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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.

Keywords: Cost–benefit analysis; Energy efficiency standards; Refrigerator; Freezer; Malaysia

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

$$y = c_0 + c_1 x + c_2 x^2 + \cdots + c_k x^k. \quad (1)$$