Energy Savings Measurement and Verification Through Awareness Program in an Educational Building Campus

Rijalul Fahmi Mustapa, NY Dahlan, Ihsan Mohd Yassin, AHM Nordin

Abstract— **Energy conservation measures (ECM) is a strategy taken to achieve efficient electrical energy utilization. Two main ECM strategy is retrofitting old inefficient loads or through awareness programme and the energy saved is being calculated through baseline energy models. Energy service company (ESCO) is in the helping hands towards retrofitting old unefficient loads without any upfront payment with the establishment of energy performance contract (EPC). There are certain problems and issues arise pertaining to baseline energy models and EPC through ESCO respectively. Baseline energy models is always associated with problems on selection of the variables that affect the energy consumption for prediction purpose. EPC payback period from the achieved savings may create legal issues and bureaucracy on the terms and aggrement. Thus there are two main intention of this paper which is to investigate the variables that affecting energy consumption through single and multiple regression model and to calculate energy savings from ECM through awareness as an alternative to retrofitting old unefficient loads. Results show that multiple regression model have higher coefficient of determination value and from the ECM that have been conducted, it can be seen that energy savings through awareness programme is achievable. It is hoped that from this work, baseline energy models can be developed with the important variables for prediction purpose and awareness program can be implemented as an alternative for retrofitting program to achieve energy savings with hassle free of legal issues and bureaucracy.**

Index Terms— **energy conservation measures; awareness; baseline energy; energy savings.**

I. INTRODUCTION

ELECTIRCITY have made a huge impact for the modernization of the world. It is inarguably that electricity is crucial for human daily activities and best potraid in [1].

Electricity or in other words electrical energy comes from the rotation of synchronous generator. Generators are being rotated with the help of turbines as a prime mover coupled together by a shaft. Different turbine utilizes different resources such as oil, coal and gas. This resources are being called non-renewable as it is depleting in the earth core from time to time. Certain renewable sources like solar photovoltaic [2-4] and wind is now being quite famous to be implement as an alternative for consumer's electricity. As the resources is depleting and who knows maybe for another 100 years the non-renewable sources are nowhere to be found, certain counter measure have to take place. The purpose is no other than to preserve the non-renewable resources so that it will take a longer time to finish. By using energy efficiently, it is a basic step to minimize the utilization of electricity. It is however important to know basically on how to deal with managing energy effectively. By definition in [5] efficiency is a measure of the degree to produce the maximum amount of outputs from a given amount of inputs. Relating the definition in [5] with the concept of efficient usage of electrical energy, it can be clearly define that efficient electrical energy utilization is when the consumption of electrical energy is low but the desired output is at its maximum.

The achievement of efficient energy utilization, can be divided into two main energy conservation measures (ECM) steps by retrofitting old inefficient loads or through awareness program related to energy management [6]. An organization may retrofit old inefficient loads with new efficient loads. Executing this kind of ECM requires huge capital costs but it can be done with the support from Energy Service Company (ESCO). ESCO is a private organization that offers service to retrofit old inefficient loads with new efficient loads. Any buildings that requires retrofitting service for ECM purpose can hire ESCO where the owner of the building will not pay any upfront payment. ESCO will be paid back with the amount of energy that have been saved from the implementation. Through this exercise, both parties i.e. building owners and ESCO have to agree in mutual with Energy Performance

Ahmad Ihsan Mohd Yassin is with Centre of Computer Engineering Studies Faculty of Electrical Engineering Universiti Teknologi MARA (e-mail: ihsan.yassin@gmail.com).

Atiqah Hamizah Mohd Nordin is with Faculty of Electrical Engineering Universiti Teknologi MARA Johor Branch, Pasir Gudang Campus. (e-mail: atiqah.hamizah@gmail.com).

Contract (EPC) bonded for a certain payback period. Mutual agreement can only be achieve if both parties are able to negotiate the term and conditions with the help of third party lawyers. This ECM steps may be successful if less legal issues and bureaucracy on the terms and aggrement from both parties can be avoided. After EMC steps have been conducted, measurement and verification steps have to be implemented in order to ensure that the calculation of energy savings are being done in the correct manner. Serving this purpose International Performance Measurement and Verification Practise (IPMVP) [7] is a protocol that have been developed to standardized the energy avoided calculation based on four options. The options are provided to facilitate building owners on how to plan and strategize the ECM prior to energy saving are being calculated.

Four options available which is Option A, (retrofit isolation:Key measurement parameter) Option B, (Retrofit isolation: All parameter measurement) Option C (whole facility) and Option D (calibrated simulations). All options is related to electrical energy measurement where building's owner have their own choice on how to decide the ECM steps. Option A is related to loads that are connected separately from other loads and not sharing input source. This type of ECM is dedicated to measure energy consumption associated with lighting and motors. Option B caters for field measurement where it is similar to Option A but no estimated value. Option A requires sub-meters that have been solely dedicated to the loads in isolation. Option C meanwhile measures energy consumption for the whole facility that is associated with the ECM steps and Option D measures energy consumption by calibrated simulations. When any organization plan to implement ECM steps, it is crucial to note that on how to conduct the ECM. As being mentioned before, ECM can be implemented by retrofitting old unefficient loads or through awareness programme. Eventhough ESCO are readily to invest the capital for retrofitting through EPC, a lot of problems and risks are at stakes. As an example, ESCO might not operate the retrofitting and go for sub-contractors because ESCO main role can be seen only as a dealer. Argumentation between ESCO and building's owner is inevitable due to hanky panky dealing that took place between building's owner, ESCO and sub-contractors.

As an alternative of ECM steps through retrofitting, the second ECM steps can be achieved through awareness program. The idea is to create policies from top management and are being executed by lower authorities. This ECM steps can be implemented anytime and anywhere with less bureaucracy and legal issues but the cooperation of the whole staff in the organization have to be very strong because awareness program is depending on the behavior of human being. One may not be so cooperative if they think that the awareness programme is a waste of time. But as an alternative to the investment of huge capital cost and payback period, awareness programme can be seen as a suitable alternative for retrofit ECM steps. In addition, awareness program as an ECM steps is related to cost effective within specific time frame in the organization. Cost effective can be described as an objective that have to be fulfill with economical use of resources. Time frame is the period where the objective is achive within the stipulated time. When this two criteria are met, the organization can have a succesfull awareness ECM implementation.

II. EDUCATIONAL BUILDINGS AND BASELINE ENERGY MODELLING

Universities can be classified as an educational buildings that have a unique functions to serve its residents. Universities primarily are being occupied with students and staff. Different location of buildings within the university compound will have different purpose. Within a university area there are buildings that serves as accomodation, class rooms, laboratories, library, administrative offices, health centre and many more. In a clear picture, there are a lot of buildings in a university compound that will have different type of energy consumption depending on the purpose of the building itself. With the rapid growth of universities in the whole world, it is expected that the energy demand in academic sector will increase directly propotional with respect to its consumption. An ugly truth have to be expected where increase of energy usage lead to the increase of green house gas (GHG) emission [8] supported in [9] where buildings are the main consumer of electricity and consume up to 40% of the electricity generation. Clear evidence in [10] indicate energy usage in building sector will move from 60% to 90% from 2003 to 2050 if no necessary action are being taken.

The alarming increase of energy demand and consumption have been an issue where ECM steps have to be implemented to conserve non-renewable resources as it is almost depleting in the world. In Malaysian educational buildings, the implementation of IPMVP to calculate, measure and verify energy savings is still relatively new. Energy that have been avoided and saved after ECM have been conducted are calculated with the help of a good baseline energy models. Baseline energy model is a tool to examine and assess the difference when any changes are being made to the system [11]. Before ECM are being implemented, the energy consumption of the building have to be measured and recorded for a certain period of time. This will be the reference period or known as the baseline period of the energy consumption. The baseline period will be the reference period to predict the energy consumption in order to adjust the baseline energy model to be the same with before ECM are being implemented. The predicted baseline will be reffered as adjusted period. It is important to obtain the adjusted period in any ECM implementation due to the fact that the independent variables have a direct impact towards energy consumption in the particular buildings. After ECM have been implemented, the measured energy consumption will referred as reporting period. Thus proper saving can be calculated when adjusted period energy consumption are being subtracted with the reporting period. Baseline models is not limited to modelling energy consumption where it is also used in [12] for solar

irradiation and predicting customer's baseline loads [13-15] for demand response and peak time rebate program. Independent variables role will have a huge contribution in modelling the relationship of the energy comsumption where accuracy of the model is solely depeding on it. Author in [16-18] have conducted studies and analysis on baseline energy models development. There are several comparative studies on different method of baseline energy modelling in [16] have been conducted in a university campus in Portugal. Regression analysis depict weak model compared to neural network model. The possibilities of a weak model is maybe due to the redundancy of independent variables that is related to the energy consumption. Authors in [17] highlighted the relationshiop of occupancy, technologies in buildings with respect to the energy consumption and demand of educational buildings in University of Texas San Antonio. Positive correlation between energy consumption and weather have been clearly prooved with missing coefficient of determination R^2 where the R^2 value is vital to show the goodness of fit of the model. Multiple regression model in [18] have been conducted in a University's residence building in South Africa. It is used to model a calorifier for retrofitting purpose. The retrofit is successful in saving 90kWh energy consumption. Single regression model in [19] depicts that dry bulb temperature is an important independent variable for a hot and cold summer baseline energy model. Authors in [20] improved a baseline energy models in [21] with occupancy data in a commercial buildings to give a stronger model where baseline energy models in [21] only use weather as the independent variables.

In Malaysian educational buildings, an energy management program that lead to reducing energy consumption in Universiti Teknologi Malaysia Johor have been conducted in [6, 22]. In [6] energy conservation steps have been conducted in Faculty of Electrical Engineering and energy efficiency index (EEI) have been developed and act as its baseline model. Measurement of EEI is based on total energy used on the particular space. Similar energy conservation steps in [6] have been implmented in [22] are being spread to other faculties in the university area. One of the conservation steps in [6] mentioned that retroffiting old lighting is one of the energy conservation steps that have been taken and reported that it saved 50% of the energy consumption in [22]. There are no clear indication on how 50% and 90kWh energy saved in [22] and [18] respectively are being measured, verified and quantified. Several commercial buildings in Malaysia [9, 23, 24] demonstrate retrofitting as an ECM steps and adopted IPMVP to measure, verify and quantify energy savings.

Thus this paper have two main intentions. The first intention is to investigate the variable that affect the energy consumption through single and multiple regression model analysis. Additionally, energy consumption will be predicted and compared with the actual data. The second intention is to demonstrate an ECM steps through awareness program that have been conducted in one level of an educational buildings within a university compound to calculate energy savings that have been achieved. This paper will demonstrate in fullfilling certain gap and limitation in [6],[22] and [18] where energy savings will be measured, verified and quantified by adopting according to IPMVP procedures that have been done in [9, 23, 24]. Furhtermore awareness program will be conducted rather than implementing retrofitting in [9, 23, 24] as an alternative option for ECM implementation. Details of the, educational buildings, data collection and variables, energy saving measurement and verification procedures, awareness programme as an ECM steps and baseline models will be discuss in the methodology chapter.

III. METHODOLOGY

A good methodology summarised clearly the framework of the topic, experimentation that will be conducted and the analysis that will be implemented. Thus any deviation to achieve the desired objective can be avoided when a good methodology are being executed. The framework of the proposed methodology is being shown in Figure 1. In Figure 1, the first part of this work is the expertiment that will be conducted for a one whole educational building (FKE's Building) while the second part of this work will be conducted at one level of an educational building (4th level of the FKE's building).

The first part of the methodology will fullfill the first objective which is to investigate the correlation of the independent variables that contributes to energy consumption. The investigation will be further enhanced by performing a prediction for hourly energy consumption. Energy consumption and independent variables data will be collected during non-lecture week. Single and multiple linear regression model will be used to analyze the correlation of the independent variables with respect to the energy consumption and energy prediction will be executed from the result of the single and multiple regression model.

The second part of the methodology have been dedicated to satisfy the second objective which is to perform an ECM through awareness programme and calculating the energy saved through a baseline energy model. this Energy consumption will be recorded to create a baseline period. ECM through awareness program will be conducted and IPMVP procedures will be followed to calculate the energy that have been saved from the ECM that have been executed. Single or multiple regression model will be used to model the adjusted baseline during reporting period. Savings will be quantified by the amount of energy avoided during the reporting period of the adjusted baseline. In addition the intention of the second objectives is to show that the framework that have been done to achieve the first objective can be used to model and predict the adjusted baseline energy consumption after ECM have been implemented to calculate the absence of energy.

The experimentation will be conducted in an educational building for both of the objectives. Detailed of the proposed methodology in Figure 1 will be elaborated deeply in the subsection.
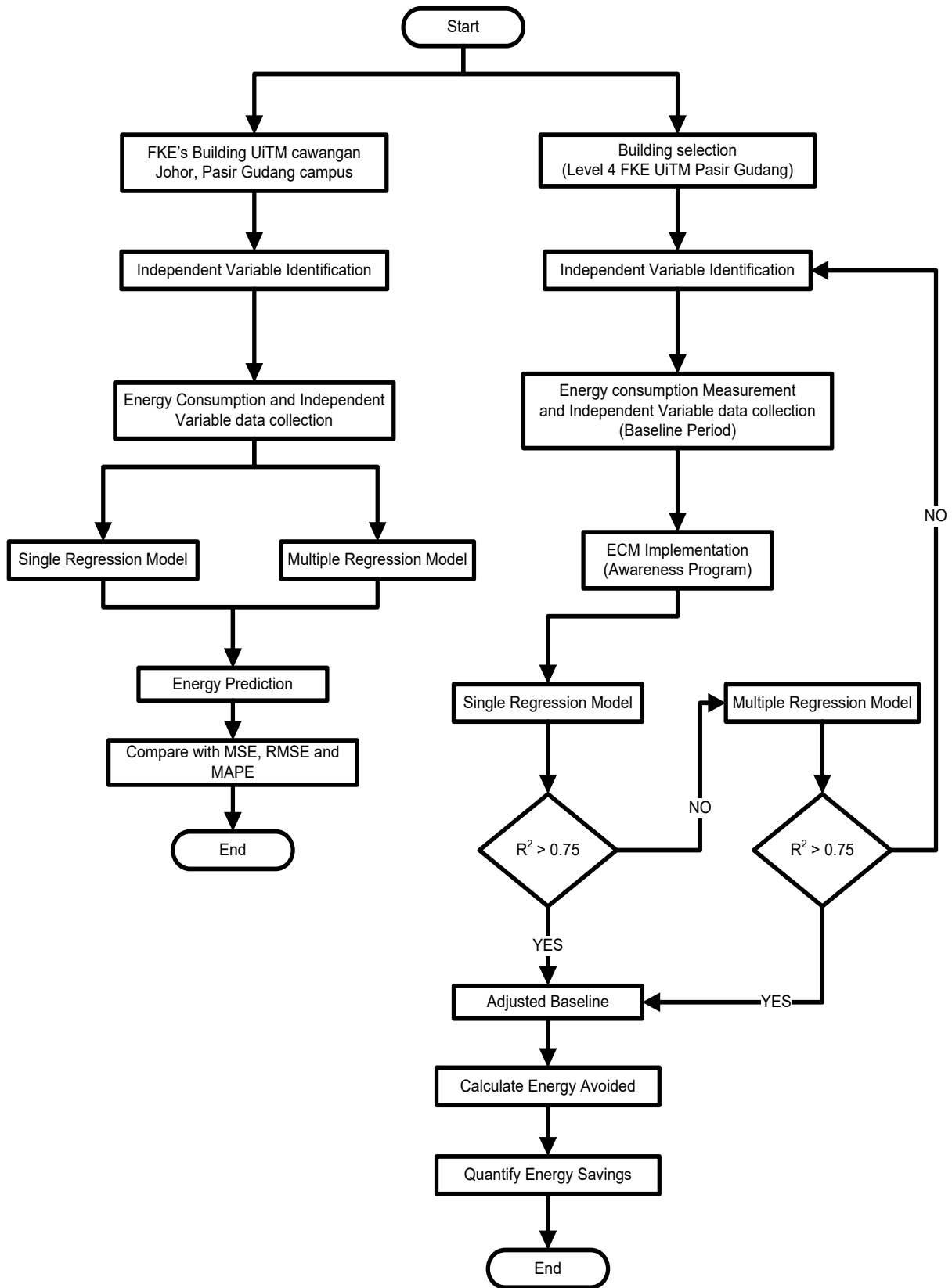
Figure 1: Framework of The Proposed Methodology

A. Academic Buidings

Due to the different characteristics, purposes and behaviour of buildings in a university compound, energy consumption will differ from one building to another. In Figure 1, the first part of this study will be conducted in the Faculty of Electrical Engineering (FKE) UiTM cawangan Johor, Pasir Gudang campus's building and the second part of the work will conducted at the 4th level of the FKE's building. FKE building consists of classrooms, laboratories, meeting rooms and staff rooms. The 4th level in the FKE's building will be used to conduct the experimentation procedures to achieve the second objective. The 4th level of the FKE's building consits of 16 lecturer's room and 4 computer laboratories. The lecturer's room contain 4 lighting points, 4 nos 13A switch socket outlets and one split unit air conditioner. All 4 computer laboratories have a centralized chiller except for assistant engineer's room where the air conditioner is a split unit.

B. Data Collection and Variables Selection

Occupancy of staff and outside temperature will be used as the independent variables for FKE's building. The 4th level of the FKE's building where ECM will be implemented shares the same independent variables.

The reason to choose occupancy and outside temperature independent variables of FKE's buildings is because this work is being conducted during non-lecture period. Due to the non-lecture period, the building's behavior is similar to office buildings where the routine is the same with normal working office hour. During non-lecture period, Staff's occupancy in FKE's building during the work is being conducted will be based on the time stamp record. Fluke 1750 will be used to record the energy cosnsumption and is being captured at 30 minutes interval. For the first objective and second objective, the energy consumption will be measured for the whole FKE's building at the 4th level respectively.

The energy consumption in the 4th level will be measured for two weeks period. The first week is the baseline period and the second week is the reporting period. The 4th level building during the measurement period act like an office building during the two weeks period because the level is occupied by lecturers and internship students.

Staff occupancy will be collected based on the time stamp of the particular day and will be assume available during office hour.Only staff that have a record of arrival and leave time will be considered available. The occupancy of the internship students for the second objective will be based on attendance recorded on the attendace sheet. The internship students occupied one computer laboratory as their work station during office hour.

Outside temperature were collected based on the recorded outside temperature in www.weatherunderground.com from the nearest satellite station Elev 14 m 1.42 °N, 103.87 °E of the building location. The first objective outside temperature is based on the recorded data while the second objective's outside temperature is based on historical data. Certain unavailable outside temperature data for the second's objective from 01:00 until 07:00 will be assumed.

C. Single and Multiple Regression Model and Analysis

The correlation of the independent variables with respect to its energy consumption have to be explore where it is important to show that the independent variables is the factor that influence the energy consumption in the respective buildings. To serve the purpose single and multiple regression model will be used where the energy consumption and the respective independent variables will be fed into the model.

For the first objective, FKE's building consist of 384 hourly energy consumption and independent variables data from 16th March 2017 until 31st March 2017. 120 hourly data points from 16th March 2017 until 20th March 2017 will be used as testing data and the remaining 264 data will be used as a training data from 21st March 2017 until 31st March 2017.The separation of data for training and testing to ensure that the energy prediction is not biased and is being compared to a different set of data.

Second objective baseline consumption will have a total of 120 hourly data point. The 120 hourly data point starts from 5th June 2017 untill 11th June 2017. The reporting period will consist of 87 hourly data point 12th June 2017 untill 15th June 2017. The 120 hourly data point will be fed into single and multiple regression model. The adjusted baseline will be predicted based on the results of single and multiple regression R^2 and the remaining 87 hourly independent variables data point will be used to predict the energy consumption.

D. Energy Prediction in FKE's Building

Hourly energy consumption will be predict for the whole FKE's building based on hourly interval prediction data. As being suggested in [25] typical electrical energy interval data is from 15 minutes to 1 hour. Hourly energy prediction will be made in two different situation.

The first situation is energy prediction with the combination of workdays, weekends and public holiday. The second situation is energy prediction that only consist of workdays. The separation from weekend and public holiday from the first situation is because during weekend and public holidays there are no high usage of electrical energy and very low compared to workdays where no occupancy at the office buildings.

The prediction horizon (energy consumption) will be compared with the actual measured energy consumption. The error of the prediction will be calculated with statistical Mean Squared Error (MSE), Root Mean Square Error (RMSE) and Mean Absolute Percentage Error (MAPE). All of the equation are being shown in (1), (2) and (3) respectively. In (1) and (2) Y_i is the predicted value and y_i is the actual value. In (3), A_t is the actual value while F_t is the forecasted value.

$$MSE = \frac{1}{n}\sum_{i=1}^{n}(Y_i - y_i)^2 \qquad (1)$$

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(Yi-yi)^2}{n}} \qquad (2)$$

$$MAPE = \frac{100}{n}\sum_{t=1}^{n}\left|\frac{A_t-F_t}{A_t}\right| \qquad (3)$$

E. Energy Savings Measurement and Verification Procedures

Energy savings measurement and verification is being calculated through several procedures based on IPMVP. Energy avoidance are being calculated by using equation (4)

$$Energy\ Savings = (AC - RC) \pm AP \qquad (4)$$

In Equation (1) AC, RC and AP is the adjusted consumption, reporting consumption and abslolute precision respectively. The adjusted consumption can be modelled with linear single regression model and multiple regression model. In modelling the adjusted consumption, the regression model error have to be taken into considerations. The standard error σ are calculated by using the formula in (5).

$$\sigma = \sqrt{\frac{\Sigma(Y-Y_i)^2}{N}} \qquad (5)$$

where Y is the actual data and Yi is the predicted data. N is the total number of data. The standard error have to be multiplied with the total number of reporting period which give the total standard error of the whole reporting in (6)

$$Standard\ Error_{(total)} = \sqrt{N_{RP}} \times \sigma$$
(6)

where N_{RP} is the number of data during the reporting period. Obtaining the value of absolute precision (AP) to calculate the saving is given in (7).

$$AP = t \times Standard\ Error_{(total)}$$
(7)

t is the t-value that can be obtain in the T-table. The t-value are being determined by the degree of freedom (DF) in (8)

$$DF = N - p - 1 \qquad (8)$$

where N is the total number of data and p is the total number of variables used for the regression model.

F. Awareness Programs as an ECM Steps

The ECM steps that will be implement is an awareness program that have been planned among staff that occupied the 4th level of FKE's building. Only one level were chosen in the FKE's building is because awareness programme is a programme that requires good cooperation from the participated staff. In order to conduct a good awareness programme, it is best to start at a small scale basis. After it is

successfully implemented, the awareness can be spread to other level in the FKE's building. The awareness programme that have been conducted in the 4th level are:

- Do not use any lighting during daylight in office room. Minimum one lighting.
- Minimum split unit air conditioner temperature at 23^0C
- Unplugged all socket outlet loads when not in use.
- Corridor lighting are being switched off. Only use minimum three ligthing points.
- All toilets lighting and exhaust fan are being switched off when not in use.

IV. RESULTS AND DISCUSSIONS

The results of this this work will be explained in two different section. Section A will discussed in detail the energy prediction performed in the FKE's building. It will covers the analysis results from the single and multiple regression model. In the single and multiple regression analysis, the results will discussed the coefficient of determination of the single and multiple regression models (R^2). Furthermore the hourly energy prediction statistical error calculation will be elaborate in terms of comparison between the statistical measurement in terms of MSE, RMSE and MAPE

Section B discussed the ECM that have been implemented in at the 4th level of the FKE's building. Single and multiple regression R^2 result will be compared and the highest value will be chosen to predict the adjusted baseline consumption. Futher discussion will be concentrated on the baseline energy model that have been predicted with conjuction of the IPMVP procedures to calculate the energy savings.

A. Energy Prediction in FKE's Building

This section contain two subsection where the first subsection will discussed the interrelation between independent variables and the energy consumption. The second subsection will demonstrate the energy prediction that have been done using single and multiple regression model.

I. Single Regression and Multiple Regression Analysis

Independent variables correlation with respect to the energy consumption by using single regression and multiple regression model for FKE's building are being shown in Figure 2 – Figure 3 and Table I respectively.

The single regression model correlation results for FKE's building in Figure 2, revealed that the R^2 value is 0.80249 for the correlation between energy consumption and occupancy. In Figure 3, the R^2 of the correlation between energy consumption is 0.46744. Clear indication of R^2 signify that occupancy of staff in FKE's building is have a direct impact towards the energy consumption of the building where by outside temperature have a moderate impact towards the energy consumption of the building. The results strengthen that occupancy of staff in FKE's building is a crucial

independent variable to be included for the energy prediction purpose. Multiple regression analysis in Table I for FKE's building have R^2 value of 0.86085. The increase value of R^2 when outside temperature and occupancy are being combined manifested that the combination of the independent variables is highly corollated with the energy consumption.

Based on the single regression model R^2 resutls, hourly energy consumption will be predict using the equation of staff occupancy for FKE's building. Occupancy's equation are being selected because the R^2 value is higher than the outside temperature and is significantly high for a single regression model. The results from the multiple regression analysis will also be used to predict the hourly consumption for FKE's building. The multiple regression model will include all the variables associated with FKE's building.

II. Hourly Energy Consumption Prediction

Figure 4 – Figure 5 shows the hourly energy consumption that have been predicted using the occupancy's single regression equation. Figure 4 is the hourly predicted energy consumption inclusive of weekends and public holidays. The energy predicted have been compared with the actual energy consumption data. Flat peak energy is clear evident that the prediction does not resemble the peak energy consumption of the actual value. Identical results is present in Figure 5 where weekends and public holidays from 24th March 2017 – 25th March 2017 and 31st March 2017 have been deducted from the prediction horizon. Multiple regression model yields regression for FKE's building which is being shown in Equation (9).

$$y = 1.6850x_1 + 4.3032x_2 - 97.476 \qquad (9)$$

In Equation (9) x_1 and x_2 is the occupancy and outside temperature independent variables respectively. The equation have been used to predict the hourly energy consumption for FKE's building and is being shown in Figure 6 – Figure 7. The hourly energy prediction are being compared with the actual value and similarity of shape is presence. Energy prediction in Figure 6 is a prediction that include weekends and public holidays. From 24th March 2017 – 25th March 2017 and 31st March 2017 are being predicted based on temperature values and occupancy value. It indicate that the prediction of the energy have to include both data. To exhibit continuity of the energy prediction the weekends and public holidays 23rd March 2017 – 25th March 2017 and 31st March 2017 are being removed and is depicted in Figure 7. In Figure 7, the energy consumption is almost identical and resembles one another. Furthermore in Figure 6 and Figure 7, there are no more flat peak prediction thus there is a solid proof that the outside temperature is the independent variable that help to increase the energy prediction to become similar with the actual energy consumption.

Table II – Table III shows the comparison of MSE, RMSE and MAPE for the hourly energy prediction using single regression model and multiple regression model respectively. In Table III, smaller value for MSE and RMSE is presence

with prediction inclusive of weekend and public holiday compared to prediction without weeknends and public holiday. MAPE indicate that the value that have a minor difference due to the possibilities of R^2 value that is almost the same.

In Table III, multiple regression hourly energy consumption prediction exhibit smaller value of error compared to single regression energy consumption prediction. The combination of occupancy and outside temperature clearly produce a lower error measurement for hourly energy prediction. Energy prediction inclusive of weekends and public holidays, shows a smaller error value with energy prediction excluding weekends and public holidays. Eventhough the error is small but the main prediction with public holiday and weekends may introduce certain risk of where the prediction is not accurate in terms of the utilization of electrical loads during the respective weekends and public holidays.
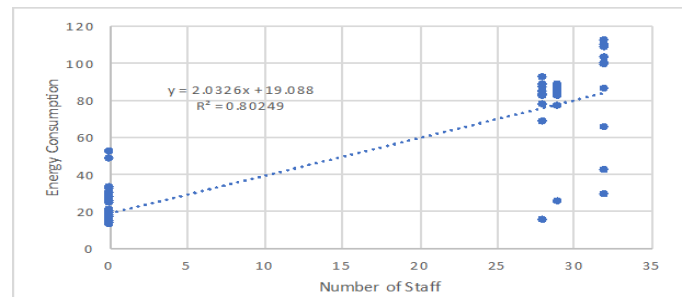

Figure 2: Correlation between Energy Consumption and Occupancy FKE's Building
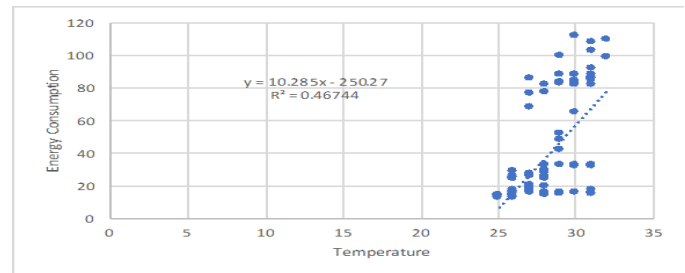

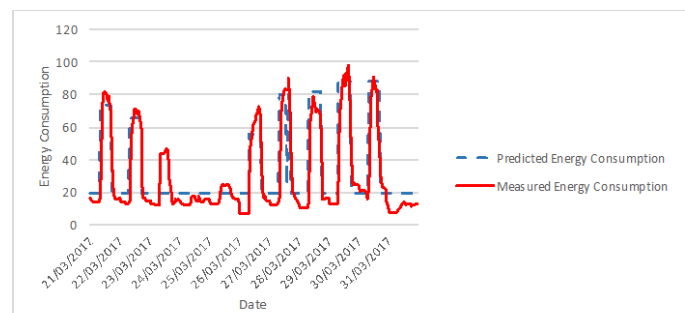Figure 3: Correlation between Energy Consumption and Temperature FKE's Building

Figure 4: Hourly Energy Consumption Prediction inclusive weekends and public holidays(single regression model)
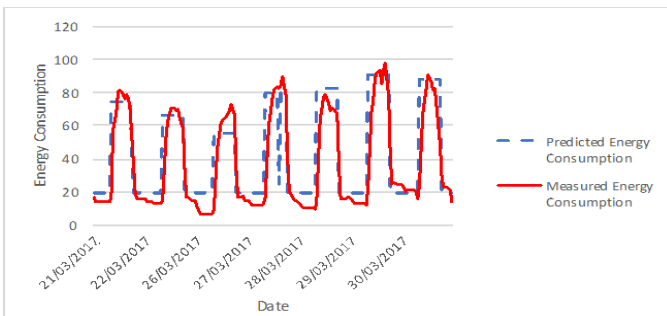
Figure 5: Hourly Energy Consumption withoud weekends and public holidays (single regression model)

TABLE I
MULTIPLE REGRESSION ANALYSIS FOR FKE'S BUILDING

Regression Statistics – FKE's Building	
Multiple R	0.92782
R Square	0.86085
Adjusted R Square	0.85848
Standard Error	11.1840
Observations	120

TABLE II
COMPARISON OF MSE, RMSE AND MAPE OF THE HOURLY
ENERGY PREDICTION SINGLE REGRESSION

Error Measurement	Enery Prediction (with weekend and public holiday)	Energy Prediction (without weekend and public holiday)
MSE	189.0746	249.0568
RMSE	13.75044	15.78153
MAPE	48.01309	48.062

TABLE III
COMPARISON OF MSE, RMSE AND MAPE OF THE HOURLY
ENERGY PREDICTION MULTIPLE REGRESSION

Error Measurement	Energy Prediction (with weekend and public holiday)	FKE's Baseline Energy Model (without weekends and public holiday)
MSE	96.7132	134.6147
RMSE	9.8343	11.6024
MAPE	29.9545	32.5403

B. ECM Through Awareness Program

The results of this section will be explained in two parts. The first part will discussed the single and multiple regression model analysis. The baseline energy models and energy that have been saved from the ECM implementation will be discussed in the second part. In the single and multiple regression analysis, the results discussed the statistical analysis and the coefficient of determination of the single and multiple regression models (R^2). The main purpose is to select which regression model will be used to predict the adjusted consumption of the baseline energy model. The best value of R^2 from the comparison of the regression analysis will be used to model and predict the adjusted baseline energy consumption. The second part of the results will discussed the calculated energy savings after the adjusted baseline energy consumption have been predicted and modelled.

I. Single Regression and Multiple Regression Analysis

Single regression analysis details are being shown in Figure 8 and Figure 9. Figure 8 and Figure 9 shows the correlation plot between energy consumption versus occupancy and energy consumption versus outside temperature respectively. The value of R^2 for energy consumption versus occupancy plot is 0.61316 and yields linear equation (11) and is shown in Figure 14.

$$y = 0.3113x + 4.561 \qquad (11)$$

While the value of R^2 for energy consumption versus outside temperature plot is 0.65685 and yiedls linear equation (12) and is shown in Figure 15

$$y = 1.4866x - 36.886 \qquad (12)$$

The multiple regression analysis results is being shown in Table IV. The value of R^2 for multiple regression is 0.7338. The observation is 120 hourly data points. The observation is the same with linear regression analysis. Table II shows the multiple regression linear equation parameters. From the value in Table V yields the linear multiple regression equation (8)

$$y = 0.1623x_1 + 0.9374x_2 - 22.0088 \qquad (8)$$

where x_1 is the occupancy and x_2 is the temperature variables respectively.

Based on the value of R^2 from all the regression model, it is obvious that multiple regression have a higher R^2 value. This is because that outside temperature is the factor that will affect the behavior of occupancy in the buildings. Futhermore in [26] demonstrate that occupancy and outside temperature have to be modelled together as an independent variable in order to provide strong model. This is due to the fact that the main contribution of the energy consumption came from the occupied staff in the building but outside temperature is the main factor of high utilization of air conditioner because the weather recorded is quite high. Eventhough the R^2 of multiple regression model is not above 0.75 but is higher than both of the R^2 result of the single regression value. Thus the baseline energy will utilize the multiple regression to model and predicted the adjusted consumption during the reporting period.
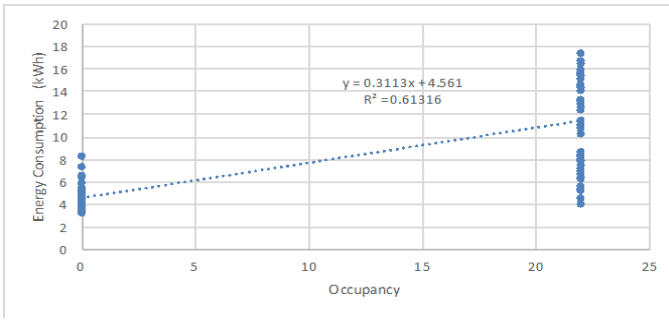
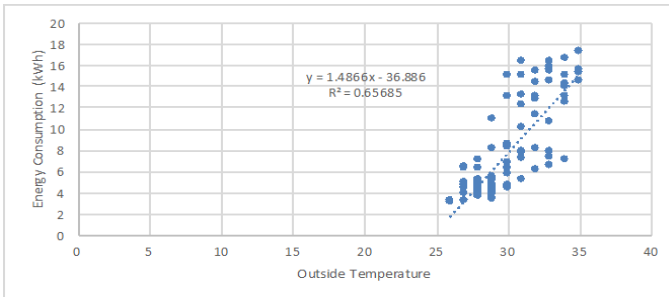Figure 8: Correlation between Energy Consumption and Occupancy

Figure 9: Correlation between Energy Consumption

TABLE IV
MULTIPLE REGRESSION ANALYSIS STATISTICS

Regression Statistics	
Multiple R	0.8566
R Square	0.7338
Adjusted R Square	0.7293
Standard Error	2.25
Observations	120

TABLE V
MULTIPLE REGRESSION LINEAR EQUATION PARAMETERS

Linear Multiple Regression Parameters	
Intercept	-22.0088
Occupancy	0.1623
Temperature	0.9374

II. Baseline Energy Model and Energy Savings

The developed baseline energy model are being shown in Figure 7. The baseline period start from 5th June 2017 until 12th June 2017. ECM was implemented at the beginning of 12th June 2017 untill 15th June 2017 and will be the reporting period of the baseline energy model. During 12th June 2017 untill 15th June 2017 the adjusted energy consumption are being shown with the measured energy consumption during the ECM implementation. Figure 8 shows the bigger picture of the reporting period during the ECM.

In Figure 8 the adjusted energy consumption are being predicted with all the occupancies and outside temperature variables that are being inserted in equation (8). In order to get the best savings, the adjusted energy consumption must be higher than the measured energy consumption during the reporting period. In Figure 8, there are certain differences exist between predicted and measured energy consumption. From 12th June 2017 up until 14th June 2017, the adjusted

consumption is higher compared to the measured consumption. But on certain parts, there are minuscule presence of the adjusted consumption were lower than the measured consumption. From 14th June 2017 until 15th June 2017, obvious lower adjusted energy consumption compared to measured energy consumption were presence. The total of the hourly energy data consumption is 87 data points.

In order to calculate the energy savings, equation (1) – (5) will be use for the purpose. The total energy consumption difference between adjusted energy consumption and measured energy consumption is 67.84kWh. The standard error σ of the multiple regression are being obtain from Table I which is 2.25. All the 87 energy consumption data point have to be multiplied with the root of the standard error as in equation (3) and will give the total standard error value of 20.986kWh. The absolute precision is being calculated with the value of total standard error are being multiplied with the t-value. From t-table, the t value for a degree of freedom of 117 calculated using equation (5) give the value of 1.98 at 95% confidence level. With the multiplication of the total standard error with the t-value, the value of the absolute precision is 41.55kWh. Thus the proper savings for the ECM during the reporting period is 67.84kWh $\pm$ 41.55kWh.

V. CONCLUSION

This paper have two main intention to achieve. The first intention is to investigate the correlation of the independent variables with respect to energy consumption. The second intention is implementing ECM through awareness program oppose to retrofitting old inefficient loads. Both intention have successfully achieved where in the first objective the value of R^2 for single regression shows that occupancy is highly correlated with the energy consumption. Combination of both occupancy and outside temperature increases the R^2 value for multiple regression model. It creates clear indication that outside temperature is the independent variables that can increase the goodness of fit of the regression model. Hourly energy consumption have been predicted using single regression and multiple regression model which suggest multiple regression model is in favor due to low statistical error measurement. Energy that have been saved with the implementation of ECM through awareness program have been measured and verified based on IPMVP steps and procedures. Baseline energy model have been developed to model the adjusted consumption using linear multiple regression model. Based on the adjusted consumption (prediction), there are proof that awareness program is able to achieve certain energy savings. Replication of the data can be made to perform a non-linear modelling method to give a better and accurate modelling because certain part of the baseline models have a non-linear relationship between the independent variables and the energy consumption.
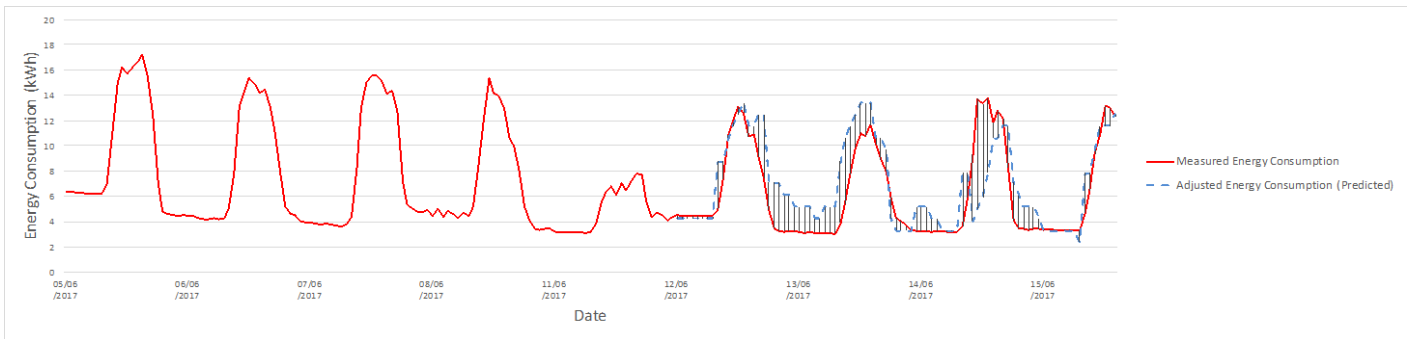
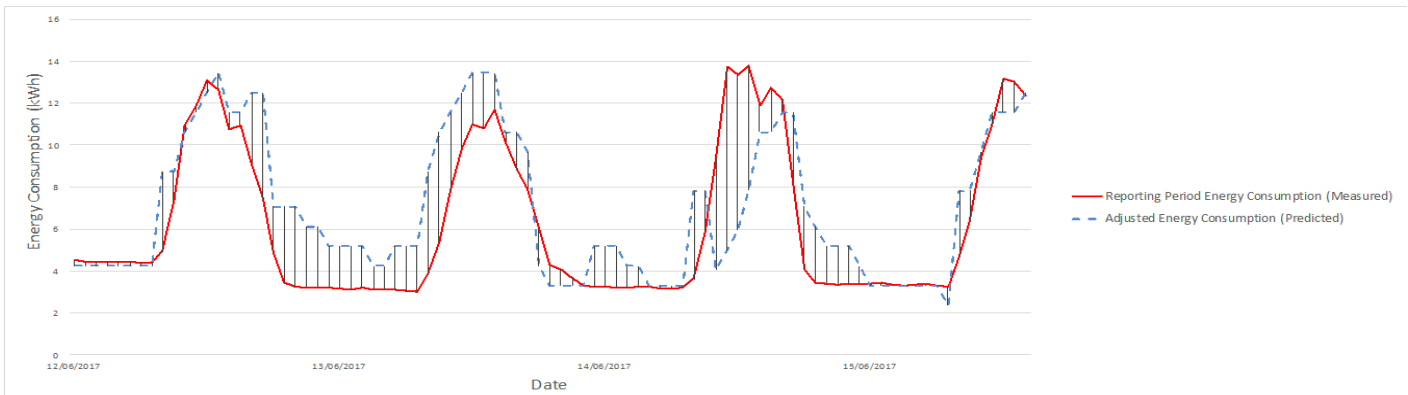Figure 7: Baseline Energy Model for FKE Building (multiple regression)

Figure 8: Baseline Energy Model for FKE Building (multiple regression)

VI.   ACKNOWLEDGMENT

VII.   REFERENCES

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Rijalul Fahmi Mustapa is a lecturer in Faculty of Electrical Engineering Universiti Teknologi MARA Johor Branch Pasir Gudang Campus. He received his Msc in Electical Engineering from Universiti Teknologi MARA Malaysia. He is currently pursuing his PhD studies in the field of power and energy modelling and prediction for measurement and verification purposes. His main research interest is in the field of electrical power quality, energy modelling and prediction.

Nofri Yenita Dahlan is the Head of Department for Center for Electrical Power Studies (CEPES) Faculty of Electrical Engineering Universiti Teknologi MARA Malaysia Selangor. She received her PhD from University of Manchester. She is an associate professor in the Faculty of Electrical Engineering. Her main research interest is energy management, planning, measurement and verification. She is a certified trainer for professional measurement and verification workshop

Ahmad Ihsan Mohd Yassin is a senior lecturer in Center for Computer Engineering Studies (CCES) Faculty of Electrical Engineering Universiti Teknologi MARA Malaysia. He received his PhD from Universiti Teknologi MARA Malaysia. His main research interest is artificial intelligence, optimization computing and signal processing He has conduct various of artificial intelligence and optimization workshop.

Atiqah Hamizah Mohd Nordin is the is a lecturer in Faculty of Electrical Engineering Universiti Teknologi MARA. cawangan Johor kampus Pasir Gudang. She received her Msc from Universiti Teknologi MARA Malaysia. Her main research interests is solar photovoltaic modelling and simulation. She is currently doing her PhD in the field of solar pv module irradiance prediction.