Evaluation of Good Practices for Industrial Heat Pump in Japan

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Mitigation Targets for GHG Emission in Japan

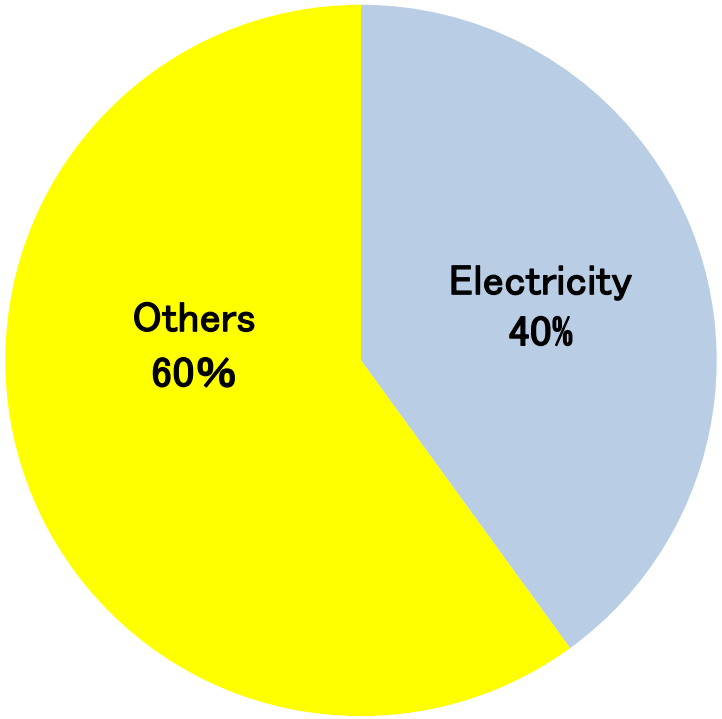
Target Year	Reduction Rate
2030	26 %
2050	80 %
2100	100 %

→ Carbon Free Society

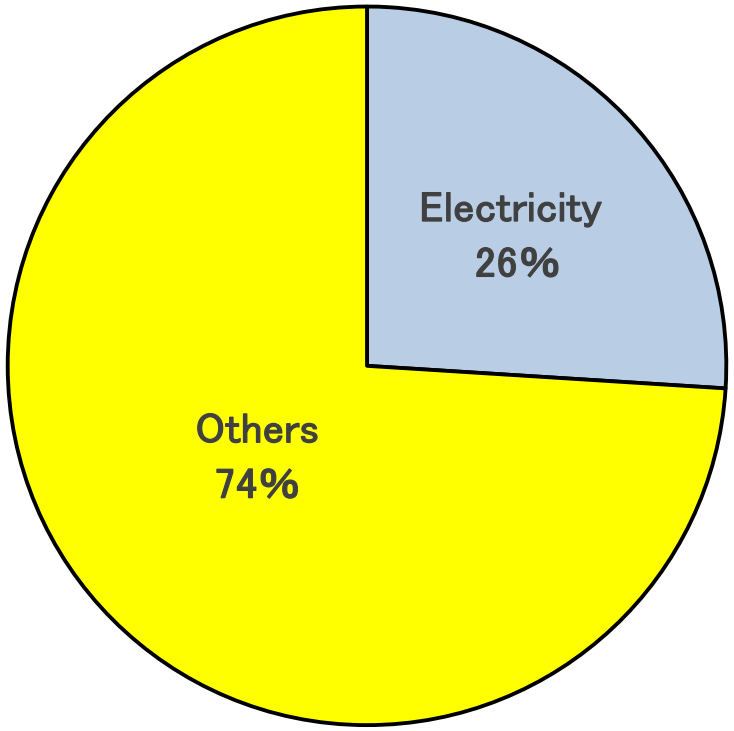
CO_2 Emission and Final Energy Consumption in Japan

CO_2 emission
1.15 billion ton

Final energy consumption
11.91EJ

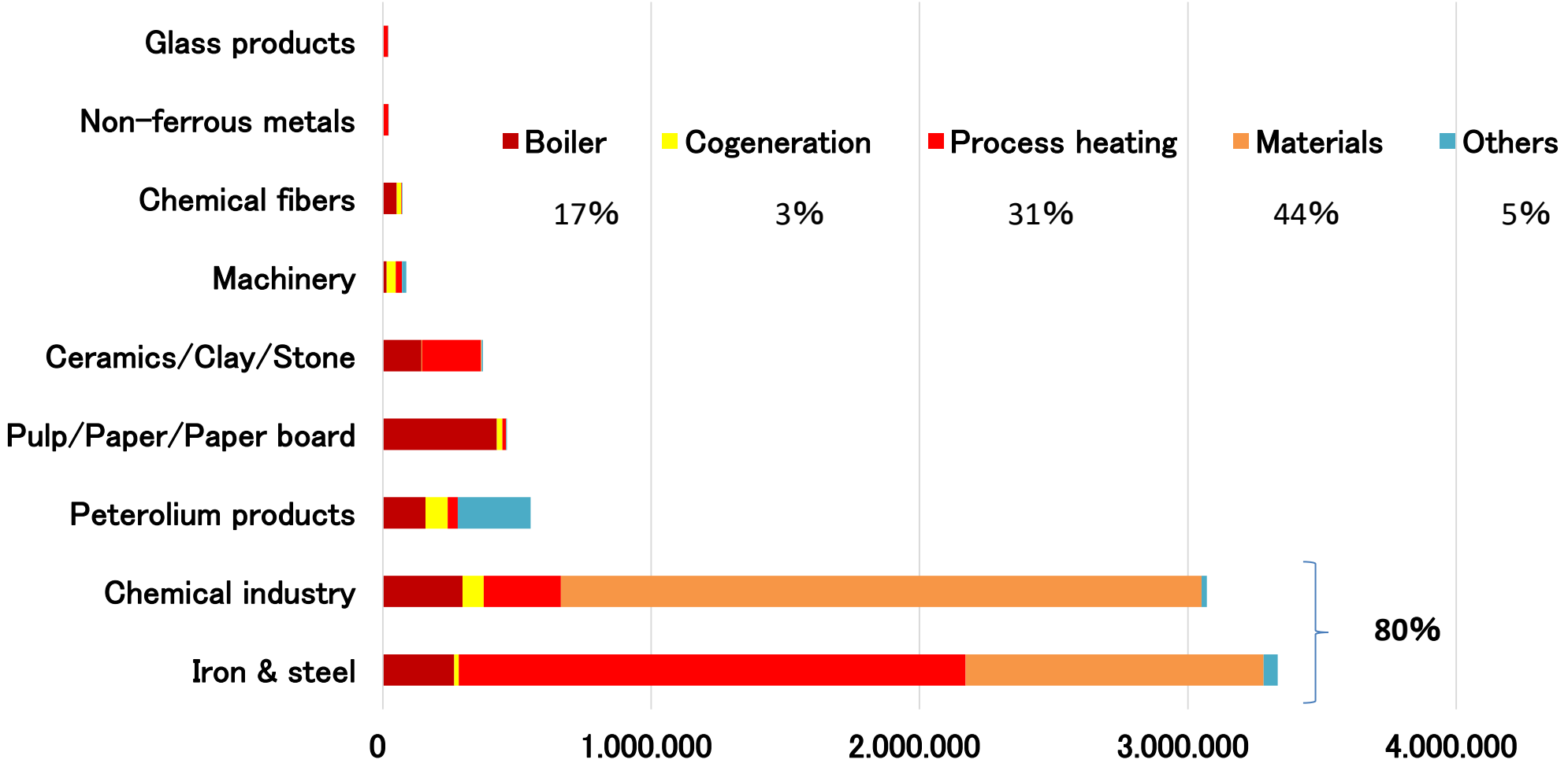


FY 2016



Fossil Fuels Use for Manufacturing Industrial Sectors

(Source: Fossil Fuels Consumption Statistics in Industrial Sectors (FY2017)

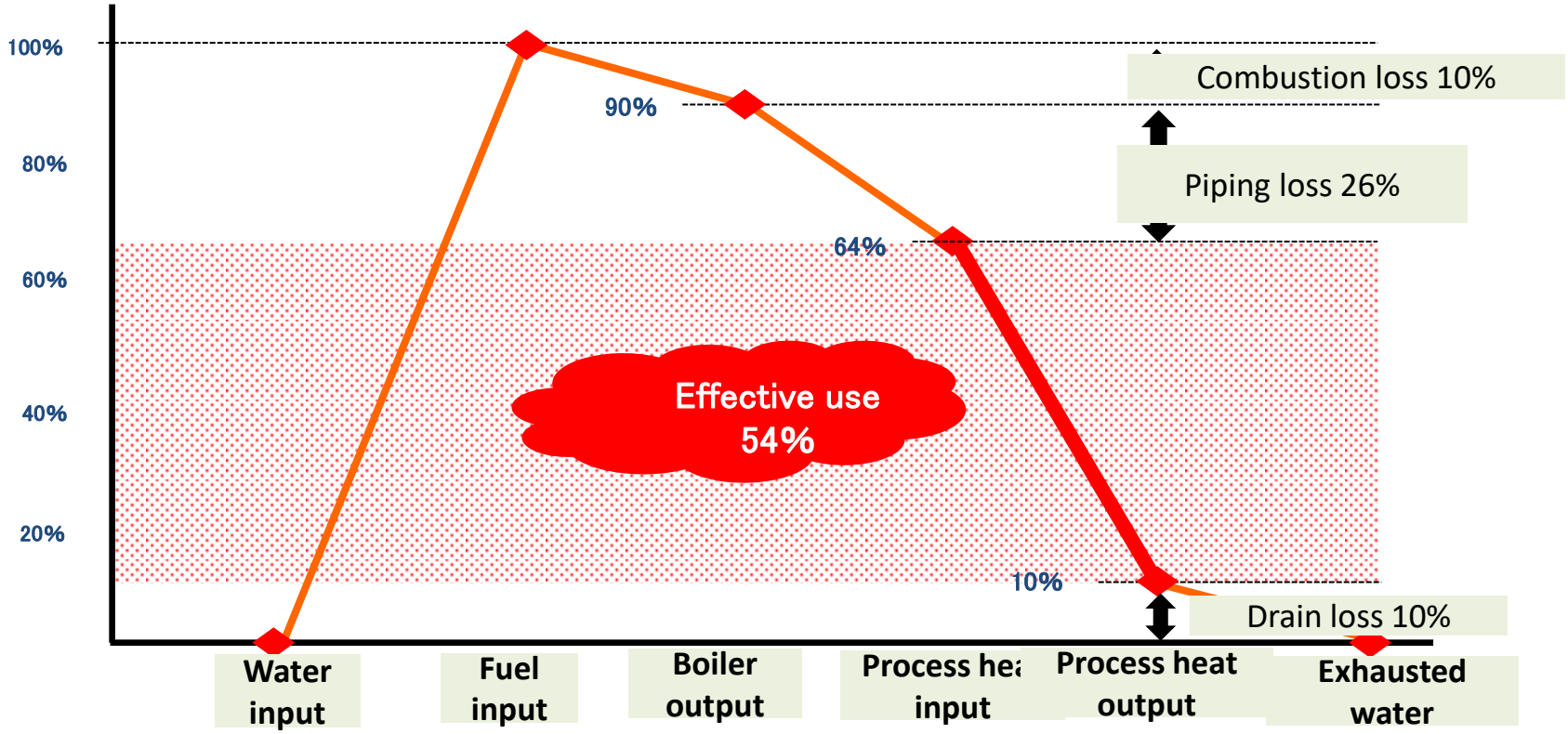


Industrial Heat Demand for Sectors

Industries	Auto steam generation (TJ)	Direct process heating (TJ)
Chemical and allied products	317,616 (43%)	1,927,446 (35%)
Pulp/paper/paper products	192,282 (26%)	32,730 (0.6%)
Iron and steel, Non-Ferrous Metals	114,377 (15%)	1,506,880 (27%)
Textile mill products	43,234 (6%)	37,954 (0.7%)
Food/beverages	30,000 (4%)	104,441 (2%)
Machinery	12,820 (2%)	86,166 (1.6%)
Electronics/information	212 (0%)	121,433 (2.2%)
Agriculture/forest/fishery	37 (0%)	41,457 (0.8%)
Others	34,342 (5%)	1,658,497 (30%)
Total	744,920(100%)	5,517,000(100%)

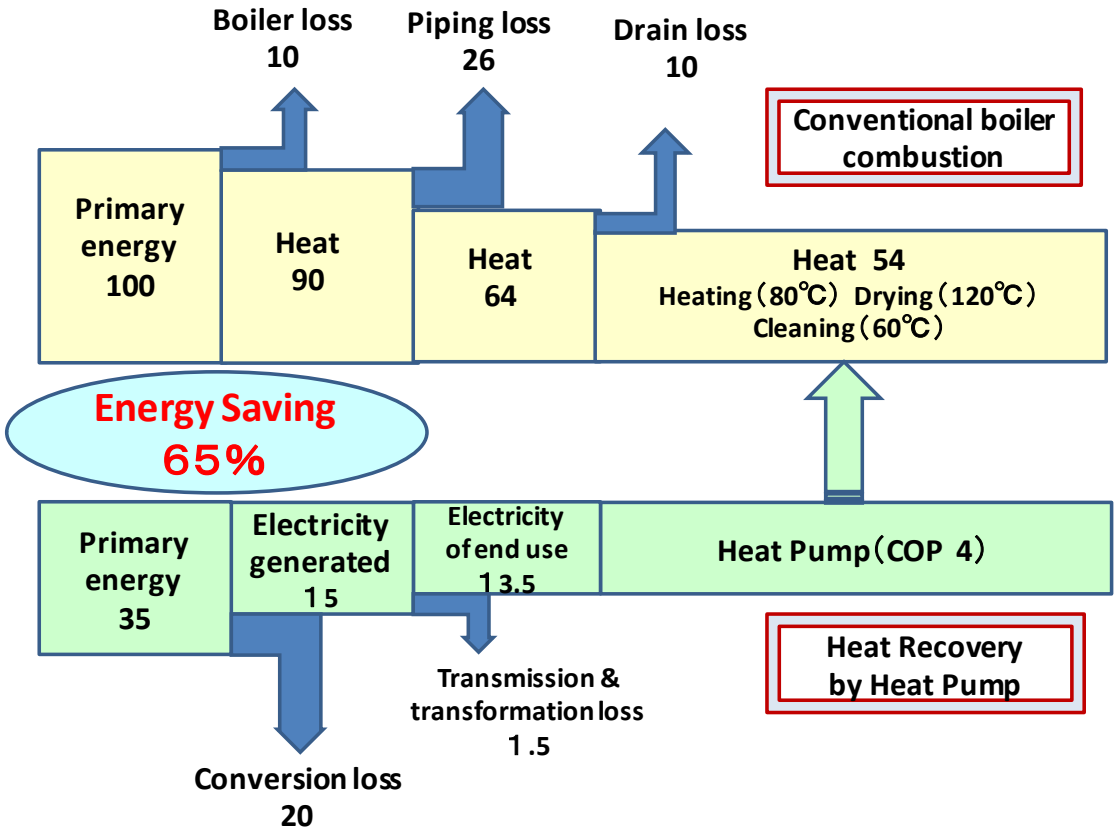
Heat Loss of Production/Transportation Stages in Factory

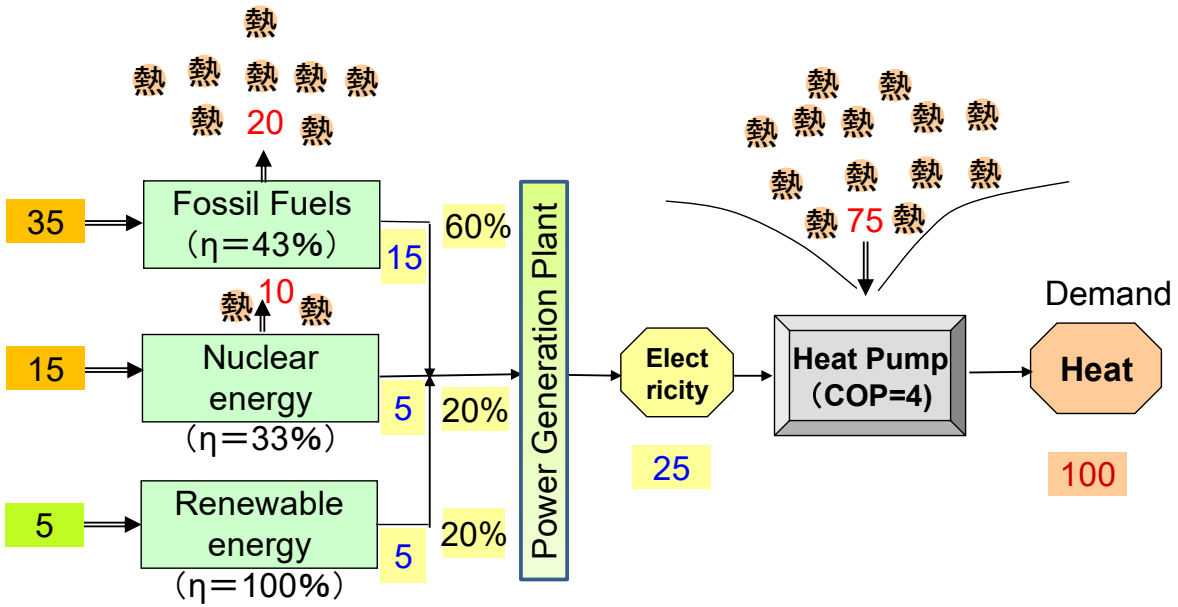
●Effective steam use is estimated by 54% in average
(based on practical data of 29 different factories)



Source：JEHC, "Booklet of Industrial Heat Pump Application"

Energy Saving Potential and Renewable Energy Contribution of HP





Share of renewable energy ＝100－（35＋15）＝50

Samples of IHPs Application
(Good Practices)

Literatures for 112 Samples of Good Practices

Literature	Sample Number	
Examples of heat pump installation in industrial sector, JEHC	No.1～19	No.1～26, 49 (Annex 35/13) No.27～48, 50～98 (new samples for Annex 48) No.1～98 (MHP or MVR)
Future Ages, Use More Electricity for Production Vol.5,JEHC (Vol.2,3.4.5)	No.20～48	
ELECTROHEAT HANDBOOK, JEHC, 2011	No.49～62	
Journal of Electro-heat, JEHC	No.63～88	
Seminar materials of JSRAE	No.89～96	
Process Innovation of Food Factory, JEHC	No.97	
Catalogue of Ebara Refrigeration Equipment & Systems Co., Ltd.	No.98	
HEAT PUMPS (1987 IEA HP Conference)	No.99 – 108	No.99～112 (AHP)
Hitachi Hyouron Vol.89 No03 (2007) Vol.92 No03 (2010)	No.109 – 112	
Total	112	

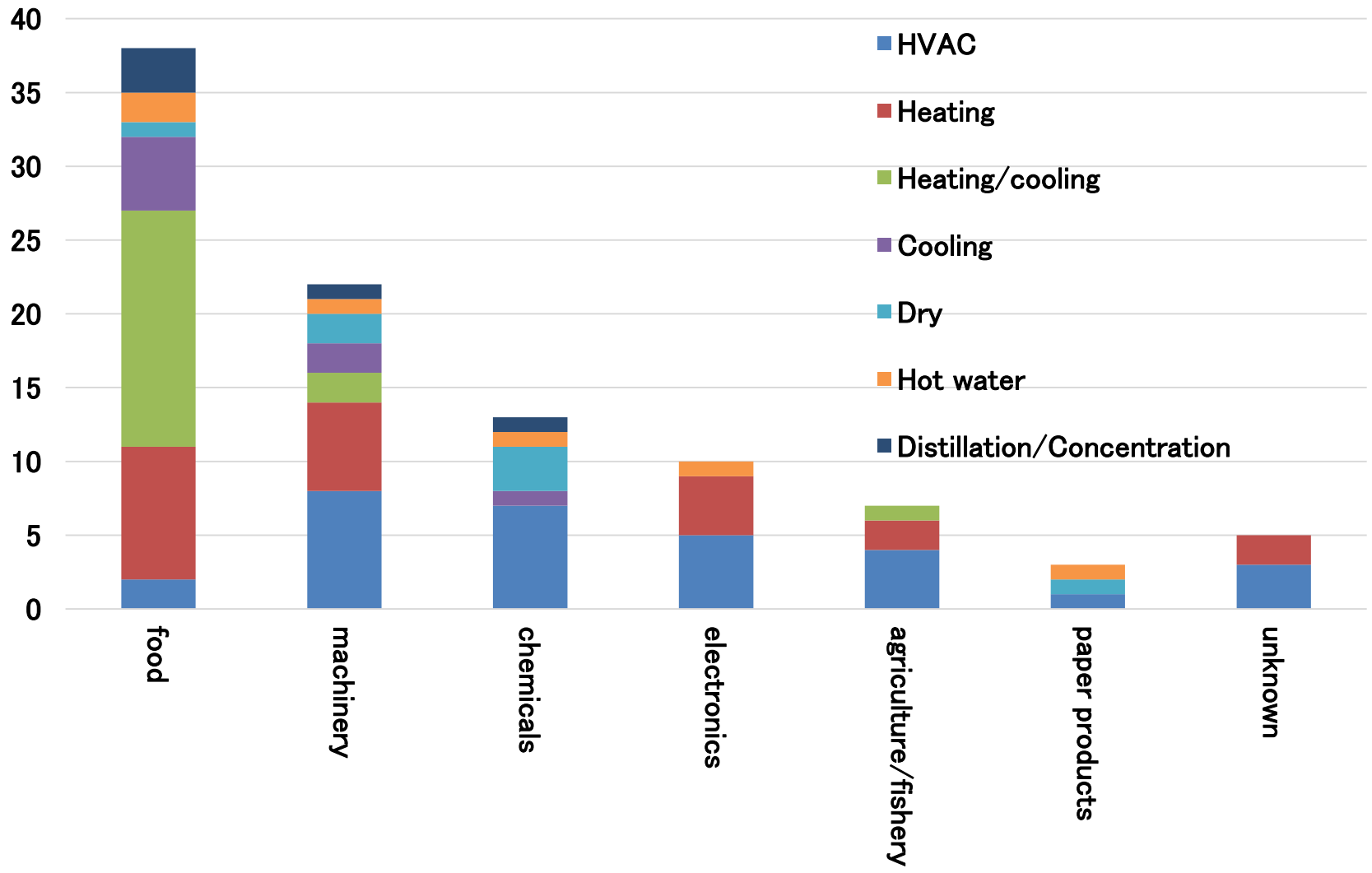
Information Items of Good Practices

- 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) [℃]
  - Heat source (In and Out) [℃]
  - Heat storage
- Effects of installation
  - Energy savings
  - CO_2 emission savings
  - Energy cost savings
  - Additional effects

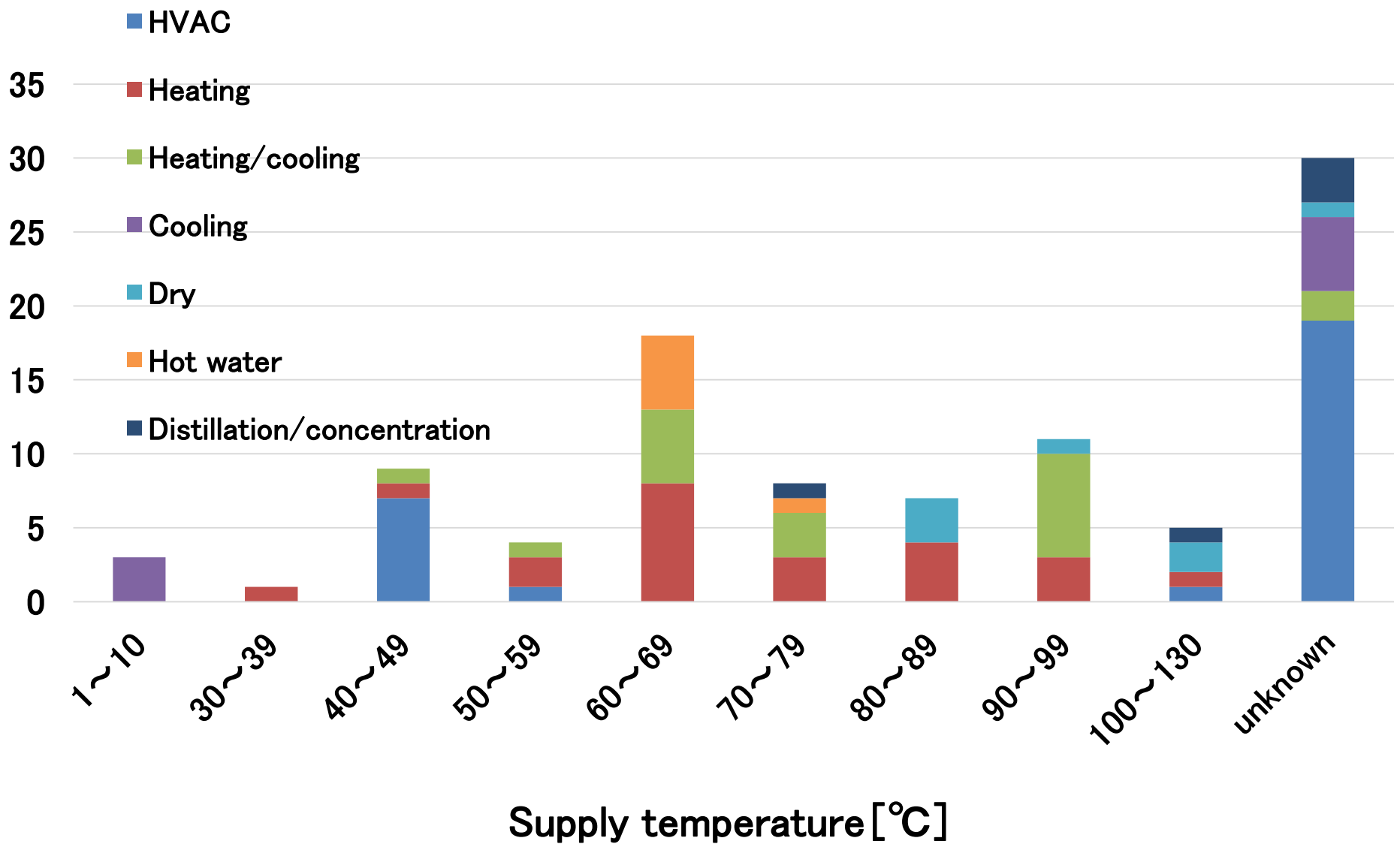
Information Matrix of Good Practices

No	.Annex	Title of project	Referance	Industry	Process applied	Location (Japan)	Year of installation	User (company)	HP manufacturer /constructor /consultant	HP technology	HP system	Working fluid (Refrigerant)	Compressor	Heating/cooling capacity (kW)	Heat Sink IN (℃)	Heat Sink OUT (℃)	Heat source/ heat sink	Heat Source IN (℃)	Heat Source OUT (℃)	Heat storage	Savings energy (%)	Savings CO2 emissions (%)	Savings energy cost (%)	additional effects
1	Annex 35/13	Electric load leveling by ice storage system in cheese production process	Examples of heat pump installation in industrial sector, JEHC	Food	Cooling	Hokkaido	2007	Yukijirushi megumilk co.Ltd.	Hitachi Appliences, Inc	MHP	Water cooled chiller	R134a	turbo				Cooling only			Ice				Saving of contract load by load leveling
2	Annex 35/13	Simultaneous heating & cooling system in food production line	Examples of heat pump installation in industrial sector, JEHC	Food	Heating/Cooling	Hyougo	2010	Kosmos Food co.Ltd.	MAYEKAWA MFG. CO., LTD	MHP	Water-source hot water supply HP	CO2	reciprocate	276		90	Simultaneous heating & cooling		10	Cold/hot water		87	80	Shortening of working hours by heat storage system
3	Annex 35/13	Simultaneous heating & cooling system in noodle production process	Examples of heat pump installation in industrial sector, JEHC	Food	Heating/Cooling	Okayama	2009	Tamura Seimen Ltd.	MAYEKAWA MFG. CO., LTD	MHP	Water-source hot water supply HP	CO2	reciprocate	56	17	90	Simultaneous heating & cooling	0	−5	Ice/hot water		31	25	Shortening of working hours by heat storage system
4	Annex 35/13	Reduction of boiler load by heating supply water in scalder process	Examples of heat pump installation in industrial sector, JEHC	Food	Hot Water Supply	Kagoshima	2008	Kagoshima Kumiai Chicken Food co.Ltd.	MAYEKAWA MFG. CO., LTD	MHP	Air-source hot water supply HP	CO2	reciprocate	80		65	Outdoor air			Hot water		65	88	Shortening of working hours by heat storage system
5	Annex 35/13	Steamless heating in broke pulper process	Examples of heat pump installation in industrial sector, JEHC	Paper products	Hot Water Supply	Shizuoka	2009	Oji Tokushushi c.Ltd.	Mitsubishi Electric Corporation	MHP	Air-source hot water supply HP	CO2	scroll	320		75	Outdoor air			Hot water	42	50		
6	Annex 35/13	Electric load leveling by water heat storage system in coolong process of reaction tank	Examples of heat pump installation in industrial sector, JEHC	Chemicals	Cooling	Saitama	2005	Saiden Chemical co. Ltd.	Toshiba Carrier Corporation	MHP	Air-cooled chiller	R410A	rotary	880			Simultaneous heating & cooling		5	Cold water	48	63		Space saving by module connection system
7	Annex 35/13	Introduction of heat pump with hot gas source in dry process of formed styrol	Examples of heat pump installation in industrial sector, JEHC	Chemicals	Drying	Tochigi	2010	Dia Chemicals co. Ltd.	MAYEKAWA MFG. CO., LTD	MHP	Hot air generation HP	CO2	reciprocate	110		90	Exhausted hot water of shaping machine				48	63		Improving safety by electricity utilization (Improving working condition at night)

Number of Process Applied to Industrial Sector (N=98)

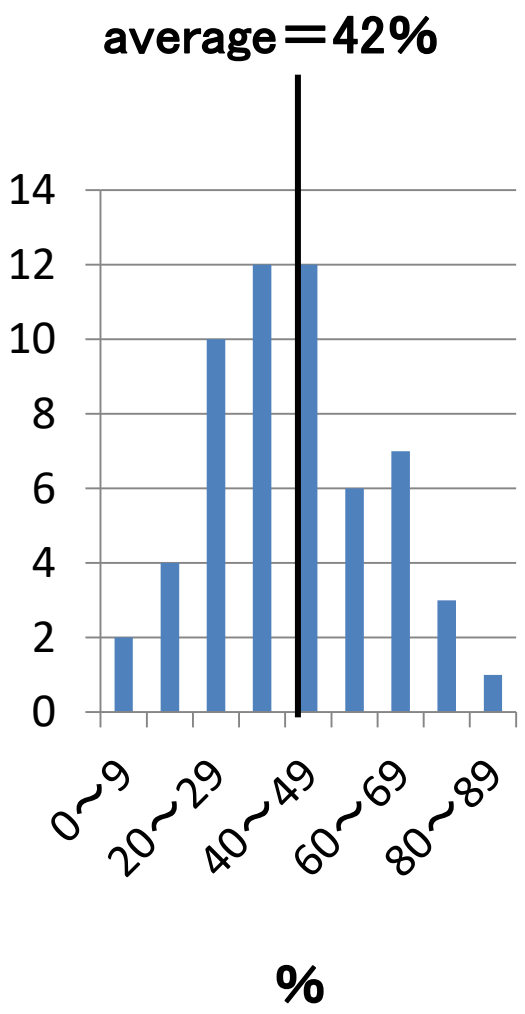


Number of Process Applied for Supply Temperature

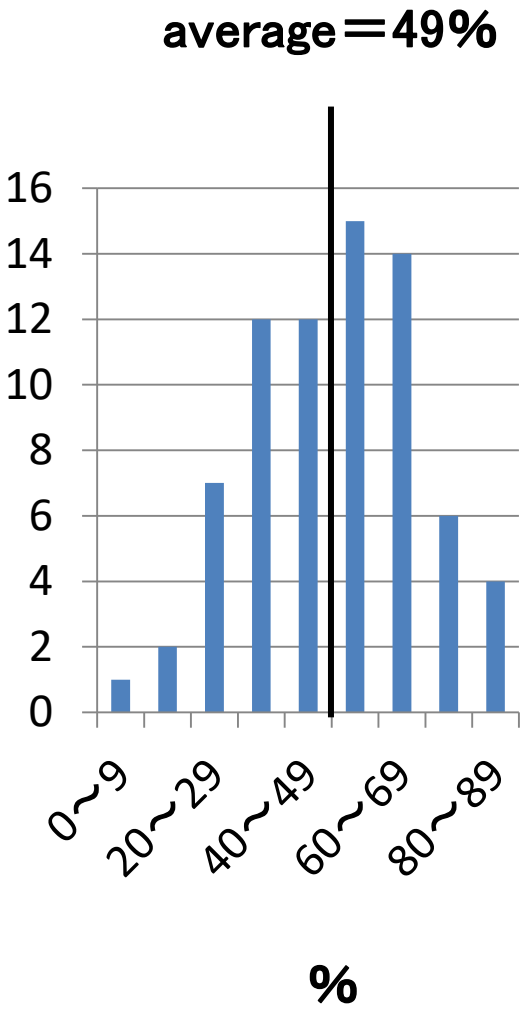


Effect of IHPs Application

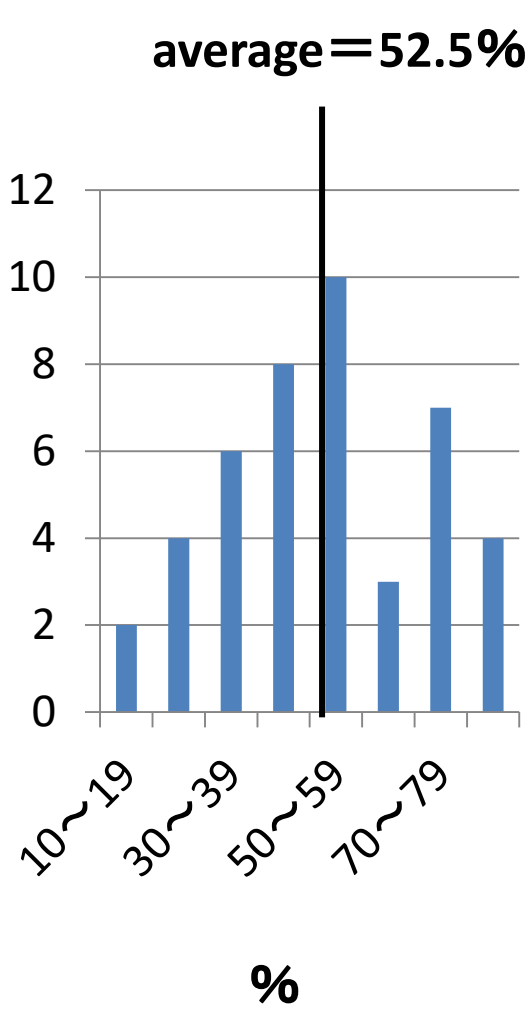
Primary energy saving



CO_2 emission saving

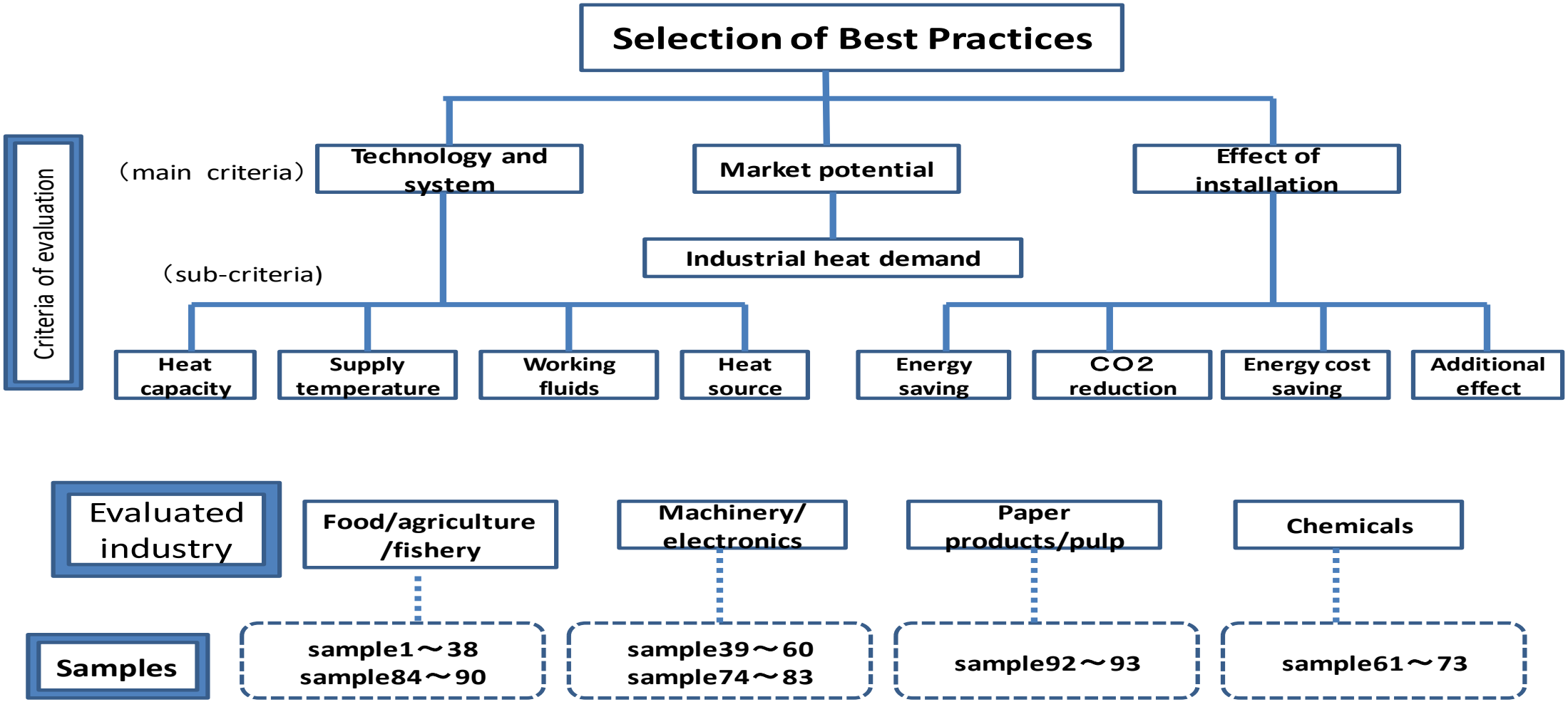


Energy cost saving



Selection of Best Practices

Structure of Hierarchy to Select Best Practice



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

①Heating/Cooling capacity ②Supply temperature ③Low GWP working fluids

④Simultaneous heating and cooling／Heat recovery

(3) Effects of application

①Energy saving ②CO_2 reduction ③Energy cost saving ④Additional effects

●【Pairwise comparison between j and k criteria】

Value of a_{jk}	Interpretation
1	j and k are equally important
3	j is more important than k
5	j is strongly more important than k

●【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

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

* 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

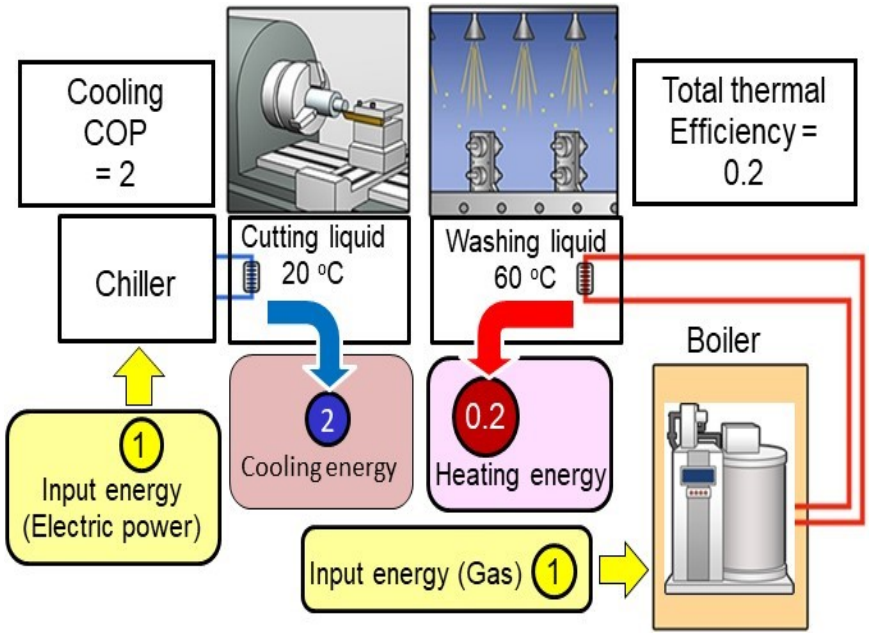
Best Practice in Machinery Industry (No.21)

Process Outline

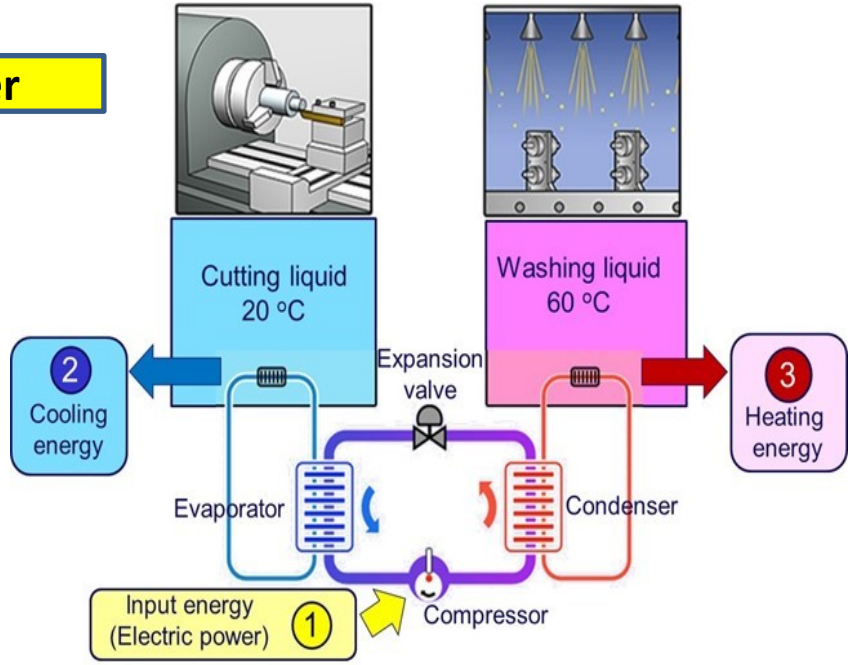
No	21
Industry	Machinery（Parts production of vehicle）
Process applied	Cutting, Washing
Heat source	Simultaneous heating/cooling （heating65℃、cooling15℃）
Objective	Eliminating the conventional boiler system
HP system	Water-water/Air-water heat pump (6+8=14 units) Heating capacity: 22kW/unit (6 units), 43kW/unit (8 units) Refrigerant : R134a
Effects	CO2 reduction 80%, energy cost saving: 79%, Pay back time : 5 year

- Simultaneuos 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.

Before



After



Best Practice in Machinery Industry (No.21)

Effects of Application

Saving of energy, steam and CO_2 emission

	Before	After	Difference
Electricity consumption[MWh/y]	193	570	＋377（+195%）
Fuel consumption [kL/y]	470	0	－470（－100%）
Steam consumption [kL/y]	6,953	0	－6,953（－100%）
CO2 emission [ton-CO2/y]	1,364	270	－1,094（－80%)

Economical effect

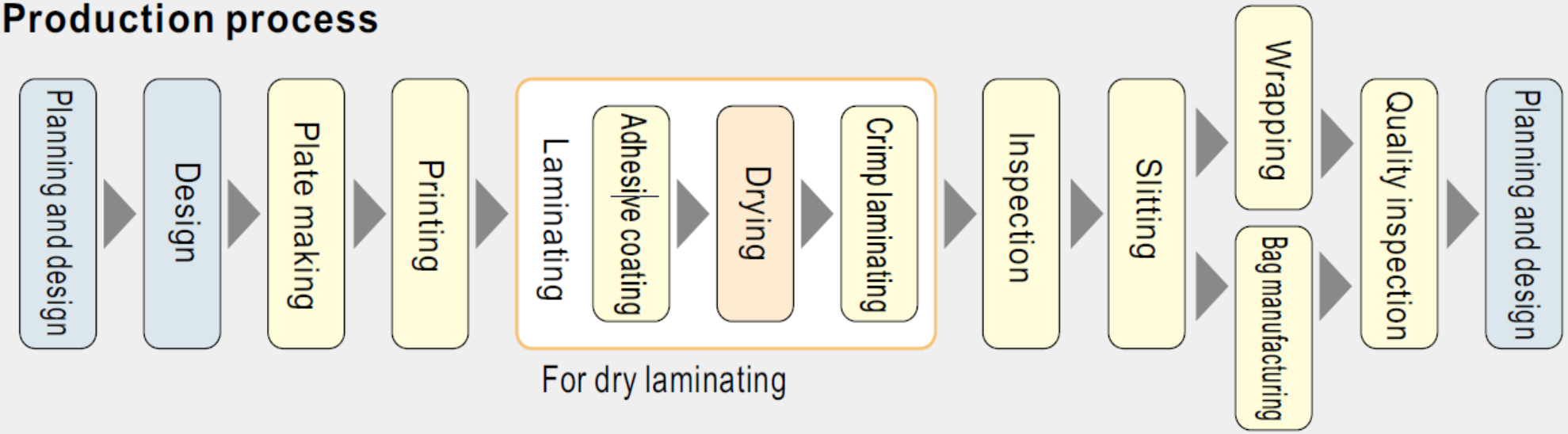
	Before (old)	After (new)	Difference
Investment	・Boiler/piping 75.3[million yen] ・Steam heating system 10.5[million yen] ・Cooling system 50.4[million yen] Total: 136.2[million yen]	Heat pump system (14 units) 91[million yen]	－45.2 [million yen]
Operation cost	・Electric bill（193MWh） 2.34[million yen/y] ・Heavy oil charges 28.1[million yen/y] ・Water charges 2.45[million yen/y] Total 32.9[million yen/y]	・Electric bill（570MWh） 6.89[million yen/y]	－26 [million yen/y] （－79%）

Best Practice in Chemicals Industry (No.32)

Process Outline

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

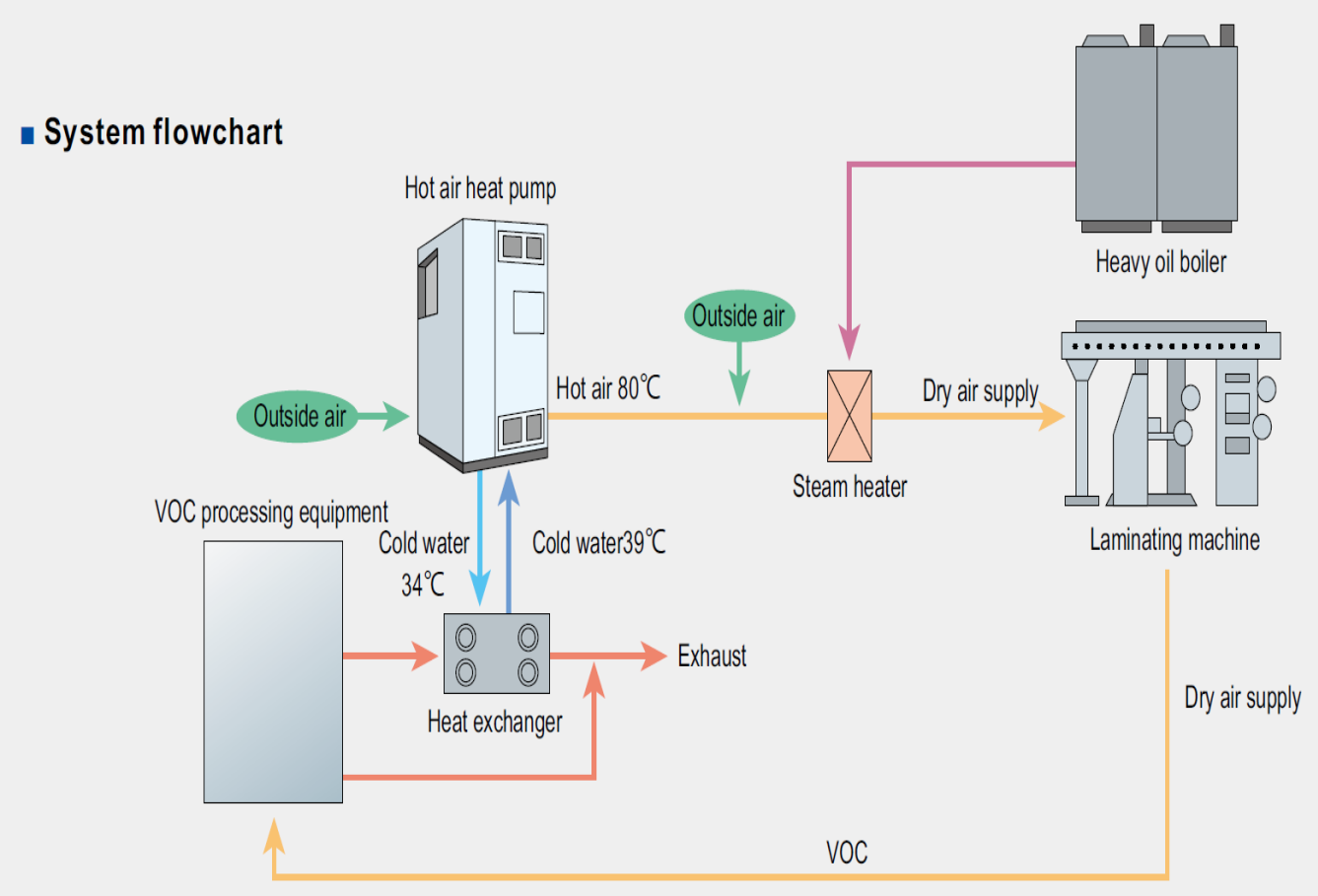
■ Production process



Best Practice in Chemicals Industry (No.32)

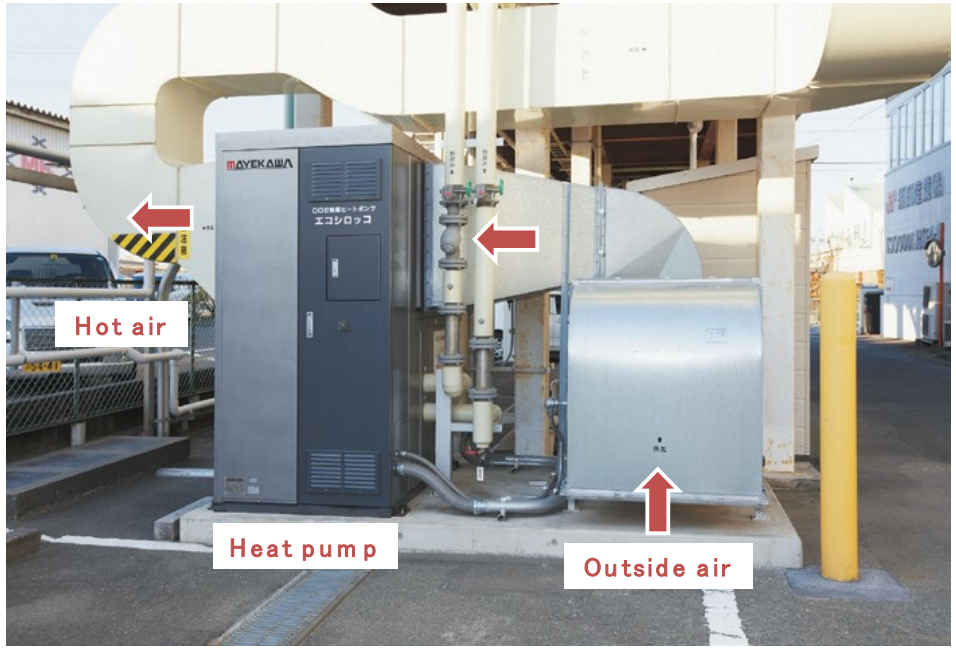
System Flow and Effects of Application

System flow



Effects of application

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

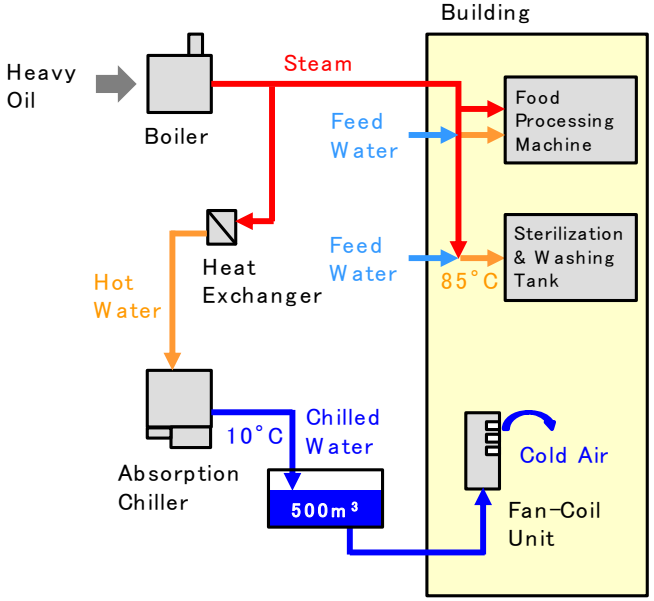


Best Practice in Food Industry (No.2)

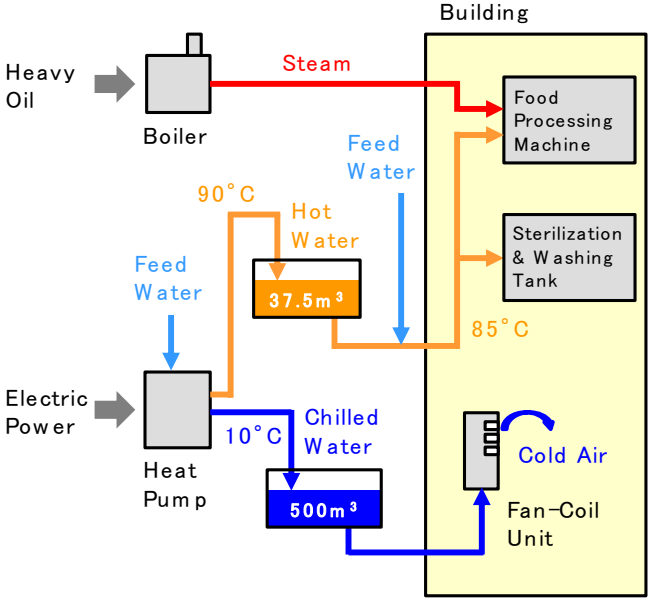
Process Outline

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

Before



After

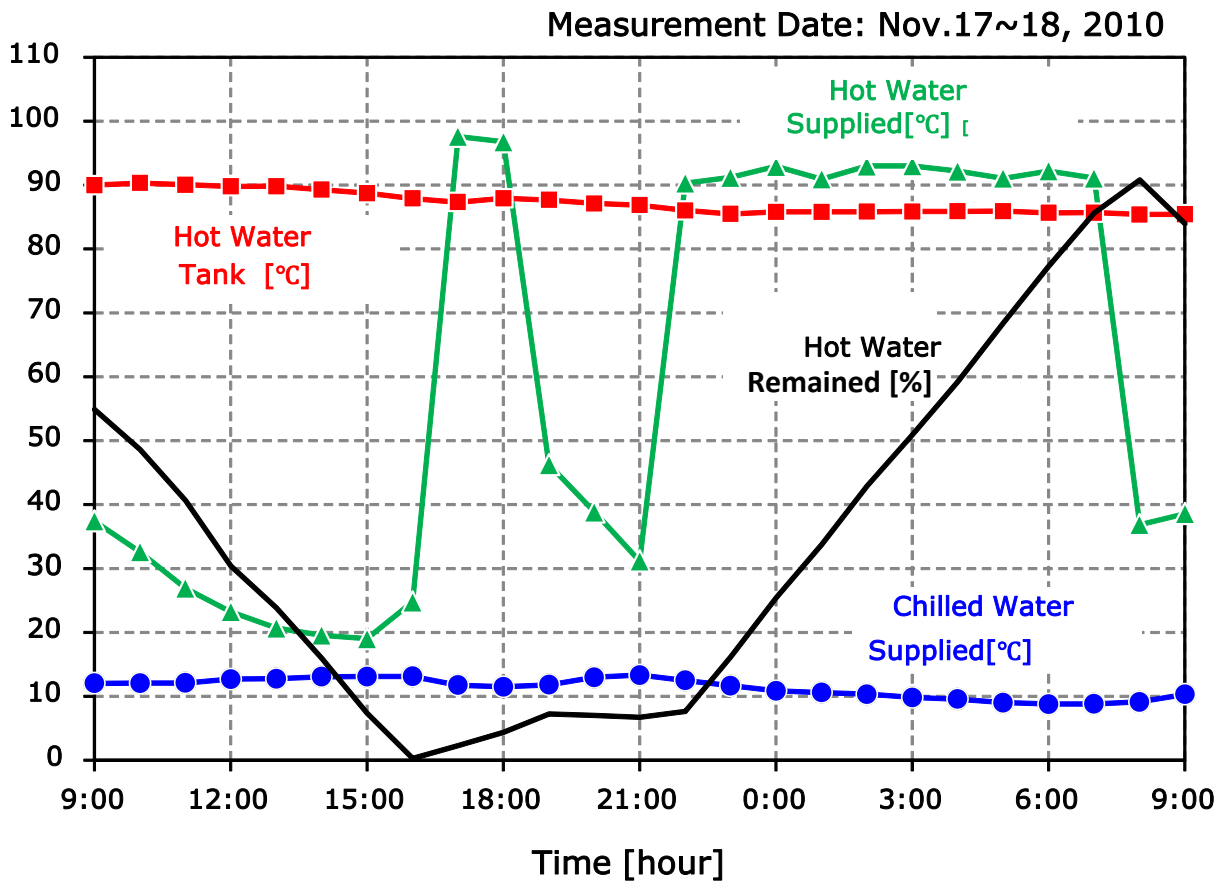


Process	Before →	After	Process
Food Processing Machine	Boiler A (Steam: 2ton/h)	Boiler A (Steam: 2ton/h)	Food Processing Machine
	Boiler A (Steam: 2ton/h)	Boiler A (Steam: 2ton/h)	
	Boiler B (Steam: 0.7ton/h)	Boiler B (Steam: 0.7ton/h)	
Sterilization & Washing Tank	Boiler B (Steam: 0.7ton/h)	Heat Pump (Hot Water: 80kW)	Sterilization & Washing Tank
	Boiler B (Steam: 0.7ton/h)	Heat Pump (Hot Water: 80kW)	
Building A/C	Absorption Chiller (Chilled Water: 500kW)	Heat Pump (Hot Water: 80kW)	Building A/C

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

Step1

Understanding of energy use at a production process

【Main items of energy use】
・heating temperature
・heat piping distance
・simultaneous heating & cooling
・exhausted heat of low temperature
・heat loss
・maintenance

Step2

Selection of heating & cooling process

【Main items of a process】
・process applied
・heating flow of the process
・temperature of the process
・type of heating

Step3

Investigation of heating capacity

【Main items of a capacity】
・daily and seasonal load of heat demand and peak demand with time
・Decision of appropriate heating capacity from the demand

Step4

Investigation of heat source and heat balance

【Main items of heat balance】
・simultaneous H/C
・exhausted heat
・outdoor air
・heat balance of demand and supply

Step5

Decision of total design framework for HP system and capacity

【Main items of HP system】
・fluctuation of heating load
・renewal plan of the conventional facility
・Necessity of heat storage

Thank you for your attention!