Analysis of energy efficiency standards for Japanese appliances

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1. SYNOPSIS

This paper analyzes the Japanese appliance energy standards and discusses the issues surrounding them from economic and technical perspectives.

2. ABSTRACT

As one of the countermeasures to achieve six percent reduction in greenhouse gas emissions agreed to at Third Conference of Parties to the Climate Change Convention, the Japanese Energy Conservation Law was revised and entered into force in April 1999. The points of the revision were (a) to strengthen efficiency standards for electrical appliances and automobiles using the "top-runner" approach, and (b) to strengthen efficiency standards in factories and buildings.

This strengthening of standards uses the "top-runner" approach, because the standards apply to the most efficient domestically-shipped models. The eight items targeted are automobiles; refrigerators; air conditioners; fluorescent lights; televisions and VCRs; photocopiers; computers; and magnetic hard-disk drives. For example, efficiency gains of 17% for televisions and 58% for VCR standby power are expected.

In this paper, the concept underlying the new electrical appliance standards is explained by comparing them with the European and American standards, and economic and technical issues arising from the use of the standards and concept are discussed. One issue is gauging the economic effects of efficient technologies. To do so, recommended retail prices sought by manufacturers were used, but the actual prices as determined by the market are considered to be more suitable for this purpose. Finally, government estimates of actual efficiency improvements in some appliances are presented and the obstacles faced in reducing future energy consumption are discussed.

3. INTRODUCTION

In May 1998, the Law Concerning the Rational Use of Energy, commonly known as the Energy Conservation Law (ECL) was revised. The ECL set forth (a) measures related to factories, (b) measures related to buildings, and (c) measures related to machinery and appliances. Under (c), measures related to machinery and appliances, a lower limit was set on the average efficiency of each manufacturer's products shipped annually. When the standards were revised, the "top-runner" approach was used. 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 development in the level. The energy savings effects of the equipment shipped in the target years were estimated and are shown in Table 1. Energy savings 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 present.

Table 1. Energy savings rate of revised standards and target year

Product	Standard Levels	Units	Improvement Rate of Energy Efficiency (%)	Target Deadline (Fiscal Year)
Automobiles		km / l		
Gasoline, Passenger Cars	6.4 – 21.2		22.8 (vs. FY1995)	2010
Gasoline, Trucks (<2.5t)	9.3 – 20.2		13.2 (vs. FY1995)	2010
Diesel, Passenger Cars	8.7 – 18.9		14.9 (vs. FY1995)	2005
Diesel, Trucks (<2.5t)	9.9 – 17.7		6.5 (vs. FY1995)	2005
Refrigerators	Varies by Volume	kWh / year	30.4 (vs. FY1998)	2004
Air Conditioners		COP*		
Heat Pump	2.85 – 5.27		62.8 (vs. FY1997)	2004 (cooling year)**
Cooling-only	2.47 – 3.64		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	58.1 (vs. FY1997)	2003
Photocopiers	Varies by Copy rate	Wh / h	30.1 (vs. FY1997)	2006
Computers	00065 - 21	W / MTOPS***	82.6 (vs. FY1997)	2005
Magnetic Hard-disk Drivers	Varies by rpm	W / GB	78.0 (vs. FY1997)	2005

Source: OECD/IEA, Energy Labels & Standards (2000), P.160.
* Coefficient of Performance (COP) = cooling or heating capacity divided by input power.
** The target year of heat pumps except direct blow/wall mounted type (<4kW) is 2007 cooling year.
*** Mega operations per second (MTOPS).

4. PROCESS FOR DETERMINING EFFICIENCY STANDARDS

There are two basic approaches used to determine the efficiency standards: the statistical method and the engineering/economics method (OECD/IEA, 2000). The former approach uses the efficiencies of all product models on the market. The standards are established at levels that eliminate a certain portion of the least efficient models. The former approach is easier to carry out, because the costs of improving the efficiency of each appliance are needed for the latter approach. The European Union (refrigerator only) and Canada use the statistical method and the United States uses the engineering/economics method. Japan's top runner approach is recognized as a special case of the statistical approach; however, engineering/economics analysis was also performed during the process for determining the standards. I was a member of the subcommittee which determined the standards for fluorescent lights, televisions, and VCRs, and will discuss the economic and technical issues arising from use of the top runner approach in this paper.

The efficiency standards in Japan were determined according to the following steps:

Step 1: To select the appliances whose efficiency standards should be established.
Step 2: To determine the range of acceptable models/kinds for each appliance.
Step 3: To determine the measuring procedures.
Step 4: To analyze the differences in the efficiencies and product prices for each appliance currently available.
Step 5: To classify appliances into categories for which standards are established separately.
Step 6: To establish target years for implementation and standards for each category by top-runner.
Step 7: To determine other details, such as labeling requirements, penalties for non-compliance, etc.

In Step 1, eight items (automobiles, refrigerators, air conditioners, fluorescent lights, televisions and VCRs, photocopiers, computers, and magnetic hard-disk drives) were selected, mainly because of their energy consumption. In Step 2, appliances whose use is special or whose model numbers are limited were eliminated. So, for example, the standards of refrigerators and air conditioners apply only for residential models, not commercial models.

In determining the efficiency standards, the fourth and fifth steps are the most important. If the differences in the efficiencies and product prices come from the adoption of efficient but expensive technologies, how to treat such technologies must be discussed. During the discussion at the conference for determining the efficiency standards in Japan, the appliances with efficient but expensive technologies were classified separately, according to whether the pay back time on efficient appliances was estimated to be longer than the average lifetime of the appliance. On the other hand, some efficient technologies were not classified separately and part of the efficiency improvement due to this is reflected in determining the efficiency standards. A list of these technologies and the included rates for their efficiency standards are shown in Table 2.

Table 2. Efficient technologies and included rate for efficiency standard

Product/Technology	Included Rate of Technology for Efficiency Standard	Rate of Improvement in Energy Efficiency
Passenger Cars		
Hybrid Engine System	0%	50%
Fuel Direct Injection	50%	15-25%
Continuous Variable Transmission (CVT)	100%	5-10%
Engine with 4 Valve and Variable Valve Timing	100%	0-3%
Electronic Fuel Injection (EFI)	100%	1-2%
Electric Controlled Power Steering	100%	2-3%
Refrigerators		
Inverter Control	100% (Separate category)	3-10%
Evacuated Insulation	100% (Separate category)	3-10%
Fluorescent Lights		
Electronic Ballast	100% (Separate category)	10-30%
Televisions		
Automatic Brightness Control	25%	
Energy Conservation Switch	25%	
Main Switch Off	50%	
VCRs (stand-by power use)		
Switch of Clock Display and Other Indicators	20%	90%

Source: METI (1998).

Efficiency standards of the refrigerators with inverter control systems (to adjust the rotation speed of the compressor) and evacuated insulation, and of fluorescent lights with electronic ballast were set up separately. This means standards for refrigerators without these technologies and fluorescent lights with traditional (magnetic) ballast also exist. An engine with fuel direct injection (FDI) is efficient, however, it is problematic in that it increases NOx. Other problem is that it would be almost impossible to change all production lines of conventional engines to FDI engines in ten years economically. So standards for automobiles were set to the averaged level of conventional engines and FDI engines (50:50). As for VCRs, the result of a survey indicated that 40% of people owning VCRs did not use the clock display function, and it was assumed that half of them would switch off the clock display if all VCRs possessed such kind of function.

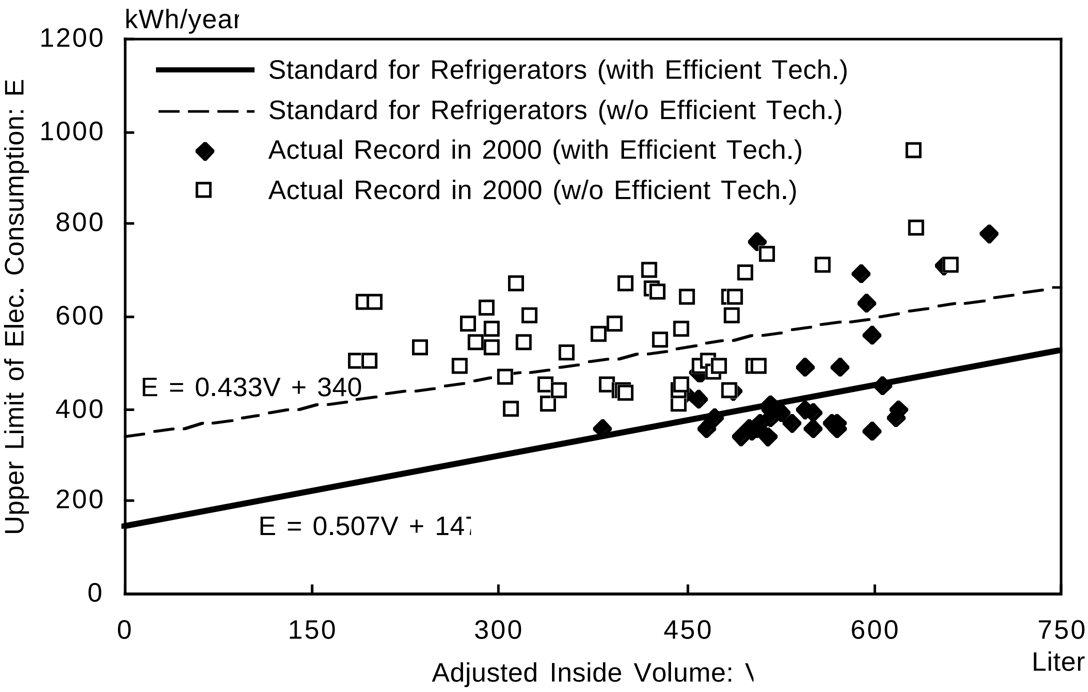
Table 3 shows the example of cost comparison of refrigerators that was picked up by the government. Although refrigerators that have an inverter control system and/or evacuated insulation are efficient, it is supposed that pay back time of them will exceed the average lifetime of refrigerators, which is twelve years. So the efficiency standard for efficient refrigerators with inverter control systems and/or evacuated insulation was established separately. Figure 1 compares the new standards for refrigerators with the actual records in 2000. On average, refrigerators with efficient technologies are 22% more efficient than inefficient ones, however, some of the refrigerators without efficient technologies are more efficient than the refrigerators with efficient technologies. This finding casts doubt on the necessity of establishing separate standards according to the adoption of efficient technologies.

Table 3. The cost of efficient and inefficient refrigerators

Efficient Technology	Manufacturer	Model Name	Adjusted Inside Volume (Liter)	Price Gap (Yen)	Gap of Annual Expense of Electricity (Yen/Year)	Pay Back Time (Year)
Inverter Control	Matsushita	NR-D36VS1	406	-	-	-
None	Fujitsu	ER-F34D	429	68,000	2,300	29.6
None	Toshiba	GR-M32T	401	68,000	2,990	23.4
Evacuated Insulation	Sharp	SJ-WE38B	496	-	-	-
None	Mitsubishi	MR-JE37S	472	52,100	2,300	22.7

Source: METI (1998).

Figure 1. New standards for refrigerators and actual records in 2000



Source: ECCJ (2000).

Cost comparison also raises the same question. The price gaps in Table 3 are the differences between the recommended retail prices sought by manufacturers. Because the actual prices that are determined on the market reflect the efficiency of each appliance and subjective discount rate of consumers, it is more suitable to judge the economics of energy efficiency with actual market prices. Recently, it has become possible to search for actual market prices through web sites[1]. Table 4 shows the comparison of the actual price gap between efficient and inefficient appliances for each manufacturer to eliminate the effects of marketing power and the reputation of each manufacturer. Pay back times are calculated at approximately four years, and are considered to reflect the implicit preferences of consumers.

Table 4. Actual price gaps of efficient and inefficient refrigerators

Manufacturer	Model Name	Adjusted Inside Volume (Liter)	Retail Price (Yen)	Price Gap (Yen)	Gap of Annual Expense of Electricity (Yen/Year)	Pay Back Time (Year)
Mitsubishi	MR-39X	499	67,000	-	-	-
	MR-YL38A	473	99,400	32,400	7,130	4.5
Toshiba	GR-R32T	401	64,900			
	GR-301BX	382	95,500	30,600	7,130	4.3
Fujitsu	ER-F43KF	559	73,900			
	ER-V43AF	552	99,400	25,500	7,360	3.5

Source: Maker catalogue and market research.

The same situation can be seen for air conditioners. For example, in 2000, Matsushita, a leading electrical appliance company in Japan, manufactured two different models of air conditioner. One more energy efficient model is intended for high load use. By comparing the prices and energy efficiency, the subjective pay back time for the manufacturer can be calculated. Matsushita estimates that the 2.8 kW type model consumes 980 kWh (216 kWh for cooling and 764 kWh for heating) of electricity per year. On the other hand, the inefficient model consumes 1,489 kWh (328 kWh for cooling and 1,161 kWh for heating) of electricity per year. The difference corresponds to about 11,700 yen[2] in electricity costs and the simple pay back time is calculated to be 4.6 years (see Table 5). Actual market prices are lower, however, the price gap is not large (for the case of 2.8 kW, 44,600 yen at a well-known large scale retail shop in Tokyo). In other words, the market allows the prices of efficient appliances to reflect the customers' subjective discount rates. The pay back times of efficient appliances for residential customers are estimated to be from three to five years. The information shown above suggests that it is suitable to use the market prices to assess the economics of efficient technologies.

Table 5 - COP and price gap of air conditioners (Matsushita)

Capability of Appliance (for cooling)	COP of Efficient Model (E Series)		COP of Inefficient Model (SG Series)		Price Gap (gap in recommended retail prices)
	Cooling	Heating	Cooling	Heating	
2.5 kW	5.49	5.67	3.91	4.11	52,000 yen
2.8 kW	5.23	5.42	3.44	3.57	53,000 yen
4.0 kW	3.81	4.29	2.80	3.21	39,000 yen

Source: Maker catalogue and market research.

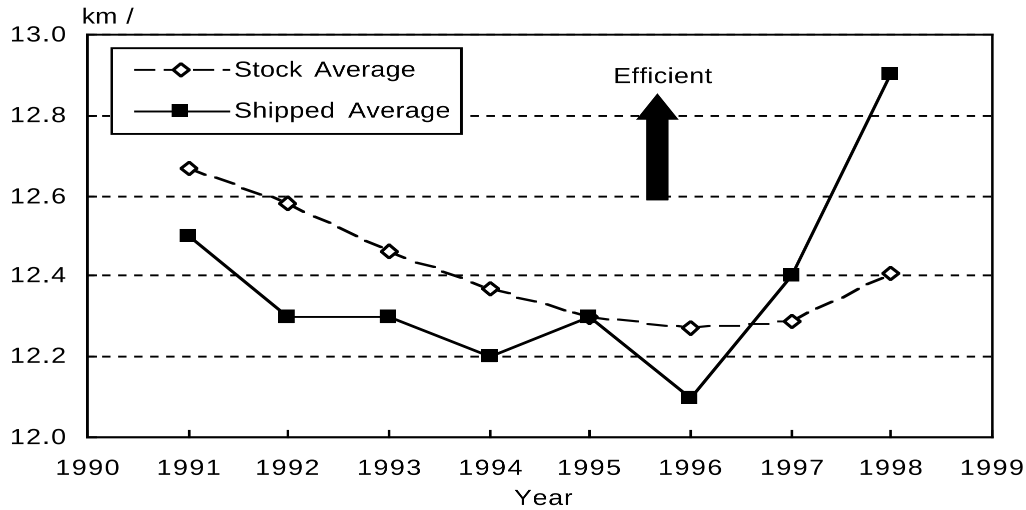
5. ESTIMATE OF ACTUAL IMPROVEMENT BY EFFICIENCY STANDARDS

The energy savings effect of equipment shipped in the target years was estimated by the government and is shown in Table 1. If energy savings rates in Table 1 are correct, approximately 51.5 TWh of electricity is conserved by the top four electric appliances (refrigerators, air conditioners, fluorescent lights, and televisions). This corresponds to be approximately 2.3% of the total primary energy consumption of Japan in 1998, if electricity is converted with 10 MJ/kWh (conversion efficiency: 36%). However, these saving rates are not achievable for the following reasons:

- Gaps in efficiency between the shipped averages and stock averages;
- Changes in consumer preference (average size and/or functions);
- Changes in use (working hours of each appliance).

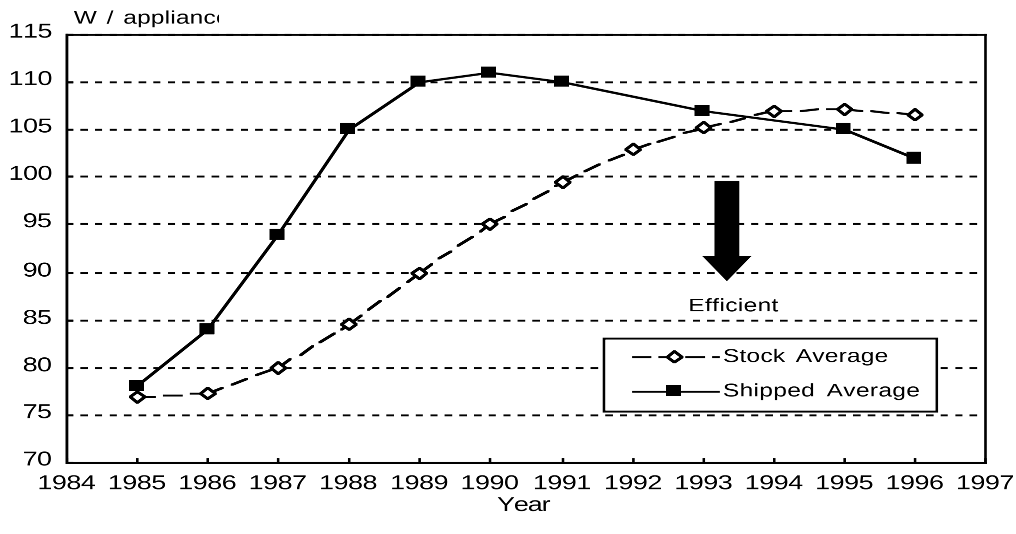
Generally, the average efficiency of the shipped base is better than that of the stock average, however, the reverse situation has occurred for passenger cars and television. From the late 80's to the early 90's, the average size of these appliances increased and the average efficiencies of shipped base decreased (Figures 2 and 3). The primary reasons for these changes are this period was the so-called "Bubble Economy" and consumer preferences had changed due to rising incomes and property. For example, the market share of recreational vehicles (RVs) grew rapidly during the 1990s. These RVs are heavier and less efficient than normal cars. According to a survey of consumer preferences, only 4% of people choose fuel economy as the most important specification in purchasing a new car (IEEJ, 2000). On the other hand, market share of efficient passenger cars with a FDI engine exceeded 10% in 2000, and total number of FDI cars reached 800 thousand (METI, 2000). It is important to take changes in future consumer preferences into account when estimating the actual effect of efficiency standards.

Figure 2. Average fuel economy of passenger cars



Source: METI (2000).

Figure 3. Average wattage of televisions



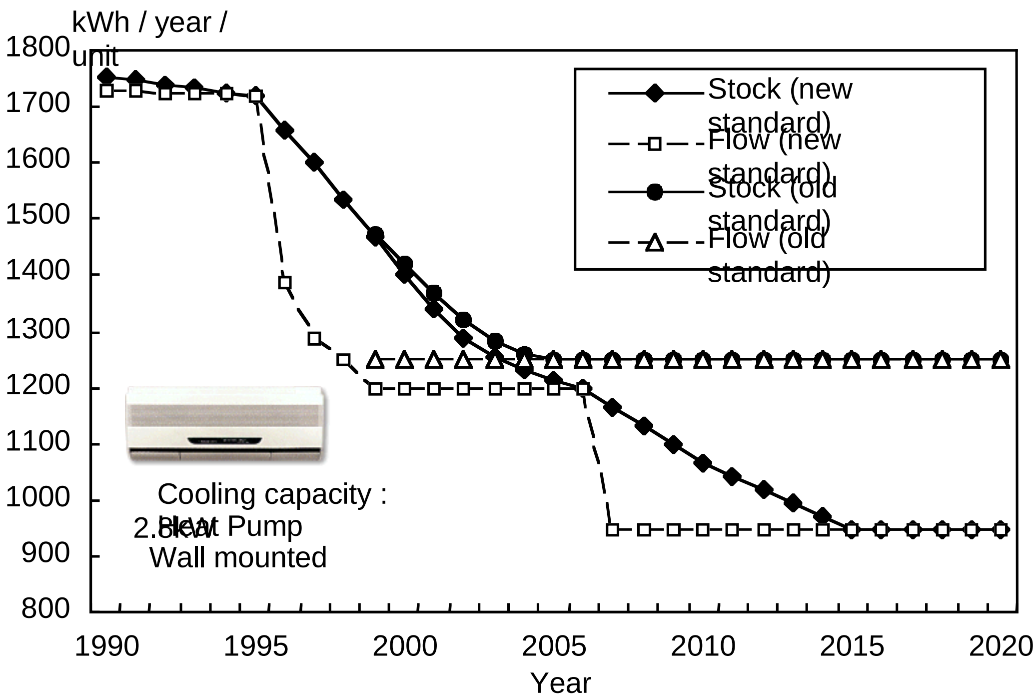
Source: METI (2000), ECCJ (1999).

Recently, METI disclosed its estimates of the actual improvements achieved by the new efficiency standards to the Division of Energy Conservation, Advisory Committee for Natural Resources and Energy. Figures 4 and 5 show the results for air conditioners and refrigerators, respectively. Under the old standards, average energy consumption of air conditioners in 2010 is estimated to be 1252.6 kWh/year/unit for both flow and stock base. Flow and stock energy consumption will decrease to be 948.6 and 1065.4 kWh/year/unit respectively under the new standards. Energy consumption per unit of stock base will be improved from the 1990 level by 39.3% in 2010. Table 6 summarizes the changes in stock energy efficiency from 1990 to 2010. The efficiency of refrigerators will be the most improved of the four appliances; however, additional improvements due to use of the top-runner approach are unlikely.

One reason for this is the classification of the appliances. If the categories were not divided by the existence of the efficient technologies described before, an additional improvement could be expected. For example, average electricity consumption of the refrigerators without efficient technologies plotted in Figure 1 is 560 kWh/year and average new efficiency standard is 512 kWh/year. If the categories with efficient technologies and without them are merged, average electricity consumption of these refrigerators should be decreased to 349 kWh/year and additional improvement is estimated to be 29%.

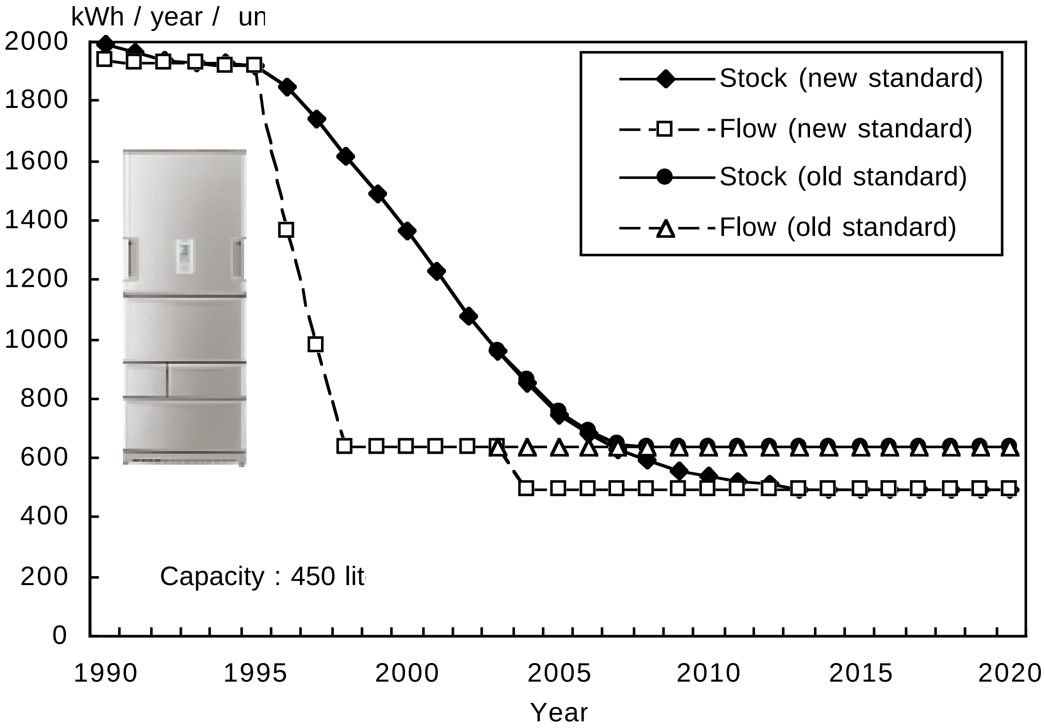
One problem for this change is the cost of small size refrigerators. As shown in Figure1, refrigerators whose adjusted inside volume are smaller than 380 liters do not have efficient technologies. This is because small size refrigerators are cheap and manufacturers are not willing to load efficient technologies onto such refrigerators. However, if the categories are merged, cost reduction in efficient technologies could be expected through mass production and learning effect. Similar statements can be mage for fluorescent lights.

Figure 4. Estimate of improvement by efficiency standard (air conditioners)



Source: METI (2000).

Figure 5. Estimate of improvement by efficiency standard (refrigerators)



Source: METI (2000).

Table 6 - Changes in stock energy efficiency from 1990 to 2010

Appliance	Energy Consumption per Appliance in 1990 (kWh/unit)	Energy Consumption per Appliance in 2010 (kWh/unit)		Rate of Improvement from 1990 to 2010		Additional Rate of Improvement by New Standard in 2010
		Old Standard	New Standard	Old Standard	New Standard	
Air Conditioner	1754.2	1252.6	1065.4	-28.6%	-39.3%	-10.7%
Refrigerator	1986.9	641.0	535.8	-67.7%	-73.0%	-5.3%
Television	192.9	177.0	151.9	-8.2%	-21.3%	-13.0%
Fluorescent Lights	193.4	179.7	172.2	-7.1%	-11.0%	-3.9%

Source: METI (2000).

In estimating the changes in total energy consumption, the following factors were taken into account:

- Diffusion rate of air conditioners per household;
- Penetration of highly insulated houses; and
- Average working hours of appliance.

Table 7 summarizes the changes in key factors and energy consumption from 1990 to 2010. Changes in other factors indicate the efforts for efficiency improvement will be negated to some extent for all appliances. As for air conditioners, a considerable increase in the number of the appliances owned will overcome the energy saving factors (efficiency improvement and a decrease in average working hours per unit). The average number of air conditioners is expected to increase from 1.27 unit per household in 1990 to 3.22 in 2010. Accordingly, the total energy consumption of air conditioners is estimated to increase from the 1990 level by 33.7% in 2010, although the energy consumption per appliance including the efficiency gained from use of house insulation will decrease by 50.2%. An increase in the number of appliances owned will also occur for televisions. As for refrigerators, increases in average size and in the use of frozen food will also increase future energy consumption. Also, increased average floor space per home and increased working hours are expected to increase energy consumption by fluorescent lights.

Total energy consumption of these four appliances per household are anticipated to decrease by 9.3% from 1990 to 2010, from 2760 kWh to 2504 kWh. However, total energy consumption will increase by 9.6%, because the number of households is expected to increase by 20.8% in the same period.

Table 7 - Changes in key factors from 1990 to 2010

Appliance	Energy Consumption per Household in 1990 (kWh/household)	Changes in Stock Energy Consumption per Appliance	Changes in Coefficient of Heat Radiation of House	Changes in Other Factors*	Changes in Total Energy Consumption	Energy Consumption per Household in 2010 (kWh/household)
Air Conditioner	711	-39.3%	-10.9%	+83.9%	+33.7%	951
Refrigerator	913	-73.0%	-	+12.5%	-60.5%	361
Television	425	-21.3%	-	+21.3%	+0.5%	427
Fluorescent Lights	711	-11.0%	-	+18.4%	+7.5%	765
Total	2,760	-	-	-	-9.2%	2,504

Source: METI (2000).

* Includes 20.8% increase in the number of households from 1990 to 2010.

6. CONCLUDING REMARKS

The top-runner approach is widely recognized as an epoch-making method to establish efficiency standards. One reason Japan can adopt such a method is the existence of many manufacturers and their ceaseless efforts for improving energy efficiency caused by competition.

However, as seen here, some issues remain in the process of determining efficiency standards. It is particularly important that the judgment of the economic trade offs of efficient technologies and the classification categories of efficiency standards should be improved.

In the future, the factors that will affect energy consumption are expected to increase energy consumption for all appliances investigated. It is quite difficult to decrease total energy consumption by efficiency standards only. Because categorized standards do not have any incentive to lead smaller sizes, additional countermeasures should be implemented.

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8. END NOTES

[1] A typical example is http://kakaku.com/ (in Japanese)

[2] 1 Euro = 110 yen