Industrial Heat Pump Applications in Japan

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CO₂ Emissions Reduction by Electrification

- Key points for significant reduction of CO₂ emissions
  - Low carbonization of electricity
  - Higher efficiency electricity usage

Transition and target of CO₂ emission factor for electricity in Japan

Heat Pump (EHP) vs. Boiler regarding CO₂ emissions under the condition that the heat load is equal

Estimation conditions
- City gas: 0.0499 kg-CO₂/MJ
- Heavy oil A: 0.0693 kg-CO₂/MJ
- Combustion efficiency: 0.9
Final Energy Consumption in Japan

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

<table>
<thead>
<tr>
<th>Sector</th>
<th>Energy Consumption (PJ/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential</td>
<td>2,200</td>
</tr>
<tr>
<td>Commercial</td>
<td>2,800</td>
</tr>
<tr>
<td>Industrial</td>
<td>6,600</td>
</tr>
<tr>
<td>Transport</td>
<td></td>
</tr>
</tbody>
</table>

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

Commercialized IHPs in Japan

Air-source Heat Pumps

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)

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

Installed results (~FY2016)

- 88.1 MW
- 84 examples: 4.9 MW (6% of government statistics)

- Voice of customer
- Effects of energy, CO2 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

<table>
<thead>
<tr>
<th>Installation Situation</th>
<th>Industry and Process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heating</td>
<td>Food (33)</td>
</tr>
<tr>
<td>Heating &amp; Cooling</td>
<td>Machinery (18)</td>
</tr>
<tr>
<td>Hot Water Supply</td>
<td>Electronics (10)</td>
</tr>
<tr>
<td>Drying</td>
<td>Chemistry (10)</td>
</tr>
<tr>
<td>Distillation or</td>
<td>Agriculture &amp; Fisheries (7)</td>
</tr>
<tr>
<td>Concentration</td>
<td>Paper (3)</td>
</tr>
<tr>
<td></td>
<td>Unknown (3)</td>
</tr>
</tbody>
</table>
Installation Situation | Type of Heat Pump

- Hot water supply type is used most often.
- Circulation heating > Once-through heating
The required heating capacity and temperature depend on the process.

- Many installations in the hundreds of kW class (700 kW ≈ 1 ton/h steam boiler)
- Many installations of 65°C or 90°C hot water supply

<table>
<thead>
<tr>
<th>Heating Capacity</th>
<th>Number of Installation Case</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q≤10 [kW]</td>
<td>4</td>
</tr>
<tr>
<td>10&lt;Q≤50 [kW]</td>
<td>12</td>
</tr>
<tr>
<td>50&lt;Q≤100 [kW]</td>
<td>7</td>
</tr>
<tr>
<td>100&lt;Q≤500 [kW]</td>
<td>19</td>
</tr>
<tr>
<td>500&lt;Q≤1,000 [kW]</td>
<td>12</td>
</tr>
<tr>
<td>1,000&lt;Q≤3,000 [kW]</td>
<td>5</td>
</tr>
<tr>
<td>Unknown</td>
<td>25</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Supply Temperature</th>
<th>Number of Installation Case</th>
</tr>
</thead>
<tbody>
<tr>
<td>T≤50 [°C]</td>
<td>18</td>
</tr>
<tr>
<td>50&lt;T≤60 [°C]</td>
<td>8</td>
</tr>
<tr>
<td>60&lt;T≤70 [°C]</td>
<td>18</td>
</tr>
<tr>
<td>70&lt;T≤80 [°C]</td>
<td>7</td>
</tr>
<tr>
<td>80&lt;T≤90 [°C]</td>
<td>15</td>
</tr>
<tr>
<td>90&lt;T≤110 [°C]</td>
<td>4</td>
</tr>
<tr>
<td>110&lt;T≤120 [°C]</td>
<td>1</td>
</tr>
<tr>
<td>120&lt;T≤130 [°C]</td>
<td>13</td>
</tr>
<tr>
<td>Unknown</td>
<td>13</td>
</tr>
</tbody>
</table>
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

<table>
<thead>
<tr>
<th>Industry</th>
<th>Machinery</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production</td>
<td>Automobile parts (Differential case)</td>
</tr>
<tr>
<td>User company</td>
<td>AISIN AW Co., Ltd.</td>
</tr>
<tr>
<td>Installed year</td>
<td>2010</td>
</tr>
<tr>
<td>Process</td>
<td>Cutting (Cooling), Washing (Heating)</td>
</tr>
<tr>
<td>Application</td>
<td>Hot Water (65°C) &amp; Cold Water (15°C)</td>
</tr>
<tr>
<td>HP manufacturer</td>
<td>Zeneral Heat Pump Industry Co., Ltd.</td>
</tr>
<tr>
<td>HP System</td>
<td>AWW Heat Pumps</td>
</tr>
<tr>
<td></td>
<td>Refrigerant: R134a</td>
</tr>
<tr>
<td></td>
<td>Heating capacity: 476 kW</td>
</tr>
<tr>
<td></td>
<td>(22 kW/unit × 6 units)</td>
</tr>
<tr>
<td></td>
<td>(43 kW/unit × 8 units)</td>
</tr>
<tr>
<td>Effects</td>
<td>CO₂ reduction: 80%</td>
</tr>
<tr>
<td></td>
<td>Primary energy reduction: 84%</td>
</tr>
<tr>
<td></td>
<td>Energy cost reduction: 79%</td>
</tr>
<tr>
<td></td>
<td>Payback period: 3.5 years</td>
</tr>
</tbody>
</table>

### Process and Application

- **Feed Material**
- **Cutting Process**
- **Washing Process**
- **Assembly Process**

- **Cooling** cutting liquid
- **Heating** washing liquid

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

**Product (Differential Case)**
Case 1 | Washing Process in Automobile Parts Production

**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.

**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.

**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

- **Simultaneous Heating & Cooling operation**
  - 10°C Evaporator→60°C Condenser
  - 15°C Compressor

- **Cooling operation**
  - 10°C Evaporator→60°C Condenser
  - 15°C Compressor

- **Heating operation**
  - 10°C Evaporator→65°C Condenser
  - 15°C Compressor

- **Graph**
  - X-axis: Time [min]
  - Y-axis: Thermal demand [kW]
  - Blue line: Cooling demand
  - Red line: Heating demand

- **Legend**
  - Green: Simultaneous Heating & Cooling operation
  - Blue: Cooling operation
  - Orange: Heating operation

- **Note**
  - No back-up boiler and chiller
Case 1 | Washing Process in Automobile Parts Production

Effects

- CO₂ emissions
  - 80% reduction
  - 1,094 ton-CO₂/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
Other Simultaneous Heating & Cooling Application

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

**Before**

- Fuel → Boiler
- Feed Water 17°C → Boiling bath (98°C)
- Feed Water 17°C → Cooling bath (1°C)

**After**

- Fuel → Boiler
- Feed Water 17°C → Boiling bath (98°C)
- Chiller
- Hot Water Tank (90°C) → Heat Pump
- Ice thermal storage tank (-5°C) → 1°C

**Application of Heat Pump**
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

<table>
<thead>
<tr>
<th>Outline of Installation</th>
<th>Process and Application</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Industry</strong></td>
<td><strong>Concentration of salt</strong></td>
</tr>
<tr>
<td>Food</td>
<td>3%</td>
</tr>
<tr>
<td><strong>Production</strong></td>
<td><strong>Feed Material</strong></td>
</tr>
<tr>
<td>Salt (from deep ocean water)</td>
<td>• Deep Ocean Water</td>
</tr>
<tr>
<td><strong>User company</strong></td>
<td><strong>Concentration (Evaporation)</strong></td>
</tr>
<tr>
<td>Muroto Kaiyoshinsosui Co., Ltd.</td>
<td>• MVR</td>
</tr>
<tr>
<td><strong>Installed year</strong></td>
<td><strong>Mechanical Vapor Recompression (MVR)</strong></td>
</tr>
<tr>
<td>2015</td>
<td>Steam temperature: 70°C (-0.07MPaG)</td>
</tr>
<tr>
<td><strong>Process</strong></td>
<td>Steam flow: 400 kg/h</td>
</tr>
<tr>
<td>Concentration</td>
<td></td>
</tr>
<tr>
<td><strong>Application</strong></td>
<td><strong>Product (Salt)</strong></td>
</tr>
<tr>
<td>Steam (70°C)</td>
<td></td>
</tr>
<tr>
<td><strong>HP manufacturer</strong></td>
<td>Mechanical Vapor Recompression (MVR)</td>
</tr>
<tr>
<td>Sasakura Engineering Co., Ltd.</td>
<td></td>
</tr>
<tr>
<td><strong>HP System</strong></td>
<td>Steam temperature: 70°C (-0.07MPaG)</td>
</tr>
<tr>
<td>Steam flow: 400 kg/h</td>
<td></td>
</tr>
<tr>
<td><strong>Effects</strong></td>
<td>Energy cost reduction: 78%</td>
</tr>
<tr>
<td>Primary energy reduction: 79%</td>
<td></td>
</tr>
<tr>
<td>Payback period: 2 years (with subsidy)</td>
<td></td>
</tr>
</tbody>
</table>
Case 2 | Concentration Process in Salt Production

**Before**

- Deep Ocean Water Tank
- Concentrated Water Tank (3%)
- Concentrated Water Tank (10%)
- Concentrated Water Tank (24%)
- Centrifugal Separator
- Steam Kettle for Concentration
- Steam Kettle for Crystallization
- Boiler
- Salt+Bittern
- Waste heat

**After**

- Deep Ocean Water Tank
- Concentrated Water Tank (3%)
- Concentrated Water Tank (10%)
- Concentrated Water Tank (24%)
- Centrifugal Separator
- Steam Kettle for Concentration
- Steam Kettle for Crystallization
- Boiler
- Salt+Bittern

**Application of Heat Pump**

- MVR
- Heat recovery

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Case 2 | Concentration Process in Salt Production

**Before**
- Heavy Oil
- Salt Water 100°C
- Waste Heat (Steam)
- Atmospheric pressure
- 110°C Steam
- Heat Loss
- Input Energy

**After**
- Heavy Oil
- Salt Water 65°C
- Waste Heat (Steam)
- Vacuum pressure
- Steam 60°C
- Electric Power
- 70°C Steam
- Heat Recovery
- Input Energy
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)
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

<table>
<thead>
<tr>
<th>Industry</th>
<th>Chemistry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production</td>
<td>Dextran (Polysaccharides)</td>
</tr>
<tr>
<td>User company</td>
<td>Meito Sangyo Co., Ltd.</td>
</tr>
<tr>
<td>Installed year</td>
<td>2017</td>
</tr>
<tr>
<td>Process</td>
<td>Distillation of methanol</td>
</tr>
<tr>
<td>Application</td>
<td>Hot water (90°C)</td>
</tr>
<tr>
<td>Contractor</td>
<td>Kimura Chemical Plants Co., Ltd.</td>
</tr>
<tr>
<td>HP manufacturer</td>
<td>Kobe Steel, Ltd. (KOBELCO)</td>
</tr>
<tr>
<td>HP System</td>
<td>HEM-HR90 (× 2 units)</td>
</tr>
<tr>
<td></td>
<td>Refrigerant: R134a+R245fa</td>
</tr>
<tr>
<td></td>
<td>Heating capacity: 800 kW</td>
</tr>
<tr>
<td>Effects</td>
<td>CO₂ reduction: 60%</td>
</tr>
<tr>
<td></td>
<td>Primary energy reduction: 60%</td>
</tr>
<tr>
<td></td>
<td>Energy cost reduction: 63%</td>
</tr>
</tbody>
</table>

## Process and Application

- **Feed Material**: Sugars
- **Fermentation**: Distillation of methanol
- **Collection of Precipitation**: Distillation of methanol
- **Acid Hydrolysis**: Dextran (Powder)
- **Collection of Precipitation**: Vacuum Concentration
- **Spray Drying**: Dextran (Powder)

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Heat Pump
Distillation Column
Product (Dextran)
Case 3 | Distillation Process in Dextran Production

**Before**

- Methanol drainage 50%
- Distillation column (Atmospheric pressure)
- Steam 120°C
- City Gas
- Boiler
- Reboiler

**After**

- Methanol drainage 50%
- Distillation column (Vacuum pressure)
- Methanol 99% over

**Application of Heat Pump**

- Waste heat
- Heat recovery

**Electric Power**

- Heat pump

**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

[Diagram showing MVR and Heat Pump processes]
## Case 4 | Distillation Process in Bio-ethanol Production

### Outline of Installation

<table>
<thead>
<tr>
<th>Industry</th>
<th>Chemistry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production</td>
<td>Bio-ethanol</td>
</tr>
<tr>
<td>User company</td>
<td>Hokkaido Bioethanol Co., Ltd.</td>
</tr>
<tr>
<td>Installed year</td>
<td>2012</td>
</tr>
<tr>
<td>Process</td>
<td>Distillation of ethanol</td>
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<tr>
<td>Application</td>
<td>Steam (120°C)</td>
</tr>
<tr>
<td>Contractor</td>
<td>Japan Chemical Engineering &amp; Machinery Co., Ltd.</td>
</tr>
<tr>
<td>HP manufacturer</td>
<td>Kobe Steel, Ltd. (KOBELCO)</td>
</tr>
<tr>
<td>HP System</td>
<td>SGH120 (× 5 units)</td>
</tr>
<tr>
<td></td>
<td>Refrigerant: R245fa</td>
</tr>
<tr>
<td></td>
<td>Steam flow: 2 ton/h</td>
</tr>
<tr>
<td>Effects</td>
<td>CO₂ reduction: 43%</td>
</tr>
<tr>
<td></td>
<td>Energy cost reduction: 54%</td>
</tr>
<tr>
<td></td>
<td>Payback period: 3.5 years</td>
</tr>
</tbody>
</table>

### Process and Application

- **Feed Material**
  - Sugar beet
  - Non-standard wheat

- **Liquefaction**

- **Fermentation**

- **Concentration of Ethanol**
  - 10% → 95% → 99.5%

- **Distillation**
  - Steam supply

- **Dehydration**
  - Zeolite membrane

- **Shipping**

### Heat Pump

### Distillation Column
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.