DEVELOPING ENERGY EFFICIENCY STANDARD AND ITS IMPACT ON REFRIGERATOR-FREEZERS ENERGY CONSUMPTION IN MALAYSIA

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ABSTRACT

Refrigerator-freezers are one of the major energy users in the residential sector of Malaysia. In line with rapid economic growth, the ownership of household refrigerator-freezers increased rapidly for the last several years. There has been a tremendous increase in the use of household refrigerator-freezers (878000 units) from 1990 to 1999 and by the year 2020, it will be about 5624000 units. So, there is a huge saving potential by introducing cost-effective energy policy like energy efficiency standards. Energy efficiency standards are cost-effective approaches that can help to improve the efficiency of these appliances.

In the present study, six household refrigerator-freezers of different capacities and models have been tested in the energy conservation laboratory to investigate the energy consumption behavior of these appliances. The test has been carried out according to ISO refrigerator-freezers test specifications. Using the experimental data of ISO test conditions, a baseline standard has been developed by the statistical method. From the baseline standard, 5 % and 10% standards as a function of adjusted volume have been developed. Impacts of energy efficiency standards have been calculated and presented in this paper as well.

1. INTRODUCTION

Turiel et al. [1], Waide et al. [2], Nakagami and Litt [3] reported that the energy efficiency standard is a government approach that limits the energy consumption of a particular appliance. It prohibits the production of in-efficient appliances from the market. The standards can be either mandatory or

voluntary in nature. It also can be in the form of a minimum allowable energy efficiency, a maximum allowable energy use. Standards can be performance based or prescriptive in nature. Performance types standards state allowable energy use or energy efficiency whereas the prescriptive standards require the presence of some feature. Mandatory Minimum Energy Efficiency Standards (MMEES) are generally the most effective means of rapidly improving the energy efficiency of household appliances. The MMEES is a government mandated standard that defines minimum levels of efficiency or maximum levels of energy consumption that must be met by all products sold in a particular jurisdiction [4-6].

Unlike many other initiatives, (MMEES) has the advantage because their benefits are comparatively simple to quantify. They treat all manufacturers, distributors, and retailers equally and the resulting energy savings can be comparatively guaranteed. Voluntary energy efficiency standards negotiated between government and manufacturers are an alternative option to MMEES. They have the merit of being less controversial and hence easier to enact [7-8]. But they can disadvantage signatory manufacturers in comparison with non-signatory manufacturers (typically domestic manufacturers as opposed to importers). The fact that voluntary standards are seldom universal and are not obligatory means that it is very difficult to persuade manufacturers to agree to a measure which will either reduce their profit margin or increase the purchase price of their goods. This arises because of legitimate fear that competitors will not follow suit. For MMEES, a small increase in production cost is usually anticipated but because in principle, this applies to all manufacturers equally, it can be safely passed on the consumer without losing market share. If the MMEES are designed properly, the consumer will more than recoup the increased purchase cost through reduced operating costs, while manufacturer sales and profits should not be adversely affected [2].

With the ongoing increase in number of these appliances, residential energy consumption in Malaysia has also increased at an average rate of 13% over the year 1990-2000 [9]. To mitigate the future demand for increased energy, government either has to build up new power plants or introduce cost effective energy efficiency strategy like standards.

Unfortunately, because of the economic downturn in South East Asian countries in 1997, government had to postpone building up of Bakun power plant, providing the emphasis on improving energy efficiency. Energy efficiency standard is one of the cost-effective approach that can help to improve the appliance efficiency. As Malaysia is going to adopt energy efficiency standards for household electrical appliances, this study is significant in that view.

2. STANDARD TEST PROCEDURE

An energy test procedure (sometimes referred to as "test standard") is the base of, and represents the technical foundation for, all energy efficiency standards, labels and other related programs. Energy labels could not be created without an energy test procedure. While modern energy efficiency measures like, labeling provides vital information about individual products, product testing by independent consumer bodies remains the impartial way to compare the energy performance of appliances. The function of test standards is to establish a uniform and repeatable procedure or standard method for measuring specific appliance characteristics.

The test has been carried out as per ISO refrigerator-freezers energy test requirements. Following is the brief overview of ISO test specifications for energy performance testing and rating of these appliances.

2.1 INTERNATIONAL STANDARD (ISO)

The International Organization for Standardization is a worldwide federation of national standard body. ISO 8187 [10] ISO 8561 [11] and ISO 7371 [12] are the relevant standards for testing the energy consumption of household refrigerator-freezers having two or more compartments. At least one compartment (the fresh food storage compartment) is suitable for storing unfrozen food, and at least one compartment (the food freezer compartment) is suitable for freezing fresh food and for the storage of frozen food at –18 ^{0}C or colder

According to the ISO standard, the test period shall be at least 24 hours long with no door openings. RH should be kept within 45%-75% inside the test chamber with –18 ^{0}C freezer temperature. The room temperature should be maintained at 32 (^{0}C) based on tropical test condition. An excellent overview of these standards for testing these appliances has been summarized by Bansal and Kruger in Ref. [13] as well.

3. APPROACHES IN DEVELOPING ENERGY EFFICIENCY STANDARDS

There are three approaches to develop energy efficiency standards. These are: (i) Statistical, (ii) Engineering, and (iii) Consensus approach. These are outlined as below:

3.1 STATISTICAL APPROACH IN DEVELOPING ENERGY EFFICIENCY STANDARDS

The statistical method is based on market research of the given appliance. The statistical approach requires fewer data and less analysis than the engineering/economic approach. The data required are those, which give a current characterization of marketplace for the products of interest. A standard level can then be selected after a decision is made as to the energy savings goal and or the number of models that it is acceptable to eliminate from the current marketplace. This approach looks at the models available at a particular time and performs a regression analysis to determine the dependence of energy use on adjusted volume[1]. After calculation of the regression line i.e. reference line, desired goal such as 5% and 10% energy savings lines are drawn from the reference line. Based on statistical approach, a baseline standard, 5% standard and 10% standard have been develop and shown in Figure 1.

3.2 ENGINEERING ANALYSIS

There are several parts to an engineering analysis, which have been widely used by Lawrence Berkeley Laboratory (LBL) for the U.S. department of energy. First, an engineering analysis is carried out for each product type to determine manufacturing costs for improving the efficiency of a baseline model [1].

The following seven steps performs the core engineering analysis:

(i) selection of appliance classes;

(ii) selection of baseline units;

(iii) selection of design options for each class;

(iv) calculation of efficiency improvement from each design option;

(v) combination of design options and calculating efficiency improvements;

(vi) developing cost estimates for each design option; and

(vii) generation of cost-efficiency curves.

3.3 CONSENSUS APPROACH

In consensus approach, two or more groups get together and decide on the standards through a joint process. These groups could be some combination of a government regulatory agency, environmental/consumers groups and appliance manufacturers. This approach was used in the United States in establishing the first national efficiency standards that were incorporated into law in 1987 [1].

[1] Adjusted volume is the sum of the volumes of the different compartments weighted by the difference in temperatures between interior of the compartment and the ambient temperature.

4. IMPACT OF ENERGY EFFICIENCY STANDARDS

Purpose of this part is to forecast energy savings, bill savings, and emission reduction after the standard enacted. In order to do so, following input data must be considered [14,17].

1. Appliance ownership
2. Average unit energy consumption per year
3. Fuel price
4. Emission factor

Using the above input data, Baseline Annual Energy (BAE), Annual Energy (AE), Bill Savings (BS), CO_2 reduction for baseline standard (i.e. average standard), 5% standard, and 10% standard has been calculated and shown in Table 1. Average baseline unit energy consumption was multiplied with the number of appliances for a particular year to get the BAE. Average unit energy consumption for 5% and 10% standards was multiplied with the number of appliances for a particular year to get the AE (5%) and AE (10%). Annual Energy Savings (AES) was calculated deducting AE from BAE. AES was multiplied with the electricity price to get bill savings. CO_2 reduction was calculated multiplying emission factor with the AES. All the prediction data discussed above is shown in Table 1.

4.1 APPLIANCE OWNERSHIP

Appliance ownership for the year 1990-1999 has been collected from Wan [19] and shown in Table 2. Based on this data, appliance ownership for the year 2000-2020 has been predicted and shown in Table 1.

4.2 AVERAGE UNIT ENERGY CONSUMPTION (AEC) PER YEAR

AEC or baseline energy consumption has been determined using statistical approach. Once the base line energy consumption could be determined, efficiency level (i.e. 5 %, 10% standards) could be reached by using same methodology described in statistical approach. Figure 1 shows the baseline standard, 5% and 10% standards. Baseline annual unit energy consumption is 946 kWh with the average adjusted capacity of 407 Litre. Average unit energy consumption for 5% and 10% standards are 900 kWh/yr and 851 kWh/yr, respectively.

4.3 ELECTRICITY PRICE

The value of energy savings (bill savings) is calculated using electricity price, which is 0.235 Sen/kWh of energy in Malaysia.

4.4 EMISSION FACTOR

Emission factor is needed to calculate the Co_2 reduction due to implementation of standards. Average emission factor is used as 0.46 kg/kWh in this analysis [14,18]. Corresponding emissions reduction could be estimated multiplying emission factor with energy savings for each standard.

5. CONCLUSIONS

Energy efficiency standards are gaining tremendous success around the world. For example, in the USA energy consumption of 510 Litre refrigerator-freezers were reduced from 1926 kWh/yr to 649 kWh/yr from 1972 to 1995 as an introduction of energy efficiency standards. Whereas, Korea has reduced its energy consumption by 18% from 1992 to 1999 [20].

It would be more effective to implement energy efficiency standard as mandatory rather than voluntary because mandatory minimum energy efficiency standards are universal and must abide by all manufacturers.

It is estimated that the energy efficiency standards will save 3978 GWh and 8216 GWh energy (**cumulative**) for 5% and 10% standards respectively, from 2003 to 2020 if the standard is enforced from the year of 2003. This means using the current average price (23.5 Sen/kWh), the total bill savings will be RM 934 million (1 USD = 3.80 RM) and RM 1930 million for 5% and 10% standards respectively. The corresponding CO_2 reduction could be achieved 1830000 and 3779000 tons for 5% and 10% standards respectively. For a country like Malaysia, the above savings are quite significant. This will help to avoid building up of new power plant as well as preventing the country from the environmental degradation.

As the energy efficiency standards and labels are complement to each other, this study will help to establish energy guide labels for household appliances in Malaysia.

Finally, it is authors' expectation that utilizing the success and experiences of the standards from the countries around the world and using the present study, policy makers of Malaysia may introduce the standards so that above savings could be achieved.

Table 1 Prediction summary of impact of standards

Year	Refrigerator (No.)	BAE (GWh)	AES (10%) (GWh)	AES (5%) (GWh)	BS(10%) (RM million)	BS (5%) (RM million)	CO2 (10%) (Tons)	CO2 (5%) (Tons)
2003	3987000	3771	378	183	89	43	174000	84000
2004	4083000	3862	387	187	91	44	178000	86000
2005	4179000	3953	397	192	93	45	183000	88000
2006	4276000	4044	406	196	95	46	186000	90000
2007	4372000	4135	415	201	97	47	191000	92000
2008	4468000	4226	424	205	99	48	195000	94000
2009	4564000	4318	433	209	101	49	199000	96000
2010	4661000	4409	442	214	104	50	203000	98000
2011	4757000	4500	451	218	106	51	207000	100000
2012	4853000	4591	461	223	108	52	212000	102000
2013	4950000	4682	470	227	1105	53	216000	104000
2014	5046000	4773	479	232	112	55	220000	106000
2015	5142000	4864	488	236	114	56	224000	108000
2016	5239000	4955	497	240	116	57	228000	110000
2017	5335000	5046	506	245	119	58	233000	112000
2018	5431000	5137	515	249	121	59	237000	114000
2019	5527000	5228	525	254	123	60	241000	116000
2020	5624000	5319	534	258	125	61	245000	118000
TOTAL			**8216**	**3978**	**1930**	**934**	**3779000**	**1830000**

Table 2 Household refrigerator-freezers ownership in Malaysia [19]

Year	Refrigerator-freezer (No.)
1990	2742000
1991	2830000
1992	2920000
1993	3012000
1994	3107000
1995	3205000
1996	3305000
1997	3407000
1998	3512000
1999	3620000

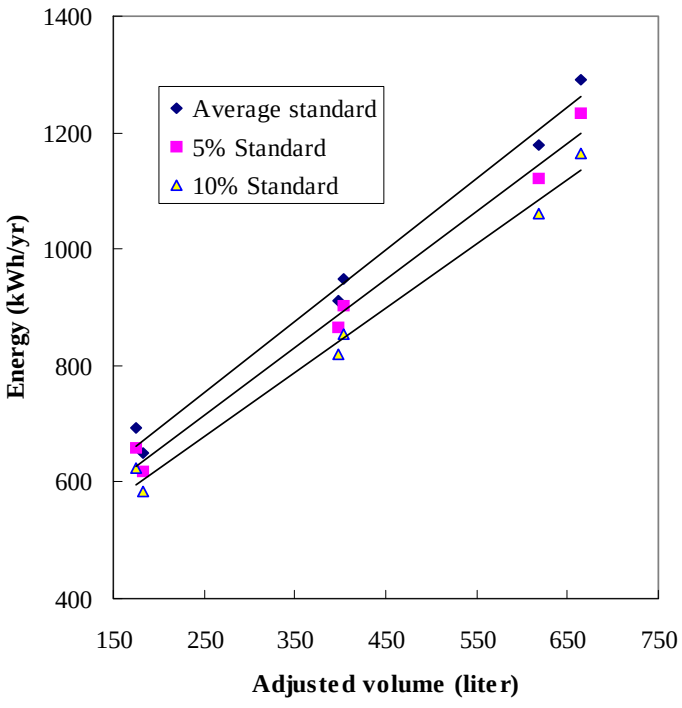

Figure 1 Annual energy consumption vs adjusted volume.

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