

**INTERACTIVE USER FRIENDLY SOFTWARE TO MODEL THE PRICE
OF HIGH ENERGY SAVING LAMPS COMPARED TO INCANDESCENT
LAMPS**

By

Nawar Binti Mohd Arif

FINAL PROJECT REPORT

**Submitted to the Electrical & Electronics Engineering Programme
in Partial Fulfillment of the Requirements
for the Degree
Bachelor of Engineering (Hons)
(Electrical & Electronics Engineering)**

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CERTIFICATION OF APPROVAL

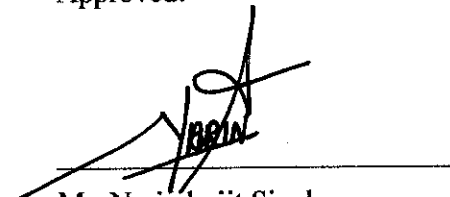
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A project dissertation submitted to the
Electrical & Electronics Engineering Programme
Universiti Teknologi PETRONAS
in partial fulfilment of the requirement for the
Bachelor of Engineering (Hons)
(Electrical & Electronics Engineering)

Approved:



Mr. Narinderjit Singh
Project Supervisor

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK

June 2007

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.



Nawar Binti Mohd Arif

ABSTRACT

The objective of this Final Year Project is to develop a probability and statistics software for an engineering application to model the price of lamps to its many desirable characteristics and then suggesting the most suitable lamp to be used. Users use this software-modeling tool to estimate the price of lamp and to forecast the billing cost for a specific lamp by using the power consumption and time of usage.

The proposed framework of the system consists of three inter related components; the database will provide input to the model, the modeling and user interface that provides a channel for the user to communicate with the system. Three stages have been identified in order to develop the system. They are variable identification, statistical model development and the development of the software. Several variables have been identified but it is observed that the main variables that is quantifiable and to have effect on price are wattage (W), brightness (lumens), diameter (mm), length (mm), average lifetime (hour) and Correlated Color Temperature CCT (K).

The model that was identified is multiple regression analysis. This model is then incorporated in an interactive interface.

ACKNOWLEDGEMENTS

I would like to pay my highest gratitude to my supervisor Mr. Narinderjit Singh for teaching, advising and assisting me throughout this project and to Dr. Afza Shafie who is always there for guidance in times of uncertainties. Their commitment and dedication in this project is beyond the university's required obligations. Without their expertise, experience and advice, the project would not have been successfully completed.

Also high on the list of acknowledgement is to Ms Siti Hawa the coordinator for Electrical and Electronics Final Year Project (FYP). Her endurance in advising me and everyone else on the right procedure of logbooks and reports are irreplaceable.

To my friend, Aezareena who had helped me so much in this field; teaching, assisting and always being there to answer problems faced throughout the development of software, thank you so much.

Finally, I would like to acknowledge all the others whose name was not mentioned on this page, but has one way or another contributed to the accomplishment of this project.

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

In this project, software that incorporates a statistical model is being developed. This model will be able to assist the users in determining the price of High Energy Saving (HES) lamps. The light characteristics of lamps have been carefully studied to provide a better understanding on how to quantify the characteristics of a light produced by a lamp. The output of the software will be used to estimate and compare the price of both high energy saving lamps and incandescent lamps. It also explains the benefits of high energy saving lamp and estimate the bill contributed by both types of lamps.

1.2 Problem Statement

The area of application for this project's software is modeling the price of high energy saving lamps. This is because different types of places and activities may require different lighting solutions. There are wide ranges of lamps available in the market that most people are not aware of the ones that are most suitable and money saving in the future.

After careful consideration, we find that it is feasible to develop modeling software for the price of HES lamps using Visual Basic.NET programming. A user-friendly interface that assists users to perform their modeling tasks efficiently has been developed. After performing probability and statistics calculations using SPSS software, the output is used as an input for the visual basic.NET in order to develop the final product. This estimation will provide the users with the price of HES lamp according to their desired characteristics. The software also calculates the difference in terms of energy and monthly expenses between high energy saving lamps and incandescent lamps. This allows the users to see the benefits of having high energy saving lamps.

1.3 Objectives and Scope of Study/Work

1.3.1 Subsection heading

The primary objective of this project is to produce a statistical model to develop software. The outcome of the project is software to estimate the price of the most energy saving lamp suitable according to their desired characteristics. In order to achieve the objective, the research focused on

- (i) Identifying the key variables in the model
- (ii) Constructing the probability and statistics model
- (iii) Simulations of the results and
- (iv) Development of user-friendly software using Visual Basic.NET programming language

1.3.2 Feasibility of the Project within the Scope and Time Frame

The allotted period is sufficient to develop comprehensive modeling of software.

1.3.3 Scope of Study

The scope of study is divided into three major parts, understanding and identifying key variables, probability and statistical modeling and software development.

CHAPTER 2

LITERATURE AND REVIEW / THEORY

2.1 Electric Light

Electrical light sources are called lamps. Lamps can be grouped into four major classes, based on their operating principles. Electric lamps now are made in a wide variety of sizes, optical properties, color, candlepower, and efficiencies. Lamps are designated by standard abbreviations that refer to diameter, shape, and wattage. Additional information may also be provided, such as length, and color rendering. [1]

Different types of building and activity may require lighting solutions relevant to that building. The principal requirements are to provide lighting for visual efficiency and safety. According to the purpose of the place that the user specifies, the software would match it to the closest luminous intensity per unit area provided by suitable lights. When discussing the quantity of light it is important to understand several important terms and definitions.

2.2 Characteristics of Light Sources

2.2.1 Strength

Lamps vary the quantity of light (lumens) produced and the directional distribution of the luminous intensity (candlepower). The illumination from a point source decreases over distance according to the inverse square law. To provide a greater luminance over larger distances requires a light source with greater candlepower. Often this implies a larger physical size of lamp.

2.2.2 Size

The trend to produce lamps is primarily driven by optical control factors and cost benefits. Smaller lamps require less material to manufacture. Smaller sources are also more convenient; they can be more easily hidden and installed in confined locations.

2.2.3 Efficacy

Efficacy is the light source output expressed in lumens per watt of power input. For energy consumption analysis, ballast losses must be included in the efficacy rating of all discharge lamps.

2.2.4 Wattage

Typically increasing the power supplied to a lamp increases light output and efficacy. Conversely, as lamps are dimmed, they become less efficient. For example, a light output that is dimmed to produce 50 percent of its standard operating light output may still consume 70 percent of its standard operating level electric energy in watts.

2.3 Units of Lights

Light units can be described as *psychophysical* as they are a combination of human response and physical units of power. They stand on their own and cannot be directly related to other physical units. The units are in the International System as defined in British Standard 3763

2.3.1 *Luminous Flux*

The light emitted by a source, or received by a surface. The quantity is derived from radiant flux (power in watts) by evaluating the radiation in accordance with the relative luminous efficiency of the 'standard eye' (V_λ)

Symbol: Φ ; Unit: Lumen

2.3.2 *Luminous Intensity*

Symbol: ℓ ; Unit: *candela*

The quantity, which describes the power of a source or illuminated surface to emit light in a given direction

Candela

Symbol: *cd*

The SI unit of luminous intensity, equal to 1 lumen per steradian

2.3.3 *Illuminance*

Symbol: E ; Unit: *lux*

The luminous flux density at a point on a surface, i.e. the luminous flux incident per unit area

Lux

Symbol: *lx*

The unit of illuminance, equal to 1 lumen per square meter

2.3.4 Luminance

Brightness is a measure of the amount of light striking a surface. It is measured in units of footcandles. One footcandle is defined as one lumen of light falling on one square foot. The metric equivalent of a footcandle (fc) is a lux (lumen per square metre)

1 footcandle = 10.76 lux ; Symbol: L

Unit: *candela per square meter*

The intensity of the light emitted in a given direction per projected area of a luminous or reflecting surface.

Note: Only for a source of *uniform* luminance is it not required to specify direction

Candela per square meter

Symbol: cd/m^2

The unit of luminance, equal to 1 candela per square meter of a projected area

2.4 Regression Analysis

In statistics, regression analysis is used to model relationships between variables, determine the magnitude of the relationships between variables, and can be used to make predictions based on the models. In this project, regression analysis models the relationship between Y which is the average lamp life of lamps and the predictors also called independent variables usually named X_1, \dots, X_p .

Characteristics of a lamp that are found to be quantifiable and to give effects on the price of a lamp are the variables of X_n . Y are the price of HES lamps, which will be estimated using the regression analysis.

$$Y = aX_1 + bX_2 + cX_3 + dX_4 + eX_5 + fX_6$$

2.5 Different statistical techniques of Correlation

Often research is not interested in differences between groups, but instead is interested in the strength of the relationship between variables. There are a number of different techniques could be used.

2.5.1 Pearson Correlation

- Used when we want to explore the strength of the relationship between two continuous variables
- Gives us an indication of both the direction (positive or negative) and the strength of the relationship
- A positive indicates, as one variable is positive, so does the other variable. A negative indicates as one variable is positive, the other variable is negative [2]

2.6 Multiple Regressions

2.6.1 Main types of research questions for multiple regressions

- How well a set of variable is able to predict a particular outcome
- Which variable in a set of variable is the best predictor of an outcome
- Whether a particular variable is still able to predict an outcome when the affects of another variable are controlled

2.6.2 Multiple Regression Solution

Therefore, multiple regressions will answer all these research questions by:

- exploring the relationship between one continuous dependent variable and a number of independent variables or predictors (usually continuous)
- investigating more complex real-life rather than laboratory based, research questions

- providing information about the model as a whole, and the relative contribution of each of the variable that make up the model
- testing whether adding an additional variable contributes to the predictive ability of the model [3]

2.6.3 Hierarchical Multiple Regression

Hierarchical multiple regressions also referred to sequential regression means that we will be entering variables in steps or blocks in a predetermined order. This has the effect of statistically controlling for these variables. In the second step, other independent variables could be entered into the 'equation' as a block but the difference this time is that the possible effect of these variables has been removed and to see whether our block of independent variables are still able to explain some of the remaining variance in our dependent variable [4].

2.7 Introductions to Microsoft Visual Basic.NET programming

The programming language chosen to create interface for the users is Visual Basic.NET programming. Visual Basic creates the process for program development and revision much easier and requires much less time and effort.

Visual Basic provides a set of visual objects (recognized as controls) that can be drawn easily onto a window (called a form). These controls eliminate the need to develop the code to construct the visual interface. The layout of the windows that contain the controls can be changed easily by dragging and dropping the controls to a new location, without necessitating a change in the code [5].

2.8 Criteria for Approval Program

2.8.1 *Functionality*

The program must meet the requirements of the application. It must deliver the functionality called for by the application.

2.8.2 *Efficiency*

The program should perform the required functions efficiently while minimizing the consumption of computer resources, including computer time and storage space.

2.8.3 *User-Friendliness*

The message to the user be clear, meaningful, and in a friendly tone.

- Provide the user with maximum mobility around the user interface
- Consistent in appearance and behavior among different windows
- Provide the user with supports in using the program to perform the task
- Flexible in accommodating user's taste and preferences
- Guard the user against errors and mistakes [6]

2.9 Steps in Program Development

2.9.1 *Analyze and Define the Problem*

A clear understanding of the problem and goals is the first step in developing the program.

2.9.2 Design the Visual Interface

Decide what data fields should appear on a form. Careful analysis to determine which VB control will be the best given the nature of a data field.

2.9.3 Define User-Program Interaction

Determine what the program should do in detail. The user's actions and system activities are recognized as events.

2.9.4 Design the Code Structure

Analyze the complex situation thoroughly before writing any code.

2.9.5 Write Code

Based on the design, develop the code to perform the activities that your program requires.

2.9.6 Test and Edit the Program

Syntax errors: result from the failure to follow the rules to put various code elements together

Semantic errors: The programmer may code the statement, $A=B=C$ thinking that the three variables will have the same value after its execution.

Logic errors: result from the differences between what the programmer believes a block of code will do and what the program actually does [7]

CHAPTER 3

METHODOLOGY/PROJECT OVERVIEW

3.1 Methodology

The workflow of this project started with a research done via library, books and the internet. Once key variables have been identified, the variables related to effect average lifetime of a lamp was quantified. Subsequently, lighting shops personnel who have knowledge of this particular matter was contacted and interviews were performed to obtain extra information related to technical aspects. With the supervision of supervisor, mathematical modeling was started once enough information was gathered. Although the data were obtained on the first semester, modeling and programming of software development will be focused on the second semester.

Table 1 : Gantt chart of The Work Outline for the First semester

No	Detail Week	3	4	5	6	7		8	9	10	11	12	13	14		
1	Project Title Research						MID SEMESTER BREAK								END OF SEMESTER ONE	
2	Review on Average lifetime of a lamp															
3	Research on average lifetime of a lamp variables															
4	Research on Probability and Statistics Modeling															

Table 2 : Gantt chart of The Work Outline for the Second semester

No	Detail Week	2	3	4	5	6	7		8	9	10	11	12	13	14		
1	Finalizing data							MID SEMESTER BREAK								END OF SEMESTER TWO	
2	Statistical modeling using SPSS software																
3	Software development using Visual Basic programming																
4	Testing data for accuracy check																

3.2 Resources Required

This project is a research project therefore the only resources required are Internet Explorer, Visual Basic, library books and experienced personnel.

3.3 Project Flow

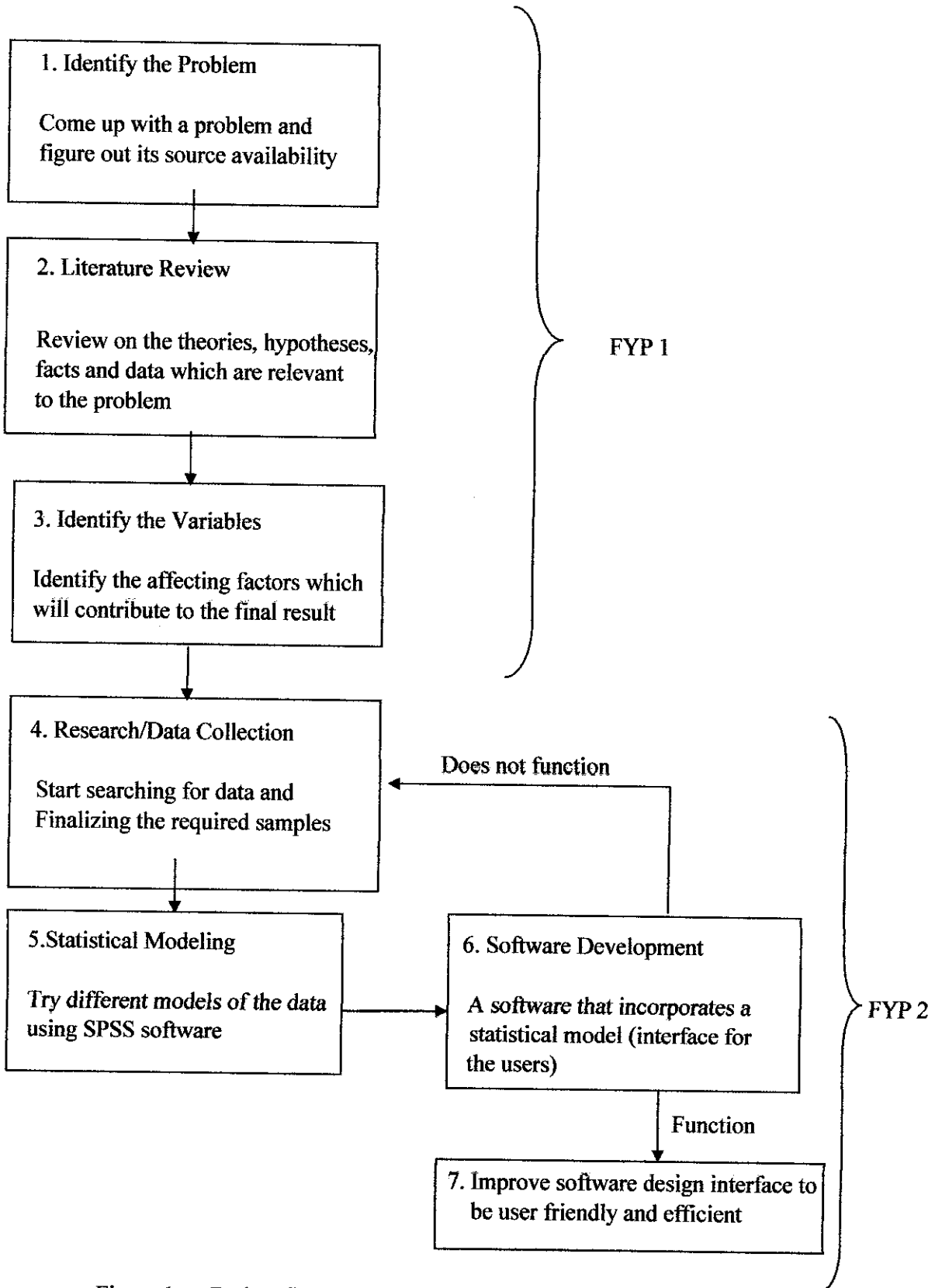


Figure 1 : Project flow of activities to be performed throughout one year

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Dependent variable determined-Price of Lamps

The cost of electric light is the cost of material associated for the lamps as each comes with different prices. Due to the budget, the software will model the price according to the desired characteristics.

4.2 Independent Variables Determined

The variables determined are:

- (i) wattage
- (ii) luminance
- (iii) length
- (iv) width
- (v) average lifetime
- (vi) correlated color temperature (CCT)

4.2.1 *Wattage*

The wattage of a bulb indicates how much energy is used by the light, not the amount of light it produces. This relates later to the power consumption and the calculated billing cost.

4.2.2 Luminance (luminous flux)

This data is important in order to decide the intensity of light at specific area for different purposes. For this purpose, we use the term illuminance.

The principal requirements are to provide lighting for visual efficiency and safety. According to the purpose of the place that the user specifies, the software would match it to the closest luminous intensity per unit area provided by suitable lights.

4.2.3 Length

Lamps are made in variety of sizes. Length is the measurement of the longest body the lamp. Choosing the desirable length of the lamp will set a suitable size of lamp for a specific area.

4.2.4 Diameter

Lamps come with different diameter size. Specifying the right size of diameter allow lamps to be installed or hidden in confined locations.

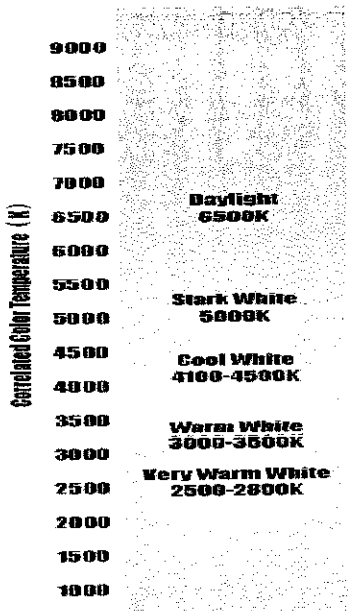
4.2.5 Average Lamp Life

Lamp life is a measure of lamp performance typically provided by lamp manufacturers. Rated lamp life is the point at which 50 percent of a statistical sample of lamps has failed. This is commonly a statistically determined estimate of average or median operational life.

For certain lamp types other criteria than failure to light can be used. For example, the life can be based on the average time until the lamp type produces a given fraction of initial luminous flux. [8]

4.2.6 Correlated Color Temperature (CCT)

A specification of the apparent color of a light source relative to the color appearance of an ideal incandescent source held at a particular temperature and measured on the Kelvin (K) scale. The CCT rating for a lamp is a general indication of the warmth or coolness of its appearance.



As CCT increases the appearance of the source shifts from reddish white toward bluish white. Therefore, the higher the color temperature, the cooler the color appearance. Lamps with a CCT rating below 3200K are usually considered warm sources, whereas those with a CCT above 4000K usually considered cool in appearance.[9]

Figure 2 : Range of Correlated Color Temperature and its colors

To help visualize the color, it is described as either "warm" or "cool." Warm lights are around 2,700K and provide a cozy and friendly atmosphere appropriate for restaurants, homes, boutiques, and retail stores. Cool lights communicate neatness and efficiency. These lights, around 4,100K, work best in office areas, classrooms, mass merchandisers, and hospitals.

Outlined below are the various color temperatures (CCT) currently available:

- 10,000K A very high CCT used in horticulture and aquarium applications.
- 6,000-6,500K A high CCT daylight source used to simulate average outdoor light conditions.

5,000K	Enhances blues, dulls reds, and imparts a bluish tint to whites and greens. Used mainly in museums, jewelry stores, and hospitals.
3,700K-4,000K	Neutral colored light. Enhances colors equally without emphasizing yellow or blue. Used mainly in showrooms, bookstores, and office areas
3,000K-3,200K	Most commonly used in homes but also in libraries, office areas, and retail stores.
2,700K	Used in restaurants, hotel lobbies, boutiques, and homes.[10]

4.3 Surveys

A survey of the lamps available at SENG HUP Company of IPOH branch was done. After explaining and given a letter of inquiries approved by the supervisor, the manager informed that he could provide the data needed but he needs to acquire them from the head quarter of Seng Hup in Kuala Lumpur. Other places where survey was done were Tesco, Giant, and Jusco. The data were then compiled and used for the modeling.

4.4 Determining the Strength of Each Relationship

Table 3 : Pearson correlation coefficients between variables of HES lamps

		Price	Watt	Diameter	Lumens	Length	AvgLife	CCT
Pearson Correlation	Price	1.000	-.009	-.061	-.123	-.245	.139	.272
	Watt	-.009	1.000	.561	.972	.421	.541	.365
	Diameter	-.061	.561	1.000	.501	-.233	.253	.240
	Lumens	-.123	.972	.501	1.000	.482	.620	.296
	Length	-.245	.421	-.233	.482	1.000	.414	.127
	AvgLife	.139	.541	.253	.620	.414	1.000	.235
	CCT	.272	.365	.240	.296	.127	.235	1.000

The size of the value of Pearson correlation (r) can range from -1.00 to 1.00. This value will indicate the strength of the relationship between the two variables. A correlation of 0 indicates no relationship at all, a correlation of 1.0 indicates a perfect positive correlation, and a value of -1.0 indicates perfect negative correlation [11]. In the set of data, it was seen that CCT gave the strongest correlation with price (0.272) of HES lamps.

4.5 Percentage of Variance in Dependent Variable Explained

Table 4 : Model summary of HES lamps

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.787(a)	.620	.55	7.97791

Predictors: (Constant), AvgLife, CCT, Diameter, Length, Watts, Lumens

Dependent Variable: Price

The value given under the heading R square in the model summary tells how much of the variance in the dependent variable (price) is explained by the model (which includes the variables average lifetime, CCT, diameter, length, watts and lumens). In this case the value is 0.620 means that the model for HES explains 62 per cent of the variance in price.

4.6 Contribution of each Independent Variable

Table 5 : Correlations between Variables for HES lamps

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	-7.528	5.918		-1.272	.212		
	Watt	4.754	.893	2.978	5.322	.000	.037	27.203
	Lumens	-.067	.013	-2.923	-5.123	.000	.035	28.287
	Diameter	-.115	.033	-.588	-3.506	.001	.409	2.445
	Length	-.033	.010	-.525	-3.303	.002	.455	2.197
	CCT	.001	.001	.099	.809	.424	.770	1.299
	AvgLife	.004	.001	.684	4.558	.000	.511	1.958

Dependent Variable: Price

In the column labelled Beta under Standardized Coefficients explains which of the variables included in the model contributed to the prediction of the dependent variable.

To compare the different variables it is important to look at the standardized coefficients, not the unstandardized ones. 'Standardized' means that these values for each of the different variables have been converted to the same scale so that it can be compared [5]. In our case to construct a regression equation, unstandardized coefficient values listed as B should be used. Therefore, the modeling for both types of lamps is;

HES lamps:

$$Y = - 7.528 + 4.754 X_{\text{Watt}} - 0.067 X_{\text{Lumens}} - 0.115 X_{\text{Diameter}} - 0.033 X_{\text{Length}} + 0.004 X_{\text{AvgLife}} + 0.001 X_{\text{CCT}}$$

It is seen in that for Beta column the largest beta coefficient is 2.978 which is from variable Watt. This means that this variable makes the strongest unique contribution to explaining the dependent variable, when the variance explained by all other variables in the model is controlled.

4.7 Hierarchical Multiple Regression

Hierarchical multiple regressions also referred to sequential regression means that we will be entering variables in steps or blocks in a predetermined order. This has the effect of statistically controlling for these variables. In the second step, other independent variables could be entered into the 'equation' as a block but the difference this time is that the possible effect of these variables has been removed and to see whether our block of independent variables are still able to explain some of the remaining variance in our dependent variable [12].

4.7.1 Hierarchical Multiple Regression

Table 6 : Model summary of HES lamp Price-Sequence 1

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.009(a)	.000	-.026	12.06156
2	.069(b)	.005	-.049	12.19501
3	.520(c)	.271	.210	10.58227
4	.588(d)	.346	.271	10.16751
5	.783(e)	.613	.556	7.93735
6	.787(f)	.620	.551	7.97791

- a Predictors: (Constant), Watt
- b Predictors: (Constant), Watt, Diameter
- c Predictors: (Constant), Watt, Diameter, Lumens
- d Predictors: (Constant), Watt, Diameter, Lumens, Length
- e Predictors: (Constant), Watt, Diameter, Lumens, Length, AvgLife
- f Predictors: (Constant), Watt, Diameter, Lumens, Length, AvgLife, CCT
- g Dependent Variable: Price

Table 7 : Model summary of HES lamp Price-Sequence 2

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.272(a)	.074	.049	11.60872
2	.282(b)	.080	.030	11.72623
3	.443(c)	.196	.129	11.11232
4	.497(d)	.247	.161	10.90645
5	.692(e)	.479	.402	9.20809
6	.787(f)	.620	.551	7.97791

- a Predictors: (Constant), CCT
- b Predictors: (Constant), CCT, AvgLife
- c Predictors: (Constant), CCT, AvgLife, Length
- d Predictors: (Constant), CCT, AvgLife, Length, Lumens
- e Predictors: (Constant), CCT, AvgLife, Length, Lumens, Watt
- f Predictors: (Constant), CCT, AvgLife, Length, Lumens, Watt, Diameter
- g Dependent Variable: Price

The value given under the heading R square in the model summary tells how much of the variance in the dependent variable (price) is explained by the model (which includes the variables average lifetime, CCT, diameter, length, watts and lumens). With different variables included, the R square value changes according its significant contribution to the dependent variable. Different sequence shows the different contribution of each variable.

It is seen that the highest R square are only obtained if all variables are included. Therefore, all variables will be used to find the price (dependent variable). When all variables are included, the result of R square is equal to multiple regressions.

4.8 Getting Started Using Microsoft Visual Basic.NET Programming

Each Visual Basic control has its own events. These events are triggered when the user takes an action. Codes are placed in the procedures that are associated with these events so that the computer behaves exactly as you would like. These events give the program life and personality.

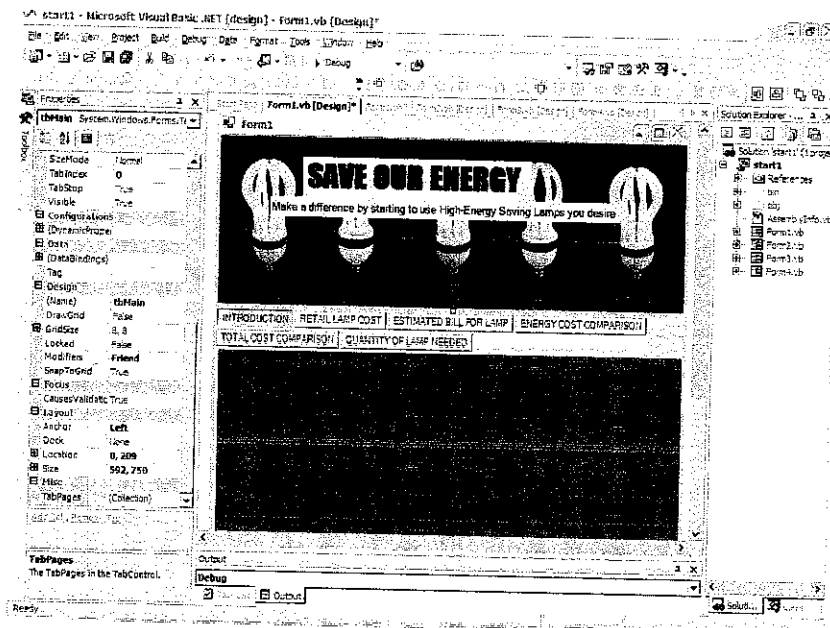
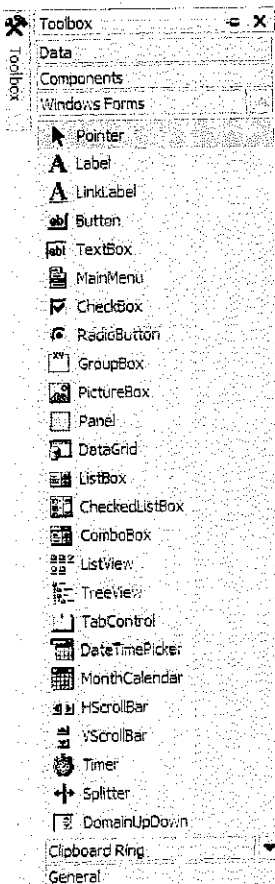


Figure 3 : Constructing the interface using Visual Basic.NET programming

4.8.1 Important Features

Many of the controls have features that can make the design of a data-entry screen more powerful and user-friendly. Each situation of user interface has appropriate VB control to use.



The VB control that enables you to enter any type of data is the text box. As its name suggests, the text box specializes in handling text data.

Tab control allows data elements to be included in one screen. Data can be saved, retrieved and updated in a single operation.

To select an item from a list, the Combo Box facilitate the users to a limited choices determined by the programmer. This is used later in the choices of Correlated Color Temperature (CCT) of lamps.

Other controls used are Label, Link label, Button, Main Menu, Picture Box and Timer.

Figure 4 : Toolbox features of VB control used in user interface

4.8.2 Property Setting

Most objects have many properties. When an object is initiated, each of these properties is assigned with an assumed setting. This setting is referred to as the default setting of the property. For example, the default setting for the first label, button and form are Label1, Button1, and Form1 respectively. The property of an object does not have significant behavior on the performance of project.

4.8.3 Programming Requirements

Preceding discussion focused on which VB controls to be used and how to arrange them on a form. It still needs to place the codes in the project before it will work the way you want. Depending on what is to be accomplished, various programming requirements are used to place specific code.

4.9 Introduction

Introduction window briefly introduces the importance of using High Energy Saving Lamps and the purpose and features of software. The features presented in the software are calculating the price of HES lamps, estimates electricity bill contribution by lamp monthly, comparison price and electricity bill contribution by HES and incandescent lamps and quantity of lamp needed according to area and lamp.

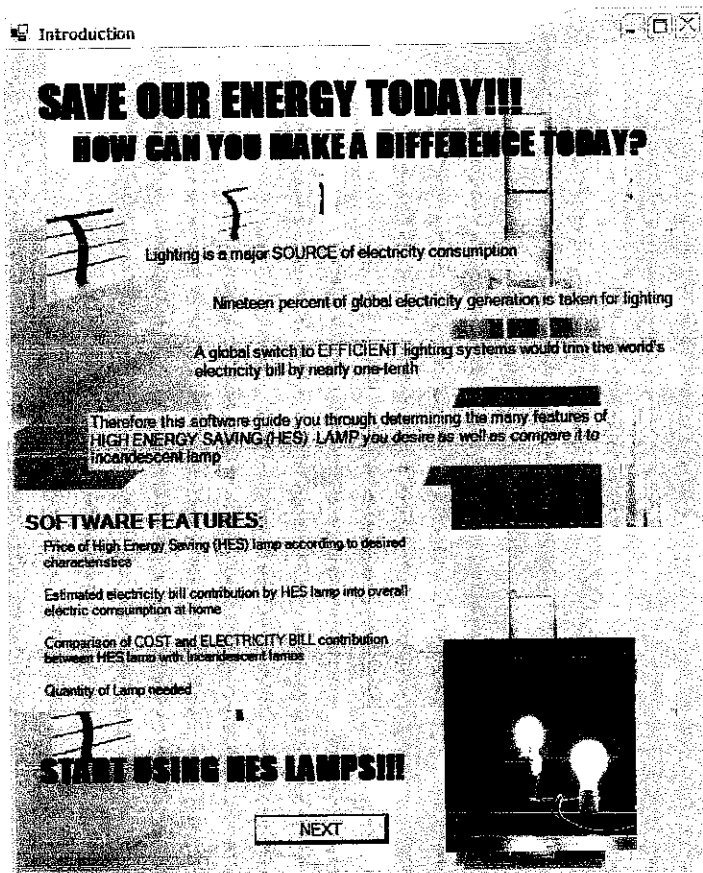


Figure 5 : Introduction window of the software

4.10 Main Page

By clicking button 'NEXT' on the Introduction window, the Main Page window will appear. This interface allows the user to specify their desired characteristics and obtain the price of HES lamps. The link labels are included to explain further about the variables and obtain the values according to their specifications.

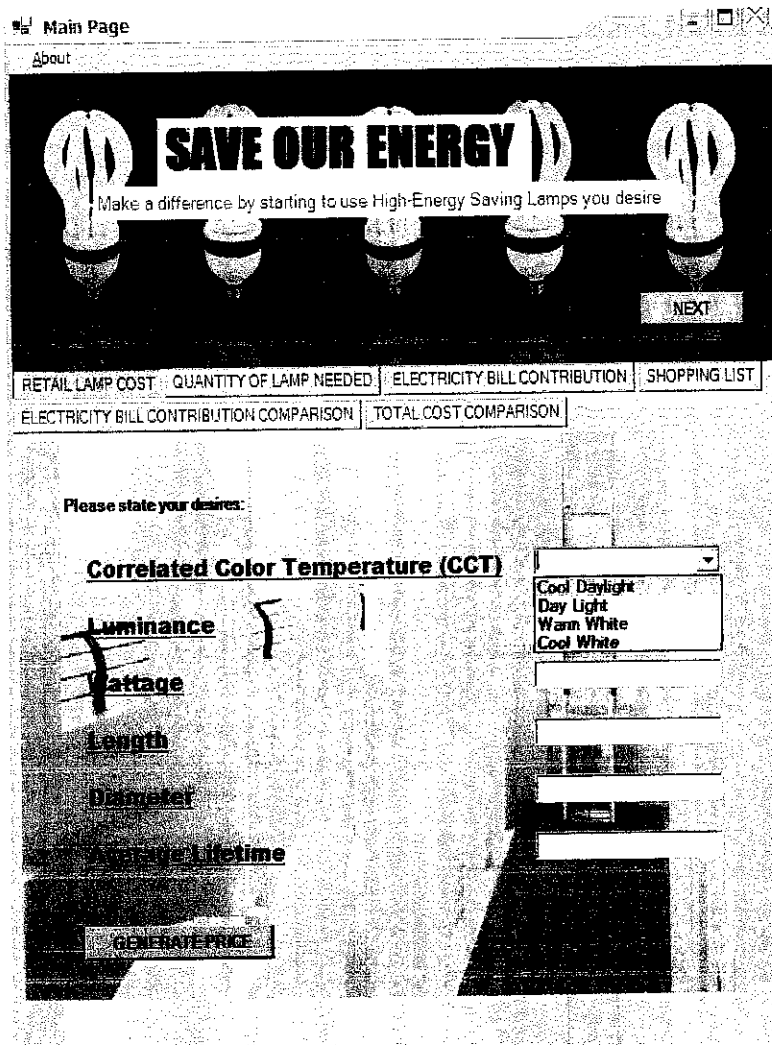


Figure 6 : The variables will be filled in with desired values

4.10.1 Correlated Color Temperature (CCT)

This window explains about the characteristics of common Correlated Color Temperature (CCT) available and the values correlated to each characteristic. Four choices are given to the user to select the most desirable color. The linear correlation graph is also displayed to give a better picture of the relationship between CCT and Price of HES lamps.

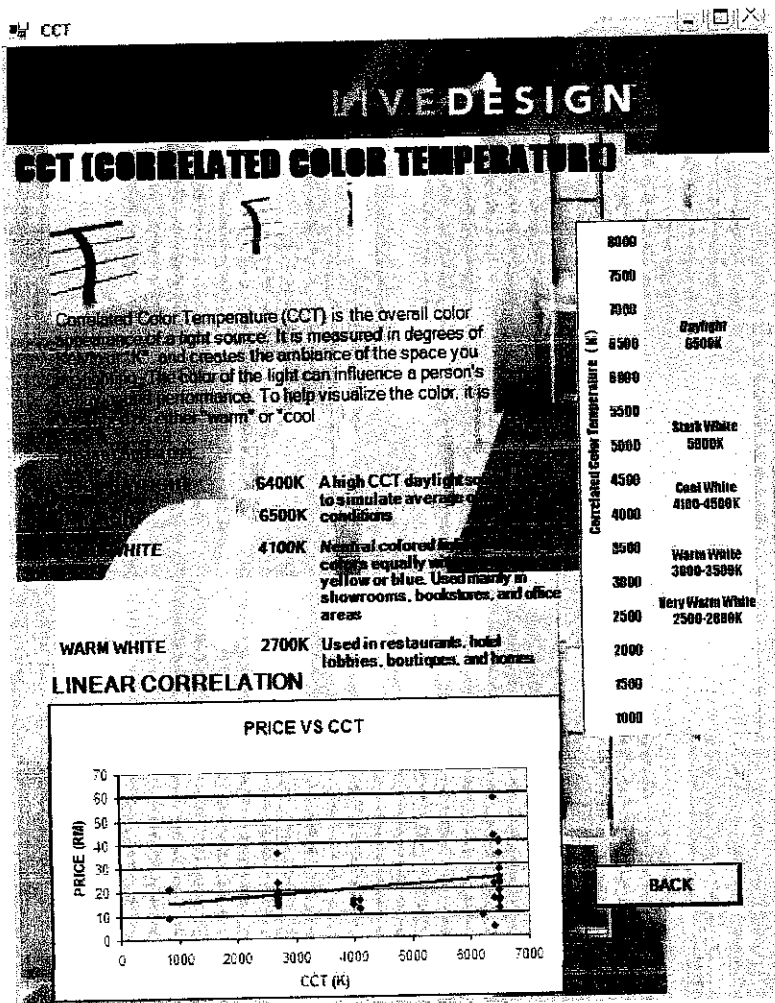


Figure 7 : Correlated Color Temperature (CCT) window

4.10.2 Luminance

Window calculates the luminance required by lamp according to the chosen activity or purpose of the room. The lumens obtained will be inserted in the lumens variable text box to determine the price.

$$\text{Luminance (lumens)} = \text{Illuminance (lx)} \times (\text{distance})^2 \quad [13]$$

Luminance = Luminous intensity assumed 1 lumen per steradian

Typical recommendations for residential rooms by Chartered Institution of Building Services Engineers, CIBSE 1994 Interior Lighting Code

Activity	Maintained Illuminance (lx)
Reading	150
Cooking	300
Bedroom	100
Bathroom	150
TV viewing	50
Dining	150
Halls, corridors	100

The results for luminance intensity based on places and activity is important, as the users will not be aware of the intensity they will need or require, therefore based on the software they could just select or specify their activity or place for the lamp usage and acquire their needed intensity.

The linear correlation graph is also displayed to give a better picture of the relationship between luminance and Price of HES lamps.

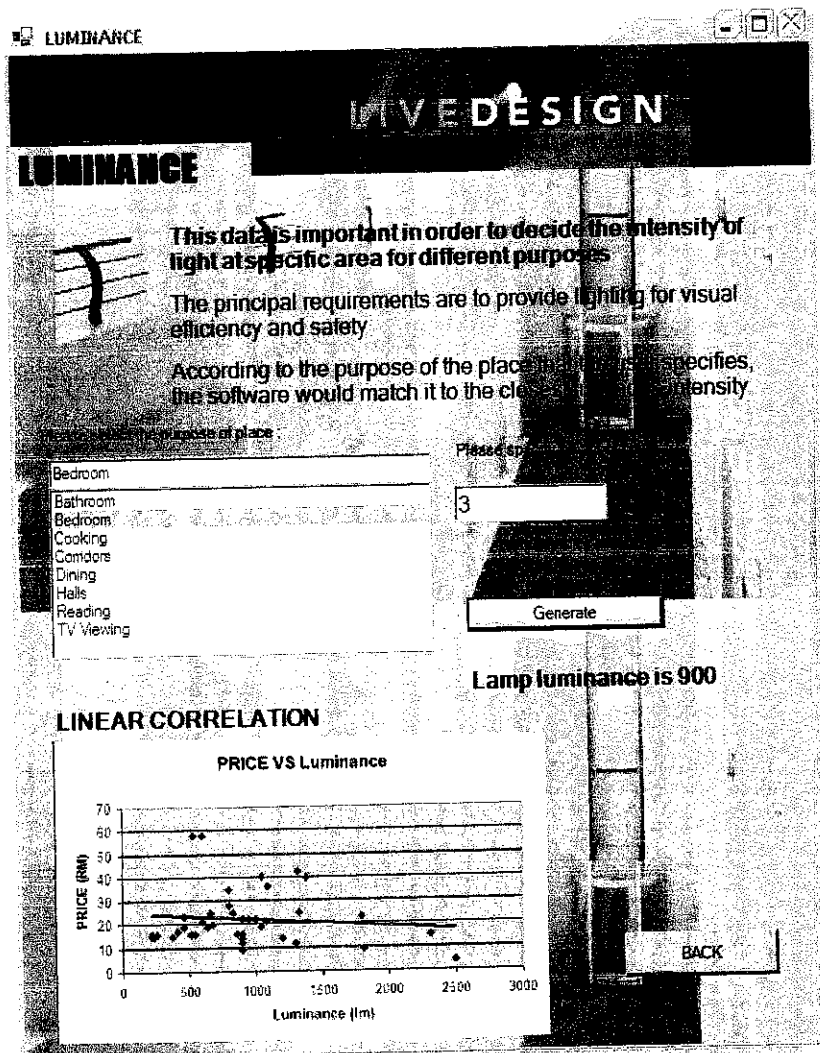


Figure 8 : Luminance window

Result shows that a room to be used as a bedroom with height of 3 meter will need lamp of 900lumens.

4.10.3 Wattage

The window explains what wattage of a lamp means and that the value affect electricity bill at home. The linear correlation graph is also displayed to give them a better picture of the relationship between wattage and Price of HES lamps.

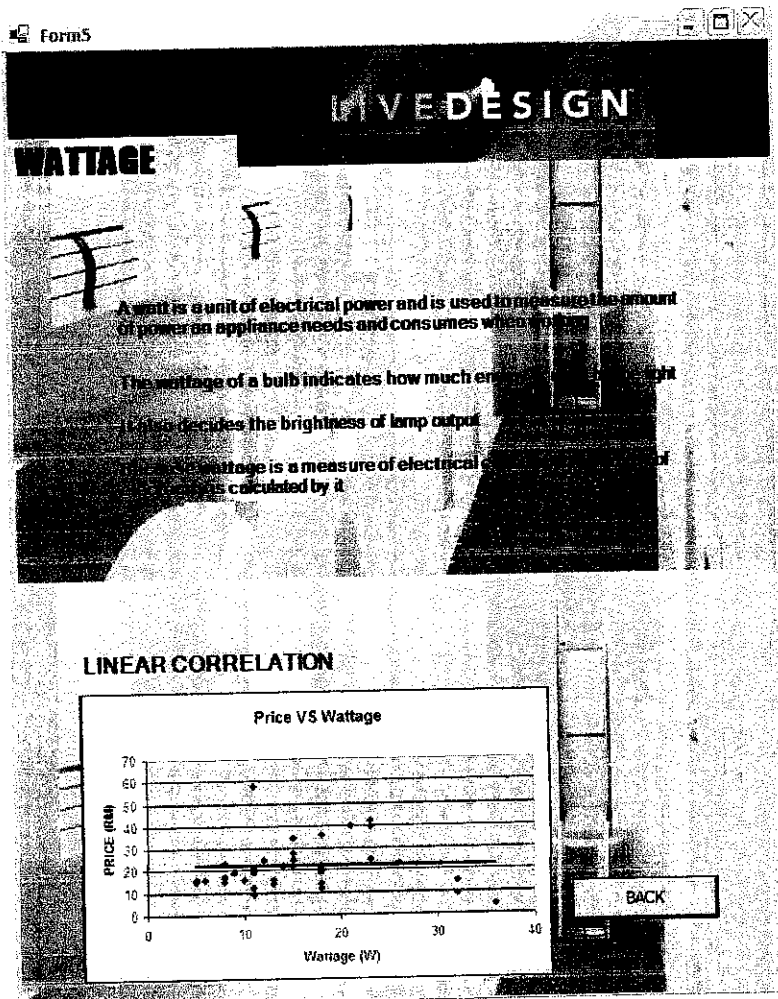


Figure 9 : Wattage window

4.10.4 Length

The window displays the dimension length is measured from and the unit of the desired length. The linear correlation graph is also displayed to give them a better picture of the relationship between length and Price of HES lamps.

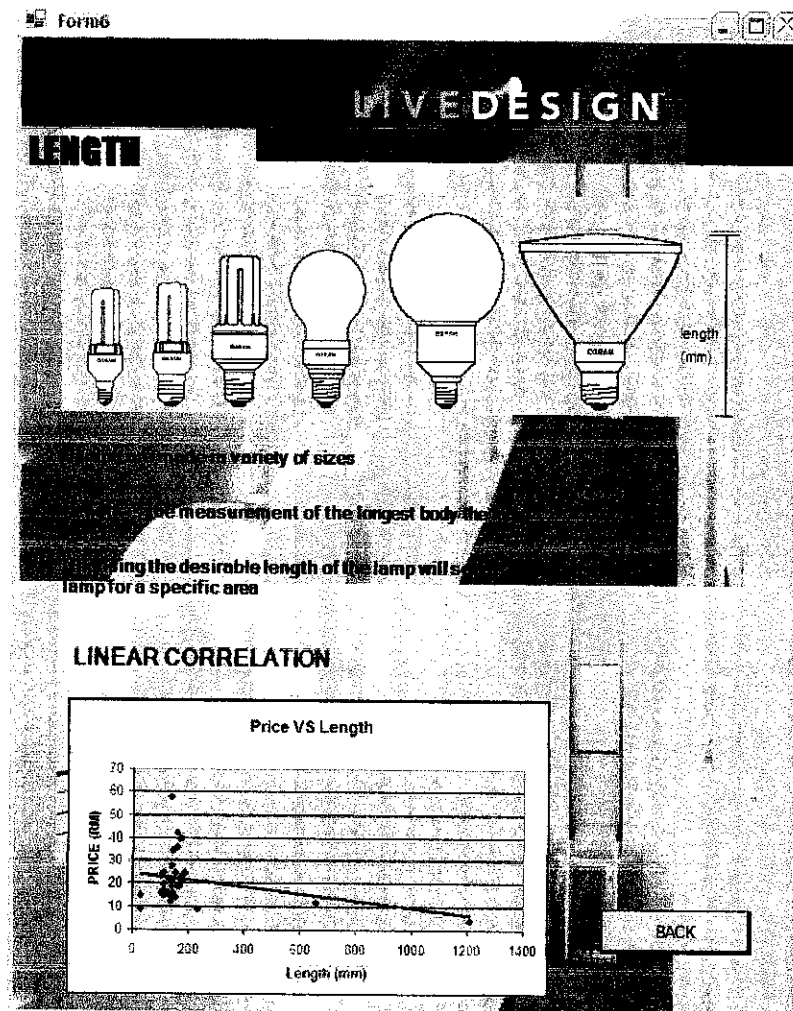


Figure 10 : Length window

4.10.5 Diameter

The window displays the dimension diameter is measured from and the unit of the desired length. The linear correlation graph is also displayed to give them a better picture of the relationship between diameter and Price of HES lamps.

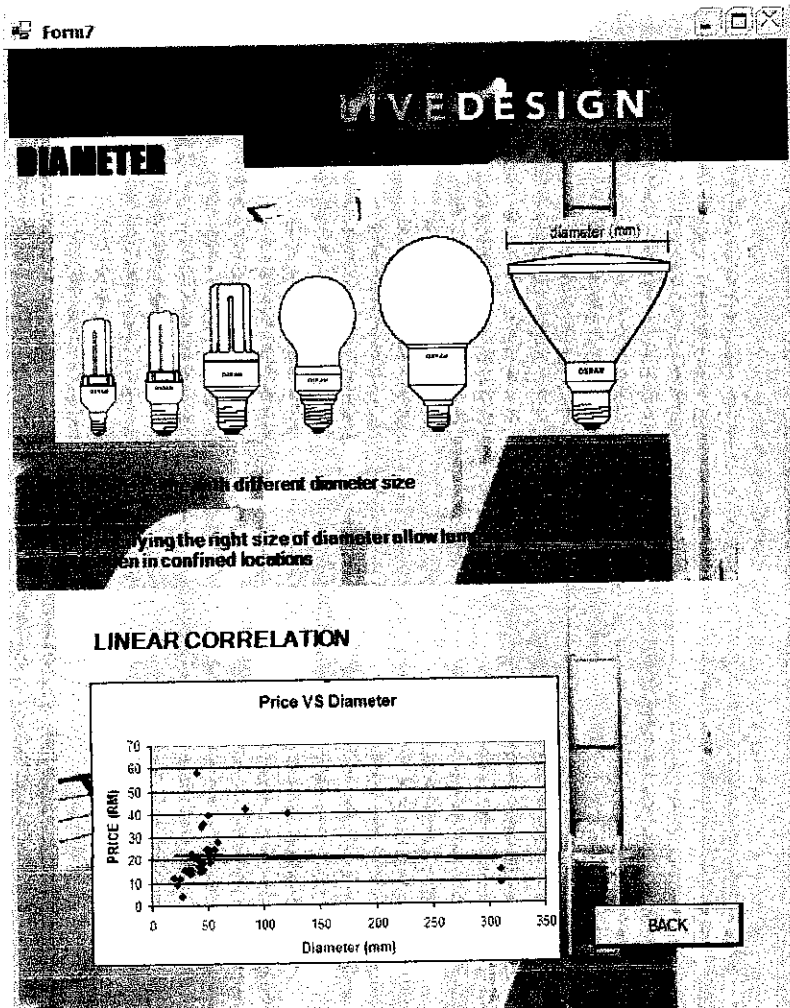


Figure 11 : Diameter window

4.10.6 Average Lifetime

Window explains the meaning of average lifetime of lamps and the common lifetime of HES lamps available in the market. The linear correlation graph is also displayed to give them a better picture of the relationship between average lifetime and Price of HES lamps.

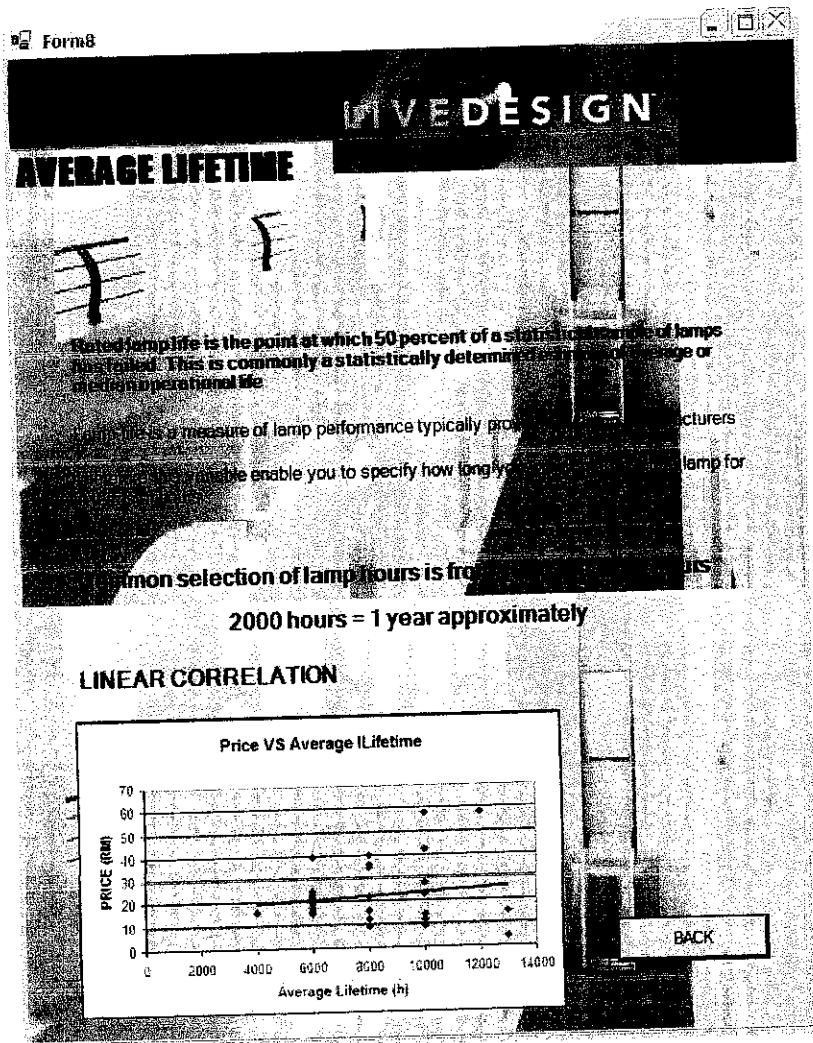


Figure 12 : Average Lifetime window

4.10.7 Price of HES lamp

Once all the values for the variables are keyed in, the software will estimate the price of HES lamp according to the constants obtained from multiple linear regressions.

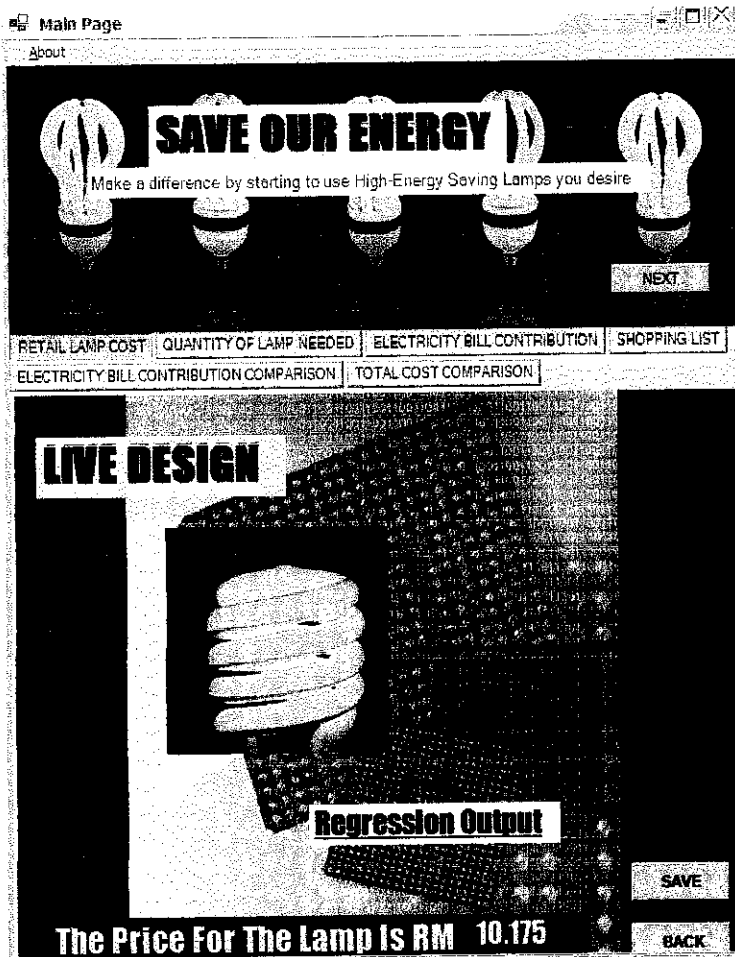


Figure 13 : Price of HES lamp estimation window

The price calculated shows RM 10.276 which is close to the real value, which is RM 11.90. Therefore, the model is seen to be quite accurate.

4.11 Quantity of Lamp Needed

In order to get a rough estimate of the number of fixtures, it is useful to note that efficient fluorescent lighting may come out to about 1.5W/ft squared [14]. Therefore, the formula as shown in the coding is used to calculate the number of lamps needed for certain area of space with certain desired wattage.

$$\text{Number of lamp needed} = (\text{Width} * \text{Length}) / \text{Watt}$$

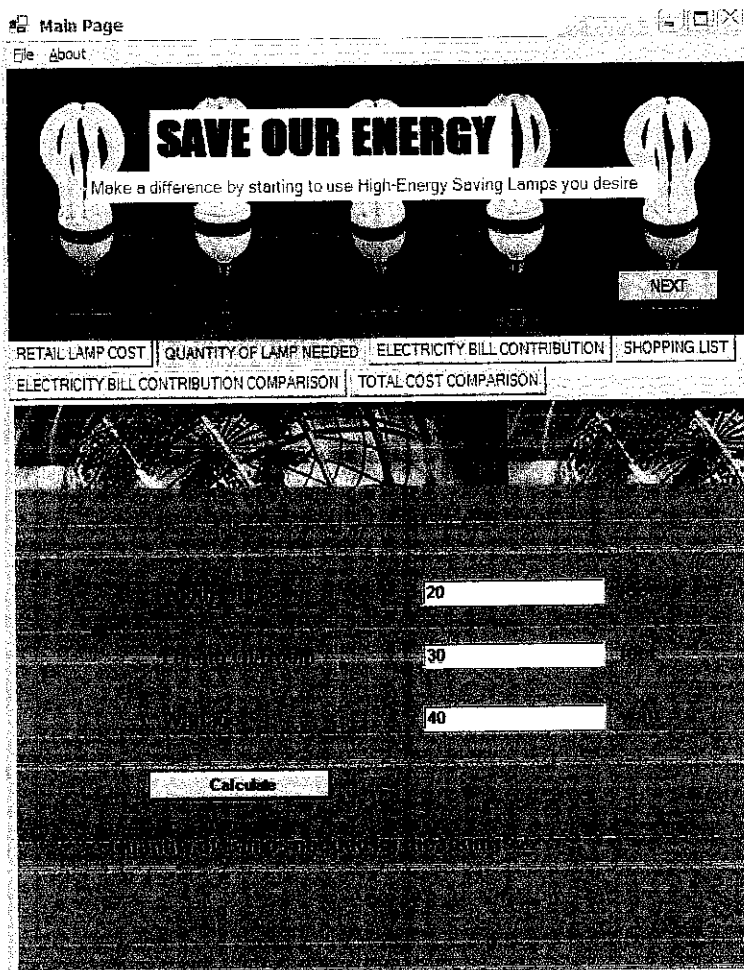


Figure 14 : Window to calculate number of lamp needed

From the window displayed, it is shown that a room with the width of 20 feet, length of 30 feet, 23 lamps with 40 watt is needed.

4.12 Generating estimated electricity bill contribution by HES lamp monthly

The electricity bill contribution by a lamp can be calculated using duration of hours used, power of lamp (wattage) and the latest tariff set by Tenaga Nasional [15].

TARIFF CATEGORY	UNIT	RATES
1. Tariff A - Domestic Tariff		
First 200 kWh (1 - 200 kWh) per month	sen/kWh	21.80
Next 800 kWh (201 - 1,000 kWh) per month	sen/kWh	28.90
Over 1,000 kWh (1,001 kWh onwards) per month	sen/kWh	31.20
The minimum monthly charge is RM3.00		

Figure 15 : The tariff that is applied in Malaysia for domestic (housing) usage

As shown below it can be calculated that the estimated of 70 hours per week using one 11 watt HES lamp will contribute RM 0.67 monthly to the overall monthly electric bill.

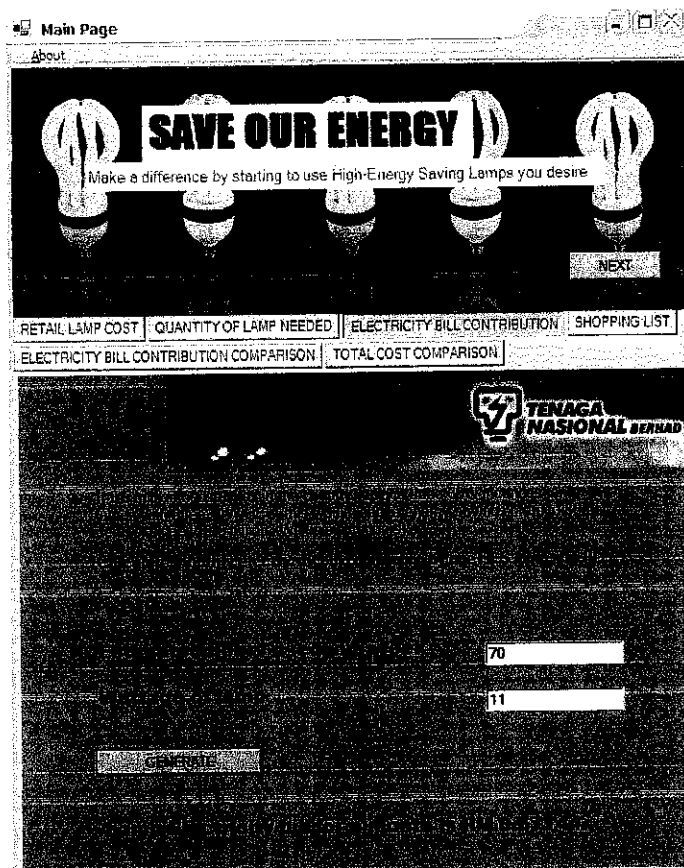


Figure 16 : Electricity bill contribution by lamp monthly

4.13 Shopping List

The shopping list features allows the user to save their chosen desired lamp, which views all their characteristics and the price of each lamp. At the end, the software is able to total up the price of the lamps, which the users plan to shop.

To activate the button 'SAVE' the software makes sure that the text box of the variables are filled in otherwise the message for example of an empty luminance text box, 'Please enter the luminance of HES lamp'.

The screenshot shows a software window titled "Main Page" with a dark background. At the top, there's a banner with the text "SAVE OUR ENERGY" and "Make a difference by starting to use High-Energy Saving Lamps you desire". Below the banner are five light bulb icons. A "NEXT" button is visible on the right. Below the banner is a navigation bar with several buttons: "RETAIL LAMP COST", "QUANTITY OF LAMP NEEDED", "ELECTRICITY BILL CONTRIBUTION", "SHOPPING LIST", "ELECTRICITY BILL CONTRIBUTION COMPARISON", and "TOTAL COST COMPARISON". The main content area features a table with the following columns: CCT, LUMINANCE, WATTAGE, LENGTH, DIAMETER, and AVERAGE LIFETIME. The table lists two types of lamps: "Cool Daylight" and "Day Light". Below the table, there's a section for "PRICES FOR LAMPS ARE RM" with two input fields containing "10.175" and "40.746". At the bottom, there's a "Print" button, a "TOTAL PRICE OF LAMPS" button, and a display showing "RM 50.921".

CCT	LUMINANCE	WATTAGE	LENGTH	DIAMETER	AVERAGE LIFETIME
Cool Daylight	827	9	168	22	8000
Day Light	1000	15	42	10	10000

PRICES FOR LAMPS ARE RM

10.175
40.746

Print TOTAL PRICE OF LAMPS RM 50.921

Figure 17 : Lists of characteristics values and price of each lamp and total price

4.14 Electricity Bill Contribution Comparison

The equivalent wattage of incandescent lamp was found from correlation between wattage of HES lamps and given wattage of incandescent lamps. Therefore the calculation of equivalent wattage of incandescent lamp was possible.

Result from correlation is

$$\text{Watt Incandescent} = 3.719 \times \text{Watt HES}$$

This allows the user to see the difference in wattage, which leads to electricity bill difference that portrays the wastes of electrical energy sources.

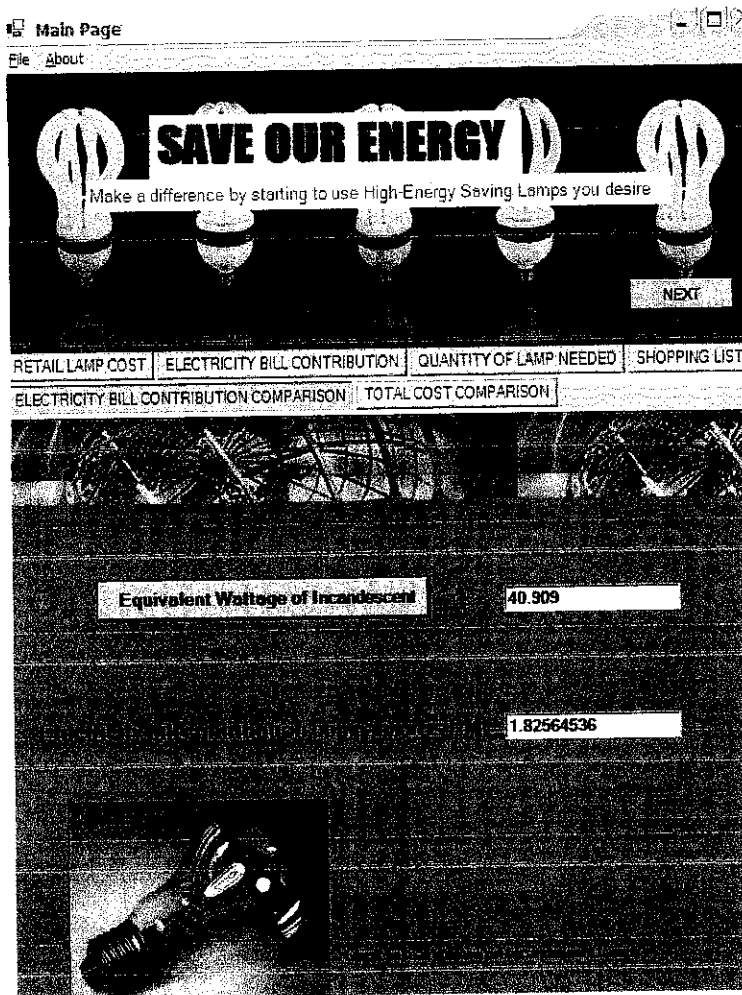


Figure 18 : Electricity bill contribution comparison by HES and Incandescent lamps

This shows that from the previous calculation of electricity bill contribution by HES lamp, it can calculate the equivalent wattage of incandescent lamp and the electricity bill comparison monthly by both lamps. In the example it clarify that 11 watt of HES equals to 40.9 watt of incandescent lamps and the cost of electricity bill which incandescent lamp exceed from HES lamp is RM 1.83 monthly.

By clicking on the picture, the software explains more about incandescent lamps as shown below.

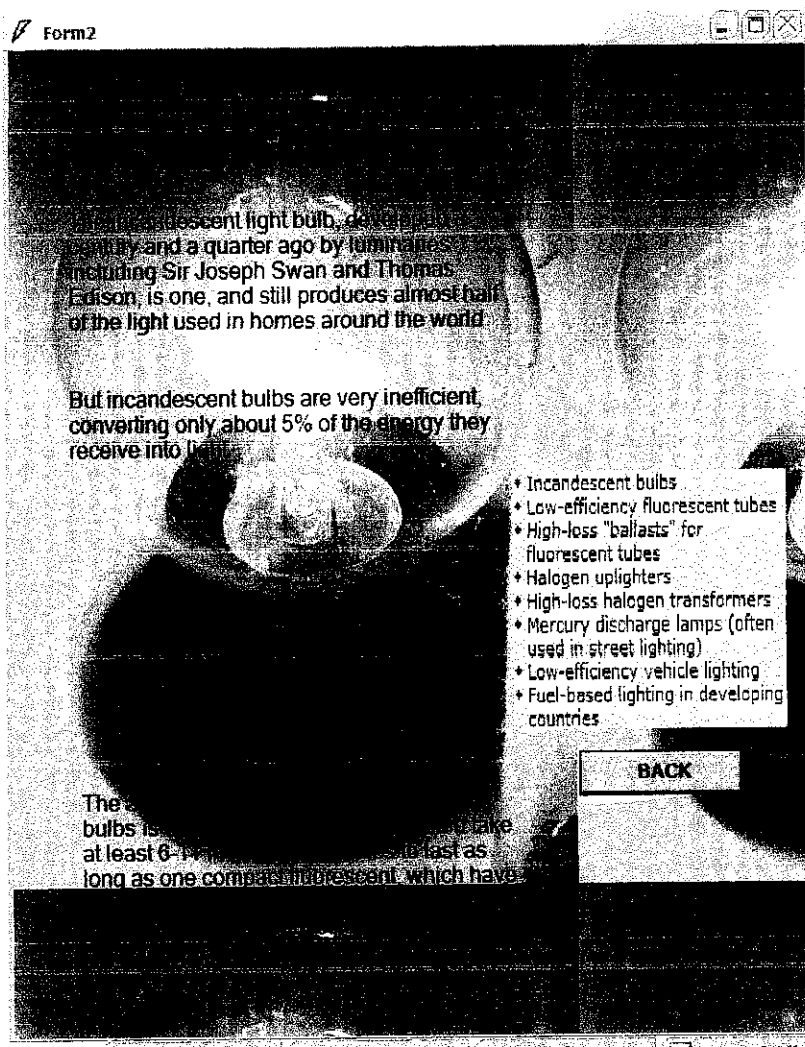


Figure 19 : Incandescent lamp window

4.15 Total Cost Comparison

This feature compares the total cost of using HES and incandescent lamps. Total cost includes price of lamp sold at the market and the electricity bill contribution in a year.

With this feature, the users can see the difference in terms of cost using HES lamps compared to incandescent lamps.

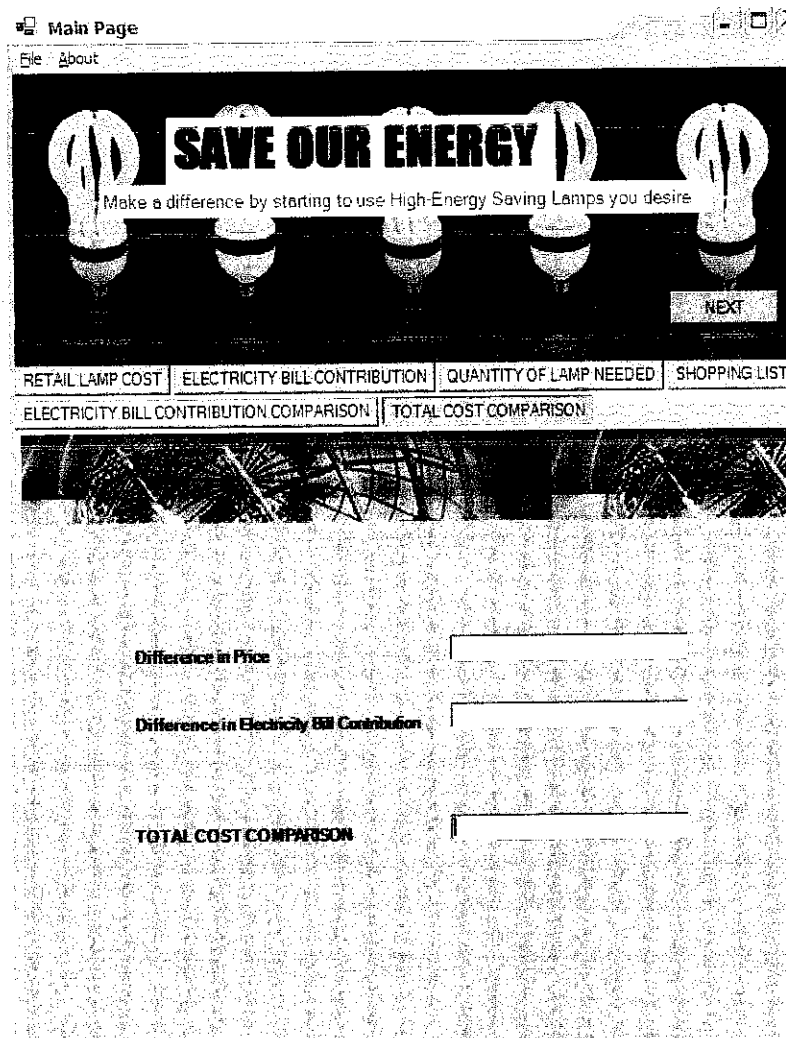


Figure 20 : Total cost comparison window

4.16 About Author

This window explains about copyrights, title of software, name of author and supervisor, date software was created and the tool used in creating the software as shown.

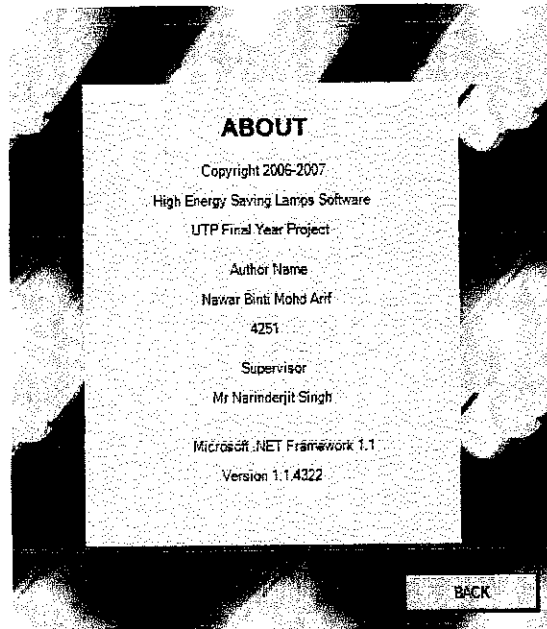


Figure 21 : About Program window

4.17 Variables Discarded

During literature review, there are certain variables that could not be used for the modeling because the data were not available for almost all lamps found during the research. The first variable that was identified but could not be included is the ambient temperature. For example, normal fluorescent lamps are designed to run in an air temperature of about 25°C with a lamp wall temperature of 40°C, which produces a vapor pressure of about 800Pa. Besides that, the variable did not seem necessary since this country consists of constant temperature where most lamps are feasibly operating. Weight is another variable that could not be included because lack of information provided by manufacturers.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

In conclusion, the main variables involved in the characteristics of which affect the price of High Energy Saving lamps were studied. The main variables identified are wattage (W), brightness (lumens), length (mm), width (mm), average lifetime (hour), and Correlated Color Temperature CCT (Kelvin).

The regression model for HES lamps shows respectable result as R square is above 60 per cent which shows that variance in the dependent variable (price) is well explained by the model (variables wattage, brightness, length, width, average lifetime, and Correlated Color Temperature CCT). It is seen that watt makes the strongest unique contribution explaining the dependent variable as it has the highest value of Beta for in the model. Modeling of the data was continued with hierarchical multiple regression and correlations to further evaluate the relationships of the different variables with the dependent variable.

Interactive software that incorporates the statistical model was completed. Finally yet importantly, the testing and editing stage of the software development made sure there are no errors in the program and the software meets its objective successfully.

5.2 Recommendations

More independent variables identification is strongly encouraged to improve accuracy of subject variable modeling. The software development part of the project has other creative moves, which are editable and open for recoding anytime as long as it does not interrupt its main function. Instead of inserting graphs into the software, it is recommended to create a feature that allows the software to simulate the statistical modeling.

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[9] Mark Rea, Lei Deng, Robert Wolsey (2005). Lighting Answers: Full-spectrum Light Sources (Volum 7, Issue 5)

[10] Copyright © 2006 1000bulbs.com (2006). Screw-In Fluorescents :2 to 200 Watt CFL :2 to 3 Compact Fluorescents :2 Watt - 2700 Kelvin - S14 Cold Cathode Fluorescent - 2W/S14/CL/27K - Litetronics Micro-Brite

Available: <http://www.1000bulbs.com/product.php?product=9229>

[11] Julie Pallant (2001). Correlation: SPSS Survival Manual Version 10 (1st Edition, pp 120) Maryborough, Victoria: McPherson's Printing Group

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[14] Marc Schiller (1992). Lighting Calculations. Simplified Design of Building Lighting (pp 62), United States of America: John Wiley & Sons. Inc.

[15] © Copyright 2004 Tenaga Nasional Berhad All Rights Reserved

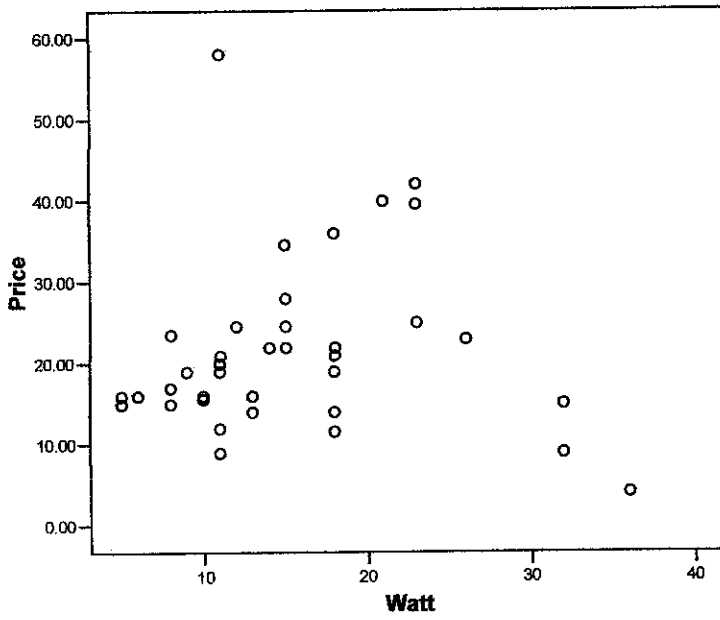
Available: http://www.tnb.com.my/tariff/newrate_domestic.htm

APPENDICES

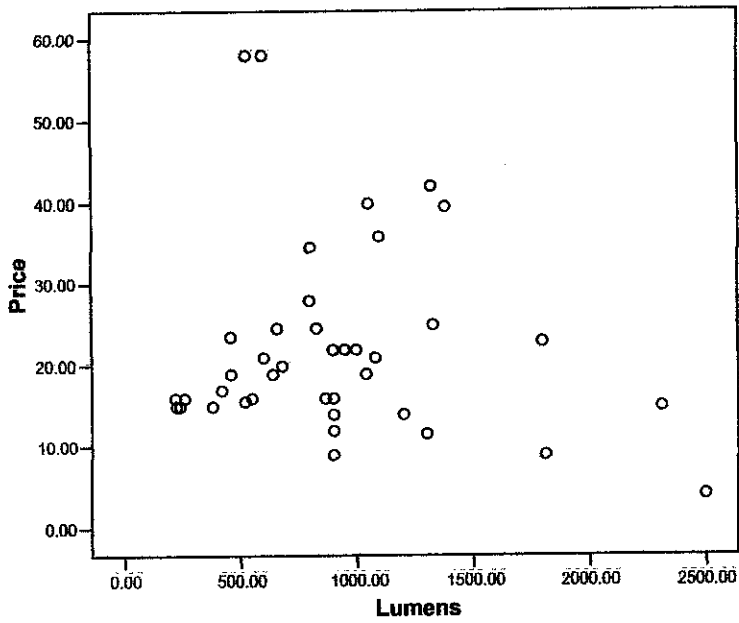
Appendix A

SCATTERPLOT CORRELATION

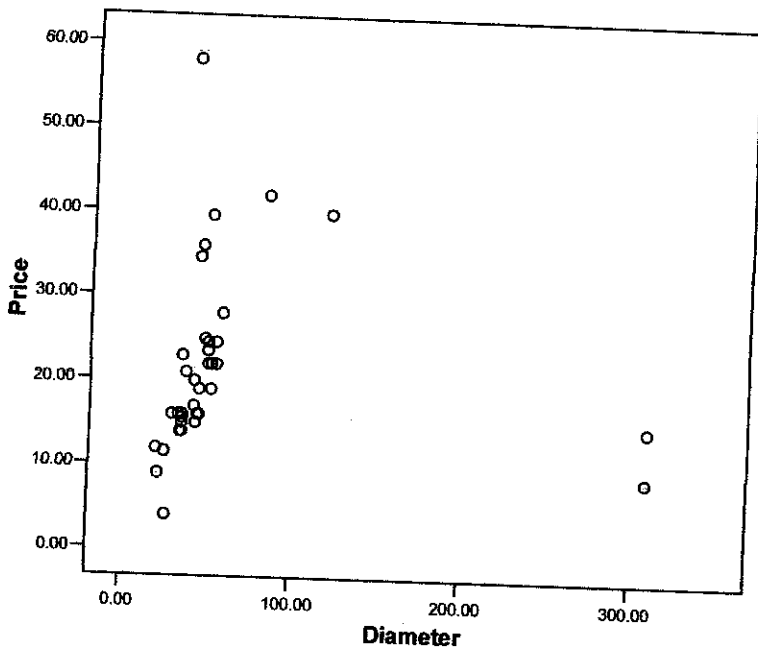
Price VS Wattage



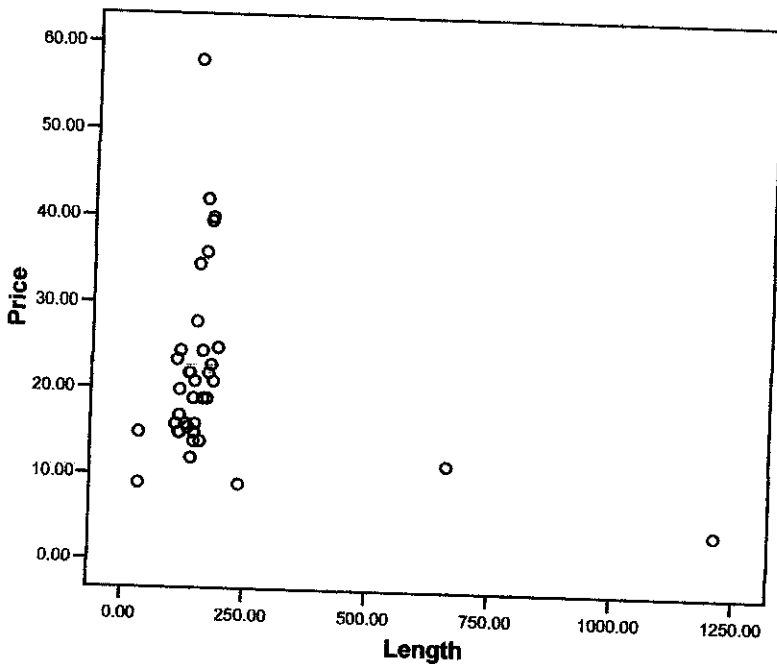
Price VS Lumens



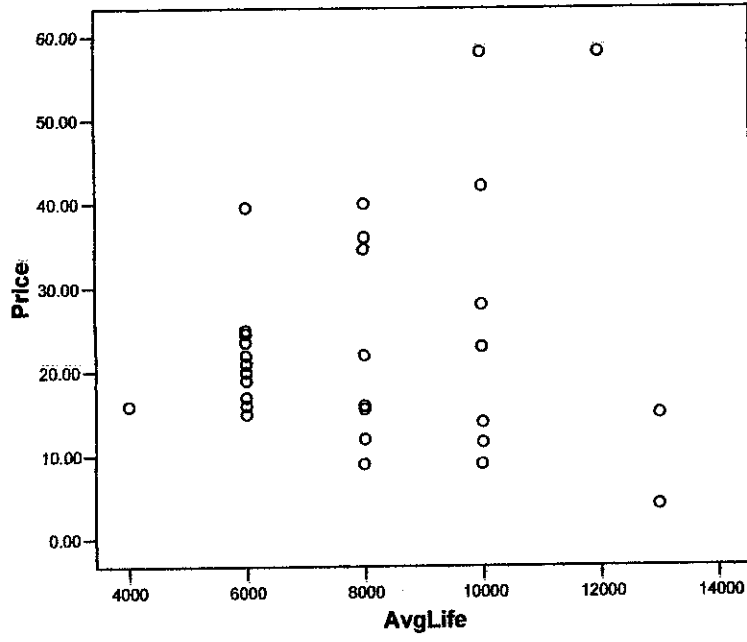
Price VS Diameter



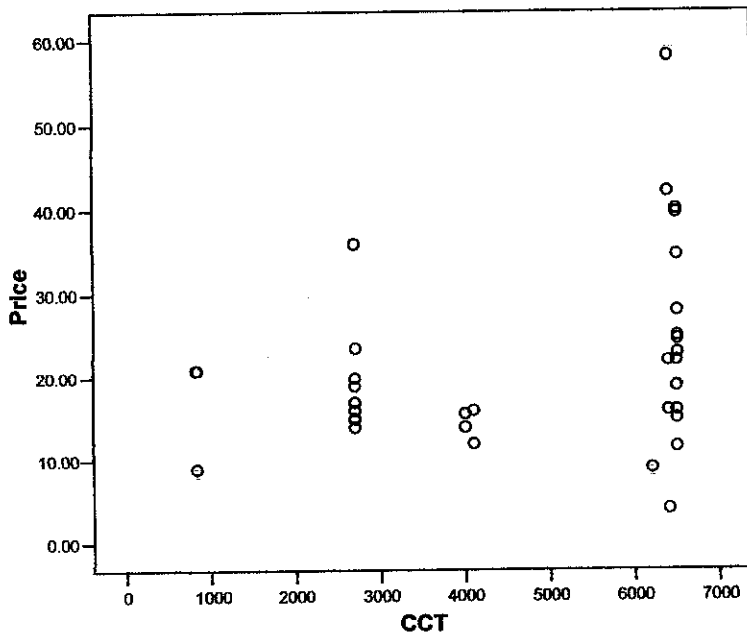
Price VS Length



Price VS Length



Price VS CCT



Appendix B

PARTIAL CORRELATION

CCT as Control Variable

Control Variables		Watt	Diameter	Lumens	Length	AvgLife	Price	CCT
-none-(a)	Watt	1.000	.561(**)	.972(**)	.421(**)	.541(**)	-.009	.365(*)
	Diameter	.561(**)	1.000	.501(**)	-.233	.253	-.061	.240
	Lumens	.972(**)	.501(**)	1.000	.482(**)	.620(**)	-.123	.296
	Length	.421(**)	-.233	.482(**)	1.000	.414(**)	-.245	.127
	AvgLife	.541(**)	.253	.620(**)	.414(**)	1.000	.139	.235
	Price	-.009	-.061	-.123	-.245	.139	1.000	.272
	CCT	.365(*)	.240	.296	.127	.235	.272	1.000
CCT	Watt	1.000	.524(**)	.971(**)	.406(*)	.503(**)	-.120	
	Diameter	.524(**)	1.000	.464(**)	-.274	.209	-.135	
	Lumens	.971(**)	.464(**)	1.000	.468(**)	.593(**)	-.221	
	Length	.406(*)	-.274	.468(**)	1.000	.398(*)	-.293	
	AvgLife	.503(**)	.209	.593(**)	.398(*)	1.000	.081	
	Price	-.120	-.135	-.221	-.293	.081	1.000	
	CCT							

** Correlation is significant at 0.01 level

* Correlation is significant at 0.05 level

a Cells contain zero-order (Pearson) correlations.

Average Lifetime as Control Variable

Control Variables		Watt	Diameter	Lumens	Length	Price	CCT	AvgLife
-none-(a)	Watt	1.000	.561(**)	.972(**)	.421(**)	-.009	.365(*)	.541(**)
	Diameter	.561(**)	1.000	.501(**)	-.233	-.061	.240	.253
	Lumens	.972(**)	.501(**)	1.000	.482(**)	-.123	.296	.620(**)
	Length	.421(**)	-.233	.482(**)	1.000	-.245	.127	.414(**)
	Price	-.009	-.061	-.123	-.245	1.000	.272	.139
	CCT	.365(*)	.240	.296	.127	.272	1.000	.235
	AvgLife	.541(**)	.253	.620(**)	.414(**)	.139	.235	1.000
AvgLife	Watt	1.000	.522(**)	.965(**)	.258	-.101	.291	
	Diameter	.522(**)	1.000	.453(**)	-.384(*)	-.101	.192	
	Lumens	.965(**)	.453(**)	1.000	.315	-.269	.198	
	Length	.258	-.384(*)	.315	1.000	-.335(*)	.034	
	Price	-.101	-.101	-.269	-.335(*)	1.000	.248	
	CCT	.291	.192	.198	.034	.248	1.000	
	AvgLife							

** Correlation is significant at 0.01 level

* Correlation is significant at 0.05 level

a Cells contain zero-order (Pearson) correlations.

Length as Control Variable

Control Variables		Diameter	Lumens	Price	CCT	AvgLife	Watt	Length
-none-(a)	Diameter	1.000	.501(**)	-.061	.240	.253	.561(**)	-.233
	Lumens	.501(**)	1.000	-.123	.296	.620(**)	.972(**)	.482(**)
	Price	-.061	-.123	1.000	.272	.139	-.009	-.245
	CCT	.240	.296	.272	1.000	.235	.365(*)	.127
	AvgLife	.253	.620(**)	.139	.235	1.000	.541(**)	.414(**)
	Watt	.561(**)	.972(**)	-.009	.365(*)	.541(**)	1.000	.421(**)
	Length	-.233	.482(**)	-.245	.127	.414(**)	.421(**)	1.000
Length	Diameter	1.000	.720(**)	-.126	.280	.395(*)	.748(**)	
	Lumens	.720(**)	1.000	-.006	.270	.527(**)	.968(**)	
	Price	-.126	-.006	1.000	.315	.272	.107	
	CCT	.280	.270	.315	1.000	.201	.346(*)	
	AvgLife	.395(*)	.527(**)	.272	.201	1.000	.444(**)	
	Watt	.748(**)	.968(**)	.107	.346(*)	.444(**)	1.000	

** Correlation is significant at 0.01 level
 * Correlation is significant at 0.05 level
 a Cells contain zero-order (Pearson) correlations.

Lumens as Control Variable

Control Variables		Diameter	Price	CCT	AvgLife	Watt	Length	Lumens
-none-(a)	Diameter	1.000	-.061	.240	.253	.561(**)	-.233	.501(**)
	Price	-.061	1.000	.272	.139	-.009	-.245	-.123
	CCT	.240	.272	1.000	.235	.365(*)	.127	.296
	AvgLife	.253	.139	.235	1.000	.541(**)	.414(**)	.620(**)
	Watt	.561(**)	-.009	.365(*)	.541(**)	1.000	.421(**)	.972(**)
	Length	-.233	-.245	.127	.414(**)	.421(**)	1.000	.482(**)
	Lumens	.501(**)	-.123	.296	.620(**)	.972(**)	.482(**)	1.000
Lumens	Diameter	1.000	.000	.111	-.084	.366(*)	-.626(**)	
	Price	.000	1.000	.325(*)	.277	.474(**)	-.213	
	CCT	.111	.325(*)	1.000	.068	.342(*)	-.018	
	AvgLife	-.084	.277	.068	1.000	-.335(*)	.168	
	Watt	.366(*)	.474(**)	.342(*)	-.335(*)	1.000	-.226	
	Length	-.626(**)	-.213	-.018	.168	-.226	1.000	

** Correlation is significant at 0.01 level
 * Correlation is significant at 0.05 level
 a Cells contain zero-order (Pearson) correlations.

Diameter as Control Variable

Control Variables		Price	CCT	AvgLife	Watt	Length	Lumens	Diameter
-none-(a)	Price	1.000	.272	.139	-.009	-.245	-.123	-.061
	CCT	.272	1.000	.235	.365(*)	.127	.296	.240
	AvgLife	.139	.235	1.000	.541(**)	.414(**)	.620(**)	.253
	Watt	-.009	.365(*)	.541(**)	1.000	.421(**)	.972(**)	.561(**)
	Length	-.245	.127	.414(**)	.421(**)	1.000	.482(**)	-.233
	Lumens	-.123	.296	.620(**)	.972(**)	.482(**)	1.000	.501(**)
	Diameter	-.061	.240	.253	.561(**)	-.233	.501(**)	1.000
Diameter	Price	1.000	.295	.160	.031	-.267	-.107	
	CCT	.295	1.000	.185	.286	.194	.210	
	AvgLife	.160	.185	1.000	.498(**)	.503(**)	.589(**)	
	Watt	.031	.286	.498(**)	1.000	.687(**)	.964(**)	
	Length	-.267	.194	.503(**)	.687(**)	1.000	.711(**)	
	Lumens	-.107	.210	.589(**)	.964(**)	.711(**)	1.000	
	Diameter							

* Correlation is significant at 0.05 level

** Correlation is significant at 0.01 level

a Cells contain zero-order (Pearson) correlations.

Wattage as Control Variable

Control Variables		Diameter	Lumens	Length	Price	CCT	AvgLife	Watt
-none-(a)	Diameter	1.000	.501(**)	-.233	-.061	.240	.253	.561(**)
	Lumens	.501(**)	1.000	.482(**)	-.123	.296	.620(**)	.972(**)
	Length	-.233	.482(**)	1.000	-.245	.127	.414(**)	.421(**)
	Price	-.061	-.123	-.245	1.000	.272	.139	-.009
	CCT	.240	.296	.127	.272	1.000	.235	.365(*)
	AvgLife	.253	.620(**)	.414(**)	.139	.235	1.000	.541(**)
	Watt	.561(**)	.972(**)	.421(**)	-.009	.365(*)	.541(**)	1.000
Watt	Diameter	1.000	-.229	-.626(**)	-.068	.046	-.072	
	Lumens	-.229	1.000	.337(*)	-.486(**)	-.266	.477(**)	
	Length	-.626(**)	.337(*)	1.000	-.266	-.031	.244	
	Price	-.068	-.486(**)	-.266	1.000	.295	.171	
	CCT	.046	-.266	-.031	.295	1.000	.048	
	AvgLife	-.072	.477(**)	.244	.171	.048	1.000	
	Watt							

** Correlation is significant at 0.01 level

* Correlation is significant at 0.05 level

a Cells contain zero-order (Pearson) correlations.

Appendix C

MULTIPLE REGRESSIONS TO FIND HES LAMP PRICE

Multiple Regression without variable CCT

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.783(a)	.613	.556	7.93735

a Predictors: (Constant), Watt, Length, AvgLife, Diameter, Lumens
 b Dependent Variable: Price

Multiple Regression without variable Average Lifetime

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.617(a)	.381	.290	10.03352

a Predictors: (Constant), CCT, Length, Diameter, Lumens, Watt
 b Dependent Variable: Price

Multiple Regression without variable Length

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.703(a)	.494	.420	9.06646

a Predictors: (Constant), AvgLife, CCT, Diameter, Watt, Lumens
 b Dependent Variable: Price

Multiple Regression without variable Lumens

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.564(a)	.318	.218	10.53106

a Predictors: (Constant), Length, CCT, Diameter, AvgLife, Watt
 b Dependent Variable: Price

Multiple Regression without variable Wattage

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.542(a)	.294	.190	10.71396

a Predictors: (Constant), Lumens, CCT, Length, AvgLife, Diameter
 b Dependent Variable: Price

Multiple Regression without variable Diameter

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.692(a)	.479	.402	9.20809

a Predictors: (Constant), Watt, CCT, Length, AvgLife, Lumens
 b Dependent Variable: Price

Appendix D
LETTER OF PERMISSION

NARINDERJIT SINGH s/o SAWARAN SINGH
LECTURER/SUPERVISOR
ELECTRICAL & ELECTRONIC ENGINEERING
UNIVERSITY TEKNOLOGI PETRONAS

31st JANUARY 2007

To Whom It May Concern,

The specified student (Nawar Binti Mohd Arif), would like to enquire data for her Final Year Project in Universiti Teknologi Petronas on a topic about Factors Effecting Suitable Lamps to be used.

1. This project evolve around data which is to be modeled and be decided on which factors are most influencing on the lamp to be chosen. All variables useful to her project such as:

- i)-lumens
- ii)-color (CCT)
- iii)-length
- iv)-diameter
- v)-average lamp life
- vi)-wattage
- vii)-cost

2. *Your cooperation is most appreciated.*

THANK YOU

NARINDERJIT SINGH s/o SAWARAN SINGH
LECTURER/SUPERVISOR
ELECTRICAL & ELECTRONIC ENGINEERING
UNIVERSITY TEKNOLOGI PETRONAS