

Cost–benefit analysis of implementing minimum energy efficiency standards for household refrigerator-freezers in Malaysia

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Abstract

The ownership of household electrical appliances especially refrigerator-freezer has increased rapidly in Malaysia. Almost every household in this country has a refrigerator-freezer. To reduce energy consumption in this sector the refrigerator is one of the top priorities of the energy efficiency program for household appliances. Malaysian authority is considering implementing minimum energy efficiency standards for refrigerator-freezer sometime in the coming year. This paper attempts to analyze cost–benefit of implementing minimum energy efficiency standards for household refrigerator-freezers in Malaysia. The calculations were made based on growth of ownership data for refrigerators in Malaysian households. The number of refrigerator-freezer has increased from 175,842 units in 1970 to 4,196,486 in 2000 and it will be about 11,293,043 in the year of 2020. Meanwhile it has accounted for about 26.3% of electricity consumption in a single household. Therefore, efficiency improvement of this appliance will give a significant impact in the future of electricity consumption in this country. Furthermore, it has been found that implementing an energy efficiency standard for household refrigerator-freezers is economically justified.

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1. Introduction

Refrigerator-freezers accounted for about 26.3% of residential electricity demand in Malaysia (Masjuki et al., 2000). Therefore, any efficiency improvement of this appliance will produce a significant amount of electricity consumption in residential sector. Many efficient refrigerator-freezers are available in the market today. Through pushing consumers to buy and use efficient refrigerator-freezers, a significant amount of electricity can be saved. This can be achieved by implementing minimum energy efficiency standards for the appliance. However, these potential energy savings should be proven economically reliable.

An energy efficiency standard is the prescribed energy performance of a manufactured product, sometimes prohibiting the manufacture of products with less energy efficiency than the minimum standards. Minimum energy efficiency standards for appliances have been enacted in Australia, Brazil, Canada, China, Europe,

Japan, Korea, Mexico, the Philippines, Russia and the US. The program can be mandatory (i.e. government law or regulation) or voluntary (i.e. agreement with manufacturers). Most countries have adopted mandatory standards while several countries such as Brazil, Japan and Korea have successfully used voluntary standards. Standards are essentially voluntary in name only in these countries; failure to meet standards is likely to result in substantial embarrassment or imposition of mandatory standards. In countries with truly optional voluntary standards (e.g. India), impact has been limited (Nadel, 1999). Based on the experience of other countries, policymakers in Malaysia should implement the program as mandatory since it works effectively in many countries.

2. Survey data in Malaysia

The data necessary for the study are the electricity data and household refrigerator-freezer data. The historical electricity data were given by the Department of Electricity & Gas Supply (2002) and Ministry of Energy (2002) and projected electricity data were given

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| Nomenclature | | | |
|--------------|--|---------------|--|
| AEI^r | Annual efficiency improvement of refrigerator-freezer (%) | PF | price of fuel (RM) |
| ANS_i^r | annualized net dollar savings in year i of refrigerator-freezers (RM) | $PV(ANS_i^r)$ | present value of annualized net saving in year i of refrigerator-freezers (RM) |
| AS_i^r | applicable stock in year i of refrigerator-freezer | r | refrigerator-freezers |
| BAU_i^r | business as usual energy consumption in year i of refrigerator-freezer (kWh) | SEC_s^r | standards energy consumption of refrigerator-freezers (kWh/year) |
| BEC_s^r | baseline energy consumption in the year of standards enacted for refrigerator-freezer (kWh/year) | SF_i^r | scaling factor in year i of refrigerator-freezers (%) |
| BS_i^r | bill savings in year i of refrigerator-freezer (RM) | Sh_i^r | shipments in year i of refrigerator-freezers |
| c, k | constant value | SSF_i^r | shipment survival factor in year i of refrigerator-freezer |
| CRF | the capital recovery factor | TEI^r | total efficiency improvement of refrigerator-freezer (%) |
| d | discount rate (%) | UES_i^r | initial unit energy savings in year i of refrigerator-freezer (kWh/year) |
| ES_i^r | energy savings in year i of refrigerator-freezer (kWh) | x | predicted year—starting year |
| IC^r | incremental cost for the more efficient refrigerator-freezer (RM) | y | value of the predicted data |
| IIC_s^r | initial incremental cost for more efficient refrigerator-freezer (RM) | y_1 | predicted of total energy consumption (GWh) |
| L^r | life span of refrigerator-freezers (years) | y_2 | predicted of residential energy consumption (GWh) |
| Na_i^r | number of refrigerator-freezers in year i | y_3 | predicted of the number of household |
| Na_{i-1}^r | number of refrigerator-freezers in year $i-1$ | y_4 | predicted of number of refrigerator-freezers |
| Na_{i-L}^r | number of refrigerator-freezers in year $i-L$ | Ysc_s^r | year of survey/test conducted of refrigerator-freezer |
| NS_i^r | Net savings in year i for refrigerator-freezers (RM) | Yse_s^r | year of standards enacted of refrigerator-freezer |
| | | Ysh_i^r | year i of shipment of refrigerator-freezer |
| | | Ytc_T^r | year target calculation for refrigerator-freezer |

Table 1
Households and refrigerator-freezers

| Year | Total (GWh) | Residential (GWh) | Households | Refrigerator-freezers |
|------|-------------|-------------------|------------|-----------------------|
| 1970 | 2175 | 326 | 1 890 282 | 175 842 |
| 1980 | 7912 | 1348 | 2 503 974 | 685 912 |
| 1990 | 19 469 | 3897 | 3 428 142 | — |
| 1991 | 21 442 | 4212 | 3 537 606 | 2 073 726 |
| 1997 | 49 080 | 8309 | — | — |
| 2000 | 52 300 | 9471 | 4 662 762 | 4 196 486 |
| 2010 | 105 762 | 19 153 | — | — |
| 2020 | 195 253 | 35 360 | — | — |

by Economic Planning Unit (1996). The number of household and refrigerator-freezers were collected from Department of Statistics (1991) and Department of Electricity & Gas Supply (2000). As shown in Table 1, the electricity consumption and the use of refrigerator-freezers in the residential sector has increased year by year along with the total electricity consumption of the country.

3. Methodology

There are some methodologies of calculating impact of energy efficiency standards, however the one described by Mahlia et al. (2002) was employed for this study. The complete equations are discussed below.

3.1. Method of predicting data

The method used to estimate the rest of the data for calculation is polynomial curve fitting. The method is attempted to describe the relationship between variable x as the function of available data and a response y . It seeks to find a smooth curve that best fits the data, but does not necessarily pass through any data points. Mathematically, a polynomial of order k in x is an expression of the form

$$y = c_0 + c_1x + c_2x^2 + \dots + c_kx^k. \quad (1)$$

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