# Historical Case Studies of Energy Technology Innovation

**CASE STUDY 12: END-USE EFFICIENCY (JAPAN).**

## THE ROLE OF STANDARDS: THE JAPANESE TOP RUNNER PROGRAM FOR END-USE EFFICIENCY

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### AUTHORS' SUMMARY

In 1998, Japan launched the Top Runner Program to improve the energy efficiency of a range of end-use products. In this Program, the most energy efficient product on the market during the standard-setting process defines the Top Runner Standard for all corresponding manufacturers and products. The Top Runner Program started 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 by 2012 had gradually expanded to include 23 products. It is now considered to be one of the major pillars of Japanese climate policy. This case study examines 12 years of experience with the Program (from 1998 to 2010). It provides an overview of the structure of the Top Runner Program, illustrates its impacts on efficiency and energy savings, discusses issues associated with the Program, and concludes with implications for efficiency programs in other countries.

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# 1 INTRODUCTION

Japan started the Top Runner Program in 1998 to improve the energy efficiency of end-use products. As part of the Energy Conservation Law, the program set mandatory efficiency standards for a variety of appliances, equipment and automobiles based on the most efficient products ("Top Runner" products) on the market. It aims to develop "the world's best energy-efficient products." Started with 9 products in 1998, it has been expanded to 23 products in 2012. It is now considered one of the major pillars of Japanese climate policy.

The purpose of this case study is to examine 12 years of experience with the Top Runner approach (1998 - 2010). Although it is often cited as an innovative method to stimulate efficiency improvements of targeted products, not only by the Japanese government but also by some European countries (e.g. Jänicke, 2008), there has been very limited evaluation, except for a couple of analyses by European researchers (Tojo, 2005; Nordqvist, 2006). This case study evaluates the effectiveness of the Top Runner approach focusing on selected products. The empirical material includes government documents and a number of in-depth interviews with manufacturers in Japan. The case study provides an overview of the structure of the Top Runner Program, illustrates its impacts on efficiency and energy savings, discusses issues associated with the Program, and concludes with implications for efficiency programs in other countries.

# 2 OVERVIEW OF THE TOP RUNNER PROGRAM

## 2.1 Products & standards

Mandatory energy efficiency standards for appliances and automobiles have been in effect in Japan since 1980. At first, they failed to induce sufficient energy efficiency improvement as they were rarely revised and were largely based on negotiation with industry without any explicit standard-setting method. When the Kyoto Protocol was adopted in 1997, Japan was required to further accelerate energy conservation efforts to achieve its 6% reduction in greenhouse gas emissions by 2008-2012 compared to 1990 levels. The Top Runner Program was expected to be an effective means of contributing to this goal by setting ambitious efficiency targets and reducing energy consumption in the residential sector. In 1998 Top Runner was adopted in the revision of the Energy Conservation Law as a new method to set targets for selected products.

The Top Runner Program includes products that fall within three categories:

1) products with large domestic shipments;
2) products that consume a substantial quantity of energy in the use phase;
3) products with substantial scope for improving energy efficiency.

The Program started in 1998 with 9 products: room air conditioners, fluorescent lamps, televisions, 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 by 2009 had gradually expanded to 21 products (see Table 1). The electricity consumed by the Top Runner targeted products sums up to more than 70% of residential electricity consumption (METI, 2004).

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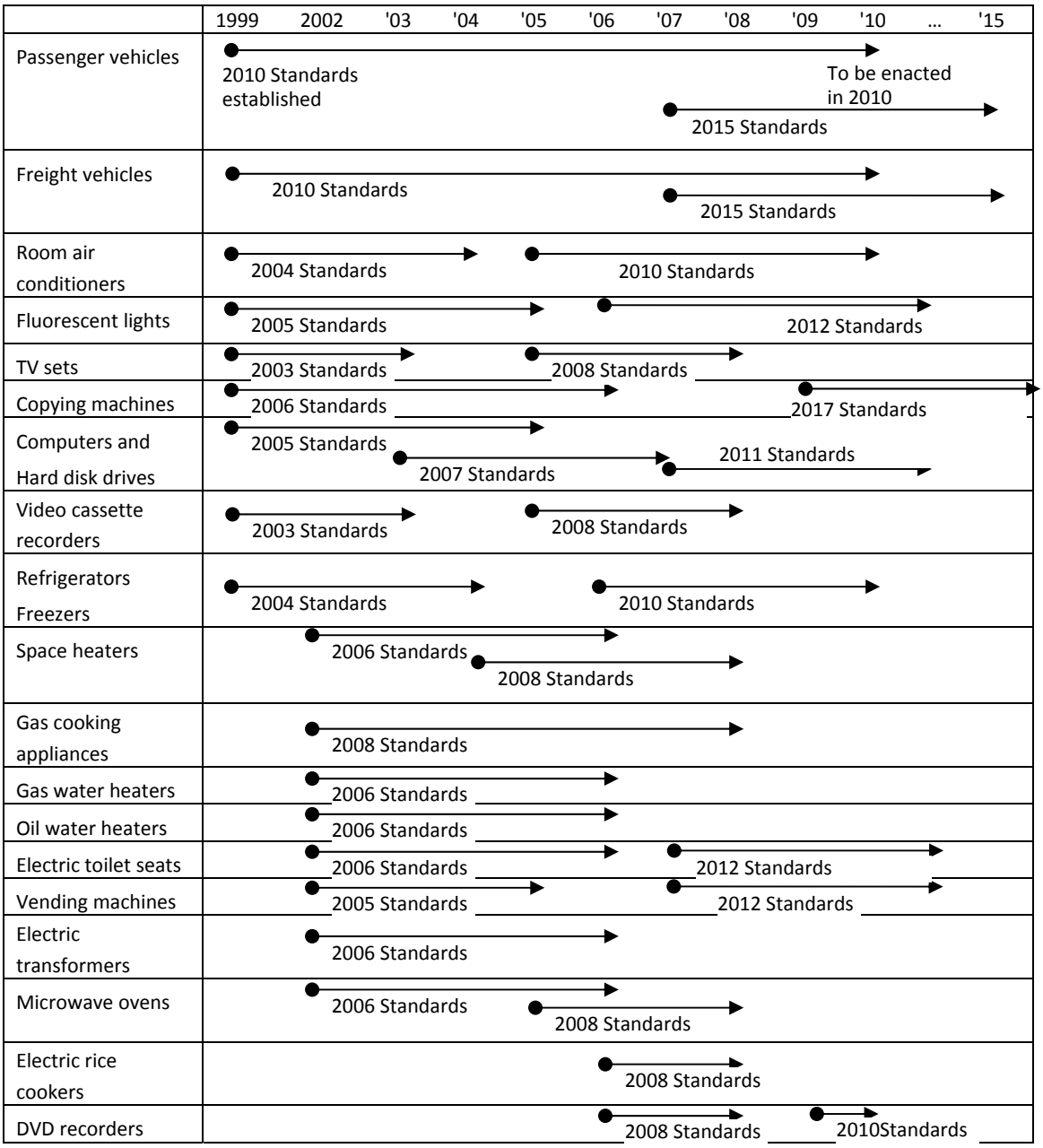
**TABLE 1. SCOPE AND TARGET YEAR OF THE TOP RUNNER STANDARDS.** NOTES: THE STARTING/ENDING POINTS OF AN ARROW SHOW THE YEAR OF DECISION/ENACTMENT OF THE STANDARDS. SOURCE: METI (2007), ECCJ (2009A), ECCJ (2010), METI (2011).




Since the most energy efficient product on the market during the standard-setting process set the Top Runner Standards, the standards are based on market data. But, the Program also takes into consideration technological analysis, i.e. Top Runner considers technological potential for efficiency improvements in the future (illustrated in Figure 1). For example, the Top Runner Standards for room air conditioners smaller than 4 kW for 2010 were defined as a 3 to 4% improvement over the Top Runner

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products in 2005 as such technological improvement was assessed to be feasible by stakeholders' discussions in the Air Conditioner Evaluation Standard Subcommittee (Air Conditioner Evaluation Standard Subcommittee, 2006).

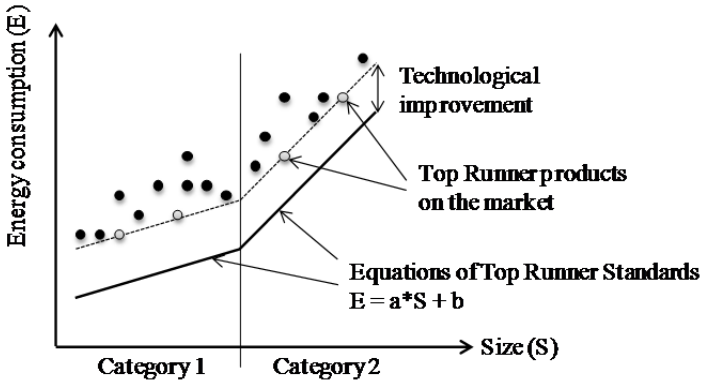


**FIGURE 1. SCHEMATIC OVERVIEW OF STANDARD-SETTING IN THE TOP RUNNER PROGRAM.** NOTE: THE TOP RUNNER PRODUCTS ARE IDENTIFIED AND BECOME THE BASIS OF THE STANDARDS, BUT THE STANDARDS ARE DECIDED WITH CONSIDERATION OF FUTURE POTENTIAL TECHNOLOGICAL IMPROVEMENTS.

Another important feature of Top Runner is that standards are differentiated based on various parameters. While it seems quite reasonable to differentiate the standards based on size and weight, technology type is also considered in the categorization. For example, liquid crystalline displays have different standards from cathode ray tube displays because different technologies used have large implication for their energy efficiency. Hybrid vehicles are also excluded from the standard-setting because conventional internal combustion engine vehicles cannot meet their high efficiency without adopting the same technology.

In order to comply with the standards, producers must make sure that the weighted average efficiency of the products they sell in a target year achieves the standards. Therefore not all of a manufacturer's products have to meet the target, but the average of all products has to. 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.

In sum, the major characteristics of the Top Runner approach can be described as:

- the Top Runners set the standard, with consideration of future potential improvements;
- differentiated standards are set based on a range of parameters;
- compliance with the standard is evaluated by corporate average product sales.

## 2.2 Institutional setting

In Japan, energy efficiency standards are discussed and determined by the Ministry of Economy, Trade and Industry (METI) and its advisory committees which comprise 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 METI, establishes

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an Evaluation Standard Subcommittee for each of the targeted products, and Evaluation Standard Subcommittees make draft standards. Figure 2 summarizes this institutional hierarchy. 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 authorizes the draft standards submitted by Evaluation Standard Subcommittees, which are finally decided by METI. It is usually takes about a year or two to set standards for one product (ECCJ, 2008).

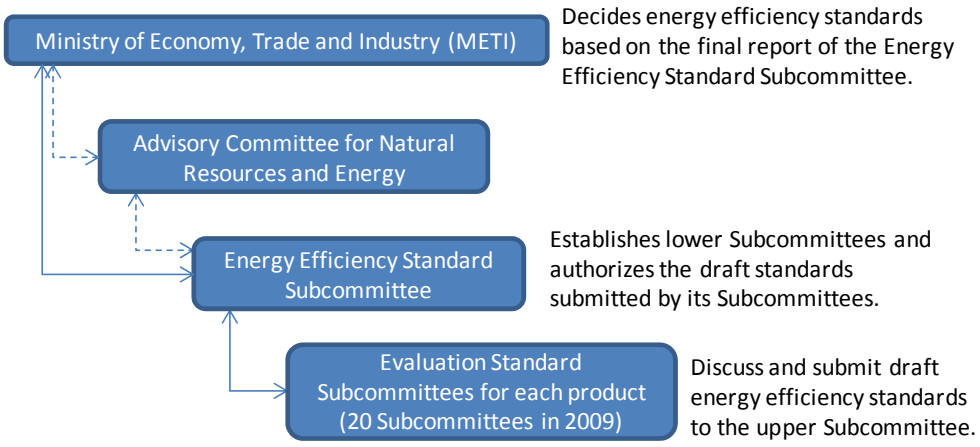


**FIGURE 2. INSTITUTIONAL FRAMEWORK FOR SETTING THE TOP RUNNER STANDARDS.** SOURCE: ECCJ (2008).

METI also considers revision of standards when the target year arrives (see Table 1). When the target year arrives, the producers submit a report on their sales and the energy efficiency of their products, and METI evaluates their compliance. In case of non-compliance the Top Runner Program uses a "name and shame" approach. The Ministry first makes a recommendation to the noncompliant producer to improve their performance. If this is not sufficient, METI makes the recommendation public. Finally, METI can order the producer to meet the recommendations (ECCJ, 2008). So far, this approach has worked very well. Although there are no records of compliance rates, so far no producers have been publicly named as noncompliant. This is due to both the structure of the Japanese appliance market, which is dominated by a limited number of domestic producers, and Japanese culture in which government pressure and public 'shaming' acts as a strong compliance mechanism.

## 3 IMPACTS OF THE TOP RUNNER PROGRAM

The Top Runner approach requires substantial energy efficiency improvements for each targeted product. The rates of energy efficiency improvement required by Top Runner standards range from 16% to 80%, which have been achieved in all products so far often with large excess (Table 2). These results highlight the Program's success in meeting targets and spurring significant efficiency improvements.

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**TABLE 2. ENERGY EFFICIENCY IMPROVEMENT OF MAJOR PRODUCTS WITH TOP RUNNER STANDARDS.** NOTES: FY = FISCAL YEAR; COP = COEFFICIENT OF PERFORMANCE (RATIO BETWEEN POWER INPUT AND POWER OUTPUT). SOURCE: ECCJ (2010).

| 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 sets using cathode ray tube displays | 16.4% decrease in kWh/year (FY 1997 vs. FY 2003) | 25.7% |
| Computers | 69.2% decrease in kWh/year (FY 2001 vs. FY 2007) | 80.8% |
| Fluorescent lights | 16.6% increase in lm/W (FY 1997 vs. FY 2005) | 35.7% |
| 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) |

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

Although the contribution of Top Runner standards to energy efficiency are difficult to disaggregate from autonomous technological improvement and changes in market demand (e.g., consumers preferring efficient products with lower energy costs), two products clearly demonstrate the Top Runner Program's impacts.

The best example is residential air conditioners. In Japan, air conditioners began diffusion in the 1970s for cooling, and later for both cooling and heating. Since then, energy efficiency increased because of technological improvements such as introducing inverters and better heat exchangers, but this trend stagnated in the mid 1990s (see Figure 3). New Top Runner Standards were adopted in 1999. The standards required a coefficient of performance (CoP) increase of 66% by 2004 compared to the 1997 level. (A CoP is the ratio between the power input and power output). The adoption of the standards had a significant impact on altering the technological trajectory from increasing heating capacity (in order to expand its market for heating) to improving energy efficiency. Figure 3 shows that the efficiency of air conditioners clearly changed both in 1998, when the Top Runner Program began, and in the 2004 target year for the air conditioning standard.

A close look into the energy efficiency trend tells us more about the standard's impact. As shown in Figure 4, not only has the Top Runner standard effectively improved the efficiency of the high-end products by 50%, it also almost doubled the efficiency of the low-end products. This shows the Top

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Runner standards have the power to eliminate low efficiency products from the market. It is reported that in the 2.8 kW class market about 70 models which sold 2 million units in 2003 went out of production to meet the 2004 Top Runner Target (Air Conditioner Evaluation Standard Subcommittee, 2006).

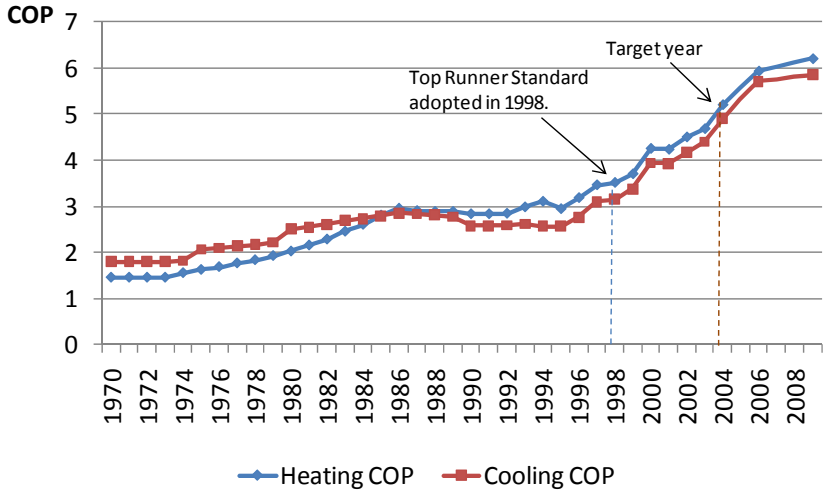


**FIGURE 3. LONG TERM TREND OF ENERGY EFFICIENCY OF ROOM AIR CONDITIONERS.** NOTES: COP = COEFFICIENT OF PERFORMANCE (RATIO BETWEEN POWER INPUT AND POWER OUTPUT). SOURCE: 1970-2004 DATA FROM MURAKOSHI (2006); 2006 AND 2008 DATA FROM ECCJ (2006, 2009B) AS AVERAGE OF 2.8 KW CLASS MODELS.

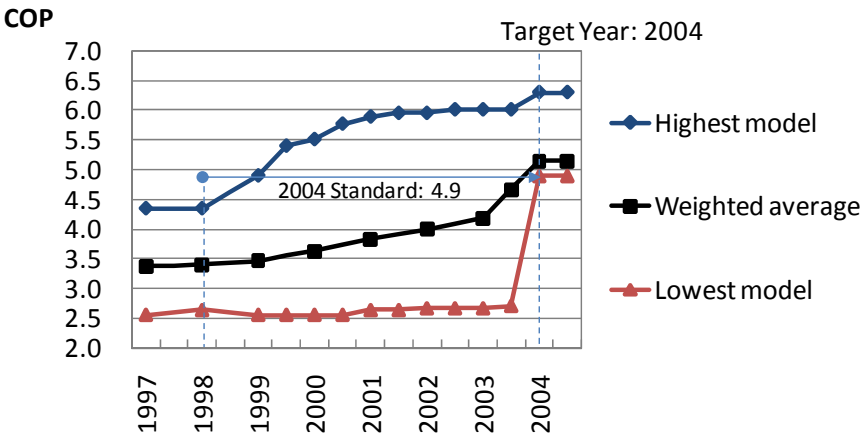


**FIGURE 4. TREND OF ENERGY EFFICIENCY OF 2.8 KW CLASS ROOM AIR CONDITIONERS (1997-2004).** NOTES: COP = COEFFICIENT OF PERFORMANCE (RATIO BETWEEN POWER INPUT AND POWER OUTPUT). SOURCE: AIR CONDITIONER EVALUATION STANDARD SUBCOMMITTEE (2006).

Another success story applies to passenger vehicles. While there were important fuel efficiency improvements in the 1970s and 1980s, efficiency stagnated, and even worsened, in the early 1990s due to the fall of gasoline prices and the increase in vehicle size. But after the introduction of Top Runner Standard, energy efficiency improvements clearly accelerated as shown in Figure 5. The penetration rate

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of the Top Runner compatible vehicles in new vehicle market increased rapidly, from 11% in 1997 to more than 90% in 2008 (Figure 6).

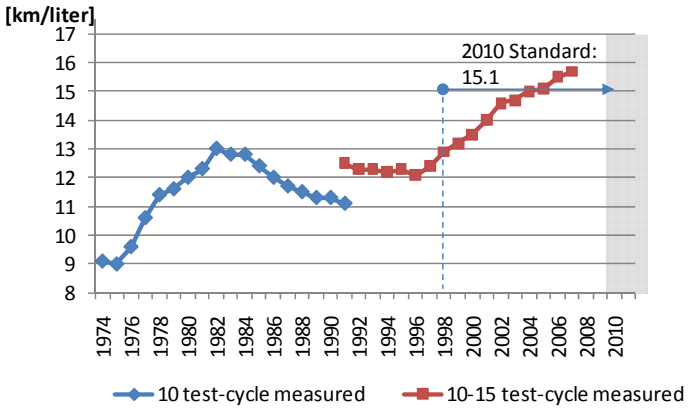


**FIGURE 5. AVERAGE FUEL EFFICIENCY OF NEW GASOLINE-FUELED PASSENGER VEHICLES SOLD IN JAPAN.** NOTES: Y-AXIS SHOWS FUEL EFFICIENCY IN KM/LITER. THE TOP RUNNER STANDARD FOR GASOLINE-FUELED PASSENGER VEHICLES OF 15.1 KM/LITER BY 2010 WAS DECIDED IN 1998 AND WAS ACHIEVED IN 2005, FIVE YEARS AHEAD OF THE TARGET YEAR. SOURCE: 1973-1993 DATA FROM METI (1996), 1994-2008 DATA FROM MLIT (2009).

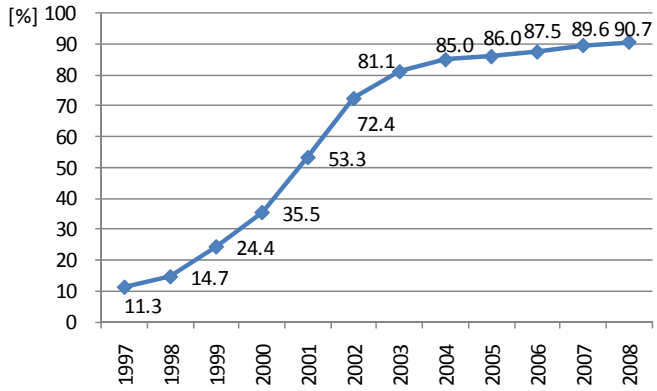


**FIGURE 6. PENETRATION RATE OF PASSENGER VEHICLES WHICH ARE 2010 TOP RUNNER STANDARDS COMPLIANT.** SOURCE: JAMA (2009).

It should be noted that not all of the fuel efficiency improvement is attributable to Top Runner Standards. The fact that fuel efficiency of passenger vehicles has started to increase since 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 the emerging market demand. In 1997, for example, Toyota launched their hybrid vehicles (Prius) which was the culmination of developments started in 1993 under the vision of top management to double fuel efficiency in "vehicles for the 21st century" without any pressure of regulation (Ikari, 1999; see also the case study on hybrid cars). Nevertheless, it is clear the Top Runner Standards set a clear market direction toward higher fuel efficiency, reducing the risks faced by firms investing in more efficient vehicles. In interviews

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conducted with the major car manufacturers in Japan in 2008, they openly recognize that the standards changed their priorities and accelerated their development activities in favor of fuel efficiency improvements.

## 4 CONCERNS WITH THE TOP RUNNER PROGRAM

Although the Top Runner Program has succeeded in driving up the efficiency of a range of end-use products, there are outstanding issues which need addressing.

One problem is the lack of explicit methods to consider consumer impacts. Since Top Runner is based on the most efficient products on the market, any increase of product price associated with improving energy efficiency is not explicitly considered. While 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 requirements for lifecycle or other cost analyses which is therefore not systematically conducted. This contrasts markedly with explicit prescriptions for lifecycle cost analysis in developing minimum energy performance standards, an approach to set energy efficiency standards for appliances which is adopted in the US, EU and other major countries (IEA, 2000).

Lack of lifecycle analysis in target-setting may lead to price increases so high that the payback period is longer than the lifetime of the product. As an example, Figure 7 shows the case of energy efficient room air conditioners sold in the winter of 2006 in Japan. Many efficient models require more than 10 years and sometimes 15 years to payback the investment cost. These may also be underestimates as the data is based on the Energy Efficiency Performance Catalogue (ECCJ, 2006) which assumes 3.6 months of cooling operation period and 5.5 months of heating operation period. Those periods are much longer than average operation periods indicated by field surveys (e.g. Nishio and Iwafune, 2009). Many efficient models on the market are sufficiently expensive that they cannot payback within the typical 10-15 year lifetime of room air conditioners.

In addition, cost effective potentials for efficiency improvement in air conditioner technologies have approached saturation. Motor efficiency of compressors is approximately 95% and total heat-insulating efficiency is over 80% with only minimal gains achieved through the 2000s. Efficiency improvements in recent years have instead been achieved mainly by expanding heat exchangers. This option is also facing constraints due to the limited space in Japanese homes. Therefore further tightening of the Standards may not be cost effective.

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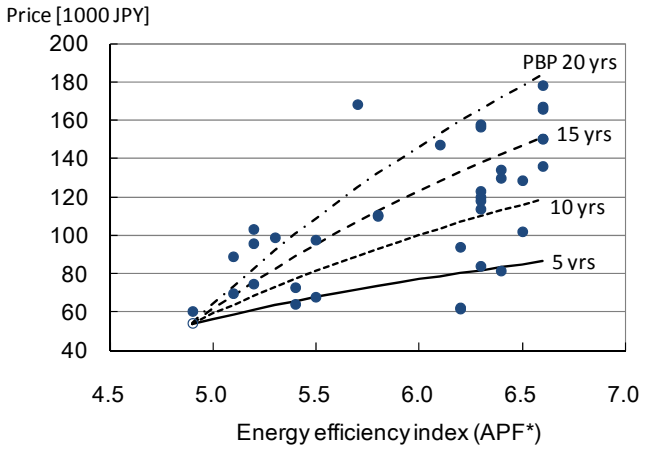


**FIGURE 7. PRICE, ENERGY EFFICIENCY AND PAYBACK PERIODS OF 2.8 KW CLASS ROOM AIR CONDITIONERS IN WINTER OF 2006.** NOTES: APF (ANNUAL PERFORMANCE FACTOR) IS ANNUAL COOLING AND HEATING DEMAND DIVIDED BY ANNUAL ENERGY CONSUMPTION TO MEET THE DEMAND. LINES SHOW THE HIGHEST PRICES FOR ENERGY SAVINGS TO PAYBACK THE PRICE INCREASE COMPARED TO THE LEAST EFFICIENT, CHEAPEST MODEL WITHIN 5, 10, 15 AND 20 YEAR PAYBACK PERIODS (PBP) BASED ON ANNUAL ELECTRICITY CONSUMPTION OF RESPECTIVE MODELS (ECCJ, 2006) AND ELECTRICITY PRICES (22 JPY/KWH) IN TOKYO. PRICES ARE DERIVED FROM MAJOR ONLINE SHOPPING SITES FOR JAPANESE CONSUMERS (+D SHOPPING AND KAKAKU.COM).

Another problem is the difficulty in determining a rate of technological improvement that is both challenging yet feasible. In the case of fluorescent lighting, Top Runner standards were set just above the most efficient products already on the market, because the Evaluation Standard Committees made a very conservative assessment on the potential of further technological improvement. Because of this the targets were achieved just after they were established, and they had no impact on efficiency improvement (see Figure 8).

The same story applies to liquid crystalline displays, whose targets were achieved almost two years before the target year of 2008. This might partly be a result of successful lobbying by industry, but more fundamentally indicates that for some products the rate of technological improvement is difficult to forecast. For example, one reason for failed target-setting of liquid crystalline displays was unexpected advancement in backlight control technology. Similarly, fluorescent lightings with inverters were diffused much faster than expected. This suggests that the Top Runner approach might not be effective for products whose rate of technological development is difficult to forecast.

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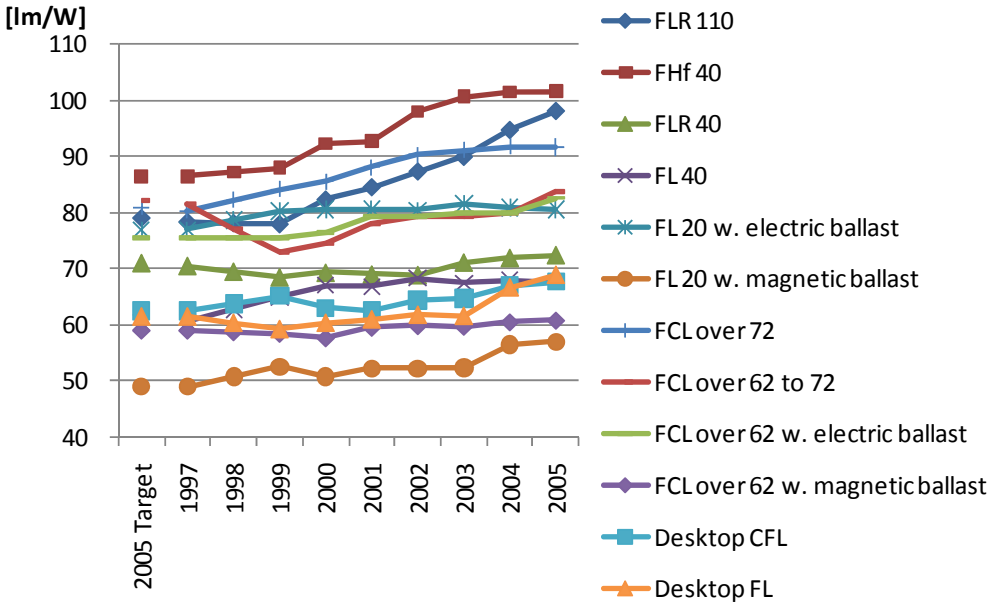


**FIGURE 8. 2005 TOP RUNNER STANDARDS ESTABLISHED IN 1997, AND ACTUAL ENERGY EFFICIENCY TREND OF FLUORESCENT LIGHTINGS (1997-2005).** NOTES: FLR = FLUORESCENT LIGHTING RAPID; FHF = FLUORESCENT LIGHTING HIGH FREQUENCY; FL = FLUORESCENT LIGHTING; FCL = FLUORESCENT CIRCULAR LIGHTING; CFL = COMPACT FLUORESCENT LIGHTING. NUMBERS ARE LAMP SIZE (W). SOURCE: FLUORESCENT LIGHTING FIXTURES CRITERIA STANDARD SUBCOMMITTEE (2008).

## 5 CONCLUSION

The Japanese Top Runner Program demonstrates an effective approach for setting mandatory energy efficiency standards based on the most efficient products on the market. After the introduction of Top Runner in 1998, there has been a strong increase in energy efficiency of the targeted products. Although the exact contribution of the Top Runner standards to such efficiency improvement is hard to isolate from autonomous technological improvement and changes in market demand, it has been successful in accelerating the trend of energy efficiency improvement of some products, such as room air conditioners and passenger vehicles. In those cases the Standards provided a clear direction to product development toward higher energy efficiency and eliminated low efficiency products from the market. This relied on the existence of technological potentials for efficiency improvement.

An important characteristic of the Japanese market that enable the successful functioning of the Top Runner Program is the market structure which is dominated by a limited number of domestic producers. They are similar in that they all have high technological competency, could accept strict standards (i.e. no producer is excluded from the market even with strict standards), had incentives to develop energy efficient products to increase competitiveness against foreign producers, and complied with the standards even without strict sanctions (related to Japanese business culture and aversion to public 'shaming').

In sum, Japanese experience with the Top Runner Program shows how ambitious policy that matches market conditions as well as technological conditions can work very well to induce remarkable energy

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efficiency improvements. Since such conditions depend on the country and the phase of technological development of products targeted, careful and adaptive design is required for effective policy-making.

## 6 FURTHER READING

Tojo (2005) provides a good summary analysis of the Top Runner program up to 2005. Siderius and Nakagami (2007) apply the Top Runner insights to a potential European context. Ellis (2007) sets out the broader context of efficiency standards and regulation in an IEA context.

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