

**OPTIMIZING DAYLIGHTING FOR  
RESIDENTIAL BUILDINGS  
IN DEPOK CITY, JAKARTA**

**By**

**ADHIE PRASETIO WIBOWO**

**Thesis submitted in fulfillment of the requirement for the degree of**

**Master of Science**

**December 2015**

## ACKNOWLEDGMENT

By saying Alhamdulillah, I would like to express much gratefulness to ALLAH SWT, who always gives strength and eases for me to work on this thesis. Besides, I would also like to show gratitude to His Messenger Prophet Muhammad SAW who becomes my inspiration to keep on learning. Then, I also want to thank my family who always accompanies, motivates and always prays for me, wife and my daughter (Bella Febrina Nurmursalina dan Najlaa Atilla Syalabia), my parents (Ayah Ibu, Papah Mamah), also my brother and sister.

My greatest appreciation and gratitude to my supervisor, Prof. AR. Abdul Malek Abd. Rahman and his wife. I am really grateful to be guided by you, thank you for your guidance and advice during the working on my thesis. For the Dean of HBP Universiti Sains Malaysia Dr. Aldrin Abdullah and all administrative staff in The School of Housing Building Planning. I thank them all.

I thanks to my friends Aizat Hisham, Noor A Shikin, Yahya Al Waraekat, Karam Al-Obaidi, Dudi Permana, other Indonesian and international students. Friends who has helped me in working on this thesis to finish.

Adhie Prasetio Wibowo

# TABLE OF CONTENTS

	Page
Acknowledgments.....	ii
Table of Contents.....	iii
List of Tables.....	viii
List of Figures.....	ix
List of Plates.....	xii
List of Abbreviations.....	xiv
Abstrak.....	xv
Abstract.....	xvi

## CHAPTER 1 : INTRODUCTION

1.1. Research Background.....	1
1.1.1 Environmental Issues .....	3
1.1.2 Sustainable Design.....	8
1.2 Problem Statement.....	9
1.3 Objectives of The Study.....	11
1.4 Aims and Scopes of The Study.....	11

## CHAPTER 2 : LITERATURE REVIEW

2.1	Introduction.....	13
2.2	Overview of Indonesian Climate Condition.....	13
2.3	The Indonesian Initiative.....	15
2.4	Housing in Jakarta.....	17
2.5	Natural Lighting (Daylighting).....	20
2.5.1	Light Reflection.....	23
2.5.2	Wall Color.....	25
2.5.3	Enlarge openings.....	25
2.5.4	Skylight.....	26
2.5.5	Louvre and Canopy.....	27
2.6	Design and Lighting Regulations in Indonesia.....	28
2.6.1	SNI (Standar Nasional Indonesia).....	28
2.6.2	Greenship (Green Building Council Indonesia): Natural Lighting....	29
2.7	Previous Studies on Natural/Daylighting.....	30
2.7.1	Townhouse in Surabaya.....	30
2.7.2	Optimization of Natural Lighting in the Interior of Offices.....	32

in South Jakarta

## CHAPTER 3 : RESEARCH METHODOLOGY

3.1	Introduction.....	37
3.2	Research Approach and Methodology.....	39
3.2.1	Methodology.....	40
3.2.1.1	Data Collection Phase.....	41
3.2.1.2	Data Analysis Phases.....	42
3.2.2	Day-lighting Factors.....	44
3.2.2.1	Sky components.....	45
3.2.2.2	Externally reflected components (ERC).....	45
3.2.2.3	Internally reflected component (IRC).....	46
3.2.3	The Measurement.....	47
3.2.4	Criteria for The quality of Natural Lighting.....	50
3.3	The Physical Experimental Study.....	51
3.3.1	Site Studies.....	52
3.3.2	Measurement Studies.....	53
3.3.2.1	The North Facing Home.....	55
3.3.2.2	The South Facing Home.....	58

## CHAPTER 4 : RESULT AND DISCUSSION

4.1	Introduction.....	64
4.2	The North Facing Home.....	68
4.2.1	The North Facing Home First Day.....	73
4.2.2	The North Facing Home Second Days.....	74
4.2.3	The North Facing Home Third Days.....	76
4.3	The South Facing Home.....	78
4.3.1	The South Facing Home First Day.....	87
4.3.2	The South Facing Home Second Days.....	88
4.3.3	The South Facing Home Third Days .....	89
4.4	Comparison between The North Facing Home and The South Facing Home in Terms of Daylighting.	91
4.4.1	First Day Comparison.....	92
4.4.2	Second Days Comparison.....	94
4.4.3	Third Days Comparison.....	95

## CHAPTER 5 : ANALYSIS AND DISCUSSION

5.1	Design Analysis of The South Facing Home.....	99
-----	---	----

5.1.1	Analysis of the internal factors in The South Facing Home.....	100
	by performing direct modification	
5.1.2	Analysis of the factor influencing natural lighting to enter into.....	104
	the house through direct observation and using software	
5.1.2.1	Building Orientation.....	104
5.1.2.2	External Factors.....	106
5.1.2.3	The Facade.....	107
5.1.2.4	Interior Material.....	109

## **CHAPTER 6 : CONCLUSION AND RECOMMEDATION**

6.1	Introduction.....	111
6.2	Meeting Benchmark (Greenship).....	111
6.3	Thesis Conclusion.....	114
6.4	Recommendation for Future Works.....	115
6.5	Conclusion.....	120

## LIST OF TABLES

		Page
Table 2.1.	Reflection Coefficients of various materials.	24
Table 2.2.	Comparisons of Field Measurement Results and Recommended Illumination Levels.	31
Table 3.1.	Recommended lighting levels.	51
Table 4.1.	Results of outside measurement over 3 days.	66
Table 4.2.	Measurement results on the 1st day at the North Facing Home	73
Table 4.3.	Measurement results on the 2nd days at the North Facing Home	76
Table 4.4.	Measurement results on the 3rd days at the North Facing Home	77
Table 4.5.	Measurement results on the 1st day at The South Facing Home	88
Table 4.6.	Measurement results on the 2nd days at The South Facing Home	89
Table 4.7.	Measurement results on the 3rd days at The South Facing Home	90
Table 4.8.	Comparison of the first day's results at The North Facing Home And The South Facing Home.	93
Table 4.9.	Comparison of the second day's results at The North Facing Home And The South Facing Home.	94
Table 4.10.	Comparison of the third day's results at The North Facing Home And The South Facing Home.	96
Table 5.1.	Results of all-day measurements to the interior of The South Facing Home	1

## LIST OF FIGURE

	<b>Page</b>
Figure 1.1. Energy consumption in Indonesia by sector.	6
Figure 3.1. Research Methodology.	40
Figure 3.2. Measurement Point with Sky Component.	45
Figure 3.3. Measurement Point with External Reflection Component.	45
Figure 3.4. Measurement Point with Internal Reflection Component.	46
Figure 3.5. Detailed Section Measurement Point.	48
Figure 3.6. Detailed Floor Plan Measurement Point.	48
Figure 3.7. Section Measurement Point.	49
Figure 3.8. Floor Plan Measurement Point.	50
Figure 3.9. The North Facing Home Façade.	56
Figure 3.10. The North Facing Home Section Measurement Point.	57
Figure 3.11. The North Facing Home Measurement Point in plan and layout.	58
Figure 3.12. The South Facing home.	59
Figure 3.13. Simulation of the sun path at The South Facing home (site Measurement).	61
Figure 3.14. The South Facing home Measurement Point in plan and layout (Ground Floor).	62

Figure 3.15.	The South Facing Home floor plan (First Floor).	63
Figure 3.16.	The South Facing Home Section Measurement Point	63
Figure 4.1.	Results of outside measurement over 3 days.	65
Figure 4.2.	Sun path by month in Indonesia.	67
Figure 4.3.	Sun path on the North Facing Home.	68
Figure 4.4.	Floor Plan of The North Facing Home .	70
Figure 4.5.	Lengthwise and athwart section of the North Facing Home .	72
Figure 4.6.	Graph showing the measurement results from the North Facing Home over 3 days.	78
Figure 4.7.	Sun Path on The South Facing Home.	79
Figure 4.8.	Façade of The South Facing Home.	82
Figure 4.9.	Floor Plan of The South Facing Home and the measurement point.	83
Figure 4.10.	Measurement point in The South Facing Home as viewed in section and layout (South Facing).	84
Figure 4.11.	Position of the sun and reflections on The South Facing Home	86
Figure 4.12.	Measurement results in the experimental house (South Facing).	91
Figure 4.13.	Outdoor measurement results .	92
Figure 4.14.	Results of the first day's measurements at The North Facing Home and The South Facing Home.	93
Figure 4.15.	Results of the second day's measurements at The North Facing	

	Home and The South Facing Home.	95
Figure 4.16.	Results of the third day's measurements at The North Facing Home and The South Facing Home.	97
Figure 5.1.	Results of outside measurements over 4 days.	100
Figure 5.2.	Results of all-day measurements to the interior of The South Facing Home	103

## LIST OF PLATES

	<b>Page</b>
Plate 1.1. Disasters that have occurred in Indonesia. From left to right: tsunami, tornado, drought, floods.	4
Plate 1.2. Global Warming Predictions.	5
Plate 2.1. Geographic map of Indonesia.	14
Plate 2.2. Different types of skylights found in Indonesian homes.	26
Plate 2.3. Different types of louvres and canopies.	27
Plate 3.1. Lux Meter, TES-3661A Model.	42
Plate 3.2. Angles of the Sun..	44
Plate 3.4. Map of the sun path in Depok.	54
Plate 3.5. Sun path at the North Facing Home (Site Measurement).	55
Plate 3.6. Sun path at the South Facing Home (site Measurement).	60
Plate 4.1. Position of the North Facing Home .	69
Plate 4.2. Floor Plan of the North Facing Home .	71
Plate 4.3. Trees from the front of the North Facing Home were removed.	75
Plate 4.4. Position of The South Facing Home.	80
Plate 4.5. Interior The south facing home	85

Plate 4.5.	Western side is bounded by a wall that divides the house from the adjoining village.	81
Plate 5.1.	Modification Interior The south facing home	101
Plate 5.2.	Existing environment.	104
Plate 5.3.	Simulation of the existing environment.	105
Plate 5.4.	Map of sun path in Depok, Java.	106
Plate 5.5.	Visualization of the building confines and external obstructing factors.	107
Plate 5.6.	Visualization of the depth of the building's façade.	109
Plate 5.7.	Visualization of external factors in terms of the façade and materials used.	110
Plate 6.1.	Typical residential area in Jakarta with narrow streets.	112
Plate 6.2.	Modification of a roof with a sky light.	116
Plate 6.3.	Modification from a louver to a clerestory window.	117
Plate 6.4.	Modification of existing windows.	118
Plate 6.5.	Modifications of interior and exterior colors.	119

## LIST OF ABBREVIATIONS

AM	-	Ante Meridiem
APEC	-	Asia-Pacific Economic Cooperation
ASD	-	Appropriate Site Development
BPS	-	<i>Badan Pusat Statistik Indonesia</i> (Indonesian National Statistics Agency)
CFC	-	Chloro Fourocarbon
EEC	-	Energy Efficiency and Conservation
EL	-	East Longitude
ERC	-	Externally reflected component
GBCI	-	Green Building Council Indonesia
IRC	-	Internally reflected component
PM	-	Post Meridiem
SC	-	Sky component
SL	-	South Latitude
UV	-	Ultraviolet
WFR	-	Window-Floor-Ratio
° C	-	Degrees Celsius

**MENGOPTIMUMKAN PENCAHAYAAN SIANG UNTUK  
BANGUNAN KEDIAMAN DOMESTIK  
DI KOTA DEPOK JAKARTA**

**ABSTRAK**

Isu berkenaan bangunan jimat dan cekap tenaga bukanlah sesuatu yang baru dan berkait rapat dengan faktor pencahayaan semula jadi terutamanya di kawasan perumahan di Indonesia. Untuk menjimatkan penggunaan tenaga elektrik yang digunakan bertujuan untuk pencahayaan, penggunaan cahaya matahari bagi tujuan pencahayaan membuahkan hasil yang memberangsangkan bagi kawasan perumahan seperti di kawasan perumahan yang padat seperti di Depok. Arkitek memainkan peranan yang sangat penting dalam usaha untuk mengurangkan penggunaan tenaga yang berteraskan tenaga fosil melalui seni bina berkonsepkan hijau yang mengoptimumkan penggunaan cahaya semula jadi seperti tenaga matahari. Oleh itu pengamatan arah cahaya bersama-sama dengan kesan pantulan atau pembiasan juga perlu diatur dengan sewajarnya untuk mewujudkan keselesaan visual ruang. Kaedah yang digunakan adalah berdasarkan pengalaman dan data pada sampel dua model perumahan yang menghadap ke arah utara dan selatan yang biasanya dijumpai di kawasan perumahan yang padat seperti di Jakarta serta disokong oleh kajian literatur dan model simulasi Ecotect. Hasil kajian menunjukkan bahawa rumah yang menghadap arah utara menepati standard pencahayaan semula jadi yang ditetapkan oleh Majlis Bangunan Hijau Indonesia (GBCI). Kesimpulannya, untuk mencapai standard yang ditetapkan oleh GBCI, pengubahsuaian perlulah dilakukan secara beransur-ansur terhadap rumah yang menghadap ke arah selatan.

**OPTIMIZING DAYLIGHTING FOR RESIDENTIAL  
BUILDING IN DEPOK CITY, JAKARTA**

**ABSTRACT**

The issue of energy-saving buildings and energy efficiency is not really new and are closely associated with natural lighting factors especially in housing in Indonesia. To save electrical energy consumption of the lighting, the use of lighting by sunlight is constantly being developed for housing, such as in dense residential areas like in Depok. Architects play a very important role to help reduce the use of energy derived from fossil energy into a green design approach by optimizing natural lighting from the sun. Therefore, the directions of light along with the effects of reflection or refraction also need to be arranged accordingly to create the visual comfort of the space. The method used was by experiential and data collection on samples of two housing models facing north and south which are commonly found in dense residential area in Jakarta strongly supported by literature studies and modelling by Ecotect simulation. From research performed, it was indicated that north facing house has met its daylight standards set by the Green Building Council of Indonesia (GBCI). To achieve the standards set by the GBCI, further modifications were made gradually to the house facing south.

## CHAPTER 1

### INTRODUCTION

#### 1.1 Research Background

The incandescent light bulb, Thomas Edison's quintessential bright idea, is well over a century old. The first electrical product that everyone wanted, arguable it created a demand for electricity itself, where none had previously existed. Now its days are most definitely numbered. The reason for this will be obvious to anyone who has ever burned their finger on a lit bulb. Ordinary incandescent bulbs—cheap, disposable and until now widely available—are incredibly inefficient. They convert only 5 per cent of the energy they use into light; the rest is converted into heat. The more daylight the interior of your home receives, the less you will have to rely on the artificial light source to provide illumination during the day, which means lower energy consumption. (Dickey, 2009).

Natural lighting, as one of the important factors that need to be utilized optimally in planning a building, should be engaged during the planning of the building structure (Evans, 1981). That is, considering the utilization of natural lighting at the very beginning of the planning process is very important. To meet the need for visual comfort in space by using artificial lighting technology is now no longer a difficult thing. However, the use of this technology will burden the energy consumption in a building. Just as we are urged to change our lifestyle to reduce our carbon footprint and consumption of electrical for artificial lighting, there is a great deal we can do to convert our existing homes into greener ones.

Architecture in Indonesia has been growing over the last three and half decades, but is yet to focus on environmental issues (Martokusumo, 2009). Most architects today only consider the efficiency of land usage and aesthetic aspects, while not paying adequate attention to the environment. Furthermore, the operating costs involved in constructing buildings today are higher than those in the past. Accordingly, it is important to study and compare recent buildings with those from the further past to see which boast a more efficient use of energy. The results of such comparisons can then be adapted and applied to the modern world.

Changes in human activities and ways of life, from traditional agrarian societies which depended upon nature into industrialized societies, have taken place in line with the development of modern technology. The growth of metropolises in today's world is happening quickly. Skyscrapers, factories, residences, townhouses and many other types of buildings are increasingly proliferating, while forests are being converted into agricultural areas. In addition, many villages have been transformed into small towns and small towns, in turn, into big cities. This chain of events has led to land becoming increasingly scarce.

Two aspects which influence human life are technology and nature. Technology is comprised of instant mechanisms which can be directly applied to life; in contrast, people are slower to adapt to the natural world and its requirements. Thanks to ever-evolving technology, human beings are leading more prosperous lives than ever before. However, the application of technology also tends to result in some side effects, of a biological, psychological, and ecological nature. Technology can cause harm to nature, including through pollution and the exhaustion of natural resources, and may ultimately endanger human life as we know it.

With all the rapid development taking place in today's fast-paced society, the question arises as to whether architects (designers), owners, and contractors are concerned about the impact of the rapidly increasing number of buildings on the environment.

There are several other issues that pose potential risks to the Earth's environment and indeed to the future development of human society. These include greenhouse gases, air pollution, acid rain, rapid population expansion, and especially climate change. Redressing climate change requires deep societal changes and a shift from fossil fuels to renewable energy sources.

#### 1.1.1 Environmental issues

As the issue of global warming becomes more prominent, people's awareness about maintaining the sustainability of the earth is also increasing. People are increasingly aware that their existence is inseparable from the support of natural resources in their surroundings. Natural resources are essentially differentiated into non-renewable natural resources and renewable natural resources. Resources that cannot be renewed will be exhausted when used continuously. In addition, using non-renewable natural resources damages the surrounding environment as it can cause pollution. Moreover, it can also deplete the ozone in the atmosphere, enhance greenhouse gases, and lead to an increase in the average global temperature, known as global warming.

Global warming is essentially defined as a phenomenon whereby the average global temperature increases from year to year, largely due to the greenhouse effect. The greenhouse effect refers to the phenomenon whereby certain gases, like carbon dioxide, methane, nitrogen oxide and CFCs, trap solar radiation in the atmosphere

which is then re-radiated so that the earth heats up (Buchdahl, 1999). Various research findings have revealed links between the increasing amount of greenhouse gases in the atmosphere and rising temperatures. As the concentration of greenhouse gases in the atmosphere continues to increase, the impact on climate increases, as does the impact on human life. As suggested by a researcher from the United Kingdom who deals with thermal comfort, Webb (An Analysis of Some Observations of Thermal Comfort in An Equatorial Climate, British Journal of Industrial Medicine, vol. 16), pointed out that since 400 years b.c., Hippocrates introduced the physical effects of the climate on the human being in the form of air temperature, humidity, wind and solar radiation.

Global warming has negative effects on many things. Plate 1.1 below illustrates the impact of global warming on local environments.



Plate 1.1 Disasters that have occurred in Indonesia. From left to right: tsunami, tornado, drought, floods.

Source: BPS, *Badan Pusat Statistik Indonesia* (Indonesian National Statistics Agency), 2004

According to the 2007 Fourth Assessment Report by the Intergovernmental Panel on Climate Change (IPCC), the average global temperature at the earth's surface has risen by  $0.74 \pm 0.18^{\circ} \text{C}$  ( $1.33 \pm 0.32^{\circ} \text{F}$ ) over the last hundred years. This increase in

global temperatures is thought to have begun in the twentieth century (*Kementrian Energi dan Sumber Daya Alam Indonesia/Indonesian Ministry of Energy and Natural Resources*, 2009). This has resulted in extreme climate change in different regions in the world, and various subsequent environmental crises. Even greater awareness on the part of the Earth's inhabitants is required to prevent any further rises in temperature.

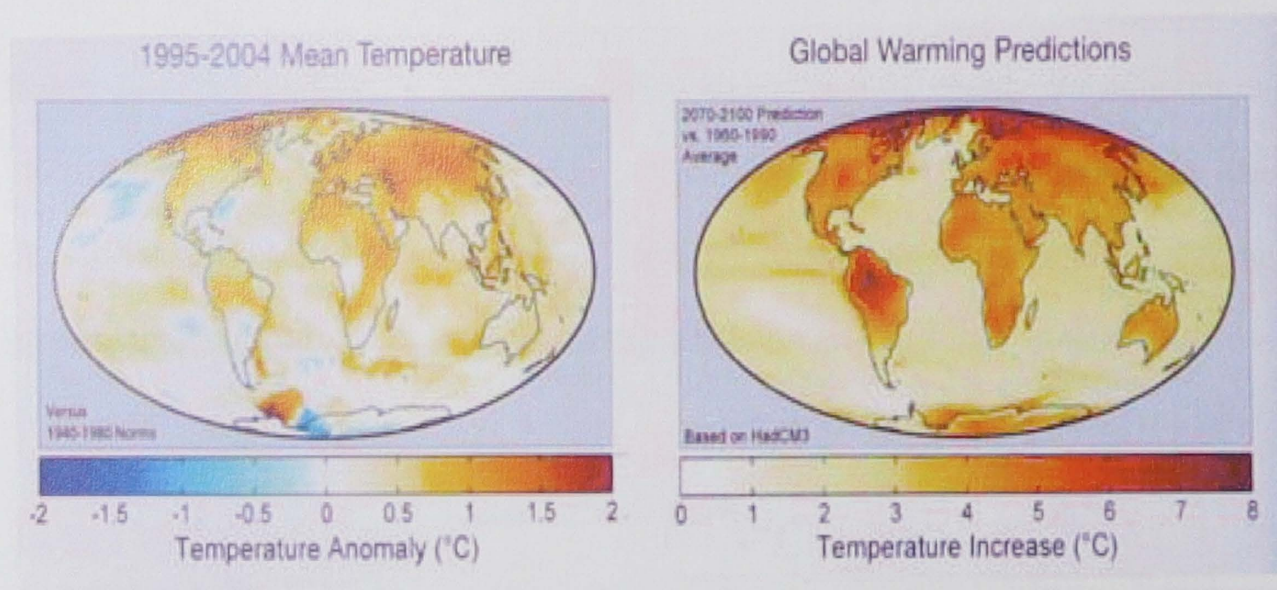


Plate 1.2 Global Warming Predictions

Source: Indonesia Energy Outlook, 2009

International concerns about climate change led to the Kyoto Protocol, negotiated in 1997, which contained legally binding emission targets to be achieved by industrialized countries during the commitment period of 2008-2012. While proponents of the Protocol celebrated it as a breakthrough in international climate policy, opponents criticized its approach, namely setting targets and timetables for emission reductions, as being seriously flawed.

In Indonesia, meanwhile, a milestone in terms of environmental awareness came with the Seminar on Environmental Management and National Development, hosted by

Pajajaran, University, in Bandung from 15 – 18 May 1972, (Humairah, 2012). Nevertheless, Indonesian consumers are still generally considered wasteful. To illustrate this, the growth of energy consumption in Indonesia was very high in the period 1985-2000, at an average of 7% per year, while global energy consumption grew at an average of 1.2% per year, and the average for APEC countries was 2.6% per year. By 2007, the growth of energy consumption in Indonesia had reached 10% per year, which can be categorized as very wasteful, and very worrying.

Based on data from *Badan Pusat Statistik Indonesia* (2009), energy consumption in Indonesia is still dominated by the industrial sector (51%), followed by the transportation sector (30%), households (11%), the commercial sector (5%), and the mining, construction and agriculture sectors (3%).

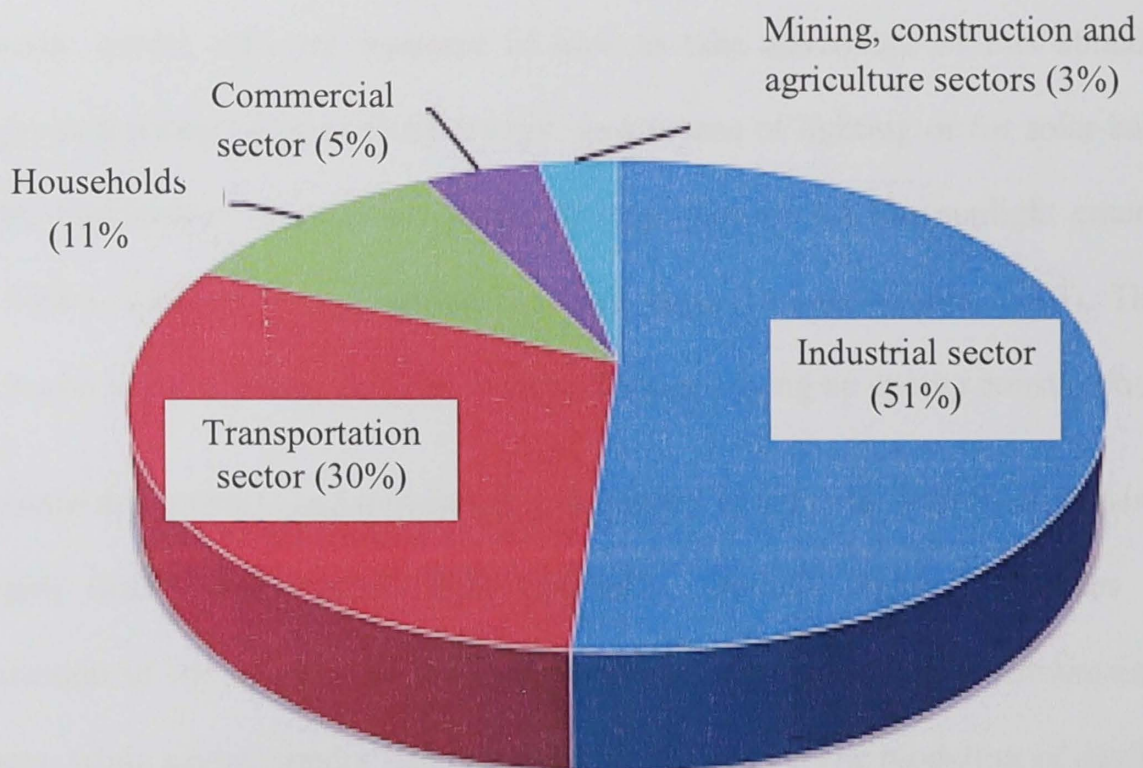


Figure 1.1 Energy consumption in Indonesia by sector

Source: BPS, *Badan Pusat Statistik Indonesia* (Indonesian National Statistics Agency) (2009)

According to *Kementrian Energi dan Sumber Daya Alam Indonesia/Indonesian Ministry of Energy and Natural Resources*, (2009), among the largest users of electricity in Indonesia are households. Households contribute to problems in more ways than one. Due to people's preference for living in landed houses, there are limitations in the amount of land available. Many areas in big cities that were initially designed as city parks have now been allocated for housing. Instead of parks that serve as areas of greenery and rainwater absorption, tightly-packed residential areas are found.

Often houses are not built in an ideal way. They are located too near to one another, causing poor ventilation and air circulation, as well as a lack of natural lighting. Despite the fact that Indonesia actually enjoys various environmental advantages, such as a year-round tropical climate with high humidity, strong solar radiation intensity, relatively high temperatures and clear skies (Lippsmeier, 1994), there are still many people who are unaware of how to take advantage of this abundant sunlight as a source of sustainable energy, as a means of lighting or for solar-based devices. Furthermore, Indonesian people in large part do not like sunlight entering their homes because of its resulting heat and glare (Honggowidjaja, 2003). Thus, they choose to use artificial comfort devices, further driving up energy consumption.

To counter this problem and mindset, it is necessary to come up with lighting design strategies that utilize natural light optimally. Optimal lighting includes the optimization of the quantity of daylight, keeping visual freshness and maintaining coolness, while saving energy (Harten & Setiawan, 1985). The modeling of daylight in buildings is a challenging problem of increasing importance. The careful management of daylight in a building is crucial in minimizing the environmental impact of a structure (U.S Department of Energy, 2006). It also has the potential to

produce positive effects on health (Webb, 1959), well-being and, possibly, productivity (Kim, 2012). In addition to these benefits, it remains a predominant factor in how a space is revealed and perceived by its users (Guzowski, 2000). Therefore, a major challenge that designers face is how to effectively combine the many performance parameters involved in daylighting with aesthetic considerations. These parameters include daily and seasonal variations, the delicate balance between sufficient illumination and visual comfort, and thermal aspects of incoming solar radiation. Only if this integration happens early in the design process can it have a significant impact on energy saving and, ultimately, building performance.

### 1.1.2 Sustainable Design

Architectural sustainability is defined as architecture which applies the approach of sustainability, in that the architect not only sets out to make a building beautiful, simply according to the wishes of its owners or the convenience of its users, but also strives to create a positive impact on the surrounding environment (Sudarwani, 2008). Sustainable architecture is a concept applied in order that natural resources are maintained and last longer. It is concerned with the potential of natural resources and aspects of the environment, such as the earth's climate system, agricultural systems, forestry, as well as industry and of course architecture (Lawrence, Agustina, 2000). Sustainable architecture encompasses concepts such as the efficient use of energy, land, new and existing materials, technology and waste management. Sustainable architecture pertains to the overall cycle of a building, starting from its development process, utilization, preservation until its demolition. One of the visions of sustainable architecture is to reduce greenhouse gas emissions, while also emphasizing the importance of quality rather than quantity in designing a building –

taking into account functional aspects, the environment, health, convenience, aesthetics and added value.

Ander (1995) in defines sustainable design as responsible energy ethics. It seeks to address the misconception that the supply of fuel is inexhaustible, while actually it will inevitably become increasingly scarce and more and more effort will need to be expended to acquire less and less fuel.

## **1.2 Problem Statement**

Along with the increasing density of population in Depok, the needs and demands of housing in the city continue to arise, while the land for housing shrinks and remains limited. As a result, some areas in the city become extremely densely populated, making each building become too close to each other.

Depok is a densely populated are with limited available land. Houses in Depok and other big cities in Indonesia, especially in Java, tend to be linear in arrangement and adjacent to one another. There is a distinct lack of space between them. In addition, streets in residential areas tend to be narrow. Indeed, some streets are only wide enough for motorcycles. It is no wonder then that the infiltration of sunlight into houses is insufficient for good natural lighting.

Lighting is one of the most important factors in space design (Noerwasito, Santosa. 2006). Designed space cannot be utilized properly if it does not provide access to lighting. Interior lighting is essential for seeing objects clearly. Without being able to see well, any activity in the space concerned will be disrupted. On the other hand, if space is too bright, it can impair vision. Thus lighting intensity needs to be regulated

to conform to the space in question as well as the activities that take place in that space.

The quality of good lighting is determined from the ratio of light reflection and the ratio of the lighting in the room. In addition, it should also pay attention to the aspects of energy consumption in efficient ways by utilizing natural lighting to get great benefits. Natural lighting coming in through the windows can be used as a source of lighting in the building as well as an effort to save energy. Therefore, it is necessary for lighting design strategies to optimally utilize the natural lighting.

Further to the issues above, this study sought to observe housing in highly populated city like Depok city as a satelite city of Jakarta. Some problems that were encountered are outlined below:

1. With the presence of houses which tend to be linear in arrangement and adjacent to one another, natural lighting during the daytime cannot optimally enter into the room.
2. Houses still use artificial lighting during the daytime because it is generally quite dark indoor.
3. Mistakes are often made in designing, selecting materials for houses, as well as in determining the dimensions and choosing the color and finishing materials. There are often further missteps when it comes to decisions about the size, interiors and exteriors of houses.

### **1.3 Objectives of the Study**

The primary objectives of the study which was undertaken are:

1. To investigate the impact of domestic building design in Jakarta, and contrast this with a green approach to architecture by building energy-efficient and healthy homes. In particular, the issue of optimizing natural lighting for domestic buildings in Depok was looked at, specifically identifying better housing models for receiving optimal sunlight.
2. To solve the problem of daylighting for domestic buildings in Depok with a view to dispensing with artificial lighting during the day. While natural lighting is fairly easy to assess, there are still only a limited number of studies which explore this.
3. To recommend strategies as a guideline for the application of daylighting in Depok.

### **1.4 Aims And Scope of the Study**

This thesis investigate and discusses how to optimize natural lighting in domestic buildings (landed houses) located in highly populated areas in Indonesia. Depok, a satellite city of Jakarta, forms the specific area of study, but the study may also be useful as a reference for other big cities in Indonesia. The objects of comparison are two houses with two different orientations, one north-facing and the other south-facing. Assessments were made to determine which had the better natural lighting, and solutions were proposed to create enough natural lighting to meet the criteria specified by GBCI. In addition, at the end of the study, recommendations are

made with regard to design solutions for terrace houses, so that these may meet the criteria established in the green building index by GBCI.

## **1.5 Outline of the Thesis**

Chapter 1 discusses the background research and the problems encountered. It also outlines the contents of the thesis.

Chapter 2 provides literature reviews about natural lighting, and discusses related research conducted by scholars as well as articles on natural lighting or daylighting in Java, Indonesia and neighboring tropical countries like Malaysia, Singapore, Thailand, and the Philippines.

Chapter 3 explains the methodology for gathering data in this research study. How the experiments were conducted, how the optimum and precise results were obtained, and how the data on research locations were collected will be elaborated on in this chapter.

Chapter 4 explains the results of the research that was performed, at the site study in Depok City.

Chapter 5, This chapter analyzes the problems found while the research was carried out and compares the results of the research with the findings from previous research.

The final chapter, Chapter 6, discusses the conclusions reached through this research. In this chapter, the researcher makes recommendations as to future research and architectural projects.

## CHAPTER 2

### LITERATURE REVIEW

#### **2.1 Introduction**

Building are the biggest polluters on the planet, responsible for a far greater proportion of the carbon dioxide emission get pumped into the atmosphere every year than cars, plane or factories. (Dickey,2009)

While Green Building Council Indonesia (GBCI) already issues *green* building certifications in Indonesia, still fewer than 5% of the country's buildings are certified and meet the criteria of being eco-friendly (Mochtar, Larasati, 2013). This chapter presents a literature review on topics related to one particular eco-friendly initiative - optimizing natural lighting for domestic buildings in Java and other tropical areas. It also touches on the illuminating effects that daylighting can have on homes.

#### **2.2 Overview of Indonesia's Climate Condition**

Indonesia is a tropical country which lies between 6 degrees northern latitude and 11 degrees southern latitude, and spreads from 97 degrees to 141 degrees eastern longitude. It is located between the continents of Asia and Australia/Oceania. As a largely equatorial country, Indonesia enjoys abundant amounts of sunshine.



Plate 2.1 Geographic map of Indonesia

Source: <http://nature.desktopnexus.com/wallpaper/439576/>

In urban areas, where most of the land is utilized for buildings, still only a few designers consider constructing energy-efficient buildings; most of them merely pay attention to economic factors – how to construct a building as cheaply as possible. They ignore the fact that energy-efficient buildings can also save costs as expenses on energy are reduced. One form of energy efficiency is the use of natural lighting during the daytime.

The external environment plays a big role in the amount of natural lighting available to buildings in densely populated residential areas. External obstructions around windows, for example, will affect the amount of natural light coming into a room (Ander, 1995). Energy-saving architecture demands that such obstacles are overcome and counts the planning for natural lighting as an integral part of the design process. However, only recently have some interior designers and architects started to take

advantage of Indonesia's favorable climate by creating more environmentally-friendly and energy-efficient architectural designs with an emphasis on optimizing natural lighting for domestic buildings – and in so doing reducing the use of artificial light using electricity generated from fossil fuels.

### **2.3 The Indonesian Initiative**

Industries, as well as the behavior of the community, are always subject to change. The building industry is no different. In Indonesia, the concept of a national initiative for sustainable building was developed by Green Building Council Indonesia (GBCI), a non-profit organization with a mission to support, promote and maintain the transformation of the building industry. As such, there is a need to foster a community which specializes in designing and maintaining good relations with the environment, as well as to create a forum and dialogue in this respect. This organization works together with the Indonesian Ministry of the Environment to perform research activities in all aspects of natural resource management, environmental impact analysis, environmental management, coastal water conservation, waste treatment technologies, environmental health, and associated legal matters. The organization is also authorized to establish criteria and gives *green building* certification to buildings which have been inspected and proven to qualify. In light of these noble efforts, the government should encourage and facilitate the initiatives of such institutions, or like-minded individuals, in carrying out research on climate change and through developing environmentally-friendly buildings.

The green concept applied by Green Building Council Indonesia prioritizes the principle of sustainability and environmentally-friendly practices. This is a new

approach in Indonesia in line with a growing market trend which concerns nature and the environment, and how to apply such practices and principles in everyday life. We know that in Europe, America and parts of Southeast Asia, this concept has been largely recognized and adopted, and many people are aware of how to lead a green way of life. GBCI is striving to instill such green principles among the Indonesian population, especially when it comes to the country's buildings. Unfortunately, GBCI's mission seems hard to achieve when it is not supported by developers, users, or even the government.

Furthermore, the reality is that many architects these days still tend to see themselves as artists, seeking to produce a masterpiece, rather than as scientists (Karyono, 2010). The net result of this mindset has been a dramatic reduction in the amount of natural light available in homes, schools and workplaces during the past half-century. In this way, it can be said that the quality of housing has declined (Heschong, 2002), and many of us still live in homes that waste energy and rely heavily on the use of artificial comfort devices (Karyono, 2010).

With this in mind, one of the important factors that needs to be utilized optimally in planning a building is natural lighting; this should be given due consideration as the planning of a building's structure is underway (Evans, 1981). On average, 54% of the total electricity used in buildings goes into lighting systems, with the purpose of attaining the highest possible level of visual comfort (Evans, 1981). Thus the harnessing of natural light can have a significant impact in terms of reducing the cost of a building's lighting system.

Planning for natural lighting should be essential and inseparable part of the design process. Energy-saving architecture is the logical and sustainable way forward. The

natural light provided by the sun is reflected by architectural elements, making it possible to reduce the use of artificial lighting, which uses electricity generated from fossil fuels. Given Indonesia's location on the equator, which allows the possibility of abundant, year-round sunlight, architects there have few constraints in exploring the possibilities of using natural lighting.

This study will look at housing located in the Jakarta area and find a house which meets the criteria set by GBCI in two aspects - Appropriate Site Development/ASD and Energy Efficiency and Conservation/EEC. By working within these two aspects, it is safe to assume that a green building can be realized.

## **2.4 Housing in Jakarta**

Due to increasing population density in Jakarta, the government has been unable to allocate enough land for green areas (Hindarto, 2007). Such spaces are desirable in a capital city like Jakarta in order to meet the recreational needs of the community and support community activities. This high population density has created an uncomfortable and inconvenient environment, causing many middle and upper-middle class residents to relocate to the suburbs. In turn, sub-urban areas have also become densely populated. Many homes in Jakarta today boast a nice facade, but inside they are dark, hot, stuffy, full of glares and generally uncomfortable. The popularity of artificial comfort devices is therefore unsurprising. Despite being relatively expensive, such devices are necessary in order to live comfortably. All of these devices require a lot of energy, which in turn increases household expenses and has a bad impact on the surrounding environment.

A lot of energy is consumed in the act of building and in buildings themselves. The World Green Building Council estimates that the construction sector absorbs 30-40% of the world's total energy (Kerr, 2008). Therefore, the application of energy-saving concepts in this sector will give a significant boost to energy sustainability. As to buildings themselves, one of the ways in which energy can be conserved is by optimizing their design to enable the use of natural potential, including lighting.

Many buildings today tend to be closed to avoid the heat, especially so as temperatures rise with global climate change. Openings, which were originally designed to allow the wind and sunlight in the house, are no longer optimized in today's buildings.

Added to this, urban residential areas in Indonesia generally leave only a small space between buildings; some buildings are even attached to other buildings, leaving no distance between them. The limitations of sheaths which are not enclosed by other sheaths in fact reduces the size of open space giving access to natural lighting. All of this means that very little natural lighting gets into most buildings. Furthermore, some people in Indonesia simply find sunlight entering their homes to be uncomfortable and prefer to use non heat-inducing artificial lighting.

Today many townhouses are appearing in Jakarta and its surrounding areas, especially in areas with high land values, as they are seen to have a high investment value. Townhouses are generally small houses built in a series and located in a complex. These complexes are known as clusters and usually adopt a *one gate system* as a security measure. One cluster typically contains no more than 30 houses. Generally, the townhouses in a cluster share facilities, such as a club house, as well as open recreational areas (Suci, 2009). In the Jabodetabek area (Jakarta, Bogor,

Depok, Bekasi, and Tangerang), cluster townhouses are increasingly easy to find. Depok, in particular, is seen as an area of great potential due to the number of campuses located there. It is predicted there will be more property build around the area to support the need for housing

Most of the building mass is lightweight. The gaps between buildings are relatively narrow so as to make full use of available land. This close distance between buildings has the effect of blocking sunlight, so that natural lighting cannot be utilized in certain parts. The buildings mostly have one or two stories, with a distance between the floor and ceiling of about 2.5-4 meters. Those buildings also have openings in the façade facing the street.

Houses provide shelter, one of the three primary needs of man in addition to food and clothing. Essentially, the primary function of a house is as a refuge from the potentially harmful effects of the physical environment, such as inclement weather or the threat of wild animals. However, as science and technology have developed, houses have come to be seen as symbols of status and prestige. Houses, of course, also require light, and we turn here to the discussion of natural lighting as an alternative to energy-sapping artificial means of lighting.

Added to this, urban residential areas in Indonesia generally leave only a small space between buildings; some buildings are even attached to other buildings, leaving no distance between them. The limitation of sheaths which are not enclosed by other sheaths in fact reduces the size of open space giving access to natural lighting. All of this means that very little natural lighting gets into most buildings. Furthermore, some people in Indonesia simply find sunlight entering their homes to be uncomfortable and prefer to use non heat-inducing artificial lighting.

## 2.5 NATURAL LIGHTING (DAYLIGHTING)

Harnessing natural lighting, or daylighting, is one of the best ways of saving on the electrical energy used for artificial lighting (Tsangrassoulis, 2008). The electrical energy used for artificial lighting in buildings is estimated to make up around 20-40% of total energy consumption (Chel, Tiwari, Chandra 2009). There is little doubt that most buildings in a town can take advantage of natural lighting effectively, thereby cutting down on utility bills and also reducing government subsidies used to supply electrical energy to communities.

Living comfort not only depends on the indoor temperature, incoming solar radiation, air quality, and weather quality, but is also determined by the quality of the lighting. Indonesia, which is rich in year-round sunshine, should prioritize natural lighting in its designs (Thojib, Adhitama, 2013). Lighting during the daytime plays a vital role in realizing sustainable architecture because it lowers energy consumption in buildings. In addition, it cuts electricity bills and promotes work efficiency through the improved health, well-being and comfort it brings about (Kim, 2012). Daylighting offers an impressive array of benefits, including the potential for added energy and cost savings if daylight controls are integrated into electric lighting systems.

On a related note, solar heat gain and heat loss from daylight apertures are also to be considered, so that energy is not wasted through excessive air conditioning in the summer, or heating in the winter. Passive solar homes are designed to take advantage of local climates by maximizing the energy from the sun to heat and cool the home

(Boone, 2005). The strategic use of external and/or internal light shelves, external shading structures, shuttering systems, plantings, or interior window treatments is among the many ways to plan for these considerations (Guzowski, 2000). There are many benefits to passive solar design for the homeowner and the environment. By reducing energy consumption, the homeowner can save money on utility bills and help prevent air pollution from electricity generating plants that burn fossil fuels. Passive solar design can easily be incorporated into any architectural style given the proper site. Such design strategies have been used effectively for hundreds of years. Although there is a small increase in the cost of construction, the home has lower annual energy and maintenance costs overall (Boone, 2005). Passive building designs have traditionally incorporated lighting techniques that reflect an area's climate, including side lighting, top lighting, and core lighting (Ander, 1995). Each of these approaches has advantages and disadvantages, depending on the climatic conditions in which the building is established. Top lighting, commonly known as sky lights, is the most effective choice (Treado, 1983).

Natural lighting has an excellent effect on interior space as it is reflected in different directions. This reflection can be enhanced by using certain finishing materials. Shiny (glossy) surfaces reflect light better than do matte (doff) surfaces. This principle also applies to artificial lighting. The concept of direct natural lighting can be applied in hallways, dining rooms, and family rooms. However, shiny materials are not recommended to be installed in workspaces as they may cause excess glare/contrast (Frazier, 2003).

In the design phase of a building, natural lighting can improve the building's quality gradually by:

- saving electricity and energy operating costs;
- providing direct light and light diffusion with natural characteristics;
- being customized to the wishes of the concerned parties;
- providing a connectedness with the outside world and its dynamic changes.

(Lyons and Lee, 1994).

Furthermore, daylight can serve as a dynamic design element, used in concert with materials and forms to shape the aesthetics and sequential experiences of interior space. Because of its transitory nature, daylight can bring visual and thermal movement, as well as contrast, which changes depending upon the time of day, season and climate (Guzowski, 2000).

Daylighting requires careful consideration of the site, including geographic location and building orientation, along with the climate and seasonal patterns of the area in question. (Guzowski, 2008) Changes in the exterior, such as new building construction, modified landscaping or planting, can alter conditions for daylighting, either causing shading or adding reflected light.

There are challenges presented by daylighting with regard to human comfort. Direct sunlight causes reflective glare and bright daylight can contrast uncomfortably with elements in an interior environment (Cuttle, 2008). Potentially uncomfortable thermal conditions may also be created in areas that receive direct sunlight. Home may be susceptible to potential damage to objects and materials in interior spaces due to excessive heat, visible light, and UV radiation. Homes which contain similar types of objects and materials will be similarly susceptible (Michalski, 2010). Planning for these risks requires collaboration among exhibition designers and conservation professionals.

The use of artificial lighting during the day is certainly a waste of energy, especially in a tropical country like Indonesia. However, efforts to incorporate sunlight/daylight into a house must be done wisely. A proper setting will result in good and economical lighting, while an improper setting will leave the occupants exposed to excessive sunlight that results in glare or high contrast so as to reduce comfort and the ability to see (Frazier, 2003).

In general, there are three factors that affect natural lighting design and several strategies to maximize daylighting into the house dan beberapa cara untuk dapat memaksimalkan daylighting masuk kedalam rumah. These are ceiling reflection (for reducing contrast), glare, and quantity (Ander, 1995). Lighting quantity is an attempt to meet the functional needs of a space related to the activities that occur in the space. Lighting quantity focuses largely on the fulfillment of visual needs (Manurung, 2009).

### 2.5.1 Light Reflection

There are several features of light that affect the amount of lighting that reaches an object. These include the following:

- Light can be bounced off and spread on an object.
- Light can pass through an object.
- Light can be biased through objects.

Table 2.1 Reflection Coefficients of various materials

Material	Reflection (%)
Aluminum, polished	70-85
Asphalt	10
Red brick	25-45
Concrete	30-50
Clear or colored glass	7
Reflective Glass	20-40
Dark Green Glass	10
Porcelain glaze (white)	60-90
Stone	5-50
Plant	25
Wood	5-40

Source: Lechner (2001)

From Table 2.1 above, it can be seen the materials and colors which can reflect good light; for instance, white or light colors can reflect light up to 70%-90% of the light that is coming. Therefore, white or light colors can be regarded as good light reflectors.