Electrical Energy Conservation for Educational Organization Using Solar Rooftop and LED Lighting Replacing

Jassada Sarasook

Abstract— *This research presents electrical energy conservation for an educational organization. The research starts by studying the general situation of electricity consumption in the workplace. This brings suitable policies including solar rooftop installation and LED lighting replacing. The case study location is a college of Nakhon Phanom University in the northeast of Thailand where a 250 kVA transformer is installed. The research period is finished for three years. The general electrical consumption was studied in the first year. Then, the policies of conservation-related solar rooftop and LED lighting were selected. Solar rooftop installation was implemented in the second year. All conventional lighting was replaced by LED lighting one year later. According to survey findings, the expenses can be classified into 4 types including electricity, water, internet, and phone. Moreover, the college expense for electricity was the highest approximately 86%. The electrical loads included air conditioner 59%, lighting 26%, computer 10%, and other approximately 5%. Polycrystalline silicon type of10.2 kW solar rooftop capacity was used. The results show that the policy of solar rooftop reduced the electricity cost by about 13.32% with 6.17 years payback period. In the third year, the LED replacing policy reduced the electricity bill by about 21.86% with 3.46 years payback period. After two policies performed, electricity cost reduced by 32.27% or about 9034 $ a year with 4.58 years payback period.*

Keywords— **Energy conservation, solar rooftop, LED lamp, electrical system, lighting system.**

1. INTRODUCTION

Nowadays, the world is forced into age of disruptive development. Technology is improved extremely running every section of societies [1]. For example, walking street supermarket becomes online market [2], class learning is improved into e-learning [3], engine vehicles are instead by electrical vehicles [4] and smart technology is applied in many sections [5][6][7]. However, they present one thing the same that is electrical energy needed for these developments. Other reasons why electricity more demands are easy transferring to another energy outstanding, inconvenient distribution and etc. [8]. According to Global Statistical Yearbook in the section of world power consumption, it reveals that average of electricity consumption was increased high rapidly. The world electricity consumption was 11,129 TWh in 1990 and it grew up to 20,568 TWh or about 84.81% in 2015 [9]. Especially, Asia countries group has the most consumed electricity since 2007 to 2015. The next have been America and Europe respectively [10]. For Thailand, according to oil and electricity situation in 2019 [11], it is found that electricity consumption is increased 3.4% when compares with the same period of prior year. Moreover since 2016 to 2018, electricity consumption increases continuously. However, main source to generate electricity is fossil energy source [12]. According to [13], in 2017, it reveals that sources of electricity generation included coal about 38.5%, natural gas 23%, nuclear at 10.3%, oil 3.3% while proportion of green energy sources just 15.9% from hydro energy and 9.0% from renewable energy. It is investigated that fossil sources are actually very high. Notice, they are waste energy hence if they are used more without another sources and conservation policies, the world will face on global energy crisis coming soon [12][14][15]. In addition, it is clear that weak point of conventional fossil energy source is CO_2 emission [16]. It brings global warming harmfully. According to [17], amount of CO_2 has increased threateningly. The ways to solve issue are effective energy consumption and looking for alternative energy source; renewable energy [18]. Therefore, many countries realize energy conservation and renewable energy [19], also Thailand.

Thailand, a country by Ministry of Energy has declared Energy Conservation Act since 1992 [20]. The designed buildings and factories have to perform energy conservation and the ways of electrical energy conservation are introduced in [21]. Lighting system is a main load in buildings and factories. Many energy conservations in lighting system are presented by many researches [22][23][24][25]. Building Energy Management System (BMS) for electrical energy conservation in lighting and air conditioning system was proposed [23]. It shows energy consumption reduced at 14.31%. Moreover, BMS was used for central chiller system. It can save energy at 9.1% [24]. By the way, intelligent and efficient light control by detecting light intensity and motion was presented in [25] which this could save energy approximately 50%. Sensors also become important in lighting control for energy conservation which they always are developed for example in [26] and [27]. Furthermore, low energy device; LED lamps are more developed. LED lamps are spread applied because of high efficiency. LED lamp is

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more efficient than florescent because not loss on side of lamp. Besides that, LED needs lower power and life time is longer [28]. Moreover, replacing of 6 W LED lamps instead 13 W complex fluorescent and 40 W incandescent could save electricity cost with 1.5 years payback period [29]. In [30], LED lamps were replaced instead of high pressure sodium and mercury for street lighting. This saved energy more than 50%. Another outstanding point of LED is light diming [31]. LED diming integrated with natural daylight for electrical energy conservation is presented in [31][32]. Because of low energy consumption, LED lamp still is used for speedy plant growth also [33]. Therefore, LED lamps technology is interested for energy conservation.

Another way to solve future energy crisis and save environment is renewable energy. An interesting renewable energy is solar energy [34][35]. Because Thailand located in tropical regions, there is high level of solar radiation [36]. PV solar cell becomes important tool for applying solar energy which transferred to electricity. According to Thailand Power Development Plan 2018 [37], the goal of solar cell energy is approximately 10,000 MW while it could generate just 2,697.26 MW in 2017 [38]. Therefore, Thai government promotes home-use solar panels [39]. Recently, the cost of solar cell is cheaper than the past [40]. Moreover, it is less impact environment also therefore many communities accept [41]. By these reasons, several factories and organization install solar rooftop for energy conservation and self-energy generating [42][43][44]. In [45], solar rooftop used in a college, it could save electricity cost with 6.7 years payback period. Also in [46], educational building conservation, it could save the bill about 46.79% with 5 years payback period. The conservation of office building using solar cell is presented in [47] which this conserved 45% of electricity consumption with 12 years payback period. From simulation of conservation by solar rooftop presented in [48], this saved electricity cost with less than 10 years payback period. Therefore, it can be said that solar rooftop can reduce electricity bill.

That all the reason why this research presented electrical energy conservation using solar rooftop and LED lighting replacing is important. Case study performs in educational organization, a campus of Nakhon Phanom university where located in north east of Thailand. The research period includes three years. The first year, data of electricity consumption is gotten. Second year, solar rooftop is installed and studied. Third year, all conventional lighting system is replaced by LED lightings completely. Finally, the electricity bill along three years is analyzed.

2. METHODOLOGY

Target Area

The case study area is educational organization, a college, campus of Nakhon Phanom University, Thailand. The location, as shown in Fig.1, refers to latitude 17.6119524 and longitude 104.1294629 [49]. This area covers 40,000 m^2 (9.88 acre). The area receives an average of 8 sunshine-hours per day. The location is near equator which provides uniform solar intensity throughout a year. Average radiation is approximately 18.0 MJ/m^2-day or 5 kWh/m^2-day (1825 kWh/m^2-year) [50]. An average temperature along yearly period is 26.1 ºC. The average lowest temperature is 21.8 ºC while average highest temperature is 31.8 ºC [51]. A transformer 250 kVA is installed in area. There are 7 buildings including four factory shop classes, a four floors building, a two floors building and finally a gym building. The four factory shop classes are used only 5 day working a week. A four floors building and two floors building are used 7 days a week. Finally a gym building is used 7 day especially in evening; 5:00 p.m. – 9:00 p.m. Another building is used 5:00 am - 7:00 p.m. a day. The lighting system outside buildings is turned on 6:00 p.m.-6:00 am every day also street lights.

Fig. 1. Target Area.

Test Procedure

The research focuses on electrical energy conservation by two policies including solar rooftop installation and LED lamps replacing. It had been success in three years (36 months); since October 2015 to September 2018. The time is separated into three periods as shown in Fig.2. Monthly electricity bills were collected for three years. The bills are in unit of Bath but in this research it is transferred to US Dollar ($) by the rate at 1 US Dollar : 31.45 Bath. The first period (12 months), it is study of electricity consumption situation of organization. Amount of electrical loads were investigated also. All data of prior performance was analyzed to plan for policies. Solar rooftop had been installed at the end of a year. After installation, electricity bills of next 12 months were gotten again to analyze the result of solar rooftop policy. Solar rooftop was placed on two floors building. It had not storage battery. Therefore, it can distribute just only on daytime integrated electricity seller, PEA (Provincial Electricity Authority) which is regional seller organization of Thailand. In night, organization buys electricity form PEA absolutely. For last period (last 12 months), all conventional lightings were replaced by LED lightings. The result of electrical energy conservation was observed from electricity bills. The research analysis was done by information of real situation when organization running. Economic analysis was performed from data at that time.

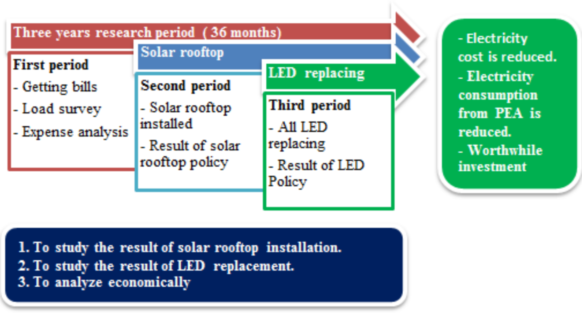


Fig.2. Research Frame.

Utility Expense Analysis

On October 2015, energy conservation project was conducted, the monthly utility costs were collected by each monthly bills including phone, water, electricity and internet cost. Overall, it is found that total cost is the highest on September while it is the lowest on May as shown in Fig. 3. Moreover, total cost varies on the cost of electricity clearly. While other expenses; phone, water and internet are very lower than once. Moreover, they are quite constant. Clearly, the main expense is electricity cost. Therefore, if organization would like to reduce monthly cost of utility, the electrical energy conservation should be focused.

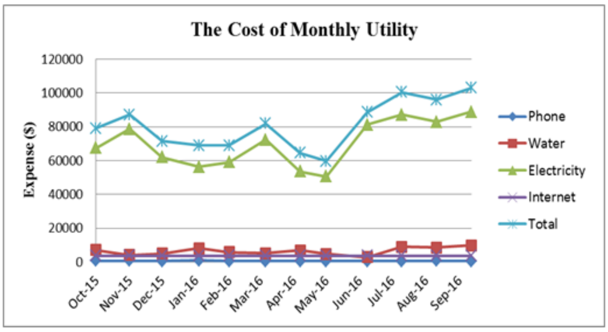


Fig.3. Monthly Expense for Utility

From information in Fig.3, total costs are plotted in Fig.4. It is noticed that the main cost along a year is electricity cost.

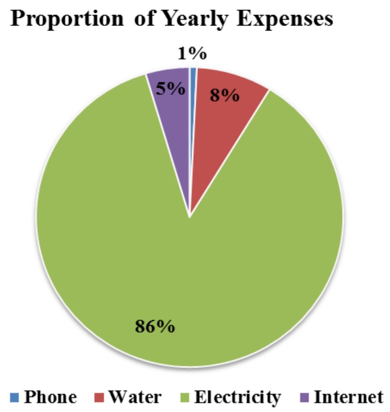


Fig.4. Expenses along Yearly Period in 2015.

The data reveals that the most expense is electricity about 86%. It is obviously much higher than other costs. The next is water expense approximately 8%. And then, internet and phone expenses are 5% and 1% of total yearly cost respectively. Interestingly, the best way possibly to save utility expense is electricity reduction. Therefore, loads survey starts in order to find suitable policy. Initially, it is known that this organization runs only on daytime while on night just only lighting system. However, all loads have to survey certainly.

Electricity Consumption Analysis

Table 1, it shows all loads in investigated organization. The most energy consumption occurs by air conditioner loads about 128322 W or 59%. The next is lighting at 55738W or 26%. The next three loads are computer, electrical kettle and fan at 10%, 3% and 2%. The lowest load is refrigerator which is less than 1%. Table 1 shows maximum load is 217566 W so the power installation of solar cell should cover all loads power. At performance ratio (PR) at 0.7, the solar cell power should be approximately 310 kW. However, installation solar power depends on budget. This research can install just 10.2 kW because of budget limitation.

Table 1. All Loads in Investigated Electrical Loads

Lists of Loads	Power
Air Conditioner	128322
Lighting*	55738
Computer	21482
Electrical Kettle	6000
Refrigerator	598
Electrical Fan	5424
Total	**217564**

* Neglected ballast loss

Fig. 5 shows proportion of electrical loads. All loads can be classified by operating time into two types, on daytime and nighttime. The daytime loads are all loads but nighttime electrical loads are lighting and refrigerator. However, refrigerator is very low while lighting is much more than one. Therefore, selected energy conservation ways correspondent with consumption situation are solar cell and LED lighting.

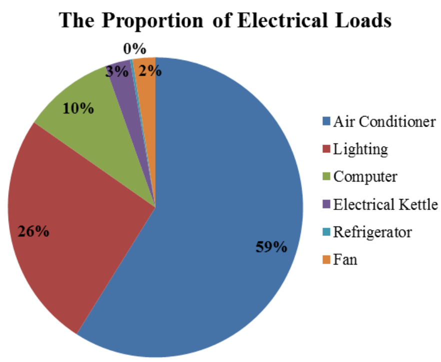


Fig.5. Proportion of All Electrical Loads

Considering solar rooftop, it is installed on the roof which far from shading effect and it is not worry about floating. Furthermore, solar cell generally generates electricity on daytime. This is correspondent to electricity consumption of organization which mostly is high on daytime also. This policy is suitable for energy conservation in daytime. However some organization cannot install full loads capacity completely covering all loads because it needs spend a high budget. Another choice, a system can replace just partial loads capacity limited by investment cost. By this way, the cost of investment can limit while electricity cost still reduces. For nighttime, a main is lighting. Initially, there were conventional lamps, fluorescent, compact fluorescent and high pressure mercury. They can be replaced by LED lighting. However, lighting loads should be surveyed scrupulously and carefully designed. All lighting loads show in table 2. Overall, the total lighting power is 55738 W.

Table 2. Lighting Loads (Neglect Ballast Loss)

Lists of Lighting Loads	Power
36W fluorescents	50508
18W fluorescents	450
400 W high pressure mercury	4000
20W compact fluorescent	780
Total	**55738**

The highest load is 36W fluorescent lamps at 50508 W about 90.61%. They were mostly installed in all buildings and around. The second load is 400W high pressure mercury at 4000 W approximately 7.18%. They only were installed in gym building. The third device used in toilet with down light luminance it is 20W compact florescent amount 780 W or about 1.40%. The lowest load is 18W fluorescent lamps at 450 W or about 0.81%. Proportion of lighting loads is shown in Fig. 6.

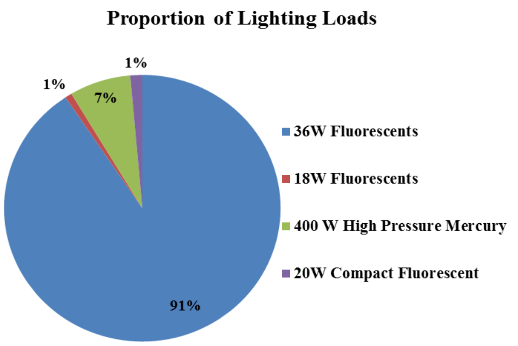
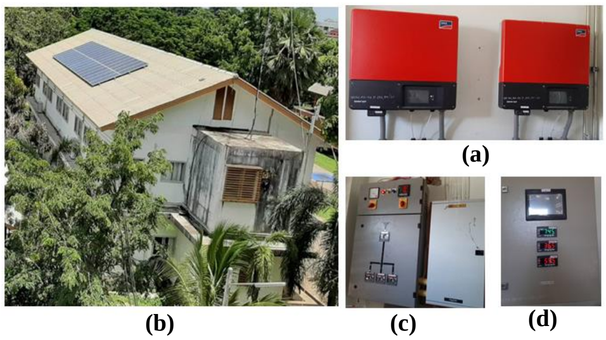


Fig.6. Proportion of Lighting Loads (Neglect Ballast Loss)

Specification of Device of Solar RoofTop

Nowadays in commercial, there are 2 types of commercial solar cells; thin film and crystalline silicon solar cell [52][53]. In this research the crystalline type was chosen because the thin-film solar panel is not suitable for solar rooftop systems as its generation capacity is less than crystalline solar panel [54]. Moreover, the efficiency of module (watt per area) of crystalline is higher than thin film. So the space area for installation is less than thin film [54][55][56][57]. The crystalline is used by considering from Tier 1 manufacturing certified by PV Tech. It is warrantee the degradation percentage is decreased not over 20% for 25 years.

For inverters presently, there are two types; central solar inverter and string solar inverter [58][59]. Two sets of 5kW string inverters were chosen in this research because they are small inverter suitable of office and especially if one inverter is failed, the rest can still generate power required. For system installation, 10.2 kW of solar rooftop was installed on a two floors building. It consists of 5.1 kW solar module amounts of 2 sets. Each set of solar modules includes 300W 17 solar panels of 1.64x0.99 m dimensions (area is 1.6236 m^2 a module) in type of crystalline. Therefore, the total area of installation solar rooftop is 55.2024 m^2. All 2 sets of solar rooftops (total of 34 solar panels) were installed on the building. They are placed heading to South direction. They were place on structure supporting with slope angle of 15^O to south because this angle generated high efficiency power of solar rooftop for Thailand [60]. The supporting structure made of steel with hot dip galvanizing. The devices of stick made of stainless. The installation feature is shown in Fig. 7.



(a)Inverters (b) Solar Rooftop (c) MDB (d) Monitoring

Fig.7. Installation of Solar Rooftop

A diagram of system is shown in Fig. 8. The system diagram consists of solar panels, protection devices and grid tie inverters. Solar rooftops are connected with grid tie inverter thought out protection sets (fuse and circuit breaker). All of them are connected to main distribution board. The real devices are shown in Fig. 9.

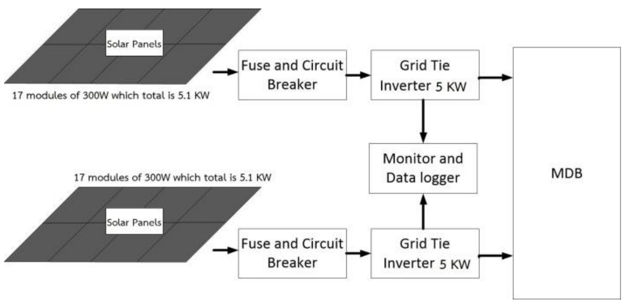


Fig.8. Diagram of Solar Rooftop Systems.

Specification of Device of LED Lighting

From data survey, amount and types of lamps were investigated. All conventional lamps were replaced by LED absolutely. Conditions of replacing were based on standard lighting according to [61] which the luminance must is not less than standard. Lists of all lightings both of old and new are shown in table 3. All conventional lightings were replaced by LED lighting. Not only that but also 90 W LED amount of 14 lamps which total power is 1260 W were added for street light. It is seen that new system gives utilization more than conventional system because of adding street light while the total power is less than another one. Total power of new system was 30129 W. On the other hand, the old system it was 55738 W in power. The 36 W fluorescents with magnetic ballasts were main device of system. They were installed in classrooms, walk ways, factory shop classes and around outside all buildings. All 36W fluorescents were replaced by 18W tubular LED lamps. The 18W fluorescent lamps were installed around the buildings and some toilets. They were replaced by 9W tubular LED lamps. For gym building which is a floor building. Earlier, it was installed by 400W high pressure mercury lamps which they were installed 10 lamps which total power was 4000W (neglecting ballast loss). All high-pressure mercury lamps have been replaced by 300W LED lamps. Finally, 20W compact fluorescent lamps were installed as the main lighting in all toilets. They have been replaced all by 10W LED. Therefore, considering table 3, it is found that total power reduces as 45.95% or about 25609 W. Considering on the total electrical loads in Table 1, after LED replacing, total load is 191955 W reducing from 217564 W. It is decreases about 11.77%.

Table 3. The Conventional vs LED Lamps

Conventional Lamps*	LED Lamps
36W fluorescents	18W tubular LED
18W fluorescents	9W tubular LED
400 W high pressure mercury	300 W LED
20W compact fluorescent	10 W LED
(not appear street light)	90 W LED**
Total Power 55738 W	**30129 W**

* Neglect ballast loss
** For new adding street light

3. RESULTS AND DISCUSSIONS

Research performs electrical energy conservation by 2 policies, solar rooftop installation and LED lighting replacing. The results are analyzed from electricity cost. Finally, the economics analysis is presented.

Solar Rooftop Installation Analysis

The cost of electricity 2 years, before and after solar rooftop installation, were collected and ploted in Fig. 9. First line (Blue line) ,which was collected since October 2015 to September 2016, is electricity cost without any energy conservation policy. Second line (Red line) which was collected since October 2016 to September 2017, is electricity cost with solar rooftop installation. Initially, both of 2 years electricity consumption is not controlled the same. Comsumtion depended on generally organization activity. All cost are the real from PEA, electricity seller of Thailand. Overview, it can be seen that electricity cost each month reduces clearly after solar rooftop installation. Two lines trends look like the same which the maximum consumption occured in September while the minimum consumption is in May. That means the activity or behaviour for investigated 2 years consumption quite the same.

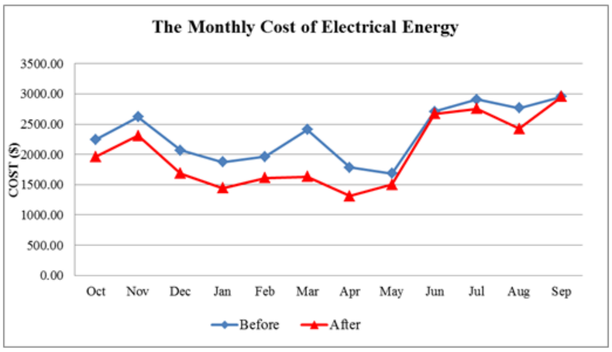


Fig.9. Cost of Electricity Comparison

Considering data in table 4, it is the results of performance. Total cost of electricity per year for before and after solar rooftop installation are shown. It is investigated that total cost electricity after solar rooftop installation is less than before performance. Electricity cost is decreased from 27995 $ to 24266 $ which this saves cost 3,729 $ or about 13.32%.

Table 4. Electricity Bills of Before and After Solar Rooftop Installation

The List	Before	After	%Saving
Cost per year ($)	27995	24266	13.32

To understand investment economic, the worthiness analysis becomes important. The details are shown in table 5. Investment cost of project is limited at 23000 $. By limited cost, it can install 2 sets of 5.1 kW solar rooftops. The saved electricity cost is 3729 $ a year. Therefore, this organization can get PB (payback period) form this investment in 6.01 years. The policy can get the goal of energy conservation because life time of solar rooftop is 25 years. In conclusion, it can be said that this project is interested.

Table 5. The Economic Analysis of Solar Rooftop Installation

The List	The Value
Investment (I)	23000 $
The Saved Cost	3729 $
PB (Payback Period)	6.17 Years

This corresponding to [45], it could save the bill of electricity with 6.17 year payback period. Also in [46], 119 kW solar rooftop installation could save 46.79% with 5 years payback period. The 50 kW solar rooftop could save 45% electricity bill [47]. These show solar rooftop can save energy. The installation capacity is high, the saved cost is high also. In [48] shows simulation of conservation by solar rooftop, it is found that it could save electricity cost with less than 10 years of payback period [48]. From all example research and this research show the payback period is less than about 10 years. Considering life time of project, it is found that solar rooftop project refering to [45][46][47] and this research is about 20-25 years. Life time is higher than payback period. Therefore it can be said that beneficial to investment. The left time is profit of investment.

Accordding to the results, it is noticed supportly that electrical conservation using solar rooftop is get target well. Personnel responsible for energy (PRE) have to understand behavior of electricity consumption before running project. In this case study, the policy is done in buildings of educational organization. Generally, main utillity cost is electricity cost approximately 86% of all expense. Electricity cost is reduced so monthly expense is more decreased. Futhuremore, an important point is type of electrical loads. Majority of electrical loads in educational organization are air condition and lighting at 59% and 26%. Generally, they run in daytime. This is corresponding to solar cell run. Solar rooftop installation just applied 10.2 kW generating solar power which much less than full load. Really, it should be replaced completely, but because of budget limitation. However, it still save electricity cost approximately 13.32% a years with 4.01 years payback period. However some loads of lighting is run in night.Therefore energy conservation for lighting system becomes performance.

LED Lighting Replacing

LED lamps were replaced all conventional lightings at the end of second period on September 2017. The electicity cost comparison before and after LED replacing are plotted in Fig. 10. The firs line (Blue line) is the electricity cost which solar rooftop running without LED replacing sinc October 2016 to September 2017, while the second line (Red line) is electricity cost which solar rooftop policy running within LED replacing sinc October 2017 to September 2018. Overall, this comparison is clear that it can save the electricity cost.

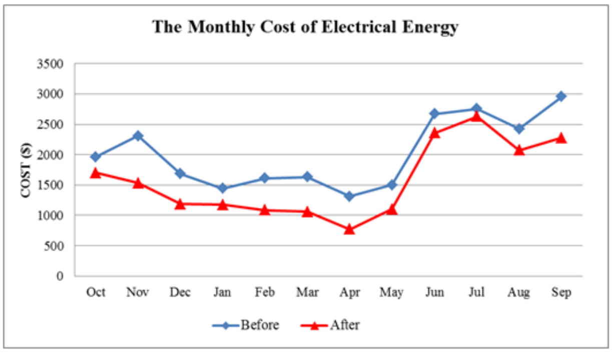


Fig.10. Electricity Cost Comparison.

It is found that electricity cost is outstanding different. The monthly electricity cost after project running is reduced clearly. That means LED replacing policy can be conserved energy. From table 6, the costs of electricity are shown. Total electricity cost reduces 5305 $ a year which it decreased from 24266 $ to 18961 $ or about 21.86%.

Table 6. Electricity Bills of Before and After LED Replacing

The List	Before	After	%Saving
Cost per year ($)	24266	18961	21.86

The worthiness of investment is important. Therefore the project economic is analyzed. The results are shown in table 7. It is found that investment cost is 18360 $ including installation and all LED lamps cost. From electricity bill for 2 years comparison; before and after LED replacing, it is found that the saved cost is 5305 $ a year with 5.56 years payback period while maintenance cost is neglected. However, the project was investigated in just only 1 year running. In a year, all LED lamps was not damaged.

Table 7. The Economic Analysis of LED Replacing

The List	The Value
Investment (I)	18360 $
The Saved Cost	5305 $
Payback Period	3.46 Years

The experiment performed just 1 year only. But after that it is not sure that LED lamps still work well along period of 3.46 years. After 1 year project running, some LED lamps probably will damage. That is the risk of project which personnel responsible for energy (PRE) needs realize. However, low energy device is a choice which can save energy. Not only that but also always preventive maintenance becomes important which help life time of device is extended. Moreover, maintenance help devices better run also. Effective maintenance plan will reduce the risk of investment in this case.

According to [62], amount of vocational college in northern east of Thailand is 153 colleges. Imaginably, if all colleges use this policy, each college can save 3305 $ a year so the cost of electricity can save 505665 $ a year. If the policy is used every college in Thailand, the saved cost is much more this. However, the main weak point of LED lamp technology is life time of diver set. Generally it is approximately 2-5 years. Therefore it is very important that technology for driver set should be developed immediately. After this problem is solved, LED lamps will be used absolutely.

Considering both of policy, it is investigated that initial investment cost is 41360 $. It can save electricity cost 9034 $ a year or about 32.27% with 4.58 years payback period. It can be said that this project is worth investment.

Table 8. The Economic Analysis of Both Policies

The List	The Value
Investment (I)	41360 $
Before	27995
After	18961
The Saved Cost	9034 $
% Save Cost	32.27%
Payback Period	4.58 Years

4. CONCLUSION

The research findings can be summarized as follows.

1. Yearly cost in the educational organization the most is electricity cost at about 86% of all utility costs. Therefore, this cost can be reduced the most.

2. Main electrical loads include air conditioner, lighting, and computer about 59%, 26%, and 10% respectively.

3. The policy of solar rooftop can save electricity costs about 13.32 %. The project has a payback period of 6.17 years. While life time of the project is 25. So, the project is worth an investment.

4. The policy of LED absolutely replacing instead of conventional lamps can be saved the cost of electricity about 21.86%. The payback period in the project is 3.46 years.

5. After two policies performance, electricity cost is saved 32.27%. The payback period is 4.58 years.

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