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Cost-benefit analysis and emission reduction of lighting retrofits in residential sector

T.M.I. Mahlia*, M.F.M. Said, H.H. Masjuki, M.R. Tamjis

Department of Mechanical Engineering, University of Malaya, 50603 Kuala Lumpur, Malaysia

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Abstract

This study projects electricity savings, cost-benefit analysis and emission reduction of lighting retrofits in Malaysia residential sector. The cost-benefit is determined as a function of energy savings due to retrofit of more efficient lighting system. The energy savings were calculated based on 25, 50 and 75% of potential retrofits of inefficient lighting in residential sector. The study found that, this strategy save a significant amount of energy and consumers money. However, an effort to create energy efficiency awareness among consumers and subsidies efficient lighting should be identified, because this efficient lighting is quite expensive in Malaysia.

Keywords: Energy savings; Lighting retrofits; Energy efficiency; Cost-benefit analysis; Emission reduction; Malaysia

1. Introduction

A lighting retrofit is replacing inefficient lighting with the efficient one. Electricity savings over time is significant enough to not only pay for the new lighting, but also produce return on the investment. This can be done by either reducing the input wattage or reducing the hours of operation of the lighting to reduce energy consumption. The studies on retrofitting inefficient lighting by reducing input wattage are presented by Refs. [1–4]. This study is also proposed to reduce wattage by retrofitting of incandescent lamp with more efficient compact fluorescent lamp (CFL) in residential sector in Malaysia. These can be replaced by energy efficient lamps that are available in 8, 14 and 18 W versions with the equivalent of 40, 60 and 100 W of incandescent light bulbs [5]. CFL lamps start instantly under 0.1 s with energy consumption 80% less than incandescent light bulb and lasting more than 5000 h. However, this lamp is quite expensive in Malaysia, it is about RM 11.90–23.90 (US$ 1 = RM 3.8), which is 8–17 times of the price of incandescent bulb. This CFL can replace incandescent light bulbs without any modification.

In incandescent lamp, electricity heats up a wire filament, causing it to glow and give the light and that is why more than 90% of the energy produced by incandescent lights is heat, not light and therefore incandescent are inefficient light sources. Meanwhile an ordinary incandescent bulb's lifetime is usually about 750 h before burning out.

This study attempts to calculate potential electricity savings, emission reduction and cost-benefit analysis of lighting retrofit policy in Malaysia residential sector at national level. This is to encourage the authority and policymakers to implement this simple strategy to reduce rapid electricity consumption growth in residential sector. Successful experimentation in efficient lighting has been conducted in commercial sector [6].

2. Collected data

Extensive data on lighting system can be found in lighting market source book presented in Ref. [7]. The uncertainty, sensitivity analyses, life-cycle cost and payback period of a lighting system can be found in Ref. [8]. However, the data required for this study are only the household data, number and wattage of incandescent bulb data. The saturation of household with electricity in Malaysia is about 97%.

* Corresponding author. Tel.: +60 3 7959 5283; fax: +60 3 7959 5317.
E-mail addresses: i_mahlia@hotmail.com, indra@um.edu.my (T.M.I. Mahlia).

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Nomenclature

A	incandescent lamp
ANS_i^L	annualized net dollar savings in year i of lighting retrofit (RM)
B	compact fluorescent lamp
BS_i^L	bill savings in year i of lighting retrofit (RM)
CRF	capital recovery factor (%)
d	discount rate (%)
EC_i^L	energy consumption (GWh)
EM_p^n	emission p for fuel type n for a unit electricity generation (kg/kWh)
ER_i^L	emission reduction in year i of lighting retrofit (kg)
ES_i^L	energy savings in year i of lighting retrofits (GWh/year)
IC^L	increment cost of lighting retrofit (RM/kWh)
NH_i	number of household in year i
NR_i^L	number of lighting retrofit in year i
NS_i^L	net saving in year i due to lighting retrofit (RM)
OH_i^L	daily operating hour of lighting
PC^L	power consumption of lighting (W)
PE_i^n	percentage of electricity generation in year i of fuel type n
PF_i	price of electricity in year i (RM/kWh)
$PV(ANS_i^L)$	present value of annualized net savings in year i for lighting retrofit (RM)
ST_i^L	saturation of inefficient lighting in year i
T	lifetime of lighting (year)
Ydr	Year of discount rate base

The number of incandescent bulbs were collected by conducting survey in 427 randomly selected household and the results are tabulated in Tables 1–4. The predicted household data, the percentage of electricity generation based on fuel type and fossil fuel emissions for a unit electricity generation were given by Refs. [9,10] and tabulated in Tables 4 and 5.

Table 1
Wattage and saturation of incandescent bulb in the household

Power (W)	Number of incandescent bulb	Saturation (%)
40	178	41.7
60	205	48.0
100	252	59.0

Table 2
Operation hours per day of incandescent bulb

Operating hours	Central value	Households
0–2	1	21
2–4	3	87
4–6	5	64
6–8	7	12
8–10	9	10
10–12	11	6

Table 3
Essential input data of incandescent bulb and CFL

Bulb type	Incandescent			CFL		
	A_1	A_2	A_3	B_1	B_2	B_3
Total watts (W)	40	60	100	8	14	18
Lifetime (h)	750	750	750	5000	5000	5000
Purchase price (RM)	1.40	1.40	1.40	18.50	18.50	18.50
Number of bulbs	7	7	7	1	1	1
Total bulb cost (RM)	9.80	9.80	9.80	11.80	15.90	23.90

Table 4
Fossil fuel emissions for a unit electricity generation

Fuels	Emission (kg/kWh)			
	CO_2	SO_2	NO_x	CO
Coal	1.1800	0.0139	0.0052	0.0002
Petroleum	0.8500	0.0164	0.0025	0.0002
Gas	0.5300	0.0005	0.0009	0.0005
Hydro	0.0000	0.0000	0.0000	0.0000
Other	0.0000	0.0000	0.0000	0.0000

3. Methodology

A survey is necessary to determine the saturation level of inefficient lighting, the operating hour of the incandescent bulb and the number of potential retrofit of the lighting system in Malaysia residential sector. Based on Table 3, lighting system A is referred to the incandescent lamp, while lighting system B is referred to CFL which is proposed lighting system that are more energy efficient. The data obtained from the survey was used to calculate projected electricity savings, emission reduction and cost-benefit analysis of lighting retrofits. The equations used for calculation are discussed in the following section.

3.1. Number of retrofits

Number of retrofits depends on the saturation level of inefficient lighting in the household with electricity. The number of retrofits is calculated by multiplication of number of household and the saturation levels of inefficient lamp. This can be represented by the following equation:

$$NR_i^L = NH_i^L \times ST_i^L \quad (1)$$

3.2. Energy consumption

Energy consumption by the lighting is the multiplication of the number of retrofits, power consumption and operating hour of the lighting. The annual energy consumption can be expressed mathematically by the following equation:

$$EC_i^L = NR_i^L \times PC^L \times OH_i^L \times 365 \quad (2)$$