Survey of Availability of Heat Pumps in the Food and Beverage Fields

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Heat Pump & Thermal Storage Technology Center of Japan

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Contents

1. Introduction

1.1 Background and significance of survey

Heat pumps have become increasingly important in the world as a technology to contribute to CO2 reduction. Heat pumps have been widely used in office air-conditioning and are expected to spread to other industrial fields from now on.

Recently, heat pumps have made great technological progress such as improved efficiency, increase in capacity, output at higher temperatures, etc. The possibility of replacing boilers, which are a conventional heat source, with heat pumps has increased in the industrial field. The Heat Pump & Thermal Storage Technology Center of Japan estimated that a reduction of approximately 33 million tons of CO2 emissions can be achieved across the whole of Japan by expanding the use of heat pumps in the industrial field.

In business categories such as food and beverage manufacturing factories, the operating temperature level is relatively low. The introduction of heat pumps into this field is considered to be easy because the temperature required in process is below 100℃ in many cases.

In this survey, CO2 reduction potential in 11 countries by applying heat pumps in the food and beverage fields was estimated for the purpose of determining the CO2 reduction effect obtained by introducing heat pumps.

1.2 General overview of the survey

A total of 11 countries, namely France, Germany, Italy, Japan, the Netherlands, Norway, Spain, Sweden, the UK, the USA, and China, were surveyed to estimate CO2 reduction potential by introducing current-technology heat pumps into the food and beverage fields. On the assumption that an electric drive compressor heat pump is used, applications at a boiler energy use end temperature of below 100℃ are selected as a heat pump applicable range. Note that MVR (mechanical vapor recompression) in the beer brewing industry was included as well.

- Countries covered by the survey: A total of 11 countries (France, Germany, Italy, Japan, the Netherlands, Norway, Spain, Sweden, the UK, the USA, and China)
- Business categories covered by the survey: Food and beverage fields (Analyzed by industrial category shown in Diagram 1 Analyzed by smaller category grouping for the countries other than China, and by middle classification for China)
- Process to which heat pumps are applied: Applications at a boiler energy use end temperature below 100℃ (MVR in the beer brewing industry was included.)
- Heat pump equipment substituted for boiler: Electric drive compressor heat pump

As a result of this estimation, it has been concluded that the emission of 40 million tons of CO2 per year can be reduced in all 11 countries by replacing applications at an end use temperature below 100℃ boiler energy in the food and beverage fields with heat pumps (with MVR in the beer brewing industry included). However, the data for China are less accurate than that for the other countries. A total CO2 reduction effect of 25 million t-CO2/year in the 10 countries other than China can be expected

Diagram 1　Industries Surveyed

(a) France, Italy, Japan, Netherlands, Norway, Spain, Sweden, United Kingdom

Food and tobacco			
	15 Food products and beverages		
		151 Production, processing and preserving (PPP)	
			1511 PPP of meat and meat products
			1512 Processing and preserving of fish products
			1513 Processing, preserving of fruit & vegetables
			1514 Vegetable and animal oils and fats
		152 Dairy products	
		153 Grain mill prod., starches & prepared animal feeds	
			1531 Grain mill products
			1532 Starches and starch products
			1533 Prepared animal feeds
		154 Other food products	
			1541 Bakery products
			1542 Sugar
			1543 Cocoa, chocolate and sugar confectionery
			1544 Macaroni, noodles,couscous & similar farinaceous prod.
			1549 Other food products, nec
		155 Beverages	
			1551 Distilling, rectifying and blending of spirits
			1552 Wines
			1553 Malt liquors and malt
			1554 Soft drinks; production of mineral waters
	16 Tabacco Products		

2-digit: Middle classification; 3-digit: Small classification; 4-digit: Sub classification

: Definition of size of industry classification in this survey

Industry classification: ISIC (International Standard Industrial Classification of All Economic Activities) Rev.3

(b) Germany

Food and tobacco		
	311/2 FOOD	
		3111 Slaughtering, preparing and preserving meat
		3112 Dairy products
		3113 Canning, preserving of freuits and vegetables
		3114 Canning, preserving and processing of fish
		3115 Vegetable and animal oils and fats
		3116 Grain mill products
		3117 Bakery products
		3118 Sugar factories and refineries
		3119 Cocoa, chocolate and sugar confectionery
		3121 Other food products
		3122 Prepared animal feeds
	313 BEVERAGES	
		3131 Distilling, rectifying and blending of spirits
		3132 Wine industries
		3133 Malt liquors and malts
		3134 Soft drinks
	314 TOBACCO	

3-digit: Middle classification; 4-digit: Sub classification

: Definition of size of industry classification in this survey

Industry classification: ISIC (International Standard Industrial Classification of All Economic Activities) Rev.2

(c) United States

Food and tobacco				
	311 Food Manufacturing			
		3112 Grain and Oilseed Milling		
				311221 Wet Corn Milling
			31131 Sugar Manufacturing	
		3114 Fruit and Vegetable Preserving and Specialty Food Manufacturing		
		3115 Dairy Product Manufacturing		
		3116 Animal Slaughtering and Processing		
	312 Beverage and Tobacco Product Manufacturing			
		3121 Beverage Manufacturing		

3-digit: Middle classification; 4-digit: Small classification; 5-digit, 6-digit: Sub classification

: Definition of size of industry classification in this survey

Industry classification: 2007 NAICS (North American Industry Classification System)

(d) China

Food and tobacco	
	Processing of Food from Agricultural Products
	Manufacturing of Foods
	Manufacturing of Beverage
	Manufacturing of Tobacco

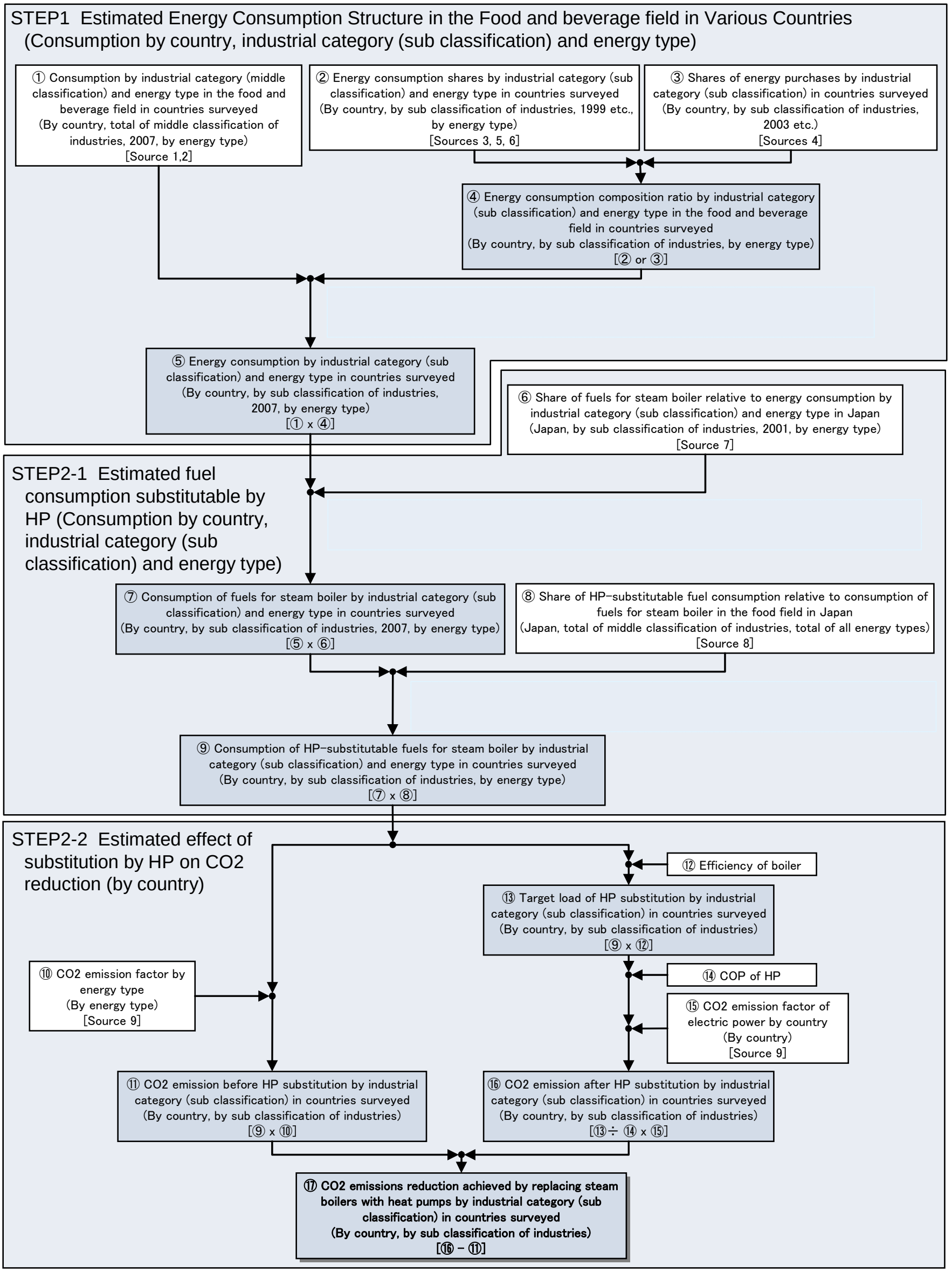
Middle classification

: Definition of size of industry classification in this survey

Classification described in “China Energy Statistical Yearbook” (China Statistics Press)

Note: Although Rev. 4 of ISIC was published in 2008, analysis was carried out based on Rev. 3 and Rev. 2 for the countries shown in (a) and (b), respectively, due to the year of statistical data used in this survey.

Diagram 2　Perspective of Survey Flow



Source

1: ”Energy Balances of OECD Countries 2009 Edition“ (IEA)
2: "Energy Balances of Non-OECD Countries 2009 Edition“ (IEA)
3: ”Structural Statistics for Industry and Services Volume 2 Energy Consumption 2000 Edition” (IEA)
4:”Structural Statistics for Industry and Services database- ISIC Rev. 3 Vol 2006 release 01”（OECD）
5: “2006 Energy Consumption by Manufacturers” (EIA)
6: “China Energy Statistical Yearbook 2008” (China Statistics Press)
7:“The structural survey of oil consumption in 2001” (Ministry of Economy, Trade and Industry)
8:“Heat Pump and Thermal Storage White Paper” (HPTCJ)
9:”CO2 Emission From Fuel Combustion 2008 Edition” (IEA)

2. Estimation of energy consumption structure (energy consumption by country, by industrial category(sub classification), and by energy type) in the food and beverage fields of countries surveyed

To estimate CO2 reduction potential by applying heat pumps, it is necessary to understand the energy consumption structure (energy consumption by country, by industrial category, and by energy type) in the food and beverage fields of each country covered by the survey. To estimate CO2 emissions before replacement, it is particularly necessary to determine energy consumption by energy type because the CO2 emission factor differs from type to type. In addition, it is desirable to understand the energy consumption structure by industrial category because the share of fuels for steam boiler relative to energy consumption that is to be replaced differs depending on each industrial category,

Therefore, in this survey, we determined the energy consumption structure by country, industrial category (sub classification), and energy type in the food and beverage fields of each country. Note that the middle classification was used for China because of limited statistical data. In this survey, we mixed and matched many different statistical materials to estimate the energy consumption structure for China because documents on relevant data were not available.

2.1 Estimation method

The “Energy Balances of OECD Countries 2009 Edition” (IEA) and “Energy Balances of Non-OECD Countries 2009 Edition” (IEA) provide statistical data on the energy consumption structure of each country (see p.32 of the reference material). In the statistical data, the energy consumption structure of each country in 2007, the most recent year, can be compared at a glance, but the breakdown by industrial category in the food and beverage fields cannot be known because the classification level of industrial category is not detailed enough.

Meanwhile, although two or more sets of statistics on the breakdown by industrial category in the food and beverage fields of each country are available, the most recent statistics on the countries covered by this survey are not available. For example, although the “Structural Statistics for Industry and Services Volume 2 Energy Consumption 2000 Edition” (IEA) (see p.33 of the reference material) indicates the breakdown of the energy consumption structure by industrial category in the food and beverage fields of each country, this document has some tasks to address; for instance, the listed data are old, only limited countries are listed, classification level of industrial category differs from country to country, etc. Also, the “Structural Statistics for Industry and Services database- ISIC Rev. 3 Vol 2006 release 01” (IEA) (see p.34 of the reference material) shows the breakdown of energy purchases[1] by industrial category in the food and beverage fields of each country, but no data

[1] There is a positive correlation between energy purchases and energy consumption. (See p.31 of the reference material)

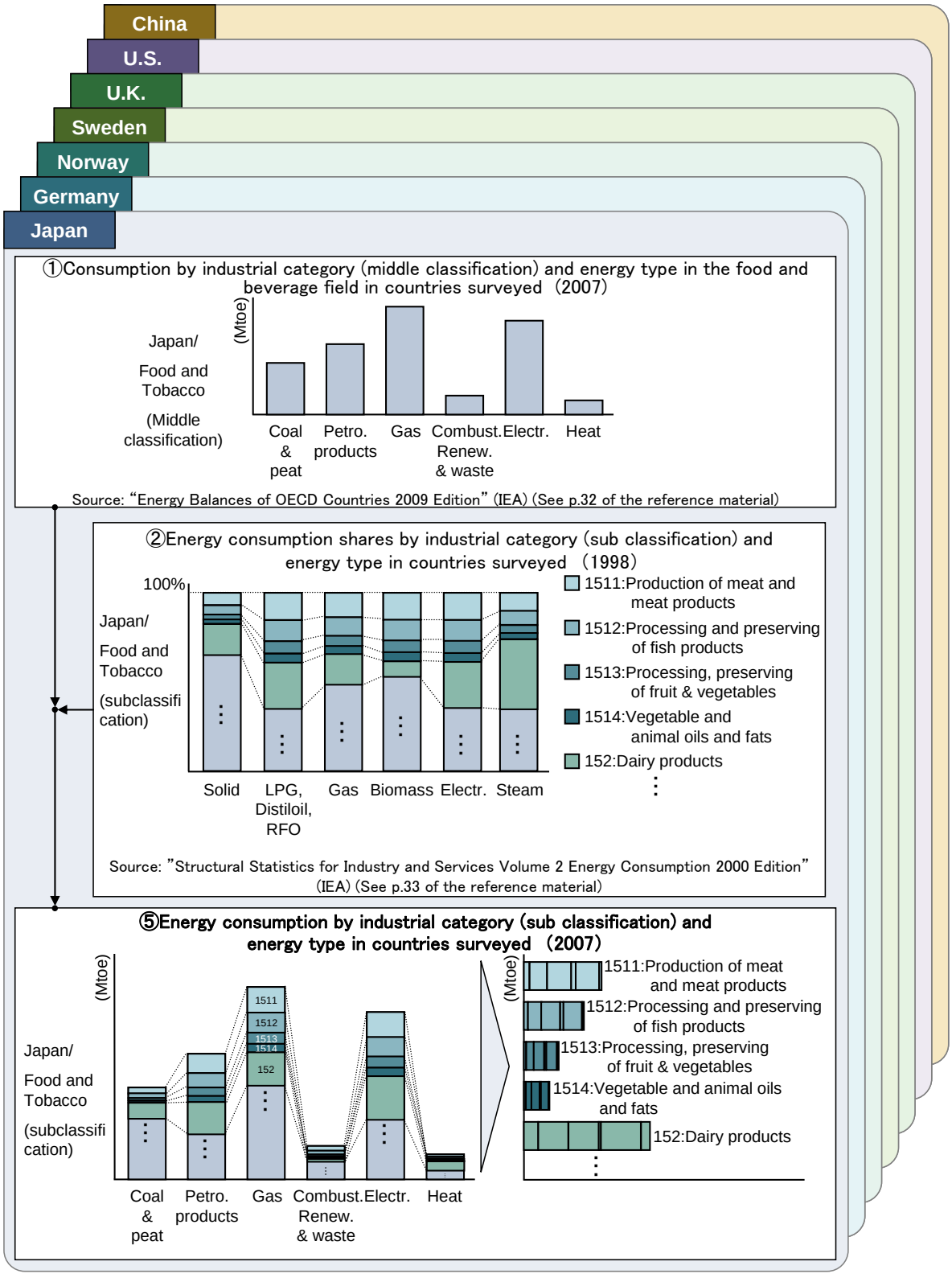
on energy consumption are listed.

In this survey, we estimated the consumption of each country by industrial category (sub category) and energy type in 2007 in the following manner. Used statistical data are listed in Diagram 6.

1) The energy consumption structure of each country in the most recent year can be compared at a glance in the "Energy Balances of OECD Countries 2009 Edition" (IEA) and "Energy Balances of Non-OECD Countries 2009 Edition" (IEA). First of all, we used these two reports to calculate "① Consumption by industrial category (middle classification) and energy type in the food and beverage fields in countries surveyed" (2007 data).
2) Next, we used various statistical data to set energy consumption ratio by industrial category (sub classification) composing the food and beverage fields and to estimate "⑤ Energy consumption by industrial category (sub classification) and energy type in countries surveyed".
3) The method by which the energy consumption shares by industrial category (subcategory) were set differs from country to country. For the countries listed in the "Structural Statistics for Industry and Services Volume 2 Energy Consumption 2000 Edition" (IEA), i.e. France, Germany, Japan, Norway, Sweden, and the UK, we set "② Energy consumption shares by industrial category (sub classification) and energy type in countries surveyed" based on this document (data up to 1999).
4) Method 3) could not be employed for other countries. Among other countries, for the countries listed in the "Structural Statistics for Industry and Services database- ISIC Rev. 3 Vol 2006 release 01" (OECD), that is, Italy, the Netherlands, and Spain, we set the energy consumption ratio by industrial category (sub classification) and energy type[2] based on "③ Shares of energy purchases by industrial category (sub classification) in countries surveyed" (2003 data).
5) Neither Methods 3) nor 4) could be employed for the remaining countries, the USA and China. We set "② Energy consumption shares by industrial category (sub classification) and energy type in countries surveyed" by examining the statistical data by country. Note that since such a subcategorized estimation for China was difficult owing to limited statistical materials, we had to estimate the energy consumption by industrial category (middle classification) and energy type as a last resort.

[2] For France, we set the share in small classification (three-digit classification in ISIC) based on energy consumption and the share in sub classification (four-digit classification in ISIC) based on energy purchases.

Diagram 3　Estimated Flow of Energy Consumption by Country, Industrial category (Sub Classification) and Energy type (Image):
Germany, Japan, Norway, Sweden, U.K., U.S. and China



Note: For China, due to limitation of statistical data, energy consumption by industrial category (middle classification) and energy type was finally estimated.

Diagram 4　Estimated Flow of Energy Consumption by Country, Industrial category (Sub Classification) and Energy type (Image):
Italy, the Netherlands and Spain

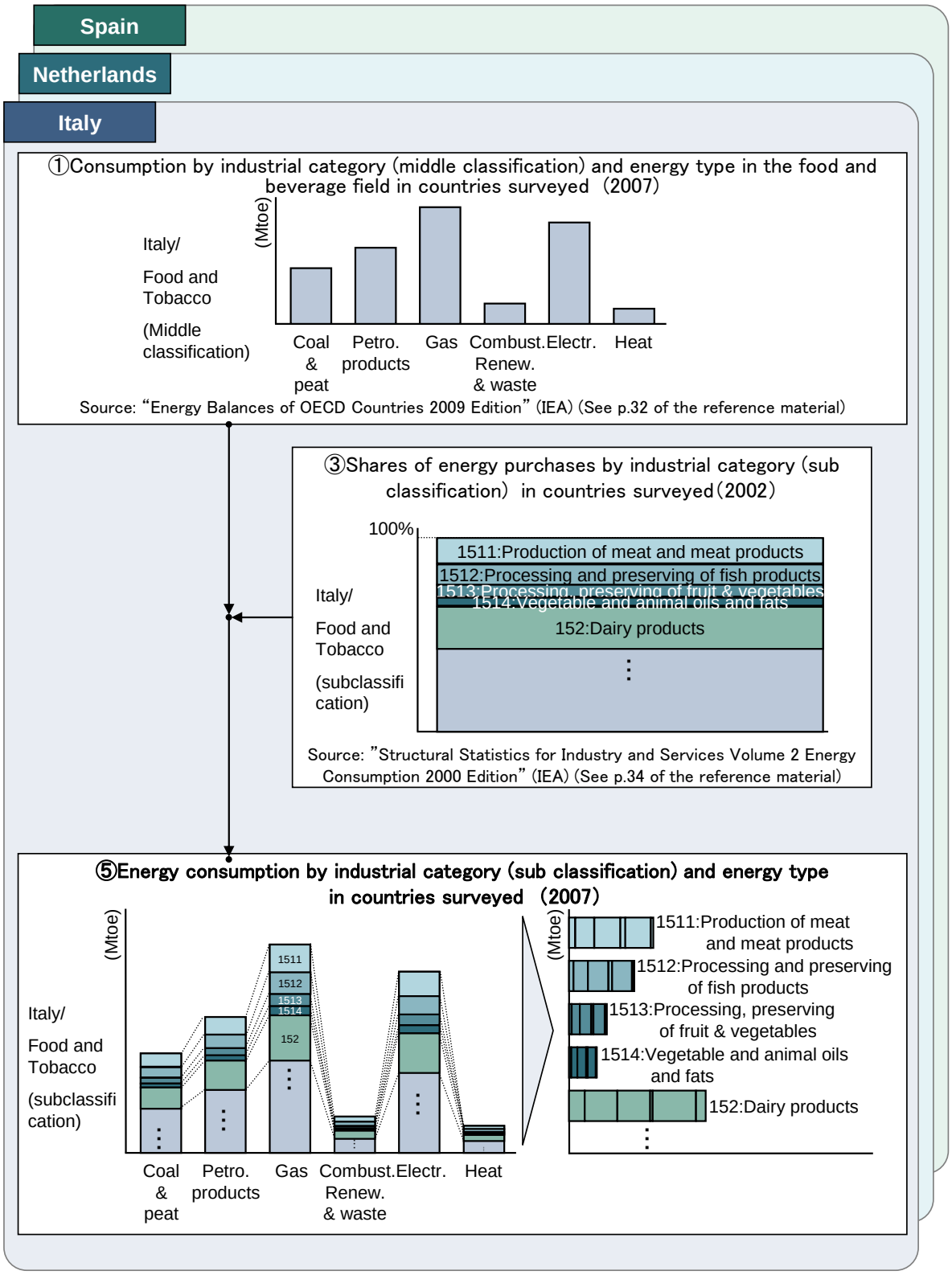


Diagram 5　Estimated Flow of Energy Consumption by Country, Industrial category (Sub Classification) and Energy type (Image):
France

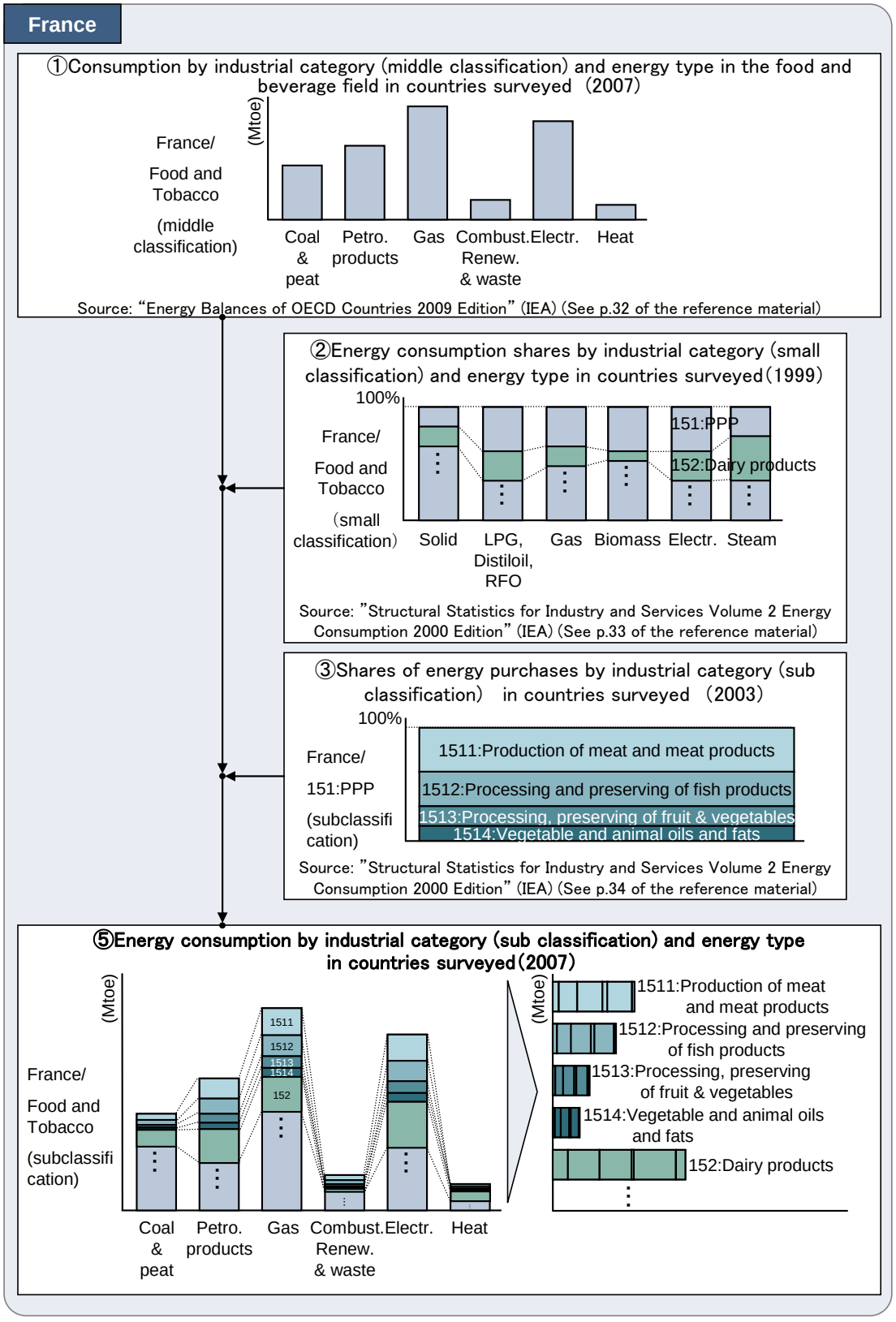


Diagram 6　Statistical Data Used for Estimation of Consumption According to Country, Industry and Kind of Energy

	① Consumption by industrial category (middle classification) and energy type in the food and beverage field in countries surveyed		④ Energy consumption composition ratio by industrial category (sub classification) and energy type in the food and beverage field in countries surveyed			
			② Energy consumption shares by industrial category (sub classification) and energy type in countries		③ Shares of energy purchases by industrial category (sub classification) in countries	
	Source	Year	Source	Year	Source	Year
France	Source 1	2007	Source 3	1999	Source 4	2003
Germany	Source 1	2007	Source 3	1994		
Italy	Source 1	2007			Source 4	2002
Japan	Source 1	2007	Source 3	1998		
Netherlands	Source 1	2007			Source 4	2003
Norway	Source 1	2007	Source 3	1997		
Spain	Source 1	2007			Source 4	2003
Sweden	Source 1	2007	Source 3	1998		
United Kingdom	Source 1	2007	Source 3	1998		
United States	Source 1	2007	Source 5	2006		
China	Source 2	2007	Source 6	2007		

Source
1: "Energy Balances of OECD Countries 2009 Edition" (IEA)
2: "Energy Balances of Non-OECD Countries 2009 Edition" (IEA)
3: "Structural Statistics for Industry and Services Volume 2 Energy Consumption 2000 Edition" (IEA)
4: "Structural Statistics for Industry and Services database- ISIC Rev. 3 Vol 2006 release 01" (OECD)
5: "2006 Energy Consumption by Manufacturers" (EIA)
6: "China Energy Statistical Yearbook 2008" (China Statistics Press)

2.2 Estimation results

The estimation results of the energy consumption structure (energy consumption by country, industrial category (sub classification), and energy type) in the food and beverage fields is shown in Diagram 7 (For detailed data by country, see p.24 of the reference material). Except for the USA and China, which have a different category classification from the other countries, among those covered by the survey, energy-intensive industries common to European countries and Japan are as shown below.

<energy-intensive industries (sub classification) common to European countries and Japan>

- Manufacture of dairy products
- Production, processing and preserving of meat and meat products
- Manufacture of bakery products
- Processing and preserving of fruit and vegetables
- Manufacture of prepared animal feeds
- Manufacture of malt liquors and malt

Diagram 7　Energy-Intensive Industries in Countries Surveyed

Mtoe

	France		Germany		Italy		Japan		Netherlands		Norway		Spain		Sweden		United Kingdom	
15 Food products and beverages	4.60	100.0%	4.35	98.7%	3.25	99.6%	4.10	99.1%	2.06	98.1%	0.37	99.6%	2.32	99.3%	0.40	99.5%	3.37	99.0%
151 Production, processing and preserving (PPP)	0.95	20.8%	0.94	21.3%	0.98	30.2%	0.82	19.7%	0.60	28.6%	0.20	55.2%	0.90	38.6%	0.13	33.7%	0.95	27.8%
1511 PPP of meat and meat products	0.59	12.8%	0.45	10.2%	0.61	18.7%	0.23	5.6%	0.20	9.6%	0.05	12.9%	0.43	18.2%	0.07	17.8%	0.53	15.5%
1512 Processing and preserving of fish products	0.06	1.2%	0.03	0.7%	0.03	0.8%	0.31	7.6%	0.00	0.0%	0.12	31.7%	0.10	4.1%	0.01	1.8%	0.06	1.6%
1513 Processing, preserving of fruit & vegetables	0.24	5.3%	0.18	4.1%	0.29	8.8%	0.11	2.7%	0.23	11.1%	0.01	3.7%	0.20	8.5%	0.03	6.8%	0.23	6.8%
1514 Vegetable and animal oils and fats	0.06	1.4%	0.27	6.2%	0.06	1.8%	0.16	3.9%	0.00	0.0%	0.03	6.8%	0.18	7.7%	0.03	7.3%	0.14	4.0%
152 Dairy products	0.81	17.6%	0.62	14.0%	0.42	12.9%	0.36	8.7%	0.27	13.1%	0.04	11.9%	0.24	10.2%	0.06	15.4%	0.27	8.0%
153 Grain mill prod., starches & prepared animal feeds	1.01	21.9%			0.35	10.6%	0.35	8.5%	0.49	23.3%	0.04	12.1%	0.31	13.1%	0.03	7.6%	0.42	12.4%
1531 Grain mill products	0.12	2.7%	0.06	1.5%	0.13	3.9%	0.06	1.3%	0.00	0.0%	0.01	2.3%	0.06	2.5%	0.02	3.8%	0.13	3.8%
1532 Starches and starch products	0.39	8.5%			0.08	2.4%	0.23	5.6%	0.00	0.0%	0.00	0.4%	0.05	2.1%	0.01	2.1%	0.11	3.1%
1533 Prepared animal feeds	0.50	10.8%	0.26	5.8%	0.14	4.2%	0.07	1.6%	0.23	10.8%	0.03	9.4%	0.20	8.4%	0.01	1.7%	0.19	5.5%
154 Other food products	1.47	32.0%		0.0%	1.00	30.6%	1.89	45.6%	0.58	27.6%	0.05	12.9%	0.55	23.6%	0.15	36.9%	1.01	29.7%
1541 Bakery products	0.34	7.4%	0.33	7.6%	0.46	14.2%	0.45	10.9%	0.24	11.4%	0.03	7.9%	0.25	10.5%	0.05	13.0%	0.43	12.6%
1542 Sugar	0.56	12.2%	0.58	13.2%	0.10	3.2%	0.18	4.3%	0.00	0.0%	0.00	0.0%	0.11	4.5%	0.02	4.3%	0.19	5.7%
1543 Cocoa, chocolate and sugar confectionery	0.19	4.2%	0.18	4.1%	0.08	2.6%	0.12	2.8%	0.09	4.2%	0.01	2.1%	0.06	2.6%	0.02	4.6%	0.19	5.5%
1544 Macaroni, noodles,couscous & similar farinaceous prod.	0.05	1.0%			0.22	6.8%	0.14	3.4%	0.00	0.0%	0.00	0.2%	0.01	0.5%	0.00	0.0%	0.03	0.9%
1549 Other food products, nec	0.33	7.2%			0.12	3.7%	1.00	24.2%	0.00	0.0%	0.01	2.6%	0.13	5.5%	0.06	15.1%	0.17	5.0%
155 Beverages	0.35	7.7%	0.81	18.4%	0.50	15.3%	0.69	16.6%	0.12	5.6%	0.03	7.5%	0.33	13.9%	0.02	5.9%	0.72	21.1%
1551 Distilling, rectifying and blending of spirits	0.08	1.7%	0.06	1.3%	0.26	7.9%	0.12	2.8%	0.00	0.0%	0.00	0.8%	0.05	2.0%	0.01	1.5%	0.15	4.3%
1552 Wines	0.05	1.0%	0.01	0.3%	0.10	3.2%	0.04	1.1%	0.00	0.0%	0.00	0.0%	0.08	3.6%	0.00	0.4%	0.01	0.4%
1553 Malt liquors and malt	0.10	2.3%	0.61	13.8%	0.01	0.2%	0.26	6.3%	0.00	0.0%	0.01	3.8%	0.08	3.5%	0.01	1.8%	0.51	15.0%
1554 Soft drinks; production of mineral waters	0.13	2.8%	0.13	3.0%	0.13	4.0%	0.26	6.4%	0.02	1.0%	0.01	2.9%	0.11	4.9%	0.01	2.2%	0.05	1.4%
16 Tabacco Products	0.00	0.0%	0.06	1.3%	0.01	0.4%	0.04	0.9%	0.04	1.9%	0.00	0.4%	0.02	0.7%	0.00	0.5%	0.03	1.0%
	4.60	100.0%	4.41	100.0%	3.26	100.0%	4.14	100.0%	2.10	100.0%	0.37	100.0%	2.34	100.0%	0.40	100.0%	3.40	100.0%

Arranged based on industry classification of ISIC Rev. 3. For Germany for which analysis was carried out based on classification different from that of ISIC Rev.3, only those industries that can be related to
Industries filled in blue are top 5 industries consuming much energy for each country.

3. CO2 reduction effect by applying heat pumps

3.1 Estimation method

3.1.1 Estimation of fuel consumption replaced by heat pumps

We set applications at an end use temperature below 100℃ boiler energy (including MVR) as a heat pump applicable range to estimate the CO2 reduction effect by applying current-technology heat pumps to the food and beverage fields of major countries according to the following procedure.

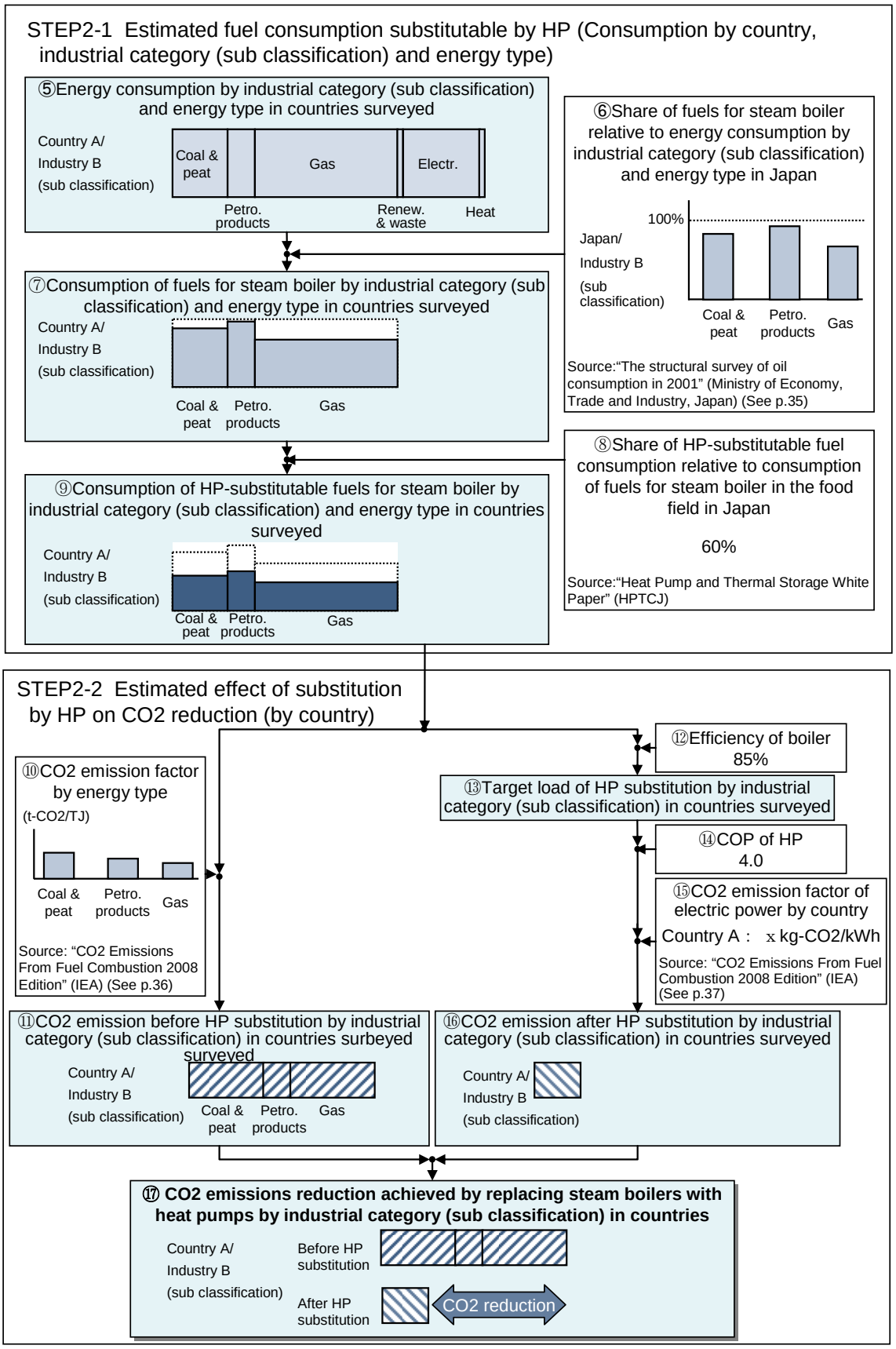
1） We obtained the "⑦ Consumption of fuels for steam boiler by industrial category (sub classification) and fuel type in countries surveyed" from the "⑤ Energy consumption by industrial category (sub classification) and energy type in countries surveyed" obtained in the previous Chapter 2 and from the "⑥Share of fuels for steam boiler relative to energy consumption by industrial category (sub classification) and energy type in Japan."

2） We estimated "⑨ Consumption of HP-substitutable fuels for steam boilers by industrial category (sub classification) and energy type in countries surveyed" from the "⑦ Consumption of fuels for steam boiler by industrial category (sub classification) and energy type in countries surveyed" and based on the assumption that "⑧ Share of HP-substitutable fuel consumption relative to consumption of fuels for steam boilers in the food field in Japan" is 60%.

3） Next, we set the coefficient of performance (COP) of the heat pump, boiler efficiency, and CO2 emission factor in power generation of each country. We estimated CO2 emissions when the calorific value equivalent to the amount of CO2 emitted from the fuel consumption for steam boilers obtained in step 2) was replaced with that of electric drive compressor heat pumps. We obtained "⑰ CO2 emissions reduction achieved by replacing steam boilers with heat pumps by industrial category (sub classification) in countries surveyed" from the difference between them.

It is required to set "the composition ratio of consumption for steam boilers to energy consumption" and "the composition ratio of applications at an end use temperature below 100℃ consumption for steam boilers" to estimate fuel consumption for boilers at an end use temperature below 100℃ where heat pumps are applied. Ideally speaking, these composition ratios should be measured and collected through a fact-finding survey of many factories in each country. In this survey, however, we set the ratios by applying to each country existing survey results in Japan.

Diagram 8　Estimated Flow of Effect of Heat Pump Application on CO2 Reduction



(1) Energy consumption structure of the boiler in Japan

We set the “Share of fuels for steam boiler relative to energy consumption by industrial category (sub classification) and energy type” based on the “The structural survey of oil consumption in 2001” a Japanese statistical document compiled through Fiscal 2001 (p.35 of the reference material).

The Heat Pump & Thermal Storage Technology Center of Japan collects information on heat pumps in Japan. For “Composition ratio of applications at a use temperature below 100℃ to consumption for steam boilers,” the center estimates the composition ratio of applications (including air-conditioning) at a use temperature below 100℃ to consumption for steam boilers in the food field to be 60%.

When preparing this material, we interviewed major domestic equipment manufacturers, sub-users, major domestic users, etc. that have knowledge about industrial processes to obtain the share of fuels for steam boilers replaceable with heat pumps relative to energy consumption. As a result, dairy products, meat products, bakery products, preservation of fruit and vegetables, and malt liquors, which are energy-intensive industries in the food and beverage fields, employ many low-temperature heating processes such as sterilization, cleansing, and fermentation (Diagram 10) and the share of applications (including air-conditioning) at a use temperature below 100℃ to steam consumption is approximately 60% or slightly more (Diagram 9).

Diagram 9 Energy Consumption Structure for Boiler in Japan

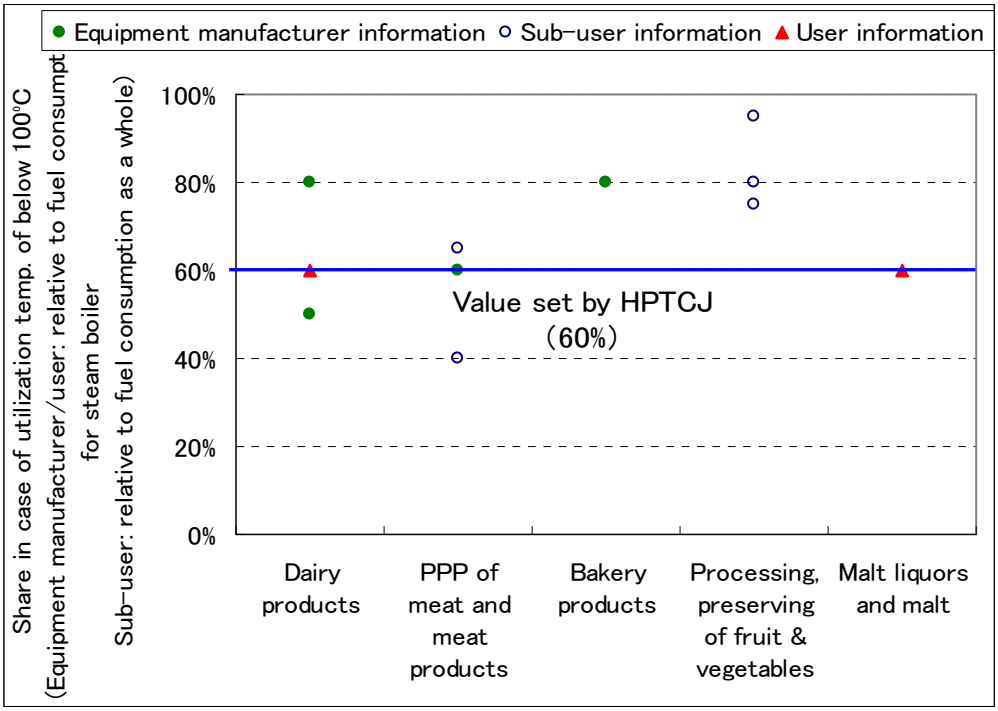
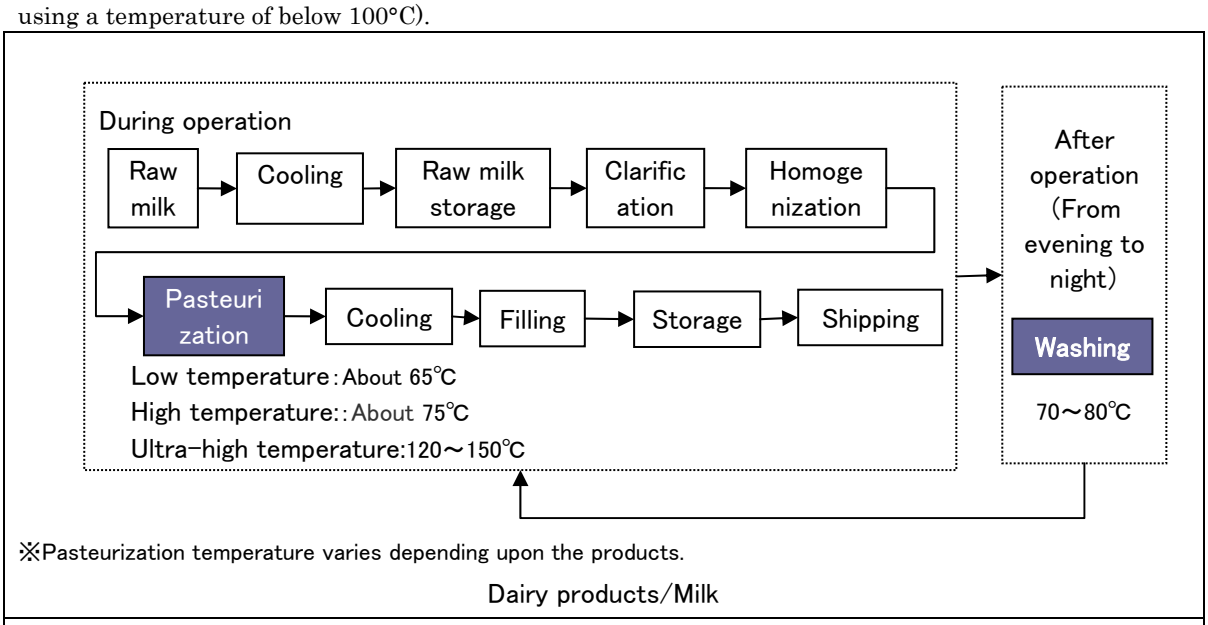


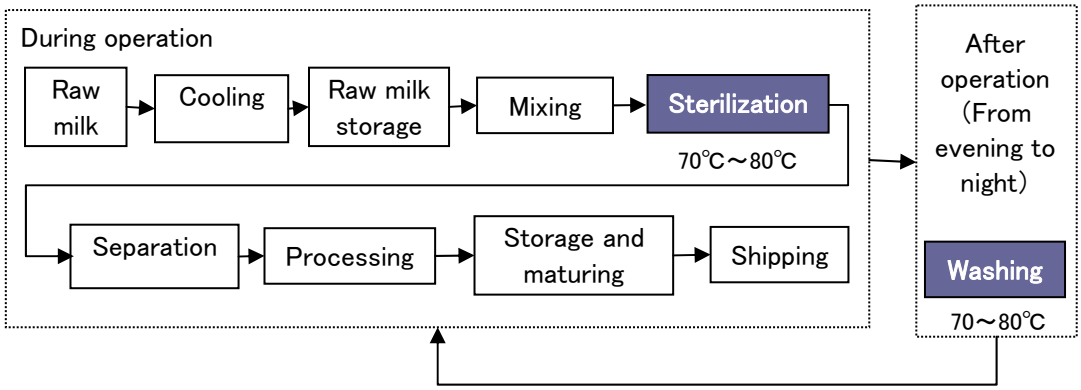
Diagram 10　Typical Production Process of Main Products

Note: The colored are steps for which heat pump is applicable (utilization temp.: warming process using a temperature of below 100°C).

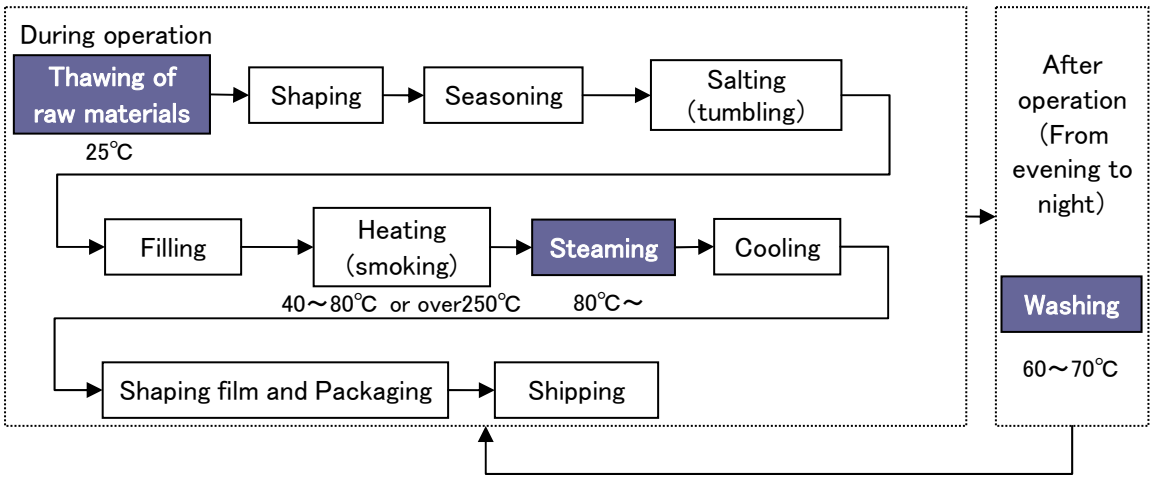


※Pasteurization temperature varies depending upon the products.

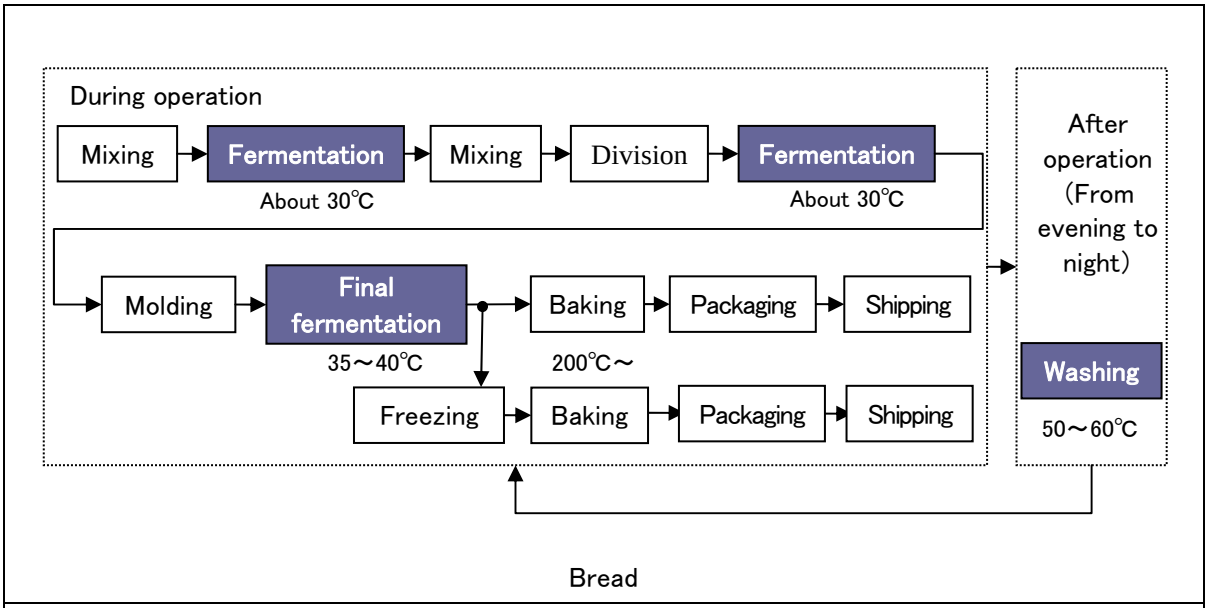
Dairy products/Milk



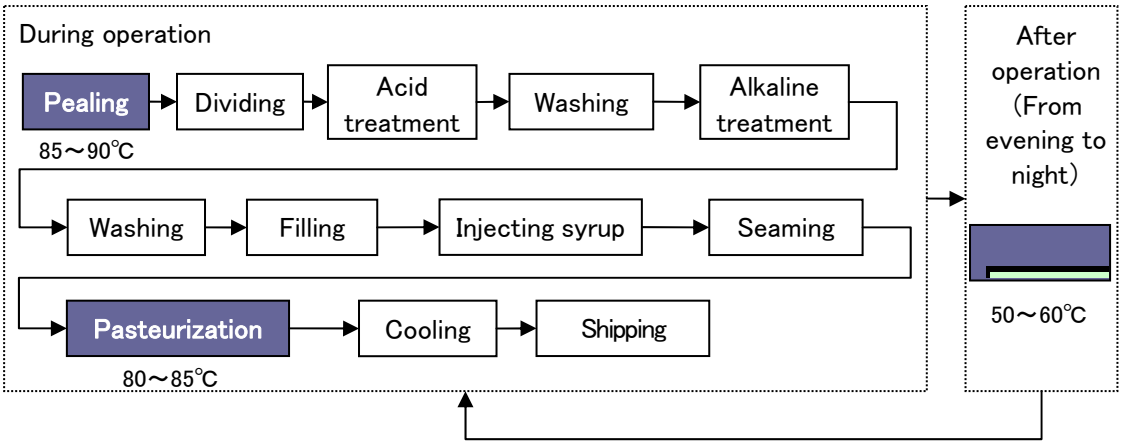
Dairy products/Cheese



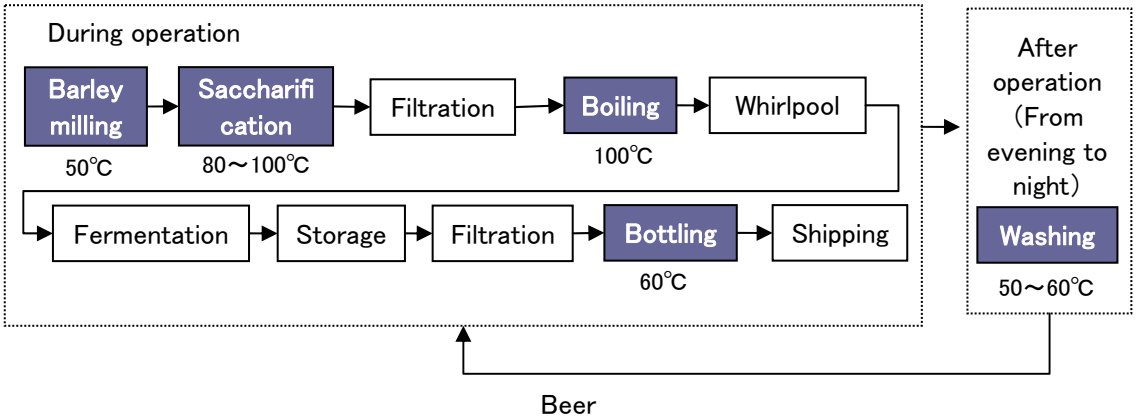
Livestock food products/Ham and sausages



Bread



Processed products of fruits and vegetables/Canned mandarin orange



Beer

Source: Manufacturer information, prepared from “Zukai Shokuhin Kako Purosesu (Illustrated Food Processing)” (Kogyo Chosakai Publishing)

(2) Applying the composition ratio of Japan to each country

According to major domestic equipment manufacturers and sub-users that have knowledge about industrial processes, many manufacturing facilities used in Japanese food and beverage fields have been imported from Europe.

Also, according to French domestic estimates, an absolute quantity of heat demand below 100℃ in the French domestic food and beverage fields is approximately 12 TWh/year, which is close to the estimation result (11.3TWh/year[3]) of heat demand obtained in this survey.

Based on the above, in this survey we decided to apply the setting values for Japan to each country for the "composition ratio of consumption for steam boilers to energy consumption" and "composition ratio of applications at a use temperature below 100℃ to consumption for steam boilers."

3.1.2 Estimation of CO2 reduction effect by applying heat pumps

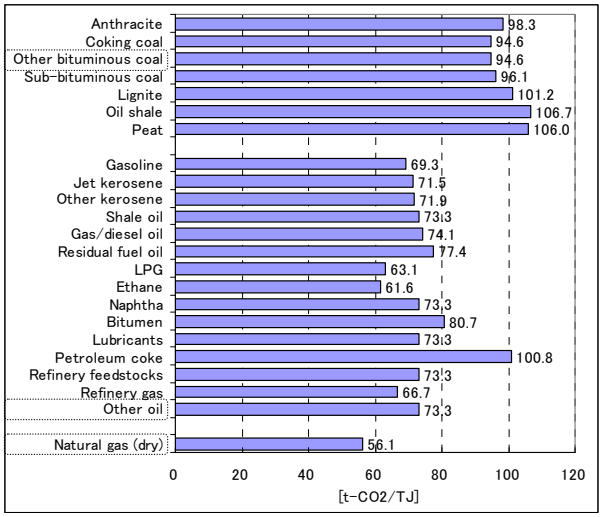
(1) Estimation of CO2 emissions in the present situation

We estimated "⑪ CO2 emissions before HP substitution by industrial category (sub classification) in countries surveyed" by multiplying "⑨ Consumption of HP-substitutable fuels for steam boiler (at a end use temperature below 100℃) by industrial category (sub classification) and energy type in countries surveyed" by "⑩ CO2 emission factor by energy type". We applied the same CO2 emission factor uniformly to every country and set coal & peat at 94.6 t-CO2/TJ (other bituminous coal), petroleum products at 73.3 t-CO2/TJ (other oil[4]), and gas at 56.1 t-CO2/TJ (natural gas (dry)).

[3] Load for steam boilers below 100℃ in the food and beverage fields in France, calculated by the estimation method "⑬ Target load of HP substitution by industrial category (sub classification) in countries surveyed"

[4] The CO2 emission factor of petroleum products differs from product to product. In this survey, we set "Other oil" as a typical value because it is an intermediate level in various products and has the same factor as crude oil.

Diagram 11　Factor of CO2 Emission from Fuel



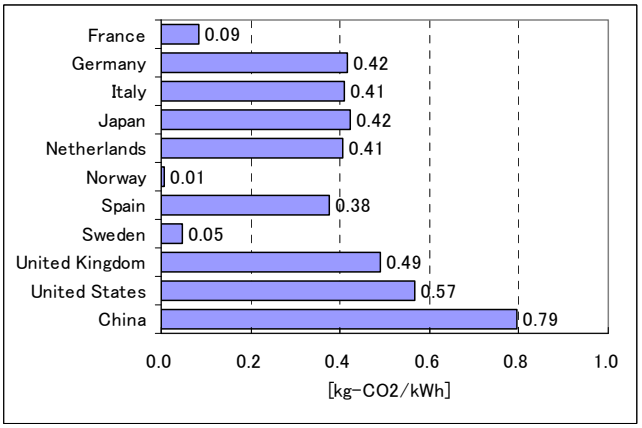
Source: “CO2 Emission From Fuel Combustion 2008 Edition” (IEA)

(2) Estimation of CO2 emissions after the application of heat pumps

First of all, we calculated power consumption by country and category after the application of heat pumps by multiplying “⑫ Efficiency of boiler” (which was set at 85% uniformly for every country) by “⑨ Consumption of HP-substitutable fuels for steam boiler by industrial category (sub classification) and energy type in countries surveyed” and then dividing the obtained value by “⑭ COP of heat pump” (which was set at 4.0 uniformly for every country).

Next, we calculated “⑯ CO2 emission after HP substitution by industrial category (sub classification) in countries surveyed” by multiplying the power consumption by “⑮ CO2 emission factor of electric power by country”.

Diagram 12　CO2 emissions per kWh from electricity and heat generation (Average 2004-2006)



Source: “CO2 Emission From Fuel Combustion 2008 Edition” (IEA)

(3) Estimation of CO2 reduction effect by applying heat pumps

We calculated "⑰ CO2 emissions reduction achieved by replacing steam boilers with heat pumps by industrial category (sub classification) in countries" by comparing CO2 emissions before and after the application of heat pumps. Note that we analyzed China with rougher category classification (middle classification) than the other countries owing to limited statistical materials.

3.2 Estimation results

A total CO2 reduction effect of 40 million t-CO2/year for all of the 11 countries covered by the survey can be expected by substituting heat pumps for steam boilers among applications at a use end temperature below 100℃ in the food and beverage fields. In particular, a significant CO2 reduction can be expected in China (15 million t-CO2/year) and the USA (14 million t-CO2).

It is instructive to look at the rate of CO2 reduction achieved by replacing applications at a end use temperature below 100℃ with heat pumps in the food and beverage fields relative to CO2 emissions in all industries. The combined CO2 reduction for the 11 countries accounts for 1.3% of CO2 emissions in the industrial field (3,140 million t-CO2/year[5]). Particularly in France, the rate of reduction reaches 4.2%.

The data for China have a lower accuracy than that for other countries. A total CO2 reduction of 25 million t-CO2/year in the 10 countries other than China can be expected.

The impact of replacing applications at a use end temperature below 100℃ with heat pumps in the food and beverage fields on CO2 emissions reduction in all industries accounts for 1.8% of CO2 emissions (1,380 million t-CO2/year) in all industries in the 10 countries excluding China.

[5] Source: "CO2 Emission From Fuel Combustion 2008 Edition" (IEA)

Diagram 13　CO2 Reduction by Substitution of Boiler by Heat Pump in Uses at Use End Temperature of below 100°C in the Food and Beverage Fields

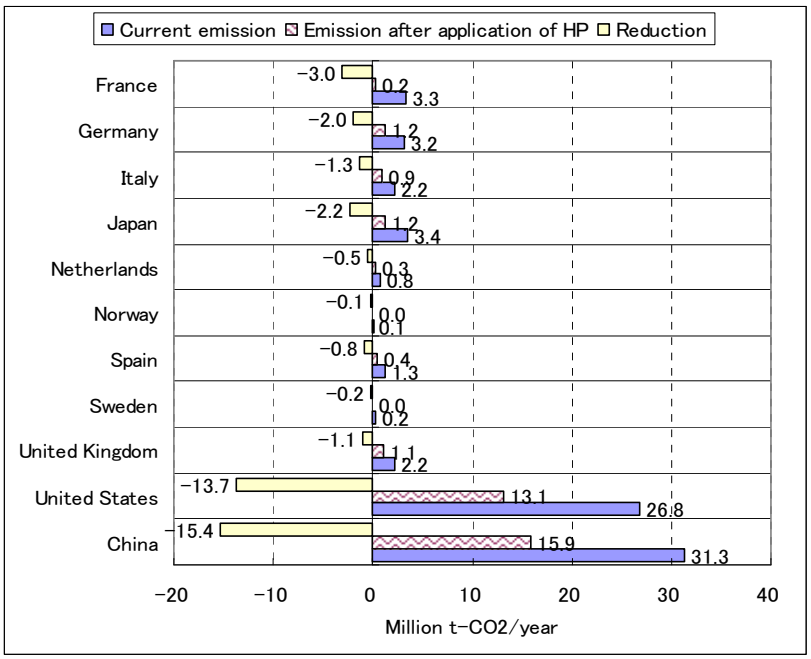
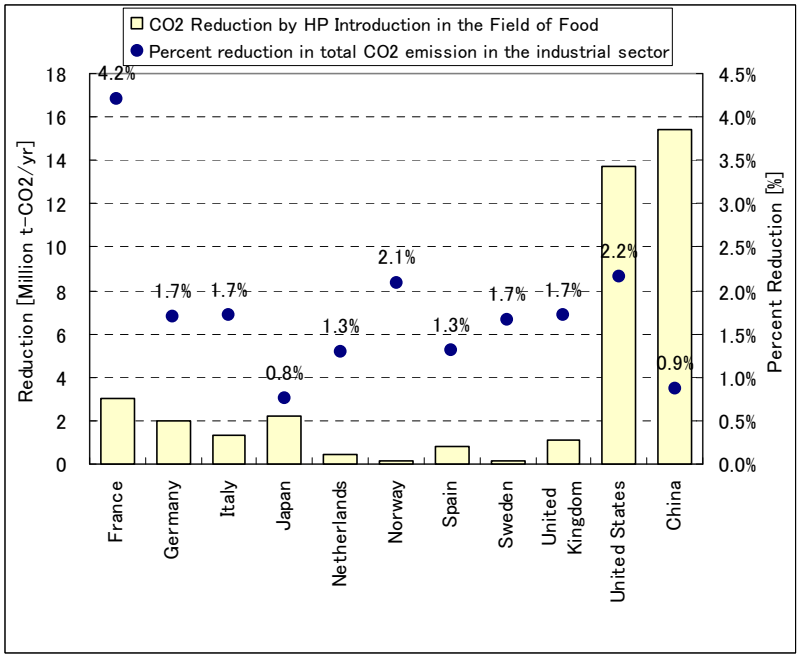


Diagram 14　Percent Reduction in Total CO2 Emission in Industrial Sector



Source: The total CO2 emission in the industrial sector was set based on “CO2 Emission From Fuel Combustion 2008 Edition” (IEA)

4. Conclusion

4.1 Importance of replacing boilers with industrial heat pumps

Advances in heat pump technology have increased the possibility of a new heat supply system in factories. There are problems in using boilers as a heat source in factories as shown below.

1) Pollutants such as CO2, SOx, and NOx are emitted because fossil fuels are generally used.

2) COP on a primary energy basis is less than 1.

3) When a steam pipe in a factory is long, steam transfer will entail a great heat loss.

Heat pumps can solve problems with boilers. When electric power is used as the driving energy, emissions of substances detrimental to the environment enumerated in Item 1) above can be significantly reduced. For Item 2), it is certain that a recent increase in the COP of the heat pump has already achieved energy saving at the present stage on a primary energy basis in comparison with boilers. The COP is likely to further improve hereafter. For 3), although the length of steam pipes may differ depending on the characteristics of the factory, a heat pump can be installed near the place where heat is required, resulting in a decrease in heat transfer loss (see p.50 of the reference material).

4.2 Heat pump introduction effect in the food and beverage fields

In the food and beverage fields among diverse manufacturing industries, the operating temperature level is relatively low. As this sector is one of the categories where heat pumps can be introduced easily, we analyzed the introduction effect in this survey. In the food and beverage fields, heat pumps can be applied to many of the manufacturing processes of typical products (meat products, bread, dairy products, beer, etc.). A substantial CO2 reduction effect can be expected from the replacement of boilers.

In this survey, first of all, we analyzed energy consumption by industrial category in the food and beverage fields of each country. Secondly, among energy consumption by industrial category, we analyzed consumption in steam boilers. Thirdly, we analyzed consumption of a process at an operating temperature below 100℃ on the steam demand side. Finally, we analyzed CO2 reduction potential achieved by converting the supply source of this energy from boilers to heat pumps.

The analysis revealed that a total CO2 reduction of 40 million t-CO2/year can be expected for the 11 countries considered. This amount is equal to 1.3% of CO2 emissions (3,140 million t-CO2/year) in the industry of all 11 countries.

Also, in the 10 countries except China, a CO2 reduction of 25 million t-CO2/year can be expected. This amount accounts for 1.8% of CO2 emissions (1,380 million t-CO2/year) in the industry of these 10 countries.

The industrial heat pump is an important technology that contributes to the prevention of global

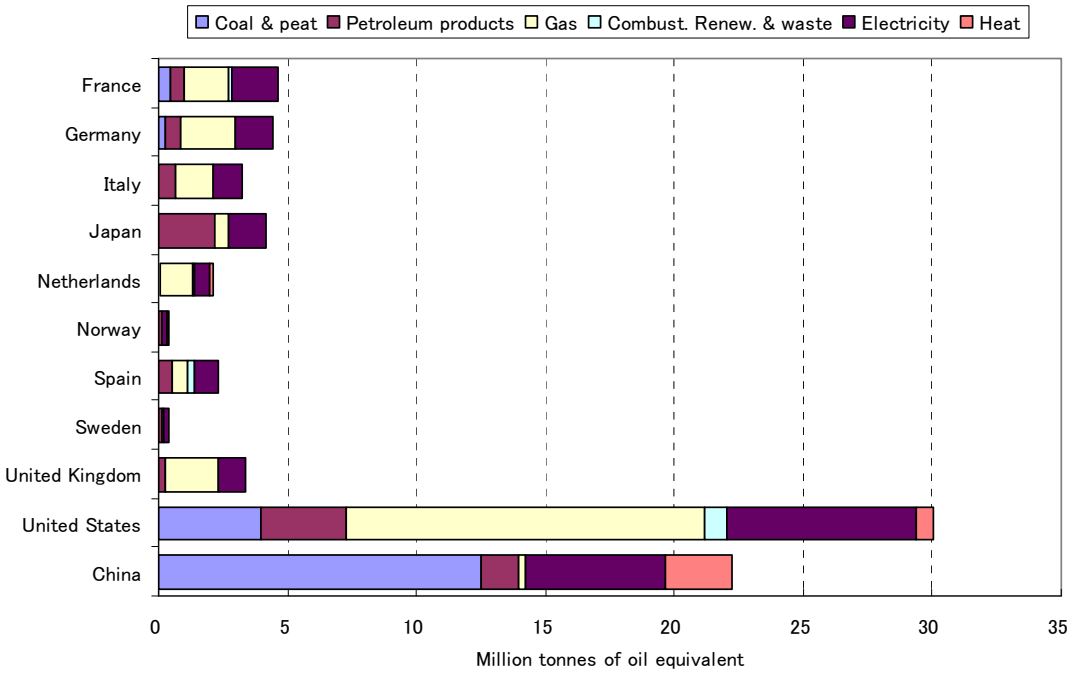
warming through CO2 emissions reduction and technological development in each country may likely make heat pumps more efficient and able to operate at higher temperatures, further expanding its areas of applicability.

5. References

5.1 Consumption by industrial category (middle classification) and energy type in the food and beverage fields in countries surveyed

The diagram below shows "① Consumption by industrial category (middle classification) and energy type in the food and beverage fields in countries surveyed".

Diagram 15 "① Consumption by industrial category (middle classification) and energy type in the food and beverage fields in countries surveyed"

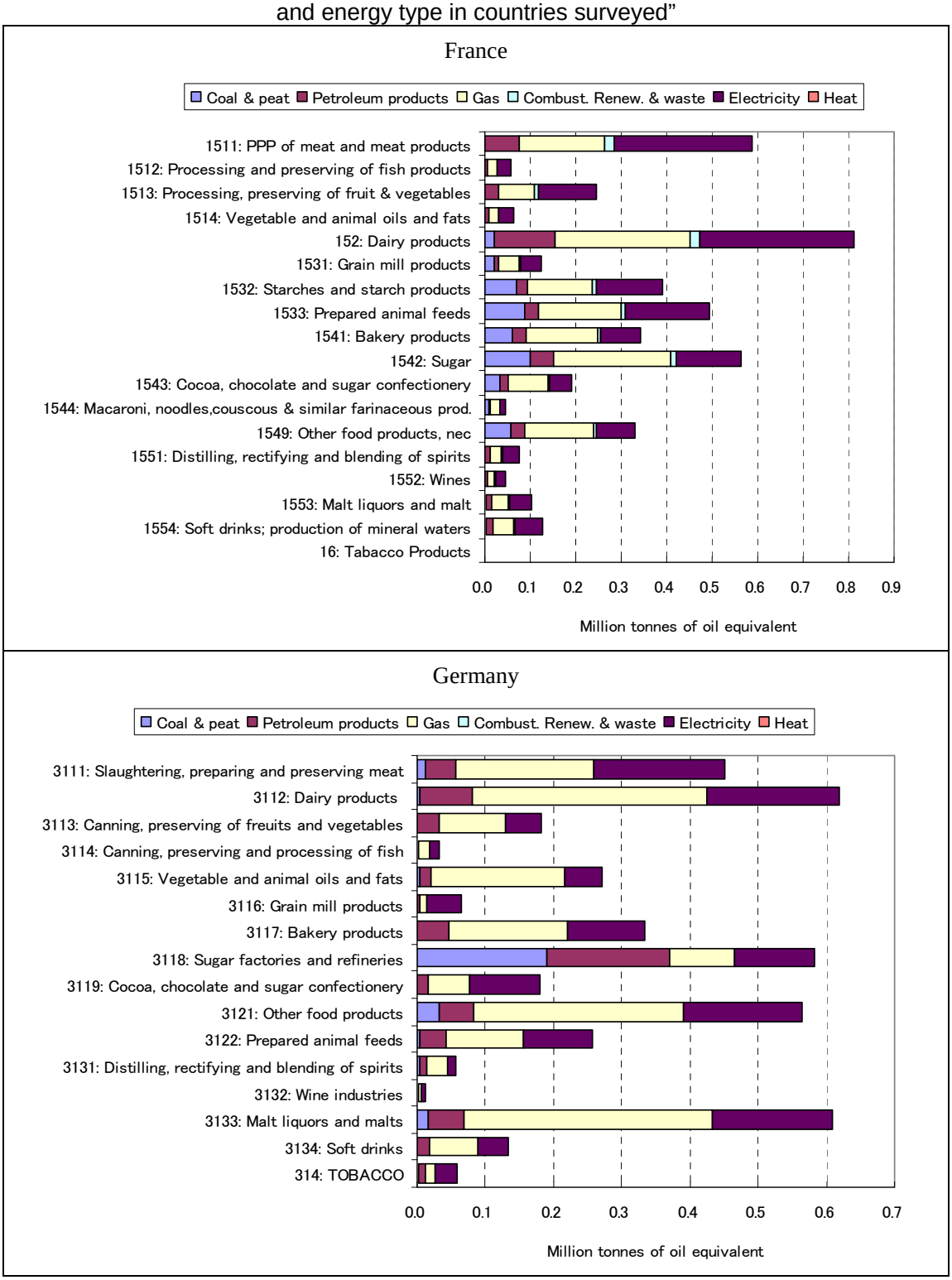


Source: "Energy Balances of OECD Countries 2009 Edition" (IEA)

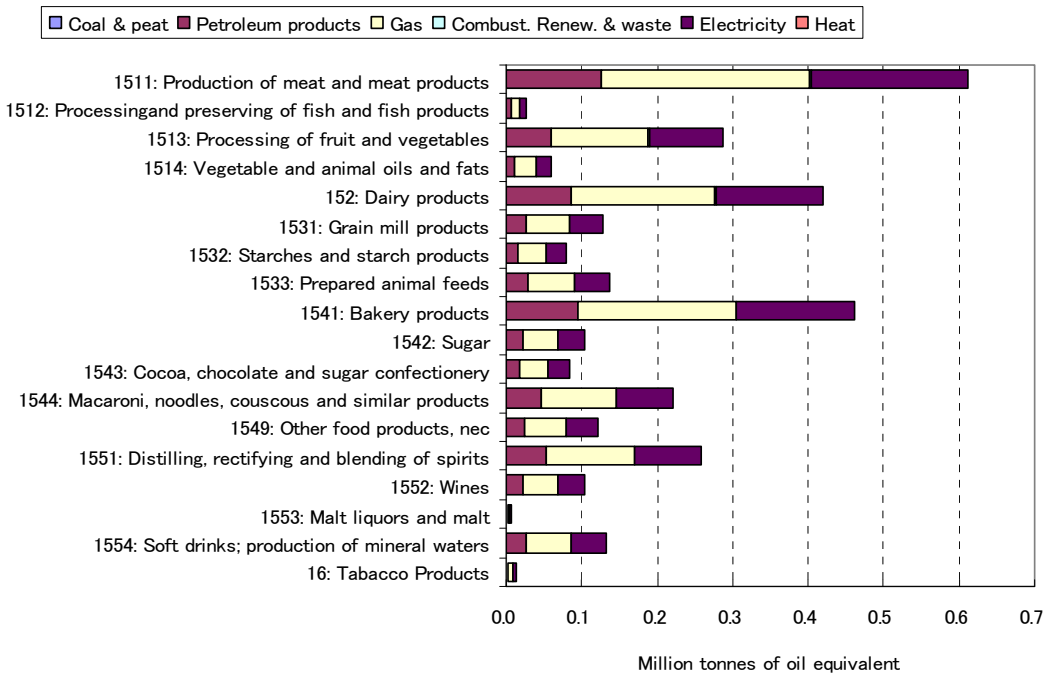
5.2 Estimation results of energy consumption by industrial category (sub classification) and energy type in countries surveyed

The diagram below shows estimation results of "⑤ energy consumption by industrial category (sub classification) and energy type in countries surveyed".

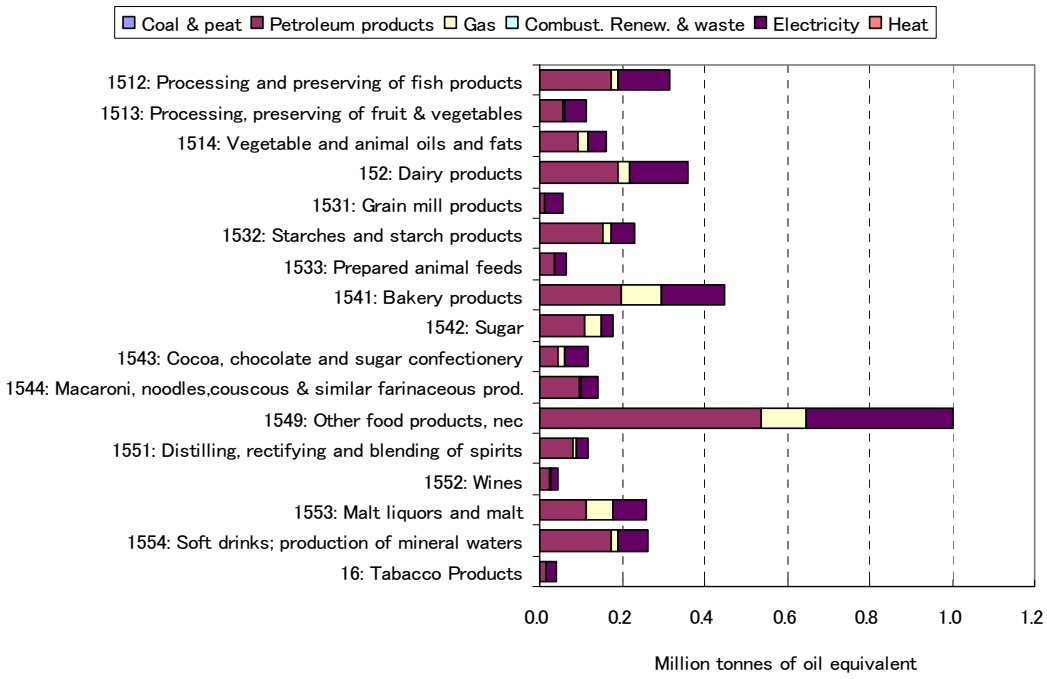
Diagram 16 Results of "⑤ energy consumption by industrial category (sub classification) and energy type in countries surveyed"



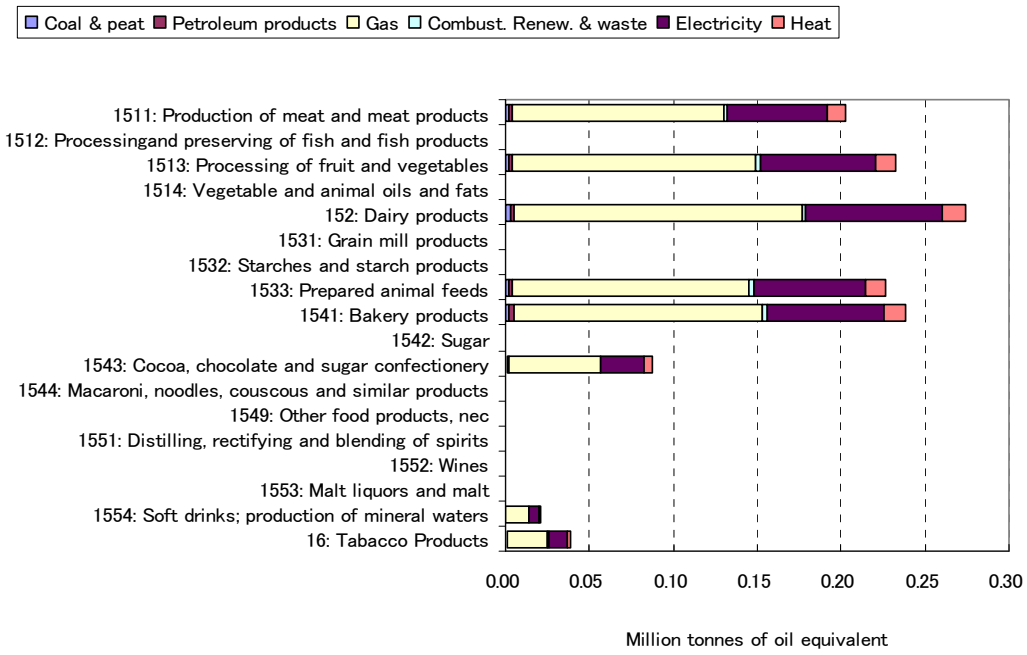
Italy


Coal & peat
Petroleum products
Gas
Combust. Renew. & waste
Electricity
Heat
1511: Production of meat and meat products
1512: Processingand preserving of fish and fish products
1513: Processing of fruit and vegetables
1514: Vegetable and animal oils and fats
152: Dairy products
1531: Grain mill products
1532: Starches and starch products
1533: Prepared animal feeds
1541: Bakery products
1542: Sugar
1543: Cocoa, chocolate and sugar confectionery
1544: Macaroni, noodles, couscous and similar products
1549: Other food products, nec
1551: Distilling, rectifying and blending of spirits
1552: Wines
1553: Malt liquors and malt
1554: Soft drinks; production of mineral waters
16: Tabacco Products
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Million tonnes of oil equivalent

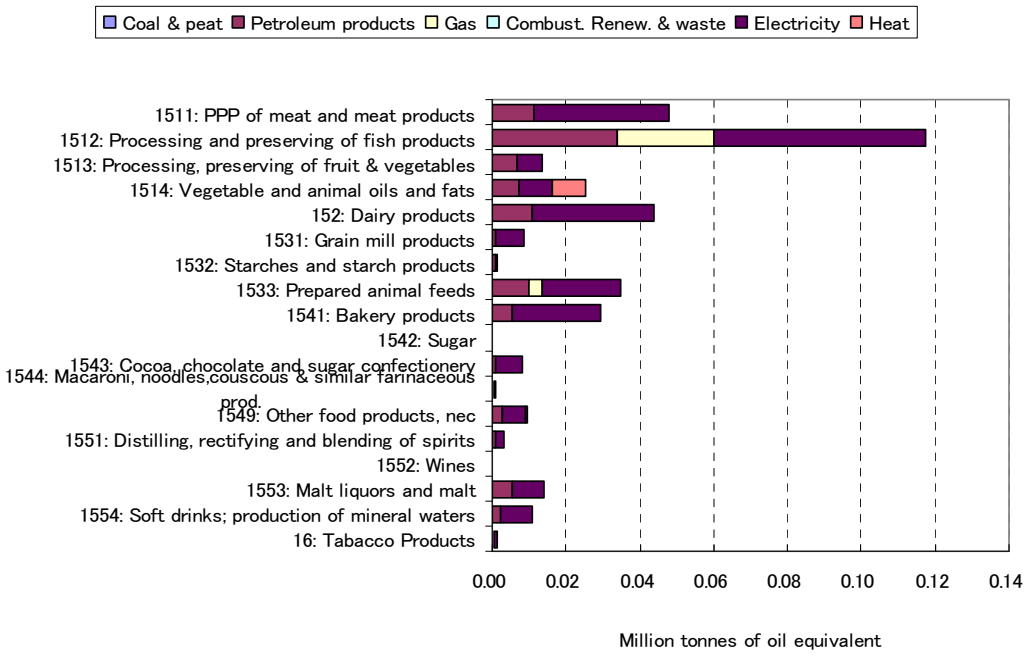
Japan


Coal & peat
Petroleum products
Gas
Combust. Renew. & waste
Electricity
Heat
1512: Processing and preserving of fish products
1513: Processing, preserving of fruit & vegetables
1514: Vegetable and animal oils and fats
152: Dairy products
1531: Grain mill products
1532: Starches and starch products
1533: Prepared animal feeds
1541: Bakery products
1542: Sugar
1543: Cocoa, chocolate and sugar confectionery
1544: Macaroni, noodles,couscous & similar farinaceous prod.
1549: Other food products, nec
1551: Distilling, rectifying and blending of spirits
1552: Wines
1553: Malt liquors and malt
1554: Soft drinks; production of mineral waters
16: Tabacco Products
0.0
0.2
0.4
0.6
0.8
1.0
1.2
Million tonnes of oil equivalent

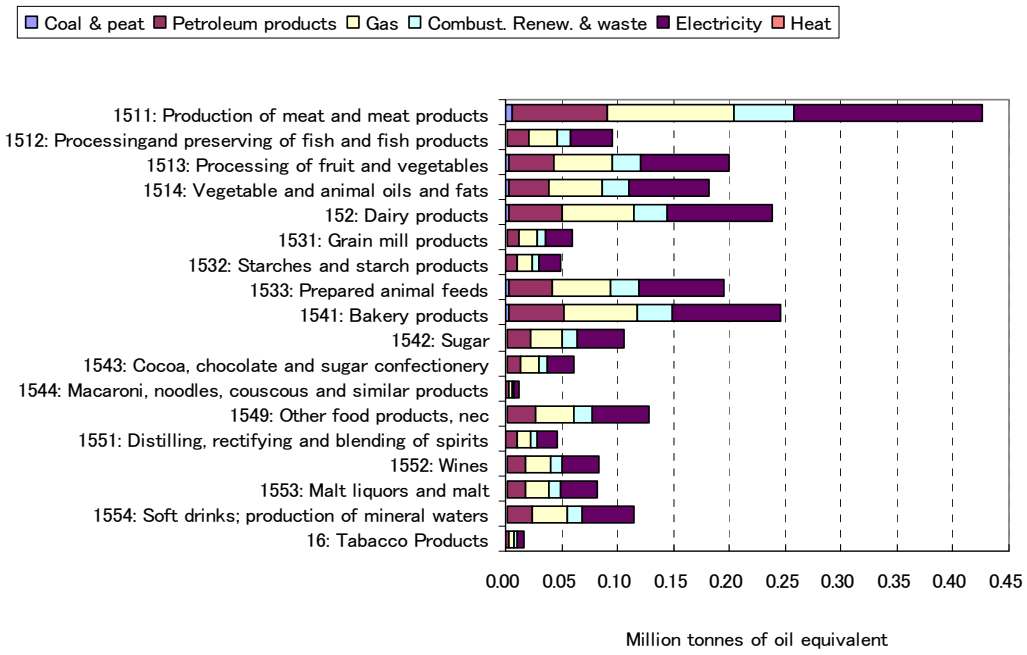
Netherlands



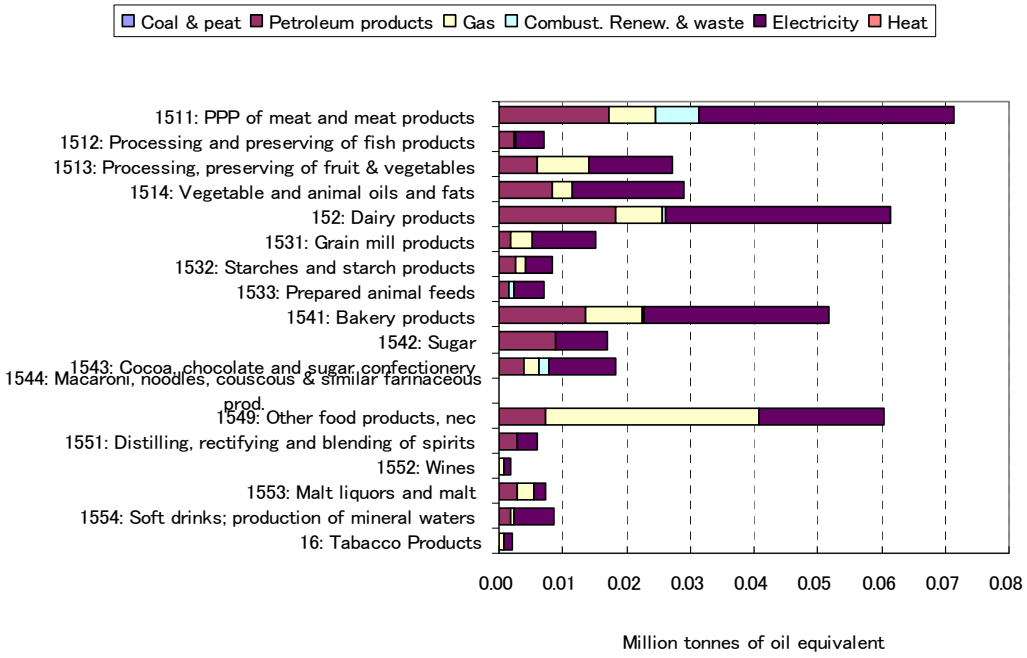
Norway



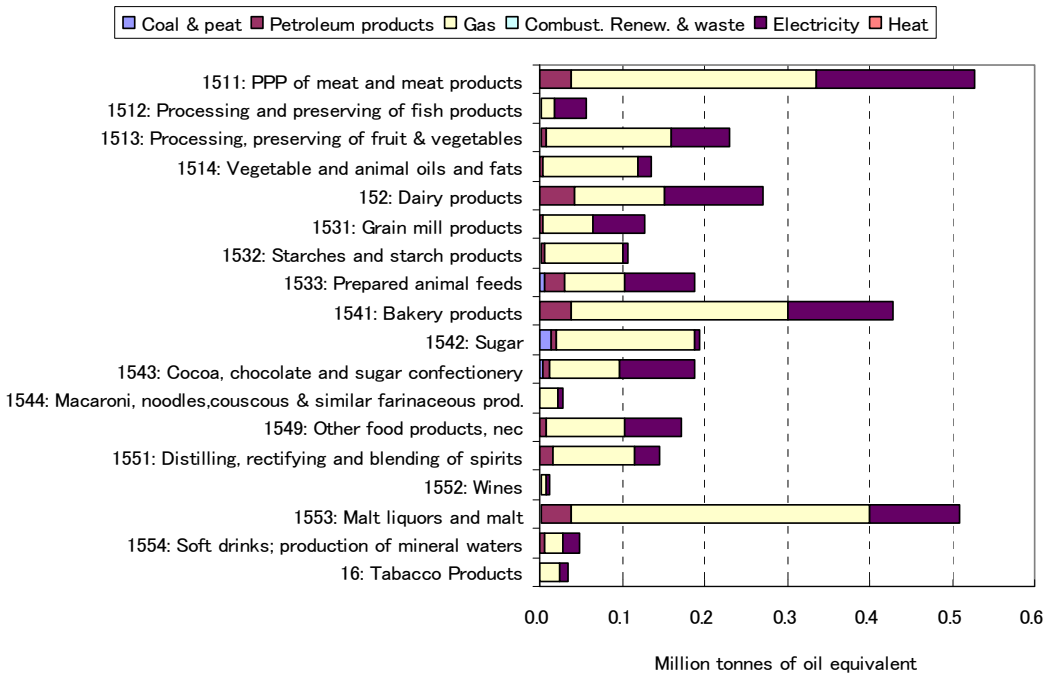
Spain



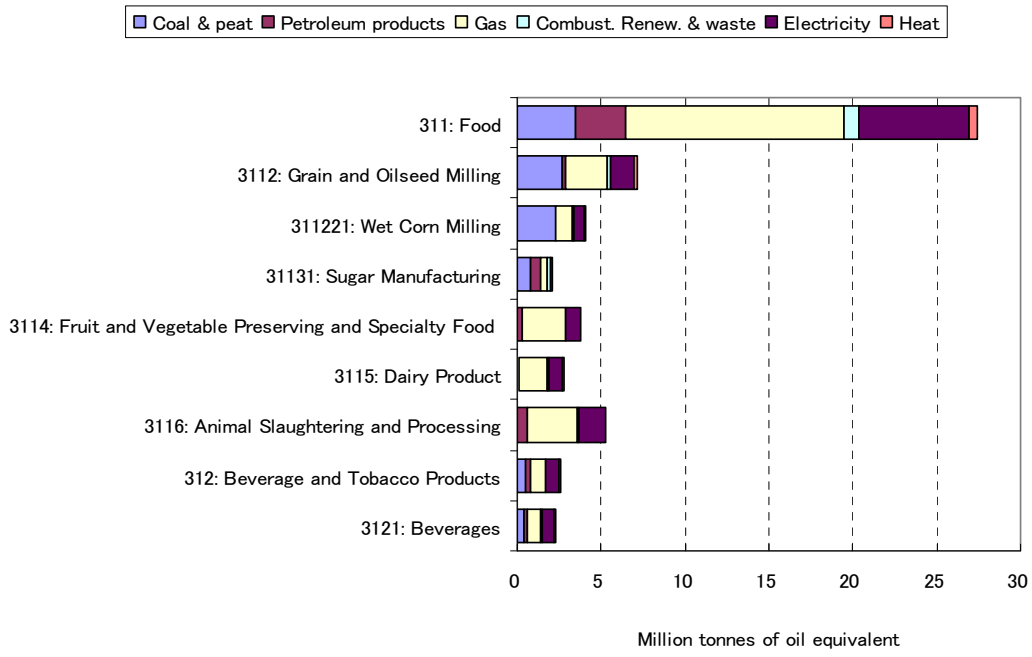
Sweden



United Kingdom

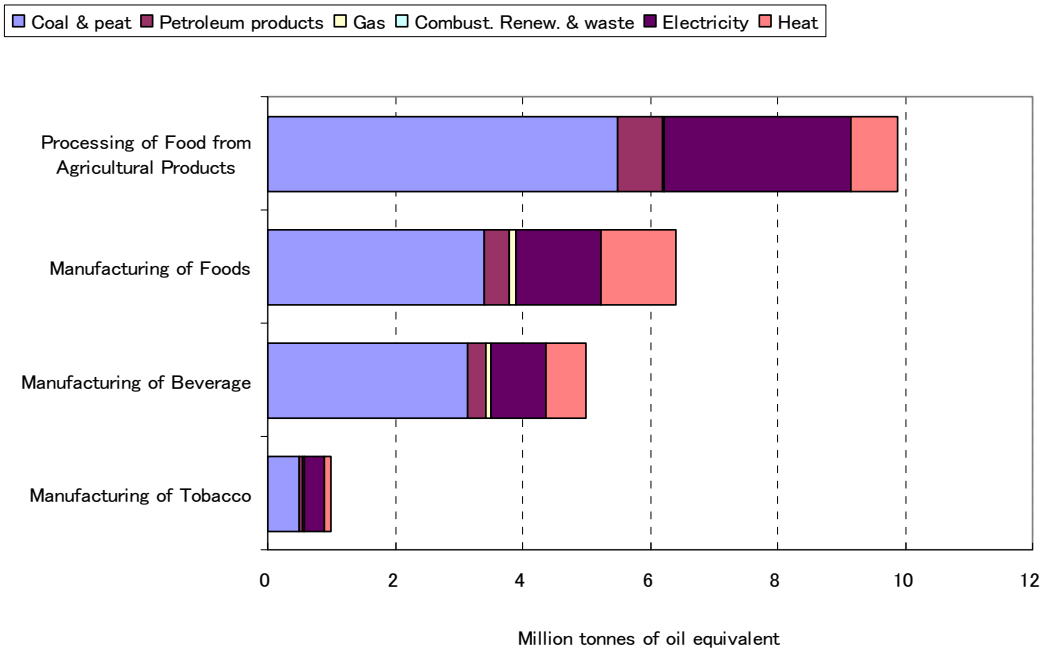


U.S.A.



* Although total data of Food and Tobacco can be figured out, breakout of respective industries cannot be figured out in full detail.

China



* Size of industry classification is rough compared with other countries.

5.3 Energy consumption and CO2 emission related data in countries surveyed

The diagram below shows final energy consumption and CO2 emission in years immediately before in countries surveyed.

Diagram 17　Final energy consumption in countries surveyed

(Mtoe)

	a. TFC (total final consumption)	b. Industry Sector	c. Food and tobacco
World	8,286.07	2,274.72	151.72
OECD	3,771.48	871.77	71.92
Countries surveyed	4,084.67	1,180.97	77.31
France	164.97	31.31	4.59
Germany	233.15	58.32	4.41
Italy	139.27	37.84	3.26
Japan	341.70	99.11	4.14
Netherlands	60.73	12.19	2.11
Norway	21.07	6.30	0.37
Spain	102.56	26.10	2.34
Sweden	34.35	12.21	0.40
United Kingdom	142.81	30.34	3.39
United States	1,587.83	291.97	30.03
China	1,256.23	575.28	22.27

Data for 2007

Source: “Energy Balances of OECD Countries 2009 Edition” (IEA)、"Energy Balances of Non-OECD Countries 2009 Edition"(IEA)

Diagram 18　CO2 emission in countries surveyed

(Million tonnes of CO2)

	a. Sectoral Approach	b. Manufacturing industries and construction
World	28,002.7	5,477.1
OECD	12,873.7	1,926.7
Countries surveyed	15,292.6	3,139.5
France	377.5	72.1
Germany	823.5	118.0
Italy	448.0	79.0
Japan	1,212.7	292.1
Netherlands	178.3	36.6
Norway	36.9	7.0
Spain	327.7	63.3
Sweden	48.3	11.0
United Kingdom	536.5	63.9
United States	5,696.8	632.7
China	5,606.5	1,764.0

Data for 2006

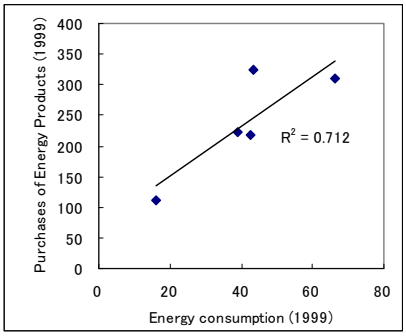
Source: "CO2 Emission From Fuel Combustion 2008" (IEA)

5.4 Correlation between energy consumption and energy purchases

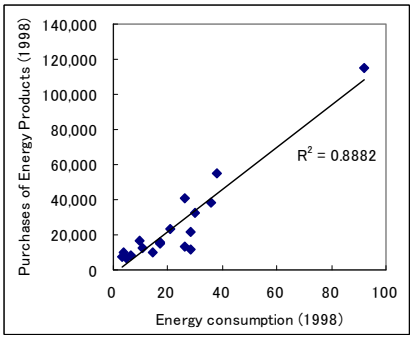
In some countries covered by this survey, it is possible to determine energy consumption and energy purchases in each category (small classification and sub classification) of the food and beverage fields. We examined the correlation between them. Although the strength of correlation differs from country to country, there is a high correlation between energy consumption and energy purchases on the whole.

Diagram 19　Correlation between Energy Consumption and Purchase Amount of Energy in Industrial categories (small classification, sub classification) in the Food and Beverage Fields in Countries Surveyed

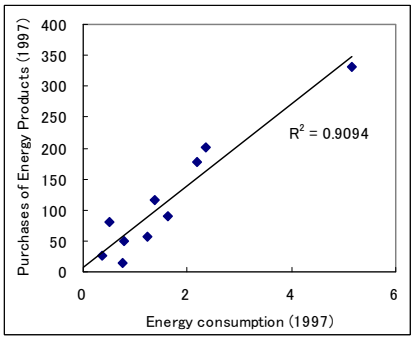
France



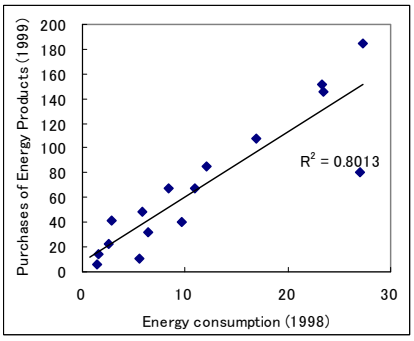
Japan



Norway



United Kingdom



Note: Consumption and purchase amount was compared with respect to different years due to limited statistical data.

Source: ”Structural Statistics for Industry and Services Volume 2 Energy Consumption 2000 Edition” (IEA), ”Structural Statistics for Industry and Services database- ISIC Rev. 3 Vol 2006 release 01” (OECD)

5.5 Source of data

Statistical data used in the survey are shown below.

5.5.1 Data related to energy consumption structure analysis

(1) Data on total energy consumption in the food and beverage fields of each country

We collected data on "① consumption by industrial category (middle classification) and energy type in the food and beverage fields in countries surveyed" from "Energy Balances of OECD Countries 2009 Edition" (IEA) and "Energy Balances of Non-OECD Countries 2009 Edition" (IEA).

Diagram 20 "① Consumption by industrial category (middle classification) and energy type in the food and beverage fields in countries surveyed" (Example: Japan)

Japan / Japon : 2007

Million tonnes of oil equivalent / *Million de tonnes d'équivalent pétrole*

SUPPLY AND CONSUMPTION / ***APPROVISIONNEMENT ET DEMANDE***	Coal & peat / *Charbon & tourbe*	Crude oil / *Pétrole brut*	Petroleum products / *Produits pétroliers*	Gas / *Gaz*	Nuclear / *Nucléaire*	Hydro / *Hydro*	Geotherm. solar etc. / *Géotherm. solaire etc.*	Combust. renew. & waste / *Comb. ren. & déchets*	Electricity / *Electricité*	Heat / *Chaleur*	Total / *Total*
Production	-	0.81	-	3.58	68.76	6.36	3.59	7.38 e	-	-	90.47
Imports	115.42	209.73	44.96	80.07	-	-	-	-	-	-	450.19
Exports	-0.92	-	-14.58	-	-	-	-	-	-	-	-15.51
Intl. marine bunkers	-	-	-5.83	-	-	-	-	-	-	-	-5.83
Intl. aviation bunkers	-	-	-6.20	-	-	-	-	-	-	-	-6.20
Stock changes	0.08	1.24	-0.31	-0.60	-	-	-	-	-	-	0.41
TPES	**114.57**	**211.78**	**18.04**	**83.05**	**68.76**	**6.36**	**3.59**	**7.38**	**-**	**-**	**513.52**
Transfers	-	-	-0.02	-	-	-	-	-	-	-	-0.02
Statistical differences	-0.35	1.08	0.82	4.85	-	-	-	-0.01	-0.01	-	6.39
Electricity plants	-64.19	-9.80	-21.30	-53.28	-68.76	-6.36	-2.84	-4.45	96.62	-	-134.37
CHP plants	-	-	-	-	-	-	-	-	-	-	-
Heat plants	-0.01	-	-0.02	-0.37	-	-	-	-0.14	-0.10	0.60	-0.04
Gas works	-	-	-1.67	1.59	-	-	-	-	-	-	-0.07
Petroleum refineries	-	-207.85	205.02	-	-	-	-	-	-	-	-2.83
Coal transformation	-16.56 e	-	-0.33	-	-	-	-	-	-	-	-16.89
Liquefaction plants	-	-	-	-	-	-	-	-	-	-	-
Other transformation	-	5.16	-5.38	-	-	-	-	-0.02 e	-	-	-0.24
Own use	-2.70	-0.00	-9.02	-2.28	-	-	-	-	-5.35	-0.02	-19.37
Distribution losses	-	-	-	-	-	-	-	-	-4.38	-	-4.38
TFC	**30.77**	**0.37**	**186.14**	**33.55**	**-**	**-**	**0.74**	**2.76**	**86.78**	**0.58**	**341.70**
INDUSTRY SECTOR	**29.78**	**0.03**	**29.57**	**7.96**	**-**	**-**	**-**	**2.73**	**29.03**	**-**	**99.11**
Iron and steel	12.97 e	-	1.74	2.05	-	-	-	-	6.18	-	22.94
Chemical and petrochem.	3.21	0.03	9.72	1.04	-	-	-	0.00	4.78	-	18.78
Non-ferrous metals	0.26	-	0.36	0.05	-	-	-	-	1.53	-	2.20
Non-metallic minerals	4.23	-	1.90	0.31	-	-	-	0.11	2.02	-	8.57
Transport equipment	-	-	-	-	-	-	-	-	-	-	-
Machinery	0.25	-	0.77	1.51	-	-	-	-	7.38	-	9.90
Mining and quarrying	0.02	-	0.24	0.08	-	-	-	-	0.08	-	0.41
Food and tobacco	-	-	2.20	0.50	-	-	-	-	1.44	-	4.14
Paper, pulp and printing	1.43	-	1.31	0.47	-	-	-	2.62	2.98	-	8.80
Wood and wood products	-	-	-	-	-	-	-	-	-	-	-
Construction	0.00	-	3.37	0.58	-	-	-	-	0.08	-	4.04
Textile	-	-	-	-	-	-	-	-	-	-	-
									2.58	-	19.32
									1.62	**-**	**82.41**
									-	-	3.67

Source: "Energy Balances of OECD Countries 2009 Edition" (IEA)

(2) Data on energy consumption composition ratio by industrial category (sub classification) in the food and beverage fields

Data on "④ Energy consumption composition ratio by industrial category (sub classification) and energy type in the food and beverage fields in countries surveyed" used in this survey differs from country to country. We calculated "② Energy consumption shares by industrial category (sub classification) and energy type in countries surveyed" and "③ Shares of energy purchases by industrial category (sub classification) in countries surveyed" from "Structural Statistics for Industry and Services Volume 2 Energy Consumption 2000 Edition" (IEA), "Structural Statistics for Industry and Services database- ISIC Rev. 3 Vol 2006 release 01" (OECD), "2006 Energy Consumption by Manufacturers" (EIA), and "China Energy Statistical Yearbook 2008" (China Statistics Press).

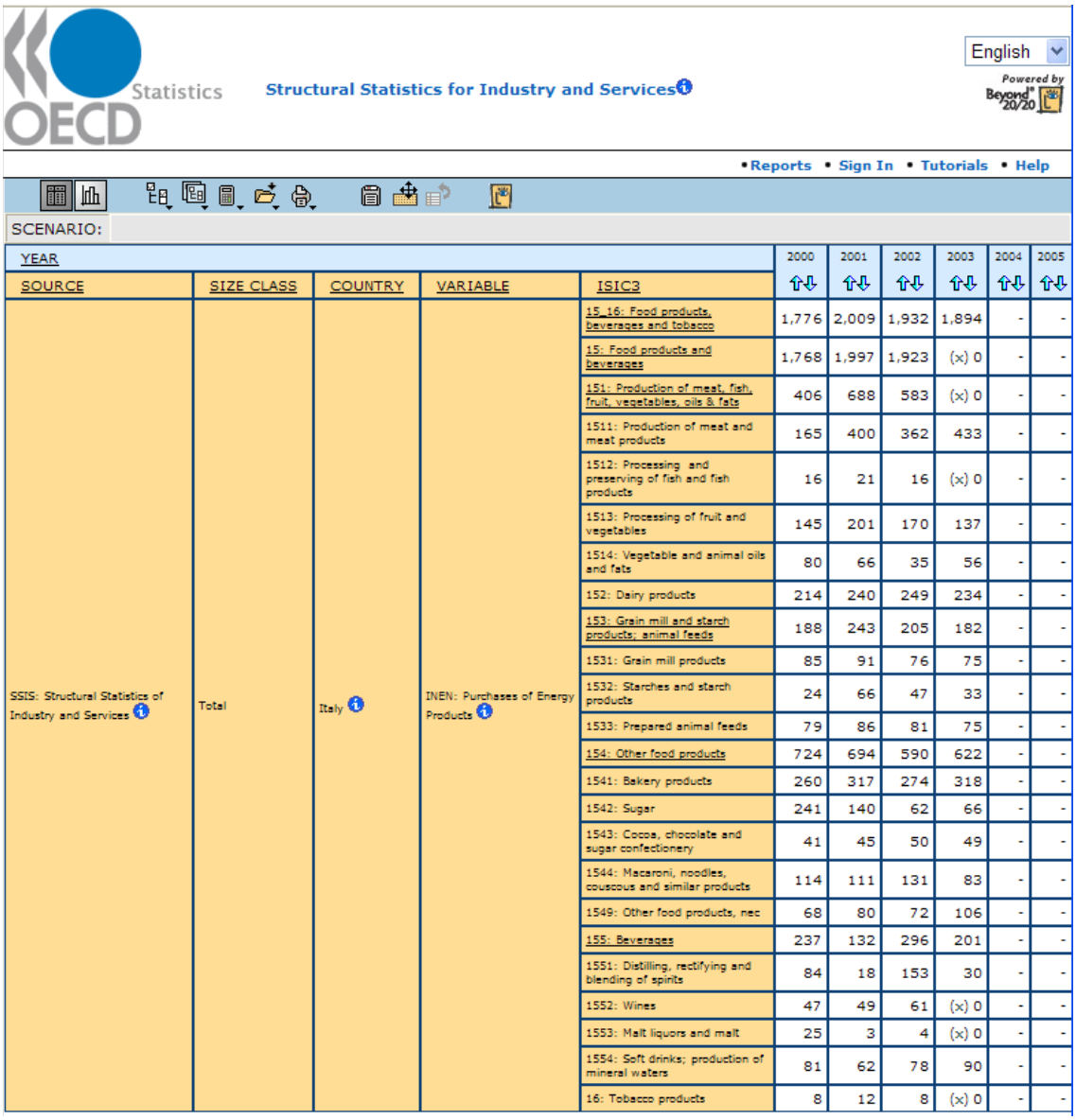
Diagram 21 "② Energy consumption shares by industrial category (sub classification) and energy type in countries surveyed" (Example: Japan)

Year: 1998 JAPAN

ISIC Revision 3 Industry Sector		Solid TJ	LPG TJ	Distiloil TJ	RFO TJ	Gas TJ	Biomass TJ	Steam TJ	Electr MWh	Own Use MWh	TOTAL TJ
15	FOOD PRODUCTS AND BEVERAGES	4,697	26,802	131,843	..	39,024	0	143,724	20,038,717	2,257,283	410,103
151	Production, processing and preserving (PPP)	1,472	4,191	26,292	..	6,454	0	22,629	4,454,073	476,321	75,358
1511	PPP of meat and meat products	0	800	6,224	..	2,898	0	6,547	1,363,971	128,051	20,918
1512	Processing and preserving of fish products	0	2,050	10,502	..	1,476	0	6,204	1,739,416	48,416	26,320
1513	Processing, preserving of fruit & vegetables	0	409	3,816	..	71	0	3,862	735,735	2,071	10,799
1514	Vegetable and animal oils and fats	1,472	932	5,750	..	2,009	0	6,016	614,951	297,783	17,321
152	Dairy products	0	502	13,176	..	2,445	0	13,037	1,958,811	110,237	35,815
153	Grain mill prod., starches & prepared animal feeds	0	1,988	12,751	..	1,773	0	14,785	1,784,441	428,602	36,178
1531	Grain mill products	0	24	818	..	69	0	669	612,060	15,762	3,727
1532	Starches and starch products	0	1,683	9,561	..	1,592	0	11,926	789,196	390,476	26,197
1533	Prepared animal feeds	0	281	2,372	..	112	0	2,190	383,185	22,364	6,254
154	Other food products	2,555	16,964	54,520	..	21,030	0	61,096	8,974,677	983,681	184,933
1541	Bakery products	9	6,487	7,921	..	7,415	0	8,645	2,215,954	187,516	37,779
1542	Sugar	2,413	1	8,054	..	3,118	0	14,267	404,409	250,148	28,408
1543	Cocoa, chocolate and sugar confectionery	0	1,100	2,020	..	1,394	0	2,391	788,956	34,370	9,622
1544	Macaroni, noodles, couscous & similar farinaceous prod.	0	574	6,399	..	470	0	7,573	554,242	15,538	16,955
1549	Other food products, nec	133	8,802	30,126	..	8,633	0	28,220	5,011,116	496,109	92,168
155	Beverages	670	3,157	25,104	..	7,322	0	32,177	2,866,715	258,442	77,820
1551	Distilling, rectifying and blending of spirits	670	814	5,120	..	617	0	6,112	375,811	50,389	14,505
1552	Wines	0	18	1,595	..	367	0	1,946	250,927	1,053	4,826
1553	Malt liquors and malt	0	886	7,354	..	4,948	0	11,512	1,181,960	151,819	28,409
1554	Soft drinks; production of mineral waters	0	1,439	11,035	..	1,390	0	12,607	1,058,017	55,181	30,081
16	TOBACCO PRODUCTS	0	1	1,041	..	77	0	798	334,909	28,479	3,020
17	TEXTILES	3,078	7,704	45,801	..	5,469	0	45,637	6,148,812	893,109	126,610
171	Spinning, weaving and finishing of textiles	3,078	6,462	40,328	..	4,016	0	40,352	4,602,970	793,721	107,949
1711	Preparation and spinning of textile fibres	470	297	9,762	..	522	0	5,162	3,034,254	571,606	25,079
1712	Finishing of textiles	2,608	6,165	30,566	..	3,494	0	35,190	1,568,716	222,115	82,871
172	Other textiles	0	1,078	3,273	..	1,371	0	3,512	911,776	85,755	12,208
1721	Made-up textile articles, except apparel	0	166	396	..	176	0	425	210,790	6,710	1,898
1722	Carpets and rugs	0	169	188	..	297	0	287	109,803	10,172	1,300
					..	0	0	133	41,271	0	505
					..	898	0	2,667	549,912	68,873	8,506
							0	1,773	634,066	13,633	6,453
									608,865	1,808	7,354
											7,223

Source: "Structural Statistics for Industry and Services Volume 2 Energy Consumption 2000 Edition" (IEA)

Diagram 22 “③ Shares of energy purchases by industrial category (sub classification) in countries surveyed” (Example: Italy)



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SCENARIO:

YEAR					2000	2001	2002	2003	2004	2005
SOURCE	SIZE CLASS	COUNTRY	VARIABLE	ISIC3						
SSIS: Structural Statistics of Industry and Services	Total	Italy	INEN: Purchases of Energy Products	15_16: Food products, beverages and tobacco	1,776	2,009	1,932	1,894	-	-
				15: Food products and beverages	1,768	1,997	1,923	(x) 0	-	-
				151: Production of meat, fish, fruit, vegetables, oils & fats	406	688	583	(x) 0	-	-
				1511: Production of meat and meat products	165	400	362	433	-	-
				1512: Processing and preserving of fish and fish products	16	21	16	(x) 0	-	-
				1513: Processing of fruit and vegetables	145	201	170	137	-	-
				1514: Vegetable and animal oils and fats	80	66	35	56	-	-
				152: Dairy products	214	240	249	234	-	-
				153: Grain mill and starch products; animal feeds	188	243	205	182	-	-
				1531: Grain mill products	85	91	76	75	-	-
				1532: Starches and starch products	24	66	47	33	-	-
				1533: Prepared animal feeds	79	86	81	75	-	-
				154: Other food products	724	694	590	622	-	-
				1541: Bakery products	260	317	274	318	-	-
				1542: Sugar	241	140	62	66	-	-
				1543: Cocoa, chocolate and sugar confectionery	41	45	50	49	-	-
				1544: Macaroni, noodles, couscous and similar products	114	111	131	83	-	-
				1549: Other food products, nec	68	80	72	106	-	-
				155: Beverages	237	132	296	201	-	-
				1551: Distilling, rectifying and blending of spirits	84	18	153	30	-	-
				1552: Wines	47	49	61	(x) 0	-	-
				1553: Malt liquors and malt	25	3	4	(x) 0	-	-
				1554: Soft drinks; production of mineral waters	81	62	78	90	-	-
				16: Tobacco products	8	12	8	(x) 0	-	-

Source: “Structural Statistics for Industry and Services database- ISIC Rev. 3 Vol 2006 release 01” (OECD)

5.5.2 Data related to the CO2 reduction effect analysis

(1) Data on Share of fuels for steam boiler relative to energy consumption by industrial category (sub classification) and energy type

We set share of fuels for steam boiler relative to energy consumption by industrial category (sub classification) and energy type based on the "Statistics on the Consumption Structure of Petroleum and Others for Fiscal 2001," statistical material collected in Japan through fiscal 2001.

Diagram 23 "⑥ Share of fuels for steam boiler relative to energy consumption by industrial category (sub classification) and energy type in Japan"

Industry classification/Fuel/Year						No. of business places consuming	Consumption					
	Industry classification name	Fuel code	Name of fuel	Fuel unit	Year surveyed		Total	For raw material	For steam boiler	For direct heating	For co-generation	Others
1211	Meat product manufacturer	2005	Total	Crude oil conversion kl	2001	397	181,808	－	119,364	16,994	22,525	22,925
1211	Meat product manufacturer	2008	Petroleum fuel	Crude oil conversion kl	2001		165,312	－	107,138	14,990	21,365	21,818
1211	Meat product manufacturer	2110	Gasoline	kl	2001		165	－	－	－	－	165
1211	Meat product manufacturer	2140	Kerosene	kl	2001		18,334	－	16,062	264	－	2,008
1211	Meat product manufacturer	2150	Light oil	kl	2001		1,602	－	180	143	－	1,279
1211	Meat product manufacturer	2158	Total of heavy oils	kl	2001		119,901	－	85,808	756	20,461	12,876
1211	Meat product manufacturer	2160	A-heavy oil	kl	2001		116,933	－	82,840	756	20,461	12,876
1211	Meat product manufacturer	2170	B-heavy oil	kl	2001		416	－	416	－	－	－
1211	Meat product manufacturer	2180	C-heavy oil	kl	2001		2,552	－	2,552	－	－	－
1211	Meat product manufacturer	2200	Liquefied petroleum gas	t	2001		19,448	－	3,918	10,664	612	4,254
1211	Meat product manufacturer	2300	Non-petroleum based fuel	Crude oil conversion kl	2001		16,496	－	12,226	2,003	1,159	1,107
1211	Meat product manufacturer	2320	Petroleum coke	t	2001		47	－	－	－	－	47
1211	Meat product manufacturer	2500	Natural gas	1000ms3	2001		15	－	－	15	－	－
1211	Meat product manufacturer	2520	City gas	1000ms3	2001		14,492	－	10,971	1,627	975	919
1211	Meat product manufacturer	2525	(City gas)	1000ms3	2001		15,211	－	11,309	1,838	1,073	990
1212	Dairy product manufacturer	2005	Total	Crude oil conversion kl	2001	337	461,454	－	376,787	6,196	58,099	20,372
1212	Dairy product manufacturer	2008	Petroleum fuel	Crude oil conversion kl	2001		376,327	－	330,765	3,776	25,295	16,492
1212	Dairy product manufacturer	2110	Gasoline	kl	2001		86	－	－	－	－	86
1212	Dairy product manufacturer	2140	Kerosene	kl	2001		9,732	－	2,730	69	5,445	1,488
1212	Dairy product manufacturer	2150	Light oil	kl	2001		492	－	－	－	－	492
1212	Dairy product manufacturer	2158	Total of heavy oils	kl	2001		348,037	－	315,325	843	19,948	11,921
1212	Dairy product manufacturer	2160	A-heavy oil	kl	2001		258,886	－	226,181	843	19,948	11,914
1212	Dairy product manufacturer	2170	B-heavy oil	kl	2001		873	－	873	－	－	－
1212	Dairy product manufacturer	2180	C-heavy oil	kl	2001		88,278	－	88,271	－	－	7
1212	Dairy product manufacturer	2200	Liquefied petroleum gas	t	2001		9,004	－	4,865	2,206	－	1,933
1212	Dairy product manufacturer	2300	Non-petroleum based fuel	Crude oil conversion kl	2001		85,127	－	46,022	2,420	32,805	3,880
1212	Dairy product manufacturer	2520	City gas	1000ms3	2001		71,987	－	39,005	2,033	27,687	3,262
1212	Dairy product manufacturer	2525	(City gas)	1000ms3	2001		78,743	－	42,571	2,239	30,345	3,589
1219	Other livestock food product manufacturer	2005	Total	Crude oil conversion kl	2001	235	86,550	－	61,381	3,505	8,627	13,037
1219	Other livestock food product manufacturer	2008	Petroleum fuel	Crude oil conversion kl	2001							
1219	Other livestock food product manufacturer	2110	Gasoline									

Source: "The structural survey of oil consumption, 2001" (Ministry of Economy, Trade and Industry)

(2) CO2 emission factor

1) CO2 emission factor for fuel combustion by energy type (fuel type)

We set "⑩CO2 emission factor by energy type" (fuel type) uniformly, based on typical values in "CO2 Emissions From Fuel Combustion 2008 Edition" (IEA).

Diagram 24 "⑩CO2 emission factor by energy type" (fuel type)

TABLE 2
SELECTED NET CALORIFIC VALUES

	Factors (TJ/10^3 tonnes)
Refined petroleum products	
Gasoline	44.80
Jet kerosene	44.59
Other kerosene	44.75
Shale oil	36.00
Gas/diesel oil	43.33
Residual fuel oil	40.19
LPG	47.31
Ethane	47.49
Naphtha	45.01
Bitumen	40.19
Lubricants	40.19
Petroleum coke	31.00
Refinery feedstocks	44.80
Refinery gas	48.15
Other oil products	40.19
Other products	
Coal oils and tars derived from coking coals	28.00
Oil shale	9.40
Orimulsion	27.50

NOTE: When converting from 10^3 t, for anthracite, coking coal, other bituminous coal, sub-bituminous coal and lignite, separate country specific net calorific values are used for production (Column A), imports (Column B), and exports (Column C). For these fuels, apparent consumption is calculated by converting production, imports, exports, and stock changes to TJ first. For international bunkers (Column D) and stock change (Column E), either a weighted average net calorific value or a factor appropriate to the dominant source of supply is used.

Step 3 Multiplying by carbon emission factors

1 The carbon emission factor (CEF) used to convert apparent consumption into carbon content is entered in Column I.

Table 3 shows the default values used in this publication.

TABLE 3
CARBON EMISSION FACTORS (CEF)

Fuel	*Carbon emission factor (t C/TJ)*
LIQUID FOSSIL	
Primary fuels	
Crude oil	20.0
Orimulsion	22.0
Natural gas liquids	17.2
Secondary fuels/products	
Gasoline	18.9
Jet kerosene	19.5
Other kerosene	19.6
Shale oil	20.0
Gas/diesel oil	20.2
Residual fuel oil	21.1
LPG	17.2
Ethane	16.8
Naphtha	(20.0) [a]
Bitumen	22.0
Lubricants	(20.0) [a]
Petroleum coke	27.5
Refinery feedstocks	(20.0) [a]
Refinery gas	18.2 [b]
Other oil	(20.0) [a]
SOLID FOSSIL	
Primary fuels	
Anthracite	26.8
Coking coal	25.8
Other bituminous coal	25.8
Sub-bituminous coal	26.2
Lignite	27.6
Oil shale	29.1
Peat	28.9
Secondary fuels/products	
BKB & patent fuel	(25.8) [a]
Coke oven / gas coke	29.5
Coke oven gas	13.0 [b]
Blast furnace gas	66.0 [b]
GASEOUS FOSSIL	
Natural gas (dry)	15.3
BIOMASS [c]	
Solid biomass	29.9
Liquid biomass	(20.0) [a]
Gas biomass	(30.6) [a]

Source: "CO2 Emission From Fuel Combustion 2008 Edition" (IEA)

2) CO2 emission factor of electricity generation

We set "⑮ CO2 emission factor of electric power by country" by country based on "CO2 Emission From Fuel Combustion 2008 Edition" (IEA).

Diagram 25 "⑮ CO2 emission factor of electric power by country"

CO_2 emissions per kWh from electricity and heat generation *

Emissions de CO_2 par kWh pour le secteur de l'électricité et de la chaleur *

grammes CO_2 / kilowatt hour

	1990	1995	1998	1999	2000	2001	2002	2003	2004	2005	2006	Average 04-06
World	..	**472**	**494**	**489**	**486**	**492**	**488**	**496**	**502**	**501**	**505**	**502**
Annex I Parties	..	*419*	*435*	*430*	*428*	*435*	*426*	*429*	*421*	*418*	*414*	*418*
Annex II Parties	..	*459*	*467*	*458*	*456*	*468*	*454*	*455*	*447*	*443*	*436*	*442*
North America	..	*526*	*555*	*542*	*539*	*566*	*522*	*527*	*526*	*522*	*512*	*520*
Europe	*399*	*357*	*338*	*328*	*326*	*325*	*332*	*326*	*316*	*306*	*306*	*309*
Pacific	*482*	*461*	*452*	*467*	*469*	*480*	*505*	*522*	*507*	*511*	*506*	*508*
Annex I EIT	..	*342*	*360*	*360*	*357*	*355*	*357*	*366*	*355*	*355*	*359*	*356*
Non-Annex I Parties	..	*627*	*643*	*633*	*622*	*618*	*619*	*630*	*651*	*646*	*652*	*650*
Annex I Kyoto Parties	..	*352*	*357*	*355*	*354*	*355*	*361*	*366*	*353*	*349*	*350*	*351*
Non-OECD Total	..	**474**	**515**	**514**	**512**	**511**	**518**	**535**	**552**	**555**	**565**	**557**
OECD Total	..	**470**	**476**	**467**	**465**	**476**	**461**	**462**	**454**	**450**	**444**	**450**
Canada	203	184	221	212	222	231	217	226	209	196	184	196
Mexico	538	507	572	561	566	568	570	576	528	555	541	541
United States	..	579	604	591	586	617	567	571	572	570	559	567
OECD N. America	..	**526**	**556**	**543**	**540**	**566**	**524**	**529**	**526**	**523**	**513**	**521**
Australia	813	808	861	867	863	890	938	919	914	922	921	919
Japan	434	411	381	397	401	402	422	445	428	427	418	424
Korea	520	540	497	482	447	477	454	449	475	460	464	466
New Zealand	128	113	216	239	230	278	250	295	275	312	309	299
OECD Pacific	**486**	**472**	**459**	**469**	**465**	**479**	**494**	**506**	**499**	**499**	**495**	**498**
Austria	245	214	208	193	180	203	196	234	228	223	214	222
Belgium	344	357	315	278	284	272	266	274	281	271	260	271
Czech Republic	597	602	589	580	596	584	561	524	525	525	527	526
Denmark	476	430	390	363	339	336	332	357	308	282	341	310
Finland	227	247	212	212	211	242	253	293	254	193	242	229
France	109	76	100	86	83	71	76	80	78	92	85	85
Germany	553	522	506	489	494	506	508	434	436	405	404	415
Greece	990	946	797	779	817	831	814	778	776	776	725	759
Hungary	433	444	432	412	410	394	391	425	392	341	344	359
Iceland	1	2	3	4	1	1	1	1	1	1	1	1
Ireland	740	727	703	697	642	668	635	600	574	582	535	564
Italy	575	545	513	494	499	483	506	516	416	413	404	411
Luxembourg	2 588	1 340	249	258	255	240	329	330	334	328	326	329
Netherlands	588	530	470	468	447	460	458	463	440	387	394	407
Norway	3	4	5	6	4	6	5	8	7	6	7	6
Poland	641	670	663	664	671	660	662	662	664	657	659	660
Portugal	516	569	471	539	479	442	512	413	452	501	416	456
Slovak Republic	376	375	351	340	267	241	215	255	240	229	223	231
Spain	427	453	379	443	430	382	434	378	382	396	350	376
Sweden	48	50	53	49	42	42	52	59	51	44	48	48
Switzerland	22	22	28	22	22	21	22	23	24	26	26	25
Turkey	568	512	530	549	519	544	472	444	419	426	438	428
United Kingdom	672	529	477	441	461	474	460	478	485	484	505	491
OECD Europe	**435**	**394**	**377**	**367**	**364**	**362**	**364**	**358**	**347**	**338**	**339**	**341**
European Union - 27	..	*416*	*392*	*383*	*382*	*378*	*382*	*376*	*363*	*355*	*354*	*357*

* CO_2 emissions from fossil fuels consumed for electricity, combined heat and power and main activity heat plants divided by the output of electricity and heat generated from fossil fuels, nuclear, hydro (excluding pumped storage), geothermal, solar and biomass. Both main activity producers and autoproducers have been included in the calculation of the emissions. Due to missing data for heat in 1990, the ratio for some countries and regions is not available.

Source: "CO2 Emission From Fuel Combustion 2008 Edition" (IEA)

(3) CO2 emissions from all industrial sectors

We set CO2 emissions from all industrial sectors by country based on “CO2 Emission From Fuel Combustion 2008 Edition” (IEA).

Diagram 26 CO2 Emission for All Industrial Sectors (Example: Japan)

Japan / Japon *

Key indicators

	1990	1995	2000	2003	2004	2005	2006	% change 90-06
CO_2 Sectoral Approach (Mt of CO_2)	1 071.43	1 156.73	1 192.39	1 222.77	1 222.36	1 227.68	1 212.70	13.2%
CO_2 Reference Approach (Mt of CO_2)	1 078.38	1 169.77	1 222.93	1 246.03	1 267.76	1 245.59	1 235.52	14.6%
TPES (PJ)	18 586	20 966	22 049	21 528	22 225	22 122	22 088	18.8%
TPES (Mtoe)	443.92	500.77	526.62	514.20	530.83	528.38	527.56	18.8%
GDP (billion 2000 US$ using exch. rates)	4 122.40	4 445.40	4 667.50	4 754.60	4 885.10	4 978.30	5 087.10	23.4%
GDP (billion 2000 US$ using PPPs)	2 867.16	3 091.83	3 246.29	3 306.90	3 397.65	3 462.45	3 538.13	23.4%
Population (millions)	123.48	125.47	126.84	127.72	127.76	127.77	127.76	3.5%
CO_2 / TPES (t CO_2 per TJ)	57.7	55.2	54.1	56.8	55.0	55.5	54.9	-4.8%
CO_2 / GDP (kg CO_2 per 2000 US$)	0.26	0.26	0.26	0.26	0.25	0.25	0.24	-8.3%
CO_2 / GDP (kg CO_2 per 2000 US$ PPP)	0.37	0.37	0.37	0.37	0.36	0.35	0.34	-8.3%
CO_2 / population (t CO_2 per capita)	8.68	9.22	9.40	9.57	9.57	9.61	9.49	9.4%

Ratios are based on the Sectoral Approach.
* Please see the note in Chapter 1 on the revisions provided by the Japanese Administration.

2006 CO_2 emissions by sector

million tonnes of CO_2	Coal/peat	Oil	Gas	Other **	Total	% change 90-06
Sectoral Approach	**431.38**	**586.81**	**189.98**	**4.54**	**1 212.70**	**13.2%**
Main activity producer elec. and heat	223.12	45.77	111.77	1.23	381.90	24.1%
Unallocated autoproducers	47.94	22.31	4.66	2.33	77.23	37.7%
Other energy industries	14.75	26.11	0.84	-	41.70	-8.3%
Manufacturing industries and construction	143.10	130.32	17.68	0.97	292.07	-0.8%
Transport	-	245.41	-	-	245.41	17.1%
of which: road	-	*219.73*	-	-	*219.73*	*17.6%*
Other sectors	2.47	116.90	55.03	-	174.39	10.4%
of which: residential	-	*41.90*	*21.54*	-	*63.45*	*13.7%*
Reference Approach	**435.95**	**614.31**	**180.71**	**4.54**	**1 235.52**	**14.6%**
Diff. due to losses and/or transformation	3.54	15.40	- 3.41	-	15.52	
Statistical differences	1.03	12.10	- 5.85	0.00	7.29	
Memo: international marine bunkers	-	*18.64*	-	-	*18.64*	*5.5%*
Memo: international aviation	-	*19.84*	-	-	*19.84*	*49.0%*

** Other includes industrial waste and non-renewable municipal waste.

Key sources for CO_2 emissions from fuel combustion in 2006

IPCC source category	CO_2 emissions (Mt of CO_2)	% change 90-06	Level assessment (%) ***	Cumulative total (%)
Main activity prod. elec. and heat - coal/peat	223.12	126.9%	16.3	16.3
Road - oil	219.73	17.6%	16.1	32.4
Manufacturing industries - coal/peat	143.10	-4.4%	10.5	42.9
Manufacturing industries - oil	130.32	-3.9%	9.5	52.4
Main activity prod. elec. and heat - gas	111.77	44.6%	8.2	60.6
Non-specified other sectors - oil	74.99	-16.0%	5.5	66.1
Unallocated autoproducers - coal/peat	47.94	59.3%	3.5	69.6
Main activity prod. elec. and heat - oil	45.77	-65.3%	3.3	72.9
Residential - oil	41.90	9.2%	3.1	76.0
Non-specified other sectors - gas	33.48	268.4%	2.4	78.4
Other energy industries - oil	26.11	-9.9%	1.9	80.3
Memo: total CO_2 from fuel combustion	*1212.70*	*13.2%*	*88.7*	*88.7*

*** Percent calculated using the total GHG estimate for CO_2, CH_4, N_2O, HFCs, PFCs and SF_6 excluding CO_2 emissions/removals from land use change and forestry.

INTERNATIONAL ENERGY AGENCY

Source: “CO2 Emission From Fuel Combustion 2008 Edition” (IEA)

5.6 Topics on heat pump technology

5.6.1 Technological development of industrial heat pump

With an increase in heating capacity and supply temperature of the heat pump, the range where the boiler can be replaced with the heat pump in industrial process is expanding. In Japan, heat pump hot water heater that supply 90℃ hot water (80kW-class heating capacity) is marketed, and heat pump hot air heater that supply 120℃ hot air (100kW-class heating capacity) started marketing in Fall 2009.

Diagram 27　70°C Warm Water Heat Pump

Performance (Note)	Capacity	Heating 357kW／Cooling 243kW
	Total COP	5.4
	Consumed power	112kW
Range of taking off temperature		Warm water 55～70℃、 Chilled water7～30℃

Note 2: Values under the conditions of inlet/outlet water temperature of warm water and chilled water of 55/65°C and 17/7°C, respectively

Source: Data from a power company

Diagram 28　80°C Warm Water Heat Pump

Warm water of 35 to 50°C coming from exhaust heat is used as the heat source, and, as standard specification, warm water of 75°C is heated to 80°C

Source: Website of a manufacturer

Diagram 29　90°C Warm Water Heat Pump

		50Hz	60Hz
Refrigerant		R-744 (CO2)	
Performance	Heating Capacity* (kW)	68.9 (67.9)	80.0 (77.6)
	Power Consumption* (kW)	16.8 (20.1)	20.5 (24.1)
	COP	4.1	3.9
	Condition	Ambient temperature DB16℃, WB12℃, Feed water temperature17℃, Supplied water temperature 65℃(90℃)	
Supplied water flow* (L/h)		1259 (829)	1461 (947)
Power		3 ϕ AC200V 50/60Hz	
Operating range	Feed water temperature (℃)	5～65	
	Feed water flow (L/min)	0～30	
	Supplied water temperature (℃)	65～90	
	Ambient temperature (℃)	-10～43	

*※Values in parenthesis are under the conditions of "Ambient temperature DB16℃, WB12℃, Feed water temperature17℃, Supplied water temperature 90℃"

Source: Catalogue of a manufacturer

Diagram 30　Heat Pump Generating Hot Air of 120°C

SPECIFICATION (for reference)		
Description		Water Heat Source CO_2 Heat Pump Hot Air Heater
Heating Capacity		125KW
Rated Brake kW		25KW
Refrigerant		R744(CO_2)
Compressor Model		Semi-hermetic Reciprocating 2-cylinder type model: C2HT
Main Motor		3φ × AC200V
Rated Cooling Capacity		9.0 ton
Operating range		Hot air outlet temp. below 120℃ Heat source water outlet temp. -10℃~25℃
Note: Capacity in above table is based on 20℃ intake air temp., 100℃ hot air leaving temp. and 20 ℃ evaporating temp.		

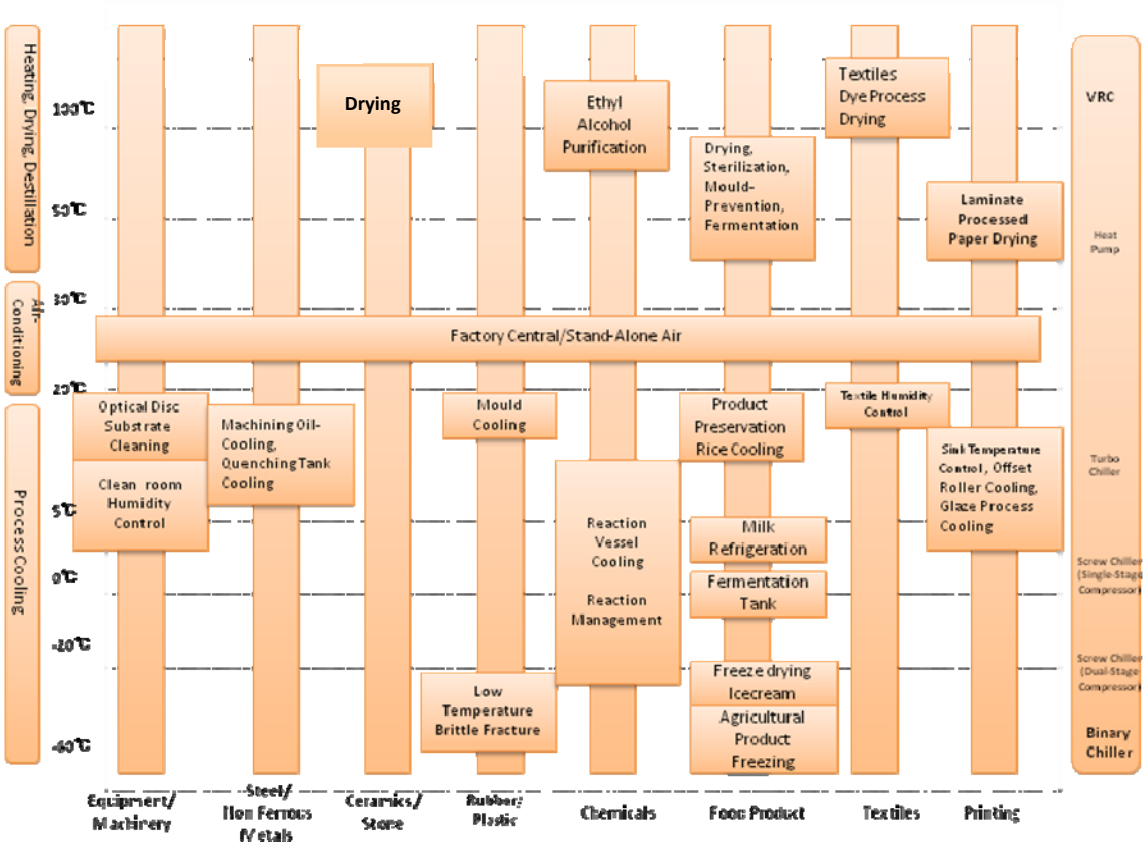
Source: Catalogue of a manufacturer

5.6.2 Status of application of heat pumps for industrial use

(1) Application range of heat pumps for industrial use

Heat pumps are widely used in various applications such as heating, drying, concentration, distillation, air conditioning, and process cooling, etc..

Diagram 31　Application range for Heat Pumps for industrial use



Source: “The Future of Manufacturing using Electricity” (Japan Electro-Heat Center)

(2) Examples of using heat pumps in the food and beverage fields

Examples of using heat pumps in the food and beverage fields in Japan are shown below.

1) Example of introducing a CO2 heat pump system of hot and cold energy simultaneous supply type

① Outline of system

The CO2 heat pump was developed for business use in the industrial sector and installed in a ham manufacturing plant in Japan. This heat pump can simultaneously supply cold energy and 85℃.hot water.

Diagram 32　Outline of CO2 Heat Pump for Commercial and Industrial Use

CO2 Heat pump

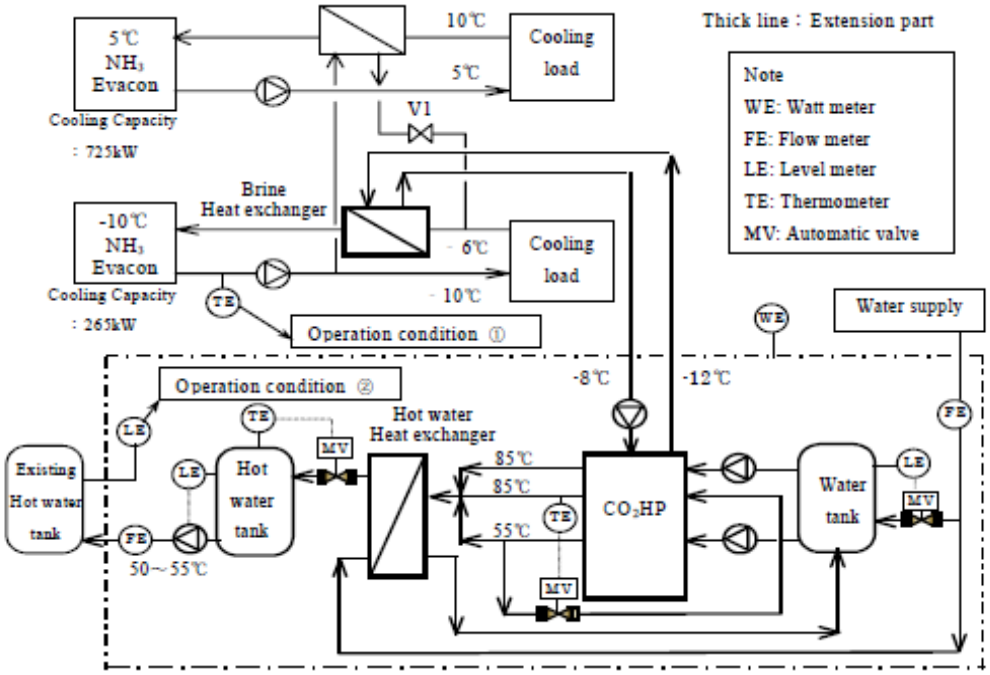
Specification of the CO2 Heat pump system

Item		Specification
Power	Brake power	231[kW]
Power consumption	Main motor	275[kW]
	Auxiliary machinery	30[kW]
	Total	305[kW]
Capacity	Cooling	317[kW]
	Heating	548[kW]
Temperature	Brine	-8[℃]→-12[℃]
	Hot water	45[℃]～55[℃]※
Target performance	Cooling COP	1.37
	Heating COP	2.37
	Total COP	3.74

※Temp. adjusted to pilot plant load demand.

Source: Japan Society of Refrigerating and Air Conditioning Engineers

Diagram 33　Schematic Outline of Ham Plant



Source: Japan Society of Refrigerating and Air Conditioning Engineers

② CO2 reduction effect by introducing heat pumps

CO2, NOx, and SOx emissions, and the annual amount and rate of curtailment of primary energy consumption in crude oil equivalent are calculated to compare yearly environmental preservation and energy savings between CO2 heat pump and the existing system (NH3 evaporative condenser + heavy oil fired boiler).

In calculating CO2, NOx, and SOx emissions, and the amount of primary energy consumption in crude oil equivalent, it is assumed that the heat pump and the existing system are operated for one year under rated and normal operation.

The CO2 heat pump achieved a 48.3% CO2 emissions reduction effect during rated operation and a 35.6% CO2 emissions reduction effect during normal operation in comparison to the existing system.

Diagram 34 Comparison of yearly environmental preservation and energy-savings of the CO2 heat pump and Existing system

		CO_2HP	Existing system	Amount of curtailment	Rate of curtailment
I	CO_2 emissions [ton]	59.8	115.7	55.9	48.3%
	NO_X emissions [kg]	12.7	96.1	83.4	86.8%
	SO_X emissions [kg]	6.3	1,072.0	1,065.7	99.4%
	Amount of primary energy consumption [kL]※	40.7	52.0	11.3	21.7%
II	CO_2 emissions [ton]	82.4	127.9	45.5	35.6%
	NO_X emissions [kg]	17.4	108.6	91.1	83.9%
	SO_X emissions [kg]	8.7	1,219.7	1,211.0	99.3%
	Amount of primary energy consumption [kL]※	56.1	56.6	0.5	0.9%

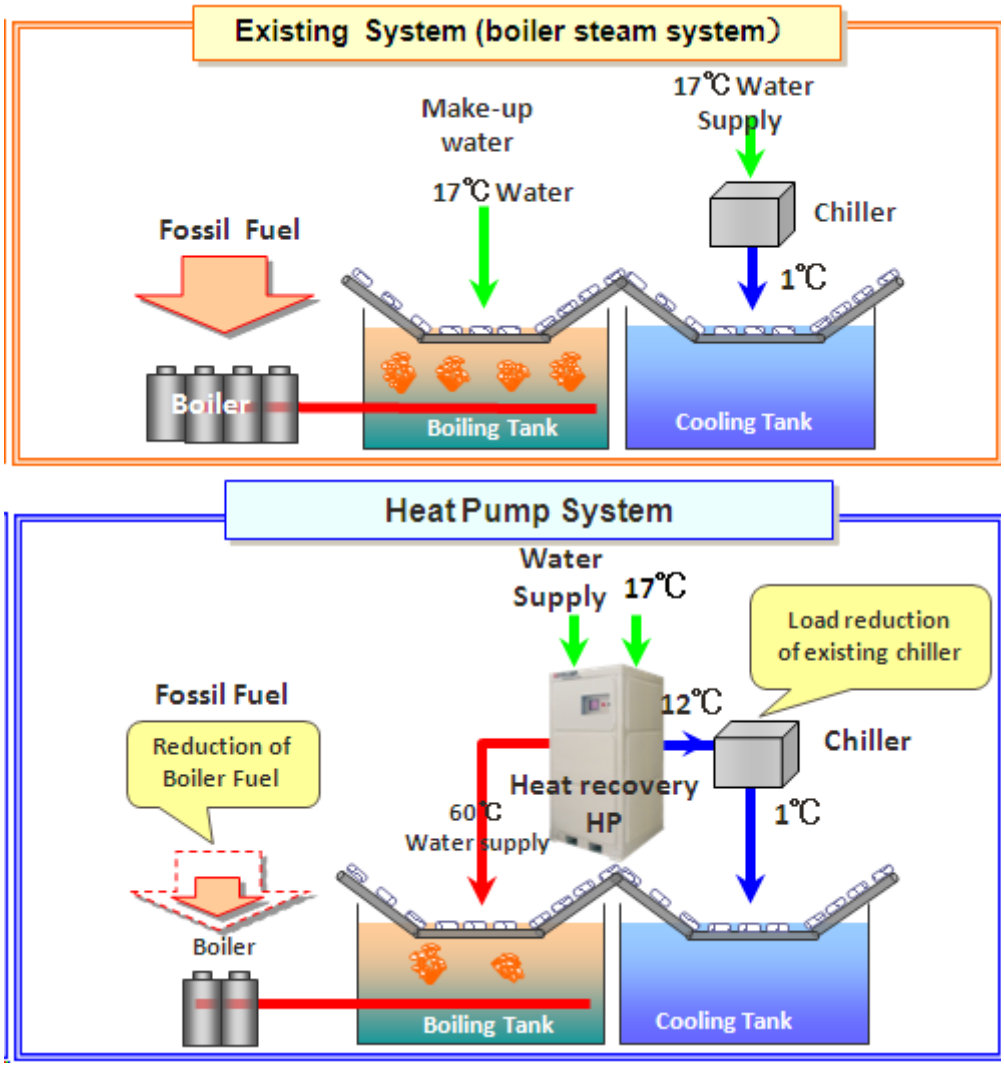
I Rated operation test values
II Normal operation test values
※ Converted into crude oil

Source: Japan Society of Refrigerating and Air Conditioning Engineers

2) Example of introducing a CO2 refrigerant heat pump system of hot and cold air simultaneous supply type in the noodle manufacturing industry

In the production process of chilled noodles, heating and cooling processes for noodles are in close proximity. In Japanese chilled noodle manufacturing factories, heat recovery heat pumps are installed, and is utilized for heating of the heating tank of noodle and cooling of the cooling tank.

Diagram 35 Example of Introduction in Chilled Noodle Factory



Source: Heat Pump & Thermal Storage Technology Center of Japan

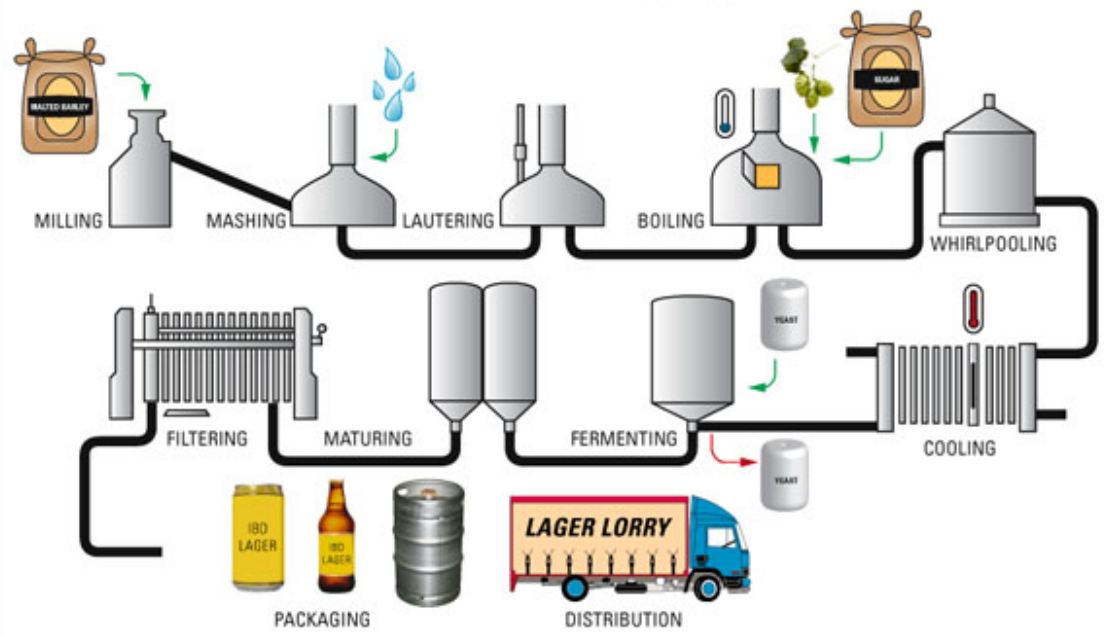
3) Example of introducing mechanical vapor recompression system (MVR[4]) to wort kettle in beer brewery

① Outline of system

Usually, a wort kettle is heated and boiled with steam at 0.2 - 0.3MPa(abs) and 120 - 133℃. Steam emitted from the top of the kettle is used to manufacture normal hot water or cold water by driving an absorption chiller. Generally, since less hot water is consumed in a beer brewery than hot water recovered in the above process, there is a huge surplus of hot water, causing the cooling tower to radiate heat.

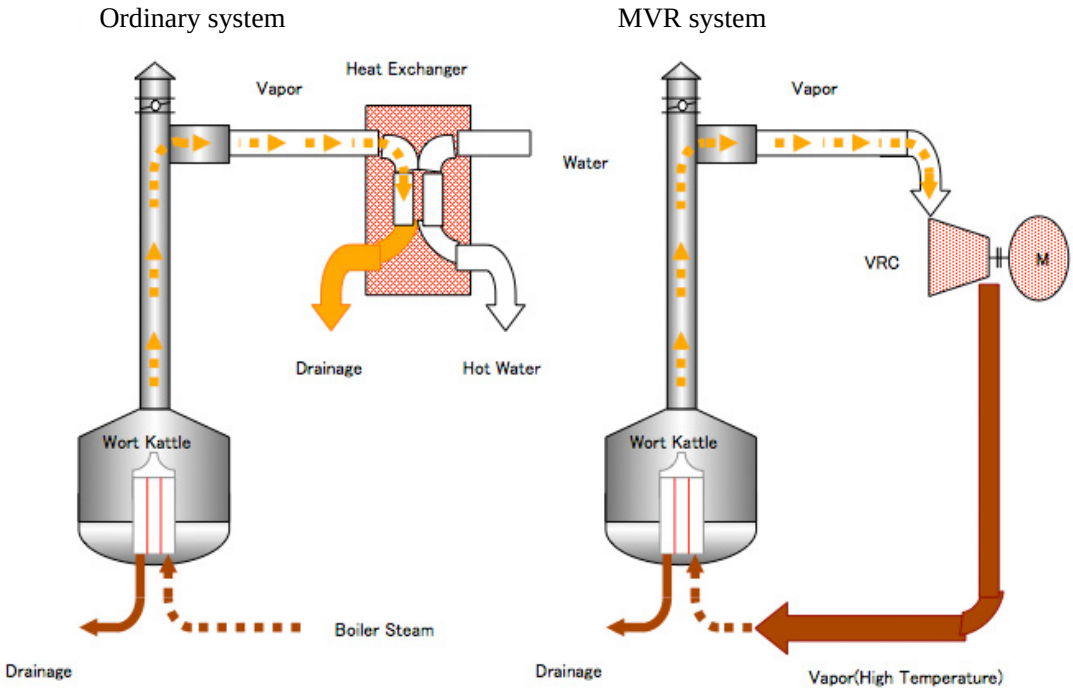
Meanwhile, in the MVR, steam rising from the kettle is directly sucked into the steam compressor to be compressed to 0.2 - 0.3MPa(abs). The compression of steam will eliminate the need for steam from a boiler except for a small amount of backup steam. In addition, neither the heat exchanger at the top of the kettle nor the cooling tower are necessary. The driving energy at this moment is only compressor power, which is 1/8 to 1/12 of the steam required for normal heating.

Diagram 36 Common Beer Brewing Process



Source: website of the Institute of Brewing & Distilling Asia Pacific Section

Diagram 37　MVR System in Boiling Wort



Source: Website of Japan Electro-Heat Center

② CO2 reduction effect by introducing MVR

As a result of introduction of MVR in Japan, the COP was 9.15.

A conventional system emitted 1860kg/h of CO2 while MVR emitted 96kg/h of CO2, which was a 95% reduction effect.

Diagram 38　MVR, Specification and Evaluation

1. Operation Conditions

Heat source temp　:100℃	Condensation temp　:125℃
Heat supply temp　:125℃	Amount of condensation heat　:6200Mcal/h
Evaporating temp　:100℃	Operating fluid　:vapor
Evaporating latent heat　:580 Mcal/h	Driving shaft power　:788kW/h

2. Equipment specification

Compressor	Motor
Model: Screw compressor	Model: VVVF, Inverter
Power: 788kW	Shaft power: 1000kW
Compression ratio: 2.3	Rotation: 2000～4000rpm

3. Heat pump performance factor

$$COP = \frac{6200\text{Mcal/h}}{788 \times 0.86\text{Mcal}} = 9.15$$

4. Energy conservation and evaluation relative to environment

	Conventional system	MVR	Difference	Annual base
Steam (T/h)	11.5	0.1	11.4	
Electricity (kWh)		788	△788	
Primary energy conversion (Mcal)	6200	1755	4444	13332 Gcal
Primary energy	Heavy oil	Electricity		
CO_2 generation (kg/h)	1860	96	1764	5292 Ton
NO_X generation (g/h)	1699	244	1455	4365 kg
SO_x generation (g/h)	5642	203	5429	16287 kg

* Assuming 3000 batches per year

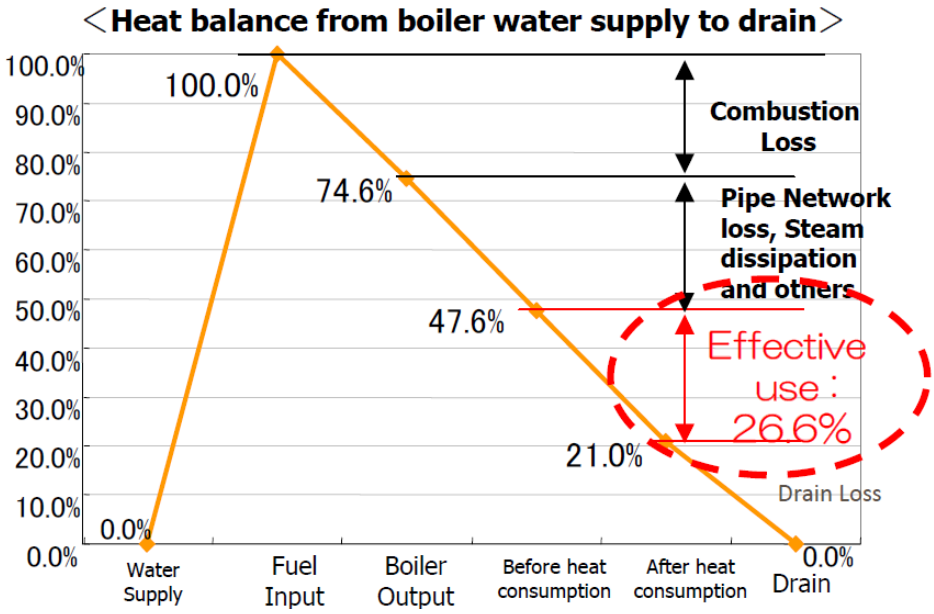
Cf: Assuming power generation efficiency to be 36.6%, primary energy consumption per kWh of power is 860 x 1/0.386 = 2228 kcal/kW.

Source: REFRIGERATION VOL.69,NO.804

5.7 Example of actual measured radiation loss entailed by steam transfer

Sufficient data on heat efficiency on the actual demand side, i.e. total heat efficiency as a system from boiler feed water to the heat demand end, has not been obtained. With an increasing awareness of energy saving, a detailed survey has been conducted only recently. As an example, the measurement result of steam boiler heat balance in an automobile plant is shown below.

Diagram 39　Example of Actual Use of Energy in Steam System



Source: Prepared from the Website of The Energy Conservation Center of Japan, "Cases of Energy Conservation in Plants and Buildings"

Effectively used energy relative to fuel-input energy in the process of feeding water to a boiler to draining in this plant was estimated to be 26.6%. About three quarters of the input energy was released to the surroundings without being effectively used.

As far as we can tell from the result, the steam central-type steam process may entail a considerable heat loss.

Meanwhile, for the heat supply system by heat pump, equipment can be installed close to the heat demand point in the process and heat loss that may be generated in great quantities in the steam process can be reduced. Furthermore, heat can be recycled by effectively using low-temperature waste heat so that a high system efficiency can be achieved. Therefore, the replacement of conventional boilers with heat pumps will be extremely important to improve the efficiency of the entire process in industrial sector.

5.8 Heat recovery technologies in food and beverage fields

Heat recovery is a very valid approach to reducing energy use and CO2 emissions and is an attractive technology that should become widespread. However, waste heat recovery in industries, such as food and beverage production, is currently limited. This is due in part to relatively low manufacturing temperatures, especially compared to those used in the steel and ceramic industries. In addition, waste heat exists in decentralized locations throughout a factory and time constraints further limit adoption, though the brewing process is an exception.

Therefore, we have calculated potential CO2 reductions through the utilization of heat pumps in the food and beverage fields focusing on the region of operating temperature below 100 degrees C as a heat pump applicable range.

Heat pump technologies has made great strides recently and in particular, it has become possible to utilize low temperature waste heat from manufacturing process, etc. by applying heat pumps.

5.9 Estimation results of primary energy consumption reduction

5.9.1 Estimation method

(1) Estimation of primary energy consumption in the present situation

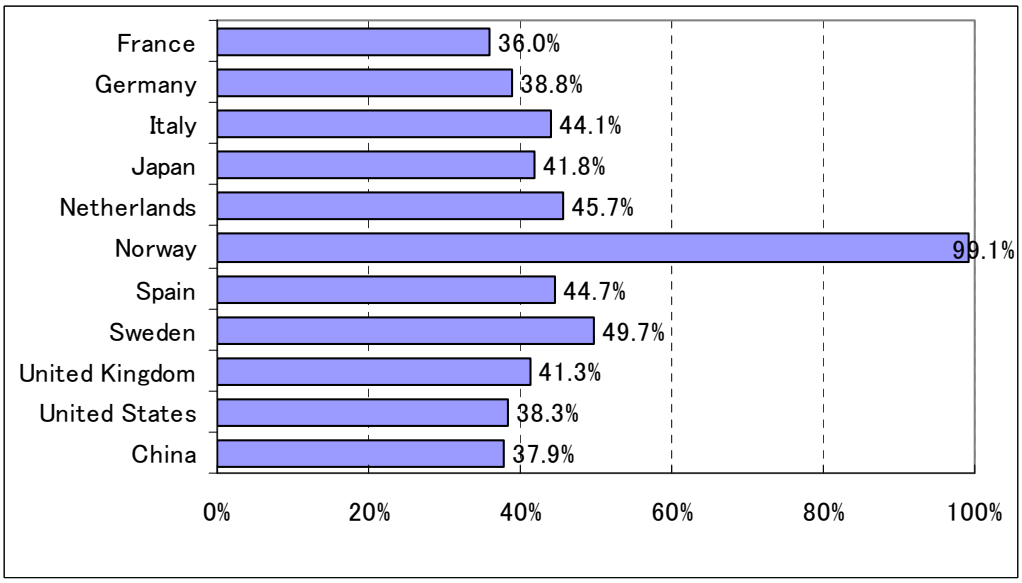
We set "⑨ Consumption of HP-substitutable fuels for steam boiler (at a end use temperature below 100℃) by industrial category (sub classification) and energy type in countries surveyed" as the primary energy consumption in the present situation. Energy types estimated are coal, petroleum products and gas, and losses in energy conversion section are excluded.

(2) Estimation of primary energy consumption after the application of Heat Pumps

At first, we calculated power consumption by country and category after the application of heat pumps by multiplying "⑫ Efficiency of boiler" (which was set at 85% uniformly for every country) by "⑨ Consumption of HP-substitutable fuels for steam boiler by industrial category (sub classification) and energy type in countries surveyed" and then dividing the obtained value by "⑭ COP of heat pump" (which was set at 4.0 uniformly for every country).

Next, we calculated "Primary energy consumption after HP substitution by industrial category (sub classification) in countries surveyed" by dividing the power consumption by "Power generation efficiency in countries surveyed".

Diagram 40　Power generation efficiency for countries surveyed



* We calculated it by dividing electricity generated at the power plants described in the document by input energy (including non-fossil fuels such as nuclear energy).

* In the document, input energy for non-fossil fuels is set as follows.

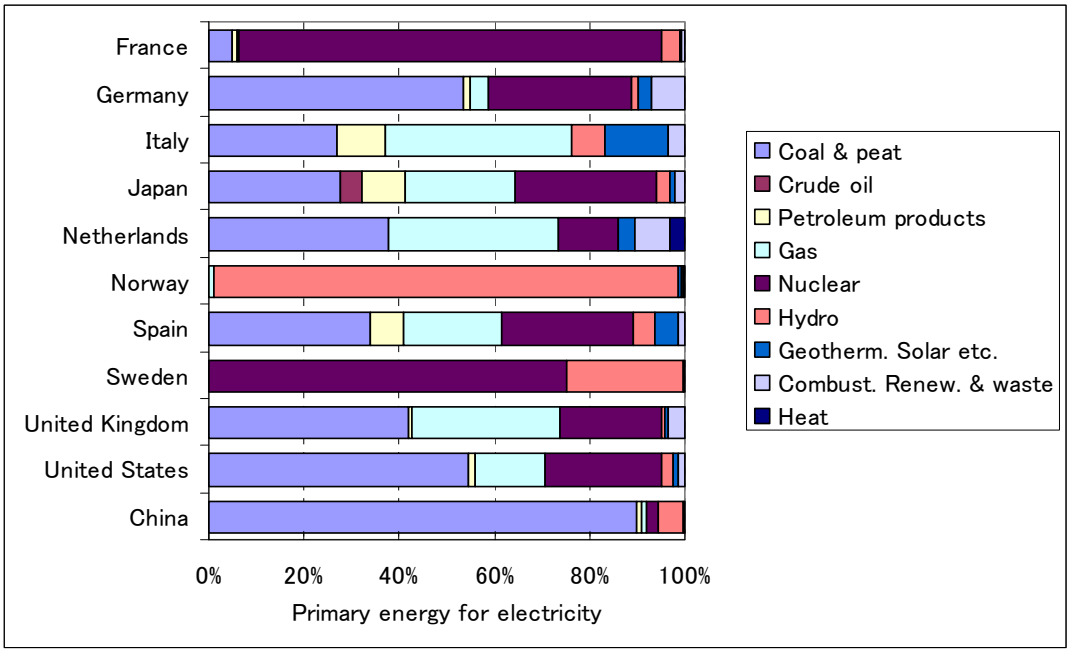
Nuclear energy; Input energy = Electricity generated / 33%

Geothermal energy; Input energy = Electricity generated / 10%

Hydro, solar, wind, tide/wave; Input energy = Electricity generated。

Source:　"Energy Balances of OECD Countries 2009 Edition" (IEA),
"Energy Balances of Non-OECD Countries 2009 Edition"(IEA)

Diagram 41　Input energy composition in power generation sector



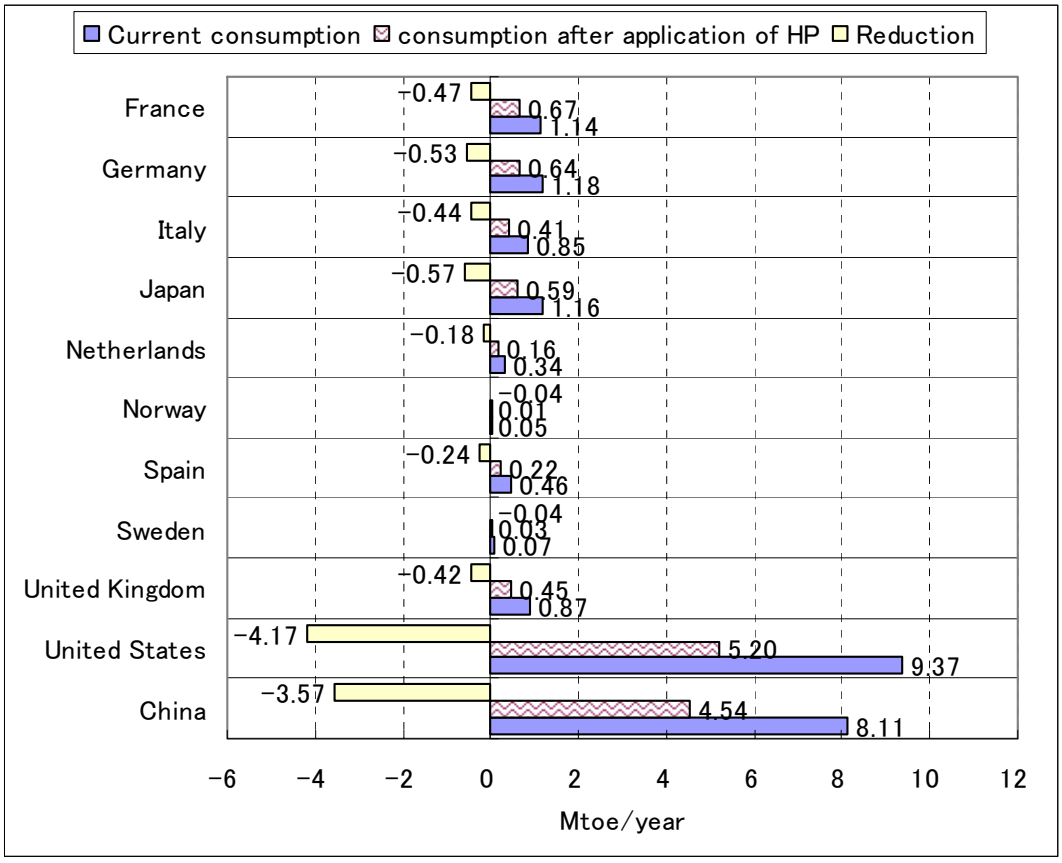
Source: "Energy Balances of OECD Countries 2009 Edition" (IEA),
"Energy Balances of Non-OECD Countries 2009 Edition"(IEA)

5.9.2 Estimation results

A total primary energy reduction effect of 11million toe/year for all of the 11 countries covered by the survey can be expected by substituting heat pumps for steam boilers among applications at a use end temperature below 100℃ in the food and beverage fields. In particular, a significant primary energy reduction can be expected in the USA (4.2 million toe/year) and China (3.6 million toe/year).

The data for China have a lower accuracy than that for other countries. A total primary energy reduction of 7.1 million toe/year in the 10 countries other than China can be expected.

Diagram 42 Primary Energy Reduction by Substitution of Boiler by Heat Pump in Uses at Use End Temperature of below 100°C in the Food and Beverage Fields



5.9.3 Source of Data

We set “Power generation efficiency in countries surveyed” based on the “Energy Balances of OECD Countries 2009 Edition(IEA)” for each country. Specifically, we calculated it by dividing electricity generated at the power plants described in the document by input energy (including non-fossil fuels such as nuclear energy).

Diagram 43　Energy Balance(Japan)

Japan / Japon : 2007

Million tonnes of oil equivalent / *Million de tonnes d'équivalent pétrole*

SUPPLY AND CONSUMPTION *APPROVISIONNEMENT ET DEMANDE*	Coal & peat *Charbon & tourbe*	Crude oil *Pétrole brut*	Petroleum products *Produits pétroliers*	Gas *Gaz*	Nuclear *Nucléaire*	Hydro *Hydro*	Geotherm. solar etc. *Géotherm. solaire etc.*	Combust. renew. & waste *Comb. ren. & déchets*	Electricity *Electricité*	Heat *Chaleur*	Total *Total*
Production	-	0.81	-	3.58	68.76	6.36	3.59	7.38 e	-	-	90.47
Imports	115.42	209.73	44.96	80.07	-	-	-	-	-	-	450.19
Exports	-0.92	-	-14.58	-	-	-	-	-	-	-	-15.51
Intl. marine bunkers	-	-	-5.83	-	-	-	-	-	-	-	-5.83
Intl. aviation bunkers	-	-	-6.20	-	-	-	-	-	-	-	-6.20
Stock changes	0.08	1.24	-0.31	-0.60	-	-	-	-	-	-	0.41
TPES	**114.57**	**211.78**	**18.04**	**83.05**	**68.76**	**6.36**	**3.59**	**7.38**	**-**	**-**	**513.52**
Transfers	-	-	-0.02	-	-	-	-	-	-	-	-0.02
Statistical differences	-0.35	1.08	0.82	4.85	-	-	-	-0.01	-0.01	-	6.39
Electricity plants	-64.19	-9.80	-21.30	-53.28	-68.76	-6.36	-2.84	-4.45	96.62	-	-134.37
CHP plants	-	-	-	-	-	-	-	-	-	-	-
Heat plants	-0.01	-	-0.02	-0.37	-	-	-	-0.14	-0.10	0.60	-0.04
Gas works	-	-	-1.67	1.59	-	-	-	-	-	-	-0.07
Petroleum refineries	-	-207.85	205.02	-	-	-	-	-	-	-	-2.83
Coal transformation	-16.56 e	-	-0.33	-	-	-	-	-	-	-	-16.89
Liquefaction plants	-	-	-	-	-	-	-	-	-	-	-
Other transformation	-	5.16	-5.38	-	-	-	-	-0.02 e	-	-	-0.24
Own use	-2.70	-0.00	-9.02	-2.28	-	-	-	-	-5.35	-0.02	-19.37
Distribution losses	-	-	-	-	-	-	-	-	-4.38	-	-4.38
TFC	**30.77**	**0.37**	**186.14**	**33.55**	**-**	**-**	**0.74**	**2.76**	**86.78**	**0.58**	**341.70**
INDUSTRY SECTOR	**29.78**	**0.03**	**29.57**	**7.96**	**-**	**-**	**-**	**2.73**	**29.03**	**-**	**99.11**
Iron and steel	12.97 e	-	1.74	2.05	-	-	-	-	6.18	-	22.94
Chemical and petrochem.	3.21	0.03	9.72	1.04	-	-	-	0.00	4.78	-	18.78
Non-ferrous metals	0.26	-	0.36	0.05	-	-	-	-	1.53	-	2.20
Non-metallic minerals	4.23	-	1.90	0.31	-	-	-	0.11	2.02	-	8.57
Transport equipment	-	-	-	-	-	-	-	-	-	-	-
Machinery	0.25	-	0.77	1.51	-	-	-	-	7.38	-	9.90
Mining and quarrying	0.02	-	0.24	0.08	-	-	-	-	0.08	-	0.41
Food and tobacco	-	-	2.20	0.50	-	-	-	-	1.44	-	4.14
Paper, pulp and printing	1.43	-	1.31	0.47	-	-	-	2.62	2.98	-	8.80
Wood and wood products	-	-	-	-	-	-	-	-	-	-	-
Construction	0.00	-	3.37	0.58	-	-	-	-	0.08	-	4.04
Textile and leather	-	-	-	-	-	-	-	-	-	-	-
Non-specified	7.40	-	7.97	1.37	-	-	-	-	2.58	-	19.32
TRANSPORT SECTOR	**-**	**-**	**80.78**	**-**	**-**	**-**	**-**	**-**	**1.62**	**-**	**82.41**
Domestic aviation	-	-	3.67	-	-	-	-	-	-	-	3.67
Road	-	-	73.10	-	-	-	-	-	-	-	73.10
Rail	-	-	0.21	-	-	-	-	-	1.62	-	1.83
Pipeline transport	-	-	-	-	-	-	-	-	-	-	-
Domestic navigation	-	-	3.80	-	-	-	-	-	-	-	3.80
Non-specified	-	-	-	-	-	-	-	-	-	-	-
OTHER SECTORS	**0.59**	**-**	**34.64**	**25.21**	**-**	**-**	**0.74**	**0.03**	**56.13**	**0.58**	**117.91**
Residential	-	-	14.33	9.32	-	-	0.52	0.03	25.03	0.03	49.25
Comm. and public services	0.59	-	16.09	15.89	-	-	0.13	-	31.03	0.55	64.28
Agriculture/forestry	-	-	2.77	-	-	-	0.09	-	0.08	-	2.93
Fishing	-	-	1.45	-	-	-	-	-	-	-	1.45
Non-specified	-	-	-	-	-	-	-	-	-	-	-
NON-ENERGY USE	**0.40**	**0.34**	**41.15**	**0.38**	**-**	**-**	**-**	**-**	**-**	**-**	**42.27**
in industry/transf./energy	0.40	0.34	40.37	0.38	-	-	-	-	-	-	41.49
of which: feedstocks	*0.39*	*0.34*	*34.29*	*0.38*	-	-	-	-	-	-	*35.41*
in transport	-	-	0.78	-	-	-	-	-	-	-	0.78
in other sectors	-	-	-	-	-	-	-	-	-	-	-
Electricity and Heat Output											
Elec. generated - TWh	**310.80**	**46.45**	**109.82**	**289.88**	**263.83**	**74.01**	**5.68**	**23.02**	**-**	**-**	**1123.49**
Electricity plants	310.80	46.45	109.82	289.88	263.83	74.01	5.68	23.02	-	-	1123.49
CHP plants	-	-	-	-	-	-	-	-	-	-	-
Heat generated - PJ	**0.53**	**-**	**0.59**	**14.70**	**-**	**-**	**-**	**5.70**	**3.54**	**-**	**25.06**
CHP plants	-	-	-	-	-	-	-	-	-	-	-
Heat plants	0.53	-	0.59	14.70	-	-	-	5.70	3.54	-	25.06

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Source: “Energy Balances of OECD Countries 2009 Edition

5.10 Variation analyses for the composition ratio of applications at a use temperature below 100℃ to consumption for steam boilers

5.10.1 Estimation method

Our previous survey, the basic case, we set “Heat demand share below 100℃ out of steam from boiler in food and beverage fields” at 60% uniformly for every country based on information collected in Japan.

Here, in this variation analyses, we set this value at 50% for 10 countries other than Japan (60% for Japan), and estimated CO2 emissions reduction and primary energy reduction.

* The other estimation method is the same as our previous survey.

5.10.2 Estimation results

As a result of this variation analyses, it has been concluded as follows.

- The emissions of 34 million tons of CO2 per year in all 11 countries and 21 million tons of CO2 per year in 10 countries other than China can be reduced with heat pumps.
- As for the primary energy consumption, 9 million toe per year in all 11 countries and 6 million toe per year in 10 countries other than China can be reduced with heat pumps.
- Both CO2 emissions and primary energy consumption can be reduced by approximately 15% compared with basic case.

Diagram 44　Estimation results of CO2 emissions and primary energy consumption in variation analyses

Million t-CO2/year

	Heat demand share below 100 degrees Celsius out of steam from boiler is set at 50% for 10 countries (60% for Japan)		
	Current emissions	Emissions after application of HP	Reduction
France	2.7	0.2	−2.5
Germany	2.7	1.0	−1.7
Italy	1.8	0.7	−1.1
Japan	3.4	1.2	−2.2
Netherlands	0.7	0.3	−0.4
Norway	0.1	0.0	−0.1
Spain	1.1	0.4	−0.7
Sweden	0.2	0.0	−0.2
United Kingdom	1.8	0.9	−0.9
United States	22.3	10.9	−11.4
China	26.1	13.3	−12.8
Total	62.9	28.9	−34.1
(10 countries other than China)	36.9	15.6	−21.2

Mtoe/year

	Heat demand share below 100 degrees Celsius out of steam from boiler is set at 50% for 10 countries (60% for Japan)		
	Current consumption	Consumptuion after application of HP	Reduction
France	0.9	0.6	−0.4
Germany	1.0	0.5	−0.4
Italy	0.7	0.3	−0.4
Japan	1.2	0.6	−0.6
Netherlands	0.3	0.1	−0.2
Norway	0.0	0.0	0.0
Spain	0.4	0.2	−0.2
Sweden	0.1	0.0	0.0
United Kingdom	0.7	0.4	−0.4
United States	7.8	4.3	−3.5
China	6.8	3.8	−3.0
Total	19.8	10.9	−9.0
(10 countries other than China)	13.1	7.1	−6.0