CHAPTER 4

RESULTS AND DISCUSSIONS

4.0 Introduction

This chapter contains results on energy efficiency standard, energy label, market transformation and its impact at national level. The chapter is started by presenting the results, observations and general conclusions from the survey and power consumption data collection. It is then proceeded with the assessment to predict the future data of TV ownership, energy consumption and percentage of fuel mix from electricity generation. Next, the statistical analysis is conducted to propose a suitable energy standard. After the statistical analysis is complete, the engineering/economic analysis is conducted to examine the potential efficiency improvement of the appliance. Together with energy efficiency standard, a suitable energy label program is also proposed and the market transformation due to the implementation of standard and label are predicted. Finally, the energy, economical and environment impact from the implementation of standard and label are presented.

4.1 Results from household survey

The household survey was conducted on 275 households, from 11 different states throughout Malaysia. The survey started on December 2002 and ended on January 2003. Out of 275 questionnaires distributed, 13 were found incomplete and as a result only 262 questionnaires were used for TV usage calculation. In this study, household TV usage are calculated as the sum of four different activities: watching broadcast TV, watching VCR/VCD/DVD, playing video games (or games console via a TV set) and surfing the Internet (via a TV set with a device known as Web-TV). The results of the survey are summarized in Table 4.1 and discussed in the following paragraphs.

Table 4.1 Contributions of TV, VCR/VCD/DVD, video game and Web TV to average household TV usage

	Homes with device	Average usage per home (h/day/home)
TV (single set)	100%	7.3
TV (multiple sets)	27.5%	10.7
VCR/VCD/DVD	80.5%	2.0
Video Game	15.6%	2.4
Web-TV	2.3%	0.7
Total single set home	[TV+VCD+V.Game+Web-TV]	12.4
Total multiple set home	[TV+VCD+V.Game+Web-TV]	15.8

As can been seen in Table 4.1, households with multiple TV sets on average consume more electricity than households with single TV sets. This is because in most households with multiple units, TV sets are utilized simultaneously, making it one of the largest household electricity consuming device. Meanwhile, the penetration of games console (device for playing video game with TV) and Web-TV are considered low because many households nowadays use their computers to play games and serve the Internet.

A very important aspect of this survey is to determine the average duration TV sets in Malaysian household are in active (on-mode) and standby mode. The total of 262 households surveyed will serve as the sample data in determining average hours TV in active and standby mode. This seems to be the best alternative as many of these data are not published at national level. From the survey, it is estimated that in an average household TV sets are active approximately 10.2 hours and in the standby mode approximately 4.5 hours daily. These values will serve as the important input data in the calculation of annual energy consumption (AEC).

Meanwhile from the survey conducted, 21 and 29 inch TV set shows the highest ownership in the Malaysian household with penetration approximately 35.8% and 28.8% each respectively. The full details regarding TV ownership, which are classified into screen sizes are presented in Figure 4.1.

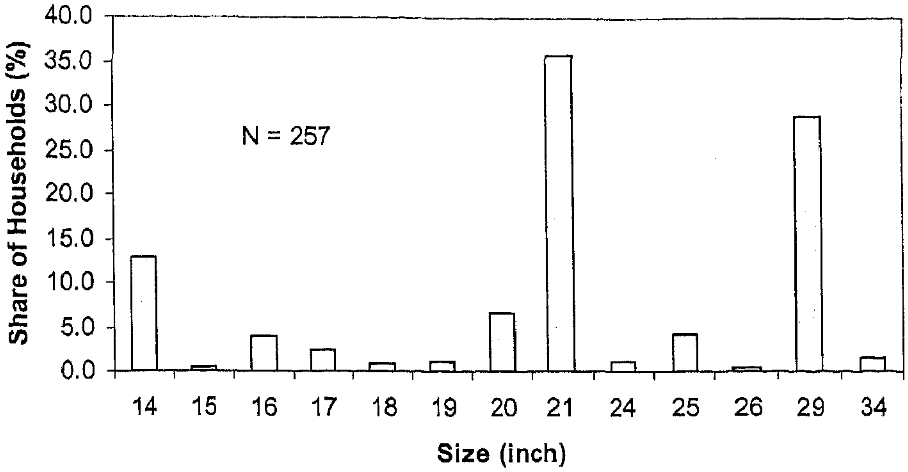


Figure 4.1 TV ownership with regard to screen size

4.2 Results from active power and standby power data collection

The power measurements were conducted only on 20 TV sets in the standby mode. The rest of the data including TV active mode data have been compiled from manufacturer's TV catalogue, market survey conducted at electrical retail shops and data published by organizations such as Energy Star (2002) and GEEA (Group for Efficient Appliances, 2001). Data published here could be adapted since many of these appliances are identical in most countries because they manufactured by only few, large, multinational companies; as a result, data collected in one country often apply to others (Meier and Huber, 1997).

From the list compiled on nearly 500 TV sets, it can be summarized that the average TV power consumption in active mode is *136* W and *3 W* in the standby mode. At this moment, it is necessary to compare this study with the study conducted by Rosen and Meier (2000). It was reported that in the United States, the average TV power consumption in the active mode was 75 W and 4.5 W in the standby mode. To justify this situation, it should be noted that this study was conducted in 1998 (published in the year 2000) and ever since TV technology has grown rapidly and the power consumption in the active mode have increased tremendously with the introduction of new technologies such as the plasma screen. As such, power consumption in the active mode has increased tremendously. On the issue of standby power, lately there are some efforts undertaken by the developed nations to reduce the standby power of appliances. Therefore the reduction of standby power from 4.5 W (study conducted by Rosen & Meier) to 3 W is in accordance with this effort since many of the TV sets in our country are shipped from a developed nations or bare a foreign brand. In addition, similar trend towards reduction in standby power (in Japan) is also reported by Nakagami *et al.* (2002).

In this study, the average TV power consumption data will be used to compute the average annual energy consumption (AEC) in the year survey is conducted which is 2003. However there is a difference between the computation conducted in this study and the computation conducted in other studies. Some studies consider two modes in the standby power, which are standby active and standby passive. This causes them to compute energy consumption of single TV set for a total of 24 hours on a single day. However, this is not the case that is considered in this study. It is due to the fact that when a TV set is not utilized, from the survey conducted we found that it is either switched to the standby mode with a remote control (sometimes are left idling the whole day) or are switched off at the plug mounted on the wall (which draws 0W). Therefore computation of energy consumption for this study are considered at 10.2 hours in the active mode and 4.5 hours in the standby mode (as shown in section 4.1). Meanwhile, Figure 4.2 and 4.3 show the power measurement distribution for TVs in Malaysia. The data have been compiled from manufacturer's TV catalogue, market survey and published data.

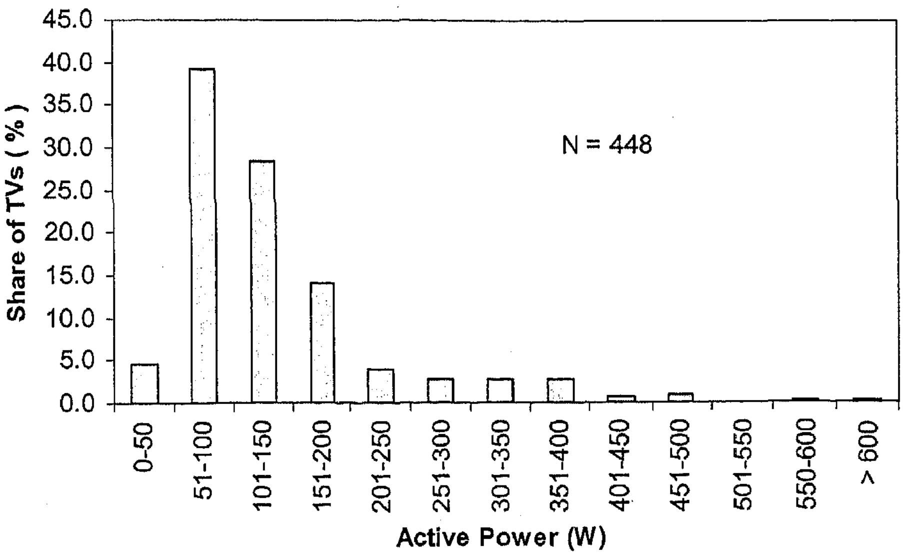


Figure 4.2 Distribution of active power for TVs

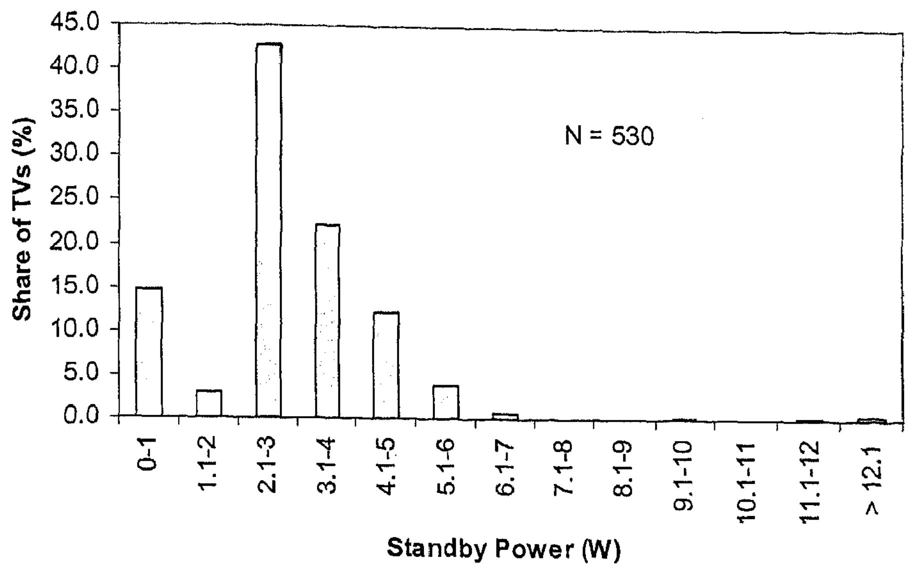


Figure 4.3 Distribution of standby power for TVs

4.3 Data collection and assessment

4.3.1 Household data

Household data were collected from Population and Housing Census of Malaysia (1970, 1980, 1991 & 2000), which is published every ten years by the Department of Statistics, Malaysia. The collected data for the number of households and the number of households possessing TV set are presented in Table 4.2.

Table 4.2 Television ownership data in Malaysian household

Year	Total households	Households with TV	Percentage of TV penetration
1970	1,890,276	186,036	9.8%
1980	2,516,295	1,226,947	48.8%
1991	3,566,859	2,741,640	76.9%
2000	4,910,921	4,049,748	82.5%

Source: Department of Statistics

4.3.2 Electricity data

The electricity consumption data were collected from National Energy Balance (1997-2001) while the predicted data were collected from Economic Planning Unit (1999). The complete data of electricity consumption growth in Malaysia from 1997 to 2020 is tabulated in Table 4.3. Meanwhile, the percentage of electricity generation based on fuel type and fossil fuel emissions for a unit electricity generation are presented in Table 4.4 and 4.5 respectively (Jaafar and Yuzlaini, 1998; Mahlia *et al.*, 2001; Annas, 2003).

Table 4.3 Electricity consumption data

Year	Total (GWh)	Residential (GWh)
1997	50,952	8,949
1998	53,195	10,158
1999	55,961	10,286
2000	61,168	11,320
2001	65,015	12,564
2020	195,253	35,360

Source: National Energy Balance; Jaafar and Yuzlaini, 1998

Table 4.4 Percentage of electricity generation based on fuel types

Year	Coal (%)	Oil (%)	Gas (%)	Hydro (%)
1990	13.80	41.90	26.20	17.80
1994	9.30	22.20	51.70	16.70
2000	7.90	5.30	78.70	8.00
2010	18.00	2.00	50.00	30.00

Source: Annas, 2003; Jaafar and Yuzlaini, 1998

Table 4.5 Emissions for a unit electricity generation based on energy sources

Fuels	Emission (kg/kWh)			
	CO_2	SO_2	NO_X	CO
Coal	1.1800	0.0139	0.0052	0.0002
Oil	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

Source: Mahlia *et al.*, 2001

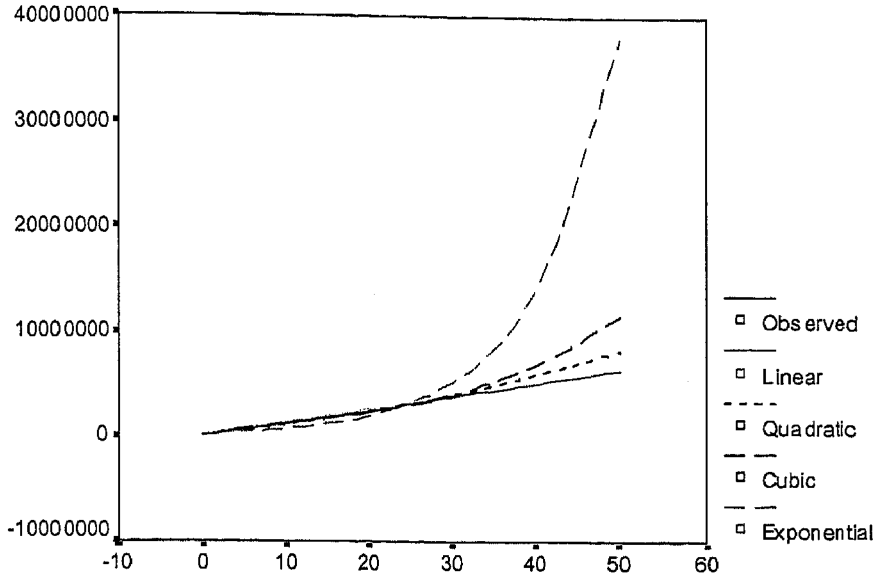
4.4 Data assessment

The data presented in Table 4.2 - 4.4 are utilized to predict the unavailable data from the year 2005 to 2010. The software used for this purpose is SPSS (Statistical Package for the Social Sciences) version 9.0 for Windows. The method that is employed for this analysis include plotting a linear, quadratic, cubic and an exponential curve. From these curves, the best-fit curve is selected for prediction purpose in this study.

4.4.1 Estimation of number of households with TV sets

```
MODEL:  MOD_2.

Independent:  INCREMEN

  Dependent Mth   Rsq  d.f.       F  Sigf      b0       b1       b2       b3

    TV      LIN  .985    2  132.86  .007 52756.4   126612
=>  TV      QUA  .998    1  258.92  .044  214519  76262.6  1682.35
    TV      CUB 1.000    0     .00 1.000  186036   118522  -2335.7  89.2670
    TV      EXP  .909    2   19.90  .047  272942    .0987

Notes:
=> Selected curve for estimation
```

Number of Households with TV



Increment of Year

Figure 4.4 Curve estimation for number of households with TV sets using SPSS

For the number of households with TV sets estimation, the quadratic curve is used for prediction. Although the cubic curve shows slightly a higher value of R-squared, however after a certain time period, the curve is expected to swing downwards. Whereby, the number of households with TV sets in this country is not expected to reduce because of the increase in second TV penetration and the increase in number of household constructions in Malaysia. Therefore the quadratic curve seems appropriate for TV sets estimation in this study. Based on the data shown in Table 4.2, the predicted number of households with TV sets is presented in Figure 4.4

4.4.2 Estimation of electricity consumption in the residential sector

```
MODEL:  MOD_1.
_

Independent:  INCREMEN

  Dependent Mth   Rsq  d.f.       F  Sigf      b0       b1       b2       b3

   RESIDENT LIN  .997     4 1424.78  .000 8351.71  1167.48
=> RESIDENT QUA  .999     3 2498.65  .000 9016.43  770.397  16.3065
 9 RESIDENT CUB  .999     3 2498.65  .000 9016.43  770.397  16.3065
   RESIDENT EXP  .994     4  718.27  .000 9408.80    .0580

Notes:
9  Tolerance limits reached; some dependent variables were not entered.
=> Selected curve for estimation
```

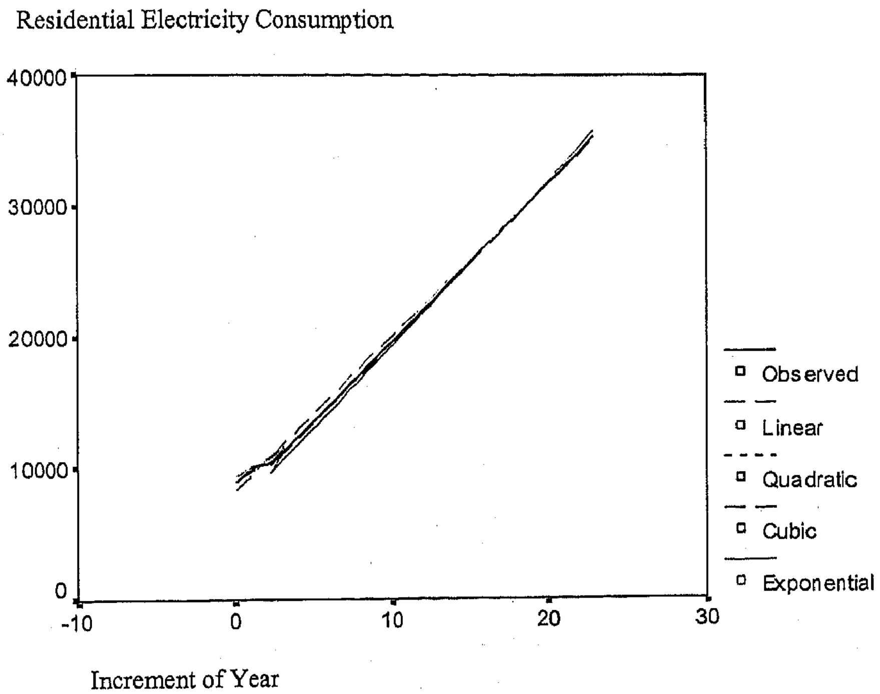


Figure 4.5 Curve estimation for electricity consumption in the residential sector

For the estimation of electricity consumption in the residential sector, the quadratic curve is used for prediction. This is because the quadratic curve tends to follow the path of the observed line and has the highest value of R-squared. Based on the data shown in Table 4.3, the predicted amount of electricity consumption in the residential sector is presented in Figure 4.5

4.4.3 Estimation for percentage of electricity generation based on fuel type (coal)

MODEL: MOD_3.

Independent: INCREMEN

	Dependent	Mth	Rsq	d.f.	F	Sigf	b0	b1	b2	b3
	COAL	LIN	.249	2	.66	.501	10.0145	.2630		
	COAL	QUA	1.000	1	1077.77	.022	13.7362	-1.3982	.0806	
=>	COAL	CUB	1.000	0	.	.	13.8000	-1.5046	.0972	-.0006
	COAL	EXP	.168	2	.40	.591	10.0081	.0176		

Notes:
=> Selected curve for estimation

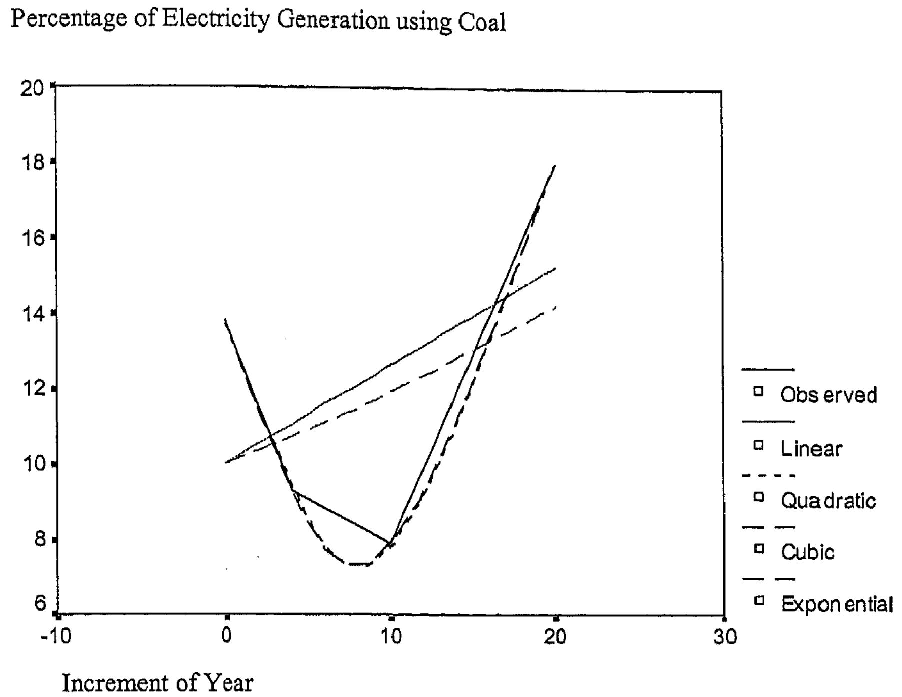


Figure 4.6 Curve estimation for percentage of electricity generation based on fuel type (coal)

For the estimation of percentage of electricity generation based on fuel type (coal), the cubic curve is used for prediction. The curve is chosen because it tends to follow the trend of the observed line more accurately and closely. Based on the data shown in Table 4.4, the predicted number of households with TV sets is presented in Figure 4.6

Using the similar procedure, the predicted percentages of oil, hydropower, gas together with coal from the year 2005 to 2010 are presented in Figure 4.7. The year 2005 was chosen because the standard is proposed beginning of 2005 in this study. The predicted data is presented in Appendix E.

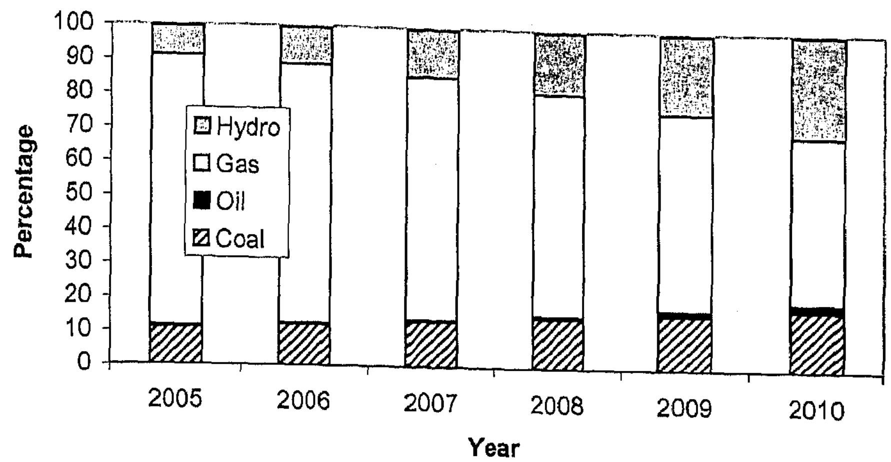


Figure 4.7 Predicted percentages of fuel mix for electricity generation in Malaysia

4.5 Estimation of TV sets annual efficiency improvement

4.5.1 On-mode

TV sets overall annual efficiency improvement is a combination of on-mode efficiency improvement and standby-mode efficiency improvement. Therefore to estimate TV sets annual efficiency improvement, the calculation is divided into two sections, which are on-mode and standby mode. For on-mode, first the power level data obtained from household survey is plotted against the year the TV set is manufactured. In this study the plot involves 14-inch, 21-inch and 29-inch TV sets. Next, a trend line is drawn through a regression analysis of all the data points. This line represents the average on-mode efficiency improvement line that will be used to compute the annual efficiency improvement. Figure 4.8 shows the plot of three sizes of TV sets to determine the on-mode annual efficiency improvement.

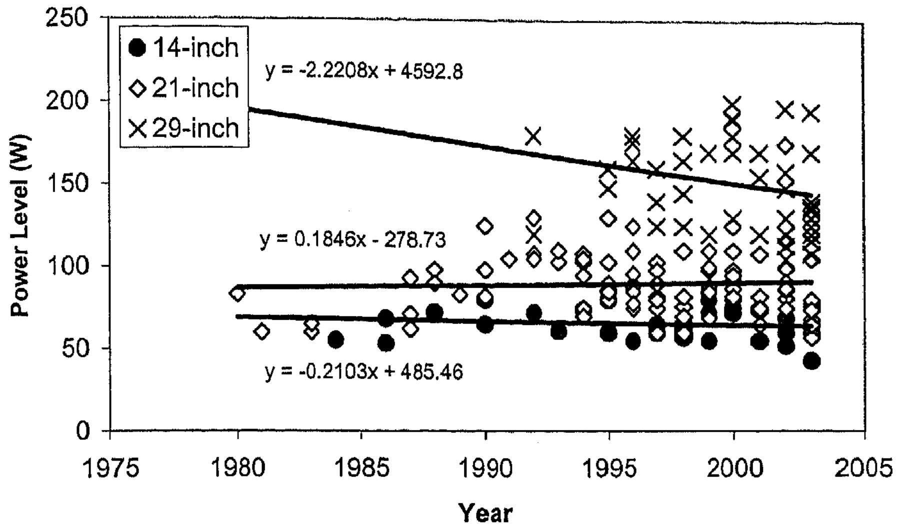


Figure 4.8 On-mode power level plot for 3 TV sizes

Hence to determine the annual efficiency improvement (AEI_{on}), it is the percentage of efficiency improvement between the year 1980 and 2000 divided by the duration between these two periods, which is 20 years. The formula is enumerated below:

$$AEI_{on} = \frac{\left(\frac{P_{1980} - P_{2000}}{P_{1980}} \times 100\right)}{20} \tag{4.1}$$

The value of average power level (P) is obtained from the equation for average on-mode efficiency improvement line shown in Figure 4.8. The results are tabulated below.

Table 4.6 Results from TV sets annual efficiency improvement estimation

Type of TV	Equation	(P_{1980})	(P_{2000})
14-inch	P = - 0.2103x + 485.46	69	65
21-inch	P = 0.1846x - 278.73	87	90
29-inch	P = - 2.2208x + 4592.8	196	151

Therefore the annual efficiency improvement for;

i) 14-inch TV

$$AEI_{14-inch} = \frac{\left(\frac{69-65}{69} \times 100\right)}{20} = 0.3\%$$

ii) 21-inch TV

$$AEI_{21\text{-}inch} = -0.2\%$$

iii) 29-inch TV

$$AEI_{29\text{-}inch} = 1.1\%$$

Hence the on-mode annual efficiency improvement is the average of annual efficiency improvement of 14-inch, 21-inch and 29-inch TV, which is 0.4. Although this is a small amount of improvement, similar results were also reported by Rosen and Meier (2000). The authors collected TV average power level data from the year 1985 to the year 1998 in the United States. Eventually they found out that the TV power level have not changed significantly since 1985. However the exact figure was not stated.

4.5.2 Standby-mode

The standby-mode efficiency improvement is adapted from Harrington and Kleverlaan (2001). It is due to the fact that impossibility to obtain this value from the household survey because manufacturers do not display standby power level on TV sets or its user manual. Even the data obtained from product catalogue only published standby power level data from the year 2002 onwards. However Harrington and Kleverlaan (2001) conducted an in depth study whereby standby power level of TV sets data were collected from the year 1970 to the year 2001. In Malaysia on the other hand, it is important to only concentrate at standby power improvement from the year 1990 onwards because most TV sets in Malaysia before this period were not equipped with standby mode or a remote control. The standby average power level plot from the year 1990 onwards as published by Harrington and Kleverlaan (2001) is illustrated in Figure 4.9.

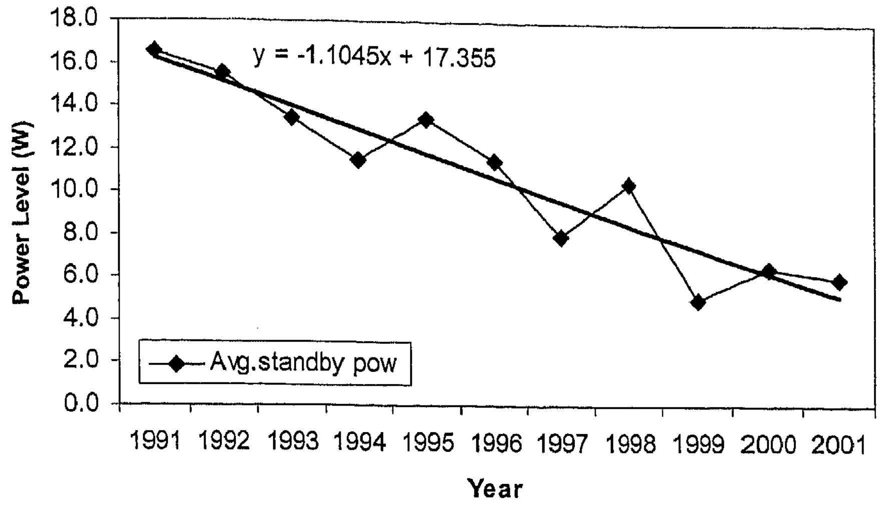


Figure 4.9 Average standby power level plot

Hence, the annual standby efficiency improvement (AEI_{st}) could be estimated by using an equation similar to equation (4.1) but considering a period of 10 years from 1991 to 2001. The calculation is shown below.

$$AEI_{st} = \frac{\left(\frac{16.3-5.3}{16.3}\times 100\right)}{10} = 6.7\%$$

4.5.3 Overall annual efficiency improvement

The TV sets overall annual efficiency improvement is a combination of on-mode efficiency improvement and standby-mode efficiency improvement. To compute this figure, the duration average TV set in on-mode and standby-mode (hours/day) are considered as an impact factor to be added on to the calculation. The duration average TV set in on-mode and standby-mode data are obtained from household survey, which are 10.2 hours/day and 4.5 hours/day each respectively. It can been seen that the on-mode annual efficiency improvement has more impact on the overall efficiency improvement because its utilized more than twice the duration of standby-mode efficiency improvement. The calculation to compute the overall efficiency improvement (AEI) is shown below:

$$AEI = \frac{0.4\%(10.2h/day) + 6.7\%(4.5h/day)}{(10.2h/day + 4.5h/day)} = 2.3\% \approx 2\%$$

Therefore, TV sets annual efficiency improvement is 2%. This means that the efficiency of a TV set improves 2% even in the absence of standard and label. This figure will used throughout this study especially in predicting market transformation.

4.6 Estimation of TV sets saturation level

It is important to compute TV sets saturation level per household in Malaysia because the data presented in the Population and Housing Census of Malaysia (1970, 1980, 1991 and 2000) are the total number of household that owns TV set and does not indicate the total number TV sets in Malaysian household. Therefore the number of TV sets per household (saturation level) needs to be estimated. It has been reported in 2002 that in a Malaysian bungalow house, the number of average TV ownership is 3 units per household whereas the low cost and medium cost house were reported to own only one unit on average (CENTREE, 2002). Therefore data of

Malaysian housing achievement and target according to the cost of houses are collected from the year 1986 to 2005. These data are compiled from the Sixth to the Eight-Malaysia Plan Report (1991, 1996 and 2001). The results are tabulated in Figure 4.7. In the calculation of TV set saturation level per household, the number of households that are not occupied is considered to be negligible. Moreover, in the calculation it is assumed that the people occupying the housing for poor do not own a TV set.

Table 4.7 Number of housing targets and achievements, 1986 – 2005

Year	Housing for poor	Low cost	Low Medium cost	Medium cost	High cost
2001-2005	16,000	232,000	131,300	110,700	125,000
1996-2000	17,229	190,597	72,582	227,956	351,116
1991-1995	N/A	261,386	N/A	282,436	103,638
1986-1990	N/A	164,396	N/A	116,782	19,750
Total	33,229	848,379	203,882	737,874	599,504

N/A = Not Available

Hence the TV saturation level per household (S) could be calculated as follows: This figure will be used throughout this study especially in predicting the impacts.

$$S = \frac{((848{,}379\times 1)+(203{,}882\times 1)+(737{,}874\times 1)+(599{,}504\times 3))}{(33{,}229+848{,}379+203{,}882+737{,}874+599{,}504)} = 1.48 \approx 1.5$$

4.7 Energy efficiency standard

4.7.1 Statistical analysis

The statistical analysis is conducted based on the active power and standby power data collection. The following criteria guided the selection of TV models:

- variation in energy consumption
- variation in screen size
- variation in screen display device

Together with the average duration (per day) TV set in standby and active mode data (obtained from household survey), these data are then used to compute the annual energy consumption for each TV sets. Next the annual energy consumption data for each TV set is plotted against its sizes (sizes are in inches) and a trend line is drawn through a regression analysis of all the data points. This line represents the average energy use baseline as of the year survey is conducted (2003). Next an average energy use baseline as of 2005 is estimated by using equation (3.1). Together with this line, a 10% energy saving line is drawn. This line represents the standard that is proposed in this study. Figure 4.10 presents the trend line for TV set's annual energy consumption (AEC) in Malaysian market.

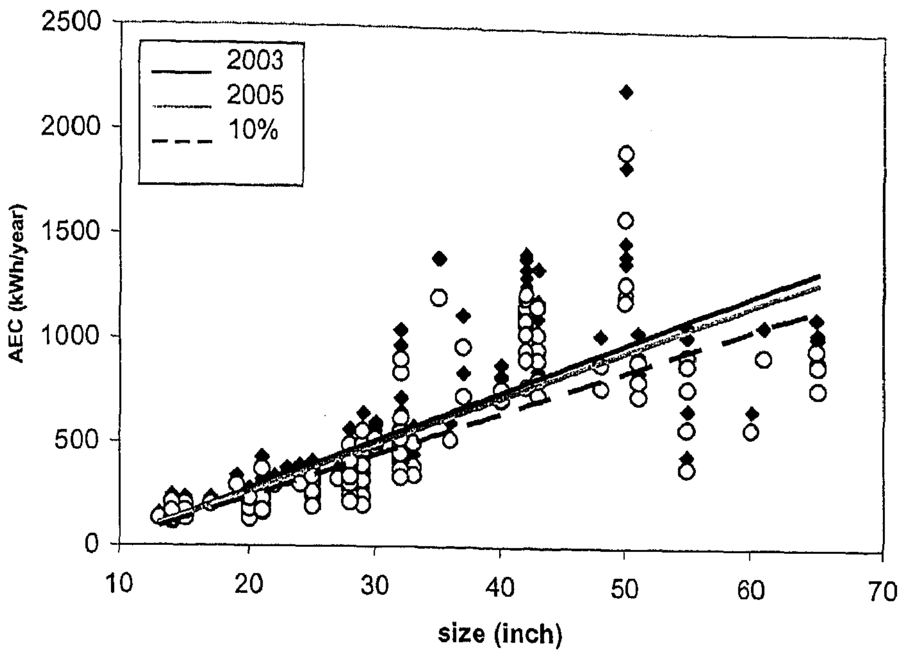


Figure 4.10 Trend line for TV set's annual energy consumption (AEC) in Malaysian market

As stated in section 3.5 in the previous chapter, supposedly all the TV sets above the 10% energy saving line will be thrown out of the market and replaced with a model of higher efficiency as suggested by Turiel *et al.* (1997). However when this is done in this study, all the plasma TVs which is considered the next generation home entertainment device will be thrown out of the market. This is because in reality, plasma TV consumes more electricity than conventional TV set. Moreover, there are no replacements for other plasma TVs which consumes electricity, lower than the 10% energy saving line.

Hence it is suggested that the TV set samples that are collected for the statistical analysis are divided according to their classes before decision to throw (or replace) which TV set out of the market be made. In this study, the classes are chosen according to the type of display device utilized in each TV set which divides it into four types of TV that exist in the market. These are conventional CRT TV, LCD TV, plasma TV and rear projection TV (PJTV). Next, the statistical analysis is conducted on each TV set classes. Figure 4.11 to 4.14 shows the statistical analysis as applied to each TV set classes.

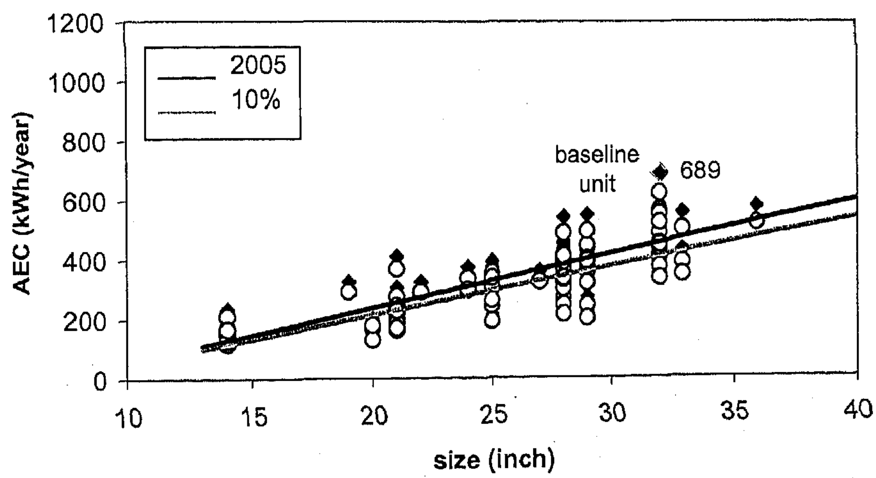


Figure 4.11 The standard (10%) and the baseline model for class I (CRT TV)

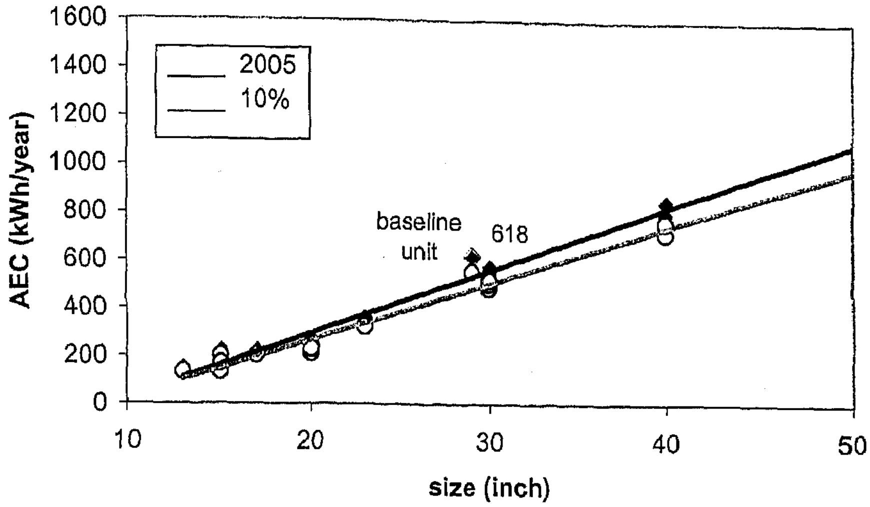


Figure 4.12 The standard (10%) and the baseline model for class II (LCD TV)

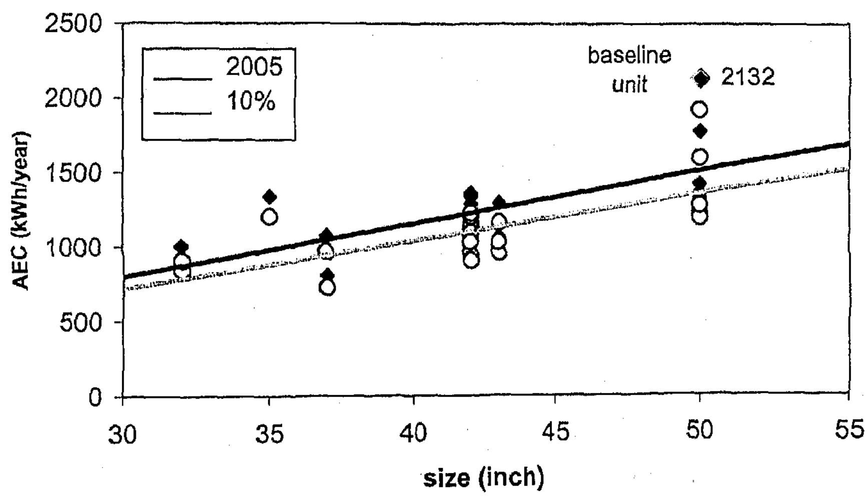


Figure 4.13 The standard (10%) and the baseline model for class III (Plasma TV)

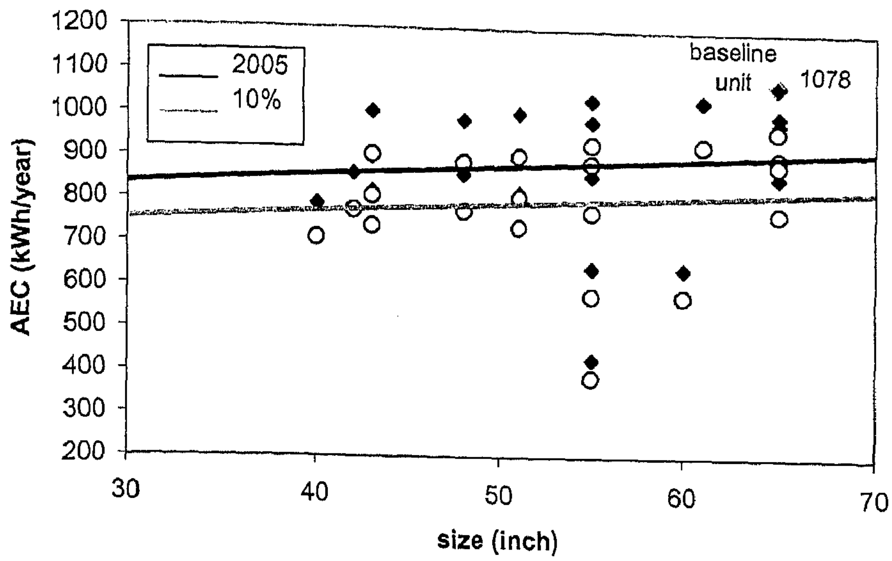


Figure 4.14 The standard (10%) and the baseline model for class IV (PJTV)

As can been seen from Figure 4.11 to 4.14, after applying the statistical approach on each TV class, any the TV sets above the 10% standard line will be regarded as inefficient and will be eliminated from the market. If as matter of fact, new models of TV (TVs which are not included in the statistical analysis yet) are shipped and introduced in the Malaysian market during the standard period, then the following are suggested.

One sample unit must be randomly selected from a pool of at least 30 units of the same model (same size and type) and sent to the Standardization Institute (Na Phuket & Prijyanonda, 2001). The model has to be tested and its particular AEC (annual energy consumption) value has to be determined by using the 10.2 hours in active mode and 4.5 hours in the standby mode model. The AEC value obtained from TV testing is compared with the AEC value obtained from 10% standard line. If the AEC value obtained from TV testing is higher than the value from 10% standard line, therefore the TV unit is incompliant with standard and is not eligible to be sold in the Malaysian market. To ease the operation of obtaining the AEC value from the 10% standard line, the equations for each class are enumerated below. The equations are obtained from Figure 4.11 to 4.14. The variable 'x' denotes the size of TV in inches.

- For conventional CRT TV (class I):

$$AEC_{CRT} = 16.338x_{CRT} - 113.99 \quad (4.2)$$

- For LCD TV (class II):

$$AEC_{LCD} = 23.818x_{LCD} - 211.02 \quad (4.3)$$

- For Plasma TV (class III):

$$AEC_{PLS} = 31.991x_{PLS} - 237.74 \quad (4.4)$$

- For Rear Projection TV (class IV):

$$AEC_{PJTV} = 1.8972x_{PJTV} + 696.6 \quad (4.5)$$

Meanwhile from Figure 4.11 to 4.14, it can be also noted that the distribution of TVs such as the LCD, plasma and PJTV are relatively low compared CRT TV. This is due to the fact that the penetration of these types of TV is still low in the market especially in a developing country like Malaysia. However, it is expected to grow in the near future. Meanwhile, the selected baseline units for each TV class which will used in the engineering/economic analysis are also indicated in Figure 4.11 to 4.14.

4.7.2 Engineering/Economic analysis

As discussed in the previous chapter, to conduct an engineering/economic analysis, the following steps are taken into consideration:

- Select appliance classes
- Select baseline units
- Select design options for each classes
- Calculate efficiency improvement from each design option
- Combine design options and calculate efficiency improvements
- Develop cost estimates (include installation and maintenance) for each design option
- Generate cost-efficiency curves

In this study, the main purpose for conducting the engineering/economic analysis is to determine the possibility of achieving the proposed 10% energy efficiency standard for each product class by analyzing the potential efficiency improvement. Engineering/economic analysis also enables us to examine the price involved for making these improvements. However the engineering/economic analysis is only an approximation to seek the potential efficiency improvement.

4.7.2.1 Selection of appliance classes

In this study, TVs are divided into 4 classes according to the type of display devices being utilized and its capacity. These classes are the conventional CRT (Cathode Ray Tube) TV, LCD (Liquid Crystal Display) TV, Plasma TV and Rear

Projection TV (PJTV). The reason for choosing these product classes are explained in Chapter 3, section 3.5.

4.7.2.2 Selection of baseline unit

For selecting the baseline unit, the least efficient TV model from each product classes are chosen. The reason for this selection is explained in Chapter 3, section 3.5. The baseline units are indicated in Figure 4.11 to 4.14 and the annual energy consumption (AEC) for each baseline unit is tabulated in Table 4.8.

Table 4.8 The baseline unit for each TV class

Class	Type of TV	Size (inch)	AEC (kWh/year)
I	CRT	32	689
II	LCD	29	618
III	Plasma	50	2132
IV	PJTV	65	1078

4.7.2.3 Selection of design option for each class

The next step for conducting engineering/economic analysis is to select design options that improves TV efficiency for each product class. Most of the design options selected for this study are replacement of the present component to a more efficient component or adjustments of the current device setting to a more energy efficient setting. The potential improved design options (or method to reduce energy consumption) for each class are obtained from suggestions made by manufacturers, researches and from references such as research papers.

Table 4.9 Potential design options improvement for each class

No	Design options	Class			
		I	II	III	IV
i	Reducing luminance/brightness level	√	√	√	√
ii	Using 1-Watt standby power technology	√	√	√	√
iii	Improving the SMPS	√	√	√	√
iv	Using efficient power amplifiers	√	√	√	√
v	Improving small signal circuitry design	√	√	√	√
vi	Improving video large signal circuitry	√	-	-	-
vii	Stereo surround sound versus DPL sound	√	-	-	-
viii	Improving the lamp efficiency	-	-	-	√

i) Reducing luminance/brightness level

The luminance/brightness level stated here is the default settings fixed by the industry. According to a research conducted by Siderius *et al.* (1998), by reducing only 5% from the original luminance setting, a significant level of electricity could be reduced. Moreover to carry out this method of improvement, there is no cost factor involved.

ii) Using 1-Watt standby power technology

1-Watt standby power technology is now vastly available in most TV sets. However the TV sets selected as the baseline unit in this study, have not adopted this technology. Based on personal communication with Meier (2004), 1-W standby technology exists in most TVs nowadays, as such the incremental cost is essentially zero.

iii) Improving switch mode power supply (SPMS)

The most effective way to reduce the power consumption of TVs is by improving the (main) switched mode power supply (SMPS). A study conducted by Siderius *et al.* (1998) shows that the efficiency of the SMPS varies between 80 and 86%. Nowadays there are technologies for improving SMPS such as the Philips® Green Chip which is utilized in the design of SMPS and costs as low as US$ 0.70 (Harris, 2003). The manufacturers claim that this device could improve the efficiency of SMPS up to 90%.

iv) Using more efficient power amplifier

Power consumption is proportional to audio output, starting at (almost) 0W when there is no audio output. A significant amount of saving in the power consumption of a typical class AB audio power amplifier could be achieved by using class D audio amplifiers. This power saving method would be significant for TV receivers employing surround amplifiers, subwoofers etc. (3-6W savings in typical listening conditions).

v) Improving design of small signal circuitry

The small signal circuitry is the partition inside a TV set that consist of radio frequency tuner, main control microprocessor, video intermediate frequency converter and infra-red remote receiver. In embedded electronic design would lead to a significant amount of mains power saving (approximately 7W).

vi) Improving design of video large signal circuitry

Based on personal communication with Siderius (2004), the video large signal circuitry is only available in CRT type TVs. This is a partition which consist of vertical (also horizontal) deflection drive amplifier and the picture tube. The power consumption of the video large signal circuitry can be reduced (approximately 1.9W at mains input) by components and software modifications.

vii) Using stereo sound compared to Dolby Pro Logic (DPL) sound system

Lately there has been a surround sound technology called Dolby Pro Logic (DPL) and DPL II, which are slowly replacing the stereo sound system. However by sticking to the stereo sound setting, approximately 15W savings could occur at mains input for class I TV. In our calculation of the annual energy savings however, the total savings are cut by half because most TVs nowadays has a feature to shutdown surround sound and utilize it only when it's applicable to broadcast in surround sound.

viii) Improving lamp efficiency

This method of improvement is only applicable for a projection TV (class IV). An article from *www.extremetech.com* has indicated that the application of 100-Watt Ultra High Performance (UHP) arc lamp can deliver more light to the projection screen than a 250 watt metal halide lamp. In the past, Huenges Wajer and Siderius (1998) have also highlighted the need to improve lamp efficiency in order to improve the efficiency of a projection TV. In our study, the replacement of metal halide lamp with UHP lamp is expected to bring approximately 40-Watt savings. In addition, UHP lamp also cost much lesser than a metal halide lamp.

4.7.2.4 Efficiency and incremental cost calculation for each design option

Efficiency improvement calculation is based on the selection of design options for each product class. This analysis takes into account the potential efficiency improvement for each design options independently. The efficiency and cost incremental estimates from using these design options are obtained from estimations made by retail outlets, manufacturers, researches and from references such as research papers. Meanwhile, the incremental costs stated in this study are the additional investment cost to produce the product with higher efficiency or with the new design option. The results of design options improvement for the baseline design (without design change) for class I, II, III and IV with AEC of 689, 618, 2132 and 1078 each respectively are presented in Table 4.10, 4.11, 4.12 and 4.13 respectively.

Table 4.10 AEC (kWh/year) and incremental cost of design options for class I

Design options	Technological improvements	AEC (kWh/year)	AEC (%)	Cost (RM)	Price (%)
0	*Baseline design*	*689*	*0*	*22,998*	*0*
1	Reducing luminance level (5%)	687	0.3	0	0
2	Using 1-W standby technology	684	0.7	0	0
3	Using efficient power amplifier	667	3.2	4.80	0.02
4	Improving SMPS (7%)	641	7.0	12	0.05
5	Using stereo sound setting	661	4.1	0	0
6	Improve video large signal circuitry	682	1.0	6.70	0.03
7	Improve small signal circuitry design	663	3.8	25.20	0.11

Table 4.11 AEC (kWh/year) and incremental cost of design options for class II

Design options	Technological improvements	AEC (kWh/year)	AEC (%)	Cost (RM)	Price (%)
0	*Baseline design*	*618*	*0*	*18,061*	*0*
1	Reducing luminance level (5%)	611	1.1	0	0
2	Using 1-W standby technology	610	1.3	0	0
3	Improving SMPS (7%)	574	7.1	12	0.07
4	Using efficient power amplifier	603	2.4	4.80	0.03
5	Improving small signal circuitry design	592	4.2	25.20	0.14

Table 4.12 AEC (kWh/year) and incremental cost of design options for class III

Design options	Technological improvements	AEC (kWh/year)	AEC (%)	Cost (RM)	Price (%)
0	*Baseline design*	*2132*	*0*	*38,254*	*0*
1	Reducing luminance level (5%)	2124	0.4	0	0
2	Using 1-W standby technology	2125	0.3	0	0
3	Improving SMPS (10%)	1918	10.0	17.00	0.04
4	Using efficient power amplifier	2110	1.0	4.80	0.01
5	Improving small signal circuitry design	2106	1.2	25.20	0.07

Table 4.13 AEC (kWh/year) and incremental cost of design options for class IV

Design options	Technological improvements	AEC (kWh/year)	AEC (%)	Cost (RM)	Price (%)
0	*Baseline design*	*1078*	*0*	*14,725*	*0*
1	Improving SMPS (7%)	1003	7.0	12	0.08
2	Using efficient power amplifier	1063	1.4	4.80	0.03
3	Improving small signal circuitry design	1052	2.4	25.20	0.17
4	Using 1-W standby technology	1075	0.3	0	0
5	Using UHP lamp	929	13.8	-304	-2.06

4.7.2.5 Efficiency and incremental cost calculation for combined design options

The efficiency improvements of the combined design options are calculated starting from the baseline unit. Then, the costs of design changes are accumulated together with the AEC improvements. The design options are calculated based on priority of the highest AEC improvements and the lowest incremental cost. The calculation results are tabulated in Tables 4.14, 4.15, 4.16 and 4.17.

Table 4.14 AEC and incremental cost of combined design options for class I

Design options	Technological improvements	AEC (kWh/year)	AEC (%)	Cost (RM)	Price (%)
0	*Baseline design*	*689*	*0*	*22,998*	*0*
1	0+Reduce luminance level (5%)	687	0.3	22,998	0
2	1+Using 1-W standby technology	682	1.0	22,998	0
3	2+Use stereo sound	654	4.9	22,998	0
4	3+Using efficient power amplifier	632	5.1	23,003	0.02
5	4+Improve SMPS (7%)	584	15.2	23,015	0.07
6	5+Improve video large signal circuitry	577	16.3	23,023	0.11
7	6+Improve small signal circuitry design	551	20.0	23,047	0.21

Table 4.15 AEC and incremental cost of combined design options for class II

Design options	Technological improvements	AEC (kWh/year)	AEC (%)	Cost (RM)	Price (%)
0	*Baseline design*	*618*	*0*	*18,061*	*0*
1	0+Reduce luminance level (5%)	611	1.1	18,061	0
2	1+Using 1-W standby technology	603	2.4	18,061	0
3	2+Using efficient power amplifier	588	4.9	18,066	0.03
4	3+Improve SMPS (7%)	544	12.0	18,078	0.09
5	4+Improve small signal circuitry design	518	16.2	18,103	0.23

Table 4.16 AEC and incremental cost of combined design options for class III

Design options	Technological improvements	AEC (kWh/year)	AEC (%)	Cost (RM)	Price (%)
0	*Baseline design*	*2132*	*0*	*38,254*	*0*
1	0+Using 1-W standby technology	2125	0.3	38,254	0
2	1+Reduce luminance level (5%)	2117	0.7	38,254	0
3	2+Improve SMPS (10%)	1903	10.7	38,271	0.04
4	3+Using efficient power amplifier	1881	11.8	38,276	0.06
5	4+Improve small signal circuitry design	1855	13.0	38,301	0.12

Table 4.17 AEC and incremental cost of combined design options for class IV

Design options	Technological improvements	AEC (kWh/year)	AEC (%)	Cost (RM)	Price (%)
0	*Baseline design*	*1078*	*0*	*14,725*	*0*
1	0+Using UHP lamp	929	13.8	14,421	-2.06
2	1+Using 1-W standby technology	926	14.1	14,421	-2.06
3	2+Using efficient power amplifier	911	15.5	14,426	-2.03
4	3+Improve SMPS (7%)	836	22.4	14,438	-1.95
5	4+Improve small signal circuitry design	810	24.9	14,463	-1.78

4.7.2.6 Life cycle cost and payback period calculation

The life cycle cost and payback periods are calculated using equation (3.3) and (3.6). In addition, some input values such as discount rate, electricity price, appliance life span, average operation hours and the data of baseline model for each class are required. The baseline units for each class have been presented in Figures 4.11 to 4.14 and the input data are tabulated in Table 4.18. The value of discount rate and TV life span are obtained from Mahlia *et al.* (2002) and Webber & Brown (1998). It is assumed that all four classes of TV have the same life span period.

Table 4.18 The input value of baseline models for each class

Variable	Class I	Class II	Class III	Class IV
Baseline AEC (kWh/year)	718	644	2220	1122
Electricity price (RM$/kWh)	0.235	0.235	0.235	0.235
Discount rate (%)	7	7	7	7
Appliance life span (years)	11	11	11	11
Average on-mode operation hours (h/year)	10.2	10.2	10.2	10.2
Average standby mode operation hours (h/year)	4.5	4.5	4.5	4.5

The cumulative impact on TV set's AEC and price as a result of design changes are presented in Tables 4.19, 4.20, 4.21 and 4.22 and Figures 4.15, 4.17, 4.19 and 4.21. Besides that, the cumulative payback period and life cycle cost for typical Malaysian TV set are shown in Figures 4.16, 4.18, 4.20 and 4.22.

Table 4.19 Life cycle cost and payback period calculation for class I

No.	Design options	AEC (kWh/year)	PP (RM)	OE (RM)	LCC (RM)	PBP (years)
0	*Baseline design*	*689*	*22,998*	*162*	*24,212*	*0.00*
1	0+Reduce luminance level (5%)	687	22,998	161	24,209	0.00
2	1+Using 1-W standby technology	682	22,998	160	24,200	0.00
3	2+Use stereo sound	654	22,998	154	24,150	0.00
4	3+Using efficient power amplifier	632	23,003	149	24,117	0.39
5	4+Improve SMPS (7%)	584	23,015	137	24,044	0.73
6	5+Improve video large signal circuitry	577	23,023	136	24,040	1.02
7	6+Improve small signal circuitry design	551	23,047	129	24,018	1.65

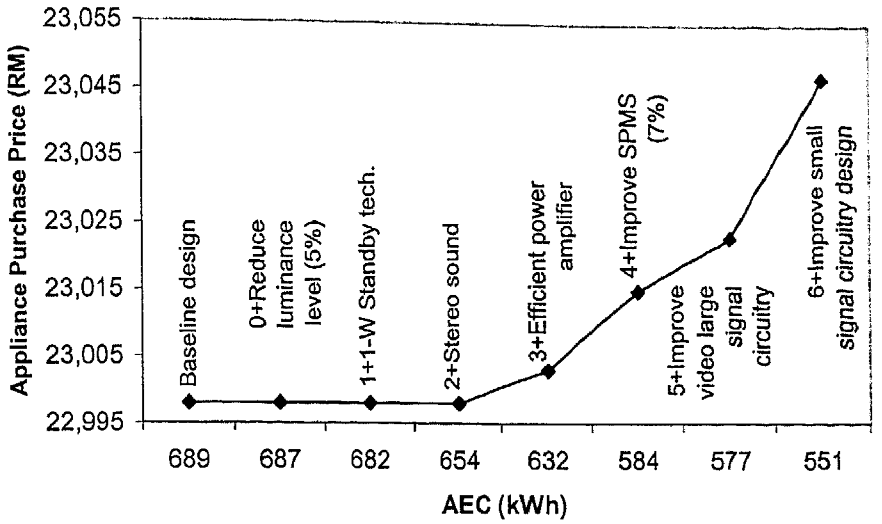


Figure 4.15 Impact of design options on purchase price and AEC for class I

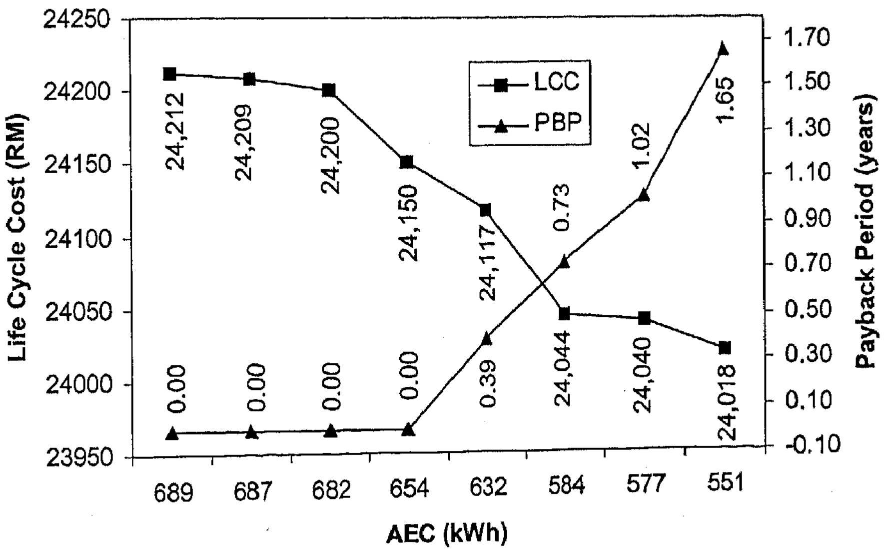


Figure 4.16 Payback period and life cycle cost for class I

Table 4.20 Life cycle cost and payback period calculation for class II

No.	Design options	AEC (kWh/year)	PP (RM)	OE (RM)	LCC (RM)	PBP (years)
0	*Baseline design*	*618*	*18,061*	*145*	*19,150*	*0.00*
1	0+Reduce luminance level (5%)	611	18,061	144	19,138	0.00
2	1+Using 1-W standby technology	603	18,061	142	19,124	0.00
3	2+Using efficient power amplifier	588	18,066	138	19,102	0.75
4	3+Improve SMPS (7%)	544	18,078	128	19,037	1.05
5	4+Improve small signal circuitry design	518	18,103	122	19,016	1.98

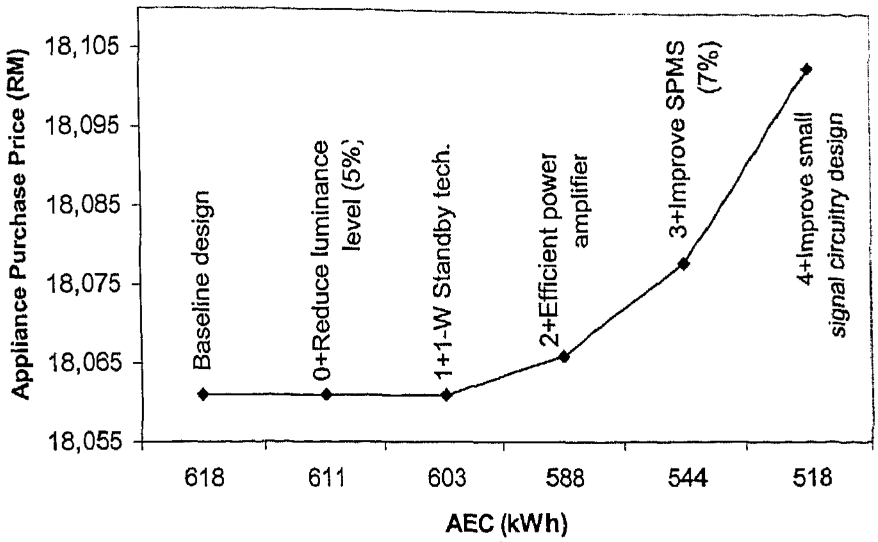


Figure 4.17 Impact of design options on purchase price and AEC for class II

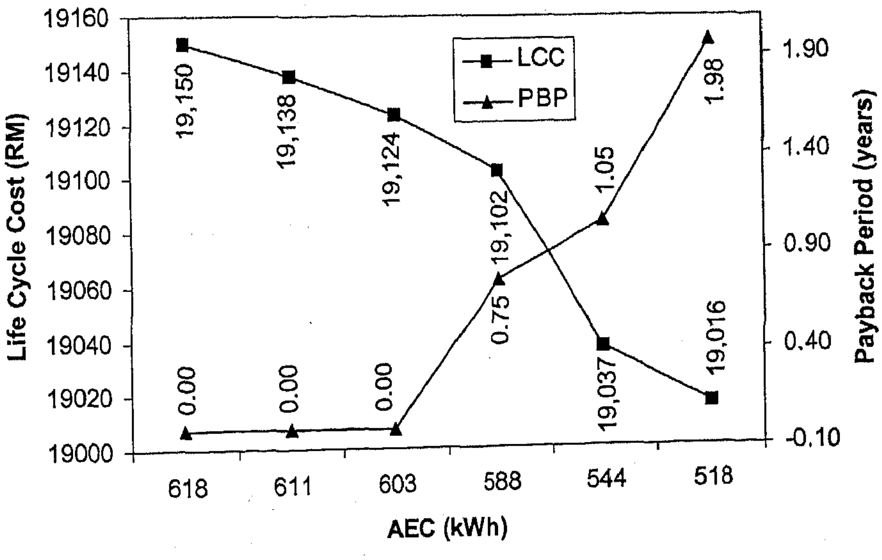


Figure 4.18 Payback period and life cycle cost for class II

Table 4.21 Life cycle cost and payback period calculation for class III

No.	Design options	AEC (kWh/year)	PP (RM)	OE (RM)	LCC (RM)	PBP (year)
0	*Baseline design*	*2132*	*38,254*	*501*	*42,011*	*0.00*
1	0+Using 1-W standby technology	2125	38,254	499	41,999	0.00
2	1+Reduce luminance level (5%)	2117	38,254	497	41,985	0.00
3	2+Improve SMPS (10%)	1903	38,271	447	41,624	0.33
4	3+Using efficient power amplifier	1881	38,276	442	41,591	0.39
5	4+Improve small signal circuitry design	1855	38,301	436	41,570	0.77

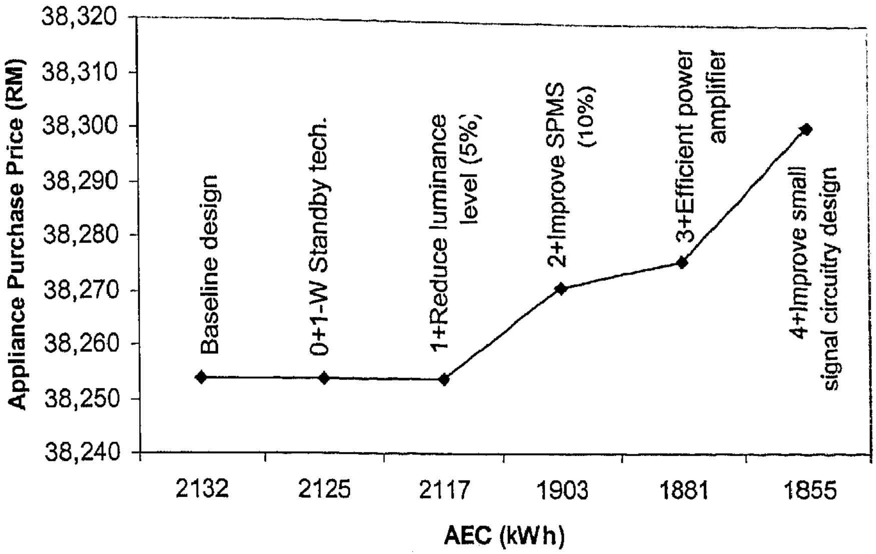


Figure 4.19 Impact of design options on purchase price and AEC for class III

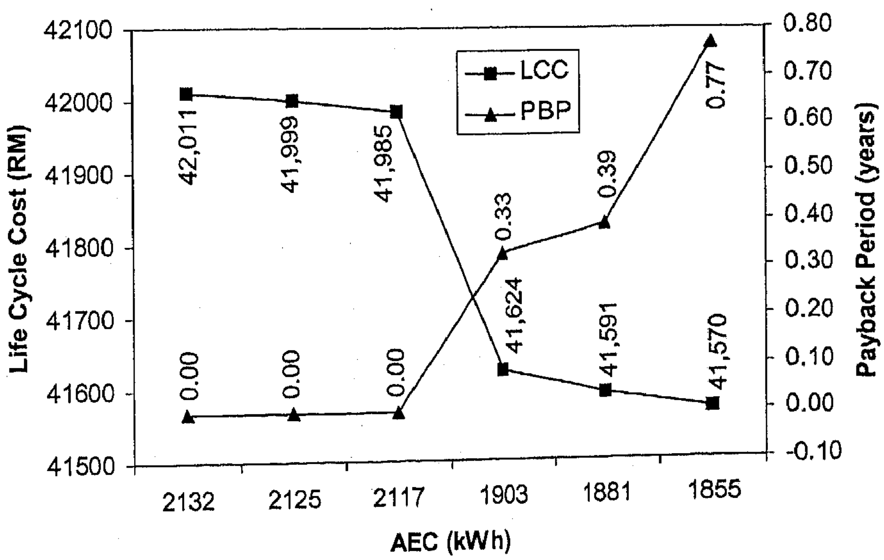


Figure 4.20 Payback period and life cycle cost for class III

Table 4.22 Life cycle cost and payback period calculation for class IV

No.	Design options	AEC (kWh/year)	PP (RM)	OE (RM)	LCC (RM)	PBP (year)
0	*Baseline design*	*1078*	*14,725*	*253*	*16,625*	*0.00*
1	0+Using UHP lamp	929	14,421	218	16,058	0.00
2	1+Using 1-W standby technology	926	14,421	218	16,053	0.00
3	2+Using efficient power amplifier	911	14,426	214	16,031	0.00
4	3+Improve SMPS (7%)	836	14,438	196	15,911	0.00
5	4+Improve small signal circuitry design	810	14,463	190	15,890	0.00

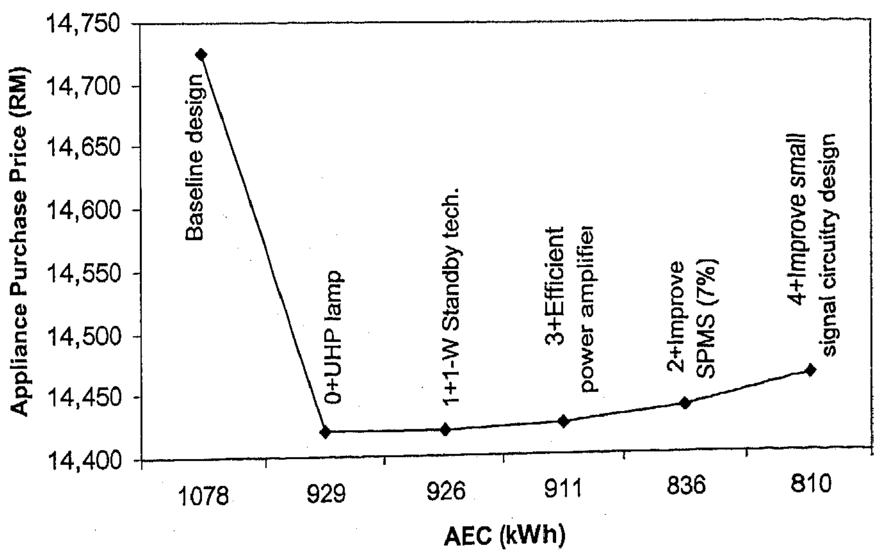


Figure 4.21 Impact of design options on purchase price and AEC for class IV

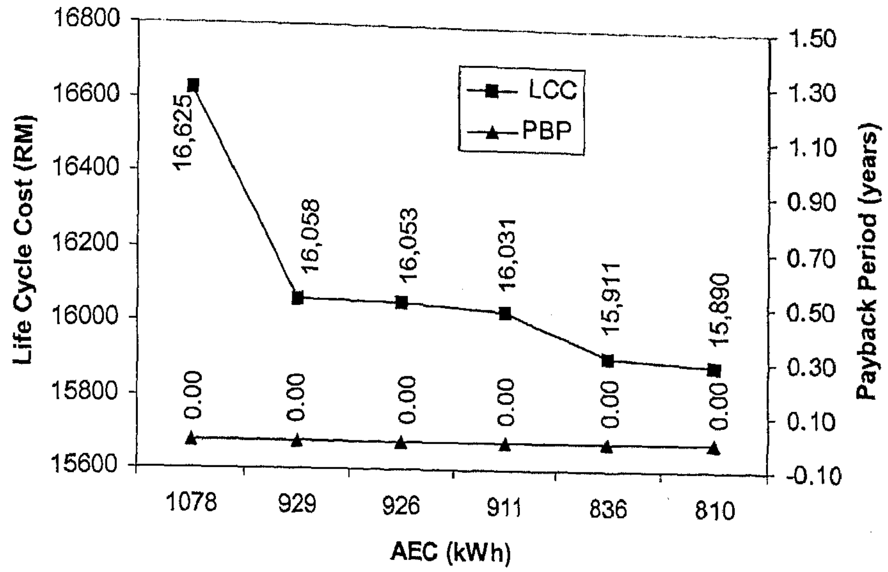


Figure 4.22 Payback period and life cycle cost for class IV

From the analysis above, it can be observed that a significant amount of improvement could me be achieved on the annual energy consumption (AEC) of TV sets in this country. The analysis show that the baseline unit from class I could be improved 20% and the baseline unit from class II could be improved 16.2% from its initial AEC value. Meanwhile the baseline unit from class III and class IV could be improved 13% and 24.9% each respectively.

Surprisingly, these improvements could be achieved with an incremental price of only 0.21%, 0.23%, 0.12% and -1.78% for each TV class. The negative price increment on class IV type of TV is due to the selection of UHP lamp as a design option, which is a new efficient technology that cost much lesser. Overall, the low (or negative) price increase shows that relatively, only small number of manufacturers give importance to the efficiency of TV set. Most of them are more interested in the aesthetics of the product, for example to manufacture a slimmer TV set and also winning the competition among manufacturers for making bigger screen size TV.

For instance, there is an emerging technology that is vastly being adapted for projection TV (class IV) which are the application of microchips and thin panels, instead of the traditional cathode ray tubes (CRT) to magnify small images onto larger screens. This technology is often referred to as "micro projection"[2] technology. However this technology is introduced merely to allow projection TVs to be one-third thinner and weigh half as much as the CRT models (yahoo tech., 2004).

With that being stated, it should be noted that the engineering/economic analysis conducted in this study is only an approximation to seek whether the 10% standard could be achieved or not. Clearly, it is proven from this study that the baseline model from each product class could overcome the standard by at least 13%. Hence, the 10% standard is achievable with a payback period far lesser than the appliance life span. Furthermore, the engineering/economic analysis will prove that the energy efficiency standard that is proposed in this study is not a torture to the manufacturers to make the necessary improvements without any basis by the policy makers in knowing that the standard is achievable or not with a minimum investment.

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[2] Micro projection televisions project small images onto larger screens in one of three ways: using liquid crystal display (LCD) panels, digital light processing (DLP) chips, or liquid crystal on silicon (LCoS) chips (source: yahoo tech., 2004).

4.7.3 Legal status

Energy efficiency standard can be set either mandatory or voluntary. The mandatory standard is usually a law or regulation set by the government that requires manufacturers achieve a specified efficiency level in all new products manufactured after a certain date (Turiel *et al.*, 1997). As for the voluntary standard, these are voluntary agreements or target levels that are usually worked out in consensus arrangement between the government and manufacturers taking part (Turiel *et al.*, 1997).

In this study, it is recommended that a mandatory standard is established. This is due to the fact that mandatory standard are generally the most effective way of rapidly improving the energy efficiency of appliances. Now that all the manufacturers have to abide by the regulation, energy savings, economical benefit and emission mitigation in this country will be boosted. Besides that, this move will also force all manufacturers to consider efficiency as one of the important factor for manufacturing TV sets apart from other factors such as aesthetics or picture clarity.

4.7.4 Expected market penetration of class I – IV type of TV

Before the calculation of market transformation due to energy efficiency standard, it is necessary to predict the market penetration of class I – IV type of TV. The purpose of predicting the market penetration is to include the percentage of market penetration of each class of TV in the calculation of market transformation. The reason for considering these market penetration values are explained in the next paragraph based on the data presented on Table 4.23.

Table 4.23 Market expectation on penetration of class I – IV type of TV

Class	Type	Display type	Price range (RM)	Screen size range[3]	Market penetration
I	CRT	Non-flat	300 – 23,000	14 – 35	97%
II	LCD	Flat screen	3,000 – 30,000	13 – 40	0.5%
III	Plasma	Flat screen	> 20,000	32 – 50	0.5%
IV	PJTV	Non-flat	≥ 4,800	40 – 65	2%

From the data presented in Table 4.23, it is predicted that the market penetration of CRT type TV is 97%. This is due to fact that CRT type of TV is still the least expensive type of TV in the market today. Moreover, in the household survey that was conducted, we found that almost all of our respondents owned a CRT type of TV.

Meanwhile it has been reported that flat screen TVs have grabbed only 3% of the global TV market (The Star, 2003). Therefore it seems logical to predict that for a

[3] It should be noted that bigger screen size TVs are continuously being manufactured. The data presented here are only the current average range of screen size available in the market.

developing country like Malaysia, the market penetration of flat screen TVs are only 1% (0.5% for plasma and 0.5% for LCD display). Moreover, flat screen TVs are still very expensive compared to other types of TV. The cheapest of them all is a 13-inch LCD TV which cost approximately RM 3000 whereby with that much of money, one can buy a pleasant viewing 29-inch CRT TV and a DVD player.

Meanwhile for PJTV, it is expected that the market penetration is 2%. This type of TV is usually the best choice for people who intend to own a big screen TV especially for those who wish to establish a home theater system. The cost of this unit is considered reasonable if its screen size is taken into consideration. For example, a 43-inch PJTV costs approximately RM 5,000 whereas the cost of a plasma screen with the same screen size is anytime more than RM 20,000. Therefore the 2% market penetration seems reasonable as CRT TV is still the number choice in this country.

4.7.5 Expected market transformation due to standard.

Introducing energy efficiency standard eliminates inefficient TV units from the market. As a result, the annual energy consumption (AEC) of the appliance will shift towards lower AEC value. In this study we are considering to implement minimum energy efficiency standard for TV sets in the year 2005. In order to calculate the average AEC distribution in the year 2005, the average AEC distribution in the year 2003 (year survey conducted) has to be calculated first. From the information presented in Figure 4.10 and considering the market penetration value for each type of TV as presented in Table 4.23, the average AEC distribution in the year 2003 is calculated to be 390 kWh/year.

Thus, the average AEC distribution in the year 2005 can be predicted by using equation (3.1). This calculation takes into consideration the annual 2% efficiency improvement (as shown in section 4.5) just before the standard is implemented in the beginning of 2005. From the calculation, the average AEC distribution will reduce from 390 kWh/year in the year 2003 to 374 kWh/year in the year 2005.

As for the calculation of market transformation and product distribution due to mandatory minimum energy efficiency standard, it is calculated by using equation (3.10) and considering the market penetration value. This calculation computes the average AEC distribution as a result of eliminating inefficient TV sets from each product class that did not meet the 10% standard. The average AEC distribution will decrease from 374 kWh/year to 287 kWh/year in the year standard is proposed. These value shows that as a result of the market transformation, the TV AEC distribution will be forced from the first curve (average of 374 kWh/year) towards the second curve (average of 287 kWh/year). The distribution results are illustrated in Figure 4.23 and the predicted market distribution curve is presented in Figure 4.24.

The average minimum efficiency standard is calculated similar to the market transformation calculation stated in the previous paragraph. However this calculation is conducted without eliminating the TV sets that did not meet the 10% standard. The reason behind this calculation is to determine the value that will serve as the borderline to graphically indicate the TV sets that will be eliminated from the market (as shown in Figure 4.24). From the calculation, the average minimum efficiency standard is predicted to be 337 kWh/year.

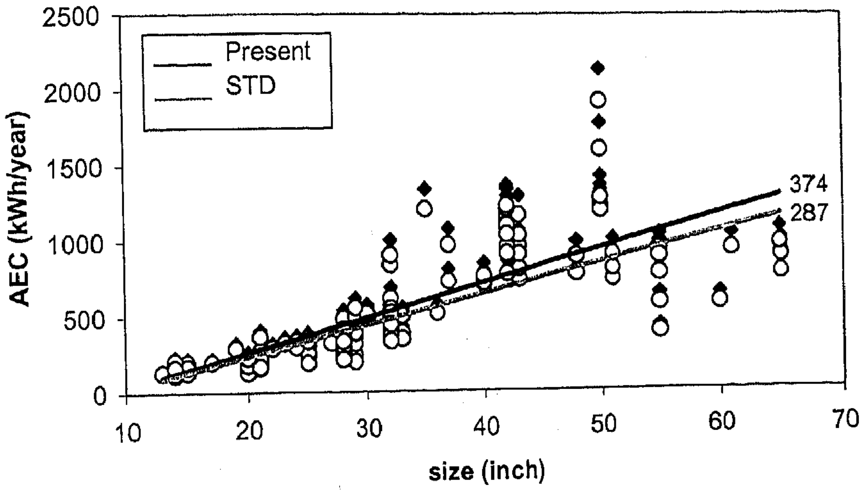

Figure 4.23 Market transformation of TV sets Average AEC in the year standard enacted

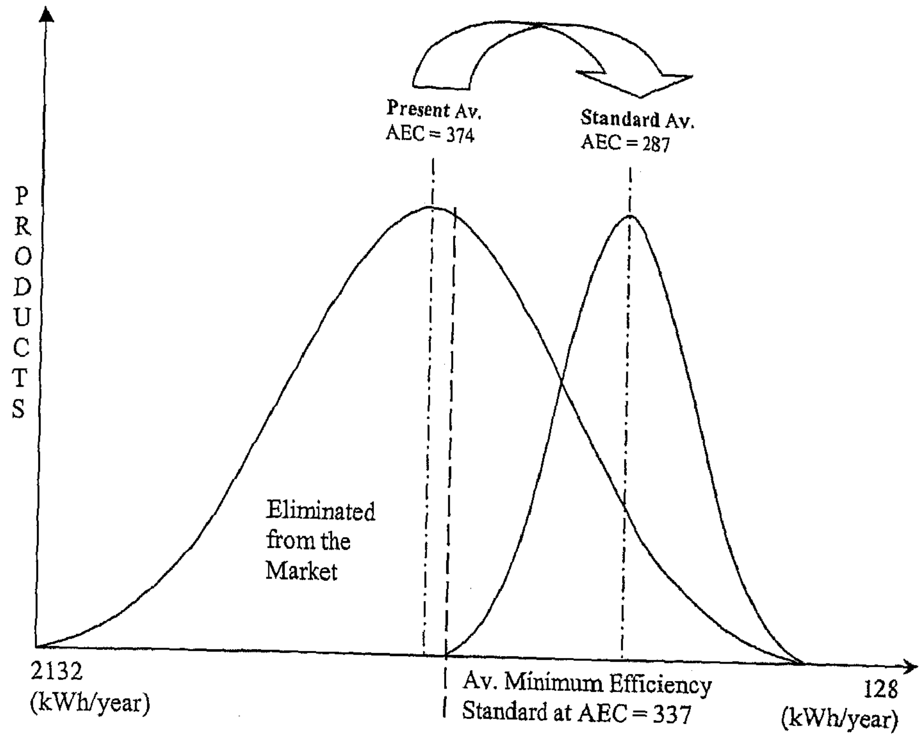

Figure 4.24 Market transformation and TV sets distribution due to implementation of standard

4.8 Energy label

4.8.1 Energy label design

There are three categories of energy labels used in various countries, which are endorsement, comparative and information-only (Wiel and McMahon, 2001). *Endorsement labels* offer a seal of approval that a product meets certain pre-specified criteria. Meanwhile the *Information-only labels* provide information on the technical performance of the single labeled product and offer no simple way (such as a ranking system) to compare energy performance between products (Wiel and McMahon, 2001). A *Comparative labels* on the other hand, use a ranking system that inform the consumers how energy-efficient a model is compared to other or provide comparative information that allows consumers to choose between models, but do not use specific categories.

Meanwhile, the details on the energy label are known to differ depending on the type of appliance. However, according to Wiel and McMahon (2001), it is important to keep a consistent label style and format across product types. This makes it easier for consumers, who can learn to understand one type of labels to evaluate different products.

In this study, the energy label design that will be used for TV sets are the *Comparative label* type which ranks appliances according to number of stars. The label is divided into 5 star grades with 5 star rating indicating the most the efficient device. This design was chosen because it is already in the drafting stage by the technical committee on the performance of household electrical appliances of Malaysia for electric fan in this country (TCPHEA, 2002). As a result, a consistent label style as suggested by Wiel and McMahon (2001) can be maintained. However, a minor improvement is conducted on the energy label which will be discussed in section 4.8.3. Figure 4.25 shows the example of energy label which is planned for electric fan in this country and will also be adapted for TV sets in this study. The complete font and color schemes for the label, together with its dimensions are presented in Appendix E.

Figure 4.25 Example of energy label (Actual size)

4.8.2 Legal status

Similar to energy efficiency standard, the legal status of energy label program could also be implemented mandatory or voluntary. The mandatory program requires manufacturers to affix all TV sets with energy label when being sold in the market. For TV sets, a mandatory status seems most effective. This provides consumers an easier way to compare the efficiency because all TV sets will be equipped with energy label. Besides that, this step will also create a healthy competition among TV manufacturers to come up with more efficient TV sets valued at a competitive price since now consumers can determine with ease the most efficient appliance.

4.8.3 Technical change on energy label

As discussed in section 4.7.1, certain type of TV set e.g. plasma TV, generally consumes more electricity simply because the type of display device being utilized differ. Therefore this type of TV should not be graded as inefficient and be eliminated from the market. Instead, in this study, the term energy efficiency index is introduced that will serve as the indicator for comparing the efficiency of various types of TV within a label grade. Therefore a minor improvement is conducted for TV set label design. The column which displays the annual energy consumption of a particular appliance in kWh (as shown in Figure 4.25) is replaced with energy efficiency index. This move is to enable various types of TV set to be granted energy label ranking as high as possible although certain type of TV may consume more electricity e.g. plasma TV which is considered the next generation entertainment device.

4.8.3.1 Energy efficiency index

Energy consumption of TV sets varies with TV size and type of display device being utilized. Thus the energy efficiency of TV sets with different size and display device can be compared by introducing an energy efficiency index. The mathematical expression of energy efficiency index has been presented in chapter 3, as in equation (3.27).

To calculate the energy efficiency index, the reference energy consumption needs to be calculated first. The reference energy consumption is calculated from equation (4.2) – (4.5) which represents the 10% standard line for class I-IV type of TV each respectively. Even if the TV samples exceed 1000 unit, the reference energy consumption value could be determined with ease from a preprogrammed spreadsheet application.

Furthermore, it could be observed from equation (3.27) that the energy efficiency index (E_i) is calculated by considering the multiplication of the value 100. This is due to the fact that without the multiplication, the value of E_i will be for example 0.70 or 0.80. Thus, when presented in the label, the general public will have difficulty determining TV set with lower E_i (TV set with lower E_i consumes less electricity). Instead, with the multiplication by 100 (and presented in the closest round number) will enable the general public to compare more easily and determine the TV set with lower E_i.

4.8.4 Star rating calculation

The star ratings are determined based on the distribution of TV set's energy efficiency index (E_i) after the standard is enacted. As a result, the star rating and the incremental step size (δ) calculation has to be altered to include E_i. Compared to the information presented in the previous chapter (Table 3.1 and equation 3.26), now the AEC value is replaced with E_i. The complete details after undertaking the alteration are presented in Table 4.24 below.

Table 4.24 Star rating calculation

Star Rating	Energy Efficiency Index
1 Star	Maximum E_i - $\delta \leq E_i \leq$ Maximum E_i
2 Stars	Minimum Value of 1 Star - $\delta \leq E_i$ 'Minimum Value of 1 Star
3 Stars	Minimum Value of 2 Star - $\delta \leq E_i$ ' Minimum Value of 2 Star
4 Stars	Minimum Value of 3 Star - $\delta \leq E_i$ ' Minimum Value of 3 Star
5 Stars	E_i' Minimum Value of 4 Star

4.8.5 Proposed star rating and E_i

The proposed star rating and E_i is calculated using equation (3.27) based on the data presented in Table 4.24. Since the standard and the label program are proposed to be enacted simultaneously in the year 2005, the star rating and E_i are calculated using the appliance AEC distribution data in this particular year. This is based on the 10% standard and the 2% annual efficiency improvement. From the calculation, it was found that the TV sets E_i in the year 2005 lay between 48 (lowest E_i) to 100 (highest E_i) with an average E_i of 85. Hence the proposed star rating for TV sets in Malaysia is tabulated in Table 4.25.

Table 4.25 Proposed star rating for TV sets in Malaysia

Star Rating	E_i	Central value (E_i)	Central value (AEC)
1 Star	$88 \leq E_i \leq 100$	94	270
2 Stars	$76 \leq E_i < 88$	82	235
3 Stars	$64 \leq E_i < 76$	70	201
4 Stars	$52 \leq E_i < 64$	58	166
5 Stars	$E_i < 52$	46	132

From Table 4.25, it can be observed that apart from the central value of E_i, the central value of AEC is also displayed. This value is calculated by modifying equation (3.26) and considering 287[4] as the reference energy consumption. The importance of this figure is that it will be used to compute the impact of energy label. The proposed energy label for TV sets in Malaysia with the inclusion of E_i is presented in Figure 4.26.

For the process of granting energy label, similar procedure as in determining the compliance with the standard are suggested. One sample unit must be randomly selected from a pool of at least 30 units of the same model (same size and type) and sent to the Standardization Institute (Na Phuket & Prijyanonda, 2001). The model has to be tested and its particular AEC (annual energy consumption) value has to be determined by using the 10.2 hours in active mode and 4.5 hours in the standby mode model. The E_i value has to be calculated and the TV unit is granted an energy label corresponding to the star rating proposal presented in Table 4.25.

[4] This value represents the average AEC distribution after eliminating TV sets that did not meet the 10% standard. Refer Figure 4.24.

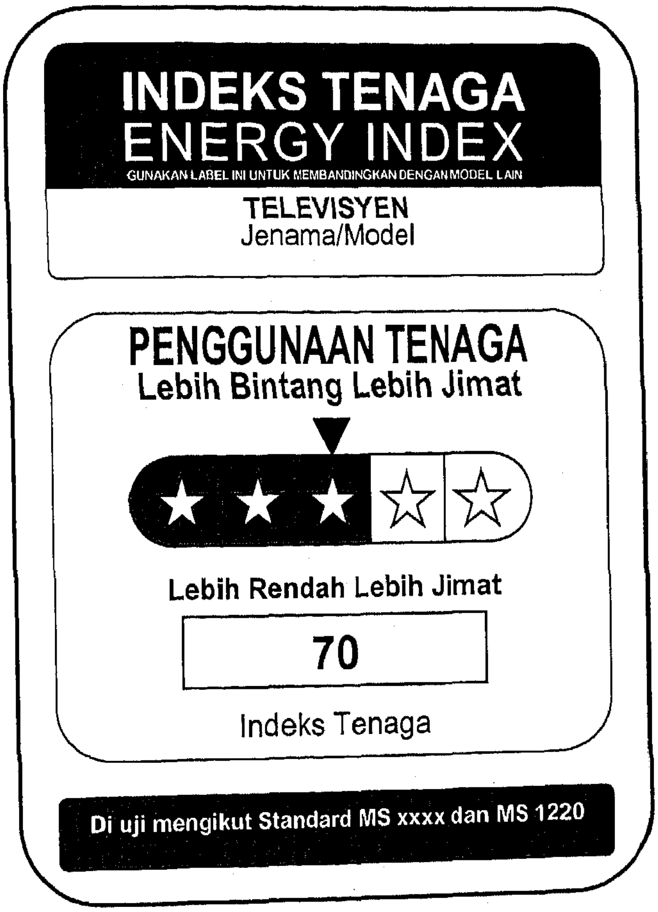

Figure 4.26 Proposed energy label for TV set in Malaysia

4.8.6 Expected market transformation due to energy label

Introducing energy label as an additional program to energy efficiency standard encourages manufacturers to produce more efficient TV sets to be sold in the market. As a result of the label, it is also expected that the consumers will purchase more efficient models from the market. This will gradually increase the penetration of more efficient models in the marketplace. The three curves which represent the unit distributions of TV sets in the market with respect to its AEC before and after the energy label is implemented, are presented in Figure 4.28. It could be observed that the market transformation forcing TV sets AEC from the first curve (average of 374 kWh/year) towards the second curve (average of 287 kWh/year) due to standard, will gradually pull the market towards the third curve (average of 201 kWh/year between the 5 star rating) as a result of label. The market transformation and the product distribution due to energy label implementation are also presented in Figure 4.27.

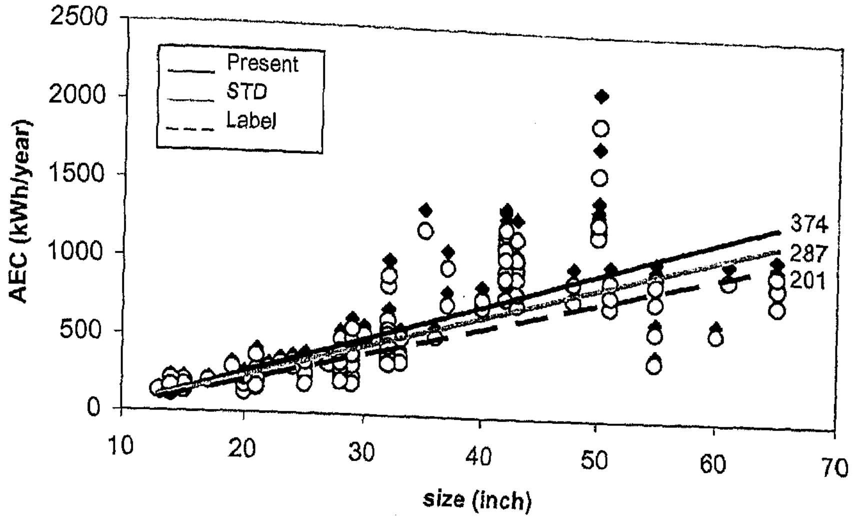

Figure 4.27 Market transformation of TV sets average AEC in the year standard and label enacted

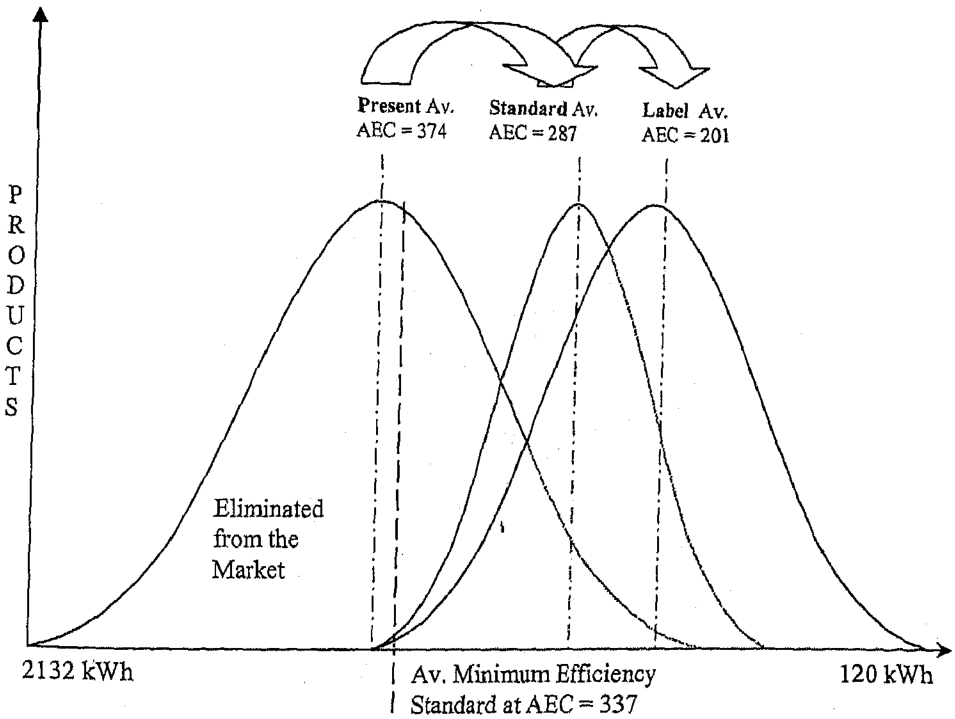

Figure 4.28 Market transformation and TV sets distribution due to standard and label implementation

4.9 Impact of standard and label

4.9.1 Impact of standard

The impact of energy efficiency standard is predicted consisting of energy, economical and environmental impact. To calculate energy, economical and environmental impact of the standard, some essential data are required. These data include appliance shipment, number of appliance affected by standard, scaling factor and average TV sets AEC in the Malaysian household. The essential data together with the calculation results are tabulated in Table 4.27. Table 4.26 and Figure 4.29 illustrate energy consumption with and without the presence of energy efficiency standard for TV sets.

Table 4.26 Energy consumption with and without the presence of TV standard

Year	Without standard (GWh)	With standard (GWh)	Energy savings (GWh)
2005	1,799	1,380	418
2006	3,614	3,065	549
2007	5,444	4,969	475
2008	7,283	6,995	288
2009	9,127	9,035	92

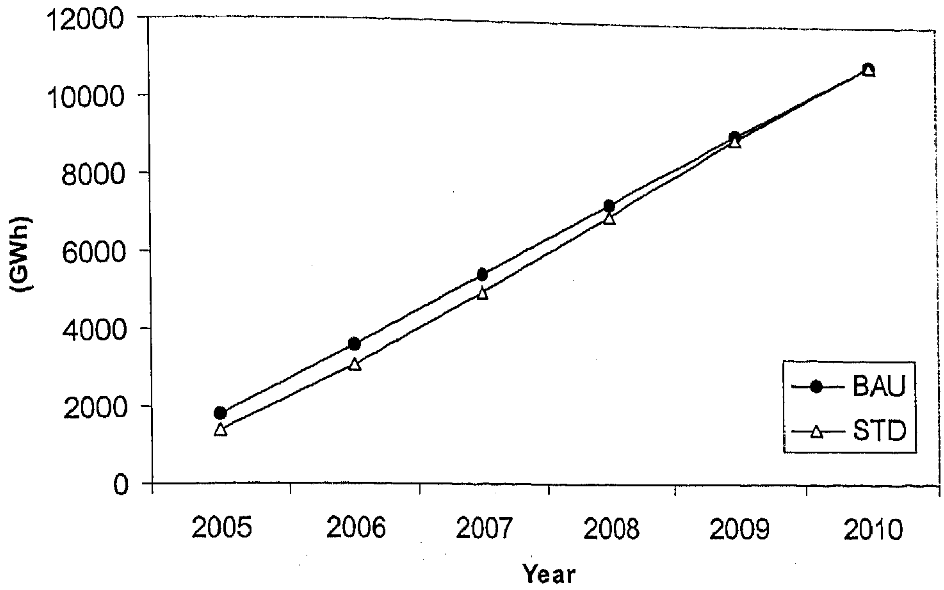

Figure 4.29 Energy consumption with and without the presence of TV standard

Table 4.27 Energy and economical impact calculation results from the implementation of TV standard

Year	Sh	AS	SF	UES (kWh)	ES (kWh)	BS (RM)	ANS (RM)	NS (RM)	PV(ANS) (RM)
2005	4809300	4809300	1.00	87	418,409,100	98,326,139	62,615,558	-169,455,686	54,690,853
2006	5052393	9861693	0.80	70	549,099,066	129,038,281	70,457,317	-96,015,513	57,514,158
2007	5300534	15162227	0.60	52	474,880,950	111,597,023	44,046,411	-65,483,217	33,602,796
2008	5553722	20715949	0.40	35	288,366,010	67,766,012	6,237,011	-55,926,484	4,446,902
2009	5811957	26527906	0.20	17	92,317,113	21,694,522	-17,701,105	-43,027,432	-11,794,994

From the tables and figure above, it could be summarized that the minimum energy efficiency standard for TV sets if implemented in 2005 will save approximately 1,823 GWh of energy at the end of 2009. This shows that an enormous amount of energy could be saved by implementing energy standard alone.

Meanwhile, the economical impact calculation will investigate the potential bill savings, net savings and cumulative present value from the implementation of energy standard. The calculation results are tabulated in Table 4.27 and illustrated in Figure 4.30.

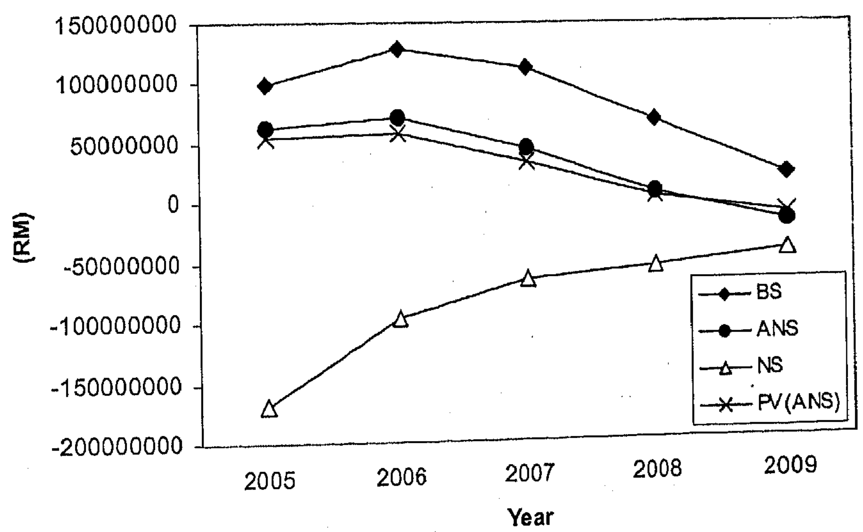

Figure 4.30 Economical impact calculation result from the implementation of TV standard

By applying the current average electricity price of RM$ 0.235 per kWh, the total bill savings (BS) will be approximately RM 428,421,976 or equivalent to US$ 112,742,625 whereas the total cumulative present value using 7% discount rate is approximately RM 138,459,717. From Figure 4.30 it could be noted that the net savings (NS) is not applicable for energy standard. This is due to the fact that the incremental cost for imposing TV standard exceeds the amount of bill savings (BS). Apart from that, it could be also noted that the annualized net savings (ANS) and the cumulative present value are only applicable till the end of 2008. Similar to net savings result, this is due to the fact that after a certain period of time, the incremental cost for imposing TV standard exceeds the amount of bill savings. However this does not indicate that the energy standard lacks its potential in bringing benefits to this country as it has been proven that energy savings continue to accrue till the expiry of standard at the end of 2009.

Additional benefit from imposing the energy standard could be determined by estimating the environmental impact of the standard. In this study, the potential CO_2, SO_2, NO_x and CO reductions are investigated. The environmental impact of the standard is calculated based on the information presented in Table 4.5 and Figure 4.7. The results are tabulated in Table 4.28 and illustrated in Figure 4.31. It could be summarized that at the end of 2009, approximately a total of 992,829 tonne CO_2 emission could be reduced. Meanwhile, within the same time period, approximately a total of 4,076,677 kg SO_2, 2,444,835 kg NO_x and 717,058 kg CO emission could be 'uced.

Table 4.28 Environmental impact calculation result from the implementation of TV standard

Year	CO_2 (tonne)	SO_2 (kg)	NO_x (kg)	CO (kg)
2005	232,878	846,191	546,108	176,025
2006	302,499	1,167,659	729,533	223,209
2007	257,414	1,086,148	642,514	183,589
2008	152,698	722,068	397,224	103,956
2009	47,339	254,611	129,456	30,280

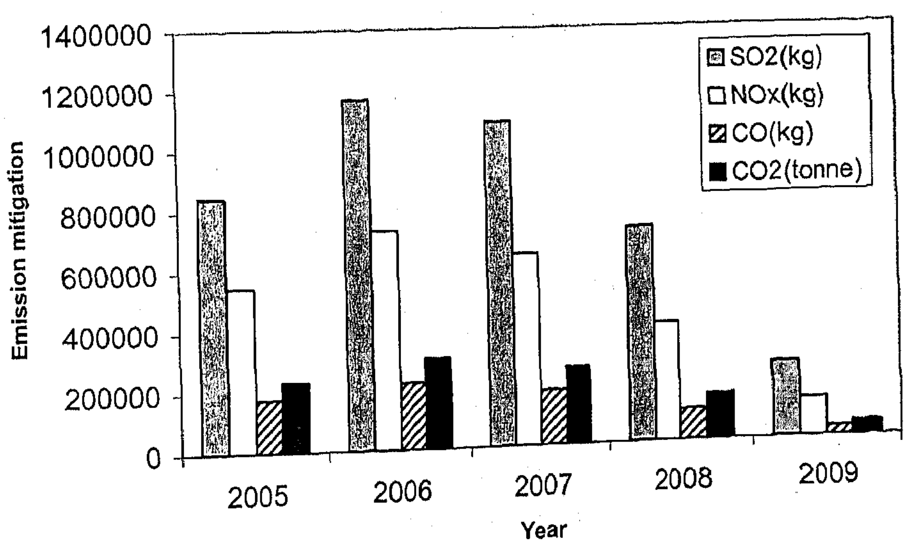

Figure 4.31 Environmental impact calculation results from the implementation of TV standard

4.9.2 Impact of label

In reality, the impact of energy label occurs over a longer period of time than the energy standard. However in this study, the impact from TV sets energy label are examined only for the effective period of energy standard. Additionally, the impact of energy label is calculated based on three scenarios (SC), which are the central values of each label rating. The scenarios are minimum expected (SC-1), nominal expected (SC-2) and maximum expected (SC-3), which corresponds to label ratings of 1 star, 3 stars and 5 stars each respectively. Since it is proposed that the energy label program is implemented simultaneously with the energy standard program, the calculation to determine the impact of label is carried out as the following. The average annual energy consumption as a result of the TV standard (as shown in Figure 4.24) is considered as the baseline energy consumption. The calculation is then proceeded similar to the calculation of impact of standard but without considering the scaling factor (SF). This is because in the calculation of label impact, the baseline energy consumption is fixed. The calculation results are presented in Table 4.29 to Table 4.32 and illustrated in Figure 4.32.

Table 4.29 Energy consumption with and without energy label for TV sets

Year	Electricity Consumption (GWh)			
	Without label[5]	SC-1	SC-2	SC-3
2005	1,380	1,299	967	635
2006	3,065	2,898	2,217	1,537
2007	4,969	4,711	3,665	2,619
2008	6,995	6,642	5,213	3,784
2009	9,035	8,584	6,754	4,924

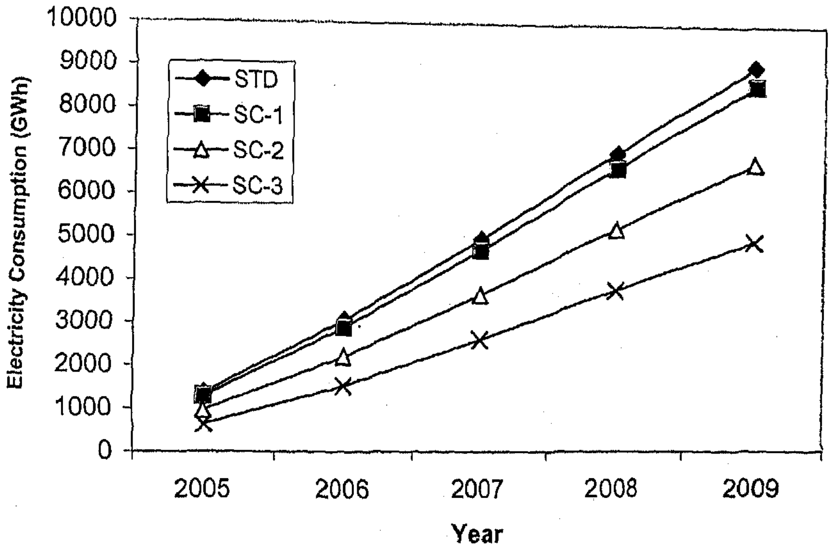

Figure 4.32 Energy consumption with and without energy label for TV sets

[5] This column represents the energy consumption without the presence of energy label program. However we considered that the energy standard is still present.

Table 4.30 Energy and economical impact calculation results from the implementation of energy label for SC-1

Year	Sh	AS	UES (kWh)	ES (kWh)	BS (RM)	ANS (RM)	NS (RM)	PV(ANS) (RM)
2005	4809300	4809300	17	81758100	19213154	12235224	-33112031	10686718
2006	5052393	9861693	17	167648781	39397464	25088895	-15572572	20480012
2007	5300534	15162227	17	257757859	60573097	38573855	2903287	29427810
2008	5553722	20715949	17	352171133	82760216	52702945	22335721	37576472
2009	5811957	26527906	17	450974402	105978984	67489005	42744892	44970774

Table 4.31 Energy and economical impact calculation results from the implementation of energy label for SC-2

Year	Sh	AS	UES (kWh)	ES (kWh)	BS (RM)	ANS (RM)	NS (RM)	PV(ANS) (RM)
2005	4809300	4809300	86	413599800	97195953	61895839	-167507919	54062223
2006	5052393	9861693	86	848105598	199304816	126920292	-78778895	103604765
2007	5300534	15162227	86	1303951522	306428608	195138327	14687216	148870096
2008	5553722	20715949	86	1781571614	418669329	266614900	112992470	190092739
2009	5811957	26527906	86	2281399916	536128980	341414965	216238867	227499207

Table 4.32 Energy and economical impact calculation results from the implementation of energy label for SC-3

Year	Sh	AS	UES (kWh)	ES (kWh)	BS (RM)	ANS (RM)	NS (RM)	PV(ANS) (RM)
2005	4809300	4809300	155	745441500	175178753	111543626	-301999994	97426523
2006	5052393	9861693	155	1528562415	359212168	228725386	-142086266	186708047
2007	5300534	15162227	155	2350145185	552284118	351662359	26365135	268281530
2008	5553722	20715949	155	3210972095	754578442	480471602	203538145	342569612
2009	5811957	26527906	155	4111825430	966278976	615270172	389616603	409980495

From the tables and figure above, it could be summarized that the energy label program for TV sets if implemented in 2005 will save approximately 1,310 GWh (SC-1), 6,629 GWh (SC-2) or 11,947 GWh (SC-3) of energy at the end of 2009. This shows that an enormous amount of energy could be saved by implementing mandatory energy label program.

Meanwhile, the economical impact of the label is also calculated by using the standard energy consumption as the baseline energy consumption and by utilizing the current average electricity price of RM$ 0.235 per kWh. The calculation investigates total bill savings, total annualized net dollar savings, total net savings in terms of actual cash flow and total present value using the 7% discount rate. The calculation results are tabulated in Table 4.33 and illustrated in Figure 4.33 to Figure 4.36.

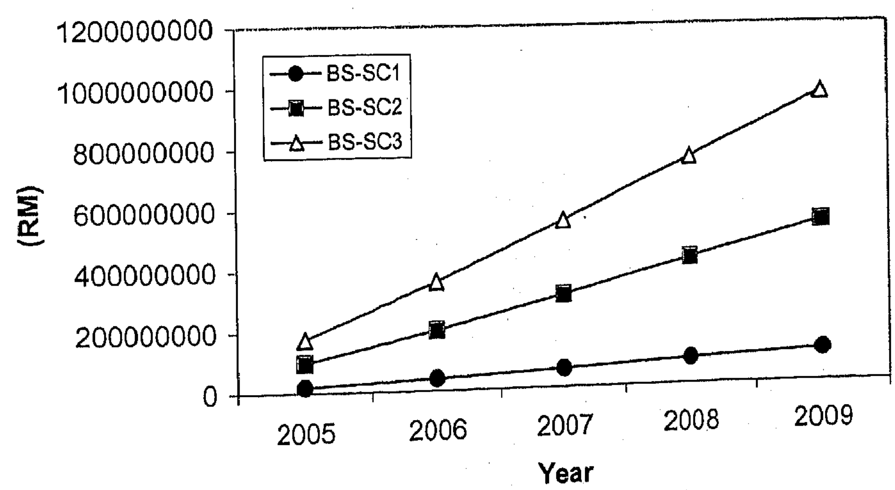

Figure 4.33 Bill savings from the implementation of energy label

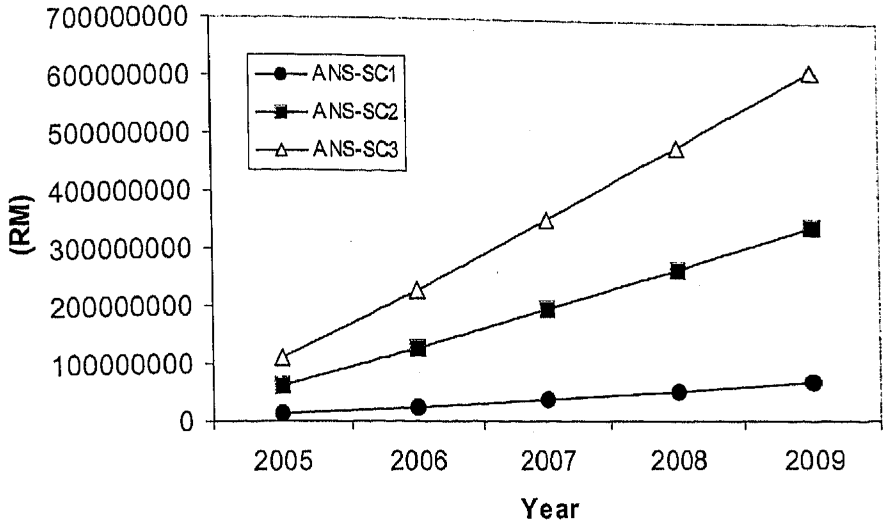

Figure 4.34 Annualized net savings from the implementation of energy label

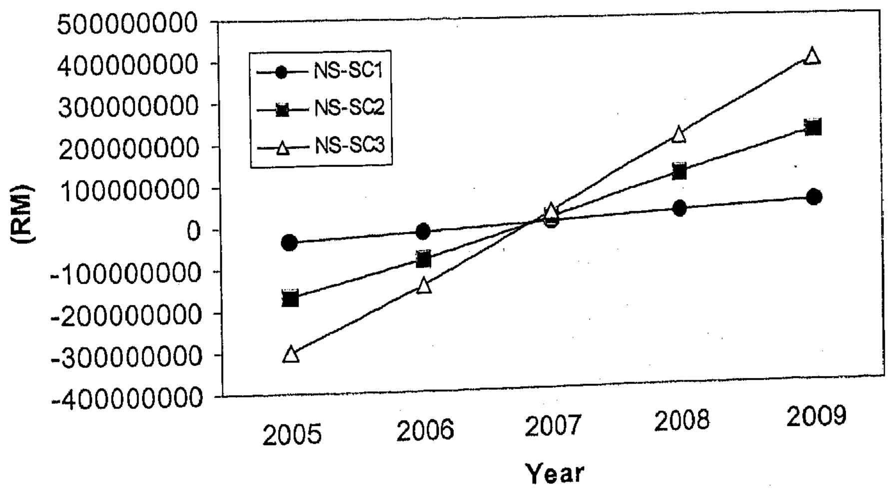

Figure 4.35 Net savings from the implementation of energy label

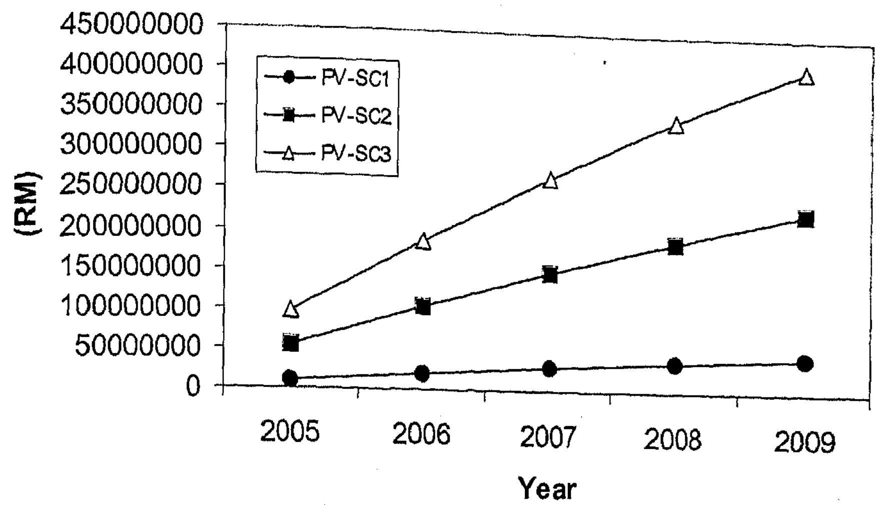

Figure 4.36 Cumulative present values from the implementation of energy label

Table 4.33 Total potential savings from the implementation of energy label

Variable	Total savings (Million RM$)		
	SC-1	SC-2	SC-3
ΣBS	308	1,558	2,808
ΣANS	196	992	1,788
ΣNS	19	98	175
ΣPV(ANS)	143	724	1,305

Based on the current average electricity price of RM$ 0.235 per kWh, the total bill savings is approximately RM 308 million (SC-1), RM 1,558 million (SC-2), 2,808 million (SC-3) or equivalent to US$ 81 million (SC-1), US$ 410 million (SC-2) and US$ 739 million (SC-3). On the other hand, the total cumulative present value using the 7% discount rate is approximately RM 143 million (SC-1), RM 724 million (SC-2) or RM1,305 million (SC-3).

Meanwhile for the calculation of environmental impact, similar to the energy standard calculation, the potential CO_2, SO_2, NO_x and CO reduction are investigated. The environmental impact of the label is calculated based on the information presented in Table 4.5 and Figure 4.7. The results are tabulated in Table 4.34 and illustrated in Figures 4.37 - 4.40.

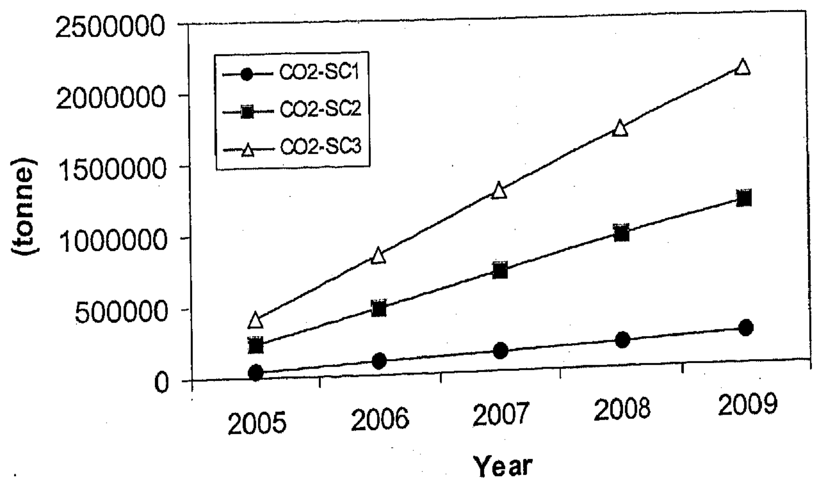

Figure 4.37 Carbon dioxide reductions from the implementation of energy label

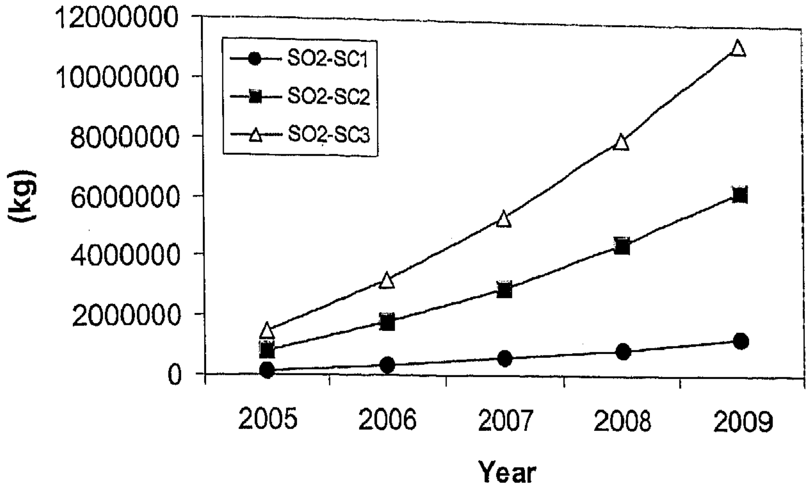

Figure 4.38 Sulfur dioxide reductions from the implementation of energy label

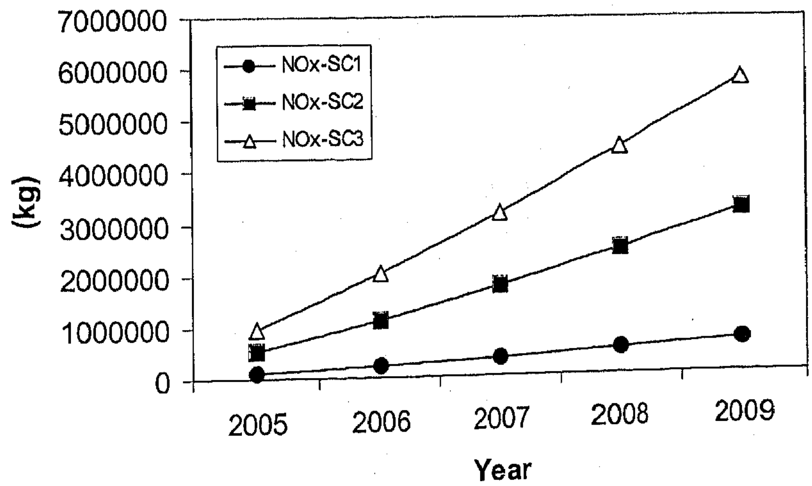

Figure 4.39 Nitrogen oxide reductions from the implementation of energy label

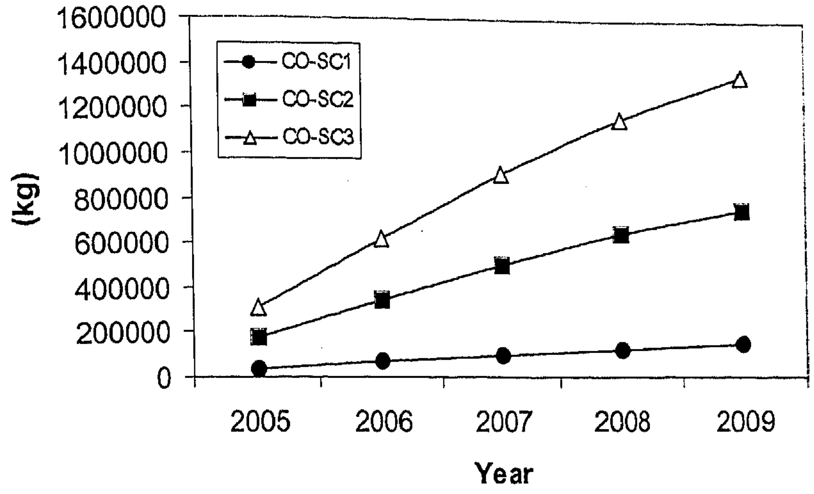

Figure 4.40 Carbon monoxide reductions from the implementation of energy label

Table 4.34 Total emissions reduction from the implementation of energy label

Element	Emissions reduction (tonne)		
	SC-1	SC-2	SC-3
CO_2	695,323	3,517,517	6,339,712
SO_2	3,237	16,376	29,514
NO_x	1,796	9,084	16,373
CO	477	2,413	4,350

From the table and figures above, it could be summarized that the total CO_2 reduction will be approximately 695,323 tonne (SC-1), 3,517,517 tonne (SC-2) or 6,339,712 tonne (SC-3). The total SO_2 reduction will be approximately 3,237 tonne (SC-1), 16,376 tonne (SC-2) or 29,514 tonne (SC-3) and the total NO_x reduction will be approximately 1,796 tonne (SC-1), 9,084 tonne (SC-2) or 16,373 tonne (SC-3). Meanwhile the total CO reduction will be approximately 477 tonne (SC-1), 2,413 tonne (SC-2) or 4,350 tonne (SC-3).

4.9.3 Impact of standard and label in combination

In this part of study, both the impacts of energy standard and energy label are combined. By doing this, the total potential impact from the implementation of standard and label for TV sets could be presented. Moreover the overall potential contribution at national level could be investigated. However, for the addition of label impact, the nominal scenario (SC-2) results (corresponds to the 3 star energy label rating) are utilized to sum up together with the total impact as a result of standard implementation.

As for the energy impact from the implementation of standard and label, it is the summation of the potential energy savings from these two programs. The results from the energy consumption with and without TV sets standard and label as well as its potential energy reductions are tabulated in Table 4.35 and 4.36. The residential energy consumption is predicted based on the information presented in Figure 4.5.

Table 4.35 Energy consumption with and without standard and label for TV sets

Year	Without standard and label (GWh)	With standard and label (GWh)	Energy savings (GWh)
2005	1,799	967	832
2006	3,615	2,218	1,397
2007	5,444	3,665	1,779
2008	7,283	5, 213	2,070
2009	9128	6,754	2,374

Table 4.36 Potential national residential energy consumption reductions with standard and label for TV sets

Year	Residential energy consumption (GWh)	Energy savings (GWh)	Potential reductions (%)
2005	16,223	832	5.1
2006	17,271	1,397	8.1
2007	18,351	1,779	9.7
2008	19,464	2,070	10.6
2009	20,609	2,374	11.5

From Table 4.35, it could be summarized that the implementation of energy efficiency standard and label for TV set in 2005 will save approximately 8,452 GWh of energy at the end of 2009. During this period, this will contribute to overall national residential energy consumption reductions of 5.1% in 2005 to 11.5% reductions in 2009.

The combination of the standard and label economical impact is the summation of bill savings, annualized dollar savings and cumulative present value of the standard and label for each year. The economical impact calculation results from the implementation of standard and label for TV sets is presented in Table 4.37 and illustrated in Figure 4.41.

Table 4.37 Economical impact calculation results from the implementation of standard and label for TV sets

Year	BS (RM)	ANS (RM)	NS (RM)	PV(ANS) (RM)
2005	195,522,092	124,511,397	-336,963,605	108,753,076
2006	328,343,096	197,377,609	-174,794,408	161,118,923
2007	418,025,631	239,184,738	-50,796,000	182,472,892
2008	486,435,342	272,851,911	57,065,986	194,539,641
2009	557,823,502	323,713,860	173,211,435	215,704,214

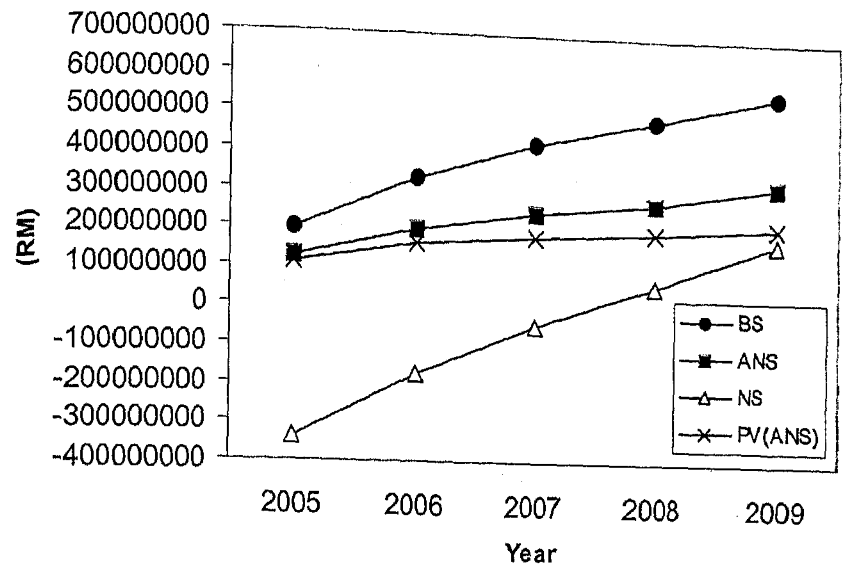

Figure 4.41 Economical impact calculation results from the implementation of standard and label for TV sets

From the table and figure above, it could be summarized that the total bill savings (BS) from the implementation of standard and label will be approximately RM 1,986,149,662 or equivalent to US$ 522,670,964 whereas the total cumulative present value is approximately RM 862,588,746.

Besides that, the environmental impact from energy efficiency standard and label is the combination of potential CO_2, SO_2, NO_x and CO reduction from these two programs. The potential CO_2, SO_2, NO_x and CO reduction result is presented in Table 4.38 and illustrated in Figure 4.42.

Table 4.38 Environmental impacts calculation result from the implementation of TV standard and label

Year	CO_2 (tonne)	SO_2 (kg)	NO_x (kg)	CO (kg)
2005	463,080	1,682,655	1,085,938	350,026
2006	769,720	2,971,156	1,856,326	567,964
2007	964,234	4,068,546	2,406,760	687,697
2008	1,096,094	5,183,124	2,851,339	746,213
2009	1,217,218	6,546,712	3,328,663	778,579

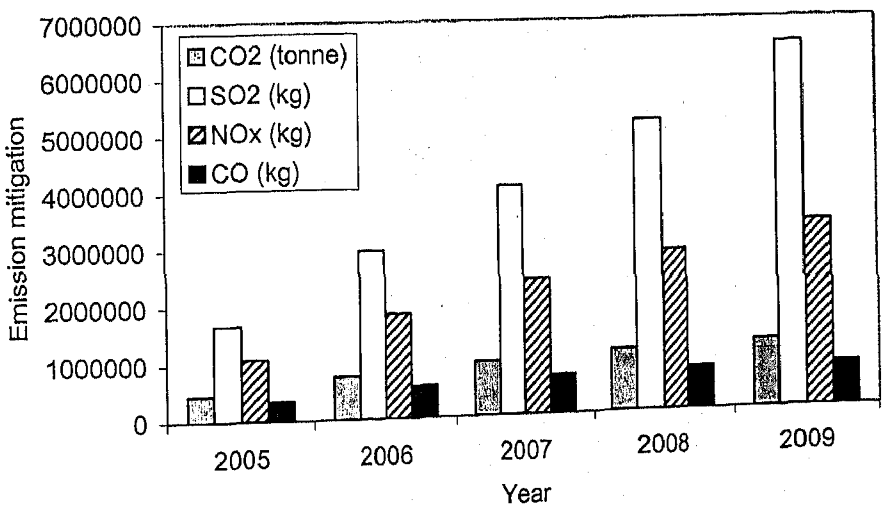

Figure 4.42 Environmental impacts calculation result from the implementation of TV standard and label

From the table and figure above, it could be summarized that the total CO_2 reduction from the implementation of standard and label *for TV sets will* be approximately 4,510,346 tonne. The total SO_2 reduction will be approximately 20,452,192 kg and the total NO_x reduction will be approximately 11,529,027 kg. Meanwhile, the total CO reduction from the implementation of standard and label for TV sets will be approximately 3,130,478 kg. Furthermore if we sum up the greenhouse gases, which are CO_2, NO_x and CO[6], it can be concluded that the potential greenhouse gas emission reductions from the implementation of standard and label for TV sets (2005 to 2009) is approximately 4.5 million tonnes. Considering that 111 million tonnes of greenhouse gas was emitted in 1996 (World Energy Council, 2001), the total of 4.5 million tonnes reductions from 2005 to 2009 contributes approximately 4.1% of reductions from the amount emitted in 1996.

Overall, it is proven in this study that the introduction of energy efficiency standard and label for TV sets in Malaysia offers great benefits for consumers, government and the environment. Moreover, resources used to generate electricity can now be used more efficiently and unnecessary wastage can be avoided. However the standard and label program are only effective for a certain period of time. As a result of TV sets 2% annual efficiency improvement, even in the absence of standard and label, in the long run the baseline energy consumption will be equal to standard energy consumption and its difference will be a constant of zero. Hence it is important to revise the standard and label program after 2009 to ensure that the positive impacts that occurs continue to accrue.

[6] The information regarding which are the greenhouse gases are obtained from www.ghgonline.org