Journal of Cleaner Production 18 (2010) 365–374

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

Cost efficiency analysis and emission reduction by implementation of energy efficiency standards for electric motors

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ARTICLE INFO

Article history:
Received 3 October 2008
Received in revised form
4 November 2009
Accepted 8 November 2009
Available online 28 November 2009

Keywords:
Cost efficiency
Electric motor
Energy efficiency
Efficiency improvement
Emission reductions
Greenhouse gas emissions

ABSTRACT

The industrial sector is the biggest electricity consumer in Malaysia. Electric motors account for more than 45% of the electricity consumption in the industrial sector in the country. Therefore, it is very important to implement energy efficiency standards for electric motors to reduce energy consumption growth in this sector. This paper attempts to calculate the cost efficiency analysis and emission reduction by implementing energy efficiency standards for electric motor in Malaysia. The energy efficiency standards are proposed based on the efficiency of electric motors from survey data. The study examines the potential energy, economical and environmental impacts of the implementation of energy efficiency standards for electric motors in three scenarios i.e. 0.5%, 1.0% and 1.5% of standards efficiency improvement. Standards also enable consumers to reduce their electricity bill and contribute to a positive environmental impact.

1. Introduction

Malaysia's economy has continued to grow rapidly in recent years. This growth was largely due to a rapid expansion of the country's industrial exports. This is one of the main factors driving the increase in the number of electric motors used in the industrial sector. This sector is the largest consumer of electricity, accounting for more than 40% of the total electricity consumption in Malaysia [1]. The energy usage is mostly by electric motors, which account for more than 45% [2]. Unfortunately, this sector mostly uses standard motors instead of high-efficiency motors that are more efficient. Since the usages of electricity in this sector are mostly by electric motors, several strategies should be taken to reduce the energy consumption of these appliances. One of the most effective strategies is to implement energy efficiency standards for electric motors.

Energy efficiency standards as the prescribed energy performance of a manufactured product, sometimes prohibit the manufacture of products with less energy efficiency than the minimum standards [3]. Based on the experiences of other countries, the introduction of energy efficiency standards and labels for electric motors will not only produce economic benefits but also indirectly decrease emissions of carbon dioxide, sulfur dioxide, nitrogen oxides, carbon monoxide and other gases. In South East Asia, Thailand and the Philippines are leading the way towards the development of national standards for energy conservation [4]. Brazil has introduced a high-efficiency electric motors policy with the main objective to reduce electricity consumption. The results indicate that with the current average tariffs of electricity, high-efficiency motors are economically more attractive than standard motors [5]. This result is definitely true based on calculations dealing with energy conservation by installing energy-efficient (EE) motors instead of standard efficiency motors. It is due to limitation in energy sources and escalating energy prices [6]. In Brazil, the first regulation of the energy efficiency act for electric motors, launched in 2002, established two sets of minimum efficiency performance standards (MEPS), for 'standard' (mandatory) and 'high-efficiency' (voluntary) motors. An updated regulation, from the end of 2005 (Edict 553/2005), established the previous high-efficiency MEPS as mandatory for all motors in the Brazilian market [7]. These new Brazilian MEPS are compatible with those implemented in Malaysia and other developing countries, while in the US electric motor business is seeking further practical solutions through electric motor efficiency technologies to reduce energy consumption. These

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doi:10.1016/j.jclepro.2009.11.005

Nomenclature

AEI_i^{em}	Annual energy efficiency improvement of electric motors in the year *i*, (%)
ANS_i^{em}	Annualized net savings in year *i* for electric motors, ($)
AS_i^{em}	Applicable stock in year *i* of electric motors
AS_{i-1}^{em}	Applicable stock in year $i-1$ for electric motors
BAU_i^{em}	Business as usual of electricity consumption in year *i* for electric motors, (kWh/y)
BEC_s^{em}	Baseline electricity consumption of electric motors, (kWh/y)
BS_i^{em}	Bill savings in year *i* for electric motors, ($)
CRF	Capital recovery factor, (%)
CCE_s^{em}	Cost of conserved energy for electric motors due to standards, ($/kWh)
C	Constant value
d	Discount rate per year, (%)
Em_p^n	Emission *p* for fuel type *n* for unit electricity generations, (kg/kWh)
ER_i^{em}	Emission reduction in year *i* of electric motors, (kg)
ES_i^{em}	Energy savings in year *i* for electric motors, (kWh/y)
IC_s^{em}	Increment cost of electric motor due to standards, ($/Unit)
IE_i^{em}	Efficiency improvement in year *i* for electric motors, (%)
IIC_s^{em}	Initial increment cost of electric motor due to standards, ($/unit)
k	Constant value
L^{em}	Lifespan of electric motors, (y)
Na_i^{em}	Number of electric motor in year *i*
Na_{i-1}^{em}	Number of electric motor in year $i-1$
Na_{i-L}^{em}	Number of electric motor in year $i-L$
NS_i^{em}	Net savings in year *i* for electric motors, ($)
PC_s^{em}	Average power consumption of electric motors in the year of standards enacted, (kW)
PE_i^n	Percentage of electricity generation in year *i* of type *n*, (%)
PF_i^n	Energy price in year *i* for fuel type *n*, ($)
$PV(ANS_i^{em})$	Present value of annualized net savings in year *i* for electric motors, ($)
RL_s^{em}	Rated load in the year of standards enacted, (%)
SEC_s^{em}	Standards energy consumption of electric motor, (kWh/y)
SEI_s^{em}	Standards efficiency improvement for electric motors, (%)
SF_i^{em}	Scaling factors in year *i* of electric motors, (%)
Sh_i^{em}	Shipment in year *i* of electric motors
SSF_i^{em}	Shipment survival factor in year *i* of electric motor, (%)
STD	Energy efficiency standards
TEI_s^{em}	Total efficiency improvement due to the standards for electric motors, (%)
TN_i^{em}	Total number of electric motors the year *i*
U_s^{em}	Usage hour of electric motors in year of standards enacted, (h)
UES_i^{em}	Initial unit energy savings in year *i* for electric motors, (kWh/y)
X	Predicted year – starting year
Y	Predicted value
Ydr	Year of discount rate base
Yse_s^{em}	Year of standards enacted of electric motors
Ysh_s^{em}	Year *i* of shipment of electric motors
η_s^{em}	Efficiency of electric motors in the year of standards enacted, (%)
$\Delta\eta_s^{em}$	Standards efficiency improvement of electric motors, (%)

Superscripts

em	Electric motor
n	Fuel type

Subscripts

s	Year of standards enacted
i	In the year *i*
T	Target year
o	Usage

technologies set new standards for heavily loaded motor efficiency, benefiting environment and US industrial competitiveness [8]. A good methodology for analyzing the actual outcome of long-term agreements on industrial energy efficiency improvement is given in Ref. [9]. Another interesting policy is to combine voluntary agreements and taxes which reduce a significant amount of energy and emission by industry in Denmark [10].

In Europe, electric motors use about 70% of the total industrial electricity share, therefore they present attractive opportunities to save a huge amount of electricity in a cost-effective way, and will contribute to mitigate climate change. The lack of global efficiency classes has prevented the large-scale adoption of high-efficiency motors in most countries around the world. The result and conclusion of energy efficiency programs in Europe are high-efficiency motors replacing standard efficiency class motors and will have significant reductions in the environmental impact [11]. However, it has to keep in mind that the efficiency of electric motors depends on available technology while the selection of electric motor is based on economic consideration including life cycle cost analysis [12,13]. Not all energy efficiency programs have been implemented without some barriers, the barriers to industrial energy efficiency program are discussed intensely in Ref. [14].

As in other countries, electric motors are widely used in the industrial sector in Malaysia to drive fans, pumps, blowers, air compressors, refrigeration compressors, conveyers, machineries, and many other types of equipment. The industries pay about MYR6 billion (USD 1 = MYR 3.50) annually for the electricity bill for electric motors in this country [15]. In a survey conducted by the Malaysia Energy Commission, it was found that out of annual sales of more than 100,000 units of motors in the country only about 2% was high-efficiency motors. When 4% more efficient motors are used, over their lifetime of 15–20 years between 420,000 MYR and 560,000 MYR would be saved [16]. There are currently no minimum efficiency level requirements for electric motors in Malaysia. Furthermore, there is no national standard for determining motor performance in this country. The introduction of minimum energy efficiency standards for electric motors is expected to happen in 2014, because it will need ample of time to prepare testing facilities. Currently there is no authoritative or independent testing facility to test and assess the energy efficiency levels of motors from various brands. The Standards and Industrial Research Institute of Malaysia (SIRIM) plans to acquire the necessary testing facility to carry out independent testing on the energy efficiency of motors in the future [17].

The Malaysian authority has realized that electric motors have contributed significantly to energy consumption. As a result, the Energy Commission (EC) recently launched an advertising and promotion campaign to promote the use of High-efficiency motors (HEMs) in Malaysia. It is a six-month campaign to encourage the use of HEMs in the industrial sector. In line with the interest shown