Good and Best Practices of Industrial Heat Pumps in Japan (Japanese Report for Task 1 and 2)

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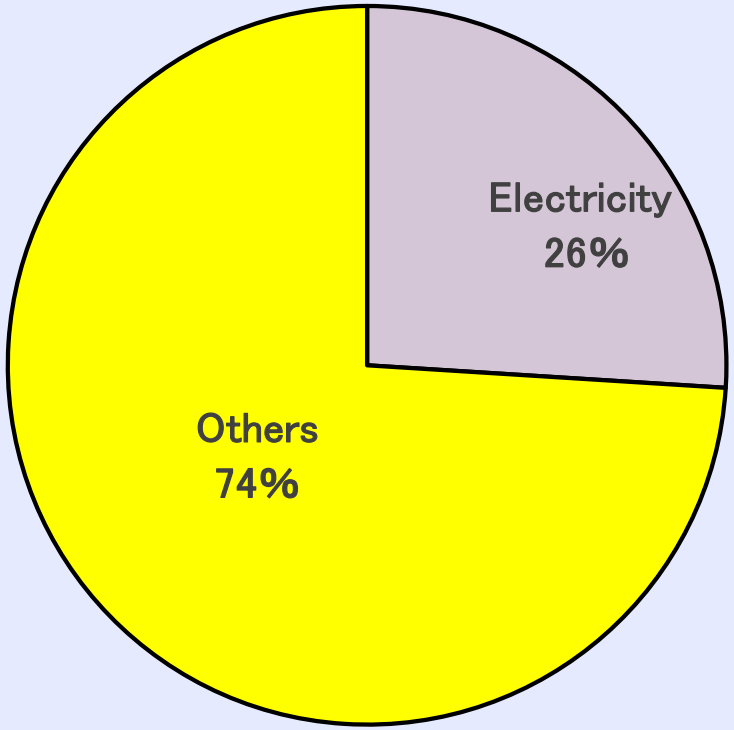
Content

- Heat Demand in Industry
- Heat Use and Role of Heat Pump in Industry
- Samples of IHPs Application (Good Practices)
- Selection of Best Practices
- Barriers for Practical Application of IHPs and Countermeasures to overcome the barriers

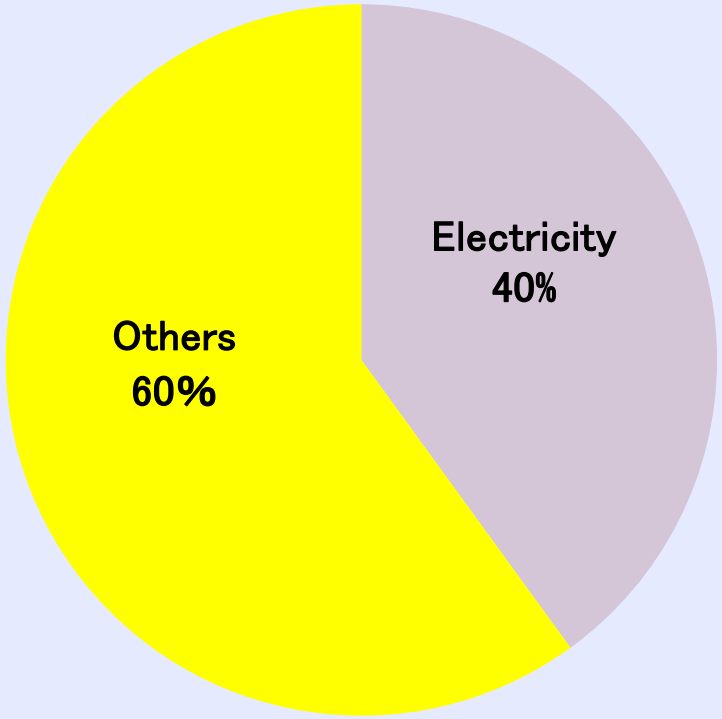
Heat Demand in Industry

Final Energy Consumption and CO_2 Emission（FY2016）

Final energy consumption
11.91EJ

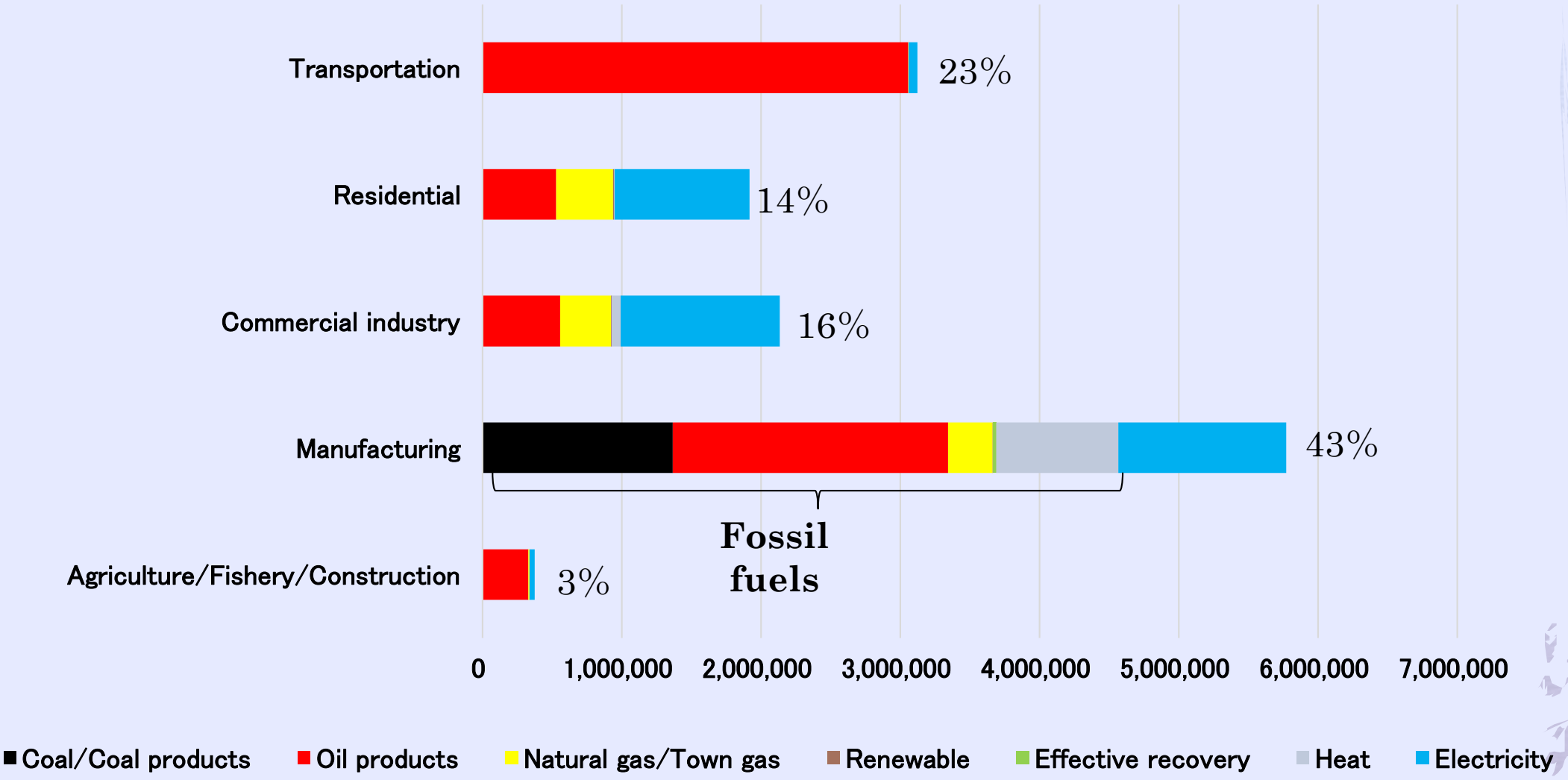


CO_2 emission
1.15 billion ton



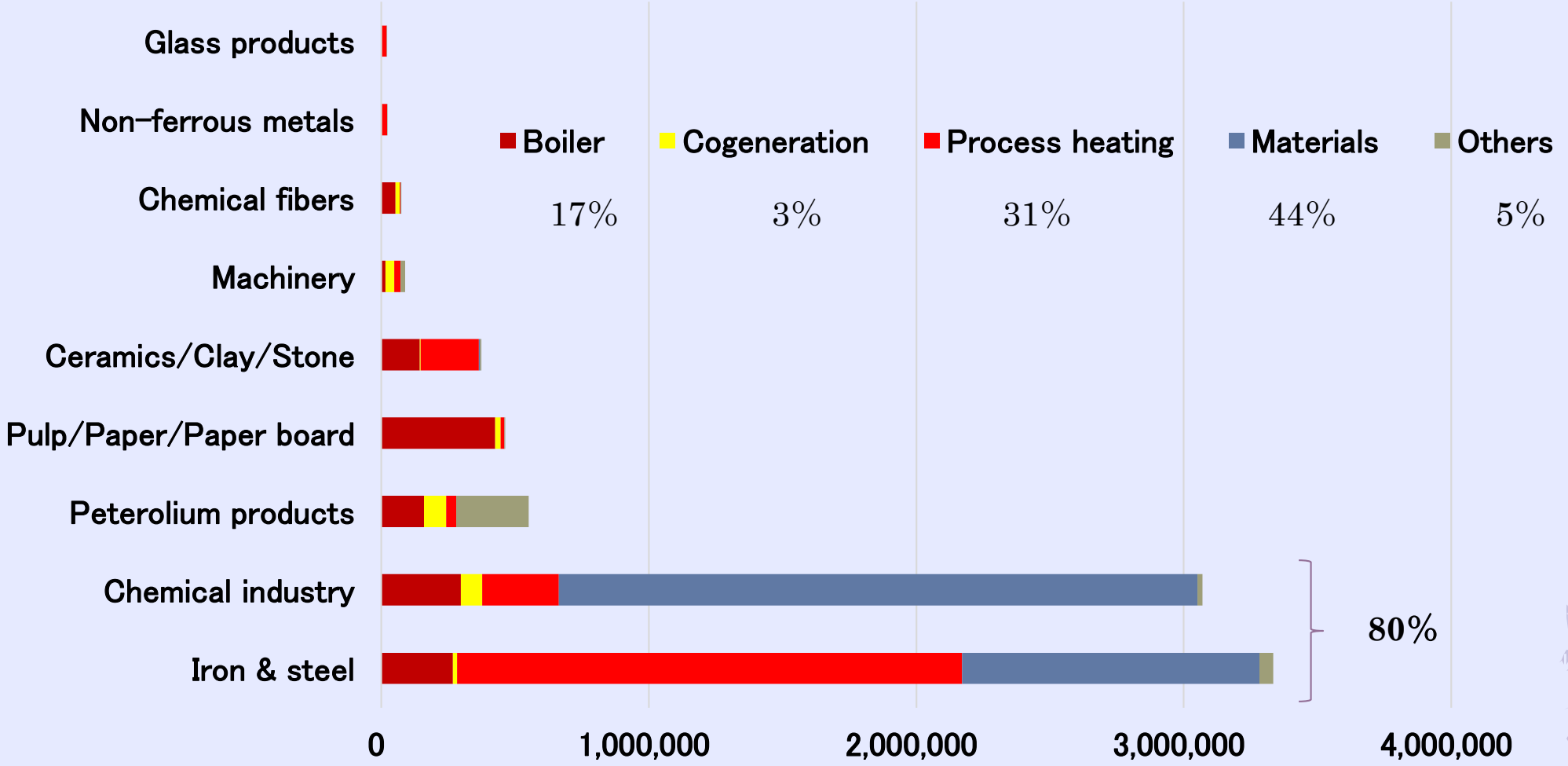
Energy Consumption of Different Sectors

(Source: General Energy Statistics, FY2016)



Application of Fossil Fuels in Manufacturing Industry

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



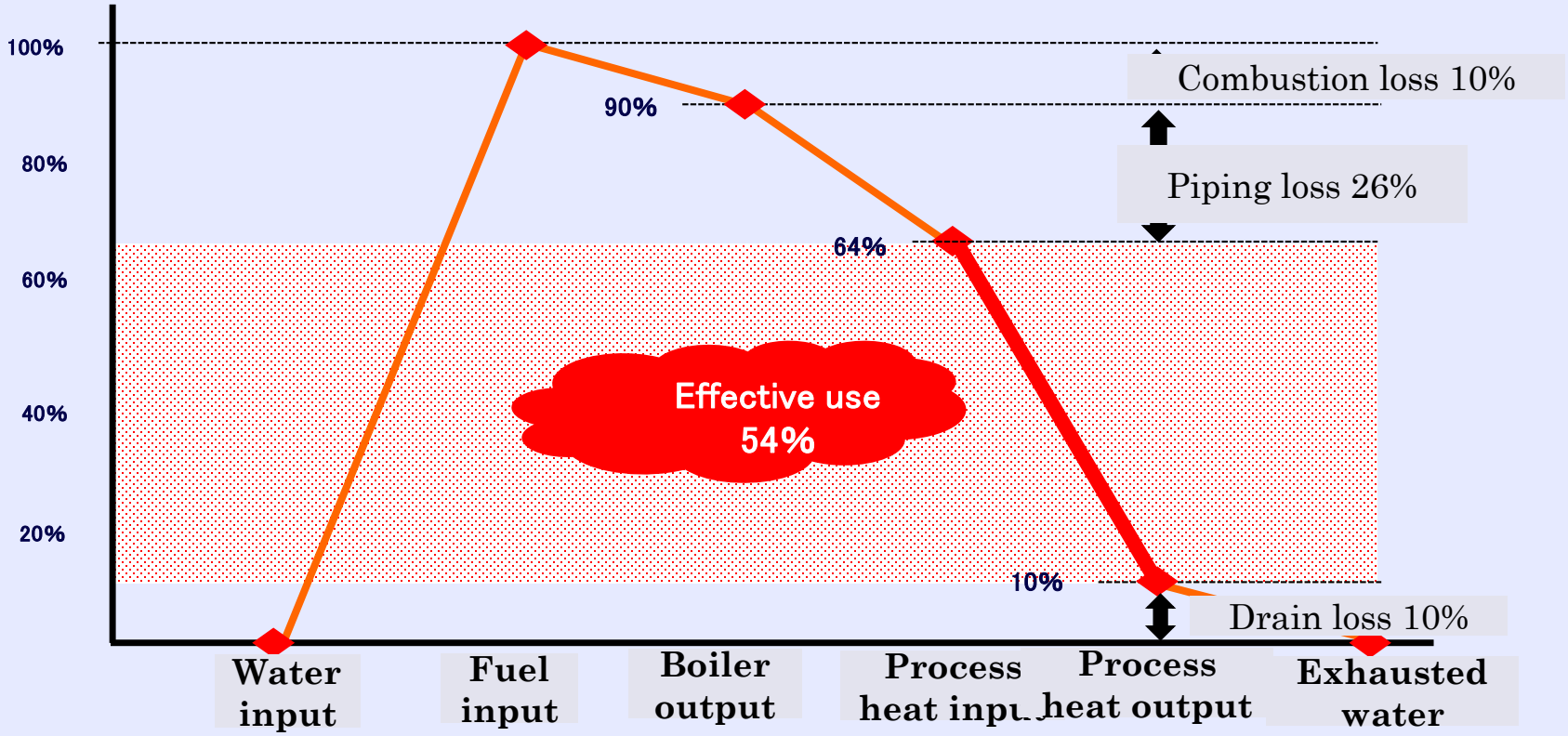
Heat Demand in Industry for Market Potential of IHPs

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 Use and Role of Heat Pump in Industry

Large Heat Loss in Production and Transportation Stages of Factory

- Effective steam use is estimated by 54% in average from practical data of 29 factories survey.



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

Problems of Heat Use in Factory

- **A large amount of heat wasted at the low temperature**

  Processes in a factory generate exhausted heat in different forms.
  Most of input energy in a factory is finally wasted as low level of heat.

- **Low effective use of steam boiler system**

  Practical steam supply system has nearly 50% of heat loss generated in processes of boiler, piping and drain.

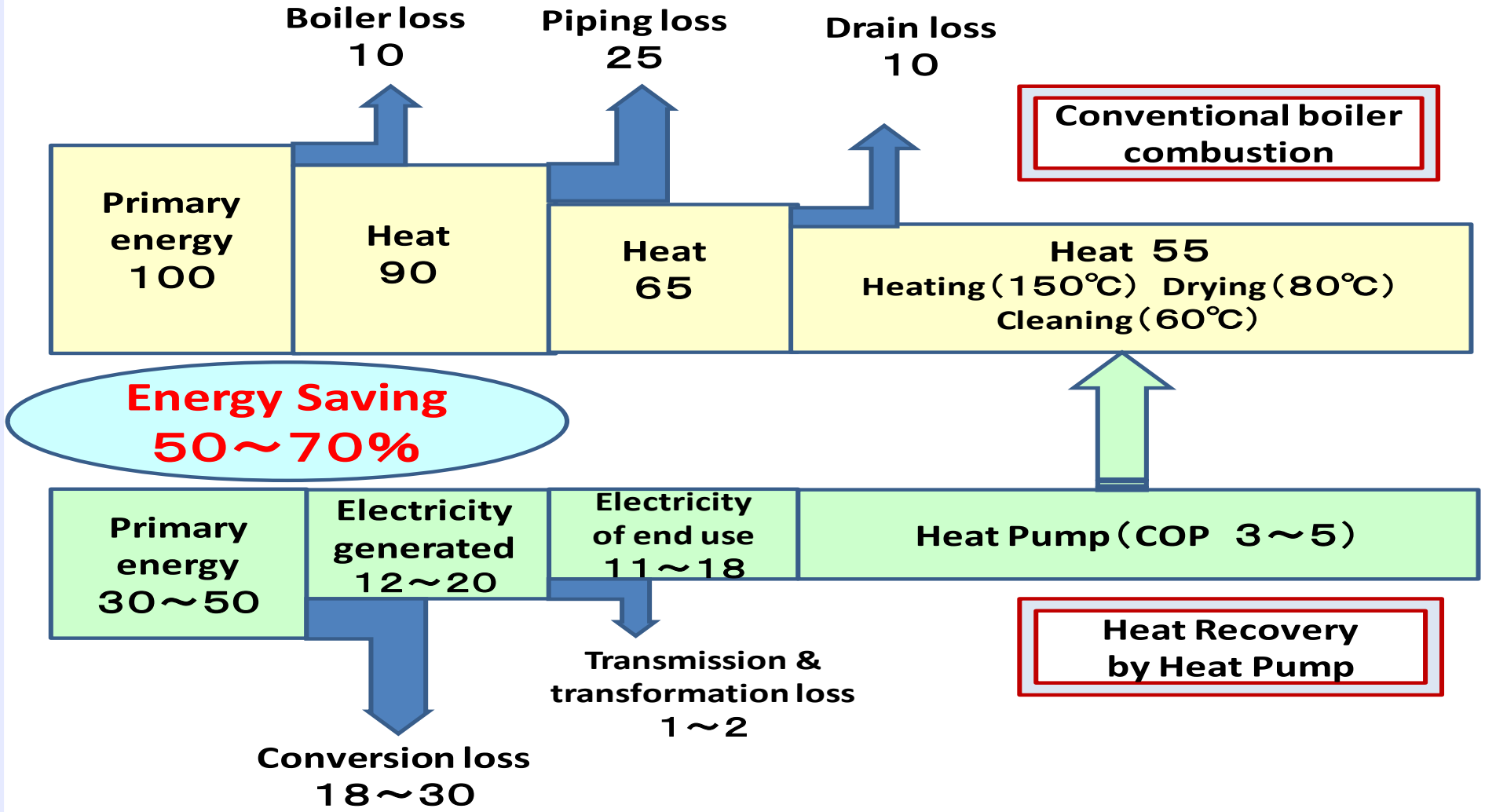
- **Uniform temperature of heat supply**

  Heat in a factory is used for heating, drying, washing, etc. at different heat levels.
  However, heat of constant temperature is supplied for those purposes.

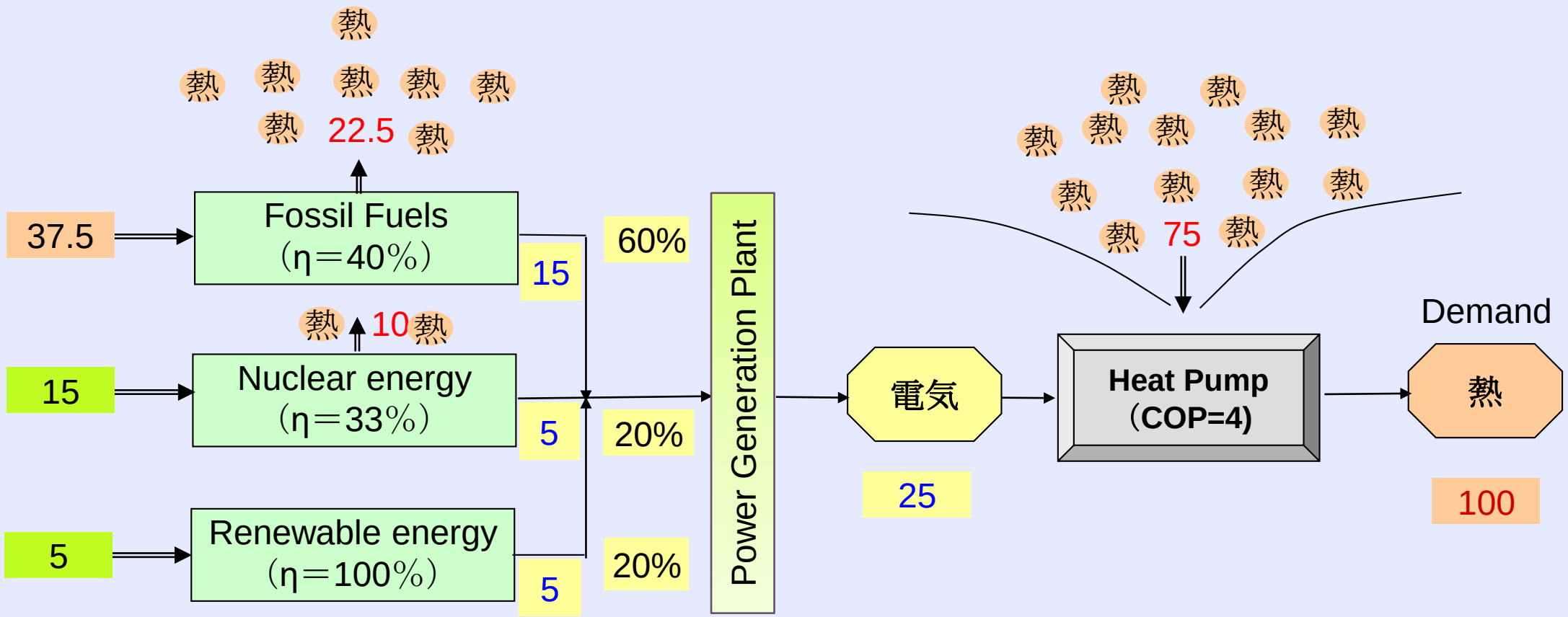
- **Separate heat supply for heating and cooling**

  Different technologies are separately adopted for heating and cooling.
  Simultaneous heating and cooling enables in production processes by HP application.

Large Primary Energy Saving achieved by IHP Application



Heat Pump is Renewable Energy Technology
（Power plant :fossil fuels 60%, renewable 20%, nuclear 20%)



Share of renewable energy ＝100－（37.5＋15）＝47.5

Samples of IHPs Application
(Good Practices)

Literatures for 112 Samples of Good Practices

Literature	Sample Number	Number of Annex 35/13
Examples of heat pump installation in industrial sector, JEHC	No.1～19	No.1～19
Future Ages, Use More Electricity for Production Vol.5,JEHC (Vol.2,3.4.5)	No.20～48	No.20～26
ELECTROHEAT HANDBOOK, JEHC, 2011	No.49～62	No.49
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	(MHP or MVR for 98 samples)
HEAT PUMPS (1987 IEA HP Conference)	No.99 – 108	(AHP)
Hitachi Hyouron Vol.89 No03 (2007) Vol.92 No03 (2010)	No.109 – 112	(AHP)
Total	112	27

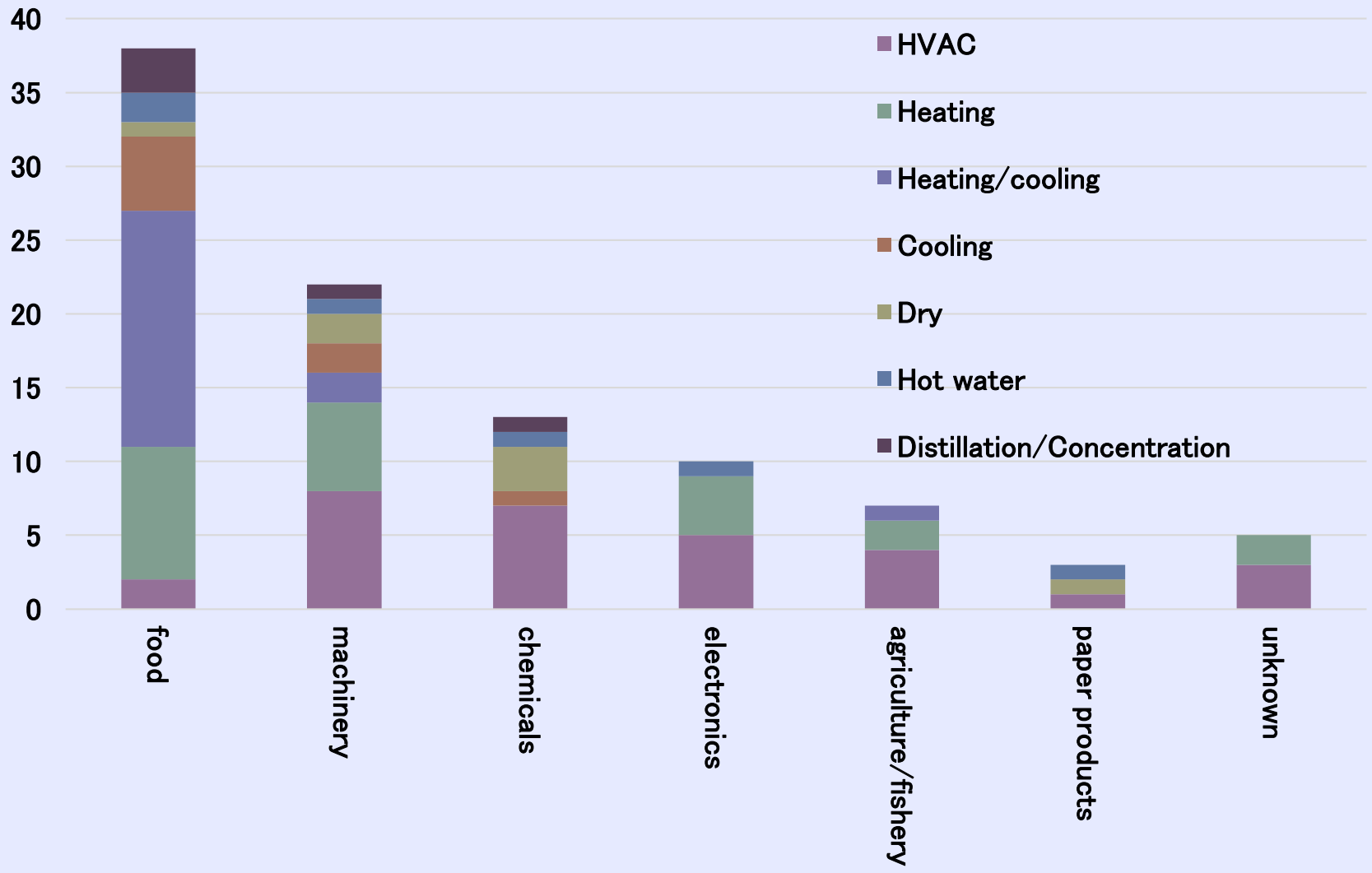
Matrix Items for Sample Information

- 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

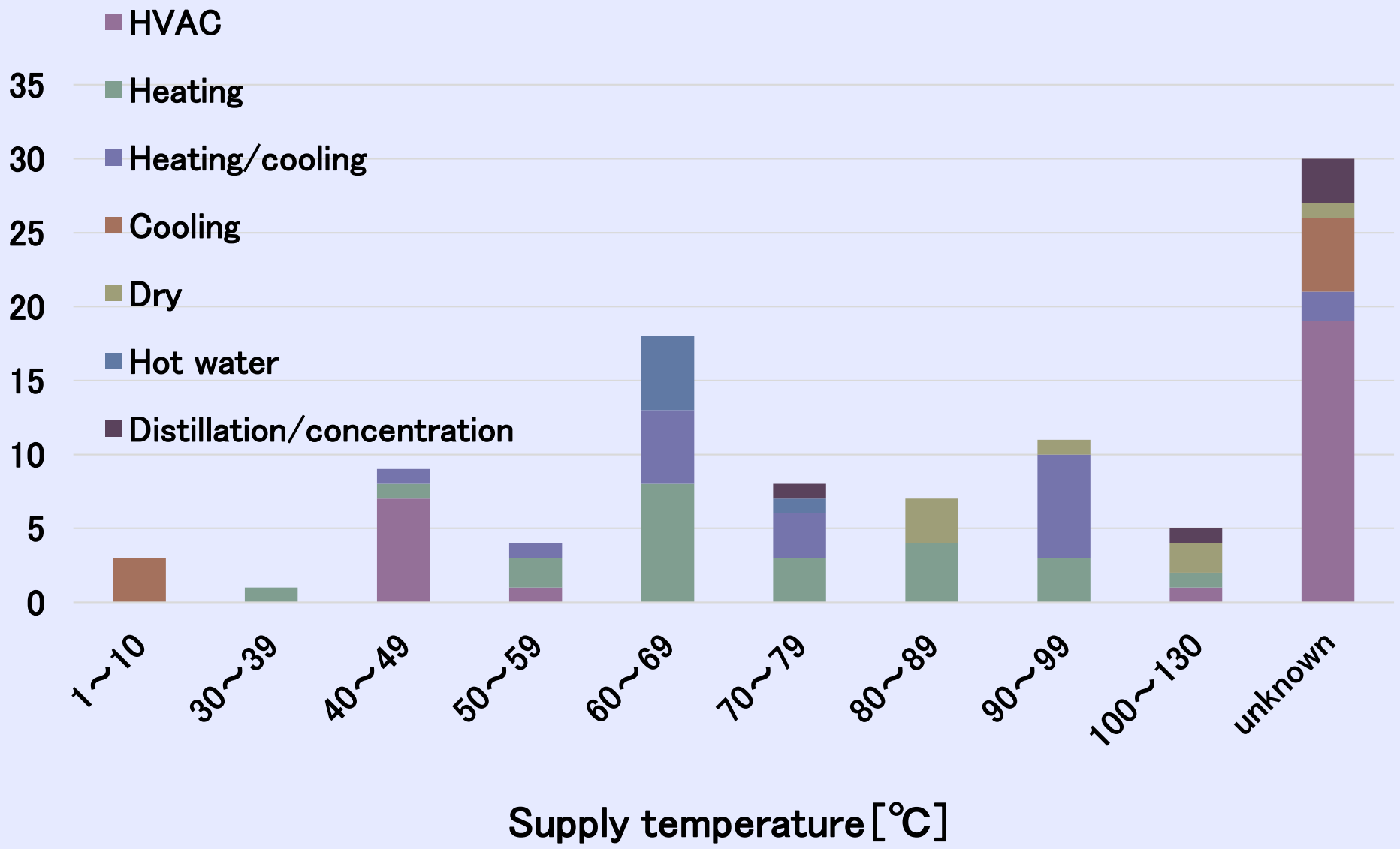
Matrix of Good Practice Information

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 for Industrial Sector (N=98)

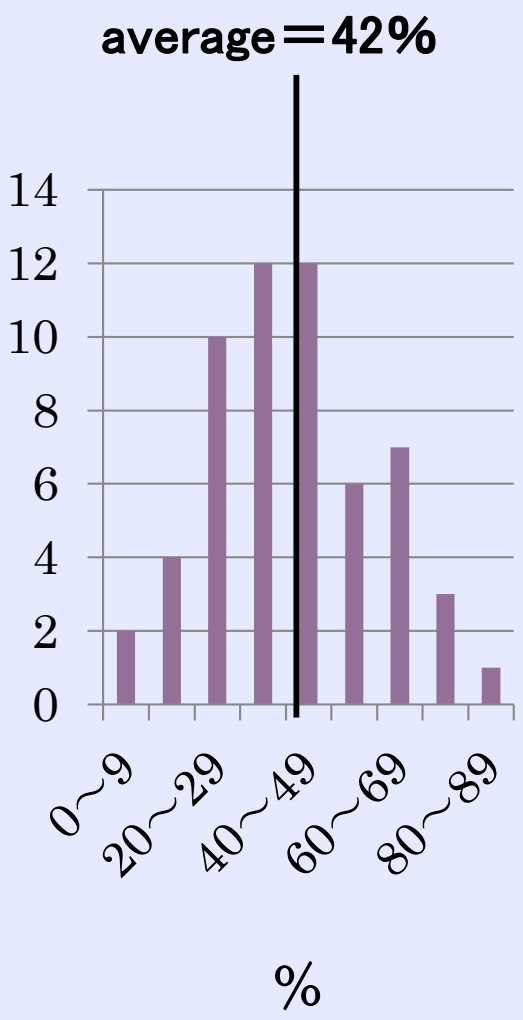


Number of Process Applied in Different Supply Temperature

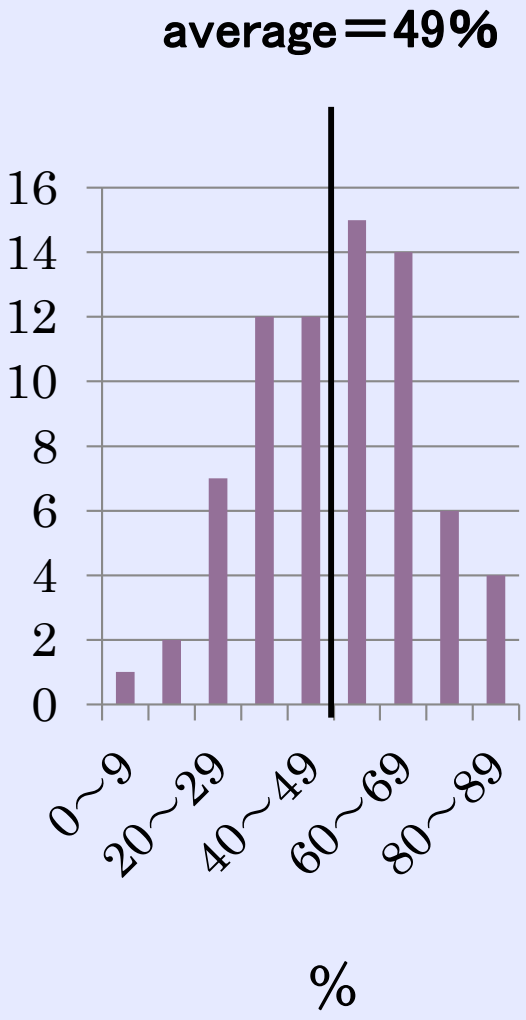


Effect of IHPs Application

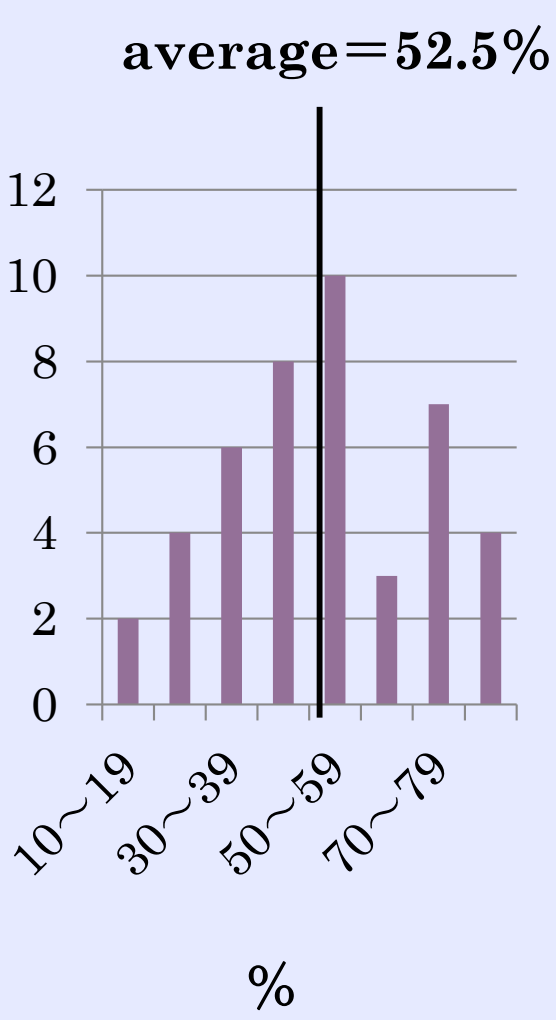
Primary energy saving



CO2 emission saving

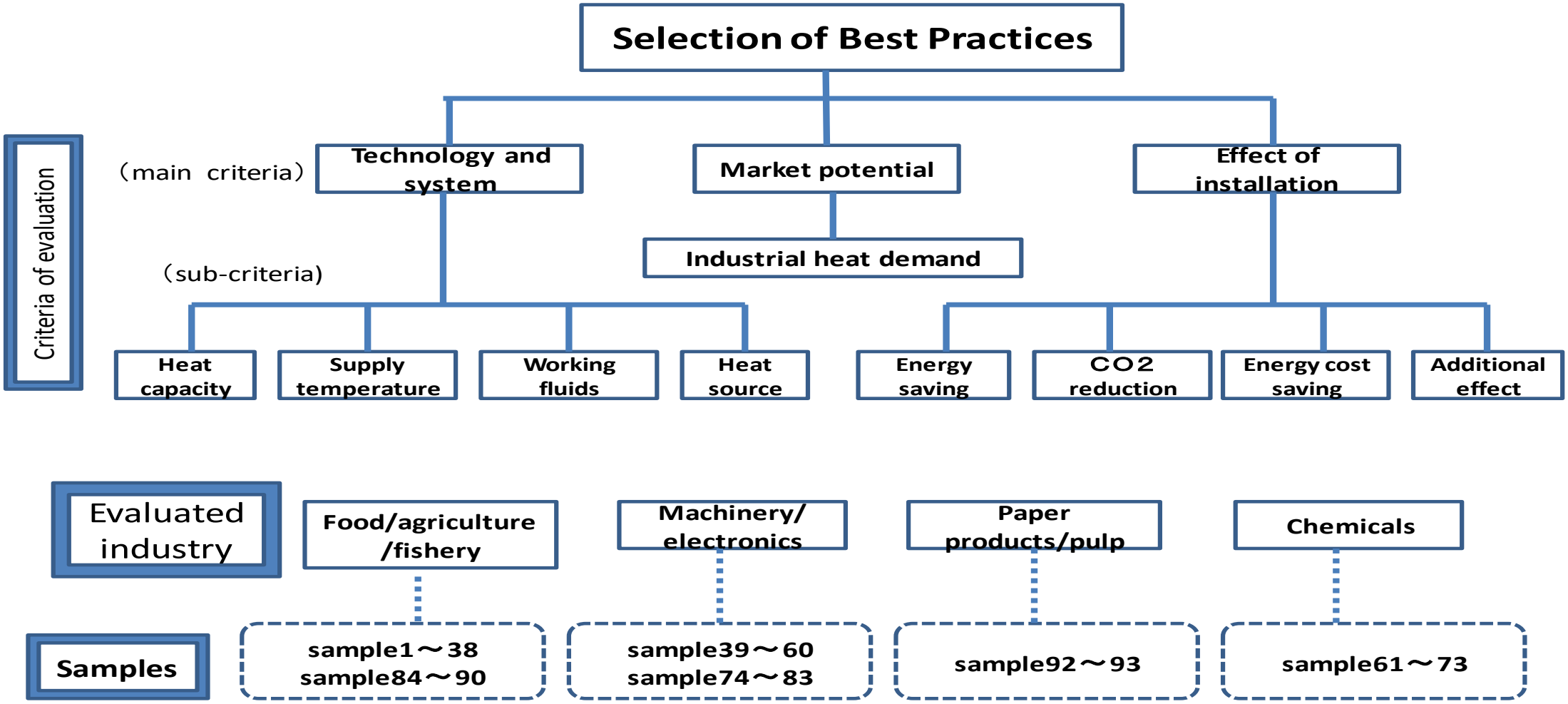


Energy cost saving



Selection of Best Practices

Structure of Hierarchy for Selection of Best Practice



Superiority Evaluated for Criteria Items

Items		Superiority		
		High (3 points)	Medium (2 points)	Low (1 point)
Market potential (Heat Demand of auto steam generation)		Large (over 100,000TJ)	Moderate (10,000～100,000TJ)	Small (below 10,000TJ)
Technology and system	Heating/cooling capacity	over 1MW	100kW－1MW	less 100 kW
	Supply temperature	over 90℃	60- 90℃	less 60℃
	low GWP working fluid	Non freon	Low GWP	high GWP
	Simultaneous heating/cooling or waste heat recovery	Both application	One application	No application
Effects	Savings energy	over 60%	30-60%	less 30%
	Savings CO2 emissions	over 70%	30-70%	less 30%
	Savings energy cost	over 70%	40-70%	less 40%
	Additional effects (Number of effects)	More than two	Two effects	Less than one

Evaluation of Criteria weighted by Different Scenario

●【Evaluation method for weight decision】⇒ 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 ②CO2 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 of market potential

Scenario 2：Priority of technology and system

Scenario 3：Priority of application effects

Best Practices evaluated 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 for different industries

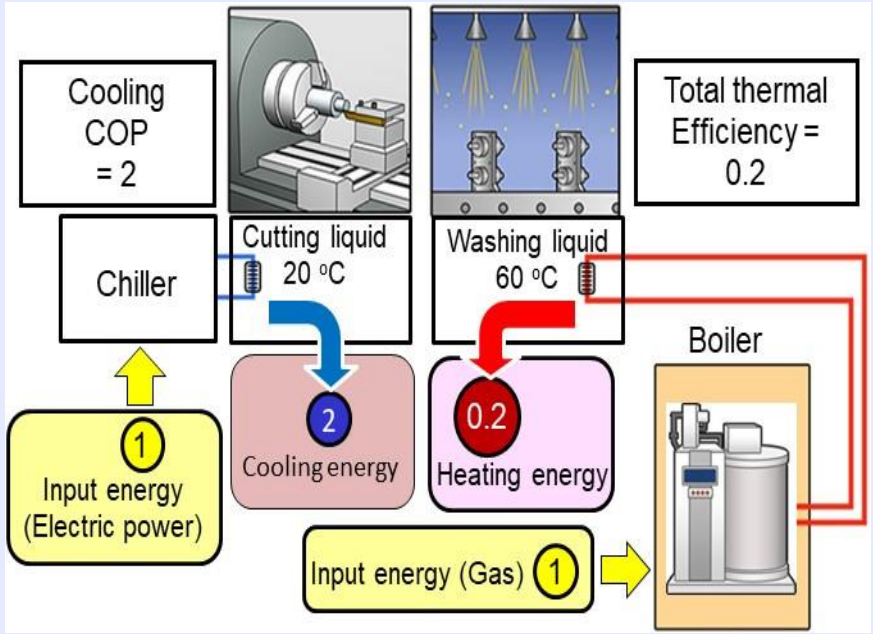
Best Practice of Machinery Industry (No.21)

Process Outline

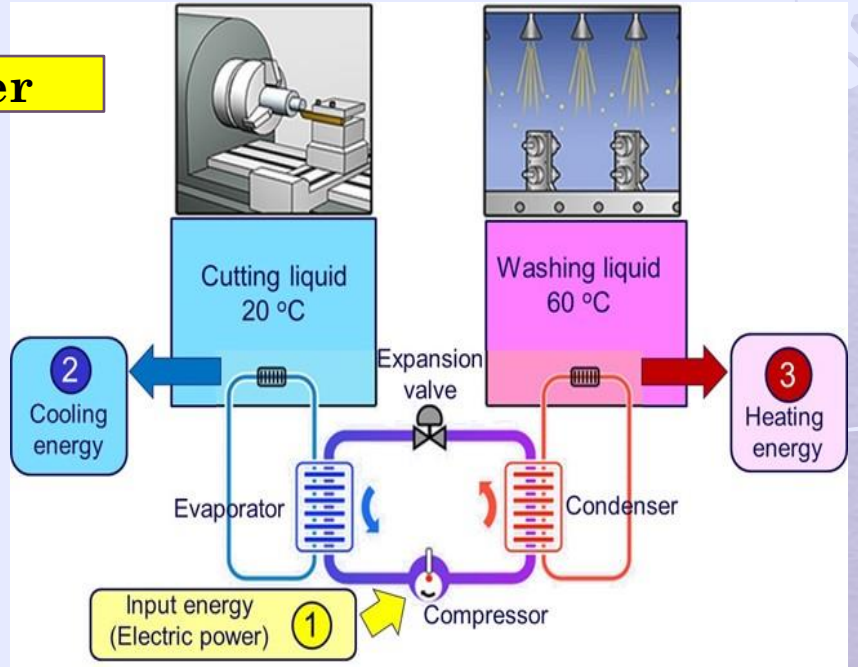
No	21
Industry	Machinery（Parts production of vehicle）
Process applied	Cutting, Washing
Heat source	Simultaneous heating/cooling （heating65℃、cooling15℃）
Objective	Eliminating the conventional boiler system
HP system	Water-water/Air-water heat pump (6+8=14 units) Heating capacity: 22kW/unit (6 units), 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 of 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

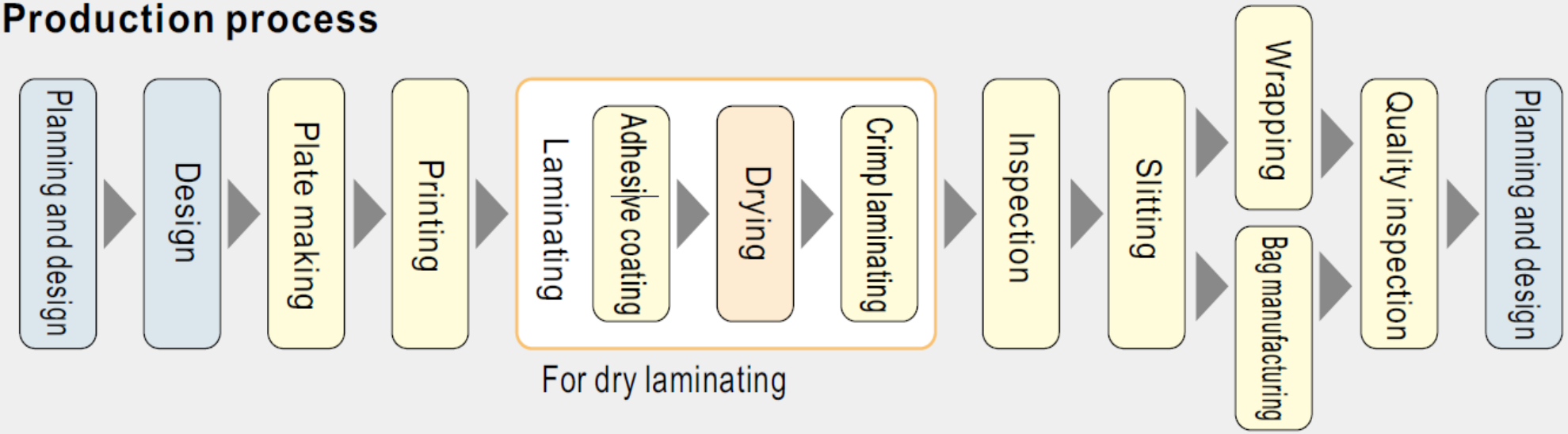
	Before (old)	After (new)	Difference
Investment	・Boiler/piping 75.3[million yen] ・Steam heating system 10.5[million yen] ・Cooling system 50.4[million yen] Total: 136.2[million yen]	Heat pump system (14 units) 91[million yen]	－45.2 [million yen]
Operation cost	・Electric bill（193MWh） 2.34[million yen/y] ・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 of 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%

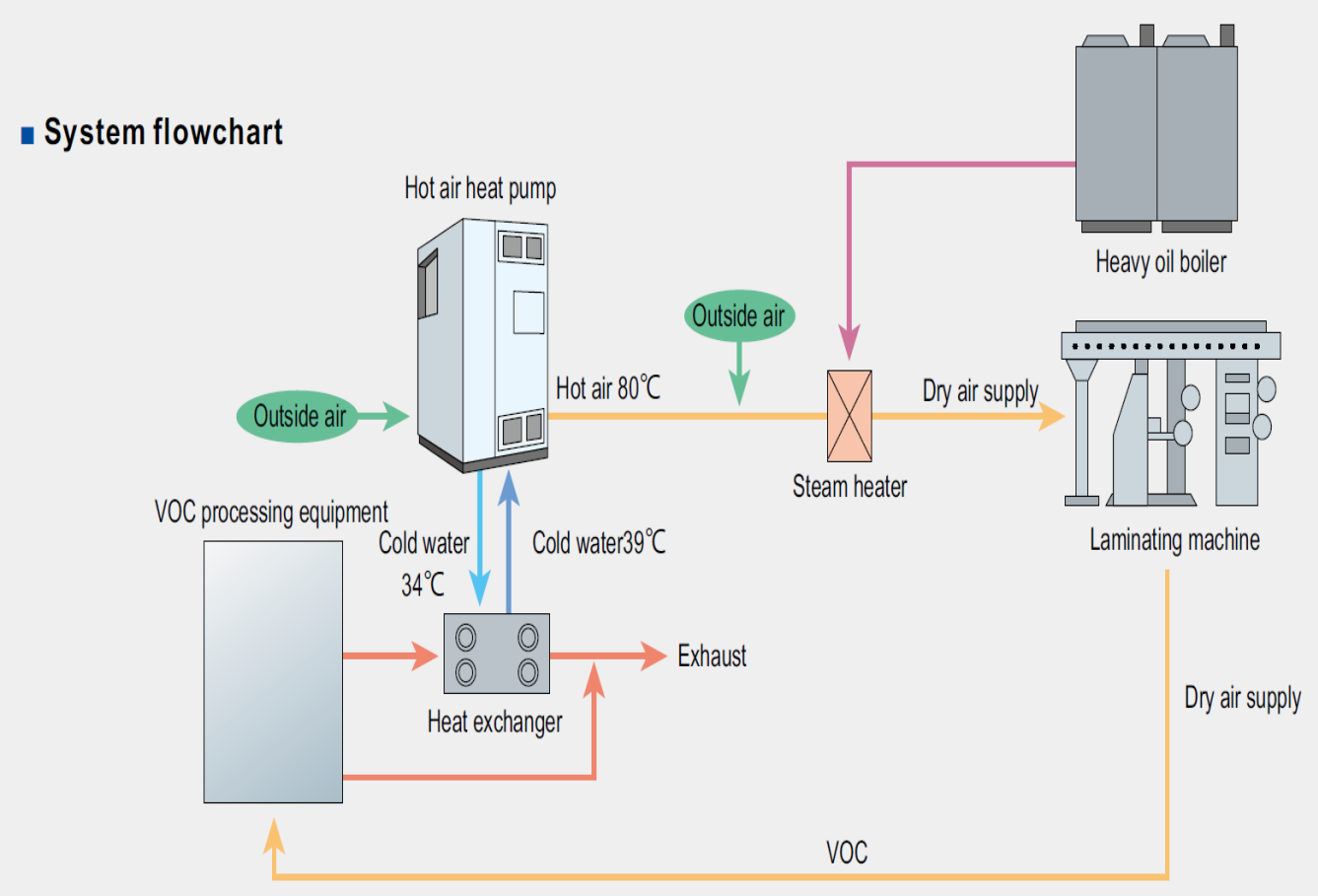
■ Production process



Best Practice of Chemicals Industry (No.32)

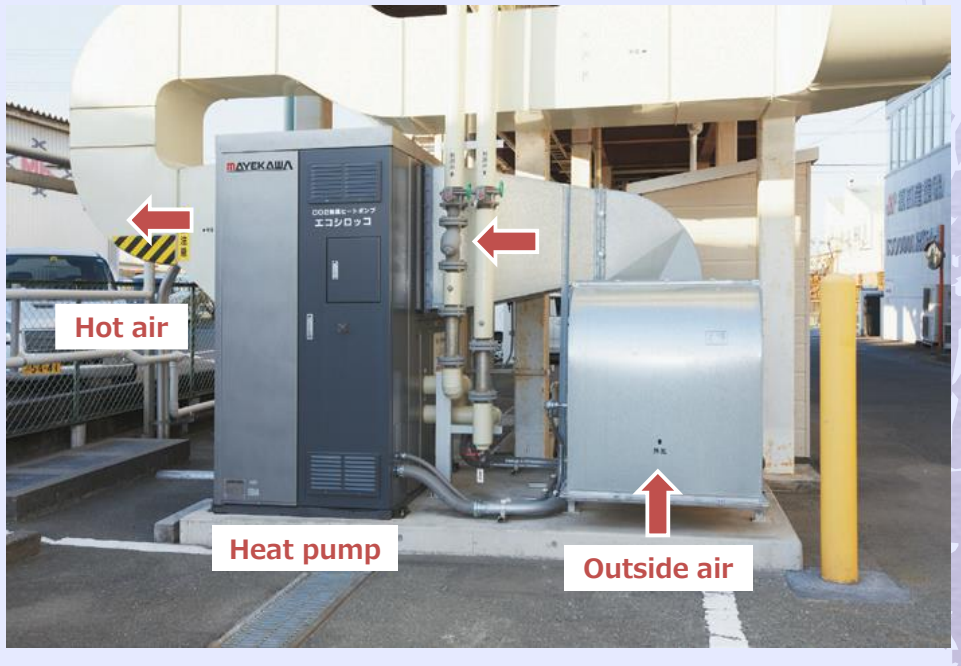
System Flow and Effects of Application

System flow



Effects of application

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

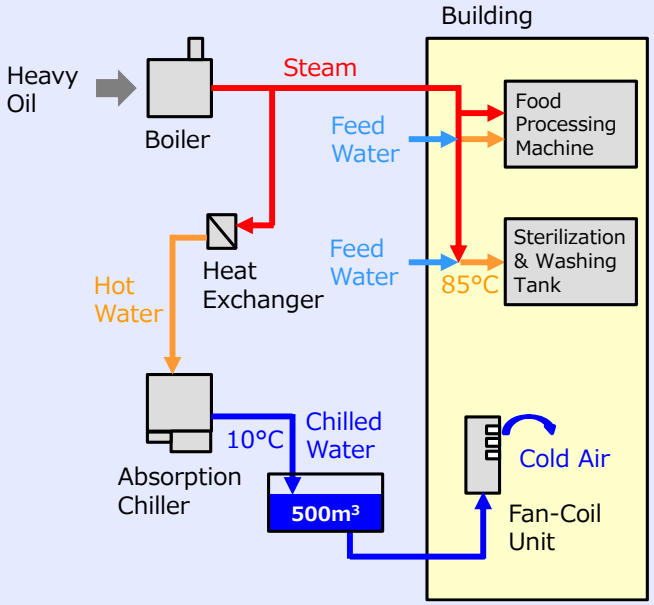


Best Practice of Food Industry (No.2)

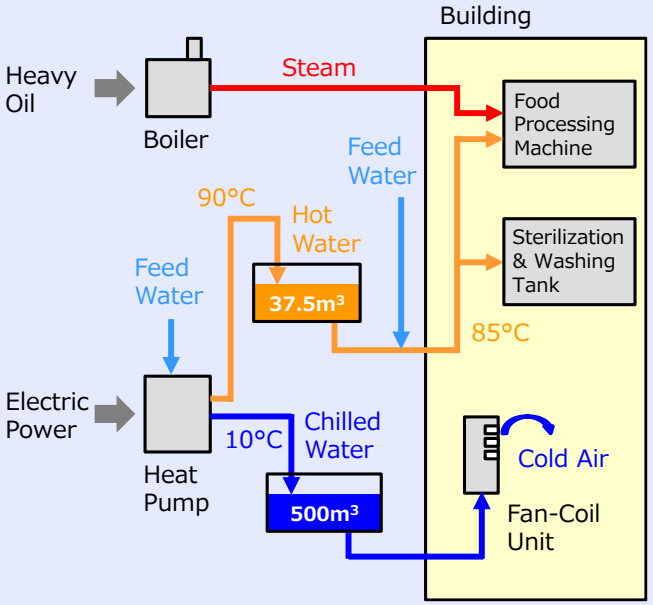
Process Outline

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

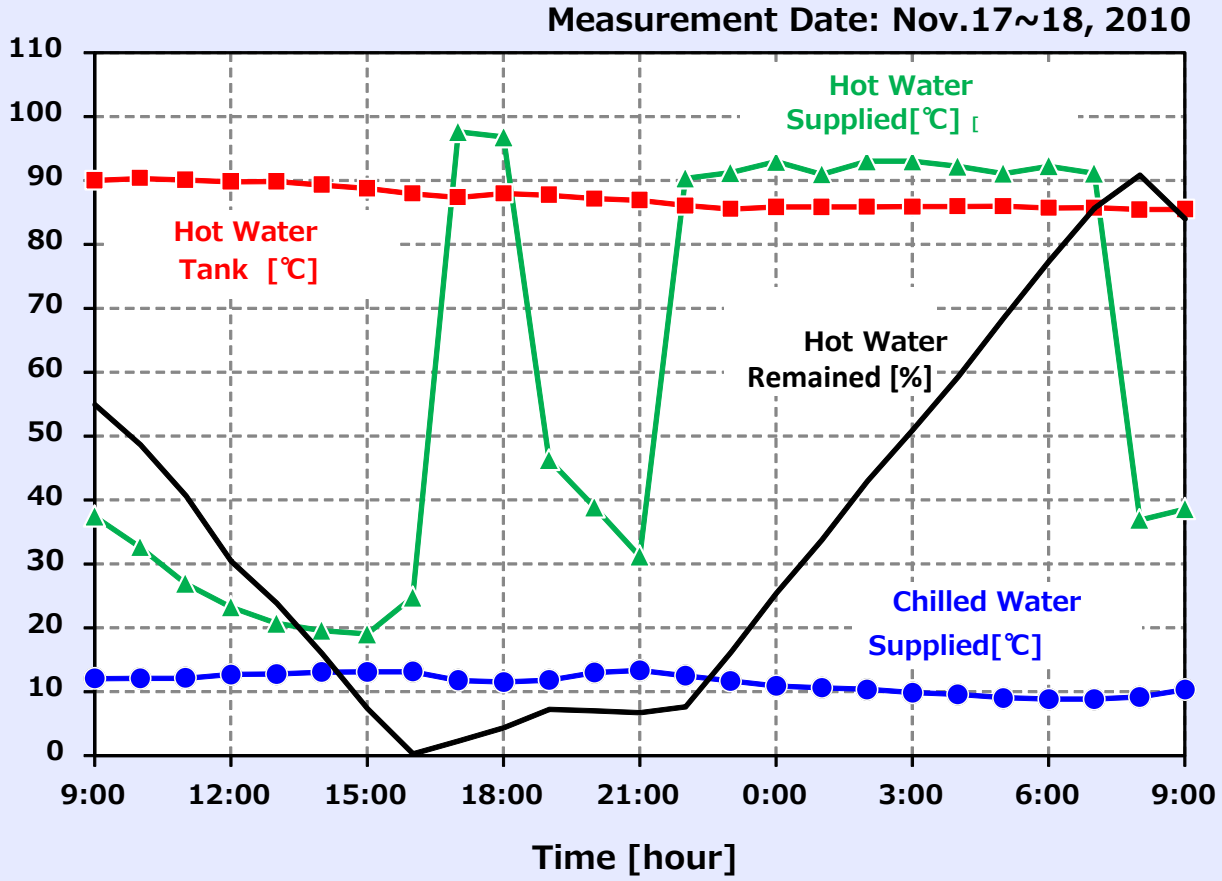


Process	Before	After	Process
Food Processing Machine	Boiler A (Steam: 2ton/h)	Boiler A (Steam: 2ton/h)	Food Processing Machine
	Boiler A (Steam: 2ton/h)	Boiler A (Steam: 2ton/h)	
	Boiler B (Steam: 0.7ton/h)	Boiler B (Steam: 0.7ton/h)	
Sterilization & Washing Tank	Boiler B (Steam: 0.7ton/h)	Heat Pump (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 of Food Industry (No.2)

Operation 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 Measures required for Practical Application of IHPs

Barriers of 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 Improve 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 a thermometer and a 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

Economical Barriers and Countermeasures

- **Low motivation of investment for new system to improve utility facilities**

•Utilities fees such as fuels, electricity and water are lower than other expenses of labor and manufacturing facilities in a production cost in many industries.

- **Avoidance of economical risk such as long term pay back time and operational trouble.**

•Pay back time for investment cost is required for short period of less than 3 years by company management.

•A field manager feels anxiety for suspending risk of production line due to troubles of oil leakage and compressor, etc.

Countermeasures

- **Improving the reliability of IHPs**
- **Reducing the initial cost**
- **Reducing the running cost**
- **Improving COP**
- **Equalization of annual expense (ex. by lease)**
- **Correct understanding of performance and life expectancy**
- **Application of subsidy and lease**

Subsidies of Japanese Government to Promote IHPs

【Name of Subsidy Work】

Support Grants to Promote Energy Saving Investments in 2018FY (Energy Use Rationalization, etc., Business Operators Support Project

【Objectives and Work Outline】

In the face of the rapidly growing need to resolve global environmental problems, Japan has been working to promote investment in energy-saving systems and to rationalize energy management. This project aims to promote energy saving in each sector, thereby building a stable and appropriate energy supply and demand structure adapted to the domestic and foreign economic and social environments. From 2018FY, the subsidy can be applied for industrial heat pump which reduce energy consumption of heat supply in the conventional boiler. The budget is approximately 19 billion yen in FY2018. The rate of subsidy is estimated from one third to half for investment cost.

【home page】

https://sii.or.jp/cutback30/uploads/koujoutani_kouboyoryo_20180518.pdf

【Name of Subsidy Work】

Initiative Research Project for New Technologies to Solve Middle and Long Term Issues in Energy and Environmental Field

【Objectives and Work Outline】

This project aims to promote initiative R&D technologies expected in the practical use around 2030. The budget is less than 100 million yen per a case.

・Development of untouchable sensor which can measure uncontrolled area with the innovative method.

・Energy saving in processes of dehydration and drying.

【Schedule】

・January, 2019 : Explanatory meeting to appeal to the public

・From January to middle of April : Public announcement

・From April to May, 2019 : Application

・From May to June : Hearing inspection

・End of June : Decision for adoption and contract

・From early in July, 2019 to end of June, 2020 : R&D period

Thank you for your attention!