A Consideration of Commercial Electricity Use Based on Measured Consumption Records

- Electricity Saving and Load Leveling Potentials at Supermarkets and Convenience Stores -

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Along with growing concerns over environment worldwide, Japan also embraces energy conservation as a matter of pressing need. Yet, even in the midst of recent economic stagnation, residential and commercial electricity consumption has remained strong, particularly in the commercial sector. The likelihood is the constant growth continues ahead.

This study focuses on a commercial electricity consumption mix, as well as beverage & food retailers whose electricity use grows high. An interim report released (December 1997) by the Power Load Leveling Subcommittee of the Basic Policy Committee, a panel under the Electricity Utility Industry Council, put that the cumulative installed capacity of freezing & refrigeration showcases would reach 18.92 GW as of 2010. Under this study, we conducted a survey to measure how much electricity was consumed by these sorts of retailers, particularly in freezing & refrigeration showcases, in a bid to learn their potentials of rational electricity use.

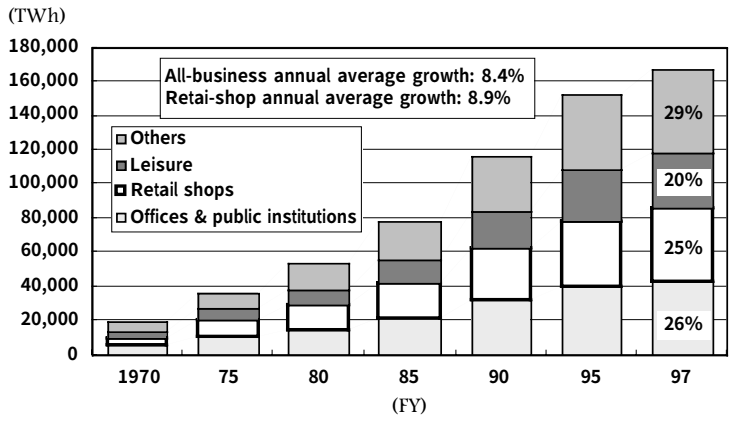
1. Background of Beverage & Food Retailers' Electricity Consumption Survey

1-1 Positioning of B&F retail business in commercial electricity consumption

Commercial sector's electricity consumption records and its consumption mix by type of business show that, as of FY1997, retail shops, including "commerce"-related businesses, accounted for about 25%, almost identical to an all-business average. But, from FY1990 to FY1997, the retail shops' electricity consumption outgrew the all-business average, or up 8.9% a year on average (Fig. 1-1).

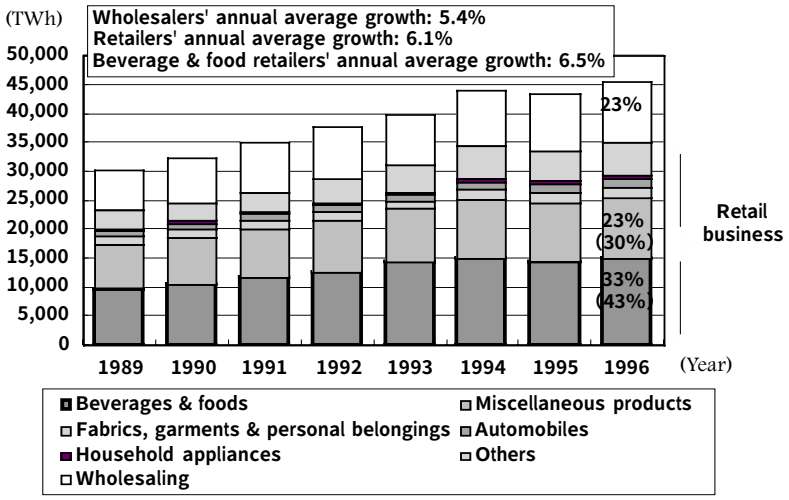
Of total electricity consumption by commercial establishments (with a workforce of 20 employees or larger) as of 1996, retailers were responsible for 77%, or more than three fourths. The growth of retailers' electricity consumption outpaced the wholesalers' and averaged 6.1% a year. By type of business, beverage & food retailers held the largest shares: 33% of whole commerce and 43% of all retail businesses. The annual growth recorded by B&F retailers, up 6.5% yearly, also outrun an all-retail-business average. Given that beverages and foods are

Fig. 1-1 Commercial Electricity Use and Consumption Mix by Type of Business



(Source) Prepared by IEEJ from the Japan Electric Power Study Committee's data.

Fig. 1-2 Commercial Electricity Use and Changing Consumption Mix by Type of Business (20 employees or larger)



(Source) Prepared by IEEJ from Structural Statistical Chart of Oil and Others.

also sold at many other retail shops not specializing in B&F but offering a variety of goods, electricity consumption involved in beverage & food retail business can be greater than suggested by these figures (Fig. 1-2).

1-2 Characteristics of B&F retailers' electricity consumption and likely trends

In reflection to consumers' growing quests for greater conveniences in both availability of diverse goods and readily shopping, the emergence of big stores and the rise of convenience stores can best characterize recent retail businesses.

Table 1-1 shows historical changes in store numbers and sales floorspace by type of business. Focusing on food retail business, general supermarkets and convenience stores alike have been on the increase in both store numbers and floorspace. General supermarkets expanded their sales floorspace by 42% and convenience stores by 62%. Above all, the stores open 24 hours more than doubled their floorspace, up sharply by 121%.

Records of annual electricity consumption per square meter of sales floorspace disclose that, by type of business, beverage & food retailers have consistently been the most electricity-intensive consumers, whose electricity use was more than double other retailers' (Fig. 1-3). One of the factors that makes B&F retailers electricity-intensive is the existence of freezing & refrigeration showcases, an electricity use specific to beverage & food retailing. According to the materials delivered by the Japan Freezer Manufacturers Association at its "Lecture Meeting and Symposium," these sorts of showcases claimed more than 60% of electricity consumed by the food supermarkets. The share is particularly striking when compared with 25% held by floorspace lighting & others and 13% by airconditioning.

Few data are available on how much electricity is consumed by showcase-related equipment in Japan. Yet, an interim report prepared December 1997 by the Basic Policy Committee of the Electricity Utility Industry Council put that the installed capacity of freezing & refrigeration showcase stocks would reach 18.39 GW as of 2010 (Fig. 1-4). The figure proves considerable if compared with a combined 185 GW installed capacity held by ten utilities as of FY1997 yearend.

Recent showcase shipments also attest a marked growth of freezing showcases of independent freezer type (Fig. 1-5). With this type, instead of a built-in freezer, an independently installed freezer runs the plural number of showcases. Showcases running on a built-in freezer are generally called the built-in freezer type. Because the independent freezer-type showcases are more electricity-intensive than the other type, their greater shipments mean ever-growing electricity consumption by the freezing & refrigeration showcases.

On the postulation that changing lifestyles, like a larger number of double-income households and consumers' quests for greater conveniences, should result in boosting demand for processed foods, typically frozen foods, further buildups of showcase stocks are likely, that, in turn, has a massive effect on commercial electricity consumption.

Thus, food retailing is the largest single business in the commercial sector that holds by far heaviest weight in commercial electricity consumption.

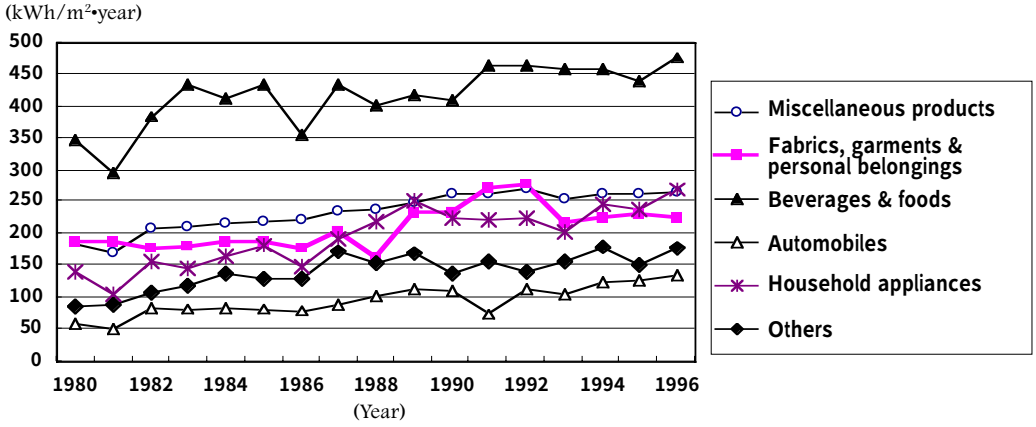
While showcase stock buildups could send electricity consumption rising further, we have known few about the actual state of electricity consumption by beverage & food retailers. For these reasons, we surveyed convenience stores and general supermarkets, both expanding their floorspace rapidly, and measured how much electricity they consumed, particularly in running their freezing & refrigeration showcases.

Table 1-1 Retail Shop Numbers by Type of Business and Sales Floorspace

Type of business	No. of retail stores							Sales floorspace (1,000m²)							
	'91	'94	'97	Shares (%)			Up/down (%)	'91	'94	'97	Average floorspace (m²)	Shares (%)			
				'91	'94	'97	'97/'91				'97	'91	'94	'97	'97/'91
Retailing total	1,605,583	1,499,948	1,419,685	100	100	100	▲ 12	109,901	121,624	128,328	101	100	100	100	17
1. Department stores	478	463	480	0	0	0	0	6,733	7,124	7,716	16,076	6	6	6	15
2. General supermarkets	1,683	1,804	1,886	0	0	0	12	9,525	11,394	13,517	7,167	9	9	11	42
3. Garment supermarkets, specialty & semi-specialty shops	233,967	216,322	193,815	15	14	14	▲ 17	17,276	17,936	17,198	89	16	15	13	▲ 0
4. Food supermarkets, specialty & semi-specialty shops	523,922	465,286	402,707	33	31	28	▲ 23	27,352	28,261	27,942	69	25	23	22	2
5. Housing-related supermarkets, specialty & semi-specialty shops	733,245	700,805	661,580	46	47	47	▲ 10	39,613	45,682	47,329	72	38	38	37	19
6. Convenience stores	23,831	28,595	36,586	1	2	3	54	2,243	2,785	3,637	99	2	2	3	62
Incl. those open 24 hours	9,699	13,431	20,531	1	1	1	112	1,008	1,441	2,230	109	1	1	2	121
7. Other supermarkets	72,033	84,505	120,577	4	6	8	67	6,969	8,207	10,741	89	6	7	8	54
8. Other retail shops	16,424	2,168	2,054	1	0	0	▲ 87	190	234	248	121	0	0	0	30

(Source) Prepared by IEEJ from FY1997 Prompt Statistics on Commerce.

Fig. 1-3 Retailers' Electricity Intensity Per Unit Floorspace by Type of Business (20 employees or larger)



(Source) Prepared by IEEJ from Structural Statistical Chart of Oil and Others.

Fig. 1-4 Projection of Installed Capacity of Freezing & Refrigeration Showcase Stocks for 2010

1997 December Interim Report, the Basic Policy Committee, EUIC

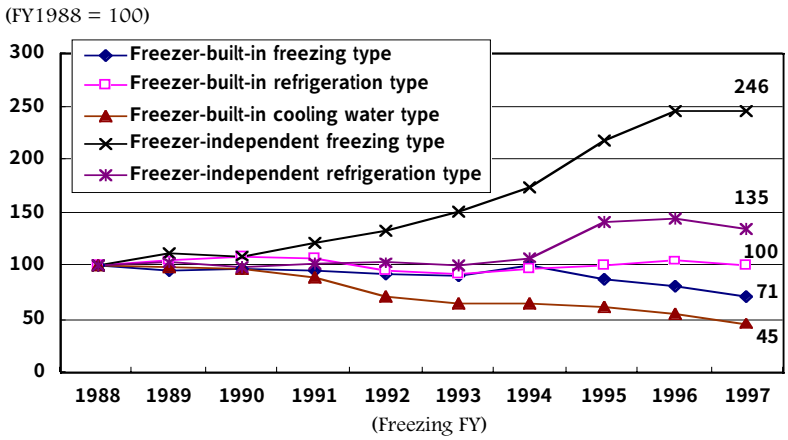
In projecting future loads, the report assumed the installed capacity of freezing & refrigeration showcase stocks as follows.

Freezing & refrigeration showcases
Installed capacity of the stocks as of 2010 18.39 GW

*Assumptions
Average usable life: 10 years
Cumulative shipments in 2001 - 2010

(Source) Prepared by IEEJ from the interim report (Dec. 1997) of the Basic Policy Committee of the Electricity Utility Industry Council.

Fig. 1-5 Shipments of Freezing & Refrigeration Showcases with 1988 As Base Year



(Note) "Freezing FY" is a fiscal year taken by F&R showcase makers that starts October every year and ends in September of the following year.

(Source) Prepared by IEEJ from the Data Book of Freezing & Airconditioning Machines 1998.

2. Convenience Stores' Electricity Consumption Survey

2-1 Outline of the survey

Table 2-1 gives the general descriptions of the survey.

As shown in Table 1-1, convenience stores have grown rapidly these years in both store numbers and floorspace. Their floorspace averages an area of around 100m^2. Given a particularly conspicuous growth of 24-hour open stores, the floorspace and business hours are assumed to shape the standards of convenience store.

Based on these conditions, Convenience Stores K and O were singled out for our survey. They are both located in the Kanto area, specifically in the outskirts, open 24 hours, and provided with parking lots.

Stores K and O alike are given a building area of about 140m^2 and a sales floorspace of about 100m^2 under the construction designs. According to utility designs, the contracts of by-time-zone lighting services are set at 25 kVA for both Stores K and O, while the contracts of low-voltage power services at 20 kW for Store K and 21 kW for Store O. Thus, the attributes of the two stores are almost identical. The survey was conducted in two phases, summer and winter, first for two weeks starting September 6, 1998, and second for a week from February 22, 1999. The primary objective of the summer-phase survey was to grasp electricity consumption patterns by use and time zone. The focal point of the winter-phase survey was to learn seasonal fluctuations in airconditioners' and freezers' electricity consumption from their summer records. For measurements, we employed "Clamp on Power High Tester 3166," a clamp-type power meter manufactured by HIOKI ELECTRIC CO. Meanwhile, under the co-

Table 2-1 Outline of Convenience Stores' Consumption Survey

		Stores surveyed	
		Store K	Store O
Location・characteristics		Kanto area, on the outskirts, standard type	
Floorspace		Total floorspace approx. 140m^2, sales floorspace approx. 100m^2	
Business hours		24 hours	
Opening date		Jan.98	Aug.98
Measurements	Objective	Summer: To get data on electricity consumption patterns by use and time zone. Winter: To learn seasonal fluctuations in electricity consumption of airconditioners and showcase freezers.	
	Periods (summer) (winter)	Sep. 6 (Sun.) noon to Sep. 19 (Sat.) midnight, 1998 Feb. 22 (Mon.) noon to Feb. 28 (Sun) midnight, 1999	
	Subjects (summer) (winter)	Major circuits Airconditioners, refrigeration showcases' freezers, master lighting services by time zone, master low-voltage power services	
	Meters in use	HIOKI ELECTRIC (Clamp on Power High Tester 3166)	
	Meters' specs	Voltage: ±0.1%rdg., ±0.2%f.s. (rdg. Reading degree, f.s. full scale) Current, effective power: ±0.1%rdg.±0.2%f.s.+ clamp on sensor accuracy Clamp on sensor accuracy: ±0.5%rdg.±0.2%f.s	
	Surveyed items	Current, voltage, power, power factor, detecting time, instantaneous value, maximum value, minimum value 10-minute cumulative value, 10-minute average	
	Meters' settings	Current: A clamp is set in each wiring within the distribution board. Voltage: Connected with a clip to the terminal within the distribution board.	

(Source) Prepared by IEEJ.

operation of the company running the convenience stores surveyed, we gained data on the open-air and room temperatures every ten minutes during the survey periods.

Table 2-2 shows the circuit makeup of the stores surveyed.

2-2 Findings and consideration

In the subsequent sections, by-time-zone lighting services are referred to simply as "lighting services," and low-voltage power services as "power services."

2-2-1 Total electricity consumption by convenience store

Fig. 2-1 shows Store K's daily electricity consumption during the survey period. Summer-phase electricity consumption was larger by nearly 10% than winter-phase records. Among others, summer-phase records unveiled a larger share held by power services, while winter-phase records did a greater share of lighting services.

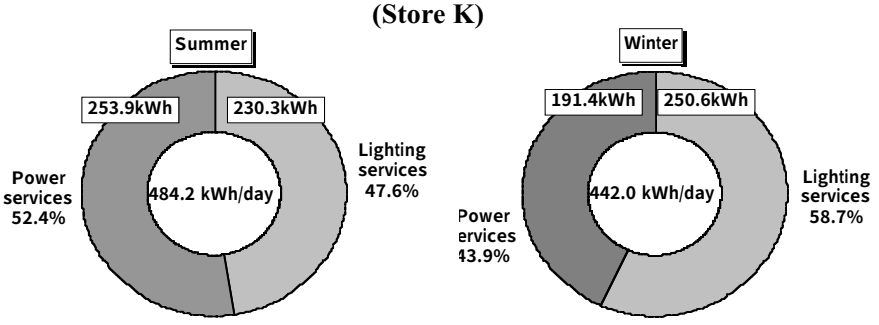
Fig. 2-2 breaks down the daily electricity consumption by circuit. The freezers that run the showcases hold the largest share of 19%, followed by 16% of airconditioners. These two circuits alone claim more than one thirds of Store K's total electricity consumption. Sales floor lighting accounts for 11%. Among others, the shares of refrigeration-showcase power source, reach-in•showcase lighting, and showcase incidental equipment of walk-in power source exceed 10% when combined.

Table 2-2 Circuit Configurations at the Stores Surveyed

Contract type	Circuit name on distribution board	Specific uses	Major load specs
Lighting services by time zone	Master		
	Sales floorspace lighting	Lighting of sales floorspace	40W × 58 lamps
	Counter・backyard lighting	Lighting of counters, offices & toilets	40W × 15 lamps
	Signboard・parking lot lighting	Signboard and lighting of parking lot	40W × 16 lamps, 200W × 4 lamps
	Shop-front signboard power source	Shop-front・building signboard power source	40W × 29 lamps
	Walk-in power source	Lighting & others inside walk-in prefabricated refrigerators	32W × 3 lamps
	Refrigeration-case power source	Lighting & others inside multi-stage refrigeration showcases	40W × 2 lamps, 32W × 12 lamps,
	Reach-in showcase lighting	Lighting & others inside freezing showcases	40W × 2 lamps, 32W × 3 lamps, 20W × a lamp
	Ice showcase(Note 1)	Freezer-built-in, flat-type freezing showcases for ice cream	300W
	Other lighting services & plugs	Plugs, microwave ovens, copying machines	1.5 kW × 2 units, 1.5 kW
Low-voltage power services	Master		
	Airconditioners	Airconditioning	Outside unit 7.6 kW, room unit 260W
	Small freezer	Thermal source of a unit of walk-in prefabricated refrigerator & 4 units of refrigeration showcases' freezers	4.5 kW, fan 100W
	Freezing stockroom	Freezer-built-in refrigeration stockroom	1.1 kW
	Reach-in showcase	Freezer-built-in reach-in freezing showcases	1.6 kW
	Multi-stage refrigeration showcase	Freezer-built-in multi-stage refrigeration showcases	1.7 kW
	Ice showcase (Note 2)	Freezer-built-in freezing showcases for ice cream	1.1 kW
	Freezer mounted on the counter	Freezer-built-in freezers mounted on the counter	0.7 kW
	Insulation case	Heat insulation units for products	1.3 kW

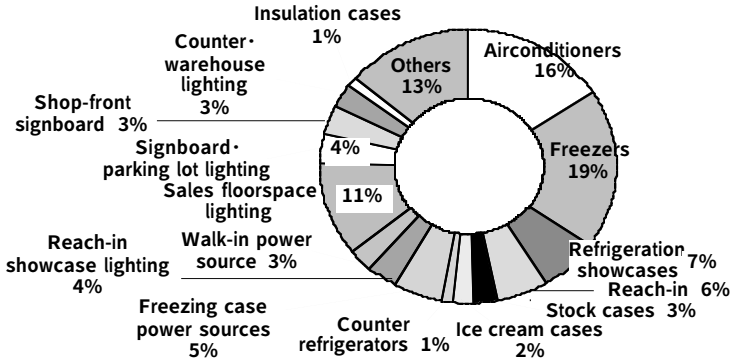
(Notes) 1. Grouped as a low-voltage circuit at Store O.
2. Grouped as by-time-zone lighting services circuit at Store K.
(Source) Prepared by IEEJ.

Fig. 2-1 Daily Electricity Consumption by Lighting and Power Services in Summer and Winter Seasons (Store K)



(Source) Prepared by IEEJ from the survey results.

Fig. 2-2 Daily Electricity Consumption Mix by Circuit in Summer (Store K)



(Source) Prepared by IEEJ from the survey results.

Table 2-3 Categories of Four Uses

Category of use	Circuit name
Airconditioning	Airconditioner
Showcase-related	Small freezer
	Freezing stock cases
	Reach-in showcase
	Multi-stage refrigeration showcase
	Ice cream case
	Under-counter freezer
	Walk-in power source
	Freezing case power source
	Reach-in showcase lighting
Lighting	Sales floorspace lighting
	Counter・backyard lighting
	Signboard・parking lot lighting
	Shop-front signboard lighting
Others	Heat insulation case
	Other lighting & plugs

(Source) Prepared by IEEJ.

If tabulated under the four uses specified in Table 2-3 (airconditioning, showcase-related, lighting, others), electricity consumption of the two stores could be as illustrated in Fig. 2-3. In summer, showcase-related consumption accounts for nearly half (48 - 49%), lighting 19 - 21%, airconditioning 16 - 18%, and others 14 - 15%. These results highlight the dominant share of showcase-related consumption.

Shown in Fig. 2-4 is a winter-phase consumption mix by use, estimated from the summer-phase survey results. The share of showcase-related consumption remains as massive as 45 - 46%, while that of airconditioning slips from the summer records to 12 - 15%.

2-2-2 Consumption patterns of convenience store

Fig. 2-5 plots Store K's changing electricity consumption by use on September 13. We singled out September 13 as a typical day of summer, because it was the hottest day during the summer-phase survey.

First, focusing on the showcase-related portion, the freezers' electricity consumption fluctuated little throughout a day except periodical steep plunges every six hours. The periodical plunges are attributable to off-cycle defrosting of refrigeration showcases (see Table 2-4 for details of defrosting). Because the rest of showcase-related items also recorded flat electricity consumption, the showcase-related portion overall shaped a baseload-like load all day long. On the other hand, airconditioning showed greater electricity consumption midday in response to higher atmospheric temperatures. As for lighting, electricity consumption in indoor lighting changed little. Outdoor lighting is put on from around 17:30 to around 6:00. As a result, it is found that, in summer, convenience stores have peak power occurring either midday or in the evening. The former contains a time zone when rising open-air temperatures sends airconditioning load up. The latter represents a time zone when the startup of outdoor lighting sends lighting load up.

Because little fluctuating showcase-related por-

Fig. 2-3 Daily Electricity Consumption Mix by Use in Summer

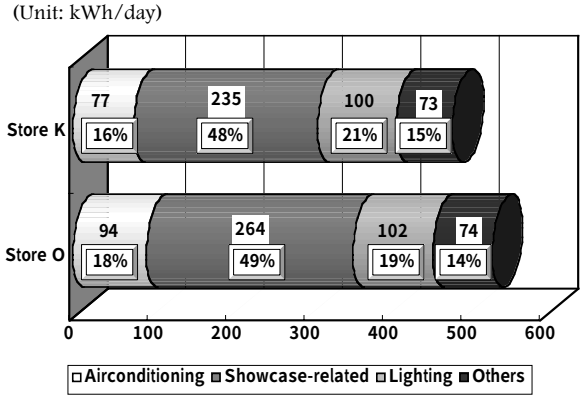
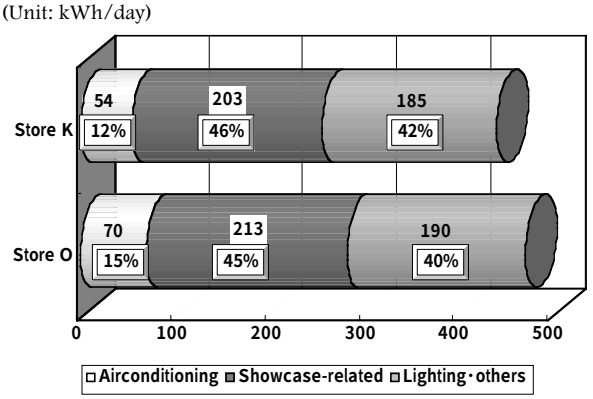


Fig. 2-4 Daily Electricity Consumption Mix by Use in Winter



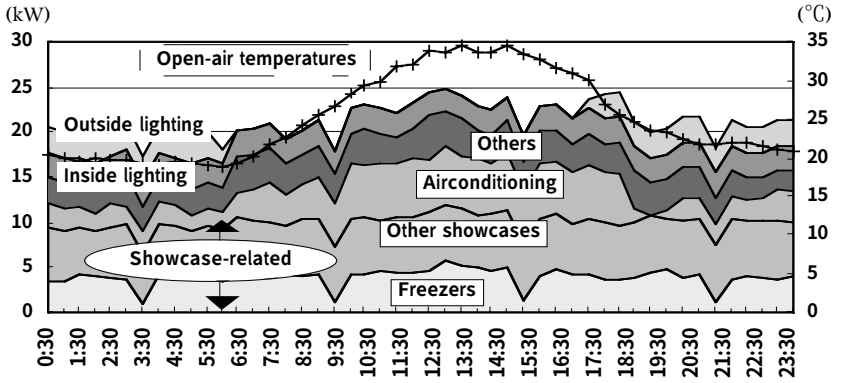
(Source) Figs. 2-3 & 2-4 alike prepared by IEEJ from the surveyed results.

tion holds nearly half of the overall load, and because the nighttime fall and rise in airconditioning and outdoor lighting loads are in a complementary relation, a convenience store as a whole keeps its load factor high at 80% or more.

Fig. 2-6 shows daily electricity consumption in winter. Freezers' electricity consumption, fluctuating scant except defrosting time, shrank from the summer records to about 2.5 kW in absolute terms. Unlike summer, airconditioning electricity use fluctuated little due to open-air temperatures. With all of freezers, airconditioning and other power sources combined, total power services plotted a virtually flat load pattern throughout a day. Lighting services showed rising electricity consumption from the evening to early morning. Perhaps the rise is attributable to the same reason as in summer: outdoor lighting lit up.

These results show that winter-season peak power occurs in a time zone when outdoor lighting

Fig. 2-5 Changes in Summer-Season Electricity Consumption by Use (Store K)



(Source) Prepared by IEEJ from surveyed results.

Table 2-4 Outline of Defrosting

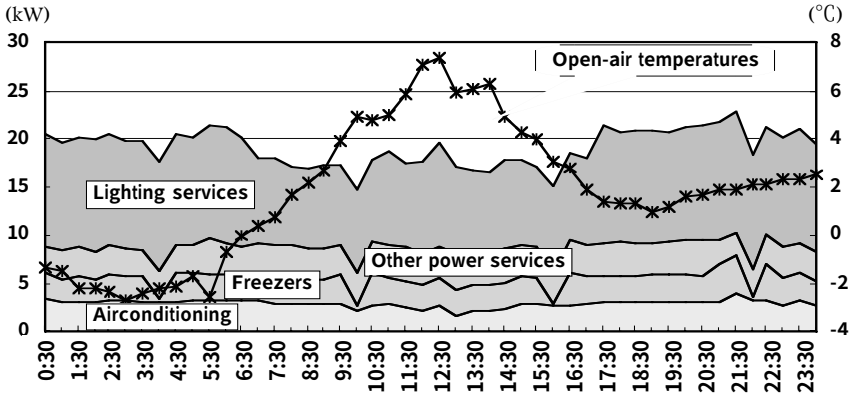
○ What's defrosting?

It is to remove frost on the evaporator of freezer-refrigerator (showcase).

Major defrosting systems	General descriptions	Employed in
Off-cycle defrosting	Defrosted by inside-air circulation, while halting the freezer's operation.	Refrigeration showcases with inside temperatures of 0°C or higher.
Heater-based defrosting	Forcedly defrosted by heat from a defrost heater installed within an evaporator, while halting the freezer's operation.	Low-temperature-zone refrigeration showcases & freezing showcases with inside temperatures of 0°Cor lower.
Hot gas defrosting	Defrosted by condensed latent heat by injecting into the evaporator by bypassing high-temperature high-pressure refrigerant discharged from the compressor.	Low-temperature-zone refrigeration showcases for fresh fish, meats and the like (though heater-based defrosting has formed the mainstream recently).

(Source) Prepared by IEEJ from various reference materials.

Fig. 2-6 Winter-Season Electricity Consumption by Use (Store K)



(Source) Prepared by IEEJ from the surveyed results.

is put on. It shapes a load curve completely featured by a nighttime peak. Meanwhile, load factor exceeded 80%.

2-2-3 Airconditioners' electricity consumption

Fig. 2-7 shows airconditioners' changing electricity consumption and varying temperatures in and outside Store K during the summer-phase survey. Airconditioning electricity consumption responded linearly to varying open-air temperatures, thus attesting the strong interrelationship between the two. In the meantime, room temperatures were kept generally at 23℃ - 25℃.

2-2-4 Showcases-related electricity consumption

Fig. 2-8 illustrates Store K's showcases-related electricity consumption by circuit on September 13. All circuits but freezers showed virtually flat electricity consumption 24 hours. A plausible explanation is that the freezer-built-in showcases were affected little by the open-air temperatures, as the room temperatures were kept constant by airconditioners. Incidental equipment, like walk-in power sources (warehouse lighting, fans, dew-preventing heaters), registered little fluctuations either.

On the other hand, freezers' electricity consumption boosted by around 1 kW - 2 kW midday. It is probably because the freezers were installed outside and affected by the open-air temperatures. Yet, thanks to the constant room temperatures, or stable ambient conditions of the showcases, the fluctuation range of the freezers' electricity use was narrower than that of airconditioners' that greatly mirrored the differences between midday and nighttime temperatures.

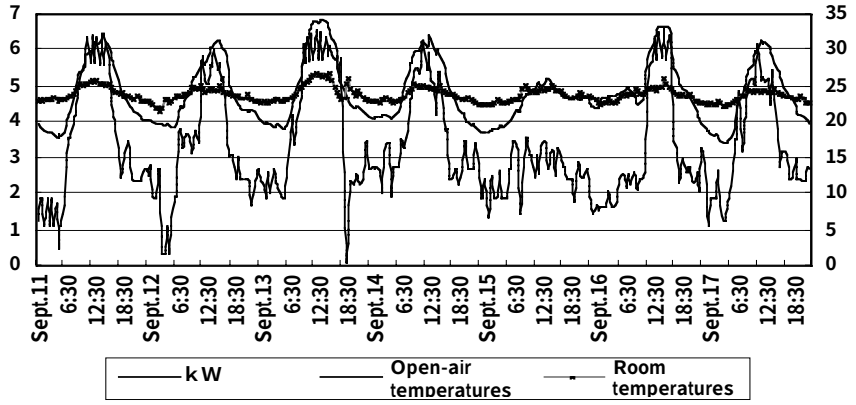
Thus, it is found that showcases-related electricity consumption fluctuates only slightly as a result of the midday boost in the freezers' electricity use.

2-2-5 Electricity consumption in lighting

Fig. 2-9 shows how much electricity was consumed in lighting by which circuit at Store K. Sales floor lighting and backyard lighting alike showed virtually constant loads 24 hours. When combined, signboard & parking-lot lighting and shop-front signboard lighting claimed a load of nearly 3 kW in absolute terms, and accounted for some 15% of Store K's nighttime electricity consumption overall.

The two stores surveyed have introduced a lighting control system for sales floorspace lighting. This system is given two control functions, constant illuminance control and daylight sensor control. Fig. 2-10 gives general descriptions of the system. Sales-floor lighting records of the two stores showed that

Fig. 2-7 Airconditioners' Summer-Season Electricity Consumption and Temperatures In and Outside (Store K)



(Source) Prepared by IEEJ from the surveyed results.

Fig. 2-8 Showcase-Related Electricity Consumption by Circuit (Store K)

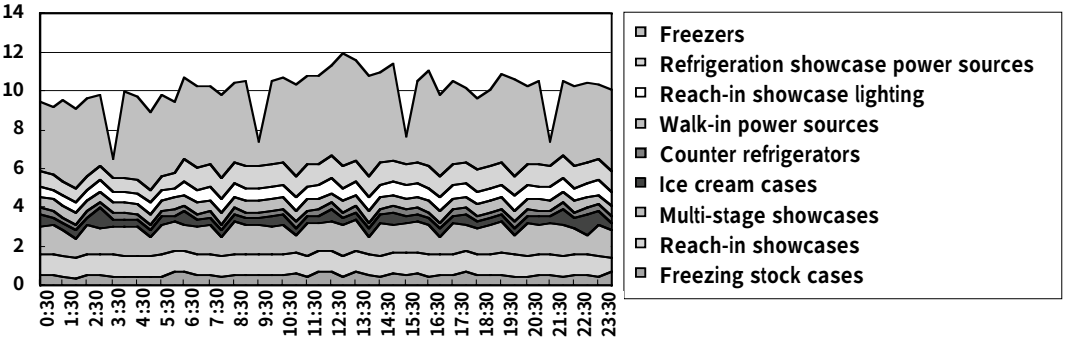
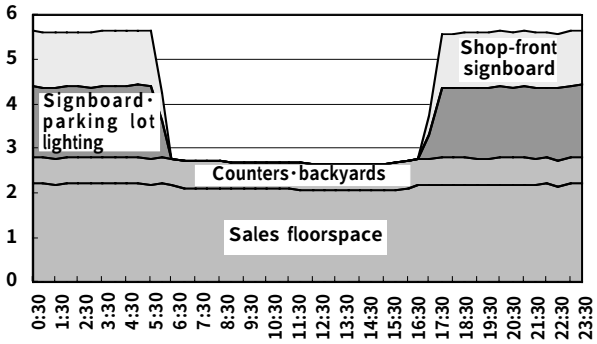


Fig. 2-9 Lighting-Related Electricity Consumption by Circuit (Store K)



(Source) Prepared by IEEJ from the surveyed results.

Fig. 2-10 Outline of Lighting Control Systems

1. Constant illuminance control

This system takes advantage of a characteristic of fluorescent lamps, that is illuminance, staying high at starting time, is gradually settled down to the designed level. In specific terms, this system has a mechanism to conserve electricity use and keep illuminance at a designed level by cutting excessive brightness at starting time by virtue of frequency control.

2. Daylight sensor control

This system allows electricity conservation by sensing natural lights with a daylight sensor installed at the window, then reducing illuminance of the lighting apparatus depending on the availability of natural lights.

(Source) Prepared by IEEJ from makers' brochures.

Store K consumed larger than Store O (Fig. 2-11). By the time the survey started, Store K has been in operation longer than half year after its opening, while Store O was newly opened a few weeks ago. The gap in Stores K's and O's electricity consumption represented the difference in cumulative lighting hours that reflected electricity-saving effects gained by the use of the constant illuminance control system.

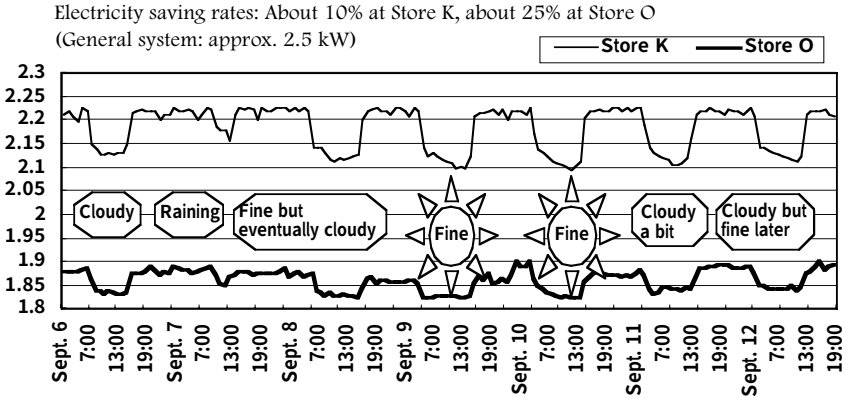
Also, with the daylight sensor control in use, daytime electricity consumption fluctuated depending on weathers.

At the time of the survey, the electricity-saving rates gained by the use of the lighting control system than otherwise were estimated at about 10% for Store K, and about 25% for Store O.

2-2-6 Electricity consumption in "others"

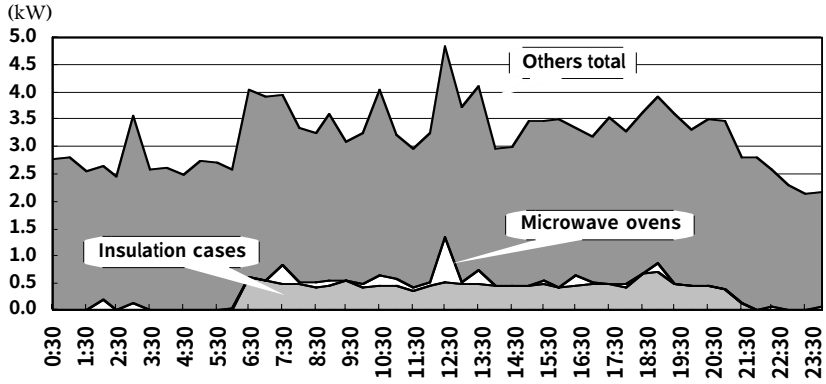
Fig. 2-12 shows electricity consumption in "others" at Store K. Overall electricity consumption in "others" jumped at around 12:30. The jump was

Fig. 2-11 Electricity Consumption in Sales Floorspace Lighting and Weather



(Note) Weather conditions based on the data from the nearest observatories.
(Source) Prepared by IEEJ from the surveyed results.

Fig. 2-12 Electricity Consumption in "Others" (Store K)



(Source) Prepared by IEEJ from the surveyed results.

caused by the greater use of microwave ovens. According to Store K's general manager we interviewed, it is a time zone when box lunches are sold well, and when the store's two microwave ovens are running almost at full capacity. With "insulation cases" and "microwave ovens" set aside from "others," a fixed load involved in the remaining appliances can be put at around 2 kW - 3 kW. Of these, major appliances are cash registers, copying machines, facsimiles, and monitors for game software sales.

3. Supermarkets' Electricity Consumption Survey

3-1 General descriptions of the survey

Table 3-1 gives general descriptions of the supermarkets surveyed and the survey contents. Subject to the survey were Stores A and S, both categorized as general supermarkets located in the Kanto area. Store A has a food sales floorspace of about 1,750m^2 and is open for 11 hours. Corresponding figures for Store S are about 800m^2 and ten hours. Store A had a shop-holiday during the survey period.

We surveyed electricity consumption by the freezers to run major showcases in an attempt to learn differences, if any, in load pattern from that of convenience stores. The survey period run six days from March 3 (Wed.) through 8 (Mon.), 1999. The meter in use and the items surveyed were the same as in the case of the convenience stores.

Next, specifics of the showcases installed and the circuits surveyed this time are depicted (Tables 3-2 & 3-3).

In both showcase numbers and freezer capacity, Store A outrun Store S by about 1.8 times. At Store A, we surveyed a total of five circuits, including four lines of refrigeration showcases and a line of freezing showcase. At Store S, we measured a total of four circuits, including three lines of refrigeration showcases and a line of freezing showcase. Store A outrun Store S by about 1.7 time in terms of combined output of the freezers surveyed.

As for defrosting systems (see Table 2-4), Store A employs defrost heaters in the showcases that contain frozen foods, while Store S does in the fresh-fish and frozen-food showcases. By the way, in regard to electricity consumption in Store A's frozen-food showcases and Store S' fresh-fish ones, the survey results covered electricity consumption by both the freezers and defrost heaters. But the survey result of Store S' frozen-food showcases covered electricity consumption by the freezers alone.

"Daily delivered" in Table 3-3 is a term peculiar

Table 3-1 General Descriptions of Supermarkets Surveyed and Measurements

Store		Store A	Store S
	Location・characteristics	Kanto area, general supermarkets	
	Food sales floorspace	1,749m^2	805m^2
	Location	B1F	1F
	Business hours	10:00 - 21:00	10:00 - 20:00
	(Closed)	4.Mar	
Measurement	Objective	To compare the load patterns of freezing & refrigeration showcases with those gained from the convenience stores.	
	Period	March 3 (Wed.) noon to March 8 (Mon.) midnight, 1999	
	Subjects	Freezers of major freezing & refrigeration showcases	

Table 3-2 No. of Installed Showcases

	Store A	Store S
Refrigeration showcases	75 units	40 units
Freezing showcases	8 units	7 units
Installed showcases total	83 units	47 units
No. of freezers for refrigeration	6	4
No. of freezers for freezing	2	2
Freezers in use total	8	6
Refrigeration freezers' capacity kW	122.5	58.3
Freezing freezers' capacity kW	33.9	30.1
Freezers' capacity total	156.4	88.4

(Source) Tables 3-1 and 3-2 prepared by IEEJ.

Table 3-3 General Descriptions of Circuits Surveyed

Circuit name		Category	No. of showcases	Freezer capacity (kW)	Defrosting	
					System	Heater capacity (kW)
Store A	Everyday-delivered products・delicatessen	Refrigeration	21	22	Off-cycle	
	Fresh fish	Refrigeration	7 units	11	Hot gas	
	Fruits & dairy goods	Refrigeration	23	32	Off-cycle	
	Frozen foods (*1)	Freezing	5	27	Defrosting heater	27
	Meats	Refrigeration	14	22	Hot gas	
	Total		60	113		27
Store S	Everyday-delivered products	Refrigeration	16	21	Off-cycle	
	Fresh fish (*2)	Refrigeration	7 units	15	Defrosting heater	13
	Fruits & delicatessen	Refrigeration	13	12	Off-cycle	
	Frozen foods (*3)	Freezing	3	18	Defrosting heater	19
	Total		39	66		32

(Notes)
*1・*2 Measured were both freezers and heaters.
*3 Measured were freezers alone.
(Source)
Tables 3-3 prepared by IEEJ.

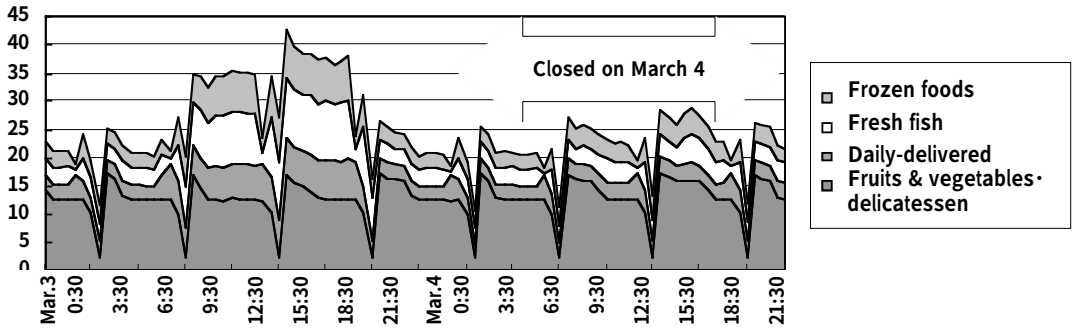
to the supermarket workers and means the "products delivered every day" such as milk, bean curd and devil's tongue.

3-2 Findings and consideration

3-2-1 Characteristics of showcase freezers' electricity use and savings by night cover

Fig. 3-1 shows changing electricity consumption by showcase freezers at Store S. Unlike the convenience stores open 24 hours, Store S' electricity use shrank after it was closed (at 20:00) and on the day off. Yet, electricity consumption involved in frozen- food showcases did not fall. Here, Store A's frozen foods-related electricity consumption records show that electricity use fell sharply off business hours (Fig. 3-2). The difference came from if or not night covers were in use. The night covers used by Store A are a kind of insulation covers that are put

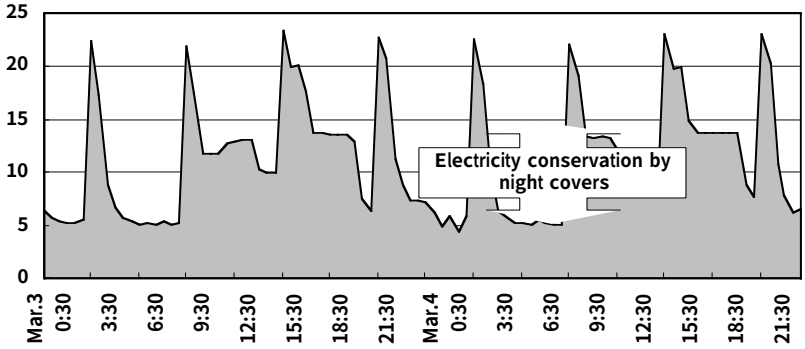
Fig. 3-1 Changing Electricity Consumption in Showcase Freezers (Store S)



(Source) Prepared by IEEJ from the surveyed results.

Fig. 3-2 Electricity Consumption in Frozen-Food Showcases (Store A)

(Unit: kW/h)



(Note) Incl. electricity consumption by electric heaters.
(Source) Prepared by IEEJ from the surveyed results.

over the opening part of the showcases off business hours. Of the showcases of the two stores surveyed this time, all but Store S' frozen-food ones were provided with the night covers.

Table 3-4 shows the freezers' hourly electricity consumption at Stores A and S on business days or shop-holiday, and during or off business hours. It was found that off-business-hour electricity consumption of the freezers of all refrigeration showcases but Store A's fresh-fish ones dropped to around 40 - 60% of their business-hour consumption records. The drop can be explained by a falling load of the freezers in reflection to fewer goods inside the showcases, and by an electricity-saving effect gained by the use of the night covers. The sharp 22% fall registered by Store A's fresh-fish showcases can be reasoned by that the showcases are not in operation after the store is closed.

As for frozen-food showcases, Store S that used no night covers in this field had electricity consumption shrinking neither off business hours nor on a shop-holiday. In contrast, at Store A, off-business-hour electricity consumption in running frozen-food showcases dropped to 70% of business-hour consumption records. In general, off-business-hour electricity consumption involved in freezing-type showcases is expected to fall scant because, unlike refrigeration showcases, they keep products inside even after business hours. Strictly speaking, Store S' electricity savings included a fall in thermal load attributable to the lights-out inside showcases. Yet, the use of night covers enabled Store S to trim its off-business-hour electricity consumption by nearly 30%.

Figs. 3-3 and 3-4 show photos of the night covers in use at Store A. Shown in Fig. 3-3 is a night cover for frozen-food showcases. A panel-like cover, housed in the top of the showcase, is pulled down when in use. Fig. 3-4 shows a night cover for refrig-

Table 3-4 Hourly Electricity Consumption of Freezers on & off Business Days and within & off Business Hours

		Store A						Store S				
		Frozen foods	Fresh fish	Daily-delivered・delicatessen	Fruits & vegetables・dairies	Meats	Total	Frozen foods	Fresh fish	Daily-delivered	Fruits & vegetables・delicatessen	Total
Business days	Within business hours	14.0	3.5	10.0	11.3	13.2	52.0	12.8	6.4	9.4	7.3	36.0
	Off business hours	9.8	0.7	4.2	4.7	7.9	27.3	12.1	3.6	4.0	3.4	23.0
	Total	11.7	2.0	6.9	7.7	10.3	38.6	12.4	4.7	6.2	5.0	28.4
	Off/within business hours	***70%***	22%	42%	41%	60%	53%	***95%***	56%	42%	46%	64%
Shop-holiday (March 4)	Within business hours							13.8	3.0	3.8	3.8	24.4
	Off business hours							12.0	2.9	3.1	2.9	20.9
	Total							12.8	2.9	3.4	3.2	22.3
	Off/within business hours							87%	97%	81%	76%	86%
All-day average	Within business hours	14.0	3.5	10.0	11.3	13.2	52.0	13.0	5.8	8.5	6.7	34.0
	Off business hours	9.8	0.7	4.2	4.7	7.9	27.3	12.1	3.5	3.8	3.3	22.7
	Total	11.7	2.0	6.9	7.7	10.3	38.6	12.5	4.4	5.8	4.7	27.4
	Off/within business hours	70%	22%	42%	41%	60%	53%	93%	59%	45%	49%	67%
Holiday/business days	Within business hours							107%	47%	40%	51%	68%
	Off business hours							99%	81%	78%	85%	91%
	Total							***103%***	62%	54%	65%	78%

Fig. 3-3 Night Cover for Freezing Showcase

Fig. 3-4 Night Cover for Refrigeration Showcase

eration showcases. For use, the cover, rolled up in the front top of the showcase, is rolled out, then hooked up at the bottom of the showcase.

3-2-2 Effect of defrosting on showcase-related electricity consumption

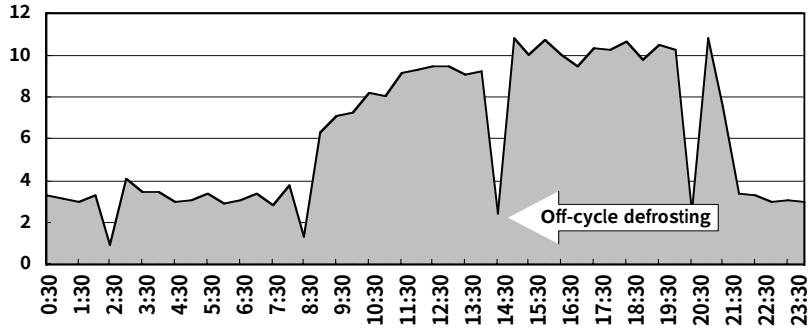
As an example of characteristic electricity consumption in running refrigeration showcases while defrosting, Fig. 3-5 shows electricity consumption by Store A's freezers to run the showcases that contain daily-delivered goods & delicatessen. It is noted off-cycle defrosting causes electricity consumption to fall six times a day. Immediately after defrosting, electricity consumption tends to boost because the freezers are forced a high-load operation in order to quench the temperatures inside the showcases that were up during defrosting.

What are characteristics of electricity consumption in running freezing-type showcases while defrosting? In case of Store S' frozen-food showcases, electricity consumption fell four times a day while defrosting, thus showing a similar trend to off-cycle defrosting (Fig. 3-1). On the other hand, Store A's frozen-food showcases (Fig. 3-2) marked greater electricity consumption while defrosting. It is because the graph represents electricity consumption of both the freezers and the defrost heaters. This suggests that, in case of freezing-type showcases, electricity consumption while defrosting sets to fall as the freezers are temporarily out of operation, but the fall is more than offset by the startup of defrost heaters. Freezing-type showcases employ electric heaters with an identical capacity to that of the freezers, or even larger. For this reason, the electric heaters have a considerable impact on electricity consumption in running the showcases.

3-2-3 Optimization of showcase-related electricity consumption by changing defrosting time

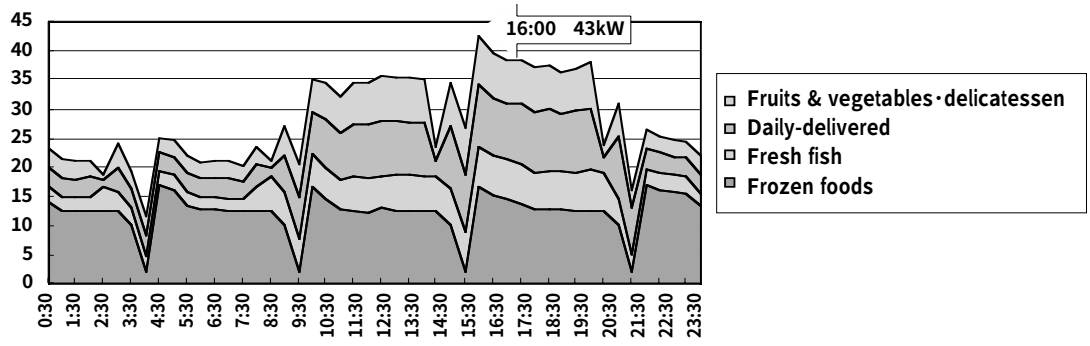
Here, we consider the impact of defrosting time on showcase-related electricity consumption based on the survey results. Fig. 3-6 shows changing electricity consumption by the freezers that run the showcases at Store S (the fresh-fish showcase-related electricity use covers the heaters too). Store S defrosts its showcases of fresh fish, daily-delivered goods, fruits & vegetables and delicatessen every six hours starting 2:30 a.m. Frozen-food showcases are defrosted every six hours from 3:30 a.m. onward. When the frozen-food showcases were defrosted at 15:30, electricity consumption by their freezers dropped, though the subsequent startup sent it rising sharply. However, given the data on frozen-food showcases do not include electricity consumption by the heaters, defrosting should involve larger electricity consumption than illustrated. As for fresh-fish showcases, on which data include the heaters' electricity use, electricity consumption increased a little when they were defrosted at 14:30. As for the showcases

Fig. 3-5 Electricity Consumption by Freezers to Run Daily-Delivered•Delicatessen Showcases (Store A)



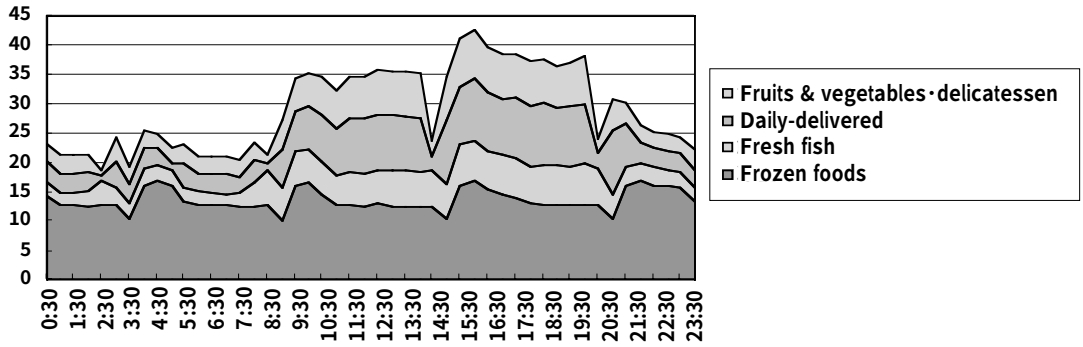
(Source) Prepared by IEEJ from the surveyed results.

Fig. 3-6 Electricity Consumption by Showcase Freezers (Store S)



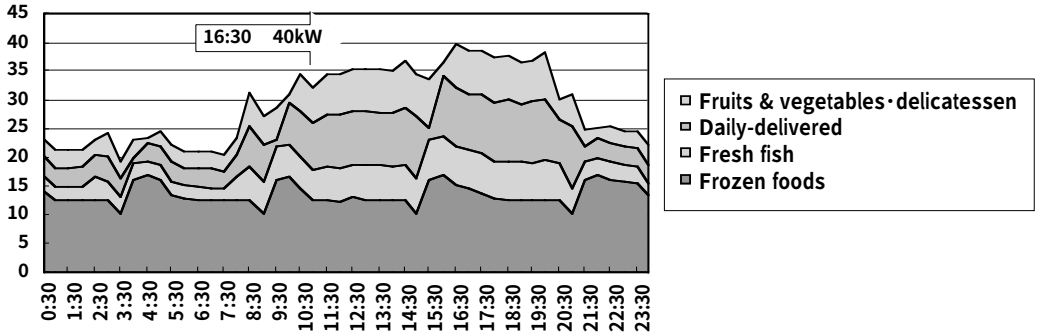
(Source) Prepared by IEEJ from the surveyed results.

Fig. 3-7 Electricity Consumption by Showcase Freezers (Store S, After Corrected)



(Source) Prepared by IEEJ from the surveyed results.

Fig. 3-8 Electricity Consumption by Showcase Freezers (Store S, After Defrosting Time Rescheduling)



(Source) Prepared by IEEJ from the surveyed results.

of daily-delivered products, fruits & vegetables and delicatessen, electricity consumption plunged when they were defrosted at 14:30, but later boosted sharply as a result of the startup.

Fig. 3-7 was prepared by correcting the graph in Fig. 3-6 by adding estimated electricity consumption for the heaters. Electricity consumed by Store S' heaters was estimated at 16.2 kW by multiplying the capacity of Store S' heaters, 19 kW, by about 85% of the measurement gained from the capacity of Store A's heaters. Consequently, electricity consumption was put at an estimated about 41 kW when defrosted at 15:30. Peak power was 43 kW, recorded at 16:00 when a post-defrosting boost occurred. This remains unchanged from the pre-correction figure.

Now, in recognition of electricity consumption boosts that occurred while defrosting and immediately after defrosting as a result of startup, we shifted defrosting time of the showcases of daily-delivered goods and fruits & vegetables to 15:30 and 16:00, respectively. Then, electricity consumption turned as shown in Fig. 3-8. Peak power shrank to about 40 kW and occurred at 16:30. This means a 7% cut in peak power simply by rescheduling defrosting time.

In this way, peak power of the showcases as a whole could be reduced if defrosting time was rescheduled or decentralized by taking advantage of electricity consumption boosts that are characteristic to defrosting and startup of the showcases. Yet, in order to optimize peak power of a store overall, it is also needed to give full consideration to the load patterns of other uses, notably airconditioning.

4. Prospects of Rational Electricity Use by Beverage & Foods Retailers

4-1 Technologies for rational electricity use by B&F retailers

Fig. 4-1 presents major technologies that enable rational electricity use by beverage & food retailers. Among them, six technologies are introduced below. Their descriptions are based on the interviews we made to relevant manufacturers this time.

4-1-1 Night covers

By now almost all refrigeration showcases have been night-cover-equipped. But, as far as freezing-type showcases are concerned, the penetration of night covers has lagged so far for the following two reasons. (1) Many of the night covers for flat-type showcases, consisting of duralumin-made panels of detachable type, require hard work for setting as well as an extra space for storage. (2) When mounted on multi-staged showcases, the open air, penetrating through the gaps between the panels, causes frosting on the products kept inside the showcases.

To eliminate these problems, relevant makers have developed new technologies, like (1) lightweight night covers of roll-in type that can be housed in existing showcases, without sacrificing electricity-saving performance equivalent to duralumin panels, and (2) multi-staged freezing showcases furnished with night cover as a standard specification. These might help the greater night cover use ahead.

4-1-2 Shifts to inverter-type showcase lighting

Inverter-type lighting and electron stabilizers, widely in use in the field of fluorescent lamps these years, set to gain a growing popularity in showcase lighting too. They can save electricity use by 20 - 30% compared with conventional lighting apparatus. From now on, most of newly shipped showcases will be of inverter-type as a standard specification. Given that showcase lighting claims some 20% of showcases-related electricity consumption, the introduction of inverter-type lighting can slash showcases-related electricity use by more than 4%.

4-1-3 Demand preset function

This system allows an about 12% cut in showcases-related electricity consumption by reducing showcase lighting in the time zone from 13:00 to 16:00, when peak power occurs, by 15%, while raising the controlled showcase temperatures by 1℃ so that a fall in thermal load of the showcases can be offset.

At present, only one maker employs this system as a standard specification. Yet, now that the company discloses the technology for free of charge, this system is likely to become popular as a standard specification of rivals' products.

4-1-4 Ice-heat-storage showcase system

With this system, the freezers of refrigeration showcases are designed to produce ice and store heat nighttime when freezing load sets to fall, then use it in powering the freezers to run the refrigeration & freezing showcases daytime when load is high. Major merits of this system are (1) smaller contract demand as a result of an about 20% cut in summer-season peak power that reflects an about 20% reduction in the installed capacity of the freezers, and (2) reduced running cost by subscribing heat-storage interruptible contracts offered to commercial users.

Under present conditions, an impediment to the spread of this system is that, because this system, not counted as an airconditioning equipment, is not eligible to the tax incentives nor national government subsidies for any investments in energy supply-demand structural reforms. In other words, the initial cost of this system involves ROI as long as about three years for big supermarkets, and even longer for small- and medium-sized supermarkets. Moreover, in equipment terms, this system requires a substantial space for heat storage tanks. If the tanks are installed on the roof, it should be built sturdy enough to endure the extra load.

If the ROI problem, the crucial bottleneck, can be eliminated or eased, the system could become popular.

4-1-5 Lighting control system

This is the lighting control system employed in the convenience stores surveyed this time. According to the maker's calculations, this system allowed the stores to cut their annual electricity consumption by about 17% compared with conventional lighting

Fig. 4-1 Less Electricity-Consuming Technologies for Beverage & Food Retailers

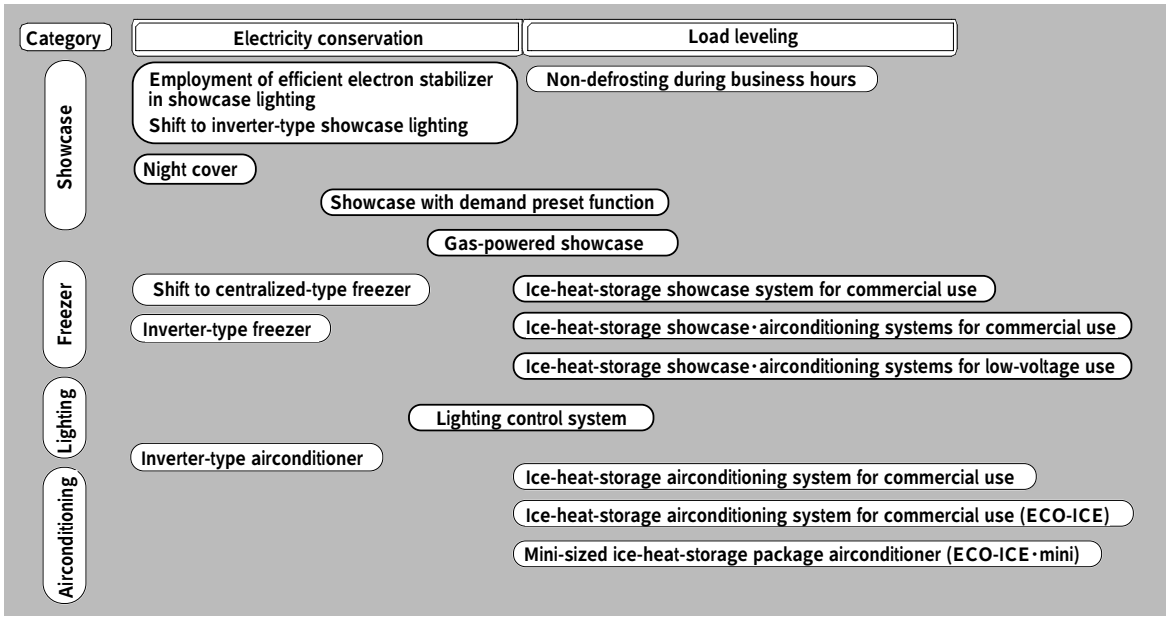


Fig. 4-2 Penetration and Possible Effects of Less Electricity-Consuming Technologies

(Source) Prepared by IEEJ.

apparatus.

If the maker's posted price was applied, ROI of the system should amounted to about three years. Yet, by buying in large quantities in a lump at the time of opening a new store, it appeared that the convenience stores were able to recover the initial cost within a year. Now that various makers offer various products of this sort, this system is likely to gain an increasing popularity among franchised stores and the like.

4-1-6 Gas-powered showcases

This is a freezer that drives a compressor with a gas engine. It represents a similar system to a gas heat pump (GHP). Its electricity consumption is about 10% less than an electric motor type. As a result, its running cost is trimmed by around 20%. A problem is that its usable life is as short as about five years, half of the ten years demonstrated by an electric motor type. An about 30% larger space need for installation can be cited as an additional problem. Market introduction of this type of showcase is scheduled for April 2000.

4-1-7 Prospects of less electricity-consuming technologies and their effects

Table 4-2 summarizes the prospects of major technologies that allow rational electricity use in terms of the prospects of their penetration and possible effects. Because an average usable life of showcase-related equipment spans around ten years, we take a time horizon of ten years or so in considering their penetration.

4-2 Conclusions

Food retailers have been positive toward the introduction of less electricity-consuming technologies and methods, in part because they are originally very cost-conscious. The headquarters of the franchised convenience stores surveyed this time has a plan to introduce an improved version of existing lighting control system into its newly opened stores from now on. Moreover, the headquarters looked aggressive enough to ask relevant makers to develop a less electricity-consuming technology, if necessary. The supermarkets were energy-conscious as well. As we informed the headquarters that no night covers were used in the freezing-type showcases at one of the two supermarkets surveyed, we received a quick response that declared a swift introduction of such night covers.

These episodes suggest that they are keenly conscious about rational electricity use. Yet, there is a spate of unfavorable circumstantial factors. They include growing concerns over how to cut initial investments, a stern fact that the commitment to less electricity-consuming methods has its own limits, and an essential requirement for the food retailers that they have to consider conveniences and amenity of their consumers first. It means to advance rational electricity use and load leveling is not necessarily an easy work for the beverage & food retailers.

Fortunately, including those described above, various technologies good for rational electricity use have been commercialized. These newly emerging technologies, if introduced at the time of opening or renewing the stores, are expected to help the beverage & food retailers advance rational electricity use, though inch by inch, in the days ahead.