FIELD SURVEY ON THE ENERGY CONSUMPTION IN RESIDENTIAL BUILDINGS IN THE NIIGATA AREA

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ABSTRACT

The purpose of this study is to investigate the actual conditions of the energy consumption of various types of inhabited houses (e.g., wooden detached houses and condominiums) in the Niigata area. A field survey was carried out from November 2002 to March 2005, and the energy consumption levels for the various uses were measured continuously. This paper describes the energy consumptions of all uses (e.g., electricity, oil, gas) in the house types.

KEYWORDS

Energy Consumption, Residential Building, Field Survey, Heating and Cooling

INTRODUCTION

Recently, a reasonable level of control of energy consumption is required to counter the threat of global warming. An amendment to the "energy saving standard" has been proposed to control energy consumption in houses. The purpose of home energy saving initiatives is to cut down the cooling and heating load by improving the performance of the shelter (i.e., insulation and air tightness, cooling, heating, and mechanical ventilation properties etc.). However, energy consumption in houses is used for a wide range of uses (for example, hot-water supply, lighting, cooking, information, communication etc.), and so any energy saving initiative must carefully consider the total energy consumption in houses.

The purpose of this study is to investigate the actual conditions of energy consumption in a range of different types of inhabited houses (e.g., wooden detached houses and condominiums) in the Niigata area. A field survey was carried out from November 2002 to March 2005, and the energy consumption levels for the various uses were measured continuously.

Research Outline

Outline of the Houses

Table 1 shows an outline of the investigated houses, and Figure 1 shows the heating degree-day of Japan. The annual average temperature of Niigata is 13.8℃. 9 detached houses and 4 condominiums are involved in this investigation. The floor areas of the detached houses and condominiums are 115~190 m^2 and 70~101m^2, respectively. Five houses investigated used only electricity, and the other houses also used gas and oil. Eleven of the occupants are married couples with children and 2 of the occupants are married couples with no child.

Measurement Method

Field survey is carried out electricity, gas oil, indoor air temperature and water temperature, respectively

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Table1 Outline of the Investigated Houses

	No.	City	Year of	Floor area [㎡]	Construction	insulation and airtightness		Energy sources				Number of occupants
						Heat loss coefficient [W/(㎡·K)]	Equivalent leakage area [㎠/㎡]	Heating	Cooling	Hot-water supply*	Kitchen	
Detached house	A01	Niigata	1996	150.00*	Wood (a part of RC)	1.40	0.77	Electricity	Electricity	Electricity	Electricity	3
	A02	Nagaoka	2001	133.86*	Wood (a part of RC)	2.20	0.71	Electricity	Electricity	Electricity	Electricity	3
	A03	Niigata	2002	117.49	Wood	2.18	0.95	Electricity	Electricity	Gas	Gas	4
	A04	Niigata	2002	130.83	Wood	2.24	0.39	Oil	Electricity	Oil	Electricity	4
	A05	Niigata	1995	148.57	Wood	2.66	4.41	Oil	Electricity	Oil	Electricity	4
	A06	Joetsu	1999	176.37	Wood	2.33	2.38	Oil	Electricity	Electricity	Electricity	2
	A07	Sanjo	2001	187.75	Wood	4.35	4.91	Electricity + Oil	Electricity	Gas	Gas	2
	A08	Niigata	2002	178.23	Wood	2.61	0.91	Electricity	Electricity	Electricity	Electricity	5
	A09	Niigata	1990	140.08	Wood	3.19	2.85	Oil	Electricity	Gas	Gas ↓ Electricity	2
Apartment	B01	Kashiwazaki ↓ Niigata	1964	101.60	RC	6.21	8.50	Oil	Electricity	Electricity	Electricity	4
	B02	Kashiwazaki	1985	80.61	RC	7.74	2.88	Oil	Electricity	Electricity	Electricity	3
	B03	Niigata	1995	70.35	RC	3.52	1.25	Gas + Oil	Electricity	Gas	Gas	4
	B04	Shibata	1989	81.67	SRC	2.44	1.47	Oil	Electricity	Gas	Gas	4

＊Hot-water supply by electricity using electric resistant heater

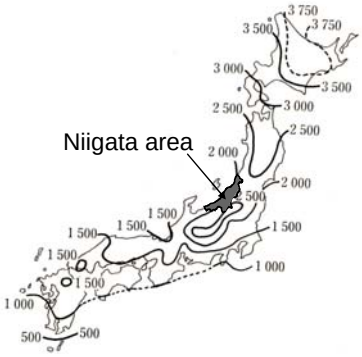


Figure1 Heating Degree-day of Japan

to collect the total energy consumption in houses. The integral power of electricity consumption (Wh) and levels of peak power (W) at the power distribution cabinet and household wall sockets are measured. The dates collected by the system of electric power measurement are transmitted to communication terminal equipment by radio transmission.

The system of gas consumption measurement is set up at the gas meter to read the meter optically. The system of oil consumption measurement is set up as a flow meter on the oil piping and recorded by a pulse data logger. The pulse signal of a solenoid pump of an unvented oil fan heater is measured by a pulse data logger where the unvented oil fan heater is used.

The measurement intervals for electricity consumption are 1 minute and for gas and oil consumption 5 minutes (m^3 or liter).

Temperature and humidity in the houses are measured at 1.1m above the floor in air-conditioned rooms (living room) and non-air-conditioned rooms, because the temperature and humidity of a house influences levels of energy consumption. Tap water temperature is measured in the water tank of the flush toilet. The temperature of the range hood in the kitchen is measured in the case of the houses using gas for cooking and hot-water supply. The measurement intervals for temperature and humidity are 15 minutes.

Categories of Energy Consumption

Table 2 shows the categories of equipment for energy consumption. In this study, energy consumption is classified into eight categories, namely air-conditioning (i.e., cooling, heating, and mechanical ventilation), hot-water supply, lighting, kitchen, refrigerator, amusement and information, housework and sanitary, and other.

Table 2 Categories of Equipment for Energy Consumption

Rough Classification		Equipment
Cooling, Heating, and Mechanical Ventilation	Cooling	Air Conditioner, Electric Fan, Dehumidifier, etc.
	Heating	Air Conditioner, Floor Heating, Fan Heater(gas, kerosene), Kotatsu, Erectric Carpet, etc.
	Mechanical Ventilation	Mechanical Ventilation system, Local Ventilation, etc.
Hot-water Supply		Electric Water Heater, Boiler(Gas, Oil)
Lighting		Lighting Equipment, Desk Lamp
Kitchen		IH Cooking Heater, Oven, Rice CookerKettle, Gas Range, etc.
Refrigerator		Refrigerator, Freezer
Amusement and Information		TV, Video, Audio, Computer, Telephone, Facsimile, Video Game, etc.
Housework and Sanitary		Washing Machine, Drying Machine, Iron, Washlet, Dryer, etc.
other		Electric Shutter, Snowmelt Energy, etc.

Energy Consumption in Niigata Area

Annual Energy Consumption

Figure 1 shows the annual energy consumption in 2003. Annual energy consumption changes from a range of 31.31GJ (A03) to 109.82GJ (A07), and the average is 70.3GJ. A03 leads to the least energy consumption for heating (10.98GJ). Although A03 uses the air-conditioner for heating, the levels of

energy consumption for heating are low due to good insulation efficiency (heat loss coefficient: 2.18W/(m^2K)), and the high performance of the air-conditioner (average of cooling and heating coefficient of performance: 5.72, catalog energy use). The energy consumption of A07 is largest for heating (45.8GJ) and hot-water supply (38.0GJ). The reason for such a large energy consumption for heating is the large floor area (187.8 m^2), the low insulation efficiency (heat loss coefficient: 4.35W/(m^2K)), and bathing in both the morning and at night by the occupants.

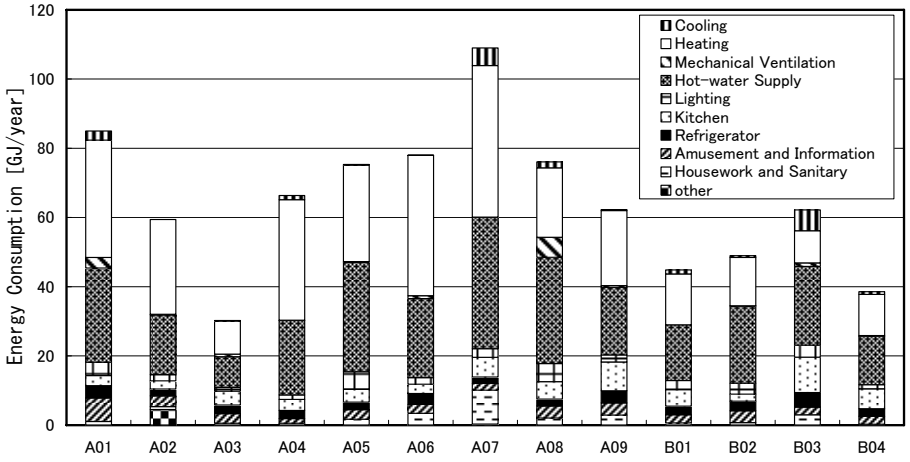


Figure 1　Annual Energy Consumption (in 2003)

Figure 2 shows annual energy consumption per floor area (in 2003). Annual energy consumption per square meter changes between a range of 0.27 GJ/m^2 (A03) to 0.97 GJ/ m^2 (B03), and the amount of energy consumption per unit of floor area has small differences.

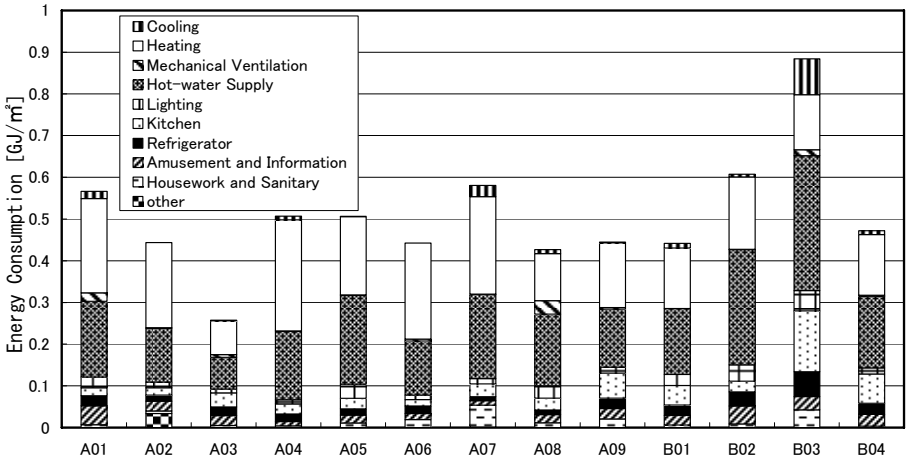


Figure 2　Annual Energy Consumption per unit of floor area (in 2003)

Figure 3 shows the average levels of energy consumption per floor area in detached houses. The total ratio of heating and hot-water supply for the year is 71% of the total energy consumption per floor area, which includes 39% (188.5MJ/m^2) of the heating system and 33% (156.3MJ/ m^2) of the hot-water supply.

Figure 4 shows the average energy consumption per floor area in condominiums. The total ratio of heating and hot-water supply for the year is 64% of the whole amount of energy consumption per floor area, which includes 40% (254.0MJ/ m^2) of the heating system and 24% (148.8MJ/ m^2) of the hot-water supply.

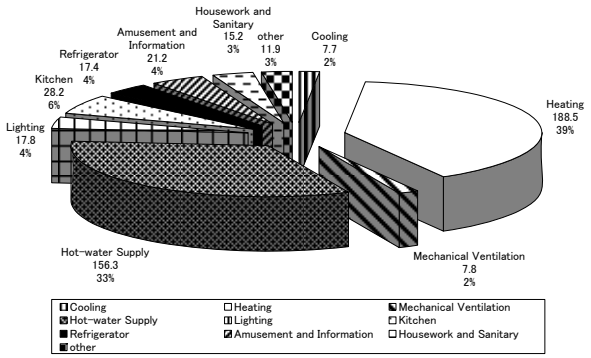


Figure 3 Average Energy Consumption per Floor Area in Detached Houses (in 2003)

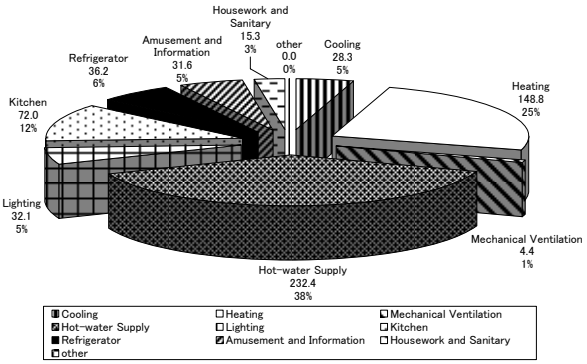


Figure 4 Average Energy Consumption per Floor Area in Condominiums (in 2003)

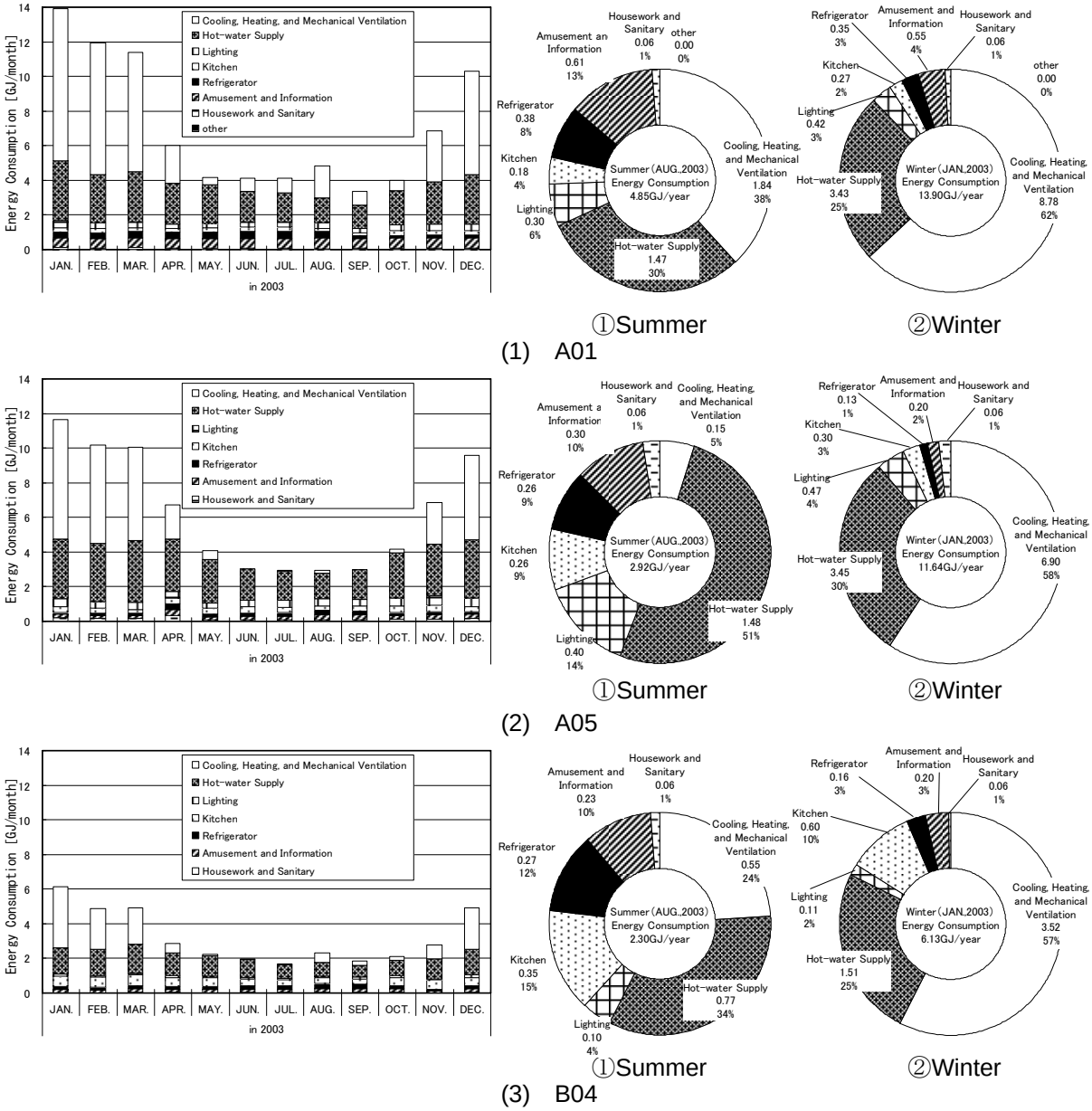


Figure 5 Monthly Energy Consumption and the Ratio of Various Uses of Energy Consumption in Summer (August) and Winter (January) (in 2003)

Monthly Energy Consumption

Figure 5 shows the monthly energy consumption and the ratio of various uses of energy consumption in summer (August, 2003) and in winter (January, 2003) at A01, A05, and B04. All the detached houses and condominiums decrease their levels of energy consumption in the spring and autumn, and increase their consumption in the winter. The factors which cause seasonal changes in the energy consumption levels are mainly differences in levels of heating and in the use of the hot-water supply.

Comparing summer (August) with winter (January) for A01 in which air-conditioning and floor heating are used continuously in all rooms, the ratio of energy consumption by cooling and heating is larger, being about 38% in summer and 62% in winter. The total ratio of hot-water supply for the year is about 30% of the total energy consumption, but in winter it is 2.3 times as large as that in summer. The total ratio of air-conditioning and hot-water supply for the year is 68% in the summer, and 87% in the winter. For other uses, levels of energy consumption are not changed according to the season.

Although A05 partially uses air-conditioning and heating, energy consumption levels in summer are low compared with A01, with the total ratio of heating being 58% (6.90GJ/month) in winter. The total ratio of hot-water supply for the year is 51% in the summer and 30% in the winter of the total energy consumption; however, total energy consumption levels in winter are 2.3 times (3.45 GJ/month) as large as in summer. The total ratio of air-conditioning and hot-water supply for the year is 56% in the summer and 88% in the winter. In other uses, energy consumption levels do not change according to the season, the same as A01.

B04 of the condominiums is partially subject to air-conditioning and heating. The ratio of energy consumption by air-conditioning and heating in the summer is 24% (0.55GJ/month), but this increased to 57% (3.52GJ/month) in winter. The total ratio of hot-water supply for the year is 34% of the total energy consumption in the summer and 25% in the winter, but total consumption levels in winter are 2.0 times (1.51GJ/month) as large as in the summer. The total ratio of air-conditioning and hot-water supply for the year is 58% in the summer and 82% in the winter. For other uses, energy consumption levels do not change according to season, the same as for detached houses.

Hourly Changes of Energy Consumption for Days

Figure 6 shows the hourly change in energy consumption for the hottest days and Figure 7 shows consumption levels for the coldest days. The upper figure shows larger energy consumption items (i.e., air-conditioning, hot-water supply, and other uses), and the lower figure shows smaller energy consumption items (e.g., lighting, kitchen, refrigerator, amusement and information, housework and sanitary, and other).

(1) A01

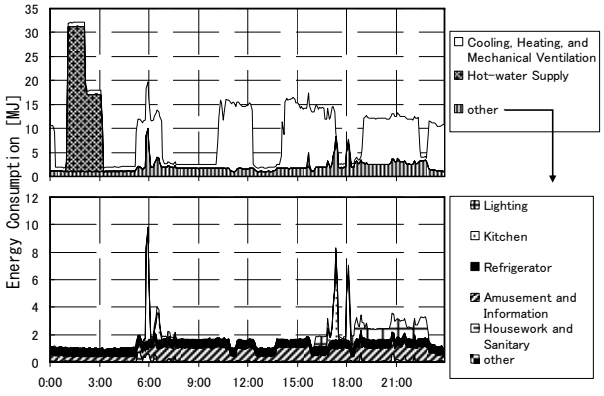
A01 is the all-electric detached house, and so heating and hot-water supply equipment only use night time electric power. In summer, the hourly energy consumption of air-conditioning (cooling) is about 13MJ, and is used intermittently. The energy consumption of hot-water supply ranges from 15 to 30MJ in the middle of the night. Energy is mainly consumed at midnight, and the maximum hourly energy consumption is about 90MJ. For other uses, the use of lighting is longer in winter compared to the summer.

(2) A05

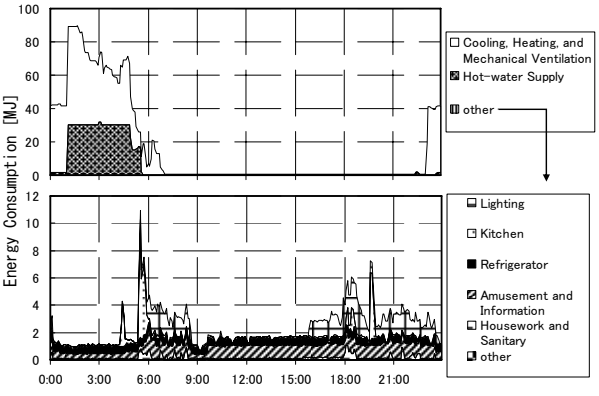
A05 is using oil for heating and hot-water supply. Cooling is hardly used at all. The hourly energy consumption of heating is about 20MJ by oil, except in the middle of the night, and is used intermittently. Oil consumption of hot-water supply forms a large peak at morning and night. In other uses, the energy of lighting and energy for the kitchen is consumed at morning and at night.

(3) B04

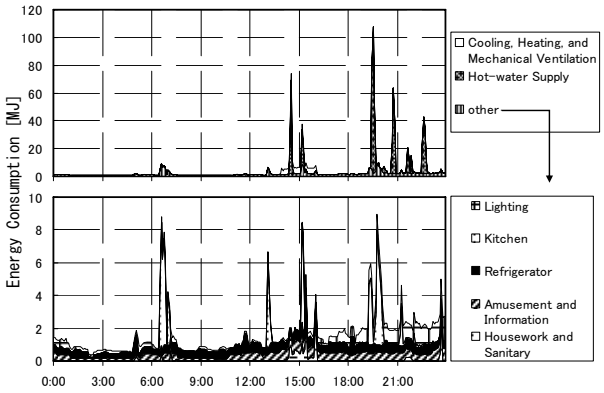
B04 is using oil for heating, and gas for hot-water supply and kitchen equipment. Cooling uses about 3MJ in the occupied time and zone. Oil consumption for heating is about 10MJ, and is used intermittently. Gas consumption for the hot-water supply makes the largest peak in the morning and at night. In other uses, gas consumption for the kitchen makes a large peak at morning and at night.



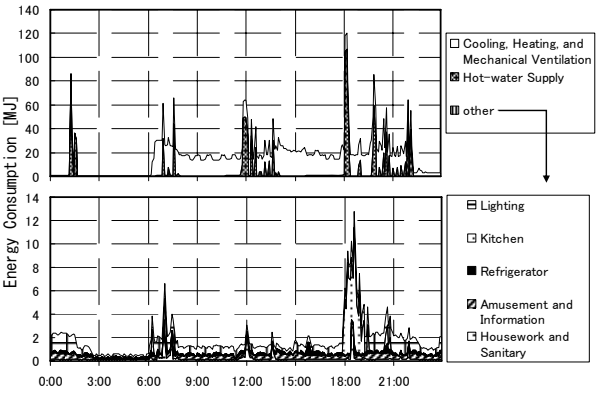
(1) A01(August 7, 2003)



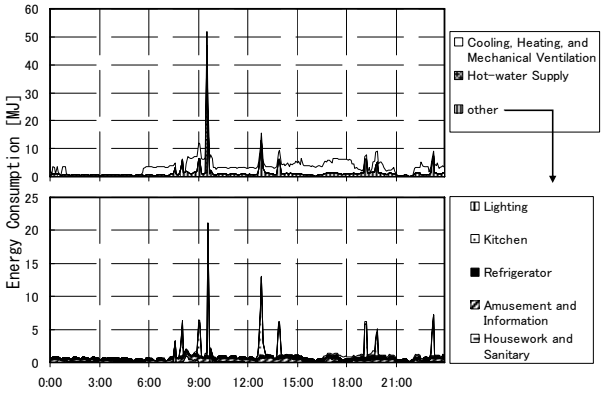
(1) A01(January 29, 2003)



(2) A05(September 13, 2003)

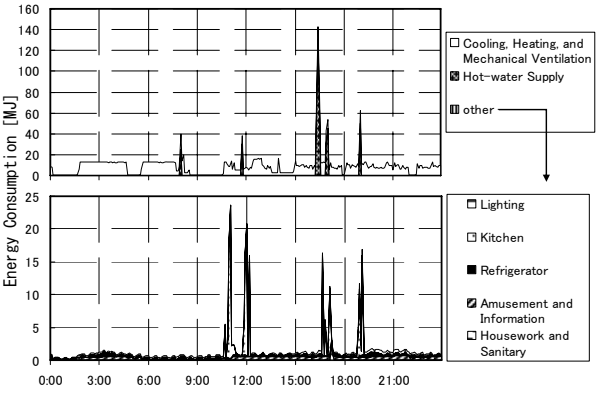


(2) A05(January 29, 2003)



(3) B04(September 13, 2003)

Figure 6 The Hourly Change in Energy Consumption for Hottest Day



(3) B04(January 1, 2003)

Figure 7 The Hourly Change in Energy Consumption for Coldest Day

Energy Consumption by Air-Conditioner

Compared to Actual Energy Use with Catalog Energy Use by Air-Conditioner

Figure 8 shows the actual energy consumption of air-conditioners compared with the catalog energy use in 2003 and 2004 for 14 air-conditioners. The energy consumption of actual energy use by air-conditioner is very widespread because of the diverging times of use.

Comparison of Actual Annual Energy Use to Catalog Energy Use

Figure 9 shows the cumulative frequency of annual energy consumption of actual energy use to catalog energy use (rated energy consumption) in 2003 and 2004. When the numerical value of the horizontal axis is equal to 1.0, the energy consumption of actual use and the catalog energy use are the

same. The electric power consumption ranges from 1.0 or less than the rated energy consumption of the catalog energy use to a catalog energy use of about 15~100% in 2003 and 2004. An air-conditioner consumes less electric power consumption than the energy consumption prescribed by the catalog energy use. The energy consumption of an air-conditioner is influenced by the room situation (e.g., the size of the room, the heat load, the preset temperature, the use time and so forth) and even if it is the same air-conditioning model, the situations of operation will be different from place to place.

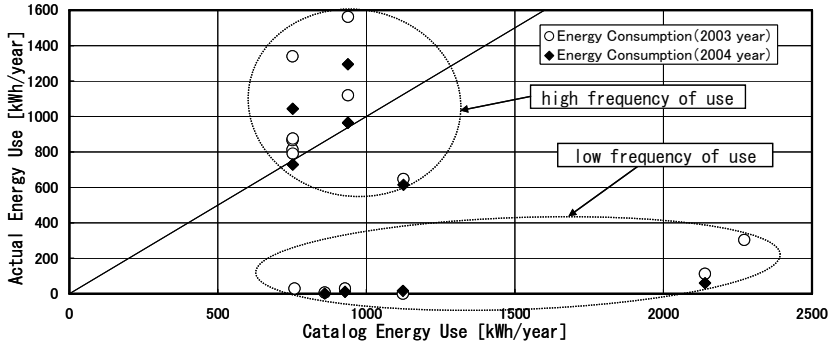
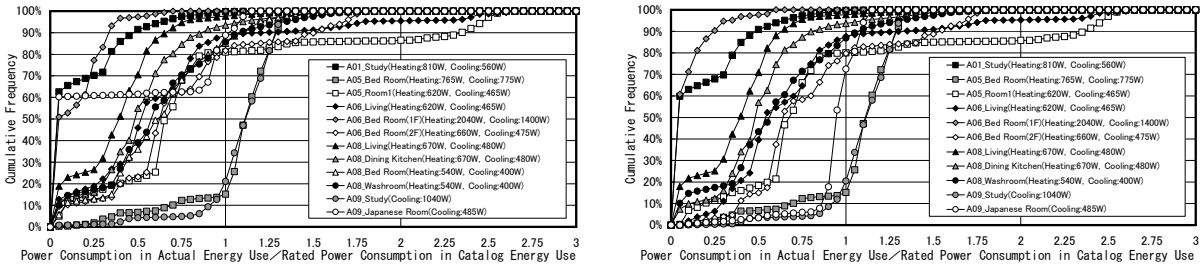


Figure 8 Energy Consumption of Air-Conditioners: Comparison of Actual Energy Use to Catalog Energy Use



(1) in 2003 (2) in 2004

Figure 9 Cumulative Frequency of Annual Energy Consumption of Actual Energy Use to Catalog Energy Use (Rated Energy Consumption)

Energy Consumption by Refrigerator

Comparison of Actual Energy Use to Catalog Energy Use by Refrigerator

Figure 10 shows the energy consumption of refrigerators, and a comparison of the actual energy use with catalog energy use in 2003 and 2004 for 13 refrigerators. The actual energy use is larger in 2003 and 2004, and the difference tends to become large when a refrigerator has a low annual energy use according to the catalog energy use.

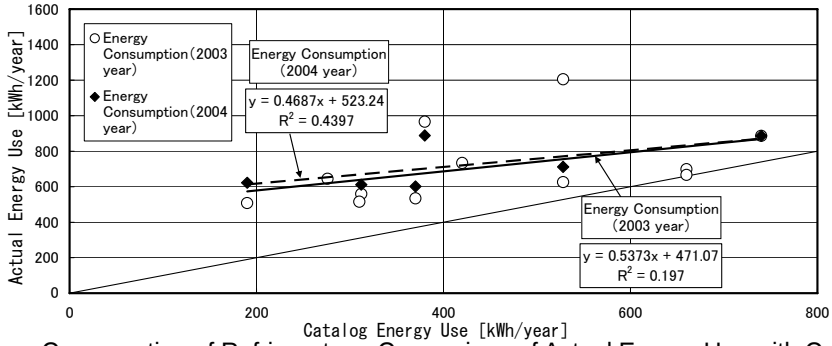
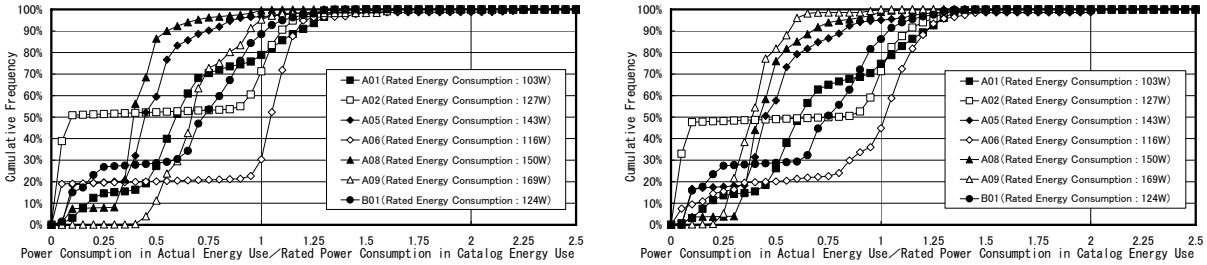


Figure 10 Energy Consumption of Refrigerators: Comparison of Actual Energy Use with Catalog Energy Use

Comparison of Actual Annual Energy Use with Catalog Energy Use

Figure 11 shows the cumulative frequency of the annual energy consumption of actual energy use compared to the catalog energy use (i.e., rated energy consumption) in 2003 and 2004. The electric power consumption of 1.0 or less rated energy consumption of the actual energy use to a catalog

energy use is about 15-100% in 2003 and about 45-100% in 2004. Refrigerators are operating at levels of power consumption that are less than the rated energy consumption levels.



(1) in 2003 (2) in 2004

Figure 11 Cumulative Frequency of Annual Energy Consumption: Actual Energy Use Compared to Catalog Energy Use (Rated Energy Consumption)

Conclusion

In order to clarify the actual conditions of the energy consumption of various types of inhabited houses in the Niigata area, a field survey was carried out from November 2002 to March 2005, and the energy consumption levels in the various houses were measured continuously. The results are summarized as follows:

1. The average annual energy consumption is 70.3GJ. Although the annual amount of energy consumption varies in each house, the differences in the amount of energy consumption per floor area are small.
2. 80% of the whole amount of energy consumption per floor area is cooling, heating, mechanical ventilation, and hot-water supply.
3. All detached houses and condominiums decrease energy consumption levels in spring and autumn, and increase in winter. In the summer, energy for cooling is consumed. The elements which affect seasonal changes in levels of energy consumption are mainly heating and hot-water supply.
4. The change in energy consumption levels for hottest or coldest days, and the patterns of energy consumption change greatly according to the use of nighttime electric power. Air-conditioning and hot-water supply are longer in winter, and increase to a peak compared to the summer.
5. The energy consumption of an air-conditioner is influenced by the living situation (e.g., the size of the room, load, preset temperature, and hour of use etc.) and even if it is the same model, the situations of operation differ.
6. Based on a comparison of the actual energy consumption with the catalog energy use, the actual energy use increases, and the difference tends to become larger for items like a refrigerator with low annual energy consumption levels for catalog energy use.

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