Energy Efficiency Standards for Japanese Appliances

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ABSTRACT

As one of the measures to achieve a 6% reduction in greenhouse gas emissions agreed to at the third Conference of the Parties (COP3) of the United Nations Framework Convention on Climate Change (UNFCCC), a the new method of determining the efficiency standards for electric appliances and automobiles, called the "Top-Runner Approach," was issued by the Japanese government in 1999. In this paper, two important activities about these efficiency standards are discussed: one is expanding the range of targeted appliances, and the other is the review of the achievement of initial targets for some of these appliances. Among the newly regulated appliances, the efficiency standards for microwave ovens and electric rice cookers are introduced in this paper. The reviews for televisions/VCRs, air conditioners, and refrigerators/freezers are discussed and it is confirmed that these efficiency standards worked well. However, some of the problems inherent in this method remain unchanged and other new issues have arisen during the review processes. It is important to cope with these issues for the further improvement of this approach.

Background

In April 1999, the new method for determining the efficiency standards for electric appliances and automobiles, called the "Top-Runner Approach," was mandated by the government in Japan to manufacturers. This approach is the mandatory minimum standard that all manufacturers whose annual production and import volumes exceed above a fixed amount (for example, 2,000 for passenger vehicles and refrigerators) must meet for all covered products.[1] The standards were determined by the subcommittee whose members are specialists from universities and research organizations, industries associations, and consumer associations by each appliance.

If some manufacturers will not achieve the target standard values by the target year, the Minister of Economy, Trade and Industry (METI) will make the case public and order them to adopt measures to follow the new standard. In the event that such an order is not followed, penalties of a fine of fewer than 1 million yen or one-year penal servitude will be imposed. Actually, these penalties are quite weak, however, being punished by the government will cause serious damage to a manufacturers' reputation and it will have a bad influence on their business.

This paper summarizes the concept of the Top-Runner Approach, its current standards and activities, the results of the first review, and future challenges in the following sessions.

[1] The products were basically selected according to the estimated amount of energy consumption and the following 17 items are chosen currently: passenger vehicles, air conditioners, fluorescent lights, TV sets, copying machines, computers, magnetic disk units, freight vehicles, video cassette recorders, electric refrigerators/freezers, space heaters, gas cooking appliances, gas water heaters, oil water heaters, electric toilet seats, vending machines, and transformers.

Introduction

The "Top-Runner Approach" is one in which the most efficient products supplied domestically have their efficiency levels taken as the next efficiency standards, including future technological improvement in the level (Figure 1). The energy saving effects of the equipment shipped in the target years were estimated and are shown in Table 1. Energy saving rates were calculated by the government with the assumptions that the average size and performance of units shipped would be the same as those at the year when these standards were determined. The target years were chosen so as to include at least twice model changes until them.

Figure 1. Schematic Image of Determining the Standard by the Top-Runner Approach

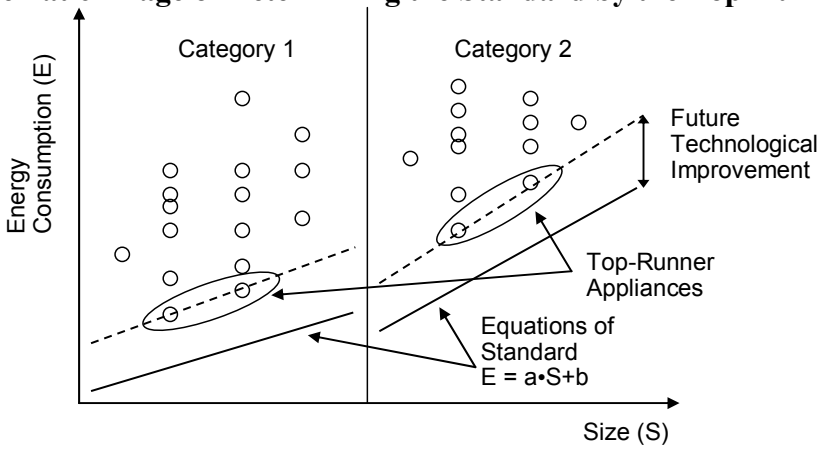


Table 1. Energy Saving Rates of Revised Standards and Target Year

Product	Standard Levels	Units	Improvement Rate of Energy Efficiency (%)	Target Deadline (Fiscal Year)
Automobiles				
Gasoline, Passenger Cars	6.4 – 21.2	km / l	22.8 (vs. FY1995)	2010
Gasoline, Trucks (<2.5t)	9.3 – 20.2	km / l	13.2 (vs. FY1995)	2010
Diesel, Passenger Cars	8.7 – 18.9	km / l	14.9 (vs. FY1995)	2005
Diesel, Trucks (<2.5t)	9.9 – 17.7	km / l	6.5 (vs. FY1995)	2005
Refrigerators	Varies by Volume	kWh / year	30.4 (vs. FY1998)	2004
Air Conditioners				
Heat Pump	2.85 – 5.27	COP*	62.8 (vs. FY1997)	2004 (cooling year)**
Cooling-only	2.47 – 3.64	COP*	14.6 (vs. FY1997)	2007 (cooling year)
Fluorescent Lights	49.0 – 86.5	lm / W	16.6 (vs. FY1997)	2005
Televisions	Varies by Screen Size	kWh / year	16.4 (vs. FY1997)	2003
VCRs (stand-by power use)	1.7 – 4.0	W	58.7 (vs. FY1997)	2003
Photocopiers	Varies by Copy rate	Wh / h	30.1 (vs. FY1997)	2006
Computers	0.0065 – 21	W / MTOPS***	82.6 (vs. FY1997)	2005
Magnetic Hard-disk Drivers	Varies by rpm	W / GB	78.0 (vs. FY1997)	2005

Source: IEA. 2000. Energy Labels & Standards.

* Coefficient of Performance (COP) = cooling or heating capacity divided by input power.

** The target year of heat pumps except direct blow/wall mounted type (<4 kW) is the 2007 cooling year.

*** Mega operations per second (MTOPS).

In setting the standards, the cost effectiveness of energy-efficient appliances was analyzed. The cost of an appliance, including the purchase price and the annual running costs, accumulates every year, and the cost of a product that achieves the energy saving standard is compared with another product that fails to meet the same standards. If the period that the latter exceeds the former is much shorter than the average lifetime, the cost effectiveness is confirmed.

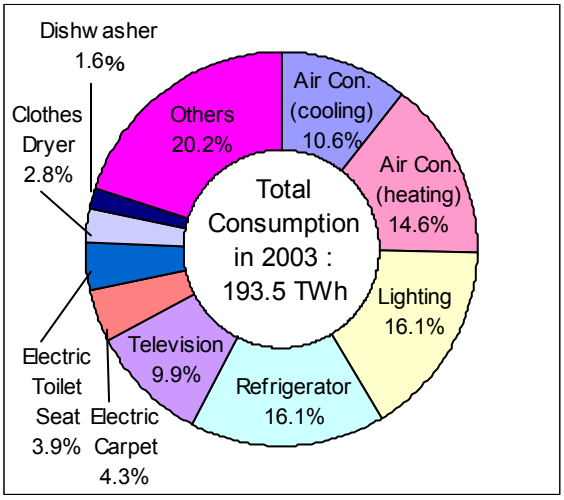
Seven years have passed since then, and two important activities about these efficiency standards are occurring now: one is the expansion of the kinds of targeted appliances and another is the revision of efficiency standards for the appliances whose first target years have arrived. This paper discusses the concepts to set the standards for these new appliances and the changes in the test methods and values of efficiency standards at this revision for some appliances.

Expansion of the Kinds of Targeted Appliances

Total consumption of final energy in 2003 has increased by 19.4% since 1990 (1.4% per year) in Japan. If it is examined by sector, energy consumption in passenger transportation (39.5%), commercial sector (33.7%), and residential sector (26.0%) has increased more rapidly than in other sectors (METI 2005a). Therefore, it is important to take effective measures to reduce energy consumption in these sectors to achieve the 6% reduction in greenhouse gas emissions agreed to at the third Conference of the Parties (COP3) of the United Nations Framework Convention on Climate Change (UNFCCC) in 1997.

Figure 2 shows the ratios of electricity consumption by household appliances in 2003. Actually, the efficiencies of the top-four electricity consuming appliances (air conditioners, fluorescent lights, refrigerators, and televisions) are already regulated as shown in Table 1. However, the Japanese government decided to set efficiency standards for other appliances to decrease energy consumption even more. Microwave ovens, electric rice cookers, vending machines, transformers, electric toilet seats, oil and gas appliances, and heavy vehicles were selected mainly because of the amount of energy they consume. This paper introduces the standards for microwave ovens and electric rice cookers below. The target year for them is 2008 and the standard is expected to improve energy efficiency by 8.5% and 11.1% from the 2004 level (microwave ovens) and the 2003 level (electric rice cookers), respectively.

Figure 2. Electricity Consumption by Household Appliances in 2003



Source: METI 2005b

Microwave Oven

The number of microwave ovens domestically shipped in 2003 was 3,547,000. About 0.70% of the microwave ovens shipped were used for commercial purposes (METI 2005c). Therefore, the efficiency standard for microwave ovens is set only for household appliances.

The efficiency is defined as the annually consumed electricity calculated by the following equation. This equation was determined by a typical usage combination of heating, thawing, oven use, and stand-by power in a house.

$$E = \left[\left(580.8A_{V285} + 66A_{V245} + 571.1A_{V125} + 205A_{V185}\right) + 31B + 6400C\right]/1000$$

where E = Annually consumed electricity (kWh/year)
A_{V285} = Electricity consumption to heat 285 g of frozen food (Wh/time)
A_{V245} = Electricity consumption to thaw 245 g of frozen food (Wh/time)
A_{V125} = Electricity consumption to heat and thaw125 g of frozen food (Wh/time)
A_{V185} = Electricity consumption to heat 185 g of drink (Wh/time)
B = Electricity consumption by oven function (Wh/time)
C = Electricity consumption in idle time (Wh/h)

Because electricity consumption of microwave ovens varies according to the inner volume, oven function, and the method of heating by oven function, the efficiency standard for it is divided into 6 categories as shown in Table 2. The improvement rate was estimated by the available technologies until the target year by the discussions at the subcommittee.

Table 2. Efficiency Standards for Microwave Ovens

Cate-gory	Oven Function	Heating Method of Oven	Inner Volume	Top-Runner Efficiency (kWh/year)	Improve-ment Rate* (%)	Target Standard (kWh/year)
A	No	–	–	60.7	1.0	60.1
B	Yes	Direct Heating	Less than 30 Liters	74.1	1.0	73.4
C			30 Liters and over	79.0	1.0	78.2
D		Radiation Heating	Less than 30 Liters	71.1	1.0	70.4
E			30 Liters and over	80.4	1.0	79.6
F		Hot Air Circulation Heating	–	74.2	1.0	73.5

Source: METI 2005c

* The rate of change of energy consumption between the solid line and the dotted line in Figure 1.

Electric Rice Cooker

The number of electric rice cookers domestically shipped in 2003 was 6,271,000; the efficiency standard for electric rice cookers is set only for household appliances.

The efficiency is defined as the annually consumed electricity calculated by the following equation. This equation was determined by a typical usage combination of rice cooking, retaining warmth, timer setting, and stand-by powers in a house. The times of rice cooking and the hours of retaining warmth, timer setting mode, and idle time varies by the maximum rice cooking capacity (METI 2005d).

$$E = \left[\left(A \bullet N_A + B \bullet H_B + C \bullet H_C + D \bullet H_D\right)\right]/1000$$

where E = Annually consumed electricity (kWh/year)
A = Electricity consumption per rice cooking (Wh/time)
N_A = Times of rice cooking per year (time/year, 290 – 350)
B = Electricity consumption to retain warmth for one hour (Wh/h)
H_B = Total hours of retaining warmth per year (h/year, 920 – 2,420)
C = Electricity consumption per hour at a timer setting mode (Wh/h)
H_C = Total hours of timer setting mode per year (h/year, 750 – 1,880)
D = Electricity consumption in idle time (Wh/h)
H_D = Total hours of idle time per year (h/year, 1,210 – 2,990)

Because electricity consumption of electric rice cookers varies according to the maximum rice cooking capacity and the heating system, the efficiency standards for it are divided into eight categories, as shown in Table 3. Electromagnetic induction heating (IH) technology was introduced in 1988 and the market share of these IH-type electric rice cookers has been increasing ever since (55% in 2003), although the prices for them are about 3 – 4 times that of normal heater types.

Table 3. Efficiency Standards for Electric Rice Cookers

Cate-gory	Heating System	Maximum Rice Cooking Capacity	Top-Runner Efficiency (kWh/year)	Improvement Rate (%)	Target Standard* (kWh/year)
A	Electro-magnetic Induction Heating	0 54 – 0.99 Liters	E_K = 0.209M + 49.5	2.0	E_K = 0.209M + 48.5
B		0.99 – 1.44 Liters	E_K = 0.244M + 84.9	2.0	E_K = 0.244M + 83.2
C		1.44 – 1.80 Liters	E_K = 0.280M + 137	2.0	E_K = 0.280M + 134
D		1.80 Liters and over	E_K = 0.252M + 135	2.0	E_K = 0.252M + 132
E	Other Method (Normal Heater)	0 54 – 0.99 Liters	E_K = 0.209M + 37.4	2.0	E_K = 0.209M + 36.7
F		0.99 – 1.44 Liters	E_K = 0.244M + 77.1	2.0	E_K = 0.244M + 75.6
G		1.44 – 1.80 Liters	E_K = 0.280M + 101	2.0	E_K = 0.280M + 99.0
H		1.80 Liters and over	E_K = 0.252M + 124	2.0	E_K = 0.252M + 122

Source: METI 2005d

* E_K : Annual electricity consumption per appliance, M : Mass (g) of water evaporation per rice cooking.

Revision of Efficiency Standards

As shown in Table 1, the first target year for televisions/VCRs, refrigerators, and air conditioners (heat pump type) has passed (2003 or 2004) and the discussions about the verification of the achievement of the efficiency standards for the first target year and the revision of them for the next target years has started in government. This sector summarizes the changes in the methods and values of efficiency standards at this revision for these appliances.

Television/VCR

The weighted average of electricity consumption of televisions with a cathode-ray tube CRT by the number of shipped appliances in 2003 was 104 kWh/year, which is 25.7% less than 1997 consumption. The target was 117 kWh/year with a 16.4% improvement; although the composition of the appliances was different slightly from the original estimation) it was

recognized that the first-round target of energy efficiency standards for televisions was achieved as a whole. Likewise, the weighted average of electricity consumption of VCRs at a stand-by mode was 1.20 W with a 73.6% reduction The target was 1.88 W and 58.7% improvement, and so it was also recognized that the first-round target of energy efficiency standards for VCRs was achieved (METI 2005e).

The important changes in televisions/VCRs are the new types of appliances. For televisions, televisions with a liquid crystal display (LCD) and a plasma display panel (PDP) have penetrated the market rapidly in recent years. According to the Japan Electronics and Information Technology Industries Association (JEITA), the numbers of CRT, LCD, and PDP televisions domestically shipped in 2005 was 3,982, 4,217, and 468 thousand respectively and the share of CRT televisions already lost the majority (JEITA 2005). Moreover, changing the surface broadcasting method from analog to digital has been in progress since December 2003 and this movement will also accelerate the switching of appliances in near future. The efficiency of televisions is defined as the annually consumed electricity calculated by the following equation.

$$E = \{(P_O - P_A/4) \times t_1 + P_S \times t_2\}/1000$$

where E = Annually consumed electricity (kWh/year)
P_O / P_S = Consumed watts in working/idle time (W)
P_A = Saved watts by power saving functions (W)
t_1 / t_2 = Standard working/idle time (4.5/19.5 hours per day)

The efficiency standards for these new types of appliances were set for the first time in 2005. The new efficiency standards for televisions are shown in Table 4. Because these new type televisions usually have a lot of built-in functions, such as a DVD player/recorder, multiple digital tuners, and HDD, plus margins for these additive functions are considered. The standards for CRT televisions were not changed; the target year for CRT televisions was continued until 2008, because it is expected the market for them will shrink rapidly and technology development will become unattractive for manufacturers.

As for VCRs, the technology has also been rapidly changing. According to JEITA, the number of VCRs domestically shipped in 2005 was 1,093,000, while the numbers of DVD recorders shipped was 4,238,000 (84% of them have a HDD and some of them even have a VCR). All currently shipped DVD recorders have at least an analog tuner and a MPEG encoder, but some of them have multiple tuners/MPEG encoders and/or digital network terminals (IEEE 1394, USB, LAN, and HDMI). Because these additional functions consume electricity more (typically, 8 W for a tuner and 6 W for MPEG encoder), efficiency standards for DVD recorders are categorized by the existence of these functions (Table 5).

Table 4. Classification of the Efficiency Standards for New Types of Televisions

	Cate-gory No.	Aspect ratio of picture tube	Number of Vertical Pixel Count	Screen Size (Tuner Type)	Top-Runner Efficiency w/o Additive Functions* (kWh/year)	Impro-vement Rate (%)	Target Standard w/o o Additive Functions* (kWh/year)	Plus Margin for One Additive Function (kWh/year)
Liquid Crystal Display	21 – 25	4:3	Less than 650	Less than 15V"	E = 46	5	E = 44	14
	26 – 30			15V" and over	E = 6.2S – 47	5	E = 5.9S – 45	14, 15
	31 – 35		650 and over	Less than 15V"	E = 52	5	E = 49	10, 14, 15
	36 – 40			15V" and over	E = 5.7S – 34	5	E = 5.4S – 32	10, 14, 15
	41 – 43	16:9	Less than 650	(Analog)	E = 8.5S – 90	5	E = 8.1S – 86	14
	44 – 47			(Digital)	E = 7.9S – 48	5	E = 7.5S – 45	14
	48 – 50		650 -1080	(Analog)	E = 8.5S – 70	5	E = 8.1S – 66	14
	51 – 54			(Digital)	E = 7.9S – 42	5	E = 7.5S – 40	14, 15
	55 – 58		1080 and over	–	E = 9.4S – 59	5	E = 8.9S – 55	14, 15
Plasma Display Panel	59 – 62	–	–	Less than 43V"	E = 8.3S + 32	5	E = 7.9S + 30	14, 15
	63 – 66			43V" and over	E = 16.7S – 329	5	E = 15.9S – 314	14

Source: METI 2005e

* E : Annual electricity consumption per appliance, S : Screen Size (V inches).

Table 5. Classification of the Efficiency Standards for DVR Recorders

Category	Recording Device	Tuner and Signal Conversion Function	Improve ment Rate (%)	Standard* (kWh/year)	Plus Margin for Digital Network Terminal (kWh/year)
A, B	HDD	Basic Specification	5	E = 0.02C + 45	4
C, D		Multiple Tuners	5	E = 0.02C + 55	5
E, F		Multiple MPEG Encoders	5	E = 0.02C + 63	5
G, H	VCR	Basic Specification	5	E = 39	5
I, J		Multiple Tuners	5	E = 39	15
K, L	HDD and VCR	Basic Specification	5	E = 0.02C + 58	5
M, N		Multiple Tuners	5	E = 0.02C + 68	5
O, P		Multiple MPEG Encoders	5	E = 0.02C + 76	5

Source: METI 2005e

* E : Annual electricity consumption per appliance; C : Built-in HDD Capacity (GB).

The efficiency for DVD recorders with HDD capacity is calculated by the following equation.

$$E = [\ \{P_{d\,\mathrm{on}} - (P_{d\,\mathrm{on}} - P_{d\,\mathrm{off}}) \times 0.2\} \times (t_1 - t_{epg}) + P_{hrec} \times t_2 + P_{hpl} \times t_3 + P_{dvd} \times t_4 + P_{epg} \times t_{epg}\ ] / 1000$$

where E = Annually consumed electricity (kWh/year)

P_{don} / P_{doff} = Electricity consumption when the sign is displayed/not displayed (W)

P_{hrec} / P_{hpl} = Electricity consumption when HDD recording/playing is working (W)

P_{dvd} = Electricity consumption when DVD is working (W)

P_{epg} = Electricity consumption of acquiring an electronic program guide (W)
$t_1 / t_2 / t_3 / t_4$ = Standard idle/HDD recording/HDD playing/DVD working time (20.5/2/1/0.5 hours per day)
t_{epg} = Standard time for acquiring an electronic program guide (varies by device)

The efficiency for DVD recorders with VCR only is calculated by the following equation.

$$E = \left[\left\{ P_{d\,\mathrm{on}} - \left(P_{d\,\mathrm{on}} - P_{d\,\mathrm{off}} \right) \times 0.2 \right\} \times \left(t_1 - t_{epg} \right) + P_{dvd} \times t_2 + P_{vcr} \times t_3 + P_{epg} \times t_{epg} \right] / 1000$$

where E = Annually consumed electricity (kWh/year)
$t_1 / t_2 / t_3 / t_4$ = Standard idle/HDD recording/HDD playing/DVD working time
P_{dvd} / P_{vcr} = Electricity consumption when DVD/VCR is working (W)
P_{epg} = Electricity consumption of acquiring an electronic program guide (W)
$t_1 / t_2 / t_3$ = Standard idle/DVD working/VCR working time (21/2/1 hours per day)
t_{epg} = Standard time for acquiring an electronic program guide (varies by device)

The standards for VCRs were not changed and the target year was extended until 2008 for the same reason as the CRT televisions.

The target year for new televisions and DVD recorders is 2008 and the government estimates energy efficiency for them in the target year will be improved by 15.3% and 22.4% from the level in 2004, respectively.

Refrigerator/Freezer

The weighted average of electricity consumption of refrigerators by the number of shipped appliances in 2004 was 290.3 kWh/year, which was 55.2% less than in 1998. The target was 449.7 kWh/year and 30.5% improvement, and so (although the composition of the appliances was different slightly from the original estimation) it was recognized that the first-round target level of efficiency for refrigerators was achieved. Likewise, the target for freezers was achieved (the target was 22.9% reduction and the actual record was 29.6% improvement). Interestingly, a lot of manufacturers (16 for refrigerators and 17 for freezers, respectively) under this regulation existed in 2004 and all manufacturers achieved the target (METI 2005f).
However, the work of revising the standard has been delayed, because there is a problem in the test condition for measuring electricity consumption by refrigerators. Current test condition is defined by the Japanese Industrial Standards (JIS) C9801 (based on ISO8561 + door opening and shutting), but it is often said that the measured electricity consumption in this mode is much less than that in actual use. The Japan Electrical Manufacturers' Association (JEMA) is now making a new method of test condition that will be officially announced in May 2006. Major changes are ambient temperature, relative humidity, distance to surrounding side walls, existence of load, and the number of times daily a door is opening and closed (Table 6). The results of a preliminary test for six models showed that electricity consumption measured with the new method is 133% – 488% larger than with the old method and they are closer to the electricity consumption in actual use (METI 2006a). Work to revise the standard will be started consecutively.

Air Conditioner (Heat Pump Type)

Averaged COP of direct blow-off, separate, and wall-hung type air conditioners whose cooling capacity is under 2.5 kW, 2.5–3.2 kW, and 3.2–4.0 kW in 2004 was 5.33, 5.14, and 4.10

respectively (METI 2006b). The standards for these categories were 5.27, 4.90, and 3.65 respectively, and the targets for all categories were achieved. Of course, the effort to improve efficiency greatly contributed to it, however, this achievement accompanied stopping the production of inefficient models (for a 2.8 kW model, about 2 million units, 70 models).

Table 6. Major Test Conditions of Electricity Consumption for Refrigerators

	Cold Air Natural Convection Method			Cold Air Forcible Circulating	
	ISO8561	**JIS C9801 (Current)**	**JIS C9801 (New)**	**JIS C9801 (Current)**	**JIS C9801 (New)**
Ambient Temperature	25°C	25°C	30°C (180 days) 15°C (185 days)	25°C	30°C (180 days) 15°C (185 days)
Relative Humidity	45 – 75 %	70 ± 5 %	30°C: 70 ± 5 % 15°C: 55 ± 5 %	70 ± 5 %	30°C: 70 ± 5 % 15°C: 55 ± 5 %
Distance to Side Walls	30 cm	30 cm	5 cm	30 cm	5 cm
Temperature Setting	Fridge: ≤ 5°C Freezer: ≤ -18°C	Fridge: ≤ 5°C Freezer: ≤ -18°C	Fridge: ≤ 4°C Freezer: ≤ -18°C	Fridge: ≤ 5°C Freezer: ≤ -18°C	Fridge: ≤ 4°C Freezer: ≤ -18°C
Loads	Fridge: No Freezer: Yes	Fridge: No Freezer: Yes	Fridge: No Freezer: Yes	Fridge: No Freezer: No	Fridge: Yes Freezer: Yes
Switch of Automatic Ice Maker	–	Turn off	– (No model)	Turn off	Turn on
Times Door is Open/Shut Daily	No	Fridge: 25 Freezer: 8	No	Fridge: 25 Freezer: 8	Fridge: 35 Freezer: 8

Source: METI 2005g, 2006a

For revising the standard, two problems arose. One problem was the size of the indoor units. Enlarging the areas of the heat exchanger is an effective way to improve efficiency, however, large indoor units have some setting restrictions. Currently, the classification by indoor unit sizes is discussed for new standards, and normal-sized air conditioners (smaller than 800 mm in width and 295 mm in height) indoor units will be allowed a more moderate target than those with larger indoor units. Another issue was the definition of efficiency. Instead of COP, annual performance factor (APF) will be adopted. This is because COP is defined in full load operation, and it is not suitable for evaluating the efficiency of inverter controlled air conditioners, which occupies almost all units at present. Because APF is calculated based on the load of the whole cooling and heating period, it is closer to actual performance. Considering these points, the revised efficiency standards will be determined as shown in Table 7. The target year is 2010 and the government estimates energy efficiency for it in the target year will be improved by 22.4% from the level in 2004.

Table 7. Revised Efficiency Standards for Air Conditioners

Category	Cooling Capacity	Size of Indoor Unit (width x height)	Top-Runner Efficiency (APF)	Improvement Rate (%)	Target Standard (APF)
A	Less than 3.2 kW	Normal Size	5.65	3.0	5.8
B		Free Size*	6.40	4.0	6.6
C	3.2 – 4.0 kW	Normal Size	4.80	3.0	4.9
D		Free Size*	5.80	4.0	6.0

Source: METI 2006b

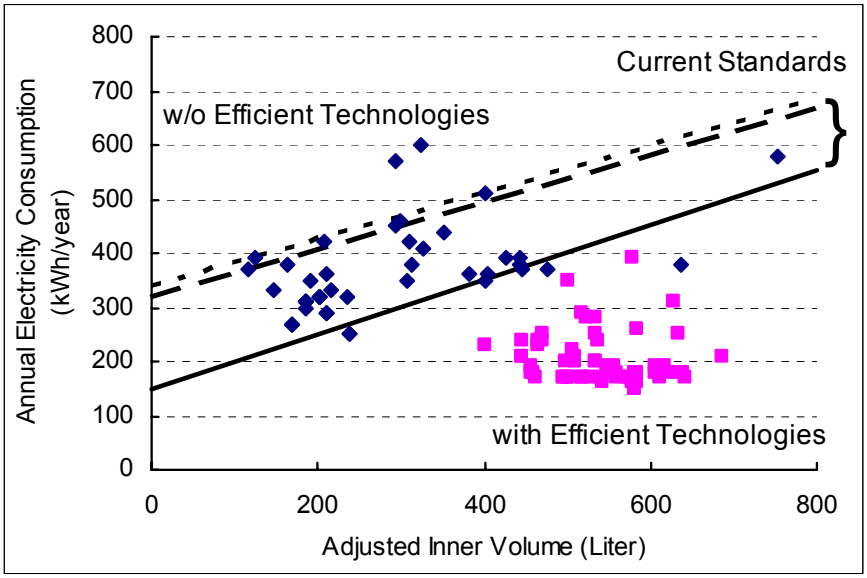
* The units whose width is larger than 800mm or whose heights is higher than 295mm.

Implementation Challenges

The Top-Runner Approach is widely recognized as an epoch-making method to establish efficiency standards. It appears the approach works well based on the energy savings at present. However, some issues in the process of determining efficiency standards still need to be resolved. One is the market shift of appliances to larger sizes. Because the standards are categorized by size for most appliances, manufacturers do not have an incentive to produce smaller, less energy-consuming appliances. This lack of incentive is the inherent problem for this approach and it is quite serious for televisions and automobiles. To overcome it, it is expected that imposing an obligation for each manufacturer to report the average appliance efficiency could be effective.

The issue of trade-off between high efficiency and production cost also remains. The efficiency standards affected air conditioners and refrigerators oppositely about this matter. As for air conditioners, energy efficient ones and less efficient ones were produced at the same time by the same manufacturer in 2000 (Nagata 2001) because operating hours differ from room to room, it makes sense to have less efficient, but cheap, air conditioners suitable for rooms where operating hours are expected to be low (e.g. bedroom). However, these less efficient, but cheap, models disappeared from the market to satisfy the standard as mentioned above. On the other hand, inefficient refrigerators still remain in the market, because the efficiency standard for refrigerators was varied by unit size. Efficient but expensive technologies (inverter control systems and/or evacuated insulation) have been applied to larger units but not smaller ones. Figure 3 compares the electricity consumption of all 110 models in the catalogues issued in October 2005. The variation in standard by volume created an inverse relationship between size and energy use: surprisingly, smaller refrigerators now consume more electricity than larger ones. One of the reasons for it is that the prices of small-sized refrigerators are cheap and the expensive, efficient technologies are not cost effective and not applied. So, it is quite difficult to merge the categories regardless of the efficient technologies for refrigerators. However, it can be expected that the existence of high efficiency targets will reduce costs of the efficient technologies and these technologies may be equipped with small-sized refrigerators in the future.

Figure 3. Electricity Consumption by Refrigerators (Models in 2005)



Source: ECCJ 2005

Concluding Remarks

This paper introduced two recent important activities about efficiency standards referred to as the "Top-Runner Approach" in Japan. Finally, I would like to talk about the relationship between the market structure and efficiency standards.

With respect to necessary condition for this approach, perhaps the numbers of the manufacturers and their competitiveness are one of the keys. Japan is suitable to adopt this approach, because there are many manufacturers and their ceaseless efforts for improving energy efficiency have been continuous. In other words, this approach may not be applicable to other countries where the number of the manufacturers is limited and/or the market is oligopolistic.

The ratios of imported units to total domestic sales have been increased rapidly for all electric appliances in Japan (for example, 40% for refrigerators and air conditioners in 2004). China and Southeast Asian countries are main exporters to Japan and electric appliances will diffuse rapidly in the near future in these countries. Because Japanese efficiency standards are applied to imported appliances, it is expected that it will also affect to the improvement of efficiency of appliances in these countries. Therefore, it is important for Japan to set stringent efficiency targets to influence the appliance efficiency standards of other countries in a period of globalization.

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