Classification of Japanese Retail Facilities to Establish Benchmark Energy Consumption

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ABSTRACT

This study proposes establishing classification of retail facilities by retail category, such as general merchandise stores, and food supermarkets, as a method for benchmarking the energy efficiency of retail facilities located in Japan. In order to evaluate the effect of classification, the authors of this study gathered the annual energy consumption data of 5,869 retail facilities and classified the samples into 11 categories. Except for a few comparisons, each category showed statistically significant differences in average energy use intensity (EUI). The results implied that classification by retail category contributes to developing a more appropriate benchmark.

This study then discusses the normalization of EUI for each retail category. The factors affecting EUI can be divided into two categories: those that cannot be controlled by the owner of retail facilities for improving energy efficiency, such as total floor area and climate, and those that can be controlled. The former factors must be taken into account in normalization. In this paper, a simple regression analysis between EUI and total floor area was carried out to quantify the influence of the size of facility on EUI. The result showed that the influence of facility size is significantly different among retail categories. Additionally, the standard deviation of the distribution of the difference between actual EUI and normalized EUI is different among retail categories. This result implies that the yardstick used to describe the unit of EUI must be developed for each retail category.

Thus, the classification by retail category contributes 1) to developing a more appropriate benchmark and 2) to assuming a more appropriate distribution of EUI around the benchmark.

Introduction

The energy consumption of retail facilities in Japan increased approximately 50% over the last two decades (Japan's Agency for Natural Resources and Energy, 2011). The energy consumption accounts for 33% of the total energy consumption of the Japanese commercial

sector. Thus, improvement in the energy efficiency of retail facilities is an important area in the commercial sector.

Development of a benchmark is beneficial to improving the energy efficiency of retail facilities. In a typical benchmarking method for commercial buildings, energy consumption data is collected for a sample of reference buildings, and is normalized with total floor area to obtain energy use intensity (EUI) (MJ/m²) (Chung et al., 2006). A benchmark system should take into account factors that significantly alter energy consumption but cannot be controlled by facilities' owners. Examples of such factors are climate conditions; physical characteristics of the facilities, such as age and size; and the business hours of the buildings. In order to reflect the influence of such factors in the benchmark, a linear regression model or more advanced regression model describing the relationships between these factors and EUI is often developed (Chung, 2011).

This study applied this normalization method to retail facilities located in Japan. The purpose of this study is to evaluate how classification of retail facilities by retail category, such as general merchandise stores and food supermarkets, contributes to developing a useful benchmark. The underlying assumption is that retail category significantly alters factors that directly affect EUI (e.g., physical properties, business hours, equipment and appliances used to provide service). Although these retail attributes might significantly alter energy consumption, there was no survey or benchmark in Japan that showed the relationship between energy consumption and retail category. In the ENERGY STAR for commercial buildings in US, the commercial buildings are classified into 15 categories. There are only two categories related to retail facilities, retail store and supermarket, although the energy performance rating provided by the program takes into account the size, operating hours, number of worker, appliance and refrigeration/freezer units and cases, and percent of the gross floor area that is conditioned (U.S. Environmental Protection Agency, 2012).

This study shows the effect of classification by retail category by using the following two methods: 1) a multiple comparison of average EUI among retail categories and 2) a regression analysis to quantify the distribution of EUI around normalized EUI as a benchmark.

Information on energy consumption and the attributes of approximately six thousand retail facilities were gathered for this study (Section 3). The facilities were first classified by a retail category explained in the next section. The averages of EUI, calculated for each category, were statistically compared among the retail categories (Section 4). A simple linear regression model was developed using total floor area to normalize EUI (Section 5). If the regression model is carried out while fully taking into account the attributes of retail facilities that cannot be controlled by the facilities' owners to improve energy efficiency, the difference between the actual EUI and the normalization benchmark can be understood as the difference created by factors which can be controlled. Thus, the standard deviation of the difference between actual EUI and estimated intensity can be used as yardstick to describe unit EUI and to measure energy efficiency of retail facilities. Although the regression model adopted in this study is very simple, the standard deviation is compared among retail categories to evaluate the difference in yardstick EUI. It should be noted that we ignored errors in reporting. For example, with floor area, the definition of the space may mean different to different people.

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Classification of Retail Facilities

The Research and Statistics Department of the Ministry of Economy, Trade and Industry (METI), Japan, conducts the Census of Commerce every five years. The purpose of the census is

to clarify the actual conditions of the nation's commerce and to obtain basic data for the formulation of commercial policy (METI, 2012). Surveyed items are the number of establishments, number of employees, number of main stores and branches, annual sales value of commodities, sales floor space, etc. The survey results are published in tabulations conforming to a retail classification. The classification is defined based on the retail goods sold in the facility, scale of floor space, the business hours, and the adoption of the self-service system as shown in Table 1.

These retail attributes could significantly alter energy consumption. For example, food supermarkets are equipped with refrigeration cabinets for storing perishable foods and therefore this category's energy consumption accounts for a large portion of the total energy consumption (Narumi et al. 2011). While the quality of the indoor environment of food supermarkets is not overly controlled, since food supermarkets adopt the self-service system and customers only stay for a short time, any cold air leakage from refrigeration cabinets can reduce cooling demand and increase heating demand. Convenience stores are establishments for food and beverages which adopt the self-service system, with a sales floor space of 30 m² or more up to less than 250 m², and business hours of 14 hours or more a day. Energy consumption for refrigeration cabinets in this category is dominant and roughly constant all throughout the day (Yuasa, 2001). Department stores do not usually adopt the self-service system and customers spend a longer time in these outlets compared to food supermarkets. Thus, the importance of quality of indoor environment is relatively higher than for food supermarkets, which would likely result in higher energy consumption for lighting and air conditioning.

The Japanese Census of Commerce, carried out in 2007, classified retail facilities into 19 categories. Table 1 shows the classification and the definition of each category. On the basis of the census classification, this study further classified retail facilities into 11 categories, namely department store, general merchandise supermarket (GMS), food supermarket, clothing supermarket, housing supermarket, home center, drug store, convenience store, specialized store and centralized store, shopping center, and others. Table 1 shows the categories used in the census that are covered by the proposed retail categories. It should be noted that shopping center is not listed as a category in the census, since the census only covers individual retail stores and shopping centers are a complex of individual stores. The authors only collected energy consumption of retail facilities and did not those of individual stores that are located in the facilities. Since energy consumption of shopping centers was available, the authors added shopping center as a retail category.

Sample and classification by retail category

The authors of this study gathered information on energy consumption and the attributes of 5,869 retail facilities in Japan. The survey was conducted in 2007, 2008, and 2009 by the committee for the Database for Energy Consumption of Commercial Buildings (DECC, 2011). A questionnaire was sent to owners or managers of commercial buildings. The first row of Table 2 lists the information gathered by the questionnaire and used in this study. This questionnaire was not specifically designed for retail facilities. Thus, the information gathered was not sufficient to classify the sample into retail categories. For classification, additional information was gathered

from available databases[1] developed for each retail category as well as web sites, and digital maps.

[1] 1) Japan supermarket directory published by Shogyokai Publishing, Co., Ltd., 2) food supermarket yearbook by Ryutsukikaku Inc., 3) department store survey yearbook by Stores Co., Ltd., 4) drug store yearbook by Ryutsukikaku Inc., and 5) white paper of shopping center by Japan Council of Shopping Centers.

Table 1. Classification of Retail Trade Used in the Census of Commerce

Retail category	Classification in Census for Commerce		Adoption of self-service†	Condition relating to sales area, business hour	Other condition
Department store	Department store	Large department store	No	Sales area ≥ 3,000 m²	Engaged in retail sales of clothing, food, and housing, where either of the sales amount of clothing, food, and housing lies from 10% to less than 70% of total retail sales, and the number of employees is 50 persons or more.
		Other department store	No	Sales area < 3,000 m²	
GMS	General merchandize supermarket	Large GMS	Yes	Sales area ≥ 3,000 m²	
		Other GMS	Yes	Sales area < 3,000 m²	
Food supermarket	Supermarket	Food supermarket	Yes	Sales area ≥ 250 m²	Sales of food and beverage exceeds 70%.
Clothing supermarket		Clothing supermarket	Yes	Sales area ≥ 250 m²	Sales of clothing exceeds 70%.
Housing supermarket		Housing supermarket	Yes	Sales area ≥ 250 m²	Sales of housing exceeds 70%.
Home center		Home center	Yes	Sales area ≥ 250 m²	Housing supermarket with sales of ironmongery goods, kitchenware, nursery plant, and seed exceeds and these sales are less than 70%.
Drug store		Drug store	Yes	Sales area ≥ 250 m²	Supermarket with drug and cosmetic products
Others		Other supermarket	Yes	Sales area ≥ 250 m²	Supermarkets that are not classified into one of the other supermarket categories.
Convenience-store	Convenience-store	Around-the-clock	Yes	Around-the-clock operation	Engaged in retail sales of food and beverage, with a sales floor space from 30m² or more to less than 250 m².
		Others	Yes	Business hour ≥ 14 hours	
Specialized store and centralized store	Specialized store	Food specialized store	No	Sales area < 250 m²	Retail sales of food, clothing, or housing goods takes up 90% or more of total retail sales.
		Clothing specialized store	No		
		Housing specialized store	No		
	Centralized store	Food centralized store	No	Sales area < 250 m²	Sales of food, clothing, or housing goods takes up 50% or less than 90% of total retail sales.
		Clothing centralized store	No		
		Housing centralized store	No		
Others	Others		No	Sales area < 250 m²	Non-self-service shops other than department store, specialized stores and centralized stores
Shopping center	A shopping center is not defined in Census for Commerce. According to Japan Council of Shopping Centers (JCSC, 2012), the definition of a shopping center is one or more buildings satisfying the following four conditions: 1) sales area is 1,500 or larger; 2) 10 or more tenants are operated; 3) the sales area of the largest tenant does not exceed 80% of the total; and 4) Joint activities are operated among tenants.				

† If the self-service system is adopted on a half or more sales space, the facility is defined as that adopting the self-service system.

Table 2. Data Collected for the Sample Retail Facilities

Data collected from DECC	Data collected by the additional survey
• Location • Share of commercial usage for total floor area • Total floor area • Monthly energy consumption for electricity, city gas, LPG, oil and water	• Retail category • Sales floor area • Share of food, clothing and housing in the total sales amount

Table 3. Number of Samples by Region

Retail category	Hokkaido	Tohoku	Hoku-shinetsu	Kanto	Chubu	Kansai	Chugoku /Shikoku	Kyusyu	Total
Department store	13%	14%	5%	16%	4%	11%	24%	13%	128
GMS	0%	5%	4%	25%	35%	12%	12%	7%	730
Food supermarket	11%	44%	3%	23%	1%	9%	7%	3%	535
Housing supermarket	9%	17%	1%	5%	40%	6%	19%	3%	266
Clothing supermarket	11%	0%	0%	44%	0%	33%	0%	11%	9
Home center	0%	1%	0%	7%	3%	8%	27%	53%	236
Drug store	0%	0%	2%	76%	0%	22%	0%	0%	41
Convenience-store	0%	44%	0%	43%	7%	6%	0%	0%	3,560
Shopping center	0%	15%	8%	32%	8%	13%	15%	9%	319
Specialized or centralized	0%	0%	0%	0%	0%	80%	20%	0%	45

Convenience stores were firstly classified because the information was available in the original DECC survey. Then, if facilities were contained in the abovementioned databases for retail categories, the facility were classified into the corresponding category. Additionally, supermarkets were classified into food, housing, clothing, or GMS using sales data. If the share of sales for food, closing or housing in the total sales amount is 70% or larger, the supermarket was classified into food, closing or housing supermarket. The supermarket without sales share of 70% or larger in food, closing or housing, was classified into GMS. Additionally, the address of facilities was inputted to the digital maps and a web search engine (Google) to find additional information. Many facilities categorized into home center, drag store, GMS, and shopping center have a website containing enough information to categorize the facility into one of the retail categories.

Following the procedure, approximately 1,200 samples could not be classified. Table 3 shows the number of valid samples for each retail category. Table 3 also shows the shares of regional classification from north placed on the left of the table to south on the right. The cooling degree day ranges from 4 to 673 while heating degree day does from 70 to 3529. It should be noted that, this paper ignored the influence of regional difference, although there is a wide variety in meteorological conditions among the regions and considerably uneven distribution in the sample.

Method for Statistical Analysis

This study carried out two analyses to evaluate the effect of developing classification by retail category for establishing a more reliable benchmark.

Multiple Comparison of EUI Among Retail Categories

First, the mean of total floor area and EUI among the retail categories were statistically compared by using a multiple comparison method, specifically, the Sidak method using Welch's

t test (Welch, 1947). The purpose of the comparison is to analyze how attributes of retail facilities differentiate EUI. In the multiple comparison procedures, the mean value was compared between each pair while familywise error rate is controlled. Fimilywise error rate is the probability of making one or more false discoveries among the hypotheses set to all the pairs. Thus, the use of familywise error is to ensure that the probability of incorrectly rejecting the null hypothesis for any of the pairwise comparisons in the family does not exceed a level of significance (Rafter et al., 2002).

Linear Regression Between EUI and Total Floor Area

A simple linear regression analysis was carried out between the EUI of retail facilities within each category and their total floor area. The total floor area is one of the most influential factors on the EUI of commercial buildings. Authors analyzed the relationship between EUI and the building attributes of office buildings (Yamaguchi et al., 2009). The results showed that larger buildings have larger EUI. As the outdoor environment affects smaller buildings more intensively, air conditioning has a larger share of the overall EUI. However, total EUI is higher for larger buildings mainly due to the higher quality of service provided in these buildings. For example, wider spaces are air-conditioned such as elevators, halls, and corridors.

If the regression coefficient to the total floor area is not zero, energy usage on floor space is inhomogeneous. If the sales area is only equipped with fluorescent lighting for illumination, EUI does not vary considerably with the floor area. As mentioned earlier, in food supermarkets, energy consumption for refrigeration cabinets is dominant in the total EUI. However, there is a trend that larger food supermarkets have lower refrigeration capacity per total floor area. This is because the floor space for clothing and housing goods increases with an increase in floor area instead of food sales area in larger food supermarkets. In order to take such structure into account in a benchmark, a linear regression coefficient with total floor area was carried out.

In addition, standard deviation of the difference between the actual intensity and estimated intensity by the regression model is also estimated and compared among the retail categories. Although more comprehensive analysis is needed to accurately reflect retail attributes that cannot be controlled by facilities' owners to improve energy efficiency, the standard deviations show the order of distribution due to factors that can be controlled by facilities' owners.

Results

Average and Standard Deviation of Total Floor Area and EUI

Figure 2 shows the cumulative frequency of total floor area and EUI of each retail category. As common logarithm is used for the axes, the EUI and total floor area are widely distributed. Table 4 lists the average and standard deviation of total floor area and EUI for each retail category.

Convenience stores have the largest EUI in the retail categories. This category's intensity is approximately 10-times larger than the minimum of a home center. Among the supermarkets, the food supermarket category has the largest EUI. The clothing supermarket and housing supermarket categories have close EUI, although the number of samples for clothing supermarkets is small (only 9). The drug store category has a relatively larger EUI compared to

the housing supermarket category. The department store, shopping center, and GMS categories have relatively close EUI.

Figure 2. Distribution of Total Floor Area and EUI of the Sample

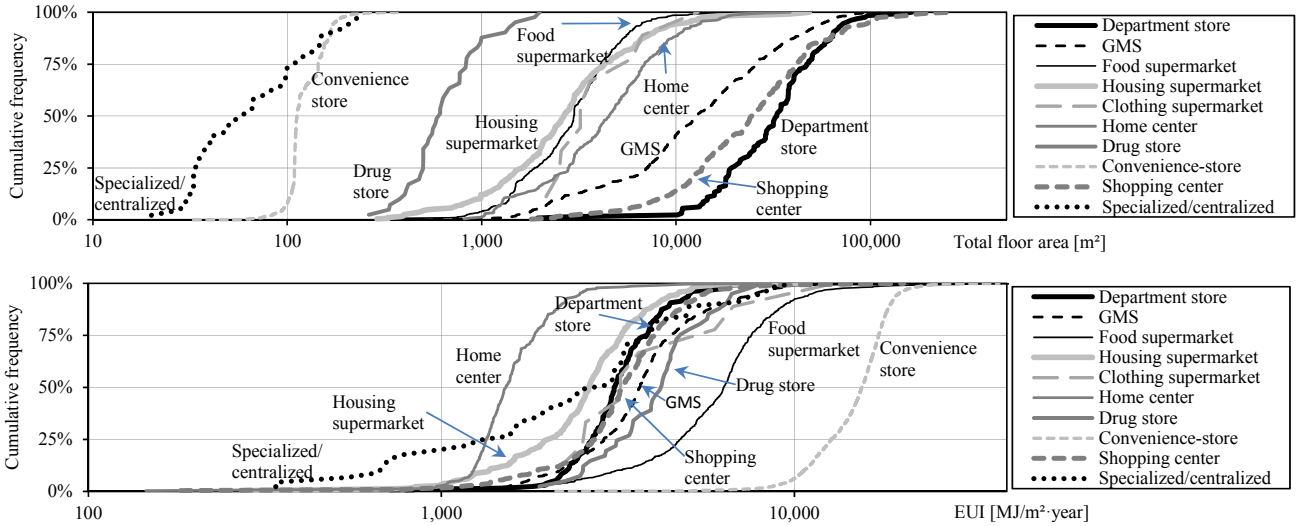

Table 4. Average and Standard Deviation of Total Floor Area and EUI

Retail category	Sample	Total floor area [m²]		Energy use intensity [MJ/ m²]	
		Ave.	S.D.	Average	S.D.
Department store	128	3.7×10^4	2.4×10^3	3.33×10^3	1.19×10^3
GMS	730	1.92×10^4	1.81×10^4	3.99×10^3	1.97×10^3
Food supermarket	535	3.38×10^3	2.21×10^3	6.6×10^3	3.96×10^3
Housing supermarket	266	4.1×10^3	5.6×10^3	2.71×10^3	1.14×10^3
Clothing supermarket	9	4.8×10^3	3.4×10^3	3.4×10^3	3×10^3
Home center	236	5.6×10^3	4.7×10^3	1.66×10^3	6.5×10^2
Drug store	41	7.3×10^2	3.9×10^2	4.3×10^3	1.43×10^3
Convenience-store	3,560	1.252×10^2	2.75×10^1	1.519×10^4	3.39×10^3
Shopping center	319	3.38×10^4	3.3×10^4	3.47×10^3	1.67×10^3
Specialized or centralized	45	8.3×10^1	6.0×10^1	3.0×10^3	2.3×10^3

Multiple Comparisons of EUI Among Retail Categories

Table 5 shows the results of multiple comparisons for total floor area and EUI among retail categories. In the table, the results for the clothing supermarket category are eliminated because of its small sample size. The left lower half of the table shows the results for total floor area and the upper right half shows the EUI. The mark '*' means that the retail categories given by the column and row have a statistically significant difference with a 5% of level of significance in the average of total floor area or EUI. Comparisons that do not have a statistically significant difference are shown by a mark of "n.s."

The comparison between department stores and shopping centers does not show a statistically significant difference in total floor area and/or EUI. The other comparisons to department stores showed a statistically significant difference in the total floor area and/or EUI.

The comparisons between GMSs and drug stores, and drug stores and shopping centers show a statistically significant difference was not observed except for those with specialized and centralized stores that have a large standard deviation in EUI within a small number of samples (45).

Table 5. Result of Multiple Comparisons Among Retail Categories

Retail category	Depart-ment store	GMS	Food s.m.	Housing s.m.	Home center	Drug store	Conve. store	SC	Sp or centr.
Department store		*	*	*	*	*	*	n.s.	n.s.
GMS	*		*	*	*	n.s.	*	*	n.s.
Food supermarket	*	*		*	*	*	*	*	*
Housing s.m	*	*	n.s.		*	*	*	*	n.s.
Home center	*	*	*	*		*	*	*	*
Drug store	*	*	*	*	*		*	n.s.	n.s.
Convenience-store	*	*	*	*	*	*		*	*
Shopping center	n.s.	*	*	*	*	*	*		n.s.
Specialized or centralized	*	*	*	*	*	*	n.s.	*	

n.s. = not significant

Linear Regression Between EUI and Total Floor Area

A simple linear regression analysis was carried out between EUI and the total floor area. Table 6 lists the regression coefficient to total floor area and the standard deviation of the difference between the actual EUI and estimated intensity by the regression model.

As shown in Table 6, the regression coefficient of department stores, housing supermarkets, home centers, and drug stores were not statistically significant. Additionally, the value of standard error for each of these retail categories is different.

Implication

This paper proposed to classify retail facilities by retail category to establish a more useful benchmark for gauging the energy efficiency of retail facilities located in Japan. First, as shown in the results of the multiple comparisons—except for the comparisons between department stores and shopping centers, GMSs and drug stores, and drug stores and shopping centers—the comparisons of retail facilities showed significant differences in the average EUI. This result implies that the retail category characterizes energy consumption of the retail facilities and a benchmark must be developed for each retail category.

The simple regression analysis showed that EUI of the GMS, food supermarket, convenience store, and shopping center categories is significantly influenced by the total floor area. As total floor area cannot be controlled to improve energy efficiency, this influence should be taken into account in benchmarking. Additionally, the standard deviation quantified for the distribution of difference between the actual EUI and the estimated intensity by the developed regression model was quantified. Although only floor area is taken into account in the regression analysis, if factors that cannot be controlled by the owners of retail facilities, such as climate, were fully taken into account, the difference between actual EUI and normalized estimated EUI by the regression model can be seen as those created by factors that can be controlled by the

owners of retail facilities, for example, by adopting energy-efficient equipment and appliances and operating them in a more energy-efficient manner. As shown in Table 6, the standard deviation differs among the retail categories. While the standard deviation can be used as the yardstick to measure EUI, the results showed that the yardstick must be developed for each category.

Based on these results, two benefits of classifying retail facilities by retail category can be deducted. First, as the average EUI is different among retail categories, the classification contributes to developing more appropriate benchmarks that reflect the characteristics of EUI in each category. Second, more appropriate distribution around each benchmark can be assumed to evaluate individual samples.

Table 6. Result of Regression Analysis

Retail category	Regression coefficient [(MJ/m²)/m²]	Significance	Standard error [MJ/m²]
Department store	0.005 ± 0.09	n.s.	1.19×10^3
GMS	-0.04 ± 0.07	**	1.80×10^3
Food supermarket	-0.71 ± 0.14	**	3.63×10^3
Housing supermarket	-0.00 ± 0.03	n.s.	1.14×10^3
Home center	-0.00 ± 0.02	n.s.	6.5×10^2
Drug store	-1.2 ± 1.1	*	1.35×10^3
Convenience-store	-84 ± 2	**	2.27×10^3
Shopping center	-0.006 ± 0.005	*	1.66×10^3
Specialized or centralized	-11 ± 11	*	2.2×10^3

Conclusion

The authors of this study gathered and investigated the annual energy consumption of 5,869 retail facilities in Japan. The retail facilities were then classified by retail category. The means of total floor area and energy use intensity (EUI) were compared among the retail categories. The underlying assumption is that retail the category significantly alters factors that directly affect energy use intensity (e.g., physical properties, business hours, equipment and appliances used to provide service). Except for a few comparisons, these retail categories showed significant differences in EUI. This result supports the abovementioned assumption and implied that classification by retail category contributes to developing a more appropriate benchmark.

Then, a simple regression analysis was carried out between EUI and total floor area in order to normalize EUI by quantifying the difference in EUI caused by difference in total floor area. The result showed that the influence of total floor area is different among retail categories. This also supports the benefit of the classification to develop benchmarks as a more appropriate benchmark can be obtained by normalizing EUI while taking into account factors that cannot be controlled by the owner of retail facilities to improve facility's energy efficiency. The result of regression analysis also showed that distribution of the difference between estimated EUI and actual EUI is different among retail categories. Although only total floor was taken into account for normalization in this paper, the result implies that classification by retail category also contributes to assuming more appropriate distribution for each retail category.

As only the influence of total floor area was taken into account to normalize EUI, more comprehensive regression analysis must be done in normalization for our future work. Additionally, the authors will analyze time series energy consumption used for each end-use,

such as those for lighting, heating, cooling, water heating, and refrigerating, for a number of retail facilities in order to understand factors that directly create the difference in EUI.

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References

Chung W. 2011. "Review of building energy-use performance benchmarking methodologies". *Applied Energy* 88: 1470-1479.

Chung W. Hui Y.V., Miu Lam Y., 2006. Benchmarking the energy efficiency of commercial buildings. *Applied Energy* 83: 1-14.

Committee for Data-base for Energy Consumption of Commercial Building, Japan Sustainable Building Consortium. *DECC-Data-base for Energy Consumption of Commercial Building*. http://www.jsbc.or.jp/decc/. Accessed March 5, 2012.

Japanese Agency for Natural Resources and Energy. 2011. *Energy white paper 2010*.

Japan Council of Shopping Centers. 2010. *List of shopping center in Japan, White paper of shopping center 2010*.

Japan Council of Shopping Centers. *Definition of shopping center*. http://www.jcsc.or.jp/english/what_sc/index.html. Accessed March 5, 2012.

METI. *Census of Commerce in 2007*. http://www.meti.go.jp/english/statistics/tyo/syougyo/index.html. Accessed March 5, 2012.

Narumi D., Shiraishi K., Yamaguchi Y., Shimoda Y., Murakami S. 2011. Study about Evaluation of Energy Saving Measures of Retail Stores, Part 1 Examination of Characteristics of Energy Consumption in Retail Stores with Refrigeration Facilities and its Modeling. In *Proceedings of the 27th Energy System, Economy, and Environment Conference*: 595-598 (in Japanese).

Rafter JA, Abell ML, Braselton JP. 2002. Multiple Comparison Methods for Means. *SIAM Review* 44: 259-278.

Ryutsukikaku Inc. 2009. *Drug store yearbook 2009* (in Japanese).

Ryutsukikaku Inc. 2010. *Food Supermarket yearbook 2010* (in Japanese).

Shogyokai Publishing, Co., Ltd. 2011 and 2010. *Japan Supermarket directory 2010 and 2011* (in Japanese).

Stores Co., Ltd. 2010. *Department store survey yearbook 2010* (in Japanese).

U.S. Environmental Protection Agency. 2012. Criteria for Rating Building Energy Performance, ENERGY STAR. http://www.energystar.gov/index.cfm?c=eligibility.bus_portfoliomanager_eligibility. Accessed May 4.

Welch, B. L. 1947. The generalization of "Student's" problem when several different population variances are involved. *Biometrika* 34: 28–35.

Yamaguchi Y., Shimoda, Y. 2009. Database and simulation model development for modeling the energy use of non-residential buildings, in *Proceedings of the 11th Building Simulation 2009,* 1482-1489. Glasgow, Scotland.: International Building Performance Simulation Association.

Y

uasa K. 2001. Investigation of Energy Consumption in Convenience-stores. In *Proceedings of the 2001 Annual Conference of the Society of Heating, Air-conditioning and Sanitary Engineering of Japan*: 1765-1768 (in Japanese).