An Energy Efficient Design Incorporating Green Building Index Measuring Tools for Industries

By

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FINAL PROJECT REPORT

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

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CERTIFICATION OF APPROVAL

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Approved:

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December 2014

CERTIFICATION OF ORIGINALITY

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

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Fong Wai Hing

ABSTRACT

Power demand increases every year while power generation does not have much change. As time goes by, there is a risk of experiencing power shortage. Therefore, by using energy efficient equipment and making use of renewable resources would help to reduce the overall power consumption. An energy efficient design implementing Green Building Index (GBI) measuring tools would allow user to save up to 30% of total power used. This project discusses the efficiency of lightings as well as mechanical loads such as chillers, smoke spill fans, and many more. DIALUX software is used to simulate the lightings design while research on mechanical equipment used is done on catalogue and the efficiency is compared and tabulated in a table.

ACKNOWLEDGEMENTS

This project would not be completed without the kind support and help from various parties and hence, I would like to take this opportunity to express my gratitude to all of them.

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ABBREVIAITONS AND NOMENCLATURES

CFM : Cubic Feet per Minute

COP : Coefficient of Performance

EER : Energy Efficient Ratio

GBI : Green Building Index.

Lux : SI unit for illuminance, also equal to one lumen per square meter.

RPM : Rotation per Minute.

T8 : Diameter of a fluorescent tube, also equal to one inch in diameter.

T5 : Equals to five eights of an inch in diameter.

VFD : Variable frequency drive.

3D : Three dimension.

CHAPTER 1
INTRODUCTION

1. Background

With the increasing of raw material to generate electricity, factories especially manufacturing factories for example food manufacturer, hard disk drive manufacturer and others are experiencing a dilemma as the cost of electricity bills is increasing as well. This has directly impact the profit making of the company as the electricity bill is not just increase by one or two percent but up to 17 percent [1].

One of the ways to reduce the cost of operation is to reduce the power consumption without sacrificing the efficiency or the production rate. In order to meet that requirement, a system will be developed in order to analyse the power consumption of the factory and will provide a solution by implementing GBI requirement. Furthermore, this project will provide the initial cost investment and the rate of return for the client to decide whether it is a good move to go for energy saving design or conventional design.

From an electrical perspective, most of the energy saving that an electrician familiar and easier to implement is lightings. However, the design of lightings according to the lux requirement of a room is not as simple. Suitable lightings have to be used and the efficiency of the lightings has to be considered. To meet GBI, designer has to make full use of sunlight without causing the temperature rise for that area which will require more cooling.

Mechanical loads are typically harder to analyze as basic knowledge are required to design the specific cooling system or air flow for a particular room. However, with the help from various parties, the mechanical side requirements are determined and only the efficiency of the equipment is to be analyzed.

2. Problem Statement

With the ever increasing of electricity bill, client has now switching their attention towards reducing the power consumption of their factory. A very good example can be observed is they are sticking out notes to switch off the lights when not in used in the office and washrooms. Reducing the electricity consumption can be done by modifying the light fittings into a different type. However, modifying the type of fittings will alter the brightness of the area. A designer has to balance between the power usage and the desired brightness of the area. Meeting GBI requirements will further reduce the power consumption for lightings but more things has to be taken into consideration especially the brightness from sunlight will damage the retina of human eye.

On the other hand, mechanical equipment such as chiller and pumps consume more energy than light fittings. Therefore a design which focuses on the efficiency of the motor will have a great impact on power consumption. Although the sizing of the chiller, pump and suitable fan sizes is under mechanical scope of work, it will be challenging if an electrical engineer is capable of suggesting and implement the concept of energy efficient into the design.

As the market is very wide, choosing specific equipment would be easy but analyzing will take a longer time. In this project, for lightings in particular, a T8 tube with power rating of 36W per tube is compared with a T5-35W tube. A comparison can be made by analyzing both fixtures with similar input power with the brightness produced. For mechanical loads on the other hand, equipment are predetermined with the help from external supervisor and analysis are carried out to determine the most efficient equipment to use to satisfy energy saving concept.

3. Objectives and Scope of Study

The objective of this project is to reduce the power consumption for industries by using energy efficient equipment such as pump, chiller and lightings. This can be done by implementing the base design follow by evaluation of the power consumption and analysis of the design. Analysis of the design will include the feasibility of the base design with as well as the energy efficient design. This analysis is to ensure energy efficient design does meet the requirement of the client as well as standards. This project can be done given the time frame of almost six months. With analysis of the design and finding data would take more time, it is expected that six months is enough to complete this project and to present a system that will effectively reduce power consumption of an industry.

CHAPTER 2
LITERATURE REVIEW AND/OR THEORY

With the recentness of price increase for electricity bill, the impact on cost of production is surely increased for all industries including food manufacturers, electronic device manufacturers, as well as service providers. It is important for factories to maintain their profit as much as possible and is better to increase it. There are two ways to do that by either charge more on their consumer or to reduce the cost of operation. With market have been challenging throughout the years, it would not be wise for these sectors to increase the price of their product. Thus, the wise way is to implement energy efficient design in which would help to reduce the cost of operation.

Energy efficient design not only does it reduces the impact to the environment but also promoting competitiveness with the reduced in cost [2]. The impact towards the environment is mainly due to the generation of electricity which produces massive amount of carbon dioxide which contributes to greenhouse effect. Although there is the existence of non-conventional generation of power, it is not sufficient to supply to all industries. Moreover, there are challenges in harnessing renewable energy. One of it is the availability of renewable energy source and the cost of building it [3]. On the other hand; less energy efficient equipment tends to produce more heat as waste which is also not environment friendly.

On the other hand, merging all devices such as pumps, chillers, and light fixtures which consumes most of the power together as a system rather than an independent device [4] instead of monitoring individual devices may not be a great idea. This is due to the efficiency of individual equipment may not be the same. Monitoring individual equipment would proof handy as some equipment are running in three-phase while others in single-phase. Selection of lesser energy efficient equipment at the start is the failure of reaching the energy efficient goal. Instead, implementing an energy saving concept at the stage of design is the best way to achieve the energy efficient concept for the particular building.

In conjunction energy efficient design in terms of architecture design, building orientation plays an important role because it determines the amount of sunlight shines towards the building which introduces heat. An addition of cooling is required to maintain the desired temperature for the building [5]. Moreover, reducing the thickness of walls, finishes, story heights etc., will further reduce the power consumption [3] in terms of cooling and lightings. This is due to lower volume of the room and lower in heights making work plane closer to the light source.

Analysis model using post occupancy for building focuses on the users' satisfaction level towards energy- efficient design [6]. This research carried out by interviewing users of the building regarding the energy efficiency performance thorough questionnaire. These research do have its own weakness which is not all users answer it correctly. Regardless of that, some interviewee may not have the energy saving concept in mind which will prove difficult to obtain the real result about their satisfaction. However, the idea of reducing cooling and heating demand by using energy efficient equipment as well as renewable sources can prove effective [7]. The idea of generating of renewable energy on site [6] can be useful to power up lower power consumption equipment.

In mechanical point of view, about 65% of overall power consumption used in an industry is by motors [8]. Mechanical equipment which consumes most of the power is chiller, boiler, and air compressor. This equipment is usually large in size and heavy. Efficiency varies and depends on the technology and reliability. Therefore, it is important to identify the utmost efficient equipment to be used in the design as it will contribute a significant amount of total cost of a building operation [9]. With the introduction of variable frequency drive (VFD) motors; power consumption can be reduced as the motor will operated based on the changes in load [10]. To explain this phenomenon, motors without VFD tends to operate at full load (100%) at all times which is not required most of the time. Power consumption of motor increased proportionally with its usage. A typical range of operation is usually kept within 50-85%. Using a VFD motors allows the change in their motor's rotation per minute (RPM) depending on the usage.

As lightings are a more prominent and having constant power consumption, an estimate of 19% of total power consumption came from lightings [11]. There are things that would affect the brightness of a room. It is mainly the height of the room, the color of wall paintings, reflection from floor, reflection from ceiling, as well as the light fixtures. In lightings, several aspects have to take into consideration while designing. Instead of focusing mainly on energy efficient, the color of a fixture did play an important role in determining the function of the room [12]. With the introduction of LED light fixture, power consumption is greatly reduced. However, there is also a drawback using LED light fixture as it is more expensive and it may not be as bright as conventional fluorescent tube. With the concern of lesser brightness produced by an LED fluorescent tube, the quantity required to achieve certain brightness will be higher which will contribute to the initial startup cost of investment.

CHAPTER 3

METHODOLOGY

METHODS (ELECTRICAL)

Understanding the usage of an area is vital in order to determine the suitable light fitting to be installed. After confirming the type of light fitting used, the quantity is then to be determine in order to achieve the lux level of the specific room. Base design is achieve through placing the light fitting in order to achieve the lux level. A MS1525 standard is then to be considered in order to improve energy saving follow by meeting GBI standard by implementing natural sunlight as one of the source of light during daytime to save energy as well as using light sensors or motion sensors. However in this project, the chosen factory is a food manufacturer which is very sensitive to sunlight. Therefore, there may not have significant changes in power consumption while implementing sunlight as the source.

Before going further, understanding the concept is vital especially before starting off by understanding the basic which is the formula to calculate the lumen required for a room.

Equation 1: $\text{Total lumen required} = \text{desired lux level} \times \text{room area}.$

Equation 2: $\text{No. of tubes required} = \frac{\text{total lumen required}}{\text{lumen per tube}}$

Equation 3: $\text{No. of fittings required} = \frac{\text{No.of tubes required}}{\text{No.of tubes in a fitting}}$

The formulas above provides a guideline for the designer to determine an approximate number of fitting required and it may not be totally correct as the height of the room are not taken into consideration.

The difference between a T8 and T5 fluorescent tube is the diameter of the tube.

Light fixtures	Diameter of tube (inch)
T8 fluorescent	$^{8}/_{8}$
T5 fluorescent	$^{5}/_{8}$

Table 1: Size of a fluorescent tube

There are various factors that needed to take into consideration when designing suitable lighting. Such factors are:

- Room proportions
- Celling height
- Reflectance from walls and celling
- Colour of surfaces
- Type of reflection from surfaces
- Type of work or how the room is used
- Type of fixtures
- Pattern of fixture installation
- Output of fixtures
- Efficiency of fixtures
- Light losses due to lamp aging
- Allowance for dirt condition

Since lightings are the only loads which can varies according to its efficiency unlike machines and motors, it is important to analyse the correct and suitable light fixture to be used as the efficiency may varies from 61% to 98%.

Equation 4: $\text{Efficiency} = \frac{\text{Measured Output}}{\text{Ideal Output}}$

The table below provides the comparison of using different type of lightings with its efficiency.

Light fixture used	Lamps lumen	Luminaire lumen	Efficiency
4 x 36W T8	13400	9514	71%
4 x 35W T5	13300	11438	86%

Table 2: Comparison between lightings with its efficiency

The usage of the room determines the lux level required. An office will require higher lux level compared to a store room and a meeting room is significantly brighter than a cafeteria. Below is a table showing the area and lux requirement for the area. These settings have to be at least complying with MS1525. It can also be set by the client in order to suits their own preferences. In most cases, consultants are required to follow the standards set by the government bodies.

Area of usage	Lux level
Street lightings, car park	10-20
Restrooms, catwalk, prayers room	100-150
Cafeteria, warehouse	200-250
Offices	300-350
Production area	450-500

Table 3: Recommended Lux in a design

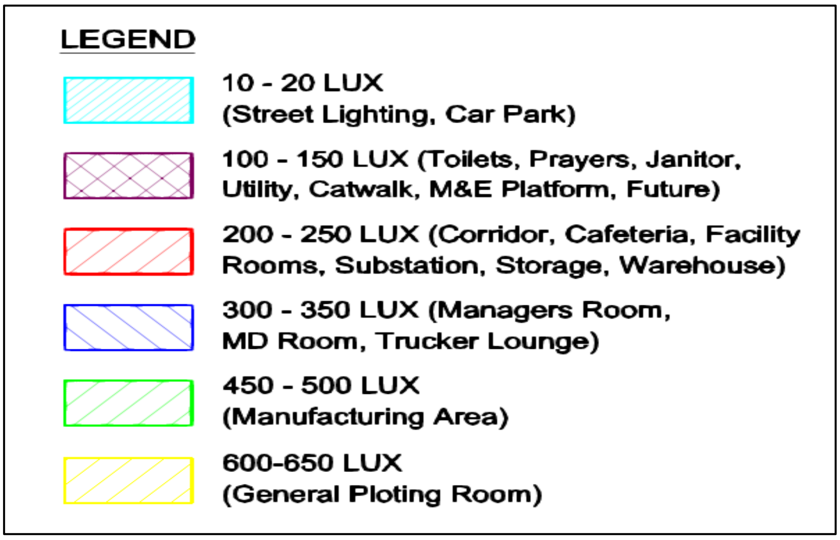


Table 4: Lux requirement for this project

The very first stage when comes to designing of the lighting in a particular area is to hatch the particular area w.r.t. the particular usage of the area. As can be observed below is the place where it is used to store hazardous material and waste. Since it is hatched blue, that area is designed to have a range from 300 to 350 lux.

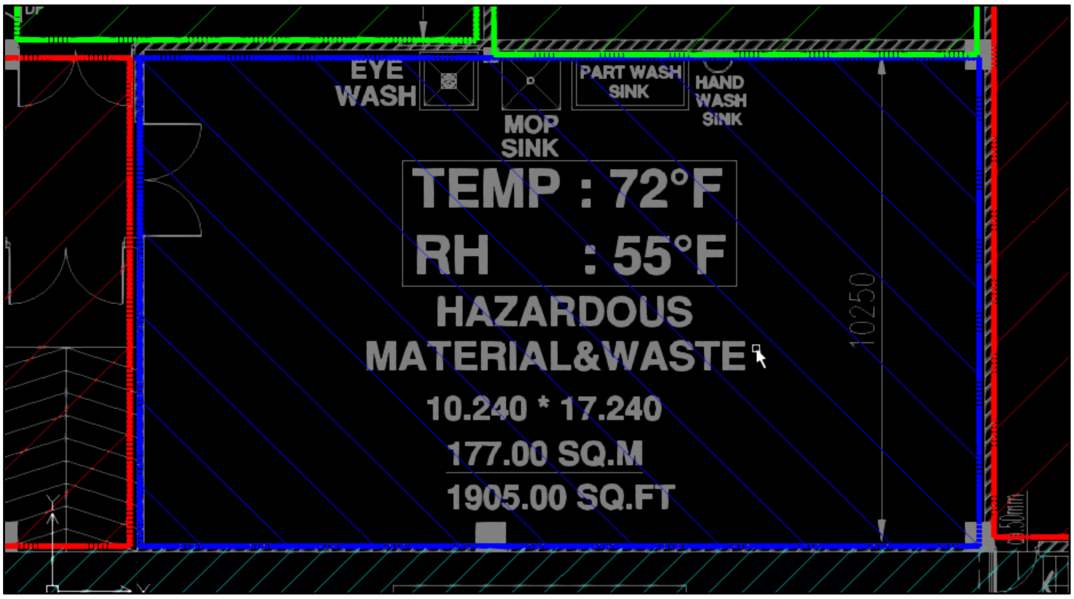


Figure 1: Hatching on specific area

After defining the lux it is required to study the architectural drawings regarding the height of the area.

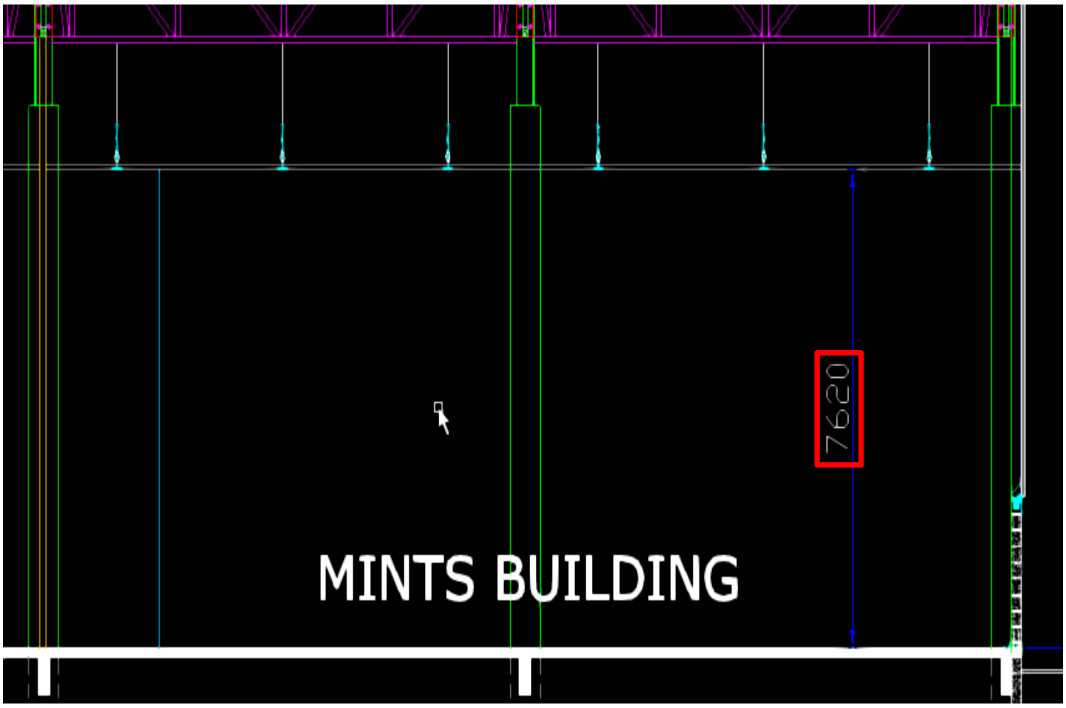


Figure 2: Height of the building

From the above figure, information that a designer can obtain from this particular mints building is the height from floor to ceiling is 7.62m. In consultant, the unit used is millimeters as measurement. This is to provide better measurement and more precise in designing.

Knowing the height of the building provides an insight for the designer to determine the suitable light fixture. There is also a factor which will determine the type of lighting a designer should use which is the used and purpose of that particular area. It is possible to use fluorescent tube in designing for a hotel lobby but it may not look grand. For this particular project, the used of fluorescent tube is common since it is a factory site. A recessed downlight will only be used in lobby, certain meeting area as well as restrooms. In places where it used to store hazardous materials, wastes and explosive materials, the light fixtures used are usually explosion proof and wall mounted. On the other hand, exterior compound used water proof lightings. The table below provides an insight of degree of protection of an enclosure.

Protection Degrees of Enclosure			
IP XX			
First Numeral		Second Numeral	
0	no protection	0	no protection
1	protected against solid objects up to 50mm	1	protected against vertically falling drops of water
2	protected against solid objects up to 12mm	2	protection against direct sprays of water up to 15°
3	protected against solid objects up to 2.5mm	3	protected against sprays up to 60° from the vertical
4	protected against solid objects up to 1mm	4	protected against water sprays from all directions
5	protected against dust	5	protected against low pressure jets of water from all directions
6	total protection against dust	6	protected against strong jets of water
		7	protected against the effects of immersion between 15cm to 1m
		8	protected against long periods of immersion under pressure

Table 5: Ingress Protection (IP)

Zone classification of an area will determine the suitable light fixture to be used. The table below provides a summary of the zone classification.

Gases, vapour or mists	
Zone 0	An area in which an explosive atmosphere is present either continuously or over long periods or frequently as a mixture of air and combustible gases, vapour or mists
Zone 1	An area where under normal operating conditions an explosive atmosphere may occasionally be present as a mixture of air and combustible gases, vapour or mists
Zone 2	An area where an explosive atmosphere is not likely to be present under normal operation but if it should occur for some reason it would normally only exist for a short time as a mixture of air and combustible gases, vapour or mists
Dusts	
Zone 20	An area in which an explosive atmosphere is present either continuously or over long time or frequently as a cloud of combustible dust in the air
Zone 21	An area where under normal operating conditions an explosive atmosphere may occasionally be present as a cloud of combustible dust in the air
Zone 22	An area where explosive atmosphere is not likely to be present under normal operation but if it should occur for some reason it would normally only exist for a short time as a cloud of combustible dust in the air

Table 6: Zone classification

With the zone classification completed, the selection of suitable light fixture can be carry on.

Swimming pool: IP67

Zone 0, 1, 2, 20, 21, and 22: IP65

Street light, compound lightings: IP65

Wet area (indoor): IP65

Restrooms: IP44, IP20

Office, production area: IP20

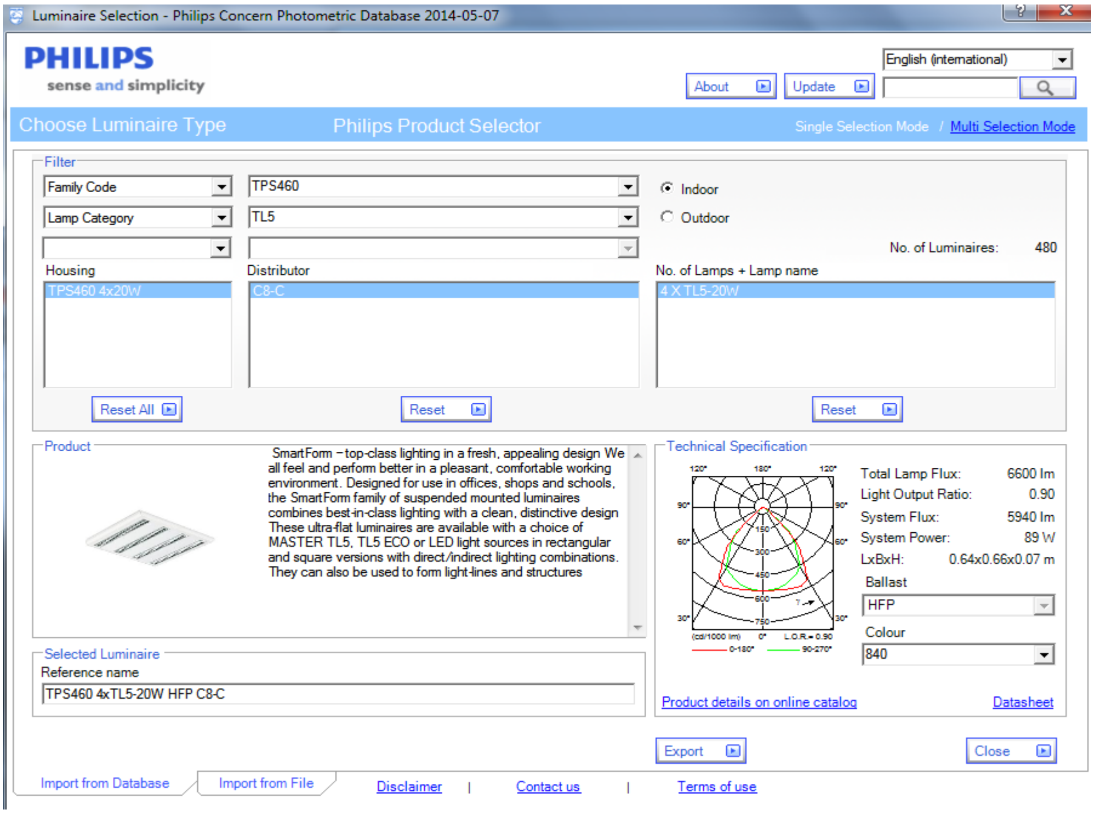


Figure 3: Selection of suitable light fixture

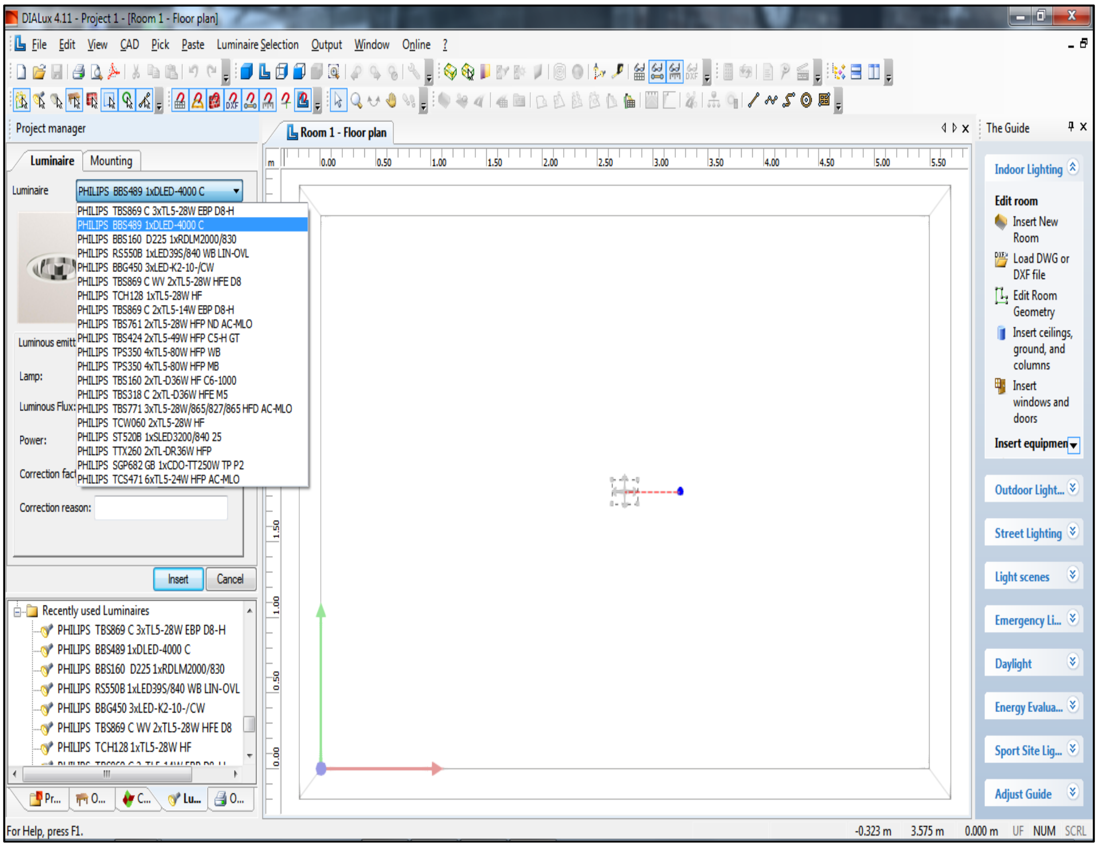


Figure 4: Placement of light fixture in DIALux software

On the other hand, in order to calculate the return of investment (ROI), several steps have to be taken into consideration. The steps are as follows:

1. Determine the amount of luminaries required
2. Cost of each luminaries
3. Total initial cost required

   Equation 5: $\text{Initial cost} = (1)\text{x}\ (2)$

4. Compare both luminaries used to calculate the additional cost
5. Calculate and compare both types of luminaires power consumption
6. With the annual saving in energy calculated, multiply with the fix cost implemented for industry for power usage.

   Equation 6: $\text{Saving in energy cost} = \text{kW x RM0.30}$

7. Determine the average life of lamps
8. The amount of lamps to be replaced

   Equation 7: $\text{lamps to be replaced} = 365\ \text{x}\ 24\ \text{x}\ 4\ \text{x}\ (1) \div (7)$

   In this equation, it is assumed that the light fixtures is operating 24 hours per day every year
9. Calculates labour cost and savings in maintenance cost
10. Payback in years is then been calculated

METHODS (MECHANICAL)

With mechanical loads consumes most of the power, it is important to determine energy efficient equipment.

Chillers can be separated into two main components:

- Centralized
  A single chiller unit which serves multiple cooling needs
- Decentralized
  Each application or machine having its own chiller

Typical range for decentralized chiller is from 0.2 tons towards 10 tons while a centralized chiller would weigh 10 tons to thousands of tons [13]. To determine an energy efficient chiller, the designer must know the following formulas:

Coefficient of Performance (COP) [14]

Equation 8: $\mathrm{COP} = \frac{\mathrm{Eu}}{\mathrm{Ea}}$

Where: Eu = Useful energy required (btu in imperial units)

Ea = Energy applied (btu in imperial units)

COP is defined as the ratio of heat removal to energy input to the compressor.

The higher the value of COP, the more efficient the equipment is.

Energy Efficient Ratio (EER) [14]

Equation 9: $\mathrm{EER} = \frac{\mathrm{Ec}}{\mathrm{Pa}}$

Where: Ec = net cooling capacity (Btu/hr)

Pa = applied electrical power (Watts)

Higher EER equals to higher efficiency.

Typical air change rate is calculated as below [15]:

Equation 10: $\mathrm{n} = 60\mathrm{q}/\mathrm{V}$

Where: n = air changes per hour (1/h)

q = fresh air flow through the room (cfm)

V = volume of the room (cubic feet)

CHAPTER 4

RESULTS AND DISCUSSION

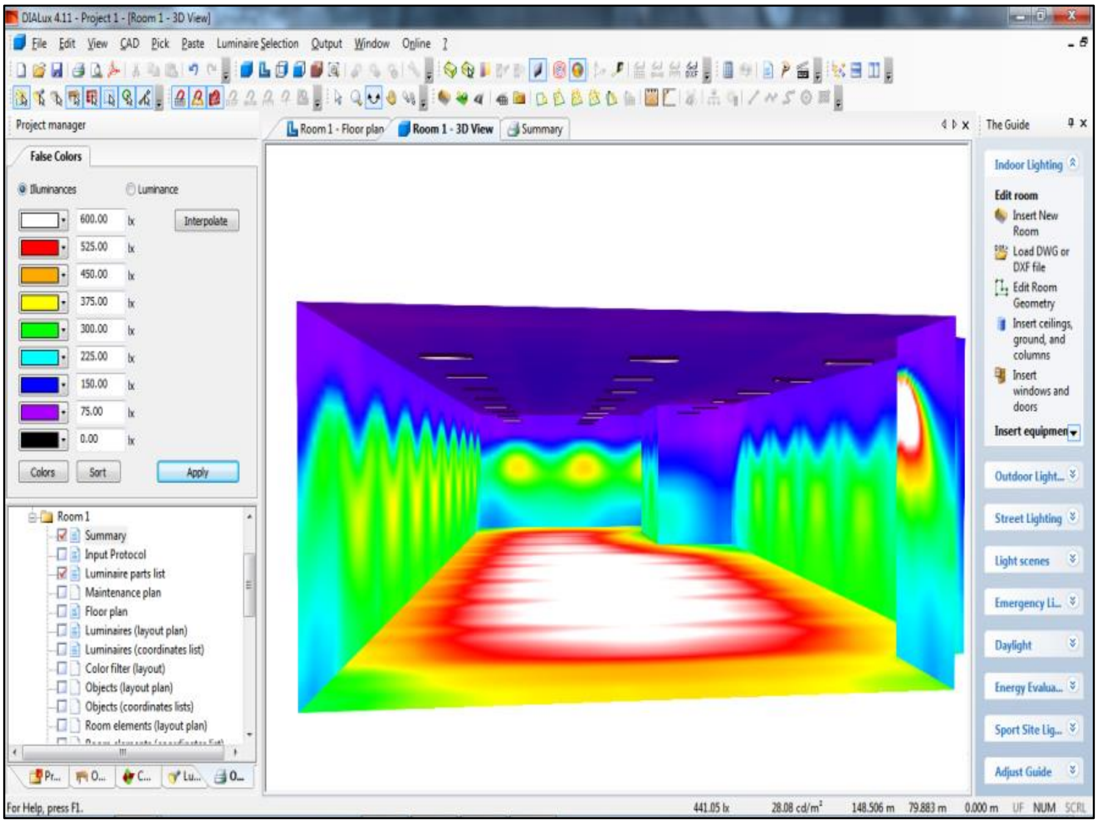
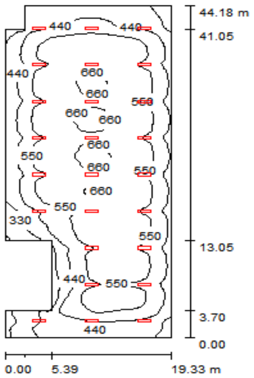


Figure 5: 3D view with result from simulation

This software enable user to view its design based on the selection of the light fixture used. A report can be generated to have a better picture about the design and average lux level achieved by this design. It is noted that the arrangement of light fixture will affect the overall average output of the achieved lux level.



Height of Room: 7.620 m, Mounting Height: 7.020 m, Light loss factor: 0.80

Values in Lux, Scale 1:568

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	523	181	689	0.346
Floor	20	506	186	659	0.367
Ceiling	80	103	76	149	0.741
Walls (10)	50	227	75	925	/

Workplane:

Height: 0.760 m
Grid: 128 x 64 Points
Boundary Zone: 0.000 m

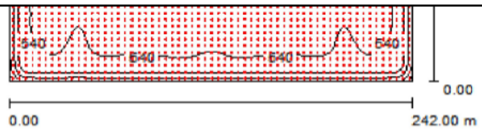
Figure 6: Summarised result for an area

The result above indicates an average of 523 lux for that particular room. Referring to the previous table regarding the requirement, it is stated to have a range within 450-500 lux level. This shows that this particular design is acceptable but a further improvement can be made in the upcoming stage of design where we shall carry out analysis about this design and find ways to improve the efficiency by manipulate the light fixture position or types of light fixture to be used.

Light fixture used	Calculations
T5 fluorescent lamp (6x54W)	324W
Quantity	25
Total power	8100W
Lux Achieved	523
Requirement	450-500
Design Acceptable?	Accepted

Table 7: Results for a room

Below shows the overall of the simulated result comparing the normal design with the energy saving design.



Height of Room: 7.620 m, Mounting Height: 7.696 m, Light loss factor: 0.80

Values in Lux, Scale 1:3275

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	532	267	561	0.502
Floor	20	530	270	561	0.510
Ceiling	80	99	79	114	0.790
Walls (4)	50	219	78	330	/

Workplane:
Height: 0.760 m
Grid: 128 x 128 Points
Boundary Zone: 0.000 m
Illuminance Quotient (according to LG7): Walls / Working Plane: 0.436, Ceiling / Working Plane: 0.187.

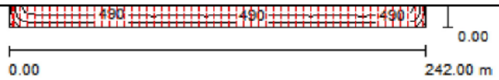
Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	3843	PHILIPS TBS318 C 4xTL-D36W HFE C2 (Type 1)* (1.000)	9514	13400	160.0
			Total: 36562301	Total: 51496200	614880.0

*Modified Technical Specifications

Specific connected load: 9.96 W/m² = 1.87 W/m²/100 lx (Ground area: 61710.00 m²)

Figure 7: A T8 4x36W light fixture used as a based design



Height of Room: 7.620 m, Mounting Height: 7.620 m, Light loss factor: 0.80

Values in Lux, Scale 1:3275

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	524	255	557	0.487
Floor	20	522	273	549	0.523
Ceiling	80	94	63	112	0.669
Walls (4)	50	218	72	404	/

Workplane:
Height: 0.760 m
Grid: 128 x 128 Points
Boundary Zone: 0.000 m
Illuminance Quotient (according to LG7): Walls / Working Plane: 0.427, Ceiling / Working Plane: 0.179.

Luminaire Parts List

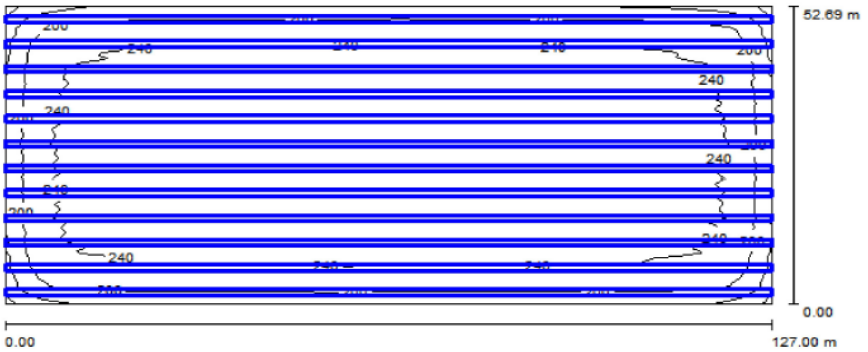
No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	3192	PHILIPS TTX260 4xTL5-35W HFP C-MB (1.000)	11438	13300	154.0
			Total: 36510097	Total: 42453600	491568.0

Specific connected load: 7.97 W/m² = 1.52 W/m²/100 lx (Ground area: 61710.00 m²)

Figure 8: A T5 4x35W light fixture used for energy efficient design

Following is the simulation of using only sunlight for different time zone.

Overall / Light scene 1 / Summary



Height of Room: 7.620 m, Light loss factor: 0.80 — Values in Lux, Scale 1:908

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	236	105	265	0.446
Floor	20	233	114	267	0.489
Ceiling	80	49	37	67	0.747
Walls (4)	50	119	48	313	/

Workplane:
Height: 0.760 m
Grid: 128 x 128 Points
Boundary Zone: 0.000 m
Illuminance Quotient (according to LG7): Walls / Working Plane: 0.501, Ceiling / Working Plane: 0.208.

Pure daylight scene, no luminaires involved.

Figure 9: Pure daylight at 10am

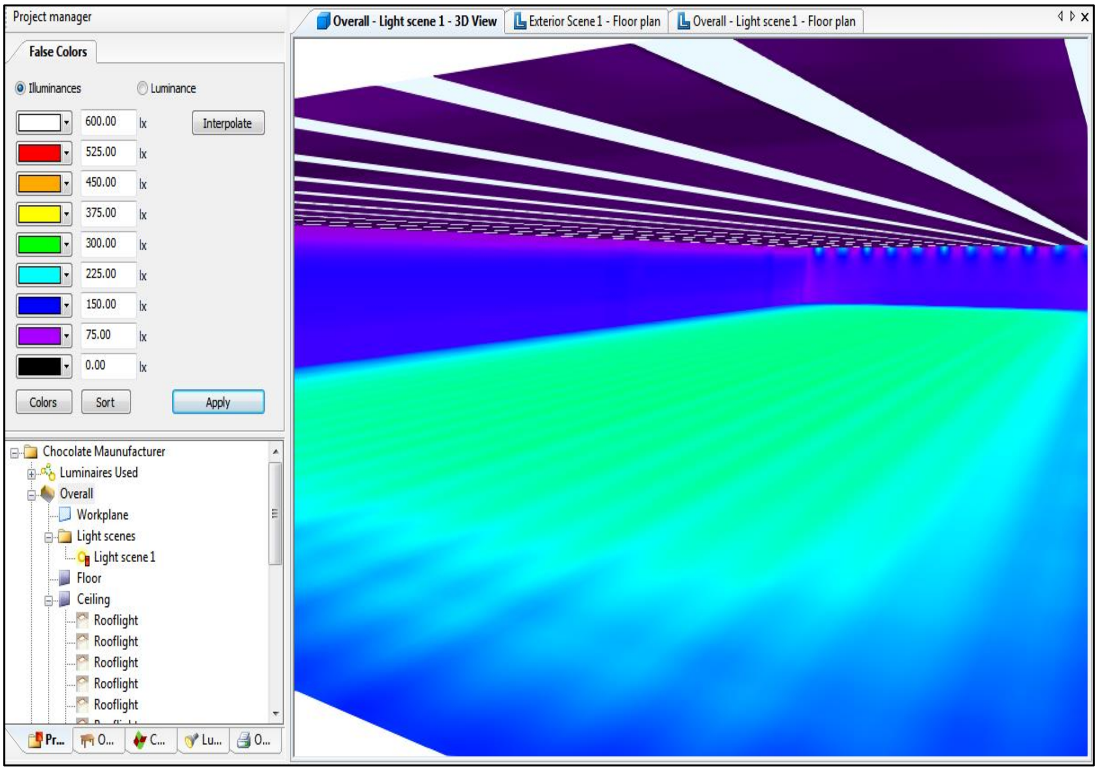
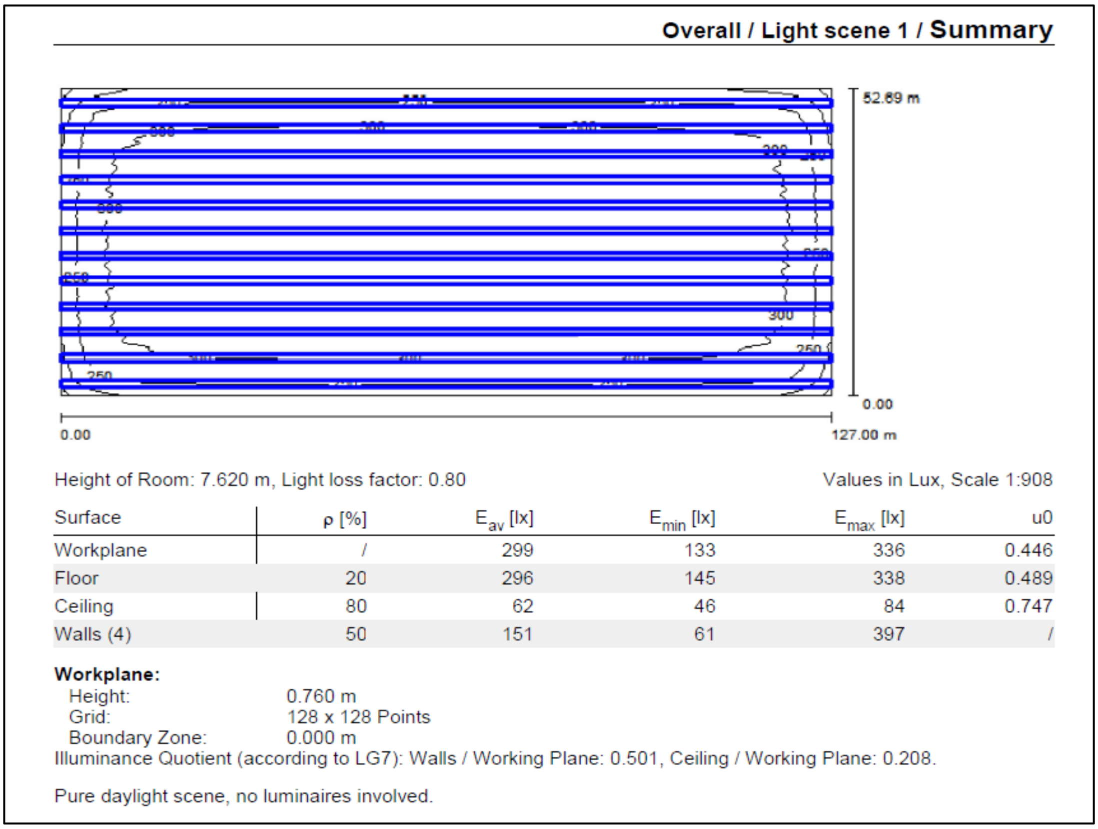


Figure 10: Pure daylight at 10am in 3D



Overall / Light scene 1 / Summary

Height of Room: 7.620 m, Light loss factor: 0.80

Values in Lux, Scale 1:908

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	299	133	336	0.446
Floor	20	296	145	338	0.489
Ceiling	80	62	46	84	0.747
Walls (4)	50	151	61	397	/

Workplane:
Height: 0.760 m
Grid: 128 x 128 Points
Boundary Zone: 0.000 m
Illuminance Quotient (according to LG7): Walls / Working Plane: 0.501, Ceiling / Working Plane: 0.208.

Pure daylight scene, no luminaires involved.

Figure 11: Pure daylight at 12pm

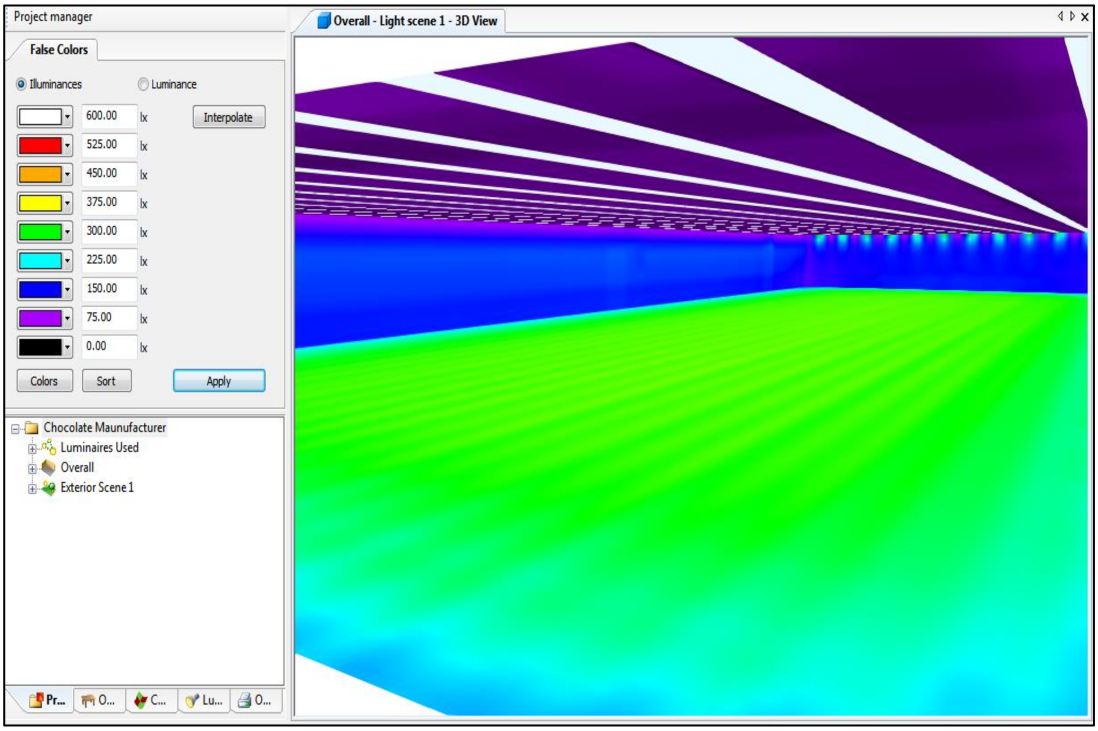
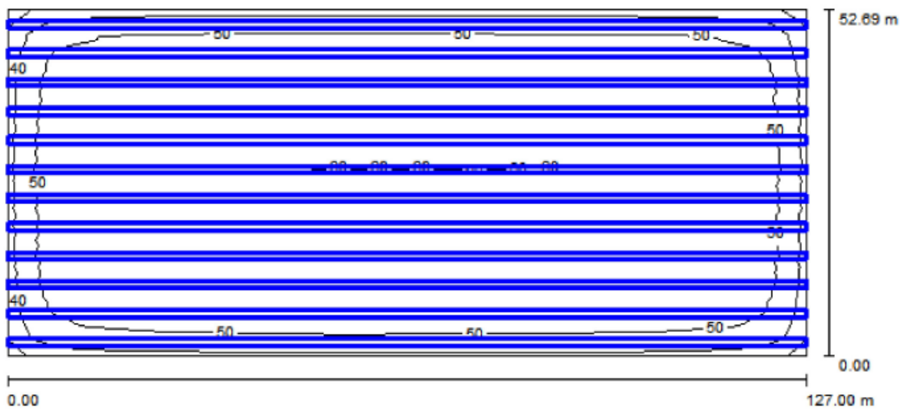


Figure 12: Pure daylight at 12pm in 3D

Overall / Light scene 1 / Summary



Height of Room: 7.620 m, Light loss factor: 0.80 — Values in Lux, Scale 1:908

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	54	24	61	0.446
Floor	20	53	26	61	0.489
Ceiling	80	11	8.37	15	0.747
Walls (4)	50	27	11	72	/

Workplane:
Height: 0.760 m
Grid: 128 x 128 Points
Boundary Zone: 0.000 m
Illuminance Quotient (according to LG7): Walls / Working Plane: 0.501, Ceiling / Working Plane: 0.208.

Pure daylight scene, no luminaires involved.

Figure 13: Pure daylight at 6pm

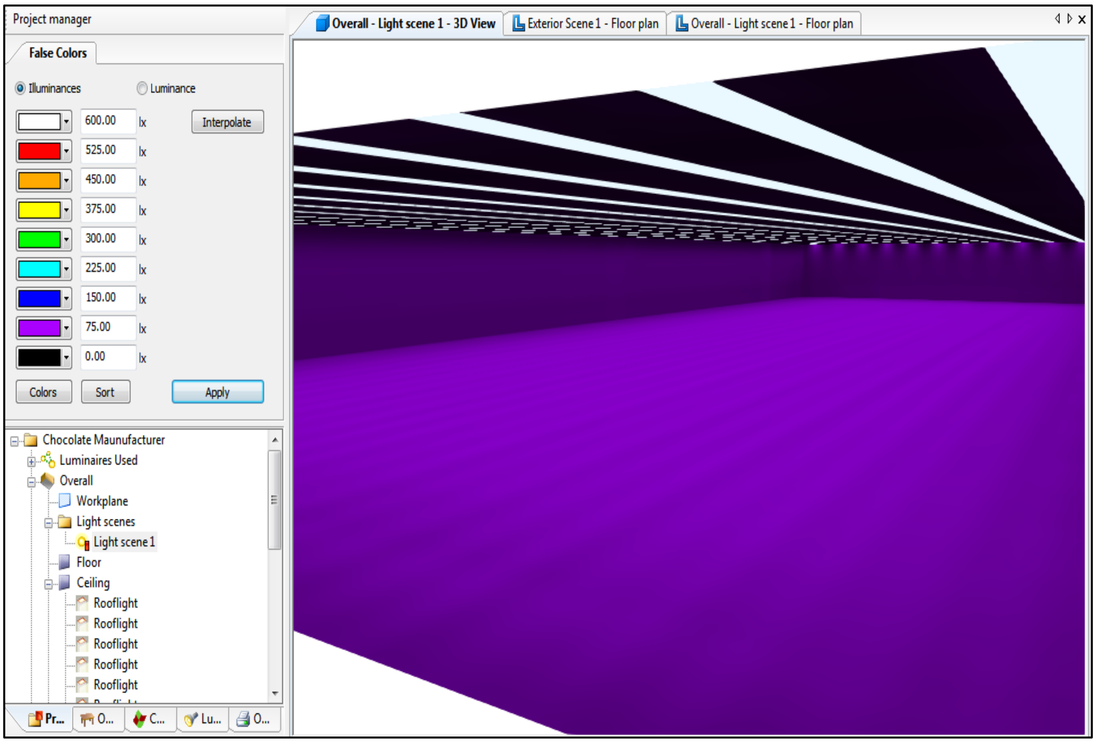


Figure 14: Pure daylight at 6pm in 3D

The result shown in Figure 9, 10, 11, 12, 13 and 14 are only on the warehouse of this project. Since warehouse only occupy little build area, the amount of saving is not significant and is not taken into consideration. Given this project is a food manufacturer which is very sensitive to the expose of sunlight, it is assumed that the design are more towards to the production area which operates at full 24 hours per day for 365 days per year.

Following is the calculation for ROI comparing both T8 light fixture and T5 light fixture.

Description	Option 1	Option 2	Benefit
	4x36W T8 Fluo	4x35W T5 Fluo	Energy saving
Initial Cost			**20.05%**
Type of lamps	36W Fluo	35W Fluo	
Total No. of luminaires	3843	3192	
Types of control gear	Electronic	Electronic	
Cost per luminaire (RM)	375	510	Total annual saving
Total initial cost (RM)	1,441,125	1,627,920	**RM146,712**
Additional initial cost		**186,795**	
Energy Cost			
Power consumption per luminaire (in Watts)	160	154	
Annual energy consumption (operating for 365 days/year and for 24 hours in a day)(in KWhr)	5,386,349	4,306,136	
Annual saving in energy (KWhr)		1,080,213	
Annual saving in energy costs (RM) @ RM0.30		**324,064**	
Maintenance Cost			
Average life of lamps (in burning hours)	36,000	40,000	
No. of lamps to be replaced per year	3,741	2,796	
Labour cost of replacement per lamp (RM)	10	10	
Total cost of replacement of lamp (RM)	37,405	27,962	
Saving in maintenance cost (RM)		9,443	
Total saving in energy & maintenance cost (RM)		146,712	
Payback in Years		**1.27**	

Table 8: Return of investment for two different types of fluorescent fittings

The following is the comparison for the mechanical loads with different efficiencies.

Air cooled condensor

unit no.	Qty	old power rating (kW)	new power rating (kW)		energy saved (kW)
1	1	11.2	8.8		2.4
2	1	16.4	9.2		7.2
				Total	9.6

Compressor pack

unit no.	Qty	old power rating (kW)	new power rating (kW)		energy saved (kW)
1	5	375	372.5		2.5
2	5	450	410		40
				Total	42.5

Cooling tower

unit no.	Qty	motor rated output(old) (kW)	motor rated output(new) (kW)		energy saved (kW)
1	1	37	27.75		9.25
2	1	37	27.75		9.25
3	1	37	27.75		9.25
4	1	37	27.75		9.25
5	1	37	27.75		9.25
6	1	37	27.75		9.25
7(standby)	1	37	27.75		9.25
				Total	64.75

Chilled water pumps

unit no.	Qty	motor power (old) (kW)	motor rated output(new) (kW)		energy saved (kW)
1	1	190	142.5		47.5
2	1	190	142.5		47.5
3	1	190	142.5		47.5
4	1	190	142.5		47.5
5	1	190	142.5		47.5
6	1	190	142.5		47.5
7	1	15	11.25		3.75
8	1	15	11.25		3.75
				Total	292.5

Condenser water pumps

unit no.	Qty	motor power (old) (kW)	motor rated output(new) (kW)		energy saved (kW)
1	1	100	75		25
2	1	100	75		25
3	1	100	75		25
4	1	100	75		25
5	1	100	75		25
6	1	100	75		25
9	1	15	11.25		3.75
10	1	15	11.25		3.75
				Total	157.5

Smoke spill fan

unit no.	Qty	motor power (old) (kW)	motor rated output(new) (kW)		energy saved (kW)
1	1	90.00	63		27.00
2	1	90.00	63		27.00
3	1	37.00	25.9		11.10
4	1	75.00	52.5		22.50
5	1	75.00	52.5		22.50
6	1	30.00	21		9.00
7	1	75.00	52.5		22.50
8	1	75.00	52.5		22.50
9	1	75.00	52.5		22.50
10	1	55.00	38.5		16.50
11	1	45.00	31.5		13.50
12	1	55.00	38.5		16.50
13	1	55.00	38.5		16.50
14	1	55.00	38.5		16.50
15	1	90.00	63		27.00
16	1	45.00	31.5		13.50
17	1	75.00	52.5		22.50
18	1	75.00	52.5		22.50
19	1	2.20	1.54		0.66
20	1	7.50	5.25		2.25
21	1	15.00	10.5		4.50
22	1	7.50	5.25		2.25
23	1	22.00	15.4		6.60
24	1	30.00	21		9.00
25	1	5.50	3.85		1.65
26	1	30.00	21		9.00
27	1	3.00	2.1		0.90
28	1	22.00	15.4		6.60
29	1	2.20	1.54		0.66
30	1	55.00	38.5		16.50
31	1	30.00	21		9.00
32	1	55.00	38.5		16.50
33	1	45.00	31.5		13.50
34	1	55.00	38.5		16.50
35	1	37.00	25.9		11.10
				Total	478.77

Fresh air fan

unit no.	Qty	motor power (old) (kW)	motor rated output(new) (kW)		energy saved (kW)
1	1	55.00	38.5		16.5
2	1	55.00	38.5		16.5
3	1	22.00	15.4		6.6
4	1	75.00	52.5		22.5
5	1	15.00	10.5		4.5
6	1	45.00	31.5		13.5
7	1	90.00	63		27.0
8	1	90.00	63		27.0
9	1	37.00	25.9		11.1
10	1	75.00	52.5		22.5
11	1	45.00	31.5		13.5
12	1	55.00	38.5		16.5
13	1	30.00	21		9.0
14	1	90.00	63		27.0
15	1	1.50	1.05		0.5
16	1	3.70	2.59		1.1
17	1	11.00	7.7		3.3
18	1	5.50	3.85		1.7
19	1	15.00	10.5		4.5
20	1	18.50	12.95		5.6
21	1	3.70	2.59		1.1
22	1	15.00	10.5		4.5
23	1	3.00	2.1		0.9
24	1	18.50	12.95		5.6
25	1	1.50	1.05		0.5
26	1	30.00	21		9.0
27	1	18.50	12.95		5.6
28	1	30.00	21		9.0
29	1	30.00	21		9.0
30	1	45.00	31.5		13.5
31	1	37.00	25.9		11.1
				Total	319.9

The summary of equipment used and savings obtained.

Equipment	Base design (kW)	Energy efficient design (kW)	Total energy saved (kW)
Air cooled condenser	27.6	18	9.6
Compressor pack	825	782.5	42.5
Cooling tower	259	194.25	64.75
Chilled water pumps	1170	877.5	292.5
Condenser water pumps	630	472.5	157.5
Smoke spill fan	1595.9	1117.13	478.77
Fresh air fan	1066.4	746.5	319.9
Total	5573.9	4208.38	1365.52

The total energy saved above is in per hour. For an annual calculation, the amount of saving is as follow:

Equation 11: $\text{Total annual saving} = 365 \text{ x } 24 \text{ x } 1365.52$

$= 11962130.40\text{kW}$

Equation 12: $\text{Total annual saving (RM)} = 11962130.40 \text{ x } 0.30$

= RM3, 588,639.12

CHAPTER 5

CONCLUSION AND RECOMMENDATION

This project is aim to enhance the power consumption of an industry by implementing an energy saving concept. Based on initial findings, it is confirmed that a T8 fluorescent fitting consumed more power but emit more brightness than a T5 fluorescent tube. However, on the difference in terms of brightness comparing T8 and T5 is very significant. The efficiency however varies accordingly.

Based on the base design using T8 fluorescent, all designs meet the lux level requirement but the efficiency is questionable. Prior to an analysis by comparing both T8 and T5 light fixtures, the result were T5 with less amount of power required produces higher lumens and therefore requires lesser number of light fixture in the design. This is due to the recent technology and improvement being made on the growing popularity of using T5 fluorescent tube. The ROI for light fixture suggest a return of investment in 1.3 years if the client decided to switch from using a T8 fluorescent to a T5 tube.

The continuation of this project on mechanical loads shows a significant amount of power saving while using the more energy efficient equipment; this provides significant cost saving for the industry. Comparing to the amount of energy saved with light fixtures, almost 10 times of power is saved in mechanical loads. This is due to the amount of power consumed in mechanical equipment is far greater than light fixtures alone. An ROI is not provided due to many different type of equipment present in the design which will consumes significant amount of time which is not available. By using energy efficient equipment in this particular project, it suggested that energy efficient equipment could save up to RM3.6million.

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APPENDICES

GENERAL BUILDING AREAS	IES STANDARDS ILLUMINATION LEVEL	MS 1525 RECOMMENDATION	PANDUAN TEKNIK JKR	NOTES
CIRCULATION AREA				
Corridors, Passageway	100	50	100	
Lift	150	100	100	
Stairs	150	100	100	
Escalator	150	150	100	
External Covered Ways	30	50	30	
ENTRANCES				
Entrance halls, lobbies, waiting rooms	150	100	100	
Enquiry desk	500	300	300	
Gate houses	300	200	200	
KITCHENS				
Foods stores	150	150-300	100	
General	500	150-300	300	
OUTDOOR				
Controlled entrance halls or exit gate	150	100	150	
Entrance and exit car park	30	50	30	
Stores, stockyards	30	50	30	
Industrial covered ways	50	50	50	
STAFF RESTAURANTS				
Centre cafeterias, dining room	300	200	300	

Table 9: Lux specification

GENERAL BUILDING AREAS	IES STANDARDS ILLUMINATION LEVEL	MS 1525 RECOMMENDATION	PANDUAN TEKNIK JKR	NOTES
MEDICAL AND FIRST AIDS CENTRES				
Consultant room, treatment areas	500		400	
Medical stores	100		100	
Rest room	150	150	100	
STAFF ROOM				
Changing locker and cleaner's room, cloakrooms lavatories	150	100	150	
Rest rooms	150	150	150	
STORE AND STOCK ROOMS	150	100	150	
Telecommunication board, switchboard rooms			500	
Cordless switchboard	300		300	
Apparatus rooms	150		150	
Teteprinter rooms	500		500	
AIRCRAFT MAINTENANCE HANGERS				
Aircraft engine testing	750		600	
Inspection and repairs (hanger)	500		500	
BOILER HOUSE GENERAL	150		150	
FIRE STATIONS				
Appliance room	300		300	
External apron	30		30	

Table 10: Lux specification

GENERAL BUILDING AREAS	IES STANDARDS ILLUMINATION LEVEL	MS 1525 RECOMMENDATION	PANDUAN TEKNIK JKR	NOTES
GARAGES				
External apron general	50		50	
Pumps	300		200	
Parking areas (interior) general repairs servicing	30		30	
Greasing, pits washing, polishing	500		300	
GAS WORKS				
Exterior walkways and platforms	50		50	
Exterior stairs and ladders	100		50	
Retort house, oil gas plants, watergas plant purifier, indoor coke, screening and handling plants	100		100	
Booster and exhauster houses	150		150	
GAUGE TOOLS ROOMS				
General	1000		600	
INSPECTION & TESTING SHOP				
Rough work e.g. counting rough Checking of stock parts	300		200	
Medium work e.g. 'go' & 'no go' gauges sub-assemblies	500		400	
Fine work e.g. radio and telecommunication equipment, calibrated scales, precision mechanism, instruments	1000		600	
Very fine work e.g. gauging and inspections of small intricate parts	1500		750	
Minute work e.g. very small instruments	3000		1000	

Table 11: Lux specification

GENERAL BUILDING AREAS	IES STANDARDS ILLUMINATION LEVEL	MS 1525 RECOMMENDATION	PANDUAN TEKNIK JKR	NOTES
LABORATORIES (GENERAL)	750		500	
LAUNDRIES & DRY CLEANING WORKS				
Receiving, sorting, washing, drying, ironing (clending) dispatch, drying cleaning, bulk machine work	300		200	
Hand ironing, pressing, inspection, mending, spotting			300	
MACHINE & FITTING SHOP				
Rough bench and machine work	300		200	
Medium bench and machine work, ordinary automatic machines, rough grinding, medium buffing, polishing	500		400	
Fine bench and machine work, ordinary automatic machines, rough grinding, medium buffing, polishing	1000		500	
PHARMACEUTICAL & FINE CHEMICAL WORKS PHARMACEUTICAL MANUFACTURE				
Grinding, granulating mixing and drying, tableting, sterilizing and washing, preparation of solutions and filling , labeling capping, cartooning, warping	500		300	
Inspection	750		400	
Fine chemical manufacture, plant processing	300		200	
Fine chemical finishing	500		400	
Raw material store	300		200	

Table 12: Lux specification

GENERAL BUILDING AREAS	IES STANDARDS ILLUMINATION LEVEL	MS 1525 RECOMMENDATION	PANDUAN TEKNIK JKR	NOTES
Inspection	750		300	
PRINTING WORKS TYPE FOUNDRIES				
Matrix making, dressing type hand and machine casting	300		300	
Front assembly sorting	750		400	
COMPOSING PRESS				
Hand composing, imposition and distribution	750		500	
Machine. Composition-keyboard	750		500	
Machine composition-casting	300		200	
Proof press	500		300	
Illuminated tables general lighting	300		200	
PRINTING MACHINE ROOM				
Presses	500		300	
Premake ready	500		300	
Printed-sheet inspection	1000		500	
GRAPHIC REPRODUCTION				
General	500		300	
Precision proofing, retouching, etching	1000		500	

Table 13: Lux specification

GENERAL BUILDING AREAS	IES STANDARDS ILLUMINATION LEVEL	MS 1525 RECOMMENDATION	PANDUAN TEKNIK JKR	NOTES
RUBBER PROCESSING FACTORIES				
Preparation needs, dipping molding, compounding calendaring	300		200	
Tyre and tube making	500		300	
SHEET METAL WORKS				
Benchwork, scribing, inspection	750		400	
Pressing, punching, shearing stamping, spinning, folding	500		300	
SLAUGHTER HOUSE				
General	500		300	
Inspection	750		400	
WELDING & SOLDERING SHOP				
Gas and arc welding rough spot welding	300		200	
Medium soldering, brazing spot welding e.g. domestic hand ware	500		300	
Fine soldering, spot welding e.g. instrument	1000		500	
Very fine soldering, spot welding e.g. radio valves	1500		750	
WOODWORKING SHOP				
Rough sawing, benchwork	300		200	
Sizing, planing, rough sanding medium and bench work gluing cooperage	500		300	

Table 14: Lux specification

GENERAL BUILDING AREAS	IES STANDARDS ILLUMINATION LEVEL	MS 1525 RECOMMENDATION	PANDUAN TEKNIK JKR	NOTES
Fine bench and machine work fine sanding, finishing	750		400	
OFFICE				
General office with mainly clerical task and typing office	500	300-400	500	
Deep plan general offices	750	300-400	300	
Business machine and typing	750	300-400	300	
Filling room	300	200	300	
Conference rooms	750	300-400	300	
OFFICES AND SHOPS				
Executive office	500	300-400	300	
Computer rooms	500	300-400	500	
Punch card rooms	750	300-400	600	
Drawing offices drawing boards	750	300-400	600	
Reference table and general	500	300-400	300	
Print room	300	300-400	300	
SHOP				
Conventional with counters	500	200-750	500	
Conventional with wall display	500	200-750	500	
Conventional with wall display	500	200-750	500	
SHOP				
Self service	500	200-750	500	

Table 15: Lux specification

GENERAL BUILDING AREAS	IES STANDARDS ILLUMINATION LEVEL	MS 1525 RECOMMENDATION	PANDUAN TEKNIK JKR	NOTES
Supermarkets	500	200-750	500	
Hypermarkets	500	200-750	500	
General	500	200-750	500	
PUBLIC AND EDUCATIONAL BUILDING ASSEMBLY AND CONCERT HALLS				
Theatre and concert halls	100		100	
Cinemas	50		50	
Multipurpose	500		300	
FURTHER EDUCATION ESTABLISHMENT				
Lecture theatres general	500	300-500	300	
Chalkboard	500	300-500	300	
Demonstration benches	500	300-500	300	
Examination halls, seminar rooms, teaching spaces	500	300-500	300	
Laboratories	500	300-500	300	
FURTHER EDUCATION ESTABLISHMENT				
Workshop	300		300	
Staff rooms, student rooms\students hostels etc				
Gymnasium				
LIBRARIES				
Shelves, book stack	150	300-500	150	

Table 16: Lux specification

GENERAL BUILDING AREAS	IES STANDARDS ILLUMINATION LEVEL	MS 1525 RECOMMENDATION	PANDUAN TEKNIK JKR	NOTES
Reading table	300	300-500	300	
Reading rooms, newspaper and magazines	300	300-500	300	
Reference libraries	500	300-500	500	
Counters	500	300-500	500	
Cataloging and sorting	500	300-500	500	
Binding	500	300-500	500	
Closed book store	100		100	
MUSEUM AND ART GALLERIES GENERAL				
Exhibits insensitive to light	300	300	300	
Light sensitive exhibits	150		150	
Specially light sensitive exhibit	50		50	
SCHOOL				
Assembly halls general	300	300	200	
Platform and stage	special lighting	special lighting	special lighting	
Teaching spaces general	300	300	200	
Teaching spaces general	300	300	200	
General where also used for further education	500	300	300	
Chalkboard	500	300	300	
Beedlework rooms	500	300	300	
Art rooms				
Laboratories	500	300	300	

Table 17: Lux specification

GENERAL BUILDING AREAS	IES STANDARDS ILLUMINATION LEVEL	MS 1525 RECOMMENDATION	PANDUAN TEKNIK JKR	NOTES
Workshop	300	300	200	
Gymnasium	300	300	200	
Music practice rooms	300	300	200	
TRANSPORTS TERMINAL BUILDING				
Airport coach and railway station				
Reception areas (desk) customs and immigration halls	500		300	
Railway stations booking offices	500		300	
Railway station parcel and left luggage offices counters	300		200	
Circulation area	150		100	
Waiting area	300		200	
HOSPITAL				
Ward unit bed heads general	30-50		50	
General	150		local lighting	
Night	0.1			
Nurse station evening	300		300	
Pharmacies dispensing bench	500		300	
Shelves	150			
Reception general	300		200	
Enquiry desk	500		300	
Laboratories	500		300	
Operating theatre suits general	400		500	

Table 18: Lux specification

GENERAL BUILDING AREAS	IES STANDARDS ILLUMINATION LEVEL	MS 1525 RECOMMENDATION	PANDUAN TEKNIK JKR	NOTES
Operating area				
Recovery room and intensive care units	30-50		bedhead	
X-ray department radio-diagnostic and rooms fluoroscopy	500		500	
Dental surgeries				
HOMES				
Living rooms general	50		50	
Casual reading	150		150	
Sewing darningsrudies desk and protuged	300		300	
Bedroom general	50		50	
Bedlead kitchen	150		150	
Kitchen working areas				
Bathrooms	100		100	
Halls and landings	150		150	
Stairs	100		100	
Workshops	300		200	
Garages	50		50	
INDOOR SPORTS AND RECREATIONAL BUILDING				
MULTIPURPOSE SPORTS HALLS				
Athletics, basketball, bowls, judo	300		200	
Hockey	700		500	
BADMINTON COURTS	300		300	

Table 19: Lux specification

GENERAL BUILDING AREAS	IES STANDARDS ILLUMINATION LEVEL	MS 1525 RECOMMENDATION	PANDUAN TEKNIK JKR	NOTES
BILLIARD ROOMS				
General	100		150	
Table	special lighting			
CARD ROOMS	300		300	
GYMNASIA GENERAL	500		300	
SWIMMING POOL				
Top pool	500		300	
Spectator areas	150		150	
Club recreational	300		200	
GENERAL				
Changing rooms showers lookers rooms	150	150	150	
TABLE TENNIS				
Club	300		200	
Recreational	200		200	

Table 20: Lux specification