is used when distillation column is not decompressed.

Conclusions

Conclusions

- Installation Situation of Industrial Heat Pumps in Japan
  - Installation target by the government is heating capacity of 1,673 MW by FY2030.
  - Heating capacity of 88.1 MW was installed before FY2016.
  - The most have been installed in “Food industry.”
  - The HP type used most often is “Circulation heating hot water supply HP.”

- Effective Applications
  - Reduction of heat load by installation near process
    - Leads to high COP operation by low temperature lift and self heat recovery
  - Simultaneous heating and cooling
    - Applied industry: Food industry, Machinery
  - Mechanical vapor recompression (MVR)
    - Applied process: Concentration, Distillation, Drying
    - In the case of high BPR for distillation, indirect self heat recovery is selected.