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Japanese Top Runner Approach for energy efficiency standards

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Abstract:

In 1998, Japan initiated a unique program—the Top Runner Approach—to improve energy efficiency of end-use products and to develop "the world's best energy-efficient products." By 2009, the program had achieved mandatory energy efficiency standards for 21 products. It is now considered as one of the major pillars of Japanese climate policy. This paper examines 12 years' experience of the program. It first overviews the structure of the Top Runner Approach and illustrating its impacts, followed by a discussion on the various issues associated with the Approach and concluding with some implications.

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1. Introduction

In 1998, Japan initiated a unique program—the Top Runner Approach—to improve energy efficiency of end-use products. As part of the Energy Conservation Law, the program set mandatory energy efficiency standards, based on the most efficient ("Top Runner") products on the market, for a variety of appliances, equipment, and automobiles. The program aims to develop "the world's best energy-efficient products." Starting with nine products in 1998, it had expanded to 21 products by 2009 and is now considered one of the major pillars of Japanese climate policy.

This paper examines 12 years' experience of the Top Runner Approach. Although it is often claimed as an innovative method for stimulating efficiency improvement of targeted products, there has so far been very limited evaluation of the Approach, confined to a couple of analyses by European researchers (Tojo, 2005; Nordqvist, 2006). This paper seeks to evaluate the effectiveness of the Approach based on case studies of selected products. The empirical material is obtained from various literatures including governmental documents and a number of in-depth interviews with manufacturers in Japan. The paper first overviews the structure of the Top Runner Approach, and then illustrates its impacts. It also discusses issues associated with the Approach, and concludes with some implications.

2. Overview of the Top Runner Approach

Mandatory energy efficiency standards for appliances and automobiles had been in effect since 1980 in Japan. However, they had failed to induce sufficient energy efficiency improvement as they were rarely revised and were largely based on negotiations with industry without any explicit standard-setting method. When the Kyoto Protocol was established in 1998, Japan was required to further accelerate energy conservation efforts to achieve its GHG emission reduction target (6% reduction by 2008–2012 compared to the 1990 level). The Top Runner Approach was expected to be an effective strategy for setting ambitious efficiency targets and reducing energy consumption in the residential sector. In 1998, the Top Runner Approach was adopted in the revision of the Energy Conservation Law as a new method for setting targets for selected products.

The scope of the Top Runner Program is based on three criteria: (1) products involving large domestic shipments; (2) products that consume a substantial amount of energy in the use phase; (3) products with considerable room to improve energy efficiency. The Program started in 1998 with nine products: room air conditioners, fluorescent lighting, television sets, copying machines, computers, magnetic disk units, video cassette recorders, refrigerators, passenger vehicles, and freight vehicles. The scope was reviewed every two to three years and gradually expanded to include 21 products by 2009 (Table 1). The electricity consumed by the Top Runner targeted products

amounts to more than 70% of residential electricity consumption (METI, 2004).

Table 1. Scope and target year of the Top Runner Standards

	1999 2002 '03 '04 '05 '06 '07 '08 '09 '10 … '15
Passenger vehicles	2010 Standards established; To be enacted in 2010; 2015 Standards
Freight vehicles	2010 Standards; 2015 Standards
Room air conditioners	2004 Standards; 2010 Standards
Fluorescent lights	2005 Standards; 2012 Standards (in review)
TV sets	2003 Standards; 2008 Standards
Copying machines	2006 Standards; 2012 Standards (in review)
Computers and Hard disk drives	2005 Standards; 2007 Standards; 2011 Standards (in review)
Video cassette recorders	2003 Standards; 2008 Standards
Refrigerators Freezers	2004 Standards; 2010 Standards
Space heaters	2006 Standards; 2008 Standards
Gas cooking appliances	2008 Standards
Gas water heaters	2006 Standards
Oil water heaters	2006 Standards
Electric toilet seats	2006 Standards; 2012 Standards (in review)
Vending machines	2005 Standards; 2012 Standards
Electric transformers	2006 Standards
Microwave ovens	2006 Standards; 2008 Standards
Electric rice cookers	2008 Standards
DVD recorders	2008 Standards; 2010Standards

Source: METI (2007), ECCJ (2009a)

Note: The starting/ending points of an arrow show the year of decision/enactment of the Standards.

The major characteristics of the Top Runner Approach can be summarized as follows:

- The Top Runners set the standard, taking into consideration technological potential.
- Differentiated standards are set based on various parameters.
- Compliance with the standard is evaluated by corporate average.

As the name suggests, the most energy efficient product on the market during the standard-setting process sets the Top Runner Standards; thus, the Approach is essentially based on market data. However, it also takes into account technological analysis, that is, the Top Runner Approach considers technological potential for efficiency improvement in the future (Figure 1). For example, the Top Runner Standards for room air conditioners (smaller than 4 kW) for 2010 were set for a 3–4% improvement over the Top Runner products in 2005, because this level of technological improvement was assessed as feasible by stakeholders' discussions in the Air Conditioner Evaluation Standard Subcommittee (Air Conditioner Evaluation Standard Subcommittee, 2006).

Another important feature of the Top Runner Approach is that standards are differentiated based on various parameters. Although it seems quite reasonable to differentiate the standards in terms of size or weight, technology type is also considered in categorization. For example, liquid crystalline displays have different standards from CRT displays because the different technology used has a significant implication for energy efficiency. Hybrid vehicles are also excluded from the analysis because normal vehicles cannot meet their high efficiency level without adopting the same technology.

In order to comply with the Top Runner Standards, producers must ensure that the weighted average energy efficiency of the products they sold in the target year achieves the requisite standards. Therefore, not all of a manufacturer's products have to meet the target, but on average, they must achieve the standards. This flexibility enables producers to provide a wide range of models to meet the market demand while guiding the overall market to higher energy efficiency.

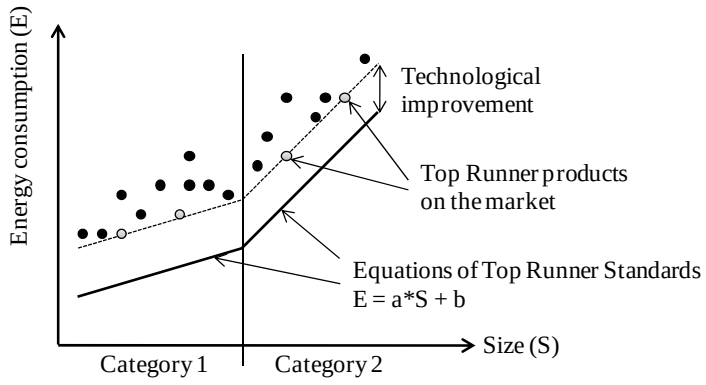


Figure 1. Schematic overview of standard-setting by the Top Runner Approach

Note: The Top Runner Products are identified and become the basis of the standards, but the standards are decided taking into consideration future technological improvement.

In Japan, energy efficiency standards are discussed and determined by the Ministry of Economy, Trade and Industry (METI) and its advisory committees comprising representatives from academia, industry, consumer groups, local governments, and mass media. The Advisory Committee for Natural Resources and Energy is in charge of overall energy policy including energy efficiency policy. The Energy Efficiency Standards Subcommittee, one of the Subcommittees under the Advisory Committee, is responsible for setting energy efficiency standards. This subcommittee, organized by the METI, establishes an Evaluation Standard Subcommittee for each of the targeted products, and Evaluation Standard Subcommittees draw up draft standards. Since detailed market and engineering information on the targeted products is required, there is strong involvement of industry associations in the standard-setting process. The Energy Efficiency Standard Subcommittee approves the draft standards submitted by the Evaluation Standard Subcommittees, and they are finally authorized by the METI. It usually takes about a year or two to set the standards for one product (ECCJ, 2008).

The METI also considers revision of standards when the target year is reached. Thus far, almost all the Top Runner Standards have been revised for their next target periods, as shown in Table 1.

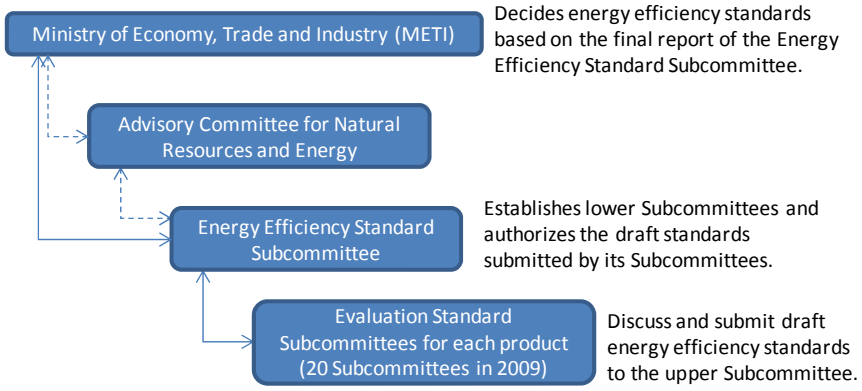


Figure 2. Institutional framework for setting the Top Runner Standards

Source: ECCJ (2008)

In the target year, the METI requires the producers to submit a report on their sales and the energy efficiency of their products, and then evaluates their compliance. In case of noncompliance, the Top Runner Program takes a “name and shame” approach. The Ministry first makes a recommendation to the noncompliant producer to improve their energy efficiency performance, goes public with the recommendation when the producer does not comply, and finally orders the producer to meet the recommendations (ECCJ, 2008). Thus far, this approach seems to be working very well. Although there no documentation on compliance rate has been made public, no producer to date has been

advertised as noncompliant. One reason for this is the structure of the Japanese appliance market, which is dominated by a limited number of domestic producers, and another is the Japanese culture, where governmental criticism works somewhat like a serious penalty.

3. Impacts of the Top Runner Approach

The Top Runner Approach requires substantial improvement of energy efficiency for each targeted product. The rates of energy efficiency improvement required by the Top Runner Standards range from 16% to 80%; these have so far been achieved for all products, and often greatly exceeded (Table 2). This implies that the Top Runner Approach has been very successful in that it has resulted in significant energy efficiency improvement, and the targets have been achieved.

Table 2. Energy efficiency improvement of major products with Top Runner Standards

Product	Estimated improvement with Top Runner Standards *	Result
Room air conditioners	66.1% increase in COP (FY 1997 vs 2004 freezing year)	67.8%
Refrigerators	30.5% decrease in kWh/year (FY 1998 vs FY 2004)	55.2%
TV receivers	16.4% decrease in kWh/year (FY 1997 vs FY 2003)	25.7%
Computers	83.0% decrease in kWh/year (FY 1997 vs FY 2005)	99.1%
Fluorescent lights	16.6% increase in lm/W (FY 1997 vs FY 2005)	78.0%
Vending machines	33.9% decrease in kWh/year (FY 2000 vs FY 2005)	37.3%
Gasoline passenger vehicles	22.8% increase in km/L (FY 1995 vs FY 2010)	22.8% (FY 1995 vs FY 2005)

Source: ECCJ (2008). FY: fiscal year

* Estimated improvement of weighted average energy efficiency of all categories within each product group

The contribution of the Top Runner Standards to energy efficiency is not clear-cut in all cases, because the energy efficiency improvements are partly a response to market demand (i.e., consumers prefer efficient products with low energy cost) and autonomous technological improvement, but we can clearly discern the impact of the Top Runner Standards with a couple of products.

The best example is room air conditioners. In Japan, use of room air conditioners for cooling became widespread in the 1970s, and later for both cooling and heating. Since then, energy efficiency has been increased by technological improvements such as the introduction of inverters and better heat exchangers, but by the mid 1990s, the trend toward improvement had stagnated. The new standards for room air conditioners based on the Top Runner Approach were adopted in 1999. The Standards required energy efficiency to be increased by 66% in COP value by 2004 compared to the 1997 level. The adoption of the Standards had a significant impact, altering the technological trajectory from the challenge of increasing heating capacity (to expand the market for heating) to one of improving energy efficiency. Figure 3 shows that the trend of energy efficiency of RACs has clearly been changed both in 1998 when the Top Runner Standards were introduced, and in 2004, the target year.

A close look at the energy efficiency trend tells us more about the impact of the Standards. As shown in Figure 4, not only has the Top Runner Standard effectively improved the efficiency of the high-end Top Runner product by 50% but also it has almost doubled the efficiency of the low-end products. This implies that the Top Runner Standard contributes strongly to eliminating low efficiency products from the market. According to reports, in the 2.8 kW-class market, about 70 models (accounting for 2 million units sold in 2003) went out of production to meet the 2004 Top Runner Target (Air Conditioner Evaluation Standard Subcommittee, 2006).

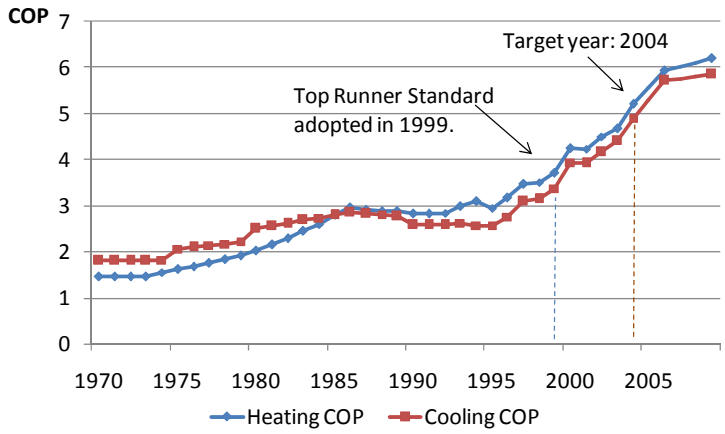


Figure 3. Long term trend of energy efficiency of room air conditioners

Source: 1970–2004 data from Murakoshi (2006), 2006 and 2008 data from ECCJ (2006, 2009b) as average of 2.8 kW class models

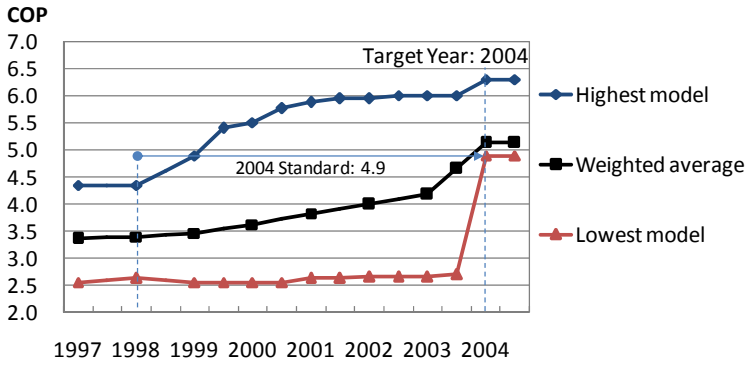


Figure 4. Trend of energy efficiency of room air conditioners (2.8 kW class), 1997–2004

Source: Air Conditioner Evaluation Standard Subcommittee (2006)

Another success story is that related to passenger vehicles. Because fuel efficiency is one of the major attributes of automobiles, there had been important improvements in fuel efficiency in the 1970s and 1980s, but the trend toward efficiency had stagnated and even worsened in the early 1990s due to the drop in gasoline prices and the increase in vehicle size. However, after the introduction of the Top Runner Standards, the trend of energy efficiency improvement has clearly accelerated as shown in Figure 5. The penetration rate of the Top Runner compatible vehicles into the new-vehicle market increased rapidly, from 11% in 1997 to more than 90% in 2008 (Figure 5).

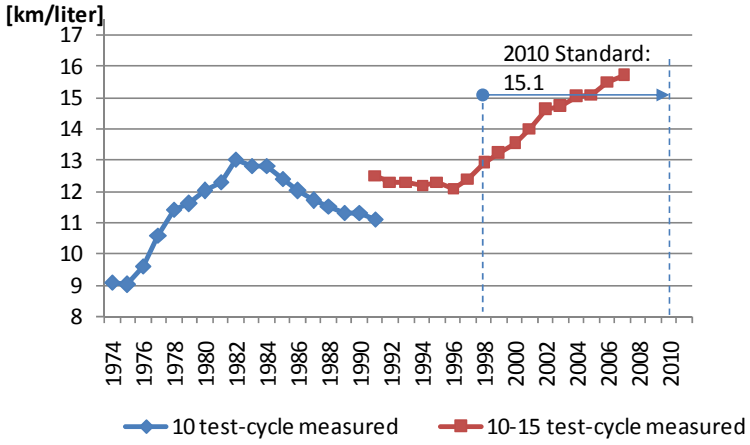


Figure 5. Average fuel efficiency of new gasoline-fueled passenger vehicles sold in Japan

Source: 1973–1993 data from METI (1996), 1994–2008 data from MLIT (2009)

Note: The Top Runner Standard for gasoline-fueled passenger vehicles (15.1 km/liter by 2010) was decided in 1998 and was achieved in 2005, five years ahead of the target year.

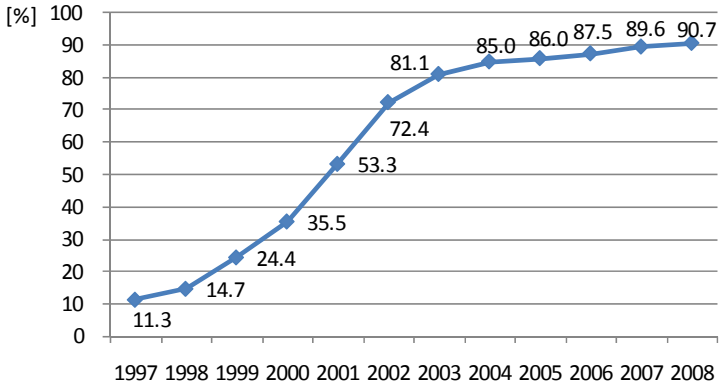


Figure 6. Penetration rate of 2010 Top Runner Standards compliant passenger vehicles
Source: JAMA (2009)

It should be noted that not all fuel efficiency improvement is attributable to the Top Runner Standards. The fact that fuel efficiency of passenger vehicles started to increase from 1997 (before the 2010 Top Runner Standards were decided) implies the effect of other factors such as the rise of environmental consciousness among consumers and the producers' response to emerging market demand . Although it is difficult to conduct a quantitative analysis on each factor's contribution, it would be reasonable to say that the Top Runner Standards set a clear market direction toward higher fuel efficiency, removed private risk in investing in more efficient vehicles, and thereby accelerated fuel efficiency improvement. Manufacturers admit that the standards changed their priority in favor of fuel efficiency improvement and accelerated their development activities for efficiency improvement; these would have been conducted anyway, but would have been delayed for a few years without the Standards .

4. Some issues

Although the achievement of the Top Runner Approach is remarkable, it also has some issues to redress.

One of the problems is lack of explicit methods for considering impact on consumers. Because the Top Runner Approach is based on the Top Runner products on the market, increase of product price accrued by improving energy efficiency is not explicitly considered. Although it is stipulated that standards should not force consumers to "purchase economically inappropriate high-priced products in the name of energy saving" (ECCJ, 2008, p.17), there is no prescription for life cycle cost analysis, and thus such analysis is not conducted appropriately. This contrasts markedly with an explicit prescription for life-cycle analysis in developing minimum energy performance standards (MEPS)

(IEA, 2000).

Lack of life-cycle analysis in target-setting might lead to prices too high for consumers to pay back within the lifetime of the product. We estimated payback periods for energy efficient room air conditioners sold in the winter of 2006 in Japan (Figure 6). The figure shows that many efficient models require more than 10 years and sometimes 15 years for payback. Because there is evidence showing that the payback figures still appear to be underestimated , many efficient models on the market are so expensive that they cannot achieve payback within the lifetime of the room air conditioners, considered to be around 10 to 15 years.

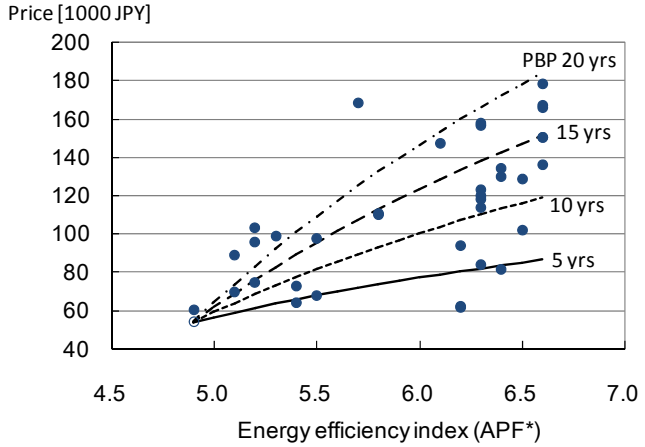
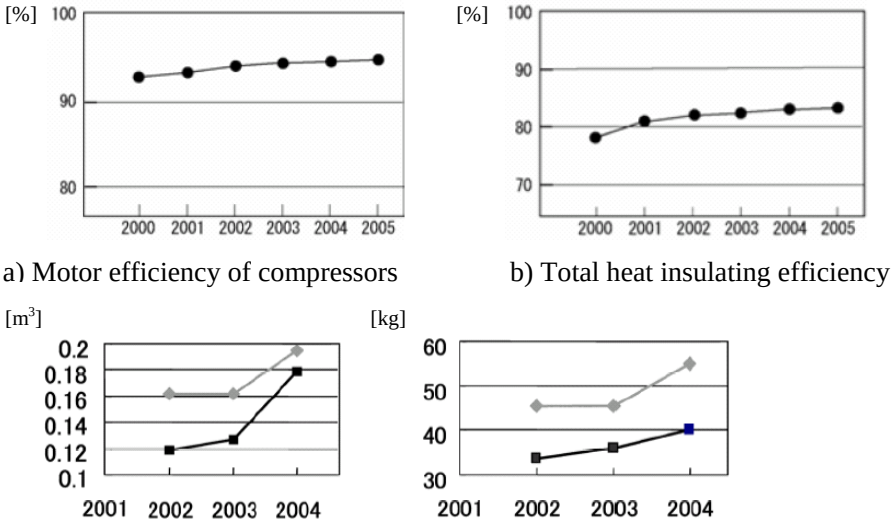


Figure 7. Price, energy efficiency, and payback periods of room air conditioners (2.8 kW class) in 2006

* APF (Annual Performance Factor) is annual cooling and heating demand divided by annual energy consumption to meet the demand.

Note: Dots show price and energy efficiency of 2.8 kW-class models sold in the winter of 2006 (ECCJ, 2006). The lines show the highest prices to payback the price increase compared to the least efficient, cheapest model in terms of energy savings within respective simple payback periods (PBP), based on annual electricity consumption of respective models (ECCJ, 2006) and electricity price (22 JPY/kWh) in Tokyo. Prices are derived from major online shopping sites for Japanese consumers (+D Shopping and kakaku.com).

In addition, cost effective potential for efficiency improvement in air conditioner technologies seems to have been exhausted. Motor efficiency of compressors is approximately 95% and total heat-insulating efficiency is over 80%; both factors are nearing saturation (Figures 7a and 7b). Instead, efficiency improvement in recent years has been achieved mainly by expanding heat exchangers (Figure 7c); this too is handicapped because of limited space in Japanese houses. Further tightening of the Standards, therefore, might not be cost effective.



a) Motor efficiency of compressors b) Total heat insulating efficiency

Figure 8. Technological improvements in room air conditioners

Source: Air Conditioner Evaluation Standard Subcommittee (2006)

Another problem is the difficulty of determining a rate of technological improvement that is feasible as well as challenging. In the case of fluorescent lighting, the Top Runner Standards were set just above the Top Runner products already on the market, because the Evaluation Standard Committees made very conservative assessments of potential for further technological improvement. Because of this, the targets were achieved just after their establishment and had no impact on efficiency improvement (see Figure 8). The same story applies to liquid-crystalline displays, whose Top Runner targets were achieved almost two years before the target year of 2008. This might be in part a result of successful lobbying by the industry, but more fundamentally indicates that for some products, the rate of technological improvement is difficult to forecast. For example, one reason for the failure of target-setting for liquid-crystalline displays was the unexpected advancement in backlight control technology. Similarly, fluorescent lighting with inverters spread much faster than the rate projected in target-setting. This implies that the Top Runner Approach might not be an effective approach for some products whose rate of technological development is difficult to forecast.

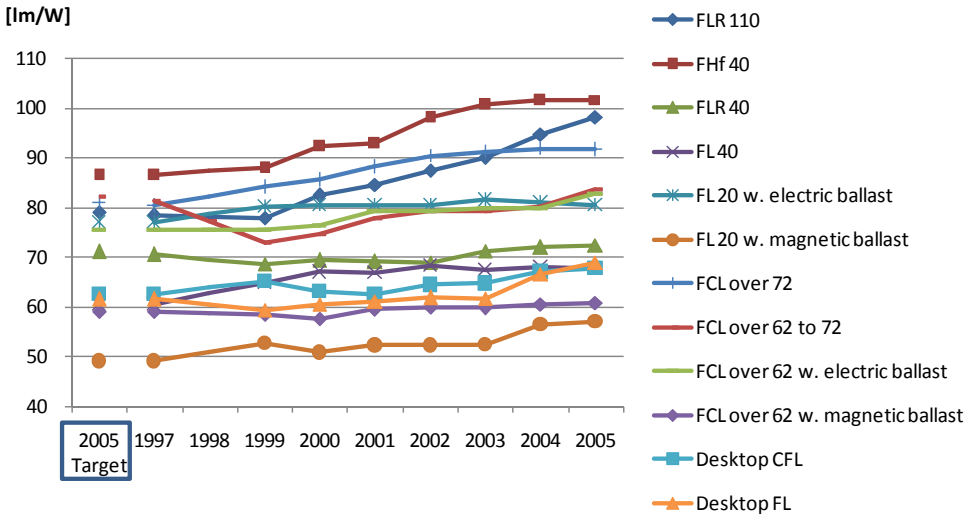


Figure 9. 2005 Top Runner Standards (established in 1997) and actual energy efficiency trend of fluorescent lighting, 1997–2005

Source: Fluorescent Lightning Fixtures Criteria Standard Subcommittee (2008)

Note: FLR: Fluorescent Lighting Rapid, FHf: Fluorescent lighting High frequency, FL: Fluorescent Lighting, FCL: Fluorescent Circular Lighting, CFL: Compact Fluorescent Lighting. Numbers are lamp size.

5. Conclusion

The Japanese Top Runner Approach is a unique approach, setting mandatory energy efficiency standards based on the most efficient product on the market. After the introduction of the Top Runner Approach in 1998, there has been remarkable growth in energy efficiency of the targeted products. Although the contribution of the Top Runner Standards to this efficiency improvement is not clear, the Standards have been successful in accelerating the trend of energy efficiency improvement of some products, such as room air conditioners and passenger vehicles. In these cases the Standards provided a clear direction for product development aiming at higher energy efficiency and eliminating low efficiency products from the market.

There appear to be some preconditions necessary for successful operation of the Japanese Top Runner Approach. One is the Japanese market structure, which is dominated by a limited number of domestic producers. These are similar in that they all have high technological competency, could accept strict standards (i.e., no producer is excluded from the market even if strict standards are strict), all had incentives to develop energy efficient products to increase competitiveness with foreign producers, and all complied with the standards even without strict sanctions. Another precondition is the existence of technological potential for efficiency improvement. When these conditions were met, the Top Runner Approach resulted in a substantial outcome.

This case study implies that ambitious policy, matching market conditions as well as technological

conditions, can work very well to induce remarkable energy efficiency improvement. Because such conditions depend on the country and the phase of technological development, careful design and adjustment are required for effective policy-making.

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