Title
China Refrigerator Information Label: Specification Development and Potential Impact

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China Refrigerator Information Label: Specification Development and Potential Impact

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Executive Summary

In the last five years, China's refrigerator market has grown rapidly, and now urban markets are showing signs of saturation, with ownership rates in urban households reaching 92%. Rural markets continue to grow from a much lower base. As a result of this growth, the Chinese government in 2006 decided to revise the refrigerator standards and its associated efficiency grades for the mandatory energy information label. In the Chinese standards process, the efficiency grades for the information label are tied to the minimum standards. Work on the minimum standards revision began in 2006 and continued through the first half of 2007, when the draft standard was completed under the direction of the China National Institute of Standardization (CNIS).

Development of the information label grades required consideration of stakeholder input, continuity with the previous grade classification, ease of implementation, and potential impacts on the market. In this process, CLASP, with the support of METI/IEEJ, collaborated with CNIS to develop the efficiency grades, providing technical input to the process, comment and advice on particular technical issues, and evaluation of the results. After three months of effort and three drafts of the final grade specifications, this work was completed. In addition, in order to effectively evaluate the impact of the label on China's market, CLASP further provided assistance to CNIS to collect data on both the efficiency distribution and product volume distribution of refrigerators on the market.

The new information label thresholds to be implemented in 2008 maintain the approach first adopted in 2005 of establishing efficiency levels relative to the minimum standard, but increased the related required efficiency levels by 20% over those established in 2003 and implemented in 2005. The focus of improvement was on the standard refrigerator/freezer (class 5), which constitutes the bulk of the Chinese market. Indeed, the new requirements to achieve grade 1 on the label are now virtually as stringent as those for US Energy Star-qualified or EU A-grade refrigerators.

When the energy information label went into effect in March 2005, refrigerator manufacturers were required to display their declared level of efficiency on the label and report it to the China Energy Label Center (CELC), a newly established unit of CNIS responsible for label program management. Because of the visible nature of the label, it was found, through a METI/IEEJ-supported study, that MEPS non-compliance dropped from 4% to zero after the label became mandatory, and that the percentage of higher-grade refrigerators increased. This suggests that the label itself does have potential for shifting the market to higher-efficiency models (Lin 2007). One challenge, however, of assessing this potential impact is the lack of a comprehensive baseline of market efficiency and a program to evaluate the market impact on a yearly basis.. As a result, the impact evaluation in this study draws upon the market transformation experience of the related EU energy information label, for which quantitative assessments of its market impact exist. By assuming a parallel process unfolding in China, it is possible to look at the potential impact of the label to 2020.

The results of the analysis demonstrates that a robust market transformation program in China focused on the energy information label could save substantial amounts of electricity by 2020, totaling 16.4 TWh annually by that year, compared to a case in which the efficiency distribution of refrigerators was frozen at the 2007 level. Remarkably, the impact of a successful market transformation program with the label would essentially flatten the consumption of electricity for refrigerator use throughout most of the next decade, despite the expectations of continued growth in total stock by nearly 190 million units. At the end of this period, total consumption begins to rise again, as the least efficient of the units have been mostly removed from the market.

Such a level of savings would reduce CO_2, SO_2, NO_x and particulate matter as well. Cumulatively to 2020, CO_2 emissions would decline by 67.5 million tonnes; SO_2 by 368,000 tonnes, NO_x by 263,000 tonnes, and particulate matter by 1.6 million tonnes.

To ensure that the information label can provide the basis for such a market transformation, additional focus should be paid to regular monitoring and supervision of the label, expansion of market survey and information collection efforts, building recognition and awareness of the benefits of buying higher-ranked models, and development of programs of consumer education and promotion in conjunction with retailers.

1 Background and Introduction

1.1 BACKGROUND TO THE PROJECT

China has an existing mandatory appliance energy efficiency minimum standards program, to which a smaller-scale mandatory energy information labeling program was added in 2005. Currently, only four products subject to mandatory standards are covered by the labeling program: refrigerators; air conditioners; clothes washers; and unitary air conditioners. The mandatory label uses a categorical approach and ranks the energy performance of the product based on “bins” defined by the percentage variance from the minimum standard (100%) or a related energy efficiency index calculated in relation to the minimum standard. The most recent refrigerator standard approved in 2003 established five labeling categories, ranging from 1 (55-65% of minimum standard energy usage) to 5 (90-100% of minimum standard energy usage). The program is administered by the China National Institute of Standardization (CNIS), with manufacturers reporting their energy consumption figures directly to the Institute. Minimum standards and energy information labeling are complementary policies that support each other. Mandatory standards set the minimum efficiency thresholds, while the information label helps consumers to identify the most efficient appliances.

As China’s minimum standards are revised, the category thresholds of the information label also have required reconsideration based on market share by efficiency level and other factors. Because China’s voluntary energy efficiency endorsement label is also linked to the thresholds in the information label, it is important to perform a careful analysis of the market and to gain a thorough understanding of technical and market trends in order to maximize the impact of consumer purchase behavior to increase energy savings.

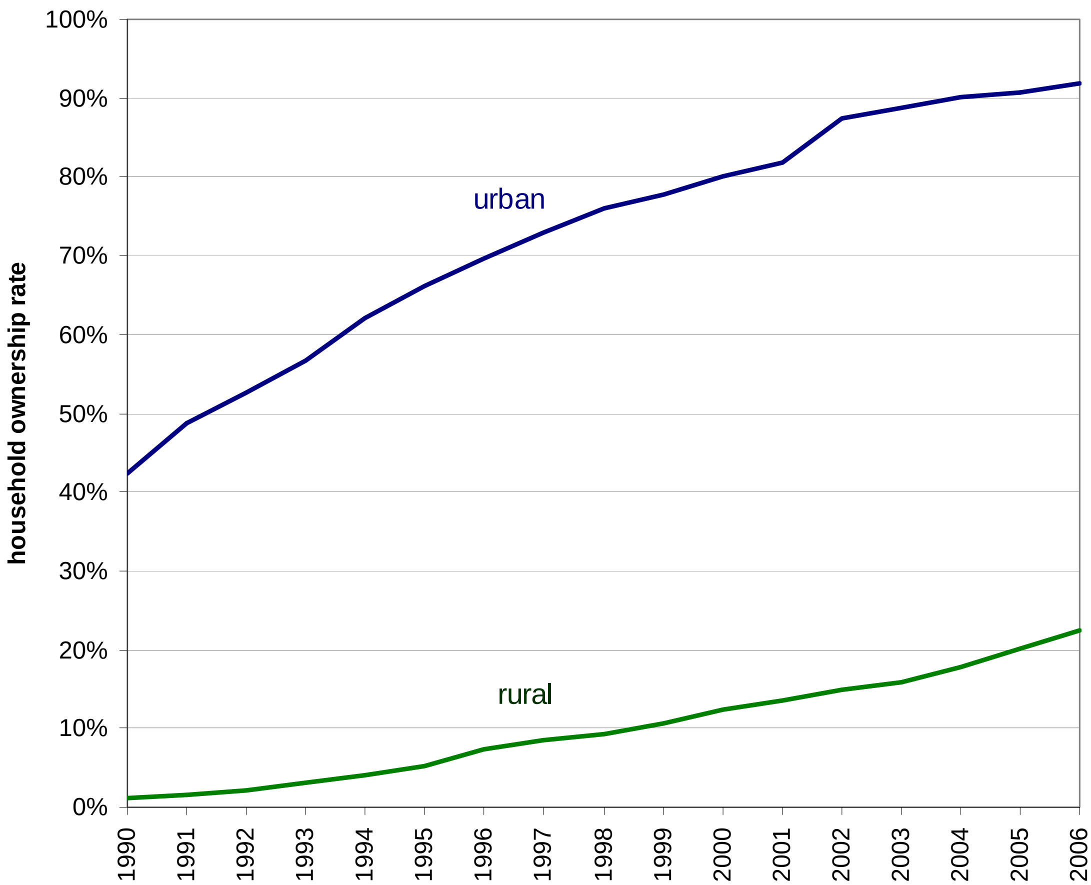
In conjunction with CNIS, CLASP technical experts reviewed the standards development timeline of the four products currently subject to the mandatory energy information label. Because refrigerators had been listed for standards revision in 2007, it was agreed that this product would be the target of the joint program to revise the energy efficiency thresholds. For this process, CLASP, with the support of METI/IEEJ, collaborated with CNIS to develop the efficiency grades, providing: technical input to the process; comment and advice on particular technical issues; as well as evaluation of the results. After 3 months of effort and three drafts of the final grade specifications, this work was completed in September 2007. In addition, in order to effectively evaluate the impact of the label on China’s market, CLASP further provided assistance to CNIS to collect data on both the efficiency distribution and product volume distribution of refrigerators on the market.

1.2 REFRIGERATOR MARKET AND 2005 INFORMATION LABEL

China is currently the world's largest manufacturer of refrigerators. Since 1985, production has grown from 1.4 million units to 35.3 million units, excluding stand-alone freezer units. Historically, the majority of refrigerators manufactured in China were destined for sale in the Chinese market, but with improvements in technology, product quality, and energy efficiency, Chinese refrigerators began to find markets overseas. By 2005, nearly half of the refrigerators produced in China were exported.

One impetus towards finding export markets is the growing saturation of the domestic market, particularly in urban areas. As show in Figure 1, urban ownership of refrigerators has already reached 92% in 2006 and growth in saturation has slowed. The rural market, often the target for re-sale of second-hand refrigerators from urban markets, continues to grow steadily. In 2006, every 100 rural households owned on average 23 refrigerators, or about one-in-four households. This market is expected to continue growing over the next decade, and may reach the levels of urban ownership by 2020.

Figure 1 Refrigerator Ownership Rates

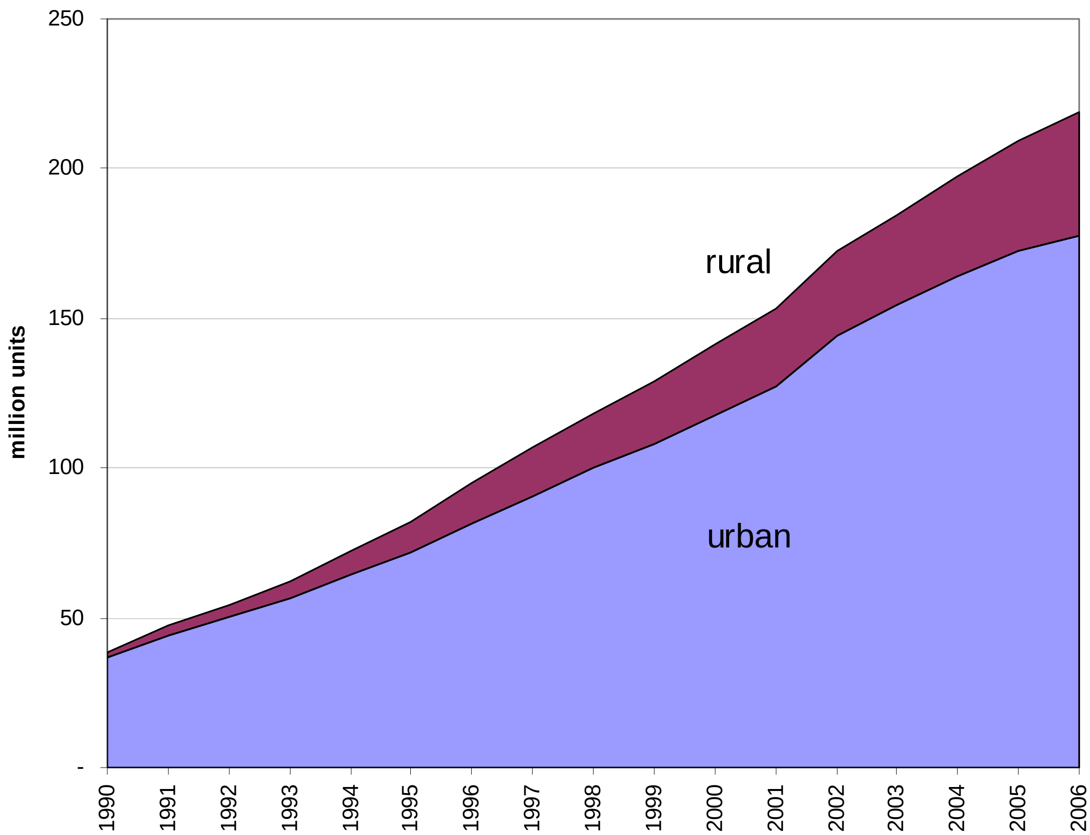


Source: National Bureau of Statistics (NBS) 2007

Similarly, the existing stock of refrigerators is largest in urban areas. Although China stopped reporting calculations of appliance stocks in the mid-1990s, it is estimated that there is a total of 219 million refrigerators currently in use in China (Figure 2).

Because refrigerators are among the largest energy consumers in the typical Chinese household, it was also among the first products subject to the modern series of energy efficiency standards developed after 1996. The first refrigerator standard in this modern series went into effect in 2000 and was subsequently revised in 2003. Under the 2000 standard, a "typical" 268 liter refrigerator could consume as much as 1.67 kWh/day; in 2003, this was reduced to 1.49 kWh/day, or a 10% improvement.[1]

Figure 2 Rural and Urban Refrigerator Stocks, 1990-2006



Source: NBS 2007.

[1] In order to allow comparisons across time, in this report, the "typical" refrigerator is considered to be 270 liters in nominal capacity with separate fresh-food and freezer compartments, and with no through-the-door features nor adjustable chiller unit. In 2000, the most common refrigerator type was 220 liters capacity and it remains the most common size today. The fastest growing segment of the market, however, is the 270 liter size.

In 2005, China launched a categorical mandatory energy information label, adapted from the categorical energy label in use in the European Union (EU) (Figure 3). Unlike the EU Label at that time, which includes A through G categories, the Chinese reduced the labeling categories to five, ranked 1 (the best) to 5 (meets the minimum standard). The label was first applied to the most energy-intensive household appliances—refrigerators and room air conditioners—but the program was later expanded on 1 March 2007 to include washing machines and unitary air conditioners. CNIS is responsible for managing this program. Unlike both the mandatory standard and the voluntary energy efficiency endorsement label, manufacturers are able to self-report the energy consumption of each model to CNIS for the energy information label.

Figure 3 China's Energy Information Label for Refrigerators

Because the information label had been under development and discussion for many years, China's 2003 refrigerator standard included the proposed category thresholds for use once the label was launched. As shown in Table 1, the thresholds were divided into five "bins". The first bin, or grade 1, included all refrigerators for which the daily energy consumption was 55% or less of the minimum standard. Except for the third bin, or grade 3, which included a 15-percentage point range, the remaining bins covered a 10-percentage point range. When applying the label to refrigerators, manufacturers were required to rank themselves within these thresholds based on their own laboratory testing results and mark the appropriate grade for the model being labeled.

Table 1 Energy Information Label Thresholds, 2005

Energy-Efficiency Grade	Energy Efficiency Index
1	$\eta < 55\%$
2	$55\% \le \eta < 65\%$
3	$65\% \le \eta < 80\%$
4	$80\% \le \eta < 90\%$
5	$90\% \le \eta \le 100\%$

η = energy efficiency index (see below)

2 Proposed Label Thresholds

2.1 THE RELATIONSHIP BETWEEN MINIMUM ENERGY PERFORMANCE STANDARDS AND THE INFORMATION LABEL

In China, the information label is directly connected to the minimum energy efficiency standard (or MEPS, minimum energy performance standard) for a product. The MEPS both serves as the reference point for the definition of efficiency thresholds as well as determines the timing of the category revisions. Because the label is mandatory, the threshold definitions are included within the official MEPS document, which are labeled "GB" or 国标 to indicate that it is a nationally applicable mandatory standard.

As noted earlier, at the establishment of the information label starting in 2005, the MEPS requirement served as the floor of the lowest category. Refrigerators that did not meet the MEPS were neither qualified to be produced nor to be labeled.

In order for a manufacturer to determine which efficiency category applied to the manufacturer's refrigerator, the MEPS document established the definition of the "Energy Efficiency Index". The energy efficiency index was defined as:

$$\eta = E_t / E_{\max}$$

Where:

η is the energy efficiency index
E_t represents the tested value of energy consumption (kWh/day), and
E_{max} is the corresponding MEPS value in kWh/day.

In turn, E_{max} is calculated as:

$$E_{\max} = (M \times V_{adj} + N) / 365$$

Where:

M = coefficient, in kWh/liter (see Table 2)
V_{adj} = adjusted volume
N = coefficient, in kWh (see Table 2)

Table 2 Coefficient Values for China Refrigerator 2003 MEPS

Class	Refrigerator Type	*M*	*N*
1	Refrigerator, no-star compartment	0.221	233
2	Refrigerator, 1-star compartment	0.611	181
3	Refrigerator, 2-star compartment	0.428	233
4	Refrigerator, 3-star compartment	0.624	223
5	Refrigerator/Freezer	0.697	272
6	Chest frozen food cooler	0.530	190
7	Chest food freezer	0.567	205

Note: the most common type of refrigerator in China and the focus of the MEPS effort is the Class 5 Refrigerator/Freezer.

The information label categories were then derived on the basis of the energy efficiency index, with 100% thus being equivalent to the MEPS value. The final thresholds adopted for the launch of the 2005 refrigerator information label are shown in Table 1. This approach established a clear and direct correspondence of the thresholds of the information label to the minimum energy performance standard.

By the time of the establishment of the energy information label in 2005, China had already implemented a voluntary energy efficiency label, managed by the China Standards Certification Center, or CSC. Although this label covered a range of products not subject to MEPS, it also included several products, such as refrigerators and air conditioners, for which MEPS did exist. In these cases, further consideration had to be given to the linkage between the information label thresholds and the energy efficiency specifications for the voluntary label. Although a great deal of debate over how to best link the two labels took place, no clear principle was established. For the first two products—refrigerators and air conditioners—the energy efficiency specification for the endorsement label (or the "evaluation value for energy efficiency," as worded in the MEPS document) was set to equal grades 1 and 2 of the information label. Thus, for refrigerators, any model that consumed 65% or less energy than allowed by the MEPS was qualified to apply for the energy efficiency endorsement label as shown in Figure 4. Such products thus could carry both the voluntary endorsement and mandatory information label.

Figure 4 China's Voluntary Energy Efficiency Endorsement Label

2.2 DESCRIPTION OF PROPOSED LABEL THRESHOLDS

In 2007, CNIS began work on development of a revised refrigerator standard. Because of the nature of the MEPS document, this meant that both the information label thresholds and the energy efficiency level for the voluntary endorsement label would need to be addressed as well. As the new MEPS levels were determined in mid 2007, work began on defining the five thresholds for the energy information label. In the 2003 MEPS document, as noted earlier, the thresholds were established so that the lowest category 5 took the MEPS as a floor value (100%), with the top category 1 applicable only to those models whose energy consumption was 55% or less than MEPS.

In the first comment draft proposal to stakeholders for revising the category thresholds, this general relationship between MEPS and the category thresholds was maintained, but the format for calculating the thresholds diverged from the straight-forward percentage-off-MEPS approach in the earlier standard. As was the case in the 2003 standard, the efficiency grade ranking of a refrigerator was derived from the “energy efficiency index” η, although two new parameters for calculation were added. The index is calculated as:

$$\eta = \frac{TestedEnergyConsumption(kWh/day)}{(M \times Vadj + N + CH) \times Sr/365} \times 100\%$$

Where:

M = coefficient, in kWh/liter (see Table 3)
V_{adj} = adjusted volume
N = coefficient, in kWh (see Table 3)
CH = 50 kWh adjustable chiller allowance[2] (15-liter capacity or above only; otherwise zero)
S_r = 1.10 for refrigerators with capacity of 100 liters or lower, otherwise 1

[2] New to the 2007 proposed MEPS is the “chiller compartment with adjustable temperature”, or 变温间室，or 冰温室。 This compartment is used to keep meats, fish or other produce at a 0°C, below that of the fresh food compartment but above that of the freezer. Currently, only about 3% of refrigerators have a chiller compartment with adjustable temperature.

In the efficiency grade calculation, the proposed *M* and *N* values were the same as those used in the 2003 standard calculation, but they no longer matched the proposed *M* and *N* values used in calculation of the MEPS. These latter values were derived by revising downwards the 2003 values by 10% for refrigerator classes 1-4, 6, 7 and 20% for the typical class 5 refrigerators (Table 3).

Table 3 M, N Values for Energy Efficiency Index, Comment Draft

Class	Refrigerator Type	Energy Efficiency Index		MEPS	
		M	*N*	*M*	*N*
1	Refrigerator, no-star compartment	0.221	233	.199	210
2	Refrigerator, 1-star compartment	0.611	181	.550	163
3	Refrigerator, 2-star compartment	0.428	233	.385	210
4	Refrigerator, 3-star compartment	0.624	223	.562	201
5	Refrigerator/Freezer	0.697	272	.558	218
6	Chest frozen food cooler	0.530	190	.477	171
7	Chest food freezer	0.567	205	.510	185

As a result of this change, the direct relationship of the energy efficiency grade calculation and MEPS was weakened compared to the 2003 approach. To achieve a similar range of efficiency grades, then, required that the percentage ranges for the energy efficiency index be lowered as well from the 55% to 100% range used in 2003. Under this proposal, to achieve grade 1 status, a class 5 refrigerator would need to achieve an energy efficiency index of 35% (i.e. consuming 35% or less energy than the 2003 minimum standard excluding adjustments for adjustable chillers and small volume refrigerators), while the least efficient would be limited to an energy efficiency index of 80%, or consuming 80% of the allowable in the 2003 standard (excluding adjustments for adjustable chillers and small volume refrigerators). The comment draft efficiency "bins" were also revised from the 2003 standard. Starting with grade 1, each bin included 10 percentage points of range, except for the lowest grade 5 bin, which was expanded to include 15 percentage points of range.

Table 4 Energy Efficiency Grades, Comment Draft

Energy-Efficiency Grade	Energy Efficiency Index	
	Refrigerator/Freezer (Class 5)	Other Classes (1, 2, 3, 4, 6, 7)
1	$\eta \leq 35\%$	$\eta \leq 45\%$
2	$35\% < \eta \leq 45\%$	$45\% < \eta \leq 55\%$
3	$45\% < \eta \leq 55\%$	$55\% < \eta \leq 65\%$
4	$55\% < \eta \leq 65\%$	$65\% < \eta \leq 80\%$
5	$65\% < \eta \leq 80\%$	$80\% < \eta \leq 90\%$

This approach using two sets of coefficients to calculate the MEPS and the energy efficiency index created some confusion, and the approach to calculating energy efficiency grades weakened the meaning of the percentage ranges. Grade 1 refrigerators were no longer defined as consuming only "*a percentage of the minimum allowable*," but as consuming only "*a percentage of 80% of the minimum allowable*." Moreover, some manufacturers expressed concern over the apparent restrictiveness of the upper-end of the range, claiming that too few models could meet grade 1 requirements under the proposed 35% or less proposal.

This cumbersome approach requiring two calculations (one for MEPS, one for the information label) was abandoned in the second review draft of the thresholds. In this draft, the separate M and N values for the MEPS calculation was dropped in favor of the explicit percentage reduction from the 2003 values as was adopted in the calculation of the threshold values. For example, for class 5 refrigerators, the earlier M=0.558, N=218 was expressed as 0.8 x (0.697, 272); the resultant MEPS values remained unchanged. This approach allowed the use of one calculation to determine both the MEPS and the energy efficiency index.

The review-draft thresholds slightly relaxed the upper end of the efficiency range, bringing it to 40% to class 5 refrigerators and 50% for the other classes. Similarly, the lowest grade 5 was narrowed in range from 15 percentage points to 10 points, bringing each bin range into equality (Table 5).

Table 5 Energy Efficiency Grades, Review Draft

Energy-Efficiency Grade	**Energy Efficiency Index**	
	Refrigerator/Freezer (Class 5)	Other Classes (1, 2, 3, 4, 6, 7)
1	$\eta \leq 40\%$	$\eta \leq 50\%$
2	$40\% < \eta \leq 50\%$	$45\% < \eta \leq 60\%$*
3	$50\% < \eta \leq 60\%$	$55\% < \eta \leq 70\%$*
4	$60\% < \eta \leq 70\%$	$65\% < \eta \leq 80\%$*
5	$70\% < \eta \leq 80\%$	$80\% < \eta \leq 90\%$

*as printed

No further comments from industry or other stakeholders were received after the review draft was issued, so the final levels for the thresholds were set in October 2007. These are essentially the same ranges as in the review draft, but with the inconsistencies of the range for other classes of refrigerators corrected (Table 6).

Table 6 Energy Efficiency Grades, Final Draft

Energy-Efficiency Grade	Energy Efficiency Index	
	Refrigerator/Freezer (Class 5)	Other Classes (1, 2, 3, 4, 6, 7)
1	$\eta \leq 40\%$	$\eta \leq 50\%$
2	$40\% < \eta \leq 50\%$	$50\% < \eta \leq 60\%$
3	$50\% < \eta \leq 60\%$	$60\% < \eta \leq 70\%$
4	$60\% < \eta \leq 70\%$	$70\% < \eta \leq 80\%$
5	$70\% < \eta \leq 80\%$	$80\% < \eta \leq 90\%$

Finally, the relationship to the voluntary energy efficiency endorsement label needed to be defined. Keeping with the relationship between the two labels established in 2005, the energy efficiency specification for the endorsement label was defined as $\eta = 50\%$ for class 5 refrigerators, and $\eta = 60\%$ for classes 1, 2, 3, 4, 6, and 7. Although now expressed in terms of the energy efficiency index instead of category thresholds, the energy efficiency specifications for the endorsement label retain coverage of both grades 1 and 2 of the information label.

2.3 Comparison to International Labeling and Standard Requirements

2.3.1 European Union

The European Union (EU) mandatory energy labeling program for household electrical appliances was introduced in September 1992 through the European Council Directive 92/75/EEC. As the predecessor to China's mandatory energy information label, EU's labeling scheme for refrigerators uses a similar energy efficiency categorization approach. Specifically, the refrigerator label uses 7 bins, ranging from A (the most efficient) to G (the least efficient). However, the EU categorization system is not based on a minimum energy performance standard, but rather uses an energy efficiency index based on the standard annual energy consumption of an appliance. As a result, the EU categorization differs from the Chinese categorization in that its Class E through G refrigerators have indexes greater than 100%.

The EU energy efficiency index is defined as:

$(AC / SC\alpha) \times 100$ where:

AC = annual energy consumption of the appliance
$SC\alpha$ = standard annual energy consumption α of appliance

The $SC\alpha$ in turn is calculated using the EU M and N coefficients (see Table 7 below).

Table 7 Coefficient Values for EU Standard Annual Energy Consumption

Category	Type of Appliance	Mα	Nα
1	Household refrigerators, without low temperature compartments	0.233	245
2	Household refrigerator/chillers, with compartments at 5 Â°C and/or 10 Â°C	0.233	245
3	Household refrigerators, with no-star low temperature compartments	0.233	245
4	Household refrigerators, with low temperature compartments *	0.643	191
5	Household refrigerators, with low temperature compartments **.	0.45	245
6	Household refrigerators, with low temperature compartments ***.	0.777	303
7	Household refrigerator/freezers, with low temperature compartments *(***).	0.777	303
8	Household food freezers, upright	0.539	315
9	Household food freezers, chest	0.472	286

Source: Commission Directive 94/2/EC of 21 January 1994

Table 8 outlines the distribution of efficiency among the EU labeling classes:

Table 8 EU Label Thresholds, 1992 – 2003

Energy Efficiency Index	Energy Efficiency Class
55 > I	A
75 > I > 55	B
90 > I > 75	C
100 > I >90	D
110 > I > 100	E
125 > I > 110	F
I > 125	G

Source: Commission Directive 94/2/EC of 21 January 1994

For cold appliances, the EU Energy Label program proved to be very effective in market transformation with rapidly rising market shares of A class appliances in recent years. About 20% of refrigerators and freezers sold in 2000 were in the most efficient A class, with proportions greater than 50% in some markets (Lebot 2004). In order to continue the labeling program's effectiveness in increasing the energy efficiency of refrigerators and freezers, Directive 2003/66/EC was introduced in July 2003 to create two additional classes without changing the M and N coefficients. The more efficient classes of A+ and A++ were introduced in this directive as an interim arrangement until a comprehensive revision of energy labeling is conducted.

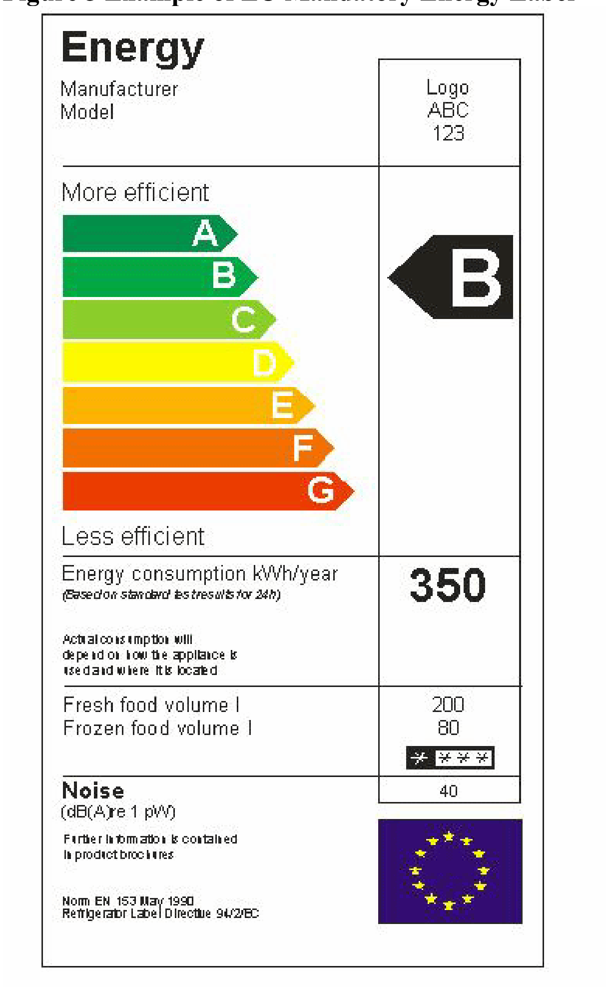
Table 8: Additional EU Energy Efficiency Classes effective July 2003

Energy efficiency index α (Iα)	"Energy efficiency class"
30 > Iα	A ++
42 > Iα ≥ 30	A+
Iα ≥ 42	A to G (same as previous)

Source: Commission Directive 2003/66/EC of 3 July 2003

In terms of the label itself, the other differences from the Chinese label is that the EU label shows energy consumption per year, not per day, and includes noise level of the refrigerator (Figure 5).

Figure 5 Example of EU Mandatory Energy Label



2.3.2 United States

The US mandatory energy labeling program was developed and implemented by the Federal Trade Commission in 1980. The energy standards, developed by the Department of Energy, for refrigerators and freezers are base unit energy consumption (UEC) calculated from equations by product class and adjusted volume. In 2001, the energy standards equations for maximum energy use were revised through introduction of stricter M and N coefficients for each product class (Figure 6).

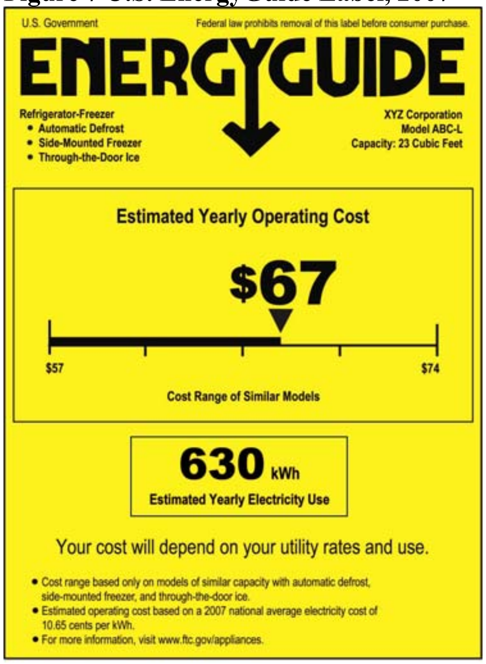
Figure 6 US Maximum Energy Use Standards

Product class	Energy standards equations for maximum energy use (kWh/yr)	
	Effective January 1, 1993	Effective July 1, 2001
1. Refrigerators and Refrigerator-freezers with manual defrost	13.5AV+299 0.48av+299	8.82AV+248.4 0.31av+248.4
2. Refrigerator-Freezer—partial automatic defrost	10.4AV+398 0.37av+398	8.82AV+248.4 0.31av+248.4
3. Refrigerator-Freezers—automatic defrost with top-mounted freezer without through-the-door ice service and all-refrigerators—automatic defrost	16.0AV+355 0.57av+355	9.80AV+276.0 0.35av+276.0
4. Refrigerator-Freezers—automatic defrost with side-mounted freezer without through-the-door ice service	11.8AV+501 0.42AV+501	4.91AV+507.5 0.17av+507.5
5. Refrigerator-Freezers—automatic defrost with bottom-mounted freezer without through-the-door ice service	16.5AV+367 0.58av+367	4.60AV+459.0 0.16av+459.0
6. Refrigerator-Freezers—automatic defrost with top-mounted freezer with through-the-door ice service	17.6AV+391 0.62av+391	10.20AV+356.0 0.36av+356.0
7. Refrigerator-Freezers—automatic defrost with side-mounted freezer with through-the-door ice service	16.3AV+527 0.58av+527	10.10AV+406.0 0.36av+406.0
8. Upright Freezers with Manual Defrost	10.3AV+264 0.36av+264	7.55AV+258.3 0.27av+258.3
9. Upright Freezers with Automatic Defrost	14.9AV+391 0.53av+391	12.43AV+326.1 0.44av+326.1
10. Chest Freezers and all other Freezers except Compact Freezers	11.0AV+160 0.39av+160	9.88AV+143.7 0.35av+143.7
11. Compact Refrigerators and Refrigerator-Freezers with Manual Defrost	13.5AV+299[a] 0.48av+299[a]	10.70AV+299.0 0.38av+299.0
12. Compact Refrigerator-Freezer—partial automatic defrost	10.4AV+398[a] 0.37av+398[a]	7.00AV+398.0 0.25av+398.0
13. Compact Refrigerator-Freezers—automatic defrost with top-mounted freezer and compact all-refrigerators—automatic defrost	16.0AV+355[a] 0.57av+355[a]	12.70AV+355.0 0.45av+355.0
14. Compact Refrigerator-Freezers—automatic defrost with side-mounted freezer	11.8AV+501[a] 0.42av+501[a]	7.60AV+501.0 0.27av+501.0
15. Compact Refrigerator-Freezers—automatic defrost with bottom-mounted freezer	16.5AV+367[a] 0.58av+367[a]	13.10AV+367.0 0.46av+367.0
16. Compact Upright Freezers with Manual Defrost	10.3AV+264[a] 0.36av+264[a]	9.78AV+250.8 0.35av+250.8
17. Compact Upright Freezers with Automatic Defrost	14.9AV+391[a] 0.53av+391[a]	11.40AV+391.0 0.40av+391.0
18. Compact Chest Freezers	11.0AV+160[a] 0.39av+160[a]	10.45AV+152.0 0.37av+152.0

Source: US Department of Energy, *TECHNICAL REPORT: Analysis of Amended Energy Conservation Standards for Residential Refrigerator-Freezers*, Oct 2005

Under the U.S. labeling program, manufacturers are required to use Department of Energy standard test procedures to prove the energy use and efficiency of their appliances. The test results are printed on the mandatory yellow EnergyGuide label displayed on refrigerators. Unlike the China label, the U.S. label does not use energy efficiency categorizations for its refrigerators. Instead, the EnergyGuide label provides an estimate of the model's energy consumption on a scale of a range for similar models. Besides a specific model's annual energy consumption, the U.S. label also shows an estimated yearly operating cost based on the national average cost of electricity. After a two-year review by the Federal Trade Commission, a new EnergyGuide Label was released in 2007 with a streamlined look displaying the same information (Figure 7).

Figure 7 U.S. EnergyGuide Label, 2007



In addition to the mandatory energy standards and labeling program, the U.S. also has a voluntary Energy Star labeling program for efficient appliances. Refrigerator models that use at least 15% less energy than required by the federal energy standards qualify for an Energy Star label (USDOE 2005).

2.3.3 Australia

Australia uses a similar scheme for the development of refrigerator MEPS but uses a different mandatory labeling scheme. Australia has had mandatory energy standards since 1980, but introduced stricter MEPS requirements in 2005. The current MEPS requirements are divided into 9 different product groups and based on cut-off levels shown in Table 9.

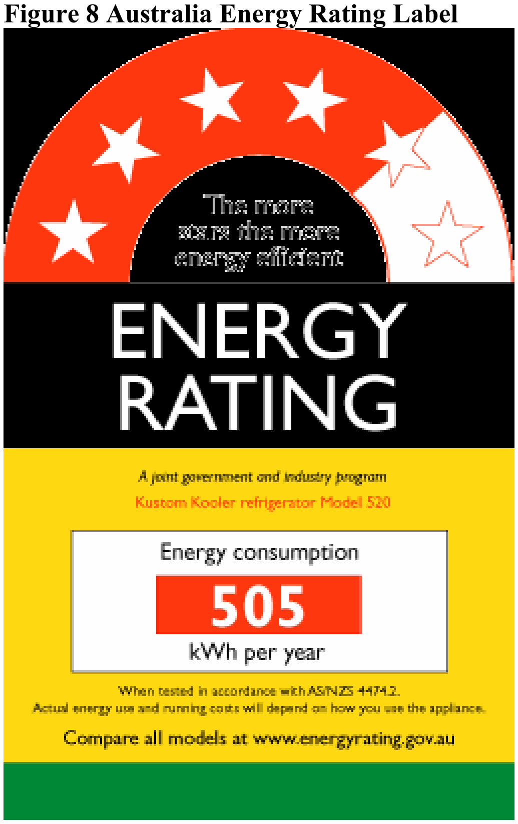
Table 9 Australia MEPS Requirements, 2005

Group	Type of Appliance	Mα	Nα
1	Refrigerator without a low temperature compartment, automatic defrost.	0.335	278
2	Refrigerator with or without an icemaking compartment, manual defrost	0.29	289
3	Refrigerator with a short or long term frozen food compartment, manual defrost	0.344	283
4	Refrigerator-freezer, fresh food compartment is automatic defrost, freezer manual defrost ("partial automatic defrost")	0.33	277
5B	Refrigerator-freezer, both compartments automatic defrost (frost free), bottom mounted freezer	0.357	411
5T	Refrigerator-freezer, both compartments automatic defrost (frost free), not side by side configuration or bottom mounted freezer (ie top mounted freezer)	0.357	311
5S	Refrigerator-freezer, both compartments automatic defrost (frost free), side by side configuration	0.169	569
6U	Separate vertical freezer, manual defrost	0.298	281
6C	Separate chest freezer, all defrost types	0.483	190
7	Separate vertical freezer, automatic defrost (frost free)	0.478	356

Source: Requirements for Refrigerators and Freezers - Minimum Energy Performance Standards (MEPS), http://www.energyrating.gov.au/rf2.html

Australia's energy rating label was first introduced in 1986 in New South Wales and Victoria and is now mandatory nationally for refrigerators and freezers. In 2000, the Energy Rating Label was revised for stricter energy efficiency standards and additional revisions are currently under review. While Australia's label also shows the energy consumption level for each model, it is markedly different from China's label in that it uses a base energy consumption and 6-star rating system (Figure 8). (EnergyRating 2007)

Figure 8 Australia Energy Rating Label



For refrigerators, the Base Energy Consumption (BEC) defines the lowest "1 star" baseline for a particular model. In general, the MEPS cut-off level is approximately equal to the 1 star level. An additional star is then awarded when the annual energy consumption of a model is reduced by a defined percentage from the BEC. For example, if the energy reduction factor per star was 20% (as is the case for Groups 2, 3, 6U and 7), then an annual energy consumption that was 0.8 of the BEC or less would achieve 2 stars (Table 10).. Similar, an annual energy consumption of 0.64 (0.8 x 0.8) of the BEC or less would achieve 3 stars and so forth. Therefore, greater number of stars on a model's energy label is used to show its higher energy efficiency.

Table 10 Australia Energy Label's Energy Reduction Factors for Star Ratings

Group	Energy Reduction Factor (ERF) for Star Ratings
1	0.14
2	0.20
3	0.20
4	0.23
5B	0.23
5T	0.23
5S	0.23
6U	0.20
6C	0.17
7	0.20

Note: 5B: bottom-mount; 5T, top-mount; 5S side-by-side; 6U vertical freezer; 6C chest freezer
Source: Requirements for Refrigerators and Freezers - Minimum Energy Performance Standards (MEPS), http://www.energyrating.gov.au/rf2.html

2.3.4 South Korea

South Korea also has MEPS for its refrigerator and other appliance products. However, it has significantly fewer product groups with the only defined categories being refrigerator, refrigerator and freezer under and above an adjusted volume of 500 liters. South Korea's energy standard is based on monthly maximum power consumption standards for each of the three product divisions. The most recent maximum power consumption standards are from January 2001, with the exception of new revisions in April 2002 for refrigerators and freezers with adjusted volume of greater than 500 liters (Table 11).

In January 2004, South Korea replaced its maximum power consumption standards with target energy performance standards (TEPS). The new TEPS levels are stricter levels of the maximum power consumption standards, and are used to for South Korea's energy efficiency rating system.

Table 11 South Korea Target Energy Performance Standards, 2004

Classification	M	N
Refrigerators	0.444	201
Refrigerator-freezers under the AV 500ℓ	0.300	353
Refrigerator-freezers above the AV 500ℓ	0.516	194

Note: M and N coefficients converted from monthly value to annual values
Source: KEMCO, Energy Efficiency Programs, http://www.kemco.or.kr/english/sub03_energyefficiency_sub03.asp

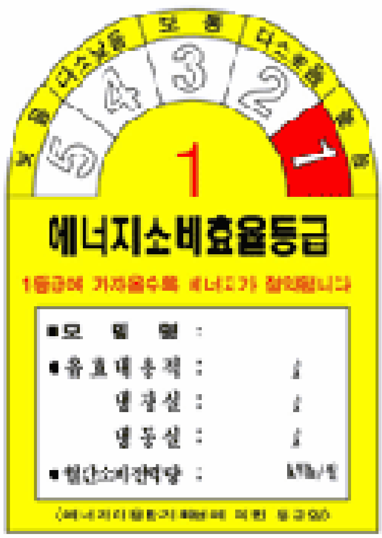
Like China, South Korea's rating system is also divided into 5 categories or grades, with grade 1 being the most efficient and 5 being the least efficient (Table 12). But unlike China, South Korea's grade index for efficiency is calculated as the model's monthly power consumption over the model's TEPS level. Consequently, grade 1 applies for all models able to meet or consume less energy than TEPS while grade 2 through 5 is for refrigerators with energy consumption levels that exceed TEPS at 20 percentage-point increments. As seen in Figure 9below, South Korea's label is similar to Australia but different from China in the use of a circular- rather than step-rating scale.

Table 12 South Korea's Energy Efficiency Index and Grading Scale

Grade Grant Index	Grade
R ≤ 1.00	1
1.00 < R ≤ 1.20	2
1.20 < R ≤ 1.40	3
1.40 < R ≤ 1.60	4
1.60 < R ≤ 1.80	5

Source: KEMCO, Energy Efficiency Programs,
http://www.kemco.or.kr/english/sub03_energyefficiency_sub03.asp

Figure 9 South Korea's Energy Label



Source: KEMCO, Energy Efficiency Programs,
http://www.kemco.or.kr/english/sub03_energyefficiency_sub03.asp

2.3.5 Japan

Details of Japan's program are available in Appendix A.

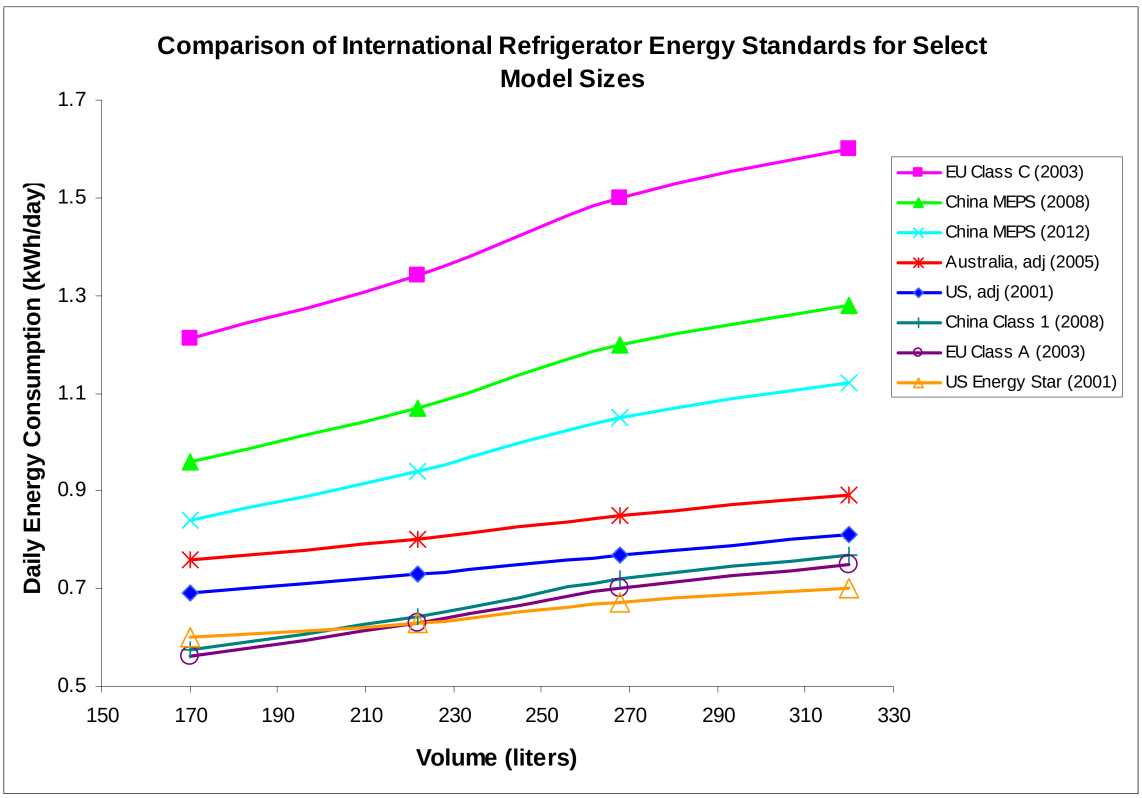
2.3.6 Quantitative Comparison of International Standards

Using the existing standards for Europe, the U.S., and Australia, a quantitative comparison of four different refrigerator model sizes was conducted to better understand how China's 2008 and 2012 proposed MEPS and information label thresholds compare on the international level. More specifically, a comparison of the daily energy consumption under each national standard was conducted for four household refrigerator models with manual defrost at 170, 222, 268 and 320 liter sizes.

For the daily energy consumption calculations, the standard used for each country was based on the following assumptions. For EU, Class 7 refrigerator/freezer with energy efficiency index of 90 for Class C threshold and index of 42 for Class A threshold were used. For the U.S., Class 1 refrigerator minimum standard and Energy Star's 15% reduction in energy consumption threshold was used. For Australia, Refrigerator Group 3 and the MEPS threshold was used.

Due to its different testing procedures, figures for Japan's top runner label standard were not included in this analysis. Japan's use of two different weighted ambient temperature tests does not allow direct comparison with results from other test procedures (see Appendix A). Similarly, the Korean figures have also been excluded because their test procedure includes an ambient temperature of 30°C. In addition, because of the difference in test procedures between China and the US and Australia, a 21% average adjustment was made to the US and Australian figures to account for the difference in ambient test temperatures (32°C in the US, 25°C in China). This adjustment is based on rounds of testing done in the 1990s of Chinese models using both ISO and US test procedures (Figure 10).

Figure 10 Comparison of International Refrigerator Energy Standards for Select Model Sizes



Notably, China's 2008 class 1 requirement puts it very close to the efficiency requirements under the EU class A and US Energy Star programs and exceeds the US 2001 MEPS, one of the most stringent in the world at the time. Indeed, at these smaller refrigerator sizes, bringing the most efficient Chinese models into world-class levels of efficiency demonstrates a dramatic improvement in the Chinese refrigerator industry over the past 15 years.

3 Market Assessment

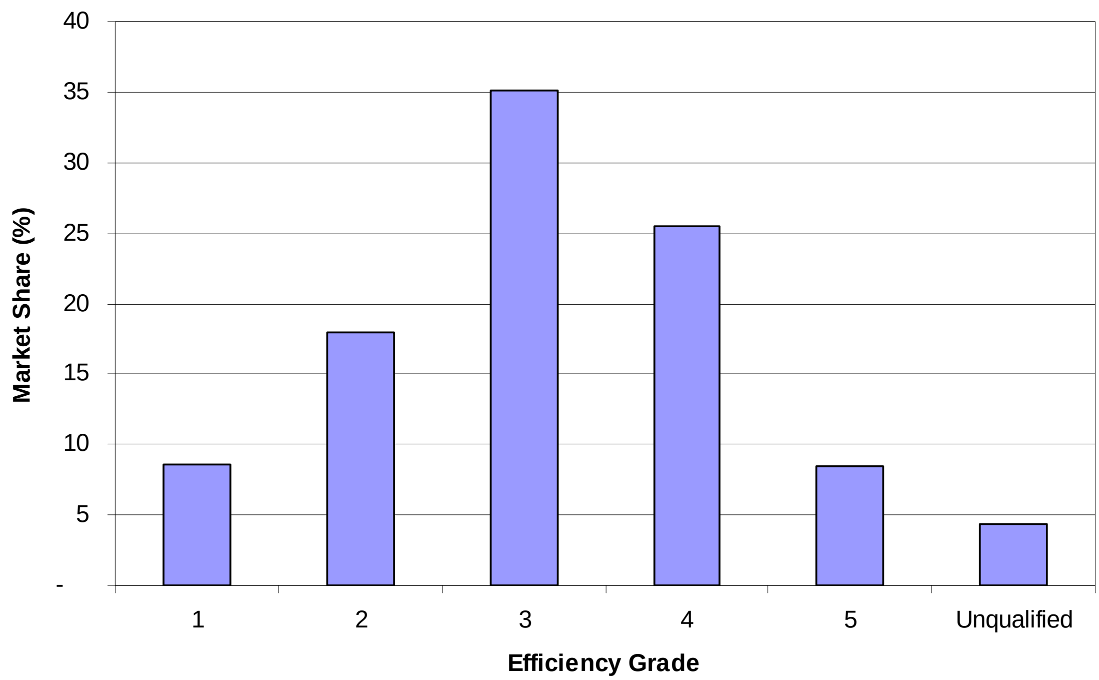
3.1 Market Share By Existing Efficiency Classifications

The purpose of the information label is to provide consumers with data on which to make informed choices and to encourage purchase of the most efficient models on the market. Similarly, it provides a transparent method of communicating energy efficiency performance to the market, encouraging manufacturers to increase efficiency to higher thresholds. They also encourage retailers to display efficient models and can be used as a selling point at the retail level. Finally, the label can be used in other programs, such as education, DSM, or incentive programs to expand the purchase of energy-efficient products (CLASP 2005).

The effectiveness of the label in achieving these goals, however, depends in part on how well it represents the range of efficiencies on the market. If the majority of models qualify for grade 1, for example, then little information is provided to the consumer to distinguish between the various models and to find one that is most efficient. Indeed, after China's initial launch of the 2005 refrigerator label, efficiency gains in the sector since the MEPS was implemented in 2003 were such that over 60% of the models on the market fell into grades 1 and 2, thus diminishing the impact both of the information label and of the related voluntary energy efficiency endorsement label.

Currently, China's refrigerator market displays a fairly normal distribution of efficiency among efficiency grades. Using the new thresholds, refrigerators achieving the new top grade account for about 8.6% of the market, while those meeting grade 2 account for another 18% of the market (Figure 11). Grades 1 and 2 combined constitute the qualified efficiency levels for China's voluntary energy efficiency label. The market share of the two levels, at 26.6%, suggests this is an appropriate starting point to distinguish the best performing refrigerators from the rest of the market and to provide a target for other manufacturers to reach. The voluntary labeling program in China, like US Energy Star, targets the top 25% of the market.

Figure 11 Market Share by Efficiency Grade using 2008 Thresholds



Note: "Unqualified" denotes models that did not meet MEPS requirements

3.2 MARKET SHARE BY SIZE

The changing market share of different capacity refrigerators in China also impacts the potential savings from market transformation. As Chinese residents have become wealthier, there has been a sustained shift towards buying larger refrigerators, thus offsetting some of the absolute savings from new efficiency standards and labeling grades. Three major size categories constitute the bulk of Chinese refrigerator purchases: 170 liters, 220 liters, and 270 liters. In 2007, the 170 liter refrigerators accounted for 15% of sales (down from nearly 100% for 170 liter and smaller refrigerators in the early 1990s), while 220 liter refrigerators accounted for the vast majority of sales, at 64% of the total. The remaining 21% included the 270 liter sizes and larger. Current trends suggest that the 170 liter size refrigerator will continue to decline in share, while that of the 270 liter size refrigerator will increase. Indeed, there is even a small but growing volume of purchases for refrigerators greater than 500 liters in capacity. For the first time, the 2008 standard includes refrigerators in this size category.

4 National Energy Savings and Pollution Impacts

4.1 METHODOLOGY

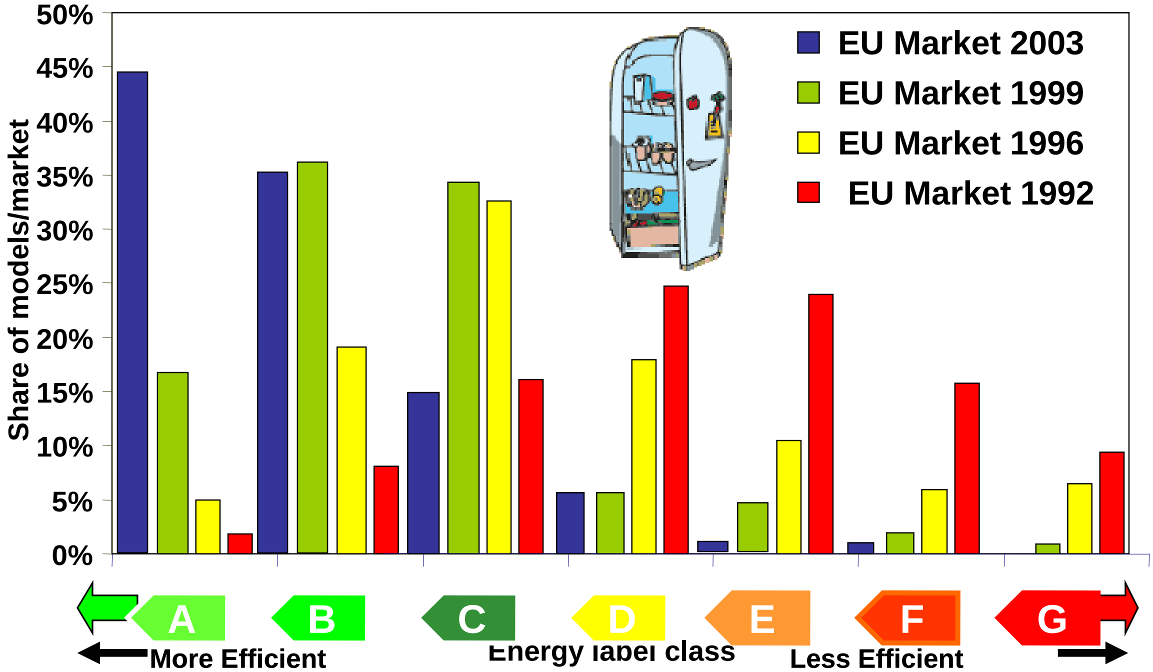
Calculation of the estimated future energy savings from China's information label presents several challenges. In the absence of a comprehensive program for label evaluation, current information is insufficient to indicate how the distribution of models by efficiency level has changed because of the label.[3].Further, no national analyses have been undertaken to try to assess the impact of the label in any distribution shift. Because China's label is modeled after the EU energy label, it is possible, however, to reference studies on the impact of the EU label on the refrigerator market and, from this, develop certain assumptions of a parallel process happening in China's refrigerator market and to assess the impact of such a transformation.

The EU label was launched in 1993. It covers 7 classes compared to China's five, and, in contrast to China, the bottom class was not linked to refrigerator MEPS, which was not mandatory at that time. As such, the market shift over the first years of its existence may be largely attributed to the impact of the label on residents' buying behavior.

After 1999, EU refrigerators became subject to MEPS, which excluded many models mainly below the EU "D" grade of the label. Since that time, the shift to higher efficiency levels has continued, and now refrigerators in Classes A (including A+ and A++) and B constitute nearly 80% of the market (Figure 12).

[3] See Lin and Fridley, *Accelerating the Adoption of Second-Tier Reach Standards for Applicable Appliance Products in China,* CLASP, 2007 for a discussion of the situation of refrigerator efficiency distribution prior to and after the label launch in 2005. This study found that the label did assist in removal of non-MEPS compliant models from the market and stimulated the move to grade 1 and 2 refrigerators in the market.

Figure 12 Impact of EU Label on Cold Appliance Market



Source: Lebot, Benoit, "European Union: Cumulative experience from a mixture of voluntary & mandatory policy approaches" IEA Workshop on Energy Efficiency Standards and Labelling, Bangalore, Oct 2004

The dramatic market shift attributed to the EU label suggests that China's label could play a similar role for the Chinese market. In this analysis, we have taken the EU experience as the starting point for projecting the market transformation impacts from China's refrigerator label through 2020.

Using the market distribution of efficiency in 2007 based on the 2008 requirements, the market share of each efficiency level is shown in Table 13. The rise in the Ordinary grade of refrigerators and decline in the Super-Efficient grade stems from the further tightening of MEPS requirements in 2012, when the efficiency grades of the label will be shifted by a further 10%. Part of the grade 2 refrigerators (Super-Efficient) move to grade 3 (Efficient), and some of the grade 4 (Efficient) models move to grade 5 (Ordinary), while some grade 5 refrigerators are removed from the market altogether.

Table 13 Market Share by Label Efficiency Levels

	2008	2012	2020
Frozen Case			
Super Efficient	27%	19%	19%
Efficient	61%	61%	61%
Ordinary	13%	20%	20%
Market Transformation Case			
Super Efficient	27%	33%	79%
Efficient	61%	60%	20%
Ordinary	13%	7%	2%

Note: Shares do not always add to 100% owing to independent rounding

By 2020, it is expected that there will remain a steady market demand for the lowest class of efficiency because of the continued expansion of the rural market where first costs are likely to remain a dominant consideration in purchase, either of a new refrigerator or one transferred from urban areas as a retirement. This latter practice, however, is being discouraged.

By 2020, it is expected that the average size of refrigerators will increase, with fewer 170 liter models and a higher proportion of 270 liter sizes. This trend, by itself, would tend to increase energy consumption because of the higher allowable consumption of larger models. Because rural users are expected to continue to demand the 170 liters models, demand for these is unlikely to disappear by 2020. Thus, we assume this size category will constitute 7% of new sales. Similarly, sales of the 220 liter models are expected to drop to 45% of the total, and that of the 270 liter models rise to 48% of the market.

The new 2008 MEPS with its second tier requirements in 2012 will increase efficiency of all sizes of refrigerators. Based on the efficiency distribution and the size categories, we have calculated average UECs for each model size at the three levels of efficiency tracked in the model, as show in Table 14

Table 14 Refrigerator UEC Values

	2008			**2012**		
kWh/year	**170-liter**	**220-liter**	**270-liter**	**170-liter**	**220-liter**	**270-liter**
Ordinary	351	391	436	307	342	382
Efficient	281	313	349	246	274	306
Highly Efficient	228	254	283	200	222	248

With these basic parameters as inputs, the model tracks each vintage of refrigerator out to 2020 and calculates the total energy consumption of the entire stock.

4.2 Potential Energy Savings

The results of the model demonstrate that the energy information label can potentially provide substantial energy and emissions savings (Figure 13). As of 2007, China's refrigerators consume in total about 96 TWh of electricity and the trend remains strongly upwards. If, during the period of the first tier of the 2008 standard (2008-2012), China's label can produce equivalent results in "pulling" the market towards the sale of higher efficiency models as we saw in the EU between 1993 and 1999, then by 2012, annual savings of electricity would reach 1.2 TWh, or 1.1% less than what would be expected if efficiency distribution did not change (Figure 14 and Table 15). Savings increase rapidly after 2012 until 2018, when sales of "Ordinary" efficiency refrigerators bottom out. Remarkably, the market transformation effects of the label alone could flatten China's refrigerator electricity consumption even as the total stock grows from an estimated 240 million in 2008 to 430 million in 2020.

Figure 13 Total Refrigerator Electricity Consumption

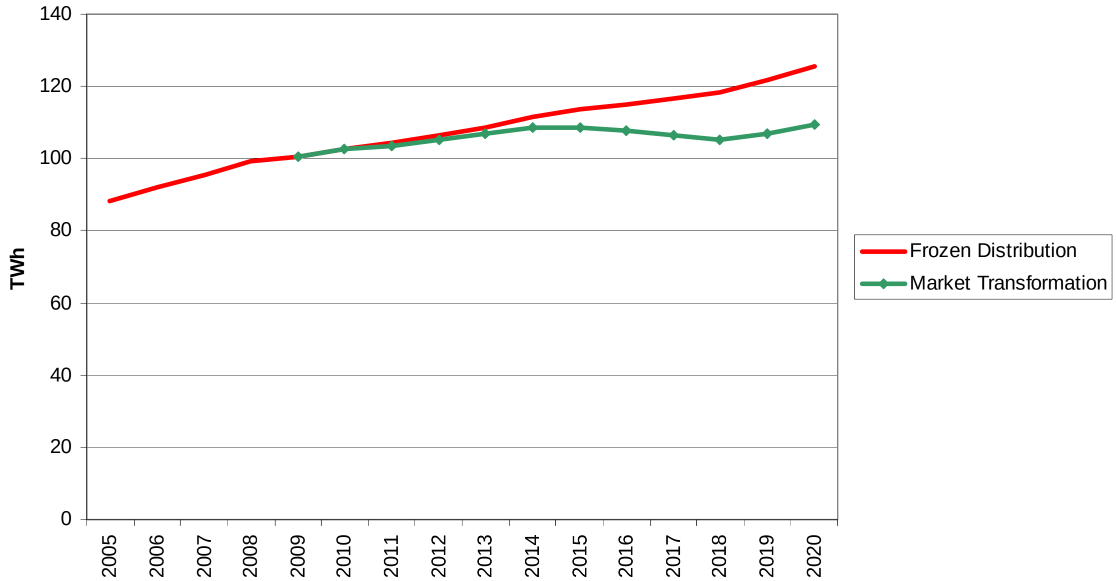
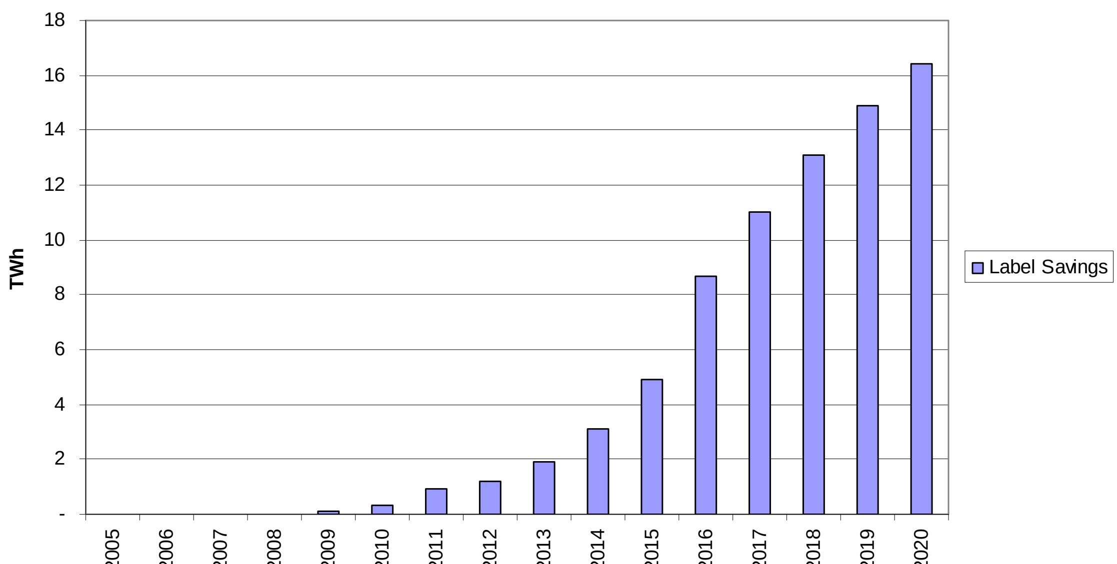


Figure 14 Electricity Savings from Label Market Transformation



By 2020, total annual savings from the label could reach 16.4 TWh, or 13% less than what would have occurred had the distribution of efficiency in the market not changed after 2008. Further, the uptake in total electricity consumption at the end of this period even in the Market Transformation case suggests that further tightening of both minimum efficiency standards and of the label category thresholds along with continued promotion of higher-efficiency labeled products would be needed to keep total electricity consumption from rising again later in the next decade.

Table 15 Refrigerator Electricity Consumption and Savings

TWh/year	2007	2012	2015	2020
Total Electricity: Frozen Distribution	95.6	106.4	113.6	125.7
Total Electricity: Market Transformation	95.6	105.2	108.7	109.3
Savings	-	1.2	4.9	16.4

4.3 POTENTIAL POLLUTION EMISSIONS IMPACTS

Electricity savings from refrigerators translate directly into reductions of other emissions, notably CO_2, SO_2, NO_x, and particulate matter. Because China does not release official emissions factors for the power sector, the coefficients used here were calculated from other sets of Chinese data. For CO_2, we used the time series of average annual heat rate of Chinese thermal power plants from the *China Electricity Yearbook* to calculate a weighted average emissions factor for all generation in China, including hydropower, nuclear, and renewables. Similarly, we used official data on emissions of sulfur dioxide and particulate matter from the electric power sector in the *China Environmental Yearbook* divided by total electricity generation to derive an average emissions factor for those pollutants. At the same time, we forecasted annual average heat rates of power plants to 2020 based on plans for both thermal and other power development, with assumptions about the roll-in of super-critical and ultra-super-critical power plants, and assumed that emissions of other pollutants would decline relative to the improvement in average plant efficiency.

Under a Market Transformation scenario, savings in CO_2 emissions would reach 1.1 million tonnes in 2012 and 14 million tonnes in 2020, or a cumulative 67.5 million tonnes. Similarly, reductions of sulfur dioxide from power plants would reach 6,000 tonnes in 2012 and 76,500 tonnes in 2020, for a cumulative reduction of 368,000 tonnes. NO_x emissions fall by 4,400 tonnes in 2012 and 54,600 tonnes in 2020, for a cumulative savings of 263,000 tonnes. Finally particulate matter emissions would fall by 27,000 tonnes by 2012, rising to 333,000 tonnes by 2020, for a cumulative reduction of 1.6 million tonnes (Figure 15, Figure 16, Figure 17, Figure 18 and Table 16).

Figure 15 Potential CO2 savings in the Market Transformation Scenario

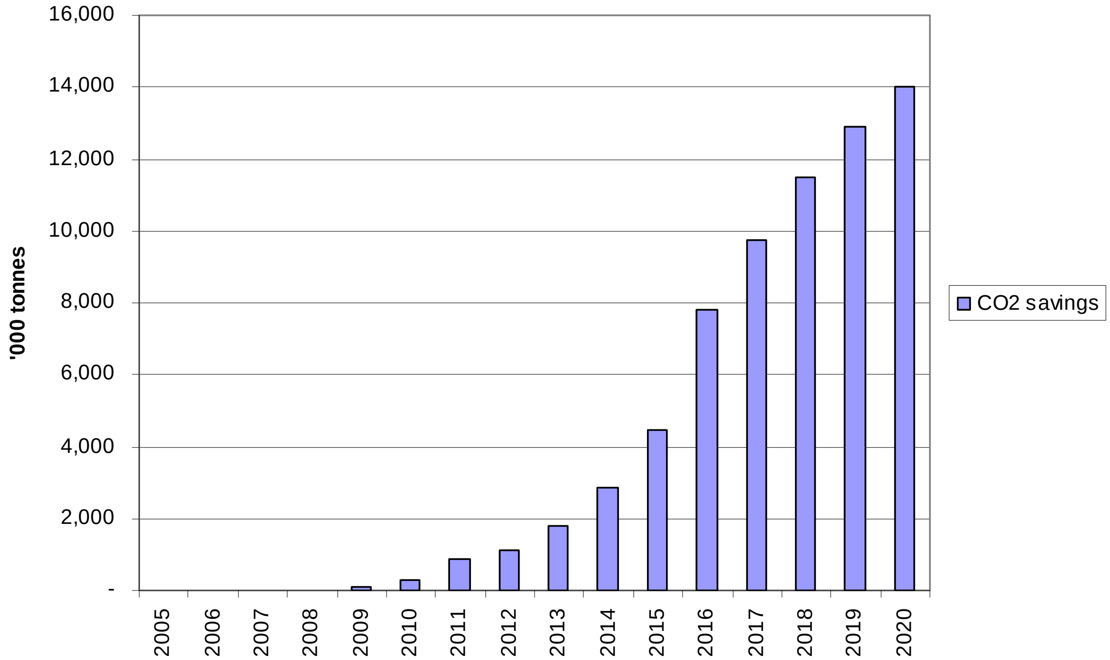


Figure 16 Potential SO_2 Savings in the Market Transformation Scenario

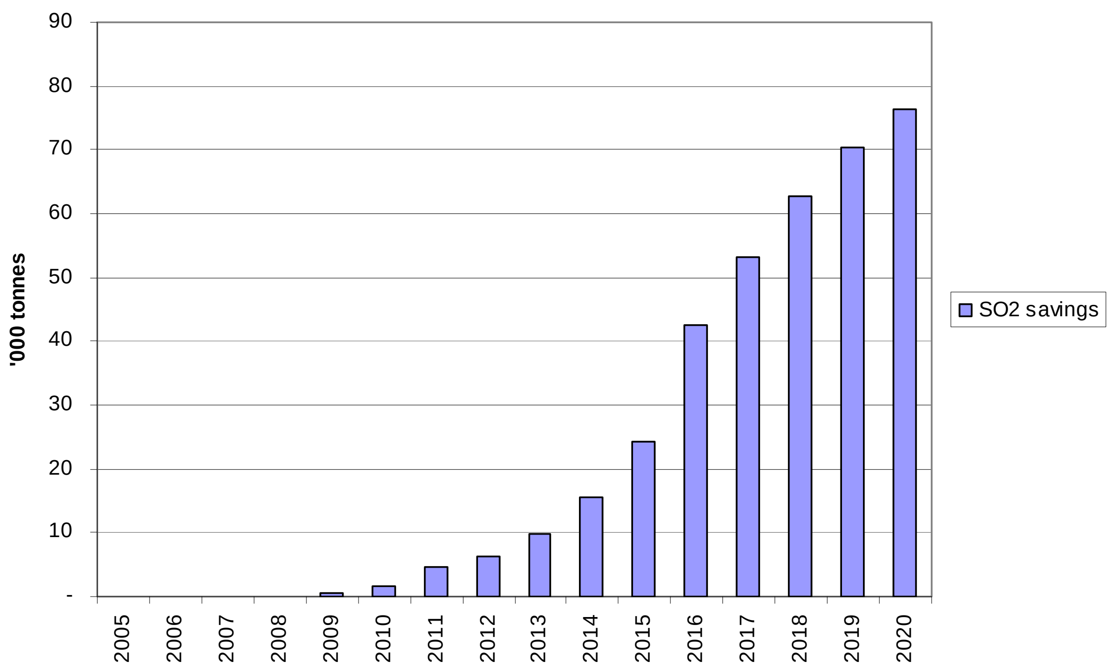


Figure 17 Potential NO_x Savings in the Market Transformation Scenario

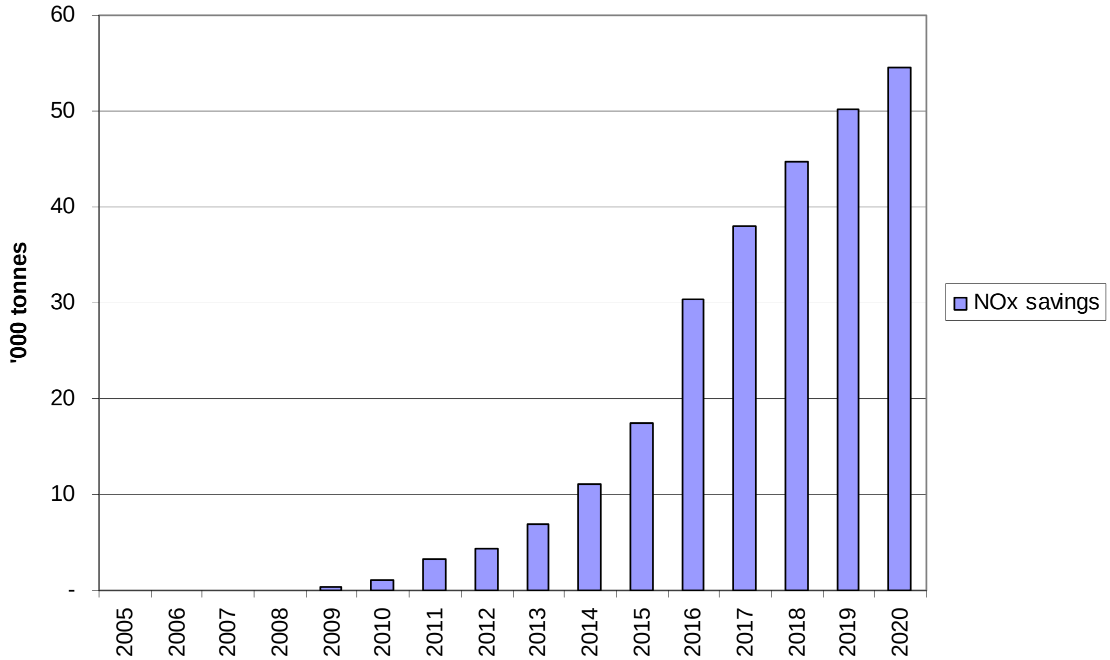


Figure 18 Potential Particulate Matter Savings in the Market Transformation Scenario

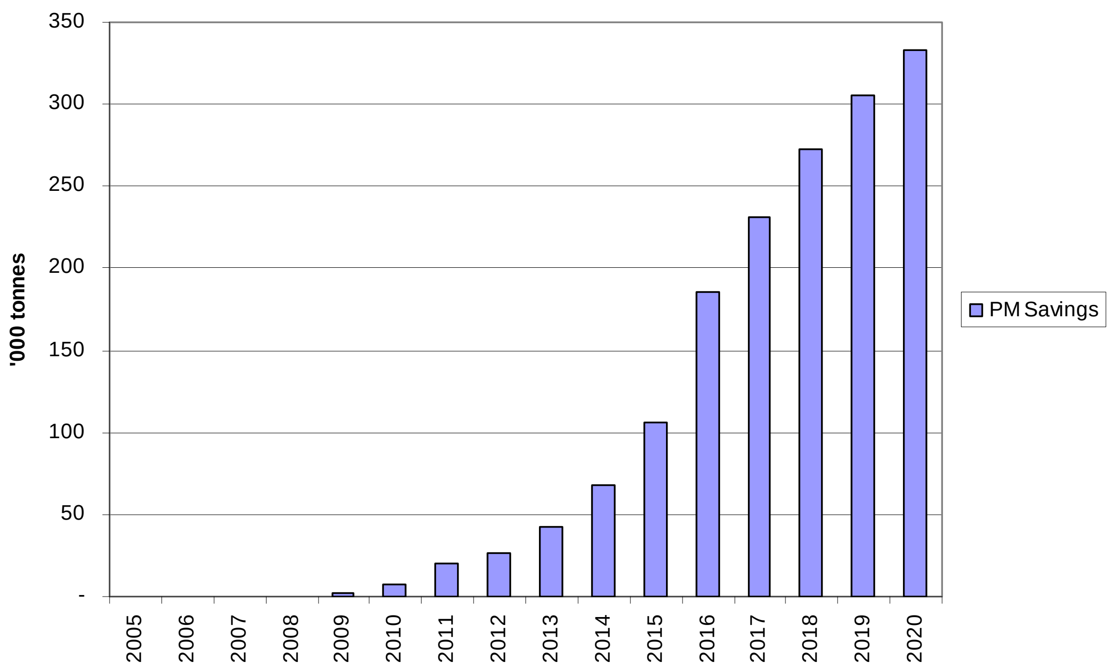


Table 16 Potential Emissions Savings from Market Transformation

thousand tonnes	2008	2012	2015	2020
CO2 Savings	-	1,137	4,463	14,031
SO2 Savings	-	6	24	76
NOX Savings	-	4	17	55
Particulate Matter Savings	-	27	106	333

Although it is not possible currently to estimate the added cost to manufacturers for upgrading the energy efficiency performance of their refrigerators, benefits to refrigerator owners will rise substantially over time as the market shifts to greater efficiency. As shown in Table 17, refrigerator owners would save a modest RMB¥700 million (¥10.8 billion) by 2012, rising to nearly RMB¥10 billion (¥147 billion) by 2020. Additional social savings would be gained from gross power generation capacity savings of up to 3.12 GW by 2020 owing to reduced electricity use.

Table 17 Potential Gross Capacity and Financial Savings

		2008	2012	2015	2020
Capacity Avoided	(MW)	-	228	932	3,120
Consumer Savings	(billion RMB¥)	-	0.7	2.9	9.8
Consumer Savings	(billion yen)	-	10.8	43.9	147.1

5 Conclusions

The energy information label for refrigerators is potentially a powerful tool for promotion of market transformation towards greater refrigerator efficiency. As the Chinese market moves towards saturation over the next 12 years, reducing the impact of the new refrigerators can lead to substantial energy and emissions savings. Looking at the experience of the European Union energy label, China potentially could flatten demand for electricity for refrigerators, even as the total stock in use continues to climb. Billions of yuan in potential savings to residents and in avoided power plant costs over the next 12 years point to the desirability of developing programs today that ensure such savings could be delivered.

Delivering these savings would require programs not only to monitor and enforce labeling accuracy, but also to survey annual shifts in efficiency distribution in the market based on labeling categories to determine the impact of the label. In particular, additional focus should be put on surveying sales models from second- and third-tier distribution channels outside of the major retails centers in large cities to gauge the response of lower-income and rural buyers. On the consumer side, programs to encourage the purchase of top-ranked models through direct promotion of the energy label, or indirectly through promotion of the voluntary energy efficiency endorsement label, which covers grades 1 and 2 of the energy label, could provide additional "push" towards the higher efficiency grades. This could include working directly with retailers to provide education and training in the benefits of high-efficiency refrigerators for consumers, and point of sale and other literature to be provided to the consumer directly. Similarly, the government can put greater emphasis on general education and promotion of the label through national and regional events such as Energy Conservation Day.

Local governments as well can assist in promoting the shift to higher efficiency through incentive programs of their own, such as new methods to provide consumer rebates for the purchase of the highest efficiency models, though such programs are rare in China and would require the identification of an appropriate funding source and mechanism. In their own activities, governments can strictly enforce the newly mandatory government procurement policy that requires the purchase of "certified" (i.e. having achieved qualification for the voluntary endorsement energy efficiency label) models. Because the policy allows local governments flexibility to exceed the national requirements, some cities may find it possible to narrow eligibility to grade 1 alone from grades 1 and 2 at present. This would be, in essence, accelerating the adoption of the next tier of the standard, when the efficiency grades are expected to tighten by a further 10% (or one grade in the label).

The China energy information label is still fairly young and only beginning to be expanded in use to products beyond the core four of refrigerators, air conditioners, clothes washers and unitary air conditioners. As the application of the label expands, developing a solid foundation today for its monitoring, enforcement, and promotion can set the stage for a sustained period of energy and emissions savings for China's economy.

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7 Appendix A: Household Refrigerator Market and Energy Conservation Regulations in Japan

7.1 Introduction

Many countries, including Japan, have introduced energy conservation standards and labeling programs (S&L programs) to achieve energy savings through improving the energy efficiency of equipment. Energy end-use appliances being used mainly the residential and commercial sector, S&L programs are often mistaken to be regulations for the residential and commercial sector, but are actually regulations covering the equipment manufacturing industry. Therefore, S&L programs are expected to lead the development and production of high energy efficiency products through policy measures, for which studies must be conducted with further insights into energy saving elemental technologies. Thus, it is important that the industrial structure of the electric industry be understood.

Furthermore, whereas the measurement of the energy consumption of equipment is essential for the implementation of an effective S&L program, Japan was faced with the challenge of discrepancies occurring between the rated power consumption and actual power consumption of refrigerators. It was because the conventional measurement method could not accommodate the differences in cooling technologies of refrigerators and the power consumption resulting from new alternative functions required by climate and lifestyles .Therefore, Japan revised the method of measurement so that power consumption could be measured based on assumptions close to the actual status of refrigerator use.

This paper will overview the structure of the electric industry in Japan and China to say that structural differences are also important contributing factors in the implementation of energy conservation policy. Next, providing the example of Japanese refrigerators, it will identify the issues brought forth upon measuring power consumption and look at how they were overcome. Finally, it will overview the Top Runner Program and Labeling Program, currently implemented in Japan, with a focus on refrigerators. The structure of Japan's electric industry and the challenges faced regarding measurement are conceived to provide useful suggestions for other countries as well.

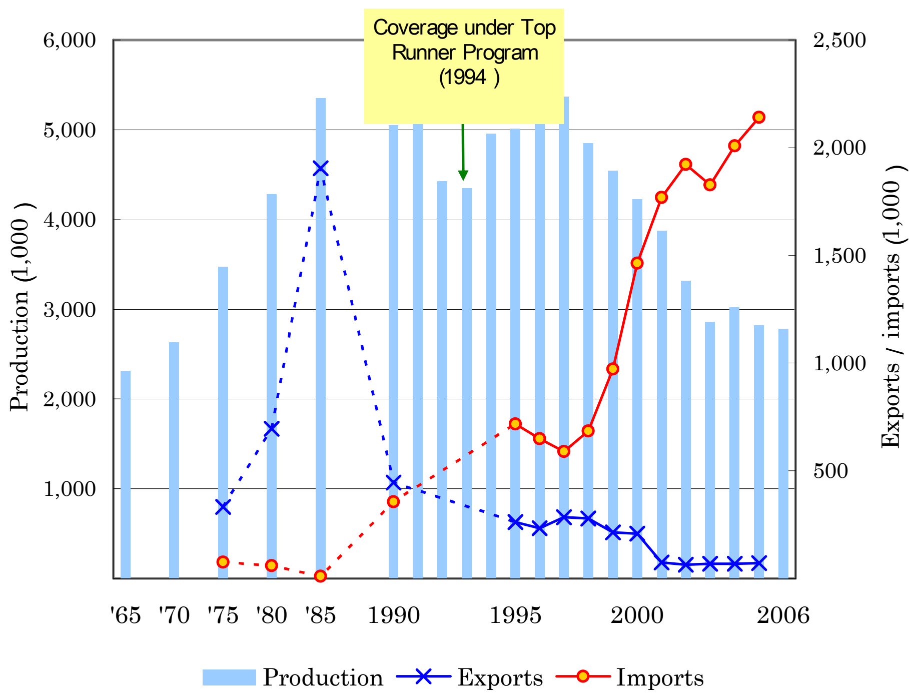
7.2 Japan's Household Electric Refrigerator Market

7.2.1 Production, Imports and Exports of Electric Refrigerators

Figure 19 presents trends in the production, imports and exports of electric refrigerators in Japan. The production volume of refrigerators stood at approximately 5.2 million units in 1991, but fell to approximately 4.3 million units with the close of the bubble economy. Then, the 1997 consumption tax raise to 5% became an incentive for consumer spending, boosting production to approximately 5.3 million units, but it has followed a downwards trend since. Imports marked a temporary decrease in 1997, but has continued to grow steadily, recording approximately 2.1 million units in 2005; whereas, exports marked 0.72 units.

The number of households has been on the increase in Japan, with single-person households the main contributor; thus, refrigerator demand is also conceived to be growing. According to the family income and expenditure survey, the amount of money spent on a refrigerator tends to be smaller in one-person households, compared to two-or-more-person households. The price of a refrigerator depends on the rated internal capacity and additional functions; it can be said that refrigerators with smaller capacity are preferred in single-person households and that models with a wide variety of additional functions tend to be avoided. Imported refrigerators are smaller than domestic models and are not as multi-functional. It is imagined that the preference for imported models of single-person households has served as a backdrop for their increase in imported refrigerators.

Figure 19 Trends in Refrigerator Production, Imports and Exports in Japan



(Source) Japan Electric Machine Industry Association

7.3 Structure of Japan's Electric Industry

Japan's electric industry has been characterized by vertically integrated management, under which the development, production and marketing of a product is all done within a single company, and at the same time, by its wide range of products, from heavy electric machinery to white goods and electric appliances (horizontal integration). This vertically and horizontally integrated management significantly contributed to the industry's growth, but developments in the globalization of the economy have accelerated the shift towards product compatibility (modularization), pressing Japan's electric industry to abandon vertically and horizontally integrated management.

According to Fujumoto (2007), Japan's household appliances industry was able to gain an advantage over overseas manufacturers through component design, linkage between development and production, consistent process management and quality assurance of customer interface. Vertical integration allowed Japanese companies to develop and produce the elemental technology of its products in-house, thus enhancing product differentiation and attracting demand for its products in both domestic and overseas markets. This phenomenon was observed in not only white goods but also in TV sets and video players.

The globalization of the economy has accelerated specialization in particular products and industrial standardization. The Japanese electric industry, whose advantage had been in products differentiation was put under pressure by the trend of "selection and concentration" to shift from vertically and horizontally integrated management to a new business framework; this transition was in response to demands for compatible models (modularization).

According to Marukawa (2005), China, where many Japanese companies expanded, promoted vertically disintegrated management as a national strategy, and thus had to rely on imported core components from overseas manufactures for elemental technologies, such as CRTs and IC chips, in the case of TV sets, and compressors, in the case of air conditioners. Meanwhile, Chinese manufacturers came to specialize in assembling core components with cheap labor. Upon purchasing elemental technologies from other manufacturers, Chinese manufacturers were capable of letting their suppliers compete against each other, and could therefore procure components for a cheaper price. Chinese manufacturers standardized the interface of components so that they could connect core components from different manufacturers, therefore enabling the combination of core components established upon different elemental technologies. This made it possible for them to procure core components at a low cost and thus reduce product prices. With the backdrop of China's industrial policy, many Japanese manufacturers that had expanded into China supply core components to Chinese manufactures and are thus managed by vertical disintegration.

Japan's electric industry, exercising vertically integrated management, is capable of developing and producing energy saving elemental technologies to match product needs, and can encompass extensive information on energy saving elemental technologies and market data. Policy decision-makers can propose policy targets that are realistic in light of current energy saving technology standards, based on the information and data possessed by private companies. However, companies with a vertically disintegrated industrial structure will only have access to limited information and data regarding the components of products; thus, the administrative costs required to promote energy efficiency improvements in appliances through policy measures are conceived to be comparatively high. Therefore, structural differences among electric industries should also be considered upon the implementation of energy conservation policies for electric appliances.

7.4 CHALLENGES EXPERIENCED AND OVERCOME BY JAPAN

7.4.1 Power Consumption of Refrigerators

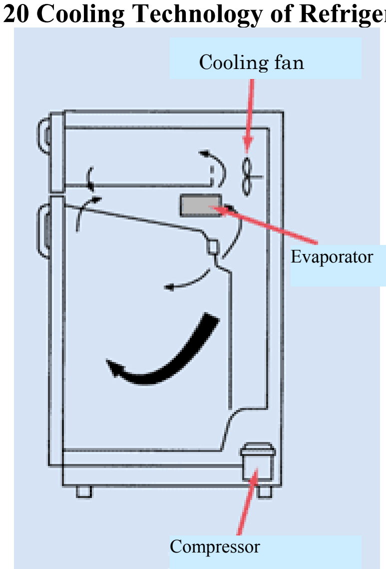
Market Needs and Diversified Functions of Refrigerators

Japan stretches from north to south, covering various climate zones from the sub-frigid zone in the north to the tropical zone in the south. Significant seasonal changes are observed all over Japan; summer begins when the rainy season, or "Tsuyu," starting in late May until late July, ends. With a humidity level of over 70%, Japanese summers are hot and humid compared to those in the European region. The high temperature and humidity of the climate has influenced Japanese lifestyle; for example, traditional Japanese houses are not partitioned with walls but kept airy to let the cool air in.

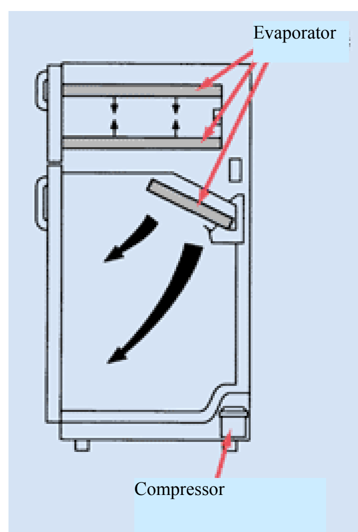
Such climatic differences have had an influence on the cooling technology employed in refrigerators. The hot and humid summer climate causes much frost to form inside refrigerators. Because it is a burden to eliminate frost from refrigerator walls, the availability of defrosting functions and their performance level are important selection criteria in purchasing refrigerators in the Japanese refrigerator market.

The cooling technology most commonly employed in refrigerators sold in Japan is indirect cooling (cold air-forced convection type), in which cold air cooled in a single evaporator is sent into both the freezer and refrigerator using a fan. Developed for the purpose of saving users the trouble of wiping frost, it is also applied in the United States. Refrigerators made in Europe and the US usually employ a direct cooling (cold air-natural convection type) technology, which employs two separate evaporators, one each for the refrigerator and freezer. Figure 20 presents the structure of indirect and direct cooling-type refrigerators.

Figure 20 Cooling Technology of Refrigerators



Cold air-forced convection type



Cold air-natural convection type

(Source) Toshiba website(http://www.toshiba.co.jp/csqa/reizouko/rei02.htm)

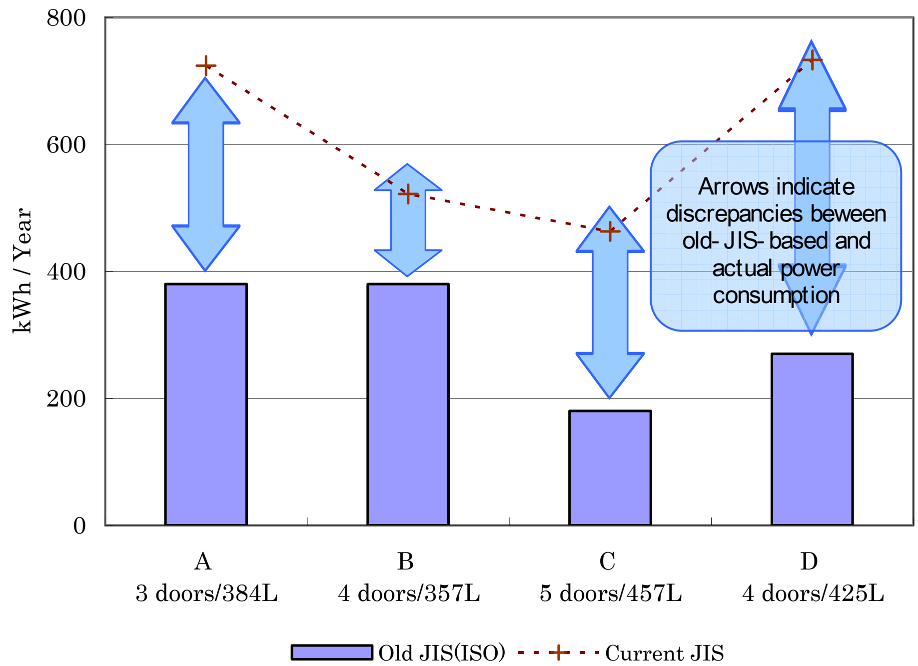
In addition to climatic variation being a factor for the different functions required of a refrigerator, diversified lifestyles are also contributors to increasing functional variety. Today, some refrigerators in the market come with a compartment where the temperature is adjusted especially for vegetables. There are also double-door models, designed to make it easier to take food in and out of the refrigerator; these models are structurally very vulnerable to frost, and thus are equipped with defrost heaters. Furthermore, some refrigerators have heaters for temperature compensation or for the prevention of water freezing in the supply line connected to the ice maker. With the addition of these diverse functions, refrigerators have become more convenient, but have consequently come to consume more power.

Discrepancies between Rated Power Consumption and Actual Consumption

Before measurement methods for refrigerators were revised to JIS C 9801-2006in May 2006, energy consumptions had been measured according to JIS C 9801-1999, which had been formulated in line with the international standard, ISO. The power consumptions calculated based on the old-JIS standard had not accommodated the increased power consumption due to the multifunctionalization of refrigerators and were discovered to differ significantly from the actual amount of power consumed.

Figure 21 displays the result of measurements made for 4 refrigerator units based on both the JIS C 9801-1999 (old-JIS）and actual use. The outcome of the sample study showed discrepancies between measurements employing JIS C 9801-1999 (old-JIS）and actual measurements for all four of the refrigerators. A particularly large difference was observed for the large refrigerator exceeding 400L in capacity. JIS C 9801-1999(old-JIS）had not adequately reflected the actual consumption status. Measurements based on JIS C 9801-2006(new JIS) have also been conducted to prove that calculations done using this method and actual power consumption measurements give extremely near values.

Figure 21 Discrepancies between Old-JIS-based and Actual Power Consumption (Sample Study)



(Source) Nakamura, Jun, H. Sasaki, K. Saito(2007),
(Note) Refrigerators A and B do not have inverters; refrigerators C and D are equipped with inverters

Generally, energy efficiency standard value programs and labeling programs are implemented based on data obtained from energy consumption measurements of electric appliances. Therefore, the discrepancies between measured power consumption (rated power) and actual power consumption undermined the effectiveness of Japan's S&L program. A contributing factor to this problem is conceived to be that the measurement method stipulated in ISO, an international standard, did not accommodated technologies and functions widely used in Japan. As a breakthrough for this issue, the measurement method was revised in May 2006, taking into consideration the types, specifications and functions of household refrigerators (JIS C 9801-2006).

The challenge faced by Japan regarding refrigerators can strike any other country. Electric appliances, the usage and functions of which are liable to change according to climate and lifestyle, have a great potential for such problems. Electric appliances are widely traded in the global economy; if a product is exported to another country with measured results based on measurement methods compatible with international standards, but consumes power in volumes different from what had been displayed at the country of origin, it will constitute a significant barrier for the international achievement of effective energy savings. Thus, it is important for other countries to take note of this issue as well.

Japan has been appealing the significance of measurement methods true to actual status at Project 1 of the Asia Pacific Partnership Building and Appliances Task Force. It seeks similar developments in the framework of the IEA implementing agreement.

7.4.2 New Measurement Methods for Refrigerators

Section 7.4.1 discussed the multifunctionalization of refrigerators and the accompanying problems regarding the measurement method for power consumption. The gap between the rated power consumption and actual consumption occurred because actual use patterns had not been reflected in the measurement method, and therefore the revisions were made in the standards related to the measurement method that had been adopted in Japan.

In order to conduct measurements under conditions closer to that of actual use application, revisions were made to the assumptions used for measurements for refrigerators. For example, measurements were conducted under load, given according to capacity[4] and with additional functions, such as automatic ice-making and deodorant functions, turned on. Furthermore, the number of times the refrigerator door was open and shut during measurement was changed from 25 to 35 times.

Also, in many households, refrigerators are set against a wall; and thus, it was determined that the power consumption of refrigerators would be measured assuming that refrigerators were set 5 centimeters away from the wall. This approach is based on the fact that heat released from the refrigerator bounces off the wall, affecting the set temperature inside the refrigerator. The installation environment of 13 million households has been surveyed to bring assumptions close to the actual status.

In addition to the abovementioned, measurements are to be made for two surrounding temperature patterns, namely 15℃±1℃ and 30℃±1℃[5]. Furthermore, the temperature inside the refrigerator was changed to 4℃, among other revisions to create installation environment close to actual use patterns.

7.5 ENERGY CONSERVATION POLICIES FOR APPLIANCES

7.5.1 Top Runner Program

Overview of Program

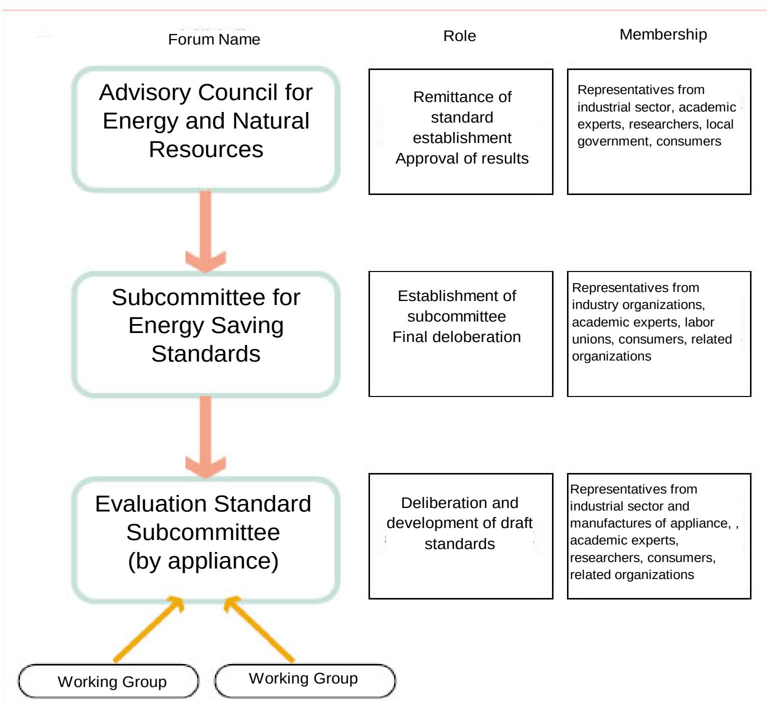
Japan's energy efficiency standards policy is stipulated in "Measures Pertaining to Machinery and Equipment" under the Law Concerning the Rational Use of Energy (Energy Saving Law), which came into effect in April 1999. It is called the "Top Runner" method because target standard values are set based upon the level of the most energy efficient product in the market at the time of determination, reflecting projected technological improvements as efficiency improvements. Manufacturers covered under the program are required to exceed the target standard value (Top Runner standard) with shipment volume-weighted average values of the appliance's efficiency values; the shipment volume is aggregated by category in the target fiscal year specifically determined for

[4]Revisions provide for a PET bottle full of water to be put it the refrigerator before measurement,

[5] Due to diverse climate, in Japan, there are local differences in annual average temperature. Therefore, functions that did not work under conventionally set temperatures would sometimes work in other regions; this was another factor for the deviation from actual use.

each appliance-type. Therefore, this program is not centered only on energy efficiency but also reflects market needs, and is thus designed to allow a product to be supplied to the market even in the event that its energy efficiency falls short of the standard value. The Top Runner standard is determined through deliberation at the Subcommittee on Energy Saving Standards established under the Advisory Council for Energy and Natural Resources, a consultative body to the Minister of Economy, Trade and Industry. An Evaluation Standard Subcommittee is established for each target appliance under the Subcommittee on Energy Saving Standards to conduct technological studies and further technical deliberation. The institutional structure for deliberations on standard values are provided in Figure 22. The committee members represent a wide range of fields, including manufacturers, academic experts, researchers and consumers. The participation of manufacturers is especially important because standard values are debated based on information beginning with energy saving elemental technology to the shipping of products. Relative information and data have been actively disclosed to the public to the extent that it would not undermine competition among manufacturers. This is conceived to be effectively functioning as an incentive not to provide false information and data in an attempt to avoid inconvenient target values from being established.

Figure 22 Process of Establishing Top Runner Standard Values



(Source)The Energy Conservation Center, Japan

Because an appliance can vary in weight, size, performance and functions, categories are established with consideration for these differences in setting Top Runner standards. For example, the larger the monitor size of a TV set, the more energy it consumes. If the Top Runner value was established based on a TV set with a small monitor size, it would be impossible to manufacture TV set of a larger size with power consumption levels under that standard; and hence, the establishment of standard values for each category classified by size.

After the target fiscal year, the Agency of Natural Resources and Energy will obtain information on the number of units shipped and energy consumption efficiency, etc. from manufacturers through reports and hearings. Those manufacturers who, as a result, have been judged to require remarkable improvements in energy consumption efficiency will be offered recommendations. Furthermore, if these recommendations are not followed, provisions for punitive actions (publication of failure, order, penal charges) will be applied.

The Energy Saving Law obligates manufacturers to display energy consumption efficiency, etc. in product catalogues or on products themselves[6]. This is for the purpose of providing consumers with information on energy conservation and with a guide for decisions of purchase. Items to be displayed include energy consumption efficiency, “product name and type,” to specify the product and the “name of the manufacturer” responsible for the display. Punitive actions similar to those for incompliance with efficiency standard values are stipulated for violations of display obligations, as well.

7.5.2 Energy Efficiency Improvements in Refrigerators

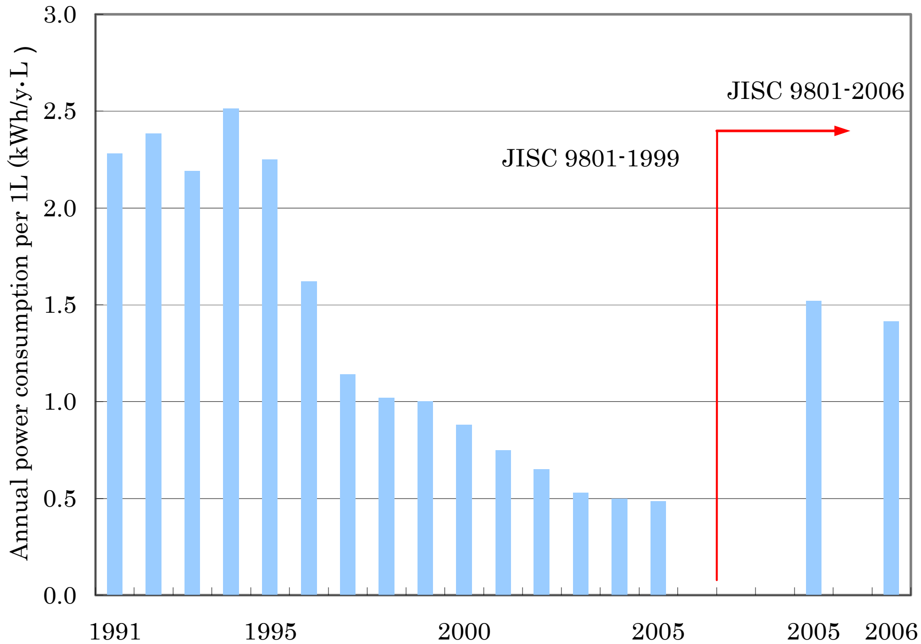
In the case of electric refrigerators, manufacturers or importers who manufacture or import 2,000 units or more are covered by the program. Also, as explained in Section 7.4.1, electric refrigerators and electric freezers vary in technology and internal volume; thus, electric refrigerators (including those combined with a freezer) are divided into 4 categories according to cooling method and rated internal volume.

Electric refrigerators and freezers have been target products under the Top Runner Program since December 1999. It required manufacturers, etc. to achieve target standard values by the target fiscal year 2004, by when, if they had successfully achieved the target standard value, they would have improved their weighted average value of energy consumption efficiency by 30.5% (449.7kWh/year) from the value for Fiscal 1998, which had been 647.3kWh/year. The actual improvements achieved was 55.2% (290.3kWh/year). A new target standard value has currently been determined for a renewed target fiscal year, Fiscal 2010; if manufacturers, etc. achieve the target standard value by the target fiscal year, they will have achieved a 21% improvement from Fiscal 2005.

Figure 23 presents trends in the annual power consumption per 1L starting from 1991. Although a temporary increase was observed in consumption in 1993 and 1994, in response to the total abolishment of the use of chlorofluorocarbons and changes in refrigerants and insulation, power consumption per 1L has been decreasing yearly, proving that efficiency improvements are progressing in refrigerators.

[6]Exclusive of those stipulated under Household Goods Quality Labeling Law

Figure 23 Annual Power Consumption per 1L (kWh/y・ L)



(Source) compiled from material from Japan Electric Machine Industry Association and Handbook of Energy & Economic Statistics in Japan 2007

7.5.3 Labeling Programs

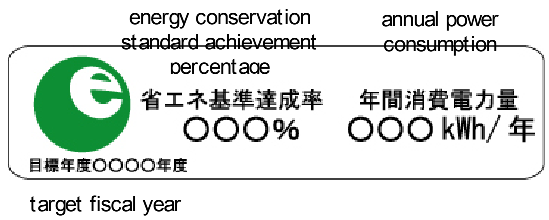
Energy-Saving Labeling Program

In order to promote the popularization of high energy efficiency products, it is important that consumers are provided accurate information on their energy efficient performance; thus, the subject was debated at the Subcommittee on Energy Saving Standards of the Advisory Committee for Energy[7]. It was determined that the following information should be provided to consumers: 1) degree of energy conservation standard achievement ratio, 2) energy conservation standard achievement percentage; 3) energy consumption efficiency; 4) target fiscal year. Against this backdrop, the Energy-Saving Labeling Program was initiated by JIS in August 2000. The Energy Conservation Label currently used is provided in Figure 24.

16 items are covered by the labeling program as of February 2008. The Energy-Saving Labeling Program is a voluntary program based on JIS standards to be used in product catalogues and products themselves.

[7]Advisory Committee for Energy and Natural Resources as of 1991

Figure 24 Energy-Saving Labeling



(Source) The Energy Conservation Center, Japan

Labeling Program for Appliance Retailers (Uniform Energy Saving Label)

The revised Energy Saving Law, which came into effect on April 2006 stipulated a new obligation for retailers to make efforts for information provision. With this, in October the same year, a program was launched for retailers to display energy conservation information of products. Products covered by the program and items to be displayed are shown in Figure 25.

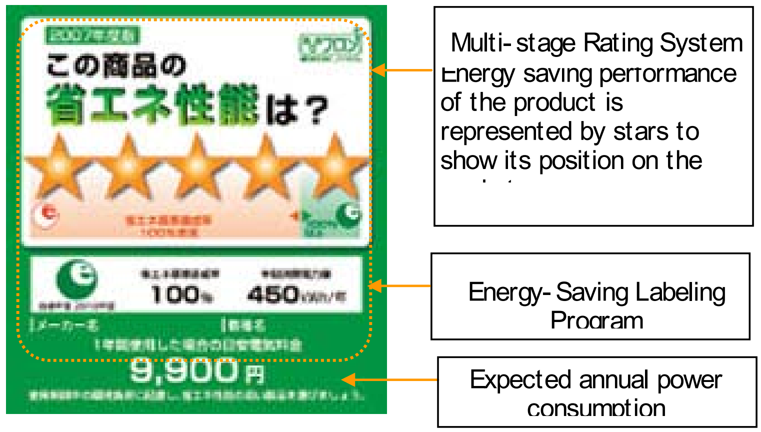
Figure 25 Labeling Program for Appliance Retailers

Product※	Energy- Saving Labeling Program	Multistage rating system (Uniform Energy Saving Label)	Expected electricity bill
Air conditioners	○	○	○
Electric refrigerators	○	○	○
Electric freezers	○		○
Fluorescent lamps	○		○
Electric toilet seats	○		○
TV sets	○	○	○
Computers	○		
Magnetic disk units	○		
Space heaters	○		
Gas cooking appliance	○		○ (Expected fuel consumption)
Gas water heaters	○		○ (Expected fuel consumption)
Oil water heaters	○		○ (Expected fuel consumption)
Electric rice cookers	○		○
Microwave ovens	○		○
VTR			○
DVD	○		○

(Source) The Energy Conservation Center, Japan

The Energy Saving Labeling Program is as explained in Section 7.5.3. In addition, the expected annual electricity bill and a multi-stage rating representing the energy saving performance of a product according to a 5-level criteria are also to be displayed for air conditioners, electric refrigerators and TV sets. Figure 26 provides the uniform energy-saving label, which combines these three elements.

Figure 26 Uniform Energy Saving Label



(Source)The Energy Conservation Center, Japan

The multi-stage rating system involves determining the ratio of appliances currently on the market that have achieved the Top Runner standards and applying that ratio to represent the state in which efficiency standards are met by 100% (in other words, the equivalent of the efficiency value to be achieved in the target fiscal year) to help determine visually the degree of achievement. In Figure 26, few models have achieved the Top Runner standard, and therefore the ratio of appliances exceeding the standard is 0-20% and the space between the first and second stars are the standard value 100% achievement line; this appliance has already met the target and is thus has been given a rating of 5 stars.

Because the multi-stage rating system requires knowledge of the status of energy saving standard achievement of the appliances in the market, it is revised on April 1, every year.

7.6 Conclusion

This paper overviewed the structure of the electric industry in Japan and in China and states that differences in industrial structure was also and important factor in implementing energy conservation measures. In order to achieve efficiency improvements in energy end-use appliances, efficiency improvements are required in energy saving elemental technology and studies on policy incentives are important. Japanese manufacturers have been managed by vertical integration, where the development and production of core components to the assembling of the final product are all done in a single company, and thus possess the information and data on energy saving elemental technology and products. This information and data have been actively disclosed to the extent that fair competition among manufacturers is not undermined. This enables the implementation of policy based on unbiased information and the curbing of administrative costs for information and data collection.

Given the globalization of the economy, management styles have shifted from vertically integrated management to horizontally integrated management; at the same time, there is a strong demand for international efforts to achieve energy savings and CO2 savings to establish a sustainable society. Therefore, it is important that energy saving technological development is further pursued. Although vertical disintegrated management may become the global standard in the future global economy, it is conceivable that companies that develop and manufacture the core components that hold the key to the energy efficiency of an appliance will be required to improve energy saving elemental technologies through policy measures. Japan's Top Runner Program, setting its policy goals based on elemental technology-specific reviews, has encouraged companies to develop elemental technologies, leading them towards higher energy efficiency product development. Japan's S&L program can serve as good reference in implementing policies in the electric industry that link industrial policy with energy saving policy. However, whether energy saving performance can be fully demonstrated in a final product assembled by vertically disintegrated management, remains yet to be discovered. It is important that studies be conducted on the energy saving performance of final products, depending on management style, from a energy conserving view point.

Discrepancies occurred between the rated power consumption and actual power consumed in Japanese refrigerators. One of the causes was that conventional measurement methods did not accommodate differences in cooling technology or emerging new functions required by climate and lifestyle. Against this backdrop, Japan revised measurement methods to JIS C 9801-2006, in order to measure power consumption under assumptions close to the actual status of use. This issue of discrepancy will undermine the effectiveness of an S&L project, and is likely to happen in any other country.

Japan has introduced the Top Runner Program and Labeling Program in an effort to improve efficiency in appliances and disseminate energy efficient appliances. Policy targets have been designed based on information and data on energy saving elemental technologies possessed by private companies in order to make the S&L program more effective. Studies on measurement methods have also been furthered to be able to measure consumptions accommodating the status of use and the elemental technology of appliances. In order to make this S&L program more effective, information and data possessed by companies regarding energy saving elemental technologies have been employed to design policy targets. Furthermore, measurement methods are also being studied for consumption measurements closer to actual consumption, accommodating the status of use and the elemental technology of the appliance to be able to conduct consumption measurements. In this way, Japan is continuing in its efforts to implement a more effective S&L program.

Furthermore, Japan has initiated its activities towards the implementation of measurement methods reflecting the actual status by actively participating in the Asia Pacific Partnership Building and Appliances Task Force's Project 1 (harmonization of measurement methods) and in the framework of the implementing agreement projected by the IEA. It is important that the challenges experienced by Japan regarding measurement methods is studied at an international level and that a society be established where energy efficient products, accurately displaying the actual status of the product, are disseminated through the market.

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