Evaluation of Good Practices for Industrial Heat Pump in Japan

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Chubu Electric Power Co., Inc.

Montreal, August 28, 2019
Mitigation Targets for GHG Emission in Japan

<table>
<thead>
<tr>
<th>Target Year</th>
<th>Reduction Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>2030</td>
<td>26 %</td>
</tr>
<tr>
<td>2050</td>
<td>80 %</td>
</tr>
<tr>
<td>2100</td>
<td>100 %</td>
</tr>
</tbody>
</table>

Carbon Free Society
CO₂ Emission and Final Energy Consumption in Japan

CO₂ emission
1.15 billion ton

Final energy consumption
11.91EJ

FY 2016
Fossil Fuels Use for Manufacturing Industrial Sectors
(Source: Fossil Fuels Consumption Statistics in Industrial Sectors (FY2017))
## Industrial Heat Demand for Sectors

<table>
<thead>
<tr>
<th>Industries</th>
<th>Auto steam generation (TJ)</th>
<th>Direct process heating (TJ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical and allied products</td>
<td>317,616 (43%)</td>
<td>1,927,446 (35%)</td>
</tr>
<tr>
<td>Pulp/paper/paper products</td>
<td>192,282 (26%)</td>
<td>32,730 (0.6%)</td>
</tr>
<tr>
<td>Iron and steel, Non-Ferrous Metals</td>
<td>114,377 (15%)</td>
<td>1,506,880 (27%)</td>
</tr>
<tr>
<td>Textile mill products</td>
<td>43,234 (6%)</td>
<td>37,954 (0.7%)</td>
</tr>
<tr>
<td>Food/beverages</td>
<td>30,000 (4%)</td>
<td>104,441 (2%)</td>
</tr>
<tr>
<td>Machinery</td>
<td>12,820 (2%)</td>
<td>86,166 (1.6%)</td>
</tr>
<tr>
<td>Electronics/information</td>
<td>212 (0%)</td>
<td>121,433 (2.2%)</td>
</tr>
<tr>
<td>Agriculture/forest/fishery</td>
<td>37 (0%)</td>
<td>41,457 (0.8%)</td>
</tr>
<tr>
<td>Others</td>
<td>34,342 (5%)</td>
<td>1,658,497 (30%)</td>
</tr>
<tr>
<td>Total</td>
<td>744,920 (100%)</td>
<td>5,517,000 (100%)</td>
</tr>
</tbody>
</table>
Effective steam use is estimated by 54% in average (based on practical data of 29 different factories).

Source: JEHC, "Booklet of Industrial Heat Pump Application"
Energy Saving Potential and Renewable Energy Contribution of HP

- ** Boiler loss**: 10
- ** Piping loss**: 26
- ** Drain loss**: 10

**Primary energy**: 100
**Heat**: 90
**Heat**: 64

**Energy Saving**: 65%
**Electricity generated**: 15
**Electricity of end use**: 13.5

**Heat Pump (COP=4)**

- **Heat**: 54
- **Heating (80°C)**
- **Drying (120°C)**
- **Cleaning (60°C)**

**Fossil Fuels**: (η=43%)
**Nuclear energy**: (η=33%)
**Renewable energy**: (η=100%)

**Conversion loss**: 20
**Transmission & transformation loss**: 1.5

**Share of renewable energy** = 100 - (35 + 15) = 50
Samples of IHPs Application (Good Practices)
<table>
<thead>
<tr>
<th>Literature</th>
<th>Sample Number</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Examples of heat pump installation in industrial sector, JEHC</td>
<td>No.1～19</td>
<td>No.1～26, 49 (Annex 35/13)</td>
</tr>
<tr>
<td>Future Ages, Use More Electricity for Production Vol.5, JEHC (Vol.2,3,4,5)</td>
<td>No.20～48</td>
<td>No.27～48, 50～98 (new samples for Annex 48)</td>
</tr>
<tr>
<td>ELECTROHEAT HANDBOOK, JEHC, 2011</td>
<td>No.49～62</td>
<td></td>
</tr>
<tr>
<td>Journal of Electro-heat, JEHC</td>
<td>No.63～88</td>
<td>No.1～98 (MHP or MVR)</td>
</tr>
<tr>
<td>Seminar materials of JSRAE</td>
<td>No.89～96</td>
<td></td>
</tr>
<tr>
<td>Process Innovation of Food Factory, JEHC</td>
<td>No.97</td>
<td></td>
</tr>
<tr>
<td>Catalogue of Ebara Refrigeration Equipment &amp; Systems Co., Ltd.</td>
<td>No.98</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>112</strong></td>
<td></td>
</tr>
</tbody>
</table>
Information Items of Good Practices

- Information on installation
  - Industrial sector of installation
  - Process applied
  - Location
  - Year of installation
  - User name

- Information on technology and system
  - Manufacturer/constructor/consultant
  - Heat pump system
  - Working fluid (refrigerant)
  - Compressor
  - Heating/cooling capacity [kW]
  - Heat sink (In and Out) [°C]
  - Heat source (In and Out) [°C]
  - Heat storage

- Effects of installation
  - Energy savings
  - CO₂ emission savings
  - Energy cost savings
  - Additional effects
<table>
<thead>
<tr>
<th>No</th>
<th>Annex</th>
<th>Electric load leveling by ice storage system in cheese production process</th>
<th>Examples of heat pump installation in industrial sector, JEHC</th>
<th>Food</th>
<th>Cooling</th>
<th>Hokkaido</th>
<th>2007</th>
<th>Yuki jin shi megumi k co, Ltd.</th>
<th>Hitachi Appliances, Inc</th>
<th>MHP</th>
<th>Water-cooled chiller</th>
<th>R134a</th>
<th>turbo</th>
<th>Cooling only</th>
<th>Ice</th>
<th>Savings of contract load by load leveling</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Annex</td>
<td>Simultaneous heating &amp; cooling system in food production line</td>
<td>Examples of heat pump installation in industrial sector, JEHC</td>
<td>Food</td>
<td>Heating/Cooling</td>
<td>Hyogo</td>
<td>2010</td>
<td>Cosmos Food Co, Ltd.</td>
<td>MAYEKAWA MFG. CO, LTD</td>
<td>MHP</td>
<td>Water-source hot water supply HP</td>
<td>CO2</td>
<td>reciprocating</td>
<td>276</td>
<td>90</td>
<td>Simultaneous bus heating &amp; cooling</td>
</tr>
<tr>
<td>3</td>
<td>Annex</td>
<td>Simultaneous heating &amp; cooling system in noodle production process</td>
<td>Examples of heat pump installation in industrial sector, JEHC</td>
<td>Food</td>
<td>Heating/Cooling</td>
<td>Okayama</td>
<td>2009</td>
<td>Tamura Seimen Ltd.</td>
<td>MAYEKAWA MFG. CO, LTD</td>
<td>MHP</td>
<td>Water-source hot water supply HP</td>
<td>CO2</td>
<td>reciprocating</td>
<td>56</td>
<td>17</td>
<td>90</td>
</tr>
<tr>
<td>4</td>
<td>Annex</td>
<td>Reduction of boiler load by heating supply water in scalding process</td>
<td>Examples of heat pump installation in industrial sector, JEHC</td>
<td>Food</td>
<td>Hot Water Supply</td>
<td>Kagoshima</td>
<td>2008</td>
<td>Kagoshima Kumiai Chicken Food Co, Ltd.</td>
<td>MAYEKAWA MFG. CO, LTD</td>
<td>MHP</td>
<td>Air-source hot water supply HP</td>
<td>CO2</td>
<td>reciprocating</td>
<td>80</td>
<td>65</td>
<td>Outdoor air</td>
</tr>
<tr>
<td>5</td>
<td>Annex</td>
<td>Steamless heating in broken Sulphur process</td>
<td>Examples of heat pump installation in industrial sector, JEHC</td>
<td>Paper products</td>
<td>Hot Water Supply</td>
<td>Shizuoka</td>
<td>2009</td>
<td>Oji Tokushushii c, Ltd.</td>
<td>Mitsubishi Electric Corporation</td>
<td>MHP</td>
<td>Air-source hot water supply HP</td>
<td>CO2</td>
<td>scroll</td>
<td>320</td>
<td>75</td>
<td>Outdoor air</td>
</tr>
<tr>
<td>6</td>
<td>Annex</td>
<td>Electric load leveling by water heat storage system in cooking process of reaction tank</td>
<td>Examples of heat pump installation in industrial sector, JEHC</td>
<td>Chemicals</td>
<td>Cooling</td>
<td>Saitama</td>
<td>2005</td>
<td>Saden Chemical co, Ltd.</td>
<td>Tohiba Carrier Corporation</td>
<td>MHP</td>
<td>Air-cooled chiller</td>
<td>R410A</td>
<td>rotary</td>
<td>880</td>
<td>5</td>
<td>Simultaneous bus heating &amp; cooling</td>
</tr>
<tr>
<td>7</td>
<td>Annex</td>
<td>Introduction of heat pump with hot gas source in dry process of formed styrol</td>
<td>Examples of heat pump installation in industrial sector, JEHC</td>
<td>Chemicals</td>
<td>Drying</td>
<td>Tochigi</td>
<td>2010</td>
<td>Dia Chemicals co, Ltd.</td>
<td>MAYEKAWA MFG. CO, LTD</td>
<td>MHP</td>
<td>Hot air generation HP</td>
<td>CO2</td>
<td>reciprocating</td>
<td>110</td>
<td>90</td>
<td>Exhausted hot water of shaping machine</td>
</tr>
</tbody>
</table>
Number of Process Applied to Industrial Sector (N=98)
Number of Process Applied for Supply Temperature

Supply temperature [°C]
Effect of IHPs Application

Primary energy saving: average = 42%

CO₂ emission saving: average = 49%

Energy cost saving: average = 52.5%
Selection of Best Practices
Structure of Hierarchy to Select Best Practice

Selection of Best Practices

Criteria of evaluation

Technology and system

Market potential

Effect of installation

Industrial heat demand

Heat capacity
Supply temperature
Working fluids
Heat source
Energy saving
CO₂ reduction
Energy cost saving
Additional effect

Evaluating industry

Food/agriculture/fishery
Machinery/electronics
Paper products/pulp
Chemicals

Samples

Sample 1~38
Sample 84~90
Sample 39~60
Sample 74~83
Sample 92~93
Sample 61~73

(main criteria)
(sub-criteria)
Weight Evaluation of Criteria Items for Different Scenario

- **Method of weight evaluation**: The analytic hierarchy process method
- **Main criteria**
  1. Market potential
  2. Technology and system
  3. Effects of application
- **Sub criteria**
  - (2) Technology and system
    1. Heating/Cooling capacity
    2. Supply temperature
    3. Low GWP working fluids
    4. Simultaneous heating and cooling / Heat recovery
  - (3) Effects of application
    1. Energy saving
    2. CO2 reduction
    3. Energy cost saving
    4. Additional effects
- **Pairwise comparison between j and k criteria**

<table>
<thead>
<tr>
<th>Value of $a_{jk}$</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>j and k are equally important</td>
</tr>
<tr>
<td>3</td>
<td>j is more important than k</td>
</tr>
<tr>
<td>5</td>
<td>j is strongly more important than k</td>
</tr>
</tbody>
</table>

- **Scenario**
  - **Scenario 1**: Priority for market potential
  - **Scenario 2**: Priority for technology and system
  - **Scenario 3**: Priority for application effects
### Best Practices selected by Scenario Analysis

<table>
<thead>
<tr>
<th>No</th>
<th>Industry</th>
<th>Location</th>
<th>User company</th>
<th>HP manufacturing company</th>
<th>Scenario 1</th>
<th>Scenario 2</th>
<th>Scenario 3</th>
<th>Reference [without weight]</th>
</tr>
</thead>
<tbody>
<tr>
<td>21</td>
<td>machinery</td>
<td>Aichi</td>
<td>Aishin・AW Co. Ltd.</td>
<td>General Heat Pump Industry</td>
<td>2.18</td>
<td>2.22</td>
<td>1.38</td>
<td>22 (2.44)</td>
</tr>
<tr>
<td>32</td>
<td>chemicals</td>
<td>Fukui</td>
<td>Suda ind. Co.Ltd.</td>
<td>MAYEKAWA MFG. Co., Ltd</td>
<td>2.66</td>
<td>2.56</td>
<td>1.46</td>
<td>21(2.33)</td>
</tr>
<tr>
<td>2</td>
<td>food</td>
<td>Hyogo</td>
<td>Cosmo food Co. Ltd.</td>
<td>MAYEKAWA MFG. Co., Ltd</td>
<td>2.16</td>
<td>2.44</td>
<td>1.25</td>
<td>20(2.22)</td>
</tr>
<tr>
<td>43</td>
<td>chemicals</td>
<td>Hokkaido</td>
<td>Hokkaido Bioethanol Co Ltd.</td>
<td>KOBE STEEL, Ltd.</td>
<td>2.65</td>
<td>2.48</td>
<td>1.46</td>
<td>19 (2.11)</td>
</tr>
<tr>
<td>7</td>
<td>chemicals</td>
<td>Tochigi</td>
<td>Diachemical Co. Ltd.</td>
<td>MAYEKAWA MFG. Co., Ltd</td>
<td>2.42</td>
<td>2.60</td>
<td>1.32</td>
<td>18(2.00)</td>
</tr>
<tr>
<td>40</td>
<td>food</td>
<td>Yamagata</td>
<td>Flesh Diner Co. Ltd.</td>
<td>MAYEKAWA MFG. Co., Ltd</td>
<td>1.94</td>
<td>2.37</td>
<td>1.1</td>
<td>18(2.00)</td>
</tr>
<tr>
<td>83</td>
<td>food</td>
<td>Kochi</td>
<td>Muroto Deep Sea Water Co. Ltd.</td>
<td>Sasakura</td>
<td>1.91</td>
<td>2.18</td>
<td>1.06</td>
<td>18(2.00)</td>
</tr>
</tbody>
</table>

* red: the best value evaluated for each industry
Four Important Items Required for Best Practice

- Recovery or recycling of low temperature heat
- Reduction of steam heat loss
- Separative heat supply for different production processes
- Simultaneous heating & cooling operation
## Best Practice in Machinery Industry (No.21)  
**Process Outline**

<table>
<thead>
<tr>
<th>No</th>
<th>21</th>
</tr>
</thead>
<tbody>
<tr>
<td>Industry</td>
<td>Machinery (Parts production of vehicle)</td>
</tr>
<tr>
<td>Process applied</td>
<td>Cutting, Washing</td>
</tr>
<tr>
<td>Heat source</td>
<td>Simultaneous heating/cooling (heating 65℃, cooling 15℃)</td>
</tr>
<tr>
<td>Objective</td>
<td>Eliminating the conventional boiler system</td>
</tr>
</tbody>
</table>
| HP system | Water-water/Air-water heat pump (6+8=14 units)  
Heating capacity: 22kW/unit (6 units), 43kW/unit (8 units)  
Refrigerant: R134a |
| Effects | CO2 reduction 80%, energy cost saving: 79%, Pay back time: 5 year |

**Before**

1. Input energy (Electric power)  
2. Cooling COP = 2  
3. Cutting liquid 20℃  
   - Chiller
4. Cutting liquid 60℃  
   - Washing liquid 60℃  
5. Heating COP = 0.2  
   - Boiler
6. Total thermal efficiency = 0.2

**After**

1. Input energy (Gas)  
2. Cooling COP  
   - Chiller  
   - 2 Cooling energy
3. Heating COP  
   - Expansion valve  
   - Heat pump
4. Heating COP  
   - Evaporator
5. Heating COP  
   - Condenser
6. Heating COP  
   - Compressor

- Simultaneous heating for washing liquid and cooling for cutting oil
- 3.0 of heating COP, 2.0 of cooling COP
- Transportation heat loss is reduced by installing HP close to process facility.
## Effects of Application

### Saving of energy, steam and CO\textsubscript{2} emission

<table>
<thead>
<tr>
<th></th>
<th>Before</th>
<th>After</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity consumption [MWh/y]</td>
<td>193</td>
<td>570</td>
<td>+377 (+195%)</td>
</tr>
<tr>
<td>Fuel consumption [kL/y]</td>
<td>470</td>
<td>0</td>
<td>-470 (-100%)</td>
</tr>
<tr>
<td>Steam consumption [kL/y]</td>
<td>6,953</td>
<td>0</td>
<td>-6,953 (-100%)</td>
</tr>
<tr>
<td>CO\textsubscript{2} emission [ton-CO\textsubscript{2}/y]</td>
<td>1,364</td>
<td>270</td>
<td>-1,094 (-80%)</td>
</tr>
</tbody>
</table>

### Economical effect

<table>
<thead>
<tr>
<th></th>
<th>Before (old)</th>
<th>After (new)</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Investment</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Boiler/piping</td>
<td>75.3[million yen]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Steam heating system</td>
<td>10.5[million yen]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cooling system</td>
<td>50.4[million yen]</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>136.2[million yen]</td>
<td></td>
<td>-45.2 [million yen]</td>
</tr>
<tr>
<td><strong>Operation cost</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electric bill</td>
<td>2.34[million yen/y]</td>
<td></td>
<td>-26 [million yen/y] (-79%)</td>
</tr>
<tr>
<td>Heavy oil charges</td>
<td>28.1[million yen/y]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water charges</td>
<td>2.45[million yen/y]</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>32.9[million yen/y]</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Best Practice in Chemicals Industry (No.32)

### Process Outline

<table>
<thead>
<tr>
<th>Number</th>
<th>32</th>
</tr>
</thead>
<tbody>
<tr>
<td>Industry</td>
<td>Chemicals (Package film production)</td>
</tr>
<tr>
<td>Process applied</td>
<td>Dry (laminating film)</td>
</tr>
<tr>
<td>Heat source</td>
<td>Hot water supply</td>
</tr>
<tr>
<td>Objectives</td>
<td>Effective use of waste heat from VOC processor</td>
</tr>
<tr>
<td>HP system</td>
<td>Water/air heat pump (108kW)</td>
</tr>
<tr>
<td>Effects</td>
<td>CO2 reduction: 72%, Energy cost saving: 75%</td>
</tr>
</tbody>
</table>

### Production process

- Planning and design
- Design
- Plate making
- Printing
- Laminating
- Adhesive coating
- Drying
- Crimp laminating
- Inspection
- Slitting
- Wrapping
- Bag manufacturing
- Quality inspection
- Planning and design

For dry laminating
Best Practice in Chemicals Industry (No.32)
System Flow and Effects of Application

System flow

Effects of application

- Primary energy saving: 60%
- CO2 reduction: 72%
- Energy cost saving: 75%

Diagram:
- System flowchart:
  - Outside air
  - Hot air
  - Heat pump
  - Heavy oil boiler
  - Laminating machine

- Effects:
  - Primary energy saving: 60%
  - CO2 reduction: 72%
  - Energy cost saving: 75%
Best Practice in Food Industry (No.2)

Process Outline

<table>
<thead>
<tr>
<th>Numbera</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Industry</strong></td>
<td>Food (Frozen food production)</td>
</tr>
<tr>
<td><strong>Process applied</strong></td>
<td>Food production, Sterilizing, Washing, HVAC</td>
</tr>
<tr>
<td><strong>Heat utilization</strong></td>
<td>Simultaneous heating and cooling</td>
</tr>
<tr>
<td><strong>Objectives</strong></td>
<td>Energy saving and energy cost saving accompanied by renewal of facilities</td>
</tr>
<tr>
<td><strong>HP system</strong></td>
<td>Water/water heat pump (80kWh/unit, 3 units)</td>
</tr>
<tr>
<td><strong>Effects</strong></td>
<td>CO2 reduction: 87%, Energy cost saving: 80%</td>
</tr>
</tbody>
</table>

**Before**

- **Heavy Oil**
  - **Boiler**
  - **Steam**
  - **Feed Water**
  - **Heat Exchanger**
  - **Hot Water**
  - **Chilled Water**

- **Food Processing Machine**
  - **Sterilization & Washing Tank**
  - **Electric Power**
  - **Cold Air**
  - **Fan-Coil Unit**

- **Building**
  - **Boiler**
  - **Steam**
  - **Feed Water**
  - **Chilled Water**

**After**

- **Heavy Oil**
  - **Boiler**
  - **Steam**
  - **Feed Water**

- **Heat Pump**
  - **Hot Water** (80°C)
  - **Chilled Water**
  - **Electric Power**
  - **Cold Air**
  - **Fan-Coil Unit**

- **Building**
  - **Food Processing Machine**
  - **Sterilization & Washing Tank**

**Process**

- **Before**
  - **Boiler A** (Steam: 2 ton/h)
  - **Boiler B** (Steam: 0.7 ton/h)
  - **Heat Pump** (Hot Water: 80°C)
  - **Absorption Chiller** (Chilled Water: 500kW)

- **After**
  - **Boiler A** (Steam: 2 ton/h)
  - **Boiler B** (Steam: 0.7 ton/h)
  - **Heat Pump** (Hot Water: 80°C)
  - **Absorption Chiller** (Chilled Water: 500kW)
Best Practice in Food Industry (No.2)

Operational mode and Effects of Application

Operational mode

Effects of application

CO2 reduction
- 87%
(−450 [ton-CO2/y])

Energy cost saving
- 80%

Pay back time
8 year
Barriers and Countermeasures for IHPs
Barriers for Information and Technology

- **Lack of data about heating demand and exhaust heat**
  - Heat demand needed for IHPs application is not understood for customers in a production process.
  - Correct information of heat demand should be surveyed for a production line.

- **Lack of knowledge and experience with heat pumps**
  - Merits of IHPs are unknown for customers in comparison with the conventional boiler system.
  - The field operator as well as the manager of the firm are lack in the ability required for IHPs application.
  - It is needed to train engineering companies specialized in industrial heat pumps.

- **Avoidance of risk to suspend the conventional production line**
  - Renewal of utility facility sometimes involves to suspend the conventional production line. Field manager avoids risk to suspend the production line.

- **Difficulty of information release**
  - Information on a production line is confidential in many firms. Managers are afraid of the leakage of the secret information.
  - Contract of official secrets is needed between a customer and a manufacturing company in order that informative data like heat balance, etc. should not be leaked out.

- **Technical Barriers**
  - Lack of reliability on high temperature heat pump technology
  - Temporal and spatial gap between heating demand and waste heat
## Countermeasures to take away Barriers

| Information collection and practical education | • Sample survey of good and best practices  
• Preparation of IHPs application guide for customers  
• Common information among stakeholders  
• Communication by means of seminar etc. |
| Monitoring and data accumulation of heat balance at a production process | • Data accumulation of heat demand and wasted heat at a factory  
• Development to reduce costs of thermometer and flowmeter |
| R&D of high temperature heat pump, etc. | • Development of compressor without lubricating oil, recovering system of expansion energy and new working fluid  
• Development of new technologies such as thermoacoustic HP, active magnetic regenerator, etc.  
• Development of high temperature heat storage |

### Effective plan of IHP application

| Step 1 | Understanding of energy use at a production process |
| Step 2 | Selection of heating & cooling process |
| Step 3 | Investigation of heating capacity |
| Step 4 | Investigation of heat source and heat balance |
| Step 5 | Decision of total design framework for HP system and capacity |

#### Main items of energy use
- heating temperature
- heat piping distance
- simultaneous heating & cooling
- exhausted heat of low temperature
- heat loss
- maintenance

#### Main items of process
- process applied
- heating flow of the process
- temperature of the process
- type of heating

#### Main items of capacity
- daily and seasonal load of heat demand and peak demand with time
- Decision of appropriate heating capacity from the demand

#### Main items of HP system
- fluctuation of heating load
- renewal plan of the conventional facility
- Necessity of heat storage
Thank you for your attention!