Energy Conservation Potential for Small-Size Buildings : A Case Study of Improving Lighting System Performance

By

Mr. Nutdhapun Ngernbumroong

A Final Report of the Three - Credit Course
CE 6998 Project

Submitted in Partial Fulfillment
of the Requirements for the Degree of
Master of Science
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Academic Year	November 1999

The Graduate School of Assumption University has approved this final report of the three-credit course, CE 6998 PROJECT, submitted in partial fulfillment of the requirements for the degree of Master of Science in Computer and Engineering Management.

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ABSTRACT

This project has studied on the energy conservation potential for small building by improving lighting system. This project is surveying of existing system of building in Case A: LCL Apartment and Case B: BTG Office and Warehouse then conducting analysis in terms of technical and non-technical aspect. The appropriate measures will be selected with each building for set saving target and plan for implementation.

Criteria for decision support on which measures should be implemented are existing system, engineering constraint, financial constraint and human and day-to-day work.

After the studying, LCL Apartment will get energy saving gain 155,313.47 kWh / Year and cost saving gain is 316,839.37 Bahts/Year. Investment cost of building is 838,522 Bahts. For BTG Office and Warehouse, energy saving gain is 346,980 kWh/Year and cost saving gain is 617,624 Bahts/Year. Investment cost of building is 1,230,152 Bahts. Building will get these gain by implemented the modification of existing system measure. Moreover, building will get energy saving gain and cost saving gain by the other measures also. The other measures are Lighting for Non-task Area, Daylighting Utilization, Lighting System Control and System Maintenance.

Also, this project is show the ideas of energy saving measures for apply with general building. The building manager or energy manager can use the consideration methods for analyze and implemented with his own building for achieve energy saving target and operation cost saving target.

ACKNOWLEDGEMENTS

I am indebted to the following people and organizations. Without them, this project would not have been possible.

I wish to express sincere gratitude to my advisor, A. Smith Tungkasmith. His patient assistance, guidance and constant encouragement have led me from the project inception to the project completion. I would like to express appreciation to my project Advisory Committee members; Prof. Dr. Srisakdi Charmonman (Chairman). Asst. Prof. Dr. Boonmark Sirinaovakul (Senior Dean), Dr. Chamnong Jungthirapanich (Dean), and assoc. Prof Somchai Thayarnyong (MUA Representative) for their comments and advice throughout the project.

I would like to thank Mr. Wichan Siwachitpong, Managing director of EEC Construction Management Co., Ltd. for his contribution. Ms. Rattaya Peanpermpat, auditor of Ernst and Young for her financial consults. Mr. Viroj Tethatapak Electrical Engineer for his technical consults. Mr. Bruno Fey Energy conservation expert of Fichtner GmbH & Co. KG for energy book from Germany. Mr. Somsak Tansiri, Deputy manager for energy book from Australia.

Special appreciation is due to my family for their fervent and continuous encouragement. Above all, I am forever grateful to my parents whose willingness to invest in my future has enabled me to achieve my educational goal.

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I. INTRODUCTION

Energy is one of the most important commodity of human life. In the long term, human have to plan and develop the use of energy source that is limited and extremely decrease. There are few alternative technologies being used today to generate energy saving. Conservation is simply a matter of applying already known engineering fundamentals and implementing a sound comprehensive energy management program. However, despite the absence of magic wands with very little capital investment recurring energy saving in the range 10 to 25 % can almost be assured for any plant that has not previously been exposed to a saving program. Nevertheless, the following certain key elements are very important:

(1) How and where to look for energy saving.

(2) What has worked successfully and economically and what has not.

(3) How to organize and promote an ongoing and effective energy conservation program.

(4) How to conduct thorough energy audits.

(5) How to apply good engineering principles.

Objectives

(1) To initiate the ideas of energy conservation in organization.

(2) To show the energy saving measures that appropriate for each building.

(3) To show the important of energy conservation that effect on operation cost.

Current Problems

(1) Building have high cost of energy.

(2) Most of existing system is conventional system that consumed energy in high levels.

(3) Lighting system in most existing building were designed without the restriction energy conservation and without regard for economic efficiency of operation.

Methodology of Study

(1) Analyze building utilization.

(2) Survey the existing system in terms of quality and quantity.

(3) Approach the building with energy conservation measures.

(4) Conduct the analysis on technical aspect and non-technical aspect.

(5) Evaluate the measures that meet to each building.

(6) Setting saving target and planning for implementation with building.

1.1 The Functions of Lighting

The primary functions of a lighting installation in a working environment are:

(1) The task must be easy to see.

(2) The visual environment must be safe and comfortable throughout the working day so as to minimize visual fatigue.

The secondary functions of the lighting installation are that it must have:

(1) Minimum overall operating costs.

(2) Construction which is easy to clean and to maintain.

These functions are considered in more details. It is important that their full impact be clearly understood.

1.2 Energy Loss in Lighting System

Lighting, although it consumes only 5 to 15 % of the total energy consumption in the building, is a highly visible end use of electricity, and such as was an early target for criticism and the subsequent subject of mandatory regulations to conserve energy. Since the beginning of the energy crisis, there has been a technical, social, and economic examination of the present energy system, designed during an age of inexpensive, readily available and apparently nondepletable fuel with a view toward energy systems responsive to current/future energy costs and sources. This general examination has resulted in a close study of the way we lighted buildings in the past and an evaluation of future criteria.

Lighting systems in most existing buildings, were designed without the restriction of conservation and in some cases, without regard for economic efficiency of operation. For example, inspeculative commercial buildings lighting system were designed with only first cost as a limitation.

These inefficient designs offer the energy specialist many opportunities to improve not only the operating efficiency of the building and thereby save energy but at the same time to improve the quality of the lighting for the benefit of the client/user. The potential for financial savings is readily apparent when it is realized that lighting represents 30 to 50 % of the operating costs of a building. With improved technology the return on investment for energy savings will increase. Growing fuel costs will also be a persuasive factor in making improvements to the lighting system to reduce kilowatts.

Not only have many lighting installations been poor utilizers of energy in terms of equipment performance, but the suitability of design has been questionable for the function of the space and its occupants needs. An improved lighting system, modified out of energy concerns, may also benefit employees and their working environment.

1.3 Energy Management for Lighting System

Energy management is gaining in importance, although it is neither a new term nor a new idea. After the initial obvious conservation steps taken by many businesses. (switch off lights, removing lamps from fixtures, reducing night time illumination for facade, sign, and advertising). The concept of energy management offers a practical approach to an ongoing problem of the effective and efficient use of energy resources.

Early standards to restrict lighting dealt only with new buildings and were confined to limiting power as an evaluation point of compliance. They did not address energy. None were design procedures, but rather established power budgets or limits that the designer should not exceed in designing the lighting system, or in making modification to an existing facility. Power reduction, however, is only one part of the conservation story.

$$\text{Energy} = \text{power} \times \text{time}$$

A savings in energy can be achieved by reducing either (connected load in watts or kilowatts) or by reducing time (hour use in kilowatt-hours). Energy-reduction options include modifying or replacing the lighting system with a more efficient one, using replacement components that use fewer watts, or modifying the operating characteristics of the building to reduce kilowatt-hours. If both power and time are reduced, the energy saving potential is further increased.

Although the opportunities for reducing energy in an existing structure are more limited than those in new system planning, from both a structural and financial aspect, efficient space is made available in commercial buildings, competition for tenants, together with the results of growing fuel costs, should be an effective incentive to modify lighting system.

Before energy can be conserved, it must be identified, by evaluating the lighting systems presently installed and used.

The consideration for the energy conservation potential in lighting system are as follow:

(1) Lighting for non-task area

(2) Modification of existing system

- (a) Lamp Substitution
- (b) Lighting Fixture Substitution
- (c) Accessories Substitution

(3) **Daylighting**

(4) Lighting System Control

(5) System Maintenance

1.4 The Reasons for Implementing a Lighting Management Program

Lighting management will help all businesses to save energy and money, and at the same time improve the quality of lighting in an office or a factory, thus aiding productivity and efficiency.

In an industrial plant the use of efficient lighting is not often considered to be of great significance because the energy consumption by the electric lighting is generally only a small component of the total energy consumption of the whole installation. Nevertheless considerable savings can be made in energy costs and lamp replacement costs if the lighting does not need switching off. In commercial buildings where the lighting is often a very significant proportion of the total energy consumption, substantial savings can be made by several method.

Lighting may also affect other sources of consumption, such as the air conditioning energy consumption. Light sources which are in common use today are more effective producers of heat than of light. Typical figures, as a percentage of the total input power, not including UV, for the common lamps are as follows:

Table 1.1. Product of Lamp.

Light source	**Visible light (per cent)**	**Heat(per cent)**
Incandescent General lighting service (GLS)	4-5	95-96
Tubular Fluorescent	22	78
High intensity discharge (HID) a) High pressure sodium b) Metal halide	 23 15	 77 85

Reference: Energy Victoria's Energy Information Center. Energy Efficient Commercial Buildings.

1.5 The Reasons for Small Building

This report focusses on small buildings for a number of reasons-primarily because significant ongoing construction activity is anticipated in this area. Most new projects over the next few years are expected to be small office developments, apartment, school, retailed stores or the refurbishment of existing buildings.

The commencement of the projects such as multi-storey office and hotel developments are likely to be less prevalent in the future. In addition, many of the design features and equipment used in large projects may not be directly transferable to smaller scale developments. This can be because of the costly and specialized nature of large projects.

As capital is usually restricted in small commercial projects, it is most important to recognize that the many benefits gained through sensible design and efficient energy use are normally achieved without additional cost.

The opportunities for refurbishment of existing buildings are growing in Thailand because of new small businesses are growing with the existing building. This report analyzes the existing lighting system it's improvement with renovation of existing building. However, for energy conservation, there are several potentials for improvement such as building envelope, air conditioning system and so on.

1.6 Organizing and Energy Management Program

First, top management must be dedicated and committed to an energy conservation program; they must be willing to provide the resources, both personnel and funds, as required. They must believe that energy conservation is most important to the future health of their company. The question always arises; How does one get top managements attention and support? There are, of course, a number of ways to try. One of the best is to present a list of energy projects with their costs and saving. **If** an energy conservation program has not existed to any great extent in the company, there no doubt will be many projects with less than a one-year payback. Such attractive investment certainly will command their attention and, in addition, they will engender their interest in a continuing energy management program. Other possible ways to obtain top-management involvement are

(1) Show the historical rise in energy costs over the past several years and how these costs have affected the company. as well as projecting energy cost into the future.

(2) Discuss potential curtailments and the effects on the company and their plant location.

(3) Attempt to find out what the competition is doing and how the company might be adversely affected in the marketplace if the company does not have an energy management program.

(4) Point out that many companies have achieved energy savings in the range 5 to 15 % with little or no investment and up to 30 % savings with projects showing less than two years payback.

Normally, top management will respond favorably to a program when confronted with facts that outline how the company can increase its profitability and possibly gain and market advantage.

Once the executive management of a company has taken this critical step of endorsing an energy management program, they must identify a person, preferably a senior manager, who, reporting to them, will corporate the entire company's or corporation's program. The most effective program has been in those organizations where the senior manager for energy reports to the highest practical corporate or company level, thus providing the necessary reinforcement in the eyes and minds of all employees of the importance placed on efficient energy use within the organization. For a company of any size, this position will require full-time attention. The person filling this position should be influential, knowledgeable and aggressive.

For implementation of the energy conservation program, building manager or person who responsible for energy conservation should stimulate and persuade the building owners and building users to see the significance of energy conservation gain. The technical officer, engineer, plant engineer or building engineer must transform the saving gain from technical terms into financial terms in low cost or no cost at the beginning of program.

This will persuade the top management to consider on energy conservation. The last thing for Thailand is, on the year 1992, government launched the Ministerial Act for designated buildings that regulate the large building and control the energy use level in the building also. The technical man should pay attention to this Act that contain the standard of energy use level of building reference. (Standard figure in Ministerial Act: Appendix A)

II. LITERATURE REVIEW

2.1 Lighting System

2.1.1 Lighting Terminology

There are several specific words that are used in the lighting system. The following lighting terminology needs to be understood before study in details in the next section.

Efficacy: Is the amount of visible light (lumens) produced for the amount of power (watts) expanded. It is a measure of the efficiency of a process but is a term used in place of efficiency when the input (W) has different units than the output (1m) and expressed in lm/W.

Color Temperature: A measure of the color of a light source relative to a black body at a particular expressed in degree Kelvin (K). Incandescents have a low color temperature (— 2800 K) and have a yellowish tone; daylight has a high color temperature (— 6000 K) and appear bluish. Today, the phosphors used in fluorescent lamps can be blended to provide any desired color temperature in the range from 2800 K to 6000 K.

Color Rendering: A parameter that describes how a light source renders a set of colored surfaces with respect to a black body light source at the same color temperature. The color rendering index (CRI) runs from 0 to 100. It depends upon the specific wavelengths of which the light is composed. A black body has continuous spectrum. Fluorescent lamps and high intensity discharge lamps (HID) have a spectrum rich in certain colors and devoid in others. For example, a light source that is rich in blue and low in red could appear white, but when reflected from a substance, it would make red materials appear faded. The same material would appear different when viewed with an incandescent lamp, which has spectrum that is rich in red.

Glare: Glare occurs when an excessively bright source, such as a luminaries, a bare lamp, a window or a patch of sunlight comes into the field of view.

Coefficiency of utilization (Cu): describe the ratio of the lumens received on the work plane from a luminaire, to the lumen emitted by the luminairie's lamp alone and describes how well luminaire distribute its light.

Lumen: A measure of light output from lamp.

Luminaire: A complete lighting unit (fixture) consisting of lamps and components to distribute the light (reflector, lens, louver) and to connect the lamps to the power supply.

Lux (lx): A quantitative unit for measuring illuminant. The illumination on a surface 1 meter square on which there is a uniformly distributed flux of 1 lumen.

2.1.2 Lighting System Requirement

Before the study in energy management starts, the basics of lighting system should be considered. In the lighting used area, to ensure that space is utilized as efficiently as possible when designing for new occupancy or when evaluating the present space layout, it is important to become familiar with the principal function of the facility, the types of tasks to be performed, the space allocated or necessary for each department activity, the worker density and traffic pattern, and the proportion of work space to circulation. Lighting should be planned, redesigned or modified to relate to task performance needs.

Task Lighting Requirement

The emphasis here is on the identification of the tasks performed in any area of the building so that the location of the lighting equipment, the orientation of the tasks, and the illumination requirements in quantity and quality may be coordinated. The objective should be to provide task-related illumination while avoiding unnecessarily high levels of uniform lighting throughout the space. Symmetrical, uniform lighting layouts may be acceptable where worker density is high; otherwise, area surrounding the tasks will be overlighted.

It is essential to know the precise location of the tasks, especially those that may require a special treatment so that the appropriate level may be provided at the task with lower levels in the surrounding. If changes in space use occur or are anticipated, flexibility of relocating luminaries should be planned. The location and angle of plane should be determined so that the recommended illumunance level is achieved in the plane of the task. Examples of this are adjustable drafting tables and vertical displays of merchandise or library stacks. Any measurements of existing or modified lighting levels should be made in that plane and no t simply on the horizontal.

Task Visibility

The visibility of a task is dependent on the quantity of light which is directed onto the task and the task area. The question of how much light is required for a task is very complex and often very continuous. For the working environment, interior lighting and the visual environment make recommendations for illuminant values for various task or types of interiors.

Task visibility also depends on having a high contrast between the task details and its background. This contrast can be reduced by the image of bright sources such as lamps, overhead luminaries, or windows in the task area.

Lighting Levels

Recommended illuminant levels are established by the illuminating Engineering Society of North America, and also by other institute. These are minimum maintained values on the task. The value for each task is selected from a range of illuminances, depending on the age of the worker, the speed and accuracy in performing the task, and the task background reflectance.

In the building survey present lighting levels should be measure. If the present maintained level for a task is higher than the level contained in the IES range for that activity, the system should be modified to reduce the quantity of light on the task and at the same time reduce the connected power and energy used. A simple retrofit method to reduce the level is to replace the existing sources with lower-watt lamps. Another solution is to control individual luminaries or groups with separate switch controls, so that selected units can be independently turned on or off or dimmed as needed to vary the illuminant in the area.

Quantity of illumination is only one aspect of task performance, and it should be noted that the quality of the light that delivers on the task plane is equally important. Any modifications in the system should consider both aspects, since the quality of the lighting may be adversely affected at the same time as quantity is reduced. On the other hand, quality may be improved with changes if visual comfort is improved through a reduction in glare.

2.1.3 Lighting System Elements

Light Sources

The most commonly used light sources are powered by electricity. Other sources of power are used but this is generally for decorative or special effects lighting purpose. The following is a brief review of the basic categories of light sources, which will give some guidance on how to select an appropriate lamp for a given application.

The families of lamps are incandescent, Fluorescent, high-intensity discharge (mercury, metal halide, high pressure sodium and low pressure sodium) Each source has its own operating characteristics of efficacy (efficiency), life, color, and ballast requirements

Incandescent

Light is produced by passing an electric current through a very thin wire filament, causing it to heat up to the point of incandescence and thereby produce light. Although they are the least efficient of the light sources and have a shorter life than any other type, incandescent lamps have many advantages over other types. Initial and replacement costs are low. Small in physical size, these point sources are easily controlled and ca be dimmed. No ballast is required. The color quality produced is the base by which many people judge the color rendition of other sources.

Tungsten halogen lamps are also incandescent sources and offer some additional advantages. An operating characteristics of the lamp cause tungsten to be removed from the bulb wall and redeposit on the filament, thus maintaining the lumen output close to 100 % throughout life. The efficacy, life, and optical control of halogen sources are also better than those of standard incandescent. A higher K rating provides excellent color rendition.

They are most appropriate for operation where:

(a) The electric lighting is required only occasionally, e.g. less than 3 hours per day

(b) Space is restricted

(c) Dimming or frequent switching is required

(d) Relatively short life is acceptable

(e) Electricity is available at very low costs

PAR Lamps

Parabolic aluminized reflector (PAR) lamps are reflector lamps with a lens of heavy, durable glass, which makes them an appropriate choice for outdoor flood and spot lighting . They are available in 75, 150 and 250 watts with longer lifetimes with less depreciation than standard incandescents.

Fluorescent

This discharge source is widely used in commercial lighting applications. Light is produces when an arc from electrodes passes through the tube and ultraviolet rays are converted into visible light by phosphor coating on the inside of the tube. To regulate current and starting voltage, a ballast is required.

Advantages of fluorescent lamps include higher efficacy and longer life than incandescent lamps. A choice of chromaticity (color temperature) and color rendition can be obtained, depending on the phosphor mix of the lamp chosen.

They are preferred where:

(a) Electric lighting is required for long periods.

(b) Large area, low brightness sources are desirable, e.g. at low mounting height.

(c) High luminous efficacies are required.

(d) The environment is not too hazardous or dirty.

(e) Only moderate capital expenditure is available.

Compact Fluorescent Lamps

These are lamps in which the small diameter fluorescent tube is folded upon itself and enclosed in a glass envelope. The energy consumption of these lamp is about 25 per cent of an incandescent lamp of comparable light output. The lamps have a Standard Edison Screw base and can be used as a direct replacement for incandescent lamps. The starter and ballast necessary for the operation of these lamps is built into the lamps themselves.

However, these lamps do not fulfill the need for a lamp of very small dimensions and low weight. It was for this reason that the alternative type of compact fluorescent lamp was developed, those in which the ballast is kept separate from lamp itself. Examples of this lamp are the PL from Philips, the DELUXE from Osram, the EUREKA from Mazda and the LYNX from Sylvania. These are miniature fluorescent lamps consisting of the two small, adjacent tubes joined at one end. The starter is housed in the base of the lamp. The 7 W, 9 W and 11 W versions provide equal light-output to the 40 W, 60 W and 100 W incandescent lamps.

High Intensity Discharge Lamps (HID)

Mercury, metal halide and high-pressure sodium make up this category of lamps. Operating characteristics of HID sources are similar to those of fluorescent, and ballast is required.

Mercury is available as a clear or phosphor-coated bulb, providing good color rendition. Self-ballasted mercury lamps are more efficient than incandescent but less efficient than standard mercury type. Efficiency is improved again in metal halide, as is color rendition by the addition of metal additives.

Metal Halide Lamps fall into a lamp efficacy range of approximately 25-125 lumens per watt. This makes them more energy efficient than mercury vapor but somewhat less so than high pressure sodium. Metal halide lamps generally have fairly good color rendering qualities. While this lamp displays some very desirable qualities, it also has some distinct drawbacks including relatively short life for an HID lamp, long restrike time to restart after the lamp has been shut off (about 15-20 minutes at 70 F) and a pronounced tendency to shift colors as the lamp ages. In spite of the drawbacks, this source deserves serious consideration and is used very successfully in many applications.

High-pressure Sodium is the most efficient of the three HID source types and has excellent lumen maintenance over life. The golden-white color quality has been a limiting factor for many interior applications, but improvements in color rendition have made its application for interior lighting acceptable for even such color-critical areas as merchandising spaces.

They have the advantages of

(a) Very high luminous efficacy, thus minimizing energy costs.

(b) Large wattages up to 2.0 kW, and therefore can be used with greater spacing to mounting-height ratios.

(c) Very long life.

However they also have disadvantages, such as

(a) High initial capital cost.

(b) Up to a 5-minute delay before full light is produced.

(c) Some color distortion.

(d) Annoying flickering and stroboscopic effects from some units.

Application Suitability

Despite the disadvantages of efficacy and life of incandescent lamps, their color rendition and the characteristics described earlier make them suitable for a variety of applications in residences, museums and merchandising spaces and for specific highlighting effects in other commercial applications. An application is suitable in terms quantity and quality of light delivered to the task if the source produces the best solution for the client's needs. For example, a well-controlled, high-candlepower beam on a small detail of an item of merchandise can be achieved with a low-voltage parabolic aluminized reflector (PAR) lamp with greater efficiency than could be achieved with any other source or fixture combination.

Fluorescent lighting accounts for a large portion of commercial and institutional applications. In higher wattages its efficacy is better than mercury vapor and equal to, or better than, some metal halide lamps. Its immediate starting capability and low cost compared to some HID installation make it still competitive for energy and operating cost.

In the HID families, mercury lamps are recommended where a higher-efficacy source than incandescent is required, while still providing good color rendition and uniformly to make people, buildings and surrounding acceptable. Metal halide is more efficient in lumens per watt and is used in indoor and outdoor applications where good color rendition is necessary. Both phosphor-coated mercury and metal halide lamps are found in such installations as supermarkets, shopping malls, banks, department stores gymnasium libraries and transportation terminals.

High pressure sodium (HPS) has been widely accepted for exterior lighting for street and highway installation, for building floodlighting and parking-lot lighting and for indoor installations in industrial facilities. The introduction of an improved color HPS lamp has opened up the same interior spaces as described for mercury and metal halide lamp use.

Not that HID sources require a warm-up period before full output is achieved, although is usable light almost immediately at a low intensity. If a power outage occurs or if lamps are turned off, a 10 to 20 minute waiting period will be necessary before the lamp will restrike, hence there is a need for a separate emergency lighting system in place of public assembly.

Low pressure sodium is confined to exterior application, or for indoor spaces, such as warehouse, where color rendition is of no concern.

It is not possible in a few pages to discuss light sources in details, and the reader should peruse specific information from manufacturers when making an evaluation of one source versus another for retrofit purposes and especially for an analysis of system replacement. The following two sections discuss some retrofit and new system suggestions as a base for further consideration and study.

Ballasts

Ballasts are current-limiting devices necessary for the operation of discharge sources. Fluorescent and HID lamps have a negative resistance, current is allowed to rise and would do so indefinitely, destroy the lamp, if a limiting device, a ballast, were not used. Ballasts also provide sufficient starting voltage to strike the arc if the supply voltage is inadequate. Ballasts should be selected for the specific voltage range and frequency of the electrical supply with which they are to be used and to provide the proper operating characteristics for the lamps in the system for maximum efficiency. Permissible voltage limits are specified by the manufacturers, and operation voltage on outside these may damage the ballast as well as reduce lamp life and efficacy. Reduced current ballasts and multilevel ballasts are suggested where a reduction in illumination can be tolerated.

2.2 General Methods for Energy Saving in Lighting System

The largest savings can be obtained by simply turning off the lighting when it is not needed. If good housekeeping and rational lighting practices are adopted further savings can be made . Poorly maintained lighting wastes energy and dollars.

Thus it is important to:

(a) Make provision for proper maintenance when planning the installation

(b) Establish a regular cleaning schedule and a procedure for its implementation

(c) Replace worn out lamps promptly

(d) Re-evaluate the lighting installation from time to time to ascertain its cost effectiveness, in the same way as any other piece of equipment or plant.

Such evaluation should:

(a) Carry out a visual task analysis to see if the correct illuminant values have been adopted.

(b) Use the most cost-effective light source and luminaires.

(c) Choose the most suitable, and adequately, maintain the finishes on the main interior surfaces because an effective lighting installation depend upon them.

(d) Install an effective lighting control system so that unwanted lighting can be switched off.

(e) Consider installing a control system when will integrate the daylighting and the electric lighting.

(f) Implement a planned maintenance program.

By applying this strategy, the company will conserve energy, save money and improve the safety and comfort of your working environment.

2.2.1 How to Save Energy in Building with Lighting System

A good time to re-evaluate the lighting in an existing building is when re-organization of plant or building . machinery or staff is contemplated. The following criteria are suggested as a guide to the planning process for the re-lighting of existing building.

(a) Analyze building usage and visual task requirements.

(b) Undertake a survey of the existing lighting in terms of the quality and quantity of lighting.

(c) Evaluate the efficiency of the existing lighting control methods.

(d) Conduct an analysis of the economics of replacing the existing lamps and luminaires with a more efficient system.

The recommended procedure for analyzing a lighting system is to conduct a survey of the building to determine what is in place. An alternative method is to review the building project plans, if available. If the building survey is done from drawing, a random check should be made of lamps and fixture in certain areas of the building to find out what substitution has been made. The task and location should be identified and the present lighting level measured and recorded. There may be an opportunity to reduce power, for example, in an existing space that is uniformly lighted to a level higher than the tasks required, by modifying the system so that it relates to task lighting requirements, with less illumination in the surrounding non task areas.

Other items to be noted during a survey of a facility include how the lighting installation in each space is controlled, and reflectance of room surfaces. In many existing buildings power and energy savings may also be achieved by an evaluation and subsequent modification of the maintenance program and operating procedures. Improving a lighting maintenance program or instituting one where non-exists, may allow some reductions in power because the system will operate closer to its initial design efficiency and perhaps fewer watts will be required to deliver the light level specified.

2.2.2 Lighting for Non-task Areas

If an overall general lighting system is changed to a system of task lighting with lower level in the surround, it may be desirable to use some of the power saved as supplementary lighting for interest and balance in the spaces: for example, on paintings, murals, for plants or on walls, or to define the boundary of the space. Pleasantness of the environment and human factors of enjoyment and well-being should not be completely sacrificed to energy efficiency.

In areas without visual tasks, review the present level if illumination and type of system in use for possible reduction or modification, provided that any changes are consistent with safety and esthetics for that application.

2.2.3 Modification of Existing System

Before undertaking any changes in the lighting, it should be understood that the installation is a system, a set of related components and elements, as interrelated to one another as lighting is to other systems in the building. Although savings can be achieved by making power reductions in components such as removing two out of four lamps in one luminaire or disconnecting a percentage of the luminaire in one areas, these measures should only be taken after a careful analysis of the entire system has been made to determine the effects of random curtailment.

There are two choices to be made in making changes in the system: a modification of the existing system or replacement of the one system with another. Modifying, or retrofitting, is the simplest way of achieving energy savings. Included are items such as replacing a light source with another of a higher efficacy. Substitutions of this nature may be made within one family of lamps or by changing from one family of sources to another, if compatible with the luminaire.

For a general analysis, The building manager should compare the existing system of building with the standard that is identified in Ministerial Act 1992 for designated building (This Act for large size building) (Appendix A)

Incandescent Replacement

The most efficacious lamps that can be used in incandescent sockets are the compact fluorescent lamps. The most popular systems are the twin tubes and double twin tubes. These are closer to the size and weight of the incandescent lamp than the earlier type of fluorescent (circline) replacements.

Twin tubes with lamp wattages from 5 to 13 watts provide amounts of light ranging from 240 to 850 lumens. Table 2.1 lists the characteristics of various types of incandescent and compact fluorescent lamps that can be used in the same type sockets. There are two types of compact fluorescent lamps. In one type of the lamp system, the ballast and the lamps are integrated into a single package; in the second type, the lamp and ballast are separate, and when a lamp burns out it can be replaced. In the integrated system, both the lamp and the ballast are discarded when the lamp burns out.

It is important to remember when purchasing these compact fluorescent lamps that they provide the equivalent light output of the lamps being replaced.

Table 2.1. Lamp Characteristics.

Lamp Type (Total Input Power)*	**Lamp Power (W)**	**Light Output (Lumens)**	**Lamp Life (Hour)**	**Efficacy (lm/W)**
100W (Incandescent)	100	1750	750	18
75W (Incandescent)	75	1200	750	16
60W (Incandescent)	60	890	1000	15
40W (Incandescent)	40	480	1500	12
25W (Incandescent)	25	238	2500	10
22W(Fl. Circline)	18	870	9000	40
44W(Fl. Circline)	36	1750	9000	40

Table 2.1. Lamp Characteristics.(Continued)

Lamp Type (Total Input Power)*	**Lamp Power (W)**	**Light Output (Lumens)**	**Lamp life (Hour)**	**Efficacy (lm/NV)**
7W (Twin)	5	240	10000	34
10W (Twin)	7	370	10000	38
13W (Twin)	9	560	10000	43
19W (Twin)	13	850	10000	45
18W(Solid-State)	-	1100	7500	61

* Includes ballast losses

Reference: Albert Thumann, P.E., C.E.M. Handbook of Energy Audits. Fifth Edition

Ballast Replacement

Ballast replacement is another measure in the modification of the existing system. Replacing the exising ballasts with low watt loss ballast and electronics ballast, the modified system will consume energy less than the existing system. The factors that have effect on decision in this measure are the number of lamp and costs of a new ballast. The costs of a new ballast are still high in the current. Thus the building manager should investigate the lamps that have potential for this measure and calculate the cost and saving to support decision. The energy consumed by ballast types iron core, low watt loss and electronics ballast are as follows;

Table 2.2. Comparison of Energy Ballast Consumed.

	Iron Core Ballast	**Low Watt Loss Ballast**	**Electronics Ballast**
Lamp	Fluorescent lamp 36 W	Fluorescent lamp 36 W	Fluorescent lamp 36 W

Table 2.2. Comparison of Energy Ballast Consumed.(Continued)

	Iron Core Ballast	**Low Watt Loss Ballast**	**Electronics Ballast**
Lamp Consumption	36 W	36 W	36 W
Ballast Loss	10 W	6.0 W	4.0 W
System Consumption	46 W	42 W	36 W
Comparison Index	100 %	91 %	78 %

Reference: Albert Thumann, P.E., C.E.M. Handbook of Energy Audits. Fifth Edition

System Modification

Without replacing one system with another, it may be possible to modify the present lighting system to improve the illuminant in the space: a compromise between the two approaches of retrofit and system redesign.

In high-ceiling areas, or if lighting levels on the task are inadequate and it is possible to do so, lower the luminaires closer to the work surface to increase the quantity of light. By lowering the luminaires, it may also become practical to reduce wattage by relrevamping the lower-wattage lamps of a higher efficacy and still maintain the recommended illuminant level on the task, provided that the light distributed from lowered fixtures is still available.

If space utilization has been changed since the building was occupied initially and without an accompanying change in the lighting system, there may be a need for removal of some luminaires, or their relocation. These may be permanently disconnected or used elsewhere in the facility. For example, if a large area has been subdivided with partition, the luminaire location may no longer be appropriate for the present space layout. In extreme cases, luminaires have been left in place bisected by the addition of a stack of filling cabinets or other floor-to-ceiling divider. Their removal improves not only the energy efficiency of the lighting in the space, but also design esthetics.

2.2.4 Daylighting

If daylighting can be effectively used, if should be considered either to replace some of the electric lighting, which can then be turned off for certain hours of the day, or as a supplementary source, so that the electric lighting in the immediate area can be reduced by switching or dimming.

In narrow room the contribution of daylighting from side windows to the illuminant on a horizontal task area is limited, and in deep room it is generally insignificant, Daylighting can however play an important part in making the interiors more pleasant than they would be if lit by electric light alone.

Most people prefer a room with daylight and enjoy the visual contact with the outside world which windows provide. The color of the daylight, its random change of intensity and color and pleasant modeling effect upon people and objects blend to give a room a distinctive appearance.

Where the room is lit by rooflights, (skylights, sawtooth roof lights or monitor roof lights) the daylight does make a substantial contribution to the overall lighting. It is this type of daylighting system which is ideal for integration with electric lighting and considerable energy savings can be made by using some form of automatic control.

2.2.5 Energy Management in Lighting by Control Devices

The correct control of the lighting system will ensure that energy is not wasted and standards are maintained. Correct control means matching the lighting to the occupancy requirements in the area. If control switching is contemplated, then the compatibility of the whole system (lamps, ballast, control devices and dimming equipment, if any) must be considered as an integral unit. The type of control device should be decided before the installation is commenced, as the cost of installing a more suitable device at a later stage may well exceed any financial saving made through lower energy usage. The type of control devices currently available are discussed below.

(a) Manual switches

The first and most inexpensive control device is the common single pole switch. Activated by the human finger it is simple to operate but relies on human frailties to operate properly.

A flexible switching arrangement in any areas is essential. A small group of luminaires operated from one switch is preferred to a whole floor area from one switch. A half-lighting arrangement that does not drastically alter the distribution of light is also advisable for certain areas. Where staff are require working shifts in an isolated part of an area, half-lighting in other areas will reduce the visual contrast which can cause fatigue.

(b) Time switches

Certain areas of business premises require some form of lighting at a time when the staff is not normally present. This could be security lighting, building floodlighting or advertising signs. Time switch control enables these requirements to be met by switching on and off at set times. The clock's mechanism can be;

(a) Daily, which operate on a 24-hour cycle.

(b) Weekly type, which can be pre-set for each day of the week.

(c) Seasonal type, which adjusts daily to compensate for the changing sunset time.

(c) Photoelectric switches

These activate an on/off relay by sensing daylight. Other types available, which vary with daylight conditions, will be discusses under automatic daylight controls.

The main use of the photoelectric (PE) switch is in the security field where lighting is required throughout the hours of darkness. Sometimes the PE switch is used in series with a time switch to control lighting that is required to switch on the dusk and off during the night. A available device is also available embodies both systems in the one unit. Car parks, advertising signs or building floodlighting would be typical uses for this device.

(d) Time delay switches

These switches are pre-programmed to switch off at a set time after switch-on. The timing mechanism can be by spring, air bellows or electronic timer. One use is to allow sufficient time to traverse a stairway or corridor before the lights are turned off. In areas of limited use such as conference rooms, the lighting could be programmed to turn off after, say, one hour. This overcomes the problem of people leaving and forgetting to turn off the lights. Should the conference proceed beyond an hour, then tne switch has to be re-activated. Such devices are often installed in bathrooms and toilets, for the same reasons.

(e) Programmable time-of-day switches

These devices take over control from the switching cycle. They are usually micro-processor based, storing the switching program for a variety of equipment on the premises. Before working out the switching cycle, an accurate survey of the occupancy rate of the area is required. The lighting requirement is then programmed into the device for each day up to one year in advance. Overriding switches are required to cater for variations in the routine. This minimizes human participation in the control of the lighting use.

(f) Programmable switches

This is a variation of the above in that the switching cycle can be interrupted by other factors automatically. For maximum demand tariffs there is a requirement to shed load when peak load demands become apparent. A system of priorities has to be developed to determine when and what load can be shed. This is done automatically or a warning is sounded before load shedding becomes vital. By keeping load peaks to a minimum, a saving in electricity rates can be achieved.

(g) Dimming controls

Very little energy is lost in the relatively modern dimmer that uses the wave chopping technique. This means that when lamps are dimmed, energy usage is reduced. An incandescent lamp dimmed to 50 percent light output is using about 65 percent of its rated energy. Fluorescent lamps require rapid-start solid state ballast before effective dimming is achieved. Other types of ballast introduce problems of unstable operation at low levels and often result in poor lamp life characteristics. High intensity discharge lamps such as mercury vapor, high pressure sodium and metal halide can be dimmed, providing the circuit is compatible. Advice on which is the most appropriate equipment for the particular installation from the dimmer manufacturer should be sought. Fixed step dimming, by introducing an extra choke into the lamp circuit, is available from most ballast manufacturers.

(h) Proximity sensor

These sensors respond to movement in the area and turn on lights. Primarily used in security situations to warn of intruders or to scare them away. They are also handy in the area where normally there is little traffic such as in a storeroom. When a person enters the storeroom the lights turn on and remain on while there is movement. After the person leaves the area, the lights are turned off by the controller.

2.2.6 System Maintenance

System maintenance is the maintenance of all systems that use or affect the use of energy. The systems are found in every kind of organization that uses energy, such as a hospital, a store, a university, a warehouse and a factory. Energy system maintenance includes such routine maintenance tasks as lubrication, examination and cleaning of electrical contacts, but it also includes such non-routine tasks as repainting walls to increase the effective lighting, cleaning fins of compressor.

A good energy systems maintenance program can save a company substantial amounts of money in wasted steam and wasted electricity and in the lost production and additional expense caused be preventable equipment breakdowns. Other benefits include general cleanliness, improved employee morale, and increased safety. In a good maintenance program, planning, scheduling and monitoring are carried out in a predictable and well-organized manner.

There are four steps in the development of a maintenance program. Step 1 is to determine the present condition of the existing facility. This step includes a detailed examination of each of the major energy-consuming systems, the output from this examination is a list of the motor, lights, transformers, and other components that make up each system, together with reports of the condition of each. Step 2 is the preparation of a list of routine maintenance tables with an estimate of the number of times that each task must be performed. This list should also include, for each task, the craft, the need material, and the appropriate equipment. These data are then incorporated in step 3 into a regular schedule for accomplishment of the desired maintenance. Step 4 is monitoring to keep the program in force as it has been initiated.

Maintenance of the lighting adjacent to reflective walls, ceiling, and floors serves several purposes in energy management. The energy consumed by lights is significant, as is the energy used by the heating, ventilating and air conditioning system to remove the heat put into a building by the lights. But the psychological value may have a greater impact. If lights are conspicuously absent from corridors and, where not needed, and from management offices, people tend to look upon energy conservation as a program that is being taken seriously, and they begin to take it more seriously themselves. Similarly, a plant where energy management has been encouraged but where no attention has been paid to lighting is often seen as a plant where energy management is not taken seriously.

Many factors modify the effectiveness of the lighting system. Of particular importance are the condition of lights, the cleanliness of luminaires, and the cleanliness of walls, ceiling and floor. When determining the conditions of this system, a light meter should be carried as standard equipment. This will show the rooms where the IES (Illuminating Engineering Society) or other lighting standards have been exceeded or where not enough light is present. There may also be some additional problems. Windows can be a source of light. If they are used this way in facility, they should be cleaned. If they are not used as a light source, consider boarding them up to avoid having to remove the heat that are not allowed in from the sun. The lighting systems in a facility are important, both in energy costs and as a morale factor.

Table 2.3. Problems and Solution: Lights, Windows, and Reflective Surfaces.

Component	Problem	Initial Maintenance Action
Light	Illuminate unused space	Remove light and store for later use elsewhere
	Flickers(Fluorescent)	Replace quickly
	Too little light	Increase lighting to acceptable levels
	Ballast Buzz	Adjust voltage or change ballast types
	Smoking	Replace ballast : check contacts and electrical wiring : do not use until condition is remedies
Wall	Dirty or greasy	Clean
	Painted with dark paint	On the next painting, use brighter paint
Floor	Hard to keep clean	Examine the possibility of changing wall surface
Window	Dirty	Clean, if used for light ; otherwise, consider boarding over to prevent solar gain and heat loss

Reference: Wayne C. Turner. Energy Management Handbook. Wiley Interscience, 1982

2.3 Methods for Selecting Appropriate Investment Option

The main idea that is important to this study is capital budgeting. Capital budgeting is the process of evaluating and selecting investment alternatives with the goal of long term cost saving or profit maximization. Long term is taken to mean any investment whose returns are expected to extend beyond one year and an investment. Since investing in energy efficiency project can represent a sizable amount of spending, procedures are needed to analyze and select alternatives properly. A good capital budgeting program involves a number of steps, as follow;

(a) Search and Identification of Energy Efficiency Investment Alternatives

This step involves an active search for new energy conservation opportunities or identification of problem areas where energy efficiency can be optimized.

(b) Estimation of Costs and Cash Flows

Once opportunities have been identified, the next step is to collect data to estimate the cost of the investment and the expected cash flows for the project. Since the future benefits from current energy savings involve uncertainties, the risks involved in cash flows and appropriate discount rate are also required to be estimated.

(c) Evaluation and Decision Making

Once opportunities have been identified and estimates made, next comes the selection. Capital investments on energy projects are generally long-term commitments. Therefore, capital expenditure decisions form the framework for an enterprise's future development and are a major determinant of its efficiency and competitive power. This requires sound appraisal techniques to measure and evaluate the benefits of an investment project and retain the best decision. Since the benefits investment proposals extend into the future, their accrual is uncertain.

(d) Re-evaluation and Adjustment

The final phase is that of re-evaluation and adjustment. While the energy project is being implemented, the actual cash flows must be compared with the initial projections and there is a need to re-evaluate the economic merits of on-going projects in order to determine whether or not to continue with it. The re-evaluation provides information to improve future estimates of cash flow, risk and the necessary adjustment.

All four steps being important, our emphasis here is on the second and third steps. (For evaluate the measure in case study in project)

The methods for financial evaluation of individual investment projects may be divided into two broad categories.

(1) Static or Traditional Technique

(2) Dynamic or Discounted Cash Flow Technique

The study case in this project may focus on payback period, Present-worth method and Internal rate of return.

(1) Simple Payback Period Method

The calculation of payback period (PB) is the one method of capital budgeting. It is the simplest and, perhaps, the most widely-employed quantitative method for evaluating the cost effectiveness of an energy saving investment.

The payback period answers the question: how long will it take for the cash benefits to pay the original costs of an investment, normally disregarding the salvage value?

$$PB = \frac{\text{Capital investment}}{\text{Annual net cash flow}}$$

Accept project if; Calculated Payback < or = Minimum (or) Predetermined Payback.

(2) Present-worth Method

The present-worth method for evaluating investment projects uses the time value of money, a specified minimum acceptable rate of return (MARR), and cash flow model to reduce the cash flow associated with a project to a single equivalent sum, Using this method, the net present worth of a project is defined to be the difference between the present worth of the project revenues and project costs. If this net present worth is nonnegative, the project in question is attractive as an investment.

$$PW = CF0 + \sum_{n=1}^{n} CFn\,(P/F, I\%, n)$$

CFn = Cash Flow of year n

CFo = Investment of year 0

Note that this approach includes all parts of an investment alternative: initial investment, annual returns, and economic life. We also include the time value of money.

The criterion used is this: if the present worth is greater than zero, it is a worthwhile project that should be given further consideration. When the present value is zero the returns are enough not only for the initial investment payback but also the interest charge on the investment money and leave some left-over for stock holders. In fact, this is the proper view point to be taken.

When we obtain fends for a project, we can assume that they are "borrowed" from the corporate treasury, but we must pay interest on it. In a sense, the treasurer is a "surrogate" banker. He or she gives us the initial investment and we make "mortgage" payments in the form of annual returns. Each returns and/or lasts long enough, it pays the debt and leaves some left-over. Otherwise, it is a bad investment.

Accept project if: Calculated NPV > 0 (or) Predetermined NPV

(3) Internal Rate of Return Method

This is defined as the discount rate which forces the present value of the future cash inflows of an investment to equal the cost of the investment itself. The internal rate of return is also known as the rate of return that a project earns. The equation for calculating the internal rate of return is given as

$$0 = CFo + \sum_{n=1}^{n} CFn\ (P/F, IRR\%, n)$$

where IRR is the internal rate of return

Accept project if : Calculate IRR > Discount Rate , Hurdle Rate (or) Required IRR

(4) Pros and Cons of the Common Methods of Analysis

Although there are a series of variations of the methods presented in previous sections, these represent the principal methods of analysis. They all have advantages and disadvantages. Consequently, no single method is dominant.

Payback period method

Payback period = Number of years required for the net income to recover the net investment without considering the time value of money

Advantages

(a) It is a measure of fluidity of investment.

(b) It is commonly used and well understood.

Disadvantages

(a) It does not measure profitability.

(b) It neglects life of assets.

(c) It does not properly consider the time and value of money.

Present-worth method

Present worth = present worth of receipts - present worth of disbursement (all present worths calculated with MARR)

Advantages

(a) It works with any cash flow pattern.

(b) It is easy to compute.

Disadvantages

(a) It is an unfamiliar measure to managers.

(b) A zero PW implies a satisfactory profit.

(c) A nonzero PW does not give a clear idea of the relative merit of the proposal.

(d) It is not possible to specify a reinvestment rate of recovered capital. (the reinvestment rate is implicitly assume to be the MARR)

Internal Rate of Return Method

IRR = That interest rate I which makes the PW of the receipts minus PW of the disbursements equal to 0

Advantages

(a) It is a familiar measure to managers.

(b) It provides an indication of the relative merit of the proposal.

Disadvantages

(a) The origin of the computational procedure is obscure-hard to explain.

(b) It implicitly assumes that capital recovered can be reinvested at the IRR.

(c) It may give more than one answer in some cases.

III. CASE STUDIES

3.1 Case A: LCL Apartment

General Description

This apartment is a 13-year old building. There are 53 rented rooms. They operate 24 hours per day and 365 days per year. The main energy consumption comes from the air conditioning system and the second priority is lighting. Apartment structure is made of reinforcement concrete for beam and column. The wall is made of block with double coating cement. The window area is 70 % of outside wall and has film coating. The roof is insulated with fiberglass insulation. The mechanical and electrical systems are installed with limited costs on design and equipment. The details of the system are shown in the next section.

General Data

Building 's Name	LCL Apartment
Address	Sukumvit Road, Bangkok
Range of service	Apartment
Operation Period	24 hours per day, 365 days per year
Total area	17,671 m^2
Building Area	14,975 m^2
Parking Lot	2,696 m^2

Energy Consumption of Building

Electrical Energy Consumption

Energy consumption	1,241,200	kW-hr / Yr
Demand Peak	400	kW
Load factor	47.8	

Transformer	1000 x 2	kVA
Voltage	12 kV / 416 V / 240 V	
Power factor	0.86	
Electricity prices	2.04	Bahts / kWh

Proportional of Energy Consumption

Air Conditioning System	72.4 %
Lighting System	26.64%
Other System	1.0 %

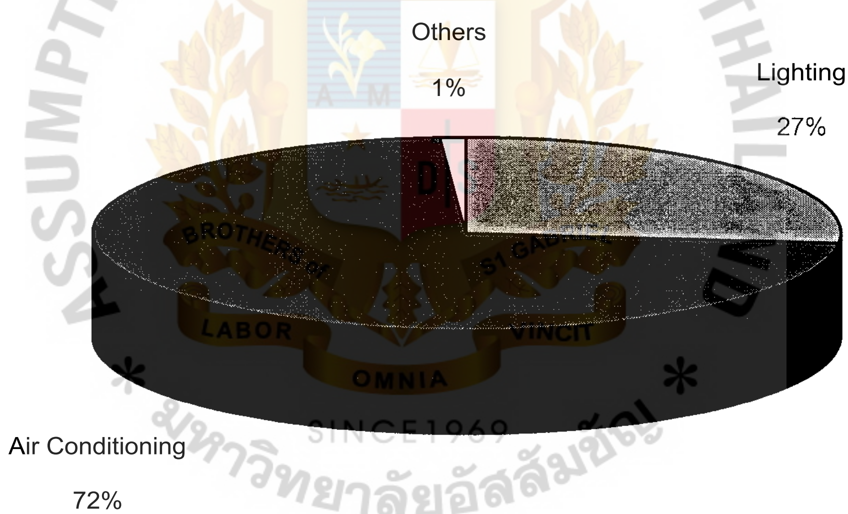

Figure 3.1. Proportional of Eenergy Consumption for LCL Apartment.

Detailed of Lighting Measurements

Table 3.1. The Total Quantity of Lamp That Used in LCL Apartment.

No.	Type	Rated (Watt)	Quantity	Total (Watt)	Ballast Loss (Watt)	Grand Total (Watt)
1	Fluorescent	10	57	570	570	1,140
2	Fluorescent	14	3	42	30	72
3	Fluorescent	18	732	13,176	7,320	20,496
4	Fluorescent	20	79	1,580	790	2,370
5	Fluorescent	32	7	224	70	294
6	Fluorescent	36	788	28,368	7,880	36,248
7	Fluorescent	40	115	4,600	1,150	5,750
8	PL	9	2	18	-	18
9	PL	18	7	126	-	126
10	PL	15	1	15	-	15
11	PL	25	3	75	-	75
12	PL	23	4	92	-	92
13	SL	18	3	54	-	54
14	SL	16	1	16	-	16
15	SL	25	181	4,525	-	4,525
16	SL	40	4	160	-	160
17	Spot light	40	1	40	-	40
18	Spot light	60	12	720	-	720

Table 3.1. The Total Quantity of Lamp That Used in LCL Apartment. (Continued)

No.	Type	Rated (Watt)	Quantity	Total (Watt)	Ballast Loss (Watt)	Grand Total (Watt)
19	Spot light	100	42	4,200	-	4,200
20	Spot light	120	4	480	-	480
21	Spot light	400	6	2,400	-	2,400
22	Spot light	900	4	3,600	-	3,600
23	Incandescent	25	29	725	-	725
24	Incandescent	40	1,178	48,400	-	48,400
25	Incandescent	60	204	12,240	-	12,240
26	Incandescent	100	279	27,900	-	27,900
27	HID	400	12	400	-	400
Total			3,739	152,786	17,810	172,556

Detailed of Lamp and Lighting Fixture.

[illegible]	[illegible]	[illegible]	[illegible]	No. of Lamp	Lamp per Fixture	Lighting Fixture	[illegible]	Ballast Loss (Watt)	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	–	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	–	.	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	–	–	[illegible]
[illegible]	Fire exit	Fluorescent	[illegible]	[illegible]	[illegible]	Exposed	[illegible]	[illegible]	[illegible]
	Stair	Fluorescent	[illegible]	[illegible]	[illegible]	Exposed	[illegible]	[illegible]	[illegible]
[illegible]	Central Stair	Fluorescent	[illegible]	[illegible]	[illegible]	Exposed	Iron core	[illegible]	[illegible]
[illegible]	Mezzanine	Fluorescent	[illegible]	[illegible]	[illegible]	Exposed	[illegible]	[illegible]	[illegible]
		Fluorescent	[illegible]	[illegible]	[illegible]	Obscure	[illegible]	[illegible]	[illegible]
		Fluorescent	[illegible]	[illegible]	[illegible]	Obscure	Iron core	[illegible]	[illegible]

Detailed of Lamp and Lighting Fixture. (Continued)

[illegible]	[illegible]	[illegible]	[illegible]	No. of Lamp	Lamp per Fixture	Lighting Fixture	[illegible]	Ballast Loss (Watt)	[illegible]
		[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]		[illegible]			[illegible]
		[illegible]	[illegible]			[illegible]		[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]		[illegible]		[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]
N	In front of lift	Incandescent	[illegible]	[illegible]		Down light		[illegible]	[illegible]

[illegible] Detailed of Lamp and Lighting Fixture. (Continued)

[illegible]	[illegible]	[illegible]	[illegible]	No. of Lamp	Lamp per Fixture	Lighting Fixture	[illegible]	Ballast Loss (Watt)	[illegible]
	(G floor)								
[illegible]	[illegible]	Fluorescent	[illegible]	[illegible]	[illegible]	Obscure	[illegible]	[illegible]	[illegible]
		Incandescent	[illegible]	[illegible]	[illegible]	Down light	[illegible]		[illegible]
[illegible]	Fountain	Incandescent	[illegible]	[illegible]	[illegible]	Down light	[illegible]	[illegible]	[illegible]
	Corridor								
[illegible]	[illegible]	SL	[illegible]	[illegible]	[illegible]	Down light	[illegible]	[illegible]	[illegible]
		Incandescent	[illegible]	[illegible]	[illegible]	Down light	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	Spot light	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	Incandescent	[illegible]		[illegible]		[illegible]	[illegible]	[illegible]

Detailed of Lamp and Lighting Fixture. (Continued)

[illegible]	[illegible]	[illegible]	[illegible]	No. of Lamp	Lamp per Fixture	Lighting Fixture	[illegible]	Ballast Loss (Watt)	[illegible]
		Spot light	[illegible]	[illegible]	[illegible]	-	-		[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	-	-	-	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	-	-	-	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-		[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-		[illegible]
[illegible]	Sauna	Incandescent	[illegible]	[illegible]	[illegible]	Down light	-		[illegible]

Detailed of Lamp and Lighting Fixture. (Continued)

[illegible]	[illegible]	[illegible]	[illegible]	No. of Lamp	Lamp per Fixture	Lighting Fixture	[illegible]	Ballast Loss (Watt)	[illegible]
		Incandescent	[illegible]	[illegible]	[illegible]	Down light	-	-	[illegible]
		Incandescent	[illegible]	[illegible]	[illegible]	Wall	-	-	[illegible]
[illegible]	Conference room	Fluorescent	[illegible]	[illegible]	[illegible]	Prismatic	[illegible]	[illegible]	[illegible]
		Fluorescent	[illegible]	[illegible]	[illegible]	Prismatic	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	—	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]		[illegible]	[illegible]		-	[illegible]

Detailed of Lamp and Lighting Fixture. (Continued)

[illegible]	[illegible]	[illegible]	[illegible]	No. of Lamp	Lamp per Fixture	Lighting Fixture	[illegible]	Ballast Loss (Watt)	[illegible]
[illegible]	TDS office	Fluorescent	[illegible]	[illegible]	[illegible]	Exposed	[illegible]	[illegible]	[illegible]
		Fluorescent	[illegible]	[illegible]	[illegible]	Exposed	[illegible]	[illegible]	[illegible]
[illegible]	Fountain	Spot light	[illegible]	[illegible]	[illegible]		[illegible]		[illegible]
		Fluorescent	[illegible]	[illegible]	[illegible]	Obscure	[illegible]	[illegible]	[illegible]
[illegible]	Laundry (1)	Fluorescent	[illegible]	[illegible]	[illegible]	Obscure	Iron core	[illegible]	[illegible]
[illegible]	Under building	Fluorescent	[illegible]	[illegible]	[illegible]	Exposed	[illegible]	[illegible]	[illegible]
		Fluorescent	[illegible]	[illegible]	[illegible]	Exposed	[illegible]	[illegible]	[illegible]
[illegible]	Office	Fluorescent	[illegible]	[illegible]	[illegible]	Obscure	[illegible]	[illegible]	[illegible]
		Fluorescent	[illegible]	[illegible]	[illegible]	Obscure	[illegible]	[illegible]	[illegible]

Table 3.2. Detailed of Lamp and Lighting Fixture. (Continued)

No.	Room	Lamp	Rated (Watt)	No. of Lamp	Lamp per Fixture	Lighting Fixture	Ballast	Ballast Loss (Watt)	Total (Watt)
		Fluorescent	20	1	1	Obscure	Iron core	10	30
		Fluorescent	36	1	1	Prismatic	Iron core	10	46
		Fluorescent	36	1	2	Exposed	Iron core	10	92
		Fluorescent	40	2	2	Obscure	Iron core	10	200
		SL	25	1	1	Down light	-	-	25
		Incandescent	60	1	1	Down light	-	-	60
20	Guest Room	Fluorescent	36	17	1	Obscure	Iron core	10	782
	1^{st}-7^{th}	Fluorescent	36	26	1	Prismatic	Iron core	10	1,196
	Floor	Fluorescent	36	156	1	Surface	Iron core	10	7,176

Detailed of Lamp and Lighting Fixture. (Continued)

[illegible]	[illegible]	[illegible]	[illegible]	No. of Lamp	Lamp per Fixture	Lighting Fixture	[illegible]	Ballast Loss (Watt)	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[illegible] Detailed of Lamp and Lighting Fixture. (Continued)

[illegible]	[illegible]	[illegible]	[illegible]	No. of Lamp	Lamp per Fixture	Lighting Fixture	[illegible]	Ballast Loss (Watt)	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Detailed of Lamp and Lighting Fixture. (Continued)

[illegible]	[illegible]	[illegible]	[illegible]	No. of Lamp	Lamp per Fixture	Lighting Fixture	[illegible]	Ballast Loss (Watt)	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]

Detailed of Lamp and Lighting Fixture. (Continued)

[illegible]	[illegible]	[illegible]	[illegible]	No. of Lamp	Lamp per Fixture	[illegible]	[illegible]	Ballast Loss (Watt)	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Detailed of Lamp and Lighting Fixture. (Continued)

[illegible]	[illegible]	[illegible]	[illegible]	No. of Lamp	Lamp per Fixture	Lighting Fixture	[illegible]	Ballast Loss (Watt)	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Detailed of Lamp and Lighting Fixture. (Continued)

No	[illegible]	[illegible]	[illegible]	No. of Lamp	Lamp per Fixture	Lighting Fixture	[illegible]	Ballast Loss (Watt)	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-	-	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-	-	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-	-	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-	-	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-	-	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Detailed of Lamp and Lighting Fixture. (Continued)

[illegible]	[illegible]	[illegible]	[illegible]	No. of Lamp	Lamp per Fixture	Lighting Fixture	[illegible]	Ballast Loss (Watt)	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Detailed of Lamp and Lighting Fixture. (Continued)

[illegible]	[illegible]	[illegible]	[illegible]	No. of Lamp	Lamp per Fixture	Lighting Fixture	[illegible]	Ballast Loss (Watt)	[illegible]
		[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]
		14 [illegible]	[illegible]	[illegible]		[illegible]		[illegible]	[illegible]
		14 [illegible]	[illegible]	[illegible]		[illegible]		[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]		[illegible]		[illegible]	[illegible]
		14 [illegible]	[illegible]	[illegible]		[illegible]		[illegible]	[illegible]

Detailed of Lamp and Lighting Fixture. (Continued)

[illegible]	[illegible]	[illegible]	[illegible]	No. of Lamp	Lamp per Fixture	Lighting Fixture	[illegible]	Ballast Loss (Watt)	[illegible]
		[illegible]	[illegible]		[illegible]	[illegible]	[illegible]		[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Detailed of Lamp and Lighting Fixture. (Continued)

No	[illegible]	[illegible]	[illegible]	No. of Lamp	Lamp per Fixture	Lighting Fixture	[illegible]	Ballast Loss (Watt)	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Detailed of Lamp and Lighting Fixture. (Continued)

[illegible]	[illegible]	[illegible]	[illegible]	No. of Lamp	Lamp per Fixture	Lighting Fixture	[illegible]	Ballast Loss (Watt)	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]

Detailed of Lamp and Lighting Fixture. (Continued)

[illegible]	[illegible]	[illegible]	[illegible]	No. of Lamp	Lamp per Fixture	Lighting Fixture	[illegible]	Ballast Loss (Watt)	[illegible]
		[illegible]	[illegible]	[illegible]		[illegible]		I	[illegible]
		[illegible]	[illegible]	[illegible]		[illegible]		I	[illegible]
		[illegible]	[illegible]	[illegible]		[illegible]		I	[illegible]
		[illegible]	[illegible]	[illegible]		[illegible]		I	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]		I	[illegible]
		[illegible]	[illegible]	[illegible]		[illegible]		I	[illegible]
		[illegible]	[illegible]	[illegible]		[illegible]		I	[illegible]
		[illegible]	[illegible]	[illegible]		[illegible]		I	[illegible]
		[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]

[illegible] Detailed of Lamp and Lighting Fixture. (Continued)

[illegible]	[illegible]	[illegible]	[illegible]	No. of Lamp	Lamp per Fixture	Lighting Fixture	[illegible]	Ballast Loss (Watt)	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	Incandescent	[illegible]	[illegible]	[illegible]	Down light	[illegible]	[illegible]	[illegible]
		Incandescent	[illegible]	[illegible]	[illegible]	Down light	[illegible]	[illegible]	[illegible]

Detailed of Lamp and Lighting Fixture. (Continued)

[illegible]	[illegible]	[illegible]	[illegible]	No. of Lamp	Lamp per Fixture	Lighting Fixture	[illegible]	Ballast Loss (Watt)	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	N	N	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	N	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	N	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Detailed of Lamp and Lighting Fixture. (Continued)

[illegible]	[illegible]	[illegible]	[illegible]	No. of Lamp	Lamp per Fixture	Lighting Fixture	[illegible]	Ballast Loss (Watt)	[illegible]
		Incandescent	[illegible]	[illegible]		Down light	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	Fluorescent	[illegible]	[illegible]		Exposed	[illegible]	[illegible]	[illegible]
		Incandescent	[illegible]	[illegible]			[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]

Detailed of Lamp and Lighting Fixture. (Continued)

[illegible]	[illegible]	[illegible]	[illegible]	No. of Lamp	Lamp per Fixture	Lighting Fixture	[illegible]	Ballast Loss (Watt)	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]

Detailed of Lamp and Lighting Fixture. (Continued)

No.	[illegible]	[illegible]	[illegible]	No. of Lamp	Lamp per Fixture	Lighting Fixture	[illegible]	Ballast Loss (Watt)	[illegible]
		Incandescent	[illegible]	[illegible]	[illegible]	Hanging	-	-	[illegible]
		Spot light	[illegible]	[illegible]	[illegible]	Down light	-	-	[illegible]
[illegible]	Car park	Incandescent	[illegible]	[illegible]	[illegible]	Down light	-	-	[illegible]
	Corridor								
[illegible]	[illegible]	Fluorescent	[illegible]	[illegible]	[illegible]	Exposed	[illegible]	[illegible]	[illegible]
		Fluorescent	[illegible]	[illegible]	[illegible]	Exposed	[illegible]	[illegible]	[illegible]
[illegible]	Squash room	Fluorescent	[illegible]	[illegible]	[illegible]	Obscure	[illegible]	[illegible]	[illegible]
		Fluorescent	[illegible]	[illegible]	[illegible]	Obscure	[illegible]	[illegible]	[illegible]
[illegible]	Engineering	Fluorescent	[illegible]	[illegible]	[illegible]	Exposed	Iron core	[illegible]	[illegible]

Detailed of Lamp and Lighting Fixture. (Continued)

[illegible]	[illegible]	[illegible]	[illegible]	No. of Lamp	Lamp per Fixture	Lighting Fixture	[illegible]	Ballast Loss (Watt)	[illegible]
	staff room	Fluorescent	00	[illegible]	[illegible]	Exposed	[illegible]	[illegible]	[illegible]
		Fluorescent	00	[illegible]	[illegible]	Obscure	[illegible]	[illegible]	[illegible]
[illegible]	Store	Fluorescent	[illegible]	[illegible]	[illegible]	Exposed	[illegible]	[illegible]	00
		Fluorescent	[illegible]	[illegible]	[illegible]	Exposed	[illegible]	[illegible]	[illegible]
[illegible]	Car park stair	Fluorescent	[illegible]	[illegible]	[illegible]	Obscure	[illegible]	[illegible]	[illegible]
[illegible]	MDB room	Fluorescent	[illegible]	00	[illegible]	Exposed	[illegible]	[illegible]	[illegible]
[illegible]	Tennis court	Incandescent	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]

Table 3.3. Data of Illumination Measurement.

Room	Maximum	Minimum	Average
In front of guest room	21	13	17
Fire exit stair	18	11	15
Central stair	22	16	19
Fitness room	129	69	99
Lobby	320	152	236
Swimming pool toilet	95	80	85
Lobby toilet	110	85	98
Conference room	620	140	397
Maid room	96	85	91
Basement	550	135	343
TDS office	720	102	210
Laundry	115	82	99
Fire exit	22	12	17
Office	236	73	125
Guest room 1^{st}-7^{th} floor (A,C)	250	47	134
Guest room 8^{th}-12^{th} floor (A,C)	102	65	84
Guest room 1^{st}-7^{th} floor (B,D)	216	18	140
Guest room 8^{th}-12^{th} floor (B,D)	338	43	154
PH (A,B,C,D)	496	28	120
Lift machine room	112	85	99
Car park	46	11	29
Squash room	360	250	305

Table 3.3. Data of Illumination Measurement. (Continued)

Room	**Maximum**	**Minimum**	**Average**
Engineering staff room	144	101	123
Store	26	18	22
Electrical room	22	15	19
Average of illumination	207	69	123

Energy Conservation Potential of Case A: LCL Apartment.

Analysis of Existing System

The existing system is composed of 4 types of lamps; Incandescent, fluorescent, compact fluorescent and spot light. All lamps are used for indoor and also outdoor lighting. Electrical energy consumption of lamps are as follows:

Fluorescent	66,370	kW
Compact fluorescent	5,081	kW
Spot light	11,440	kW
Incandescent	89,665	kW

The main energy consumption is consumed by incandescent lamps. The use of incandescent lamps is in guestroom areas and also on interior lighting at the lobby.

For a general analysis, the total area is 14,975 Sq.m. and total energy consumption is 172,556 watt. Then, the specific energy use index for this building is 11.52 W / Sq.m. That is very low compared with the standard from Ministerial Regulation (16 W/ Sq.m.). However, in the other survey data, LCL apartment still has other energy conservation potentials and the building owner will get the saving.

According to the survey data of LCL apartment, the conservation potential can be considered on the following:

(1) Lamp and lighting existing system

(2) Engineering constrain

(3) Financial constrain

(4) Human and day-to-day constrain

Lighting for non-task areas

For the measures that do not require investment or no cost measures, building manager should campaign the policy of measures and stimulate the users to pay attention to or keep in mind for an energy saving policy such as switching off when going out or not using if unnecessary. For the area that is not a work place, building manager should separate the circuit of lighting and also other electrical equipment. The suggestion is the manager should separate lighting by working area for switch off as zoning when no one is working. This measure is no cost and possible to save the energy.

Modification of existing system

According to the general dada and survey data, the measures that building should consider are as follow:

(a) Incandescent replacement

Existing system

The survey data assist the building manager or energy manager that the building has a potential for saving by incandescent replacement measures. Buildings still use incandescent lamp in several area.

Table 3.4. Survey Data of Incandescent Lamps.

Rated (Watt)	No. of Lamps
25	17
40	1,171
60	204
100	279
Total	1,671

Suggestion for improvement

For this measure, the energy manager or building manager should investigate the feasibility for replacing incandescent lamps with compact fluorescent.

Technical analysis

The building manager should consider technical aspects by comparing the existing data of energy consumed by incandescent lamps with the energy consumption of compact fluorescent lamps.

Table 3.5. Energy Consumption of Compact Fluorescent Lamps.

Rated (W)	**Equivalent (W)**	**No. of Lamps**	**Energy Saving (W)**
9	25	17	272
9	40	1,171	36,301
13	60	204	9,588
25	100	279	20,925
Total		1,671	67,086

Then,

Energy saving = 67,086 x 365 x 7 x 0.75 / 1,000

= 128.553.55 kWh / year

Energy saving = 128,553.55 x 2.04

= 262,249 Bahts / year

By considering on technical aspects, the building saves energy cost for 262,249 Bahts per year and energy saving is 128,553.55 kWh per year. This saving amount is a large portion of energy consumed by the building save from this measure.

Financial analysis

Payback period

compact fluorescent cost is 285 - 295 Bahts/ lamps and no labor cost. The investment costs for this measure are as follows:

Table 3.6. Compact Fluorescent Investment.

Rated (W)	No. of Lamp	Unit Cost (Bahts)	Investment (Bahts)
9	17	285	4,845
9	1,171	285	333,735
13	204	285	58,140
25	279	295	82,305
Total	1,671	-	479,025

Then,

Total cost = 479,025 Bahts

Cost saving = 262,249 Bahts / year

Payback period = 1.82 year

Net present worth

i = 9 % (From KTB information)

Life time = 3 year

PW = - 479,025 + 262,249 (P/F, 9%,1) + 262,249 (P/F, 9%,2) + 262,249 (P/F, 9%,3)

PW = 184,989

Internal rate of return

Life time = 3 year

0 = - 479,025 + 262,249 (P/F, IRR%,1) + 262,249

(P/F, IRR%,2) + 262,249 (P/F, IRR%,3)

IRR = 29.5 %

(b) Energy saving lamp replacement

Existing system

The survey data identify, for this measures the building still uses low efficiency of fluorescent lamp as follows:

Table 3.7. Energy Saving Lamp Replacement.

Rated (W)	No. of Lamp
20	79
40	115
Total	194

Suggestion for improvement

Technical analysis

This measure will replace fluorescent lamp 20 and 40 W with 18 and 36 W lamps that have equal of illuminance. The building can save energy consumption as shown in the next table:

Table 3.8. Energy Saving Gain of Energy Saving Lamp Replacement.

Rated (W)	**Existing Lamp (W)**	**No. of Lamp**	**Energy Saving (W)**
18	20	79	158
36	40	115	460
Total		194	618

Then,

Energy saving	=	618 x 365x7x0.75 / 1,000	kWh / year
		1,184.24	kWh / year
Cost saving	=	1,184.24 x 2.04	Bahts / year
	=	2,416	Bahts / year

After the building uses the higher efficiency lamp they can save energy of 1,184.24 kWh per year and cost saving is 2,416 Bahts per year.

Financial analysis

Generally, this measure is a no cost measure. The building may replace the existing lamp with a higher efficiency lamp when the life time of the existing lamp is over. Costs of lamps are 62 Bahts per lamp for 18 W and 72 Bahts per lamp for 36 W.

(c) Luminaires replacement

Existing system

The installation of lighting fixture in this building that have potential of improvement for energy saving are shown in following table:

Table 3.9. Luminaires Replacement.

Fluorescent (W)	Type of Lighting Fixture	No. of Lighting Fixture
2x36 W	Obscure	69
2x36 W	Exposed	6
4x36 W	Obscure	11
3x18 W	Prismatic	2
2x18 W	Exposed	3
2x18 W	Obscure	113
4x18 W	Obscure	5
4x18 W	Prismatic	2
Total		211

Suggestion for improvement

Technical analysis

This measure may install a reflector with the existing lighting fixture. Technically, the lighting that can be modified are shown in the above table. The reflector will let the lamp release the illuminant for double. Then the building can reduce the 1 lamp per lighting fixture and illuminant still the same. Reflector efficiency is 80 - 100 % of existing illumination.

Energy saving = [(86 x 28) + (125x46)] x 365 x 7 x 0.75 / 1000 kWh/year

= 14,288 kWh/year

Cost saving = 14,288 x 2.04 Bahts/year

= 29,147.52 Bahts/year

Financial analysis

Payback period

Table 3.10. Luminaires Replacement Investment.

Rated (W)	Type	No. of Lamp	Unit Prices (Bahts)	Total (Bahts)
1x36W	Obscure	74	706	52,212
1x36W	Exposed	1	706	706
3x36W	Obscure	11	919	10,107
2x18W	Prismatic	2	509	1,019
lx18W	Exposed	3	408	1,225
lx18W	Obscure	113	408	46,124
3x18W	Obscure	5	576	2,880
3x18W	Prismatic	2	576	1,152
Total		211	-	115,424

Labor cost	=	250	Bahts / unit
Total labor cost	=	52,750	Bahts
Grand total cost	=	168,174	Bahts
Cost saving	=	29,147.52	Bahts / year
Payback period	=	5.76	year

Net present worth

i	=	9 % (From KTB information)
Life time	=	10 year

PW = - 168,174 + 29,147 (P/F, 9%,1) + 29,147 (P/F, 9%,2) + 29,147 (P/F, 9%,3) + 29,147 (P/F, 9%,4) + 29,147 (P/F, 9%,5) + 29,147 (P/F, 9%,6) + 29,147 (P/F, 9%,7) + 29,147 (P/F, 9%,8) + 29,147 (P/F, 9%,9) + 29,147 (P/F, 9%,10)

PW = 19,171

Internal rate of return

Life time = 10 year

0 = - 168,174 + 29,147 (P/F, IRR%,1) + 29,147 (P/F, IRR %,2) + 29,147 (P/F, IRR %,3) + 29,147 (P/F, IRR %,4) + 29,147 (P/F, IRR %,5) + 29,147 (P/F, IRR %,6) + 29,147 (P/F, IRR %,7) + 29,147 (P/F, IRR %,8) + 29,147 (P/F, IRR %,9) + 29,147 (P/F, IRR %,10)

IRR = 11.5 %

(d) Ballast replacement

Existing system

With the fluorescent lamps, there are installing iron core ballast. Iron core ballast have power loss for 10 W per lamp.

Lamps that can be replaces with low watt loss ballast are;

Table 3.11. Ballast Replacement.

Rated (W)	**Type**	**No. of Lamp**
18	Iron core	607
36	Iron core	702
Total		1,309

Suggestion for improvement

Technical Analysis

Energy saving measure is replacing existing ballasts with low watt loss ballasts that consume lower power loss save energy for 4.5 W per lamp.

Then,

Energy saving	=	1,309 x 4.5 x 365 x 7 x 0.75 / 1,000	kWh/year
	=	11,287.7	kWh/year
Cost saving	=	11,287.7 x 2.04	Bahts/year
	=	23,026.85	Bahts/year

Financial analysis

Payback period

Cost of low watt loss ballast for 18 W and 36 W fluorescent lamp is 116 Bahts per lamp. Then , total costs for replace of low watt loss ballast with existing luminaires are:

Table 3.12. Ballast Replacement Investment.

Rated (W)	**No. of Lamp**	**Unit Prices (Bahts)**	**Total cost (Bahts)**
18	607	116	70,509
36	702	116	81,544
Total	1,309	-	152,053

Labor cost	=	30	Bahts / lamp
Total labor cost	=	39,270	Bahts
Grand total	=	191,323	Bahts

Cost saving = 23,026.89 Bahts / year

payback period = 8.31 year

Net present worth

9 % (From KTB information)

Life time = 5 year

PW = - 191,323 + 23026.89 (P/F, 9%,1) + 23026.89 (P/F, 9%,2) + 23026.89(P/F, 9%,3) + 23026.89(P/F, 9%,4) + 23026.89 (P/F, 9%,5)

PW = - 101,711

Internal rate of return

Life time = 5 year

0 = - 191,323 + 23026.89 (P/F, IRR%,1) + 23026.89(P/F, IRR %,2) + 23026.89(P/F, IRR %,3) + 23026.89(P/F, IRR %,4) + 23026.89(P/F, IRR %,5)

IRR = 0 %

Daylighting

The LCL apartment can be approached by the daylighting measure at the area of the guestroom corridor and lobby. From the consideration on building data, the windows with film coating still let the light pass through it; at the lobby area, the advantages of daylighting is the natural view of outside building. The energy saving for this measure is approximately 3 % of energy consumption by lighting system and no investment. The building just prepares the garden view for the customers to sight from the inside of the building. Although this measure hardly saves energy it makes the more attractive view for the lobby area. The consequence is the more customers for lobby areas restaurants. For the corridor area, buildings should be managed by the switching off and on of lamps one after another. Light from outside is adequate for visibility in the day time.

Lighting System Control

For this measure, the building already installed the key switches for each guestroom. Then the lighting and other electrical appliance be switched off when no one in the room. The other control devices such as proximity sensor does not proper for this building. Since this building is used as a services apartment, there are a lot of public areas that serve for general people. On the other hand, the building still uses the normal switch to control the lighting in all public area and landscape lighting. Then control devices such as time switch are suitable to control the lighting that need to control as a routine work and photoelectric switch is appropriate to control the lighting for landscape and outdoor area that depend on sunlight impact.

The advantages of automatic control for business buildings such as service apartments are the more comfort for building managers to control the lighting and manage the staff. That is another important thing for buildings that have financial constraints and also staff shortage. It is wasteful for managers to manage the staff who only switch on and off the lighting system. The control device will replace fort their duty and manager can manage the staff in planning or scheduling the maintenance program instead. The building manager should focus on the devices that help manage the operation of the building.

The costs of control devices such as photoelectric switches, proximity switches or timer switches, are not high investment for this measure but the payback for this measure is that the manager can make efficient use of the human resource.

System Maintenance

Approached on system maintenance, building managers have to be leaders for the maintenance program for each system in the building. First, the system maintenance should focus on preventive maintenance. The building has a maintenance schedule regularly since the building has been regarded the important of prompt building will make customers satisfied when they ask for services. Building managers just control the maintenance staff to keep inspecting the working conditions and reporting as a routine work. From the previous approach, the manager may use the automatic control system to replace the staff for some routine but not created work. The other important thing is, the data that staff collect from routine work should be analyzed by staff to recheck the working conditions of equipment and let the staff adjust the system in normal conditions. This will help the building save energy and costs also.

Conclusion

The energy consumption of lighting system for LCL apartment is 26 % of total energy consumption. Building managers or energy managers should pay more attention to lighting system although it consumes a small portion but it has potential for energy saving program.

Factors that affect costs of electricity are users and equipment. Energy managers should approach standard measures and study the feasibility of each measure. The first priority is the no-cost measure, system maintenance that keep machine or equipment working in normal conditions compared with the standard from manufacturers or specification. This measure is the main task of building managers to lead and control engineering staff to keep running the maintenance schedule and analyze the problems or trouble shooting. LCL apartment has maintenance staff adequate for running the maintenance program. The manager just organize and control teamwork to achieve the schedule. System maintenance assists managers to save costs for replacing with new machine or equipment safe for use with the highest efficiency and durability.

LCL apartment has potential as no cost measure, daylighting and lighting for non-task areas that can save energy for buildings. For acceptance of the top management, the building manager needs to stimulate them by showing the cost saving or amount of money that they will get from the energy saving measures. The measures that are appropriate LCL apartment are;

(1) Incandescent Replacement

(2) Energy saving lamps replacement

(3) Luminaires modification

(4) Ballast replacement

According to the above measures, building managers have to consider on technical and financial aspects. Technical aspects from the analysis section shows that all of 4 measures are possibles. The measures are:

(1)	Incandescent Replacement	38	% of lighting consumption
(2)	Energy saving lamps replacement	0.03	% of lighting consumption
(3)	Luminaires modification	4.33	% of lighting consumption
(4)	Ballast replacement	3.41	% of lighting consumption

However, the financial aspect is the most important for decision making if a building needs investment. The financial analysis section shows that some measures can save more energy but it does not work. The payback period shows the rough payback time that an investor will get the money back .The investor can use payback information together with the present-worth and internal rate of return (IRR). PW and IRR give information that involve the decreasing of money value with timeline and interest rate that investor will get. For the comparison, LCL apartment use MARR = 11 % and interest rate 9 % for decision making. Then the two measures that are appropriate are:

(1) Incandescent replacement

(2) Luminaires modification

For the energy saving lamp replacement buildings have no need to invest in one time payment but its can replace lamps by lamps when the life time of a lamp has expire.

The another appropriate method for saving energy for LCL apartment is the control system. Managers have to search the new technology that is suitable for their buildings because at present there are several control devices of products that match buildings on prices and system also. The control system is suitable for buildings such as LCL apartment that have limited staff and have routine work.

The financial aspect will support information that influences to decision making of building owners significantly. Managers should have a plan for investment by first priority till last and prepare the total of cash inflow and outflow of measures as a 3-5 years master plan. This proposal format will let the investor or owner be willing to support this plan to achieve the target of energy conservation gain.

In parallel, energy managers or building managers should set up the internal training program to keep the conservation in employees minds The promotion poster or campaign notice are not appropriate to promote the conservation in working areas (since the clean and nice view). However, the energy saving program at least will save cost of operation and this is also the point to promote the company and build the company image in terms of the environmental and energy conservation. This point is interesting for foreign customers. Moreover, energy conservation is part the ISO 14000 requirement also.

3.2 Case B: BTG Office and Warehouse

General Description

This building was established in January 1953. It is 46 years old office building that is used as the head office and the factory warehouse. The factory produces glass bottles. The building construction is made of brick and cement double coating. The column is the reinforcement concrete. This office has 2 storeys that all part use as office area. The windows are wooden frame with transparent glass and plastic curtains. The windows area is 40 % of outside wall area. The roof has no insulation. The warehouse part does not have windows.

The building consumes energy for 24 hours-operation and 365 day per year. Electricity that is use for the building is for lighting. Air conditioning and other system. The installation of system is conventional designed and need maintenance. The details of system and energy conservation potential are shown in the next section.

General Data

Building 's Name	BTG Office
Address	Rasburana Road, Bangkok
Range of service	Office and Warehouse of factory
Operation Period	24 hours per day, 365 days per year
Total area	14,280 m^2
Building Area	12,280 m^2
Parking Lot	2,000 m^2

Energy Consumption of Building

Electric Energy Consumption

Energy consumption	4,034,330	kW-hr / Year
Demand Peak	1,200	kW

Transformer	333x3	kVA
	500x3	kVA
Voltage	12 kV / 416 V / 240 V	
Power factor	0.88	
Electric prices	1.78	Bahts / kWh

Proportional of Electrical Energy Consumption

Air Conditioning System	54.2
Lighting System	29.8
Motor	11
Other	5

Figure 3.2. Proportional of Energy Consumption for BTG Office and Warehouse.

Detailed of Lighting Measurement

Table 3.13. The Total Quantity of Lamp That Used in BTG Office and Warehouse.

No.	Type	Rated (W)	Quantity	Total (W)	Ballast Loss (W)	Grand Total (W)
1	Fluorescent	36	2,681	96,516	26,810	123,326
2	Fluorescent	18	30	540	300	840
3	Mercury	150	94	14,100	-	14,00
4	Mercury	250	109	27,250	-	27,250
5	Mercury	500	12	6,000	-	6,000
6	Sodium	1200	1	1,200	-	1,200
7	Halogen	500	13	6,500	-	6,500
8	Halogen	1000	5	5,000	-	5,000
Total			2,945	157,106	27,110	184,216

Lighting Measurement

Detailed of Lamp and Lighting Fixture.

[illegible]	[illegible]	[illegible]	[illegible]	No. of Lamp	Lamp per Fixture	Lighting Fixture	[illegible]	Ballast Loss (Watt)	Total (Watt)
[illegible]	[illegible]	Fluorescent	[illegible]	[illegible]	[illegible]	Exposed	Iron core	[illegible]	[illegible]
[illegible]	Lobby	Fluorescent	[illegible]	[illegible]	[illegible]	Obscure	Iron core	[illegible]	[illegible]
[illegible]	Machine room	Mercury	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	Corridor	Fluorescent	[illegible]	[illegible]	[illegible]	Exposed	[illegible]	[illegible]	[illegible]
[illegible]	Work Shop	Fluorescent	[illegible]	[illegible]	[illegible]	Exposed	Iron core	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	Warehouse 1	Mercury	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Detailed of Lamp and Lighting Fixture. (Continued)

[illegible]	[illegible]	[illegible]	[illegible]	No. of Lamp	Lamp per Fixture	Lighting Fixture	Ballast	Ballast Loss (Watt)	[illegible]
	Zone B								
[illegible]	Mechanical shop	Fluorescent	[illegible]	[illegible]	[illegible]	Exposed	Iron core	[illegible]	[illegible]
[illegible]	Warehouse 1	Mercury	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]
	Zone C	Fluorescent	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		Fluorescent	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	Guard room	Fluorescent	[illegible]	[illegible]	[illegible]	Transparent	Iron core	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	Purchase Dept	Fluorescent	[illegible]	[illegible]	[illegible]	Exposed	Iron core	[illegible]	[illegible]

[illegible]	[illegible]	[illegible]	[illegible]	No. of Lamp	Lamp per Fixture	Lighting Fixture	[illegible]	Ballast Loss (Watt)	Total (Watt)
		Fluorescent	[illegible]	[illegible]	[illegible]	Grille	Iron core	[illegible]	[illegible]
		Fluorescent	[illegible]	[illegible]	[illegible]	Prismatic	Iron core	[illegible]	[illegible]
[illegible]	Delivery**Dept**	Fluorescent	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		Fluorescent	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		Fluorescent	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	QA Dept	Fluorescent	[illegible]	[illegible]	[illegible]	Exposed	Iron core	[illegible]	[illegible]
		Mercury	[illegible]	[illegible]	[illegible]	Exposed		[illegible]	[illegible]
[illegible]	Warehouse 2 Zone A	Fluorescent	[illegible]	[illegible]	[illegible]	Exposed	Iron core	[illegible]	[illegible]
		Fluorescent	[illegible]	[illegible]	[illegible]	Obscure	Iron core	[illegible]	[illegible]
[illegible]	Warehouse 2 Zone B	Mercury	[illegible]	[illegible]	[illegible]	Exposed	[illegible]		[illegible]
[illegible]	Ground floor	Fluorescent	[illegible]	[illegible]	[illegible]	Exposed	Iron core	[illegible]	[illegible]

[illegible]	[illegible]	[illegible]	Rated (Watt)	No. of Lamp	Lamp per Fixture	Lighting Fixture	Ballast	Ballast Loss (Watt)	Total (Watt)
[illegible]	[illegible]	Mercury	[illegible]	[illegible]	[illegible]				[illegible]
	[illegible]	Fluorescent	[illegible]	[illegible]	[illegible]	Exposed	Iron core	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

No	[illegible]	[illegible]	[illegible]	No. of Lamp	[illegible]	Lighting Fixture	Ballast	Ballast Loss (Watt)	Total (Watt)
		Fluorescent	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		Fluorescent	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		Fluorescent	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]		[illegible]	[illegible]
		[illegible]	[illegible]		[illegible]	[illegible]		[illegible]	[illegible]
		[illegible]	[illegible]		[illegible]	[illegible]		[illegible]	[illegible]
		[illegible]	[illegible]		[illegible]	[illegible]	—	[illegible]	[illegible]
		[illegible]	[illegible]		[illegible]	[illegible]	—	[illegible]	[illegible]
		[illegible]	[illegible]		[illegible]	[illegible]		[illegible]	[illegible]
[illegible]	Material	Fluorescent	[illegible]		[illegible]	Exposed	Iron core	[illegible]	[illegible]
[illegible]	Warehouse 1	Fluorescent	[illegible]	[illegible]	[illegible]	Exposed	Iron core	[illegible]	14,720
	Zone D	Mercury	[illegible]		[illegible]	Exposed			3,000

[illegible]	[illegible]	[illegible]	[illegible]	No. of Lamp	Lamp per Fixture	Lighting Fixture	Ballast	Ballast Loss (Watt)	Total (Watt)
		Fluorescent	[illegible]	[illegible]	[illegible]	Prismatic	Iron core	[illegible]	[illegible]
		Fluorescent	[illegible]	[illegible]	[illegible]	Grille	Iron core	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Energy Conservation Potential of Case B: BTG Office and Warehouse

Analysis of existing system

BTG office and warehouse has 3 buildings; main office and 2 building of warehouse. Most of lamp use is fluorescent and HID lamps respectively. Electrical consumption of lamps is as follows:

Fluorescent	124,166
Mercury	47,350
Sodium	1,200
Halogen	11,500

For a general analysis, the total area is 12,280 Sq.m. and total energy consumption of lighting is 184,216 W. Then, consumption of electric lighting equipment is 15 W / Sq.m.. That is lower than 16 W / Sq.m. according to the standard from ministerial regulations.

Lighting for non-task area

The non-task areas for BTG office and warehouse are the office area that does not work utilization such as the meeting room. This measure that campaigns for the switching off of lightswhen not in use. For warehouse areas, there are use areas all the time but not all areas: for delivered, stock and inventory checking for products. Then this measure is not appropriate for this building and does not have energy saving potential.

Modification of existing system

The appropriate measures for this building that are possible to save energy are as follows:

(a) Luminaires modification

Existing system

In general, fixture types and numbers which can be improved are as shown:

Table 3.15. Detailed of Luminaires Modification.

Rated (W)	Type of lighting fixture	No. of lighting fixture
2x 36	Exposed	901
Total		901

Suggestion for improvement

Technical analysis

The building manager should consider to install reflector add with existing lighting fixtures. If they use a reflector fixture, light intensity will increase around 100%. Then the number of lamps per fixture can be decreased by one.

Then,

Energy saving	=	(46 x 901) x 365 x 24 x 0.75 / 1,000	kWh/year
	=	272,300	kWh/year
Cost saving	=	272,300 x 1.78	**Bahts/year**
	=	484,695	**Bahts/year**

Financial analysis

Payback period method

Investment costs to improve existing fixtures with reflector and decrease the lamps are as follows :

Table 3.16. Luminaires Modification Investment.

Rated (W)	Type	No. of Fixture	Unit Cost	Total Cost
lx 36	Exposed	901	706	636,106
Total		901		636,106

Labor cost = 250 Bahts/ unit

Total labor cost = 225,250 Bahts

Total investment cost = 861,356 Bahts

Cost saving = 484,695 Bahts/year

Payback period = 1.78 year

Present-worth method

I = 9 % (From KTB Information)

Life time = 10 year

PW = -861,356 + 484,695 (P/F,9%,1) + 484,695 (P/F,9%,2) + 484,695 (P/F,9%,3) + 484,695 (P/F,9%,4) + 484,695 (P/F,9%,5) + 484,695 (P/F,9%,6) + 484,695 (P/F,9%,7) + 484,695 (P/F,9%,8) + 484,695 (P/F,9%,9) + 484,695 (P/F,9%,10)

PW = 2,250,290

Internal rate of return

Life time = 10 year

0 = -861,356 + 452,382 (P/F,IRR%,1) + 452,382 (P/F, IRR %,2) + 452,382 (P/F, IRR %,3) + 452,382 (P/F, IRR %,4) + 452,382 (P/F, IRR %,5) + 452,382 (P/F, IRR %,6) + 452,382 (P/F, IRR %,7) + 452,382 (P/F, IRR %,8) + 452,382 (P/F, IRR %,9) + 452,382 (P/F, IRR %,10)

IRR > 50 %

(b) Ballasts Replacement

Existing system

Existing fixtures use iron core ballasts which can be improved as follow;

Table 3.17. Datailed of Ballasts Replacement.

Rated (W)	**Ballast Type**	**No. of Lamps**
18	Iron core	115
36	Iron core	2,411
Total		2,526

Suggestion for improvement

Technical analysis

From the test with 36 W and 18 W fixture which use iron core ballasts compares to fixture with low watt loss ballasts. Low loss ballast have advantages such as less ballast loss, lower temperature, longer lifetime, less noise and less maintenance.

Then,

Energy saving =(2,526) x 4.5 x 365 x 24 x 0.75/ 1,000 kWh / year

	=	74,680	kWh / year
Cost saving	=	74,680 x 1.78	Bahts/ year
	=	132,929	Bahts/ year

Financial analysis

Payback period method

Table 3.18. Ballasts Replacing Investment.

Rated (W)	No. of Lamp	Unit Cost (Bahts)	Total Cost
18	115	116	13,340
36	2,411	116	279,676
Total	9,576	-	293,016

Labor cost = 30 Bahts / unit

Total labor cost = 368,796 Bahts

Cost saving = 132,929 Bahts / year

Payback period = 2.77 year

Present-worth method

I = 9% (From KTB information)

Life time = 5 year

PW = -368,796 + 132,929 (P/F,9%,1) + 132,929(P/F,9%,2) + 132,929(P/F,9%,3) + 132,929(P/F,9%,4) + 132,929 (P/F,9%,5)

PW = 148,538

Internal rate of return

Attractive period = 5 year

0 = -368,796 + 132,929(P/F,IRR%,1) + 132,929(P/F, IRR %,2) + 132,929(P/F, IRR %,3) + 132,929(P/F, IRR %,4) + 132,929 (P/F, IRR %,5)

IRR = 23.5 %

Daylighting

For the warehouse areas, the manager cannot apply daylighting utilization since the affect with quality of product. The office area still use some light from natural light source but it is not much saving energy from this measure. For this building there are not significant saving the energy.

Lighting system control

The system control devices for the warehouse is not complicated one. The appropriate way is just group the lighting circuit to match with the pattern of utilization of area. By this measure, the building user can switch off and on for a particular area not the whole area. The other control device is a photoelectric switch that may be used with timer switch to control the lighting at the outdoor area, sign board and corridor as night light. For the details of the control device, the building manager should contact the supplier directly because there are several kinds and features that meet to each application of building. Suppliers shall give more details on technical and financial information.

System maintenance

The maintenance program is always done for this building. From survey contents, the lighting fixture condition are clean especially in the office area. In the warehouse area, the conditions are quite clean but still need to be clearer. It is installed at high ceiling and thus is hard to clean it. However, the maintenance schedule should focus on cleaning and inspecting the working condition of equipment for loss of preventive action. This measure just keeps it working in normal conditions but it saves costs for use of the equipment in longer time.

Conclusion

Energy consumption of lighting system for BTG office and warehouse is 29.8 % of all electric consumption. Index of energy consumption for lighting is 15 W/m^2 close to the standard 16 W/ m^2. Thus, energy managers or building managers should find the method for saving more energy. From survey data, the standard should be approached for all and decide what measures have potential. Then the manager should start at no cost measure but for BTG office and warehouse the no cost measure such as lighting for non-task areas and daylighting does not save energy and costs as a big portion. The system maintenance for BTG is always done and BTG manager still running the maintenance schedule as well. Therefore, measures that save the energy as a large portion is modification existing system; the measures are as follows;

(1) Luminaires modification

(2) Ballasts replacement

From technical aspect consideration, the calculation shows that the potential of modification is in very high potential. The proportion of energy saving gain are

(1) Luminaires modification 22 % of lighting consumption

(2) Ballasts replacement 6.17 % of lighting consumption

The technical analysis that get from calculation is in high potential of conservation. The next step is to analyze the financial aspect to ask for the support from the top management. After the financial calculation, the result of payback period, PW and IRR should be compared with the predetermined figure. For BTG, the measure is above attractive level both technical and financial aspect. Then the manager should propose the target and plan of the energy conservation program by the technical and financial information to support the planning for the investor decision making. Another method that is suitable for BTG is internal training and promotion campaign. BTG has a lot of employees as a workers ,then promotion campaign such as small poster or notice paper to attach to the board or wall at working areas will let them start to know the saving measure and cooperate with energy saving as a routine. Internal training is a method to stimulate every level of employees to keep the company achieving the goal of saving. For the organization such as BTG, the cooperation of employees is the most important factor for achieving the target of the conservation program.

IV. CONCLUSIONS

What we get from the research and study of energy conservation by improvement lighting system performance. The basic concepts of energy conservation are preventing the loss and more efficient utilization. The building should survey and analyze the loss of energy that occurs and find the way to get rid of the loss or transfer it into the useful energy. For the lighting system the standard measures are;

(1) Lighting for non-task area

(2) Modification of existing system

(3) Daylighting

(4) Lighting system control

(5) System maintenance

The building manager has to analyze the existing system to generate energy conservation potential the building has. For the analysis of existing system, the manager should collect the relevant data that support the energy saving program at first technical data of lighting system for analysing the current situation.

The conservation potential should considerable on the following;

(1) Lamp and lighting existing system

(2) Engineering constraints

(3) Financial constraints

(4) Human and day-to-day constrain

4.1 Lighting for Non-task Area

Table 4.1. Comparison of Lighting for Non-task Area Measure.

CASE A : LCL Apartment	**CASE B : BTG Office and Warehouse**
The general description shows that the LCL Apartment have a potential on lighting for non-task area. Lighting for non-task area of LCL apartment is meeting room storeroom and some part of building that does not use for day-to-day working. This measure just the initial measure for stimulating the employees for energy saving program. The importance for LCL is characteristics of building as a services business, the measures that switch-off in non-task areas should not affect to the day-to-day working.	For the general room such as the meeting room at the BTG office after approached by this measure, they get the potential on this also. Moreover, the day-to-day working is in more fixed time than the services business. Then BTG office and warehouse can manage the switch-off lighting in non-task area more effectively. Managers can arrange the stock area or inventory areas that are never used or periodically used and switch it off in fixed time also.
Ideas to be applied in with General Buildings	
The general building that approach with lighting for the non-task area measure need to study the factor as follows: (1) Day-to-day working: If day-to-day working is a routine and fixed area. Building can switch-off lighting for non-task area as a large portion of energy saving gain. (2) Existing system: The existing system and building is also important. The	

Table 4.1. Comparison of Lighting for Non-task Area Measure. (Continued)

office that used working areas on efficiency condition may not have this potential. The existing system that has grouped lighting circuit as zoning will be implemented easily also. (3) Employees cooperation. This will affect to this measure can achieved or not. Because employees that use area or does not use area should switch off the lighting. (4) For this measure is no cost measure. It is an initial measure that stimulates the employees and lets the manager consider the easiest method to save energy. What are the ideas that are benefited from this approach? The building should start with the simplest methods to save energy and encourage the employees to cooperate with the program.

4.2 Modification of Existing System

Table 4.2. Comparison of Modification of Existing System Measure.

CASE A : LCL Apartment	CASE B : BTG Office and Warehouse
The first priority for energy saving in LCL apartment is no cost measures in modification. Buildings still use 20 W and 40 W fluorescent lamps then if they replace with 18 W and 36 W fluorescent lamp. They can save energy in small amount. If they replace immediately, the	BTG office and warehouse does not have incandescent lamps and normal efficiency fluorescent installed. Then Incandescent replacement and high efficiency fluorescent replacement do not approach with this building. Fluorescent lamps are mostly

Table 4.2. Comparison of Modification of Existing System Measure. (Continued)

CASE A : LCL Apartment	CASE B : BTG Office and Warehouse
salvage value of existing lamp should be consider and does not attractive to implemented. This measure just implemented when the life time of existing lamps has come. The second priority is incandescent replacement. LCL has 1,671 incandescent lamps installed which consumed energy in high level. Then energy saving calculation is 128,553.55 kWh / year, 38 % of total lighting consumption. That is a large portion of energy saving. Financial analysis is also support for investment in this measure. Payback period is short. Also the IRR and PW that is in high value compared with predetermined figure. The consideration for day-to-day working is incandescent lamps release a soft light for decorate lighting. The building should considered on the feeling of guests with the lighting in the	installed. Then the measure that we consider are luminaires replacement and ballast replacement. Luminaire modification by installed reflector with existing lighting fixture is very appropriate for BTG. The technical analysis proves that BTG can save energy in a very large amount. Because there are a lot of lighting fixtures that have potential for modification. Ballast replacement is another feasibility measure to be implemented for BTG building since the number of ballast that has potential. The technical analysis also supports that building will get energy saving in a large amount. Also financial analysis influences the decision for investment. Payback periods are not so long, IRR and PW is in attractive level for investment.

Table 4.2. Comparison of Modification of Existing System Measure. (Continued)

CASE A : LCL Apartment	CASE B : BTG Office and Warehouse
guestroom or other place because incandescent lamps may make the room more luxurious than fluorescent. The measure that may not implement is luminaire replacements. The technical analysis shows a small amount of energy saving when modified the lighting fixture with reflectors. Because the lighting that have potential are in small amounts. Also the financial analysis, the payback period is so long and IRR too close with the predetermined figure. Then the owner may not invest implement this measure. The measure that is not appropriate for implementation is ballast replacement.The technical aspect still shows energy saving gain in a small amount. Moreover, the financial analysis shows the payback period in a very long time , IRR less that predetermined figure	
and PW is a negative value. The cause is	

Table 4.2. Comparison of Modification of Existing System Measure. (Continued)

<table>
<tr><th>CASE A : LCL Apartment</th><th>CASE B : BTG Office and Warehouse</th></tr>
<tr><td>ballast prices are very high and amount of energy saving with low loss ballast is very little. Also the number of lamps and ballast that has potential is small.</td><td></td></tr>
<tr><th colspan="2">Ideas to be applied in with General Buildings</th></tr>
<tr><td colspan="2">The first thing before approach this measure is evaluation the existing system to find the loss way on the existing system. Such as low efficiency lamps installed , high energy consumed equipment or low efficiency equipment installed
Building should find the way to reduce the loss and try to eliminate the loss.
The measures that are suitable for each building depend on several factors:
(1) Incandescent Replacement: This measure depends on the number of lamps installed and the market prices of lamps
(2) Luminaires Replacement and ballast replacement: This measure depends on the number of lighting fixtures that have potential, working hours and the prices of equipment.
A very small amount of eqiupment and working hours makes the measures unattractive for investment.
What are the ideas that are benefited from this approach?
The main point is existing system with a high loss and consumed energy in large portion should be implemented in first priority. The condition is the financial analysis will support the information for decision making to implement investment. The building that uses low efficiency equipment in high level for a long period will</td></tr>
</table>

Table 4.2. Comparison of Modification of Existing System Measure. (Continued)

CASE A : LCL Apartment	CASE B : BTG Office and Warehouse
get more energy saving gain than the building that uses less.	

4.3 Daylighting

Table 4.3. Comparison of Daylighting Measure.

CASE A : LCL Apartment	CASE B : BTG Office and Warehouse
Daylighting utilization with LCL apartment is added to more building attractiveness and reduce the lighting that unnecessary to switch on for area that near the natural light source.	Daylighting utilization is not suitable for buildings such as a factory or a warehouse because the effect of daylight with product or task visibility.
Ideas to be applied in with General Buildings	
Daylighting utilization is appropriate for the area such as the corridor or rest area but not suitable for the working area that needs the stable light for work. Daylighting is not stable lighting, it depends on time, seasons and climate also. What are the ideas that are benefited from this approach? The point is we should get the light from a natural source as much as possible. The remarkable thing is the natural light must not suffer with day-to-day working and the main characteristic of building.	

4.4 Lighting System Control

Table 4.4. Comparison of Lighting System Control Measure.

CASE A : LCL Apartment	CASE B : BTG Office and Warehouse
Lighting control devices such as photo electric switches or timer switches are very appropriate with LCL apartment. In the case of using the engineering staff more effectively, the control devices will assist the staff in doing the routine work.	Lighting system control for BTG building to manage the schedule for switch on and off according to the working area in the warehouse and use the photoelectric switch to control the outdoor lighting in the nighttime.
Ideas to be applied in with General Buildings	
There are a lot of control devices in the market. The building has its own characteristics of utilization. But managers can apply the control devices to match with the existing system to get more comfortable in day-to-day working. By technically, automatic control devices is more useful but cost is still high. Then, when we need to apply with this measure it should take information for support and compare the energy saving gain and comfort with the devices cost. What are the ideas that are benefited from this approach? The modern technology will assist the manager to work more efficiently. The equipment will be helpful but not replace human being. Moreover, energy saving will result consequently.	

4.5 System Maintenance

Table 4.5. Comparison of System Maintenance Measure.

<table>
<tr><th>CASE A : LCL Apartment</th><th>CASE B : BTG Office and Warehouse</th></tr>
<tr><td>LCL apartment is a services business that needs more focus on the preventive maintenance program. The existing system is highly complicated system. Each system is important to business and could not failed. Then, managers should control and regulate the maintenance program to avoid the large failure of equipment.</td><td>System of BTG and warehouse is a simple system. The maintenance program always is done by staff. The general condition of the system is still good. BTG office and warehouse should keep this measure regularly.</td></tr>
<tr><th colspan="2">Ideas to be applied in with General Buildings</th></tr>
<tr><td colspan="2">For a general building that has a complicated system, system maintenance is very significant. A complicated system needs maintenance very closely and regularly. Manager should generate the schedule and follow up with the schedule. For the building that has a simple system, this measure is more easily implement by general staff and the technical staff.

What are the ideas that are benefited from this approach?

The system maintenance is very important for all systems in each building. We can divided them into two cases: Preventive maintenance and Passive maintenance. The implementations on this measure are planning and generating the maintenance schedule and follow up. In the other way to fix the equipment to working in normal conditions. The system maintenance will elongate the lifetime of equipment and use it</td></tr>
</table>

Table 4.5. Comparison of System Maintenance Measure. (Continued)

CASE A : LCL Apartment	CASE B : BTG Office and Warehouse
more efficiently.	

The saving gain that building will get after the improvement not only saves the costs of operation but also lengthens the period of operation and high efficiency utilization of machine or equipment.

For the implementation plan, the manager needs to summarize the measure ascends by the most priority till last. No cost measure is the first priority for implement. The checklist of measure that are possible and appropriate for the building. The checklist may help engineering staff to remind the easiest measures for energy saving program. The implementation plan can prepare as a 3-5 years plan. The master plan should comprise of action plan and cash inflow and outflow for the project. The payment of project or investment of project should share by interval of time not one time investment. What we will get, when we will do and how mush we invest, managers have to manage this for the optimum target.

The interdependency of measures is also focused. Since the measures will be implemented together, the saving gain will not be much as the only one measure implemented.

The policy of the top management or the company is very important. The commitment from top management is also important for implementation. Actually, before starting the project the committee or team needs to be set up. This team will do the analysis of the existing system, measures approach, set target and plan and implementation.

During the implementation, the project team need to monitor and control the project and evaluate the energy saving gain. The method to identify the trend of energy consumption of buildings is the energy consumption index. The index may different for each building and business. Product of business such as room rent, product, area or other divide by energy consumption. Buildings need to record this index to see the tendency of energy consumption. These will help to analyze and method to protect the loss also.

The objectives of this project just stimulate the building manager or a relevant person to knows the significant of energy management. The basic concept of energy management and energy audit for the lighting system is that they should do things by themselves internally for a small building. However, for details of energy audit according to ministerial act, the large building that is designated building needs to hire the registered consultants to audit the energy consumption and set the target and plan and implementation with agreement of buildings.

The last thing about the implementation of the energy conservation program is the cooperation of all employees in the organization.

APPENDIX A

MINISTERIAL REGULATION B.E. 2538

MINISTERIAL REGULATION B.E. 2538 Issued under the Energy Conservation Promotion Act B.E. 2535

(Prescribing the standards, Criteria and Procedures for Energy Conservation of Designated Building)

CHAPTER 3 ENERGY CONSUMPTION OF THE BUILDING

Article 4 Consumption of electric lighting within the building, excluding its parking area.

(1) In case of electric lighting within the building, it shall be at a sufficient illumination level for each category of works and by the acceptable method of engineering.

(2) Consumption of the electric lighting equipment in the building, not including its parking area, shall not exceed the following values:

Category of Building [(1)]	**Max. Lighting load (W/m^2 of Utilized Area)**
(a) Offices, hotels, Educational buildings, and Hospitals / Recovery Centers	16
(b) Shops, Supermarkets or Shopping Center [(2)]	23

(1) A building which is utilized for multi purposes shall be valued as in the table in accordance with its task area usage.

(2) Include electric lightings, generally used for advertisement of goods, except for those used in a goods store-front display window.

BIBLIOGRAPHY

English References

1. AIT-ADME RUE Team. Financial Evaluation of Energy Efficiency Projects. Bangkok: Energy Technology Program, School of Environment, Resources and Development, Asian Institute of Technology, 1995.

2. Blank, Leland T. and Anthony J. Tarquin. Engineering Economy. Third Edition. Singapore: Mcgraw-Hill, 1989.

3. Energy Victoria's Energy Information Center Energy Efficient Commercial Buildings. Victoria. Autralia: Renewable Energy Authority Victoria (Energy Victoria), 1994.

4. Loftness, Robert L. Energy Handbook. Second Edition. New York. USA: Van Nostrand Reinhold Company, 1984.

5. National Energy Management Program. Saving Energy Through Lighting Management. Australia: Standard Association of Australia, 1992.

6. Thumann, Albert. Handbook of Energy Audits. Fifth Edition. GA.USA: The Fairmont Press, 1998.

7. Turner, Wayne C. Energy Management Handbook. USA: Wiley Interscience, 1982.

Thai References

1. สำนักกำกับและอนุรักษ์พลังงาน กรมพัฒนาและส่งเสริมพลังงาน กระทรวงวิทยาศาสตร์ เทคโนโลยีและสิ่งแวดล้อม. คุณลักษณะเฉพาะของอุปกรณ์ประหยัดพลังงาน. กรุงเทพมหานคร: สำนักกำกับและอนุรักษ์พลังงาน กรมพัฒนาและส่งเสริมพลังงาน กระทรวงวิทยาศาสตร์ เทคโนโลยีและสิ่งแวดล้อม, 2542.

2. สำนักกำกับและอนุรักษ์พลังงาน กรมพัฒนาและส่งเสริมพลังงาน กระทรวงวิทยาศาสตร์ เทคโนโลยีและสิ่งแวดล้อม. การอนุรักษ์พลังงานในอาคาร. กรุงเทพมหานคร: สำนักกำกับและอนุรักษ์พลังงาน กรมพัฒนาและส่งเสริมพลังงาน กระทรวงวิทยาศาสตร์ เทคโนโลยีและสิ่งแวดล้อม, 2541.

3. สำนักกำกับและอนุรักษ์พลังงาน กรมพัฒนาและส่งเสริมพลังงาน กระทรวงวิทยาศาสตร์ เทคโนโลยีและสิ่งแวดล้อม. การอนุรักษ์พลังงานในอุตสาหกรรม. กรุงเทพมหานคร: สำนักกำกับและอนุรักษ์พลังงาน กรมพัฒนาและส่งเสริมพลังงาน กระทรวงวิทยาศาสตร์ เทคโนโลยีและสิ่งแวดล้อม, 2541.