TRIBHUVAN UNIVERSITY

INSTITUTE OF ENGINEERING

PULCHOWK CAMPUS

THESIS NO.: M-185-MSESPM-2021-2024

"Variation Analysis in Cooling load between Single Pane Window and Double Glass Window in an Air-Conditioned Space"

by

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A THESIS

SUBMITTED TO THE DEPARTMENT OF MECHANICAL AND AEROSPACE ENGINEERING IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN ENERGY SYSTEM PLANNING AND MANAGEMENT

DEPARTMENT OF MECHANICAL AND AEROSPACE ENGINEERING

LALITPUR, NEPAL

JUNE, 2024

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The undersigned certify that they have read, and recommended to the Institute of Engineering for acceptance, a thesis entitled “Variation Analysis in Cooling load between Single Pane Glass in and Double-Glazing Glass in an Air-Conditioned Space” submitted by Archana Sah (078MSESP001) in partial fulfillment of the requirements for the degree of Master of Science in Energy System Planning and Management.

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ABSTRACT

This thesis compares the changes in the cooling load of an- air-conditioned space if double-glazing glass is used in windows instead of when single-pane glass. It investigated the effect of glass and its solar gain capacity in indoor temperature and finally on the air conditioning of the building. It is based on the principle that different types of glass have different solar gain constants and solar radiation gained through the glass directly alters the cooling load. For the energy-efficient method, glass having the lowest gain is preferred which would reduce radiation gain. Solar gain of double glaze glass is almost half of the single glaze glass due to the air insulation. So, just by changing the glass type used in windows, a huge amount of air conditioning energy can be saved.

Taking an air conditioning space, located in the Pulchowk Lalitpur, the total cooling load is calculated. It is calculated by simple CLTD method i.e., cooling load temperature difference method. For simplification, a commercial ASHRAE calculation sheet is used to calculate the value of CLTD. Further environmental conditions and correction coefficient are taken according to the latitude. To make the calculation more precise and efficient, calculations are done for June and July at 12 PM, 2 PM, and 4 PM. The maximum cooling load is recorded for June at 4 PM. Further, Calculations are completed by taking this peak value of the cooling load.

The calculations are completed for both types of glass keeping every other factor constant, changing the gain constant only. The maximum value of cooling load recorded in June at 4 PM is around 13TR for single pane glass while this value decreased to 12TR when double glazing glass is used. The cost of installation of double glass is more than single glass. But this ultimately decreased the cost of installation in HVAC and Operation cost of HVAC due to the lower capacity installed. The results show that double glaze glass was more than 10% energy efficient for the selected AC-spaced and the payback period is calculated around 1 year 8 months.

Index terms- Single glaze glass; double glaze glass; Solar gain, Energy saving, Cooling load, Payback Period

ACKNOWLEDGEMENT

This current study is the outcome of extensive collaboration and support from various individuals within the institute and outside of the institute. I wish to express my sincere appreciation to Prof. Dr. Tri-Ratna Bajracharya, who not only served as the Ex-Deal of the Institute of Engineering but also acted as my thesis supervisor. He provided me with the opportunity, essential resources, and invaluable guidance, offering insightful suggestions throughout the entire thesis project.

I would like to take this opportunity to express a deep sense of gratitude and thankfulness to Dr. Nawaraj Bhattarai, Program Coordinator, Energy System Planning and Management, Department of Mechanical Engineering, Pulchowk Campus for allowing me to carry out this study. My gratitude also goes to Associate Prof. Dr. Shree Raj Shakya and Assistant Prof. Dr. Anita Prajapati for their continuous motivation and support throughout the thesis work. I am thankful to the entire MSESPM personnel for creating an excellent interactive atmosphere for thesis work. I appreciate the suggestions, information, assistance, and productive criticism from colleagues and teachers.

I would also like to express my thankfulness to Er. Sunil Risal, External supervisor, for providing me with his valuable time, ideas, and methodologies. His mentorship has been a great help in finalizing the draft of this thesis. His insights into the energy-efficient HVAC system are beyond admiration. I am profoundly thankful to my parents for their unwavering emotional support during this challenging thesis journey. My master’s degree is solely dedicated to my Late Grandfather Mr. Ramdev Sah. Last, but not least, I extend my appreciation to my colleagues, namely Er. Dhiraj Shah, Er. Sajal Shrestha, Er. Baijnath Shah and Sulochana Pant. Lastly, I am thankful to all those who have directly or indirectly assisted me with my thesis work.

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LIST OF ABBREVIATIONS

kWh	Kilowatt Hour
BTU/hr	British Thermal Units per hour
C	Celsius
DGG	Double glazing glass
F	Fahrenheit
ISHRAE	Indian society of heating refrigeration and air conditioning engineers
ASHRAE	American society of heating refrigeration and air conditioning engineers
Kg/s	Kilogram per second
Kg/m	Kilogram per minute
M	Meter
Mm	Millimeter
NOAA	National oceanic and atmospheric administration
TWh	Terawatt Hour
U	Overall Heat gain Factor

CHAPTER ONE
INTRODUCTION

1.1 Background

Energy and the world's prosperity and well-being are closely related. An exponential increase in energy consumption has been observed in air conditioning (AC) due to the progress of industrialization and urbanization. While the developed world was once at the forefront of energy use for air conditioning, today's developing nations account for a greater portion of energy consumption.

The energy demand for space cooling has more than tripled, making it the building end-use with the fastest rate of growth after 1990. With about 2 billion AC units in use worldwide, space cooling is the main factor influencing the need for new capacity to fulfill peak power demand as well as the demand for electricity in buildings. One in five individuals live in a residential unit, which makes up 68% of all air conditioners.

Only 10% of people worldwide, or 35% of the population, live in nations where the average daily temperature is higher than 25°C. They also don't own air conditioning. The next ten years are predicted to see an unprecedented need for cooling due to rising living standards, and population growth due to global warming. By 2030, there may be an additional two-thirds increase in the number of installed air conditioners. (International Energy Agency, 2019)

For a long time, several attempts have been made to cut down the cooling load of buildings. Glass used in buildings is directly linked with the cooling load. Choosing a glass with a lower U-value can significantly reduce the conducted heat gain. This is due to the absorptivity and conductivity properties of glass. Unlike earlier days, today’s windows are considered a way to energy efficient technology and for enhancement of comfort. an advanced technology just now appearing on the market. A study at the Berkeley Lab suggested that windows can be used to reduce the total annual consumption of energy by 15% to 25% if a correct adjustment is made and energy-efficient glass is selected. (Energy Efficient Window, 2007)

Air conditioning systems, which are common in commercial buildings, can be considered as both a boon and a bane. They provide relief from hot summers and stifling humidity, but their energy use strains power systems and contributes to greenhouse gas emissions. As global temperatures rise, the demand for efficient cooling systems is more essential. (Dr.I.Satyanarayana, October 2016)

The difference in cooling loads between single and double-pane windows in air-conditioned rooms is an important part of building design and energy efficiency. The usage of windows in buildings has long been recognized as an important influence on both energy consumption and indoor air quality. Windows give natural light and ventilation, but they also allow heat gain and loss, which can dramatically affect a building's energy requirements. (Gregg D. Ander, Dec, 2016)

One of the difficult tasks in building design is to plan a way to reduce cooling loads. Cooling loads are the amount of energy necessary to keep a pleasant indoor temperature, particularly during the hot summer months. These loads can be considerably influenced by the type and design of windows used. Single-pane windows, for example, are less effective at reducing cooling loads than double-glazed windows. This is because double glass windows have a lower heat gain coefficient, which decreases the proportion of heat waves that enter the building through the windows. A study conducted in South Korea examined the unremitting heating and through cooling loads of electrochromic glazing in one of the crowded residential buildings and suggested that double-glazed windows with lower emissivity coatings and shading devices can dramatically lower cooling loads. The study employed a computer model to analyze the performance of several window types. It was discovered that electrochromic glass with a lower emissivity coating and shading devices reduced cooling loads by up to 23.7% compared to clear double glazing. Also, the same study showed that electrochromic windows with a lower emissivity coating and shading devices outperformed other types of glazing glasses in reducing cooling demands. The results revealed that electrochromic windows with a lower emissivity coating and shading devices lowered cooling loads by up to 14,082.1 kWh compared to clear double glazing. In contrast, single-pane windows have higher heat gain coefficients, which can increase cooling loads. The same study discovered that single-pane windows had higher cooling loads than double-glass windows due to a higher heat gain coefficient. (Oh, 2020, Feb 29)

An analysis of the heating and cooling loads of electrochromic glass in big-rise domestic structures in South Korea was discovered. The study employed a computer model to examine the performance of several window types and discovered that single-pane windows had cooling

loads of up to 4294.7 kWh, compared to 14,082.1 kWh for electrochromic glazing with a lower emissivity coating and shading devices.
(Hwan, 2018)

A significant amount of engineering effort has gone into developing windows that are both thermally efficient and able to provide a sufficient level of thermal comfort. Common windows lose between 10% and 25% of the heat from heated ambient air in cold climes. The increased solar radiation that enters homes through glass windows in hot weather significantly raises the cooling burden. Windows with deposited films on the glass sheets and selective solar radiation characteristics enable customization of the window's transmissivity, reflectivity, and absorptivity. The solar control film can be made to reflect or absorb solar radiation according to the wavelength of the incident light, which serves to maintain and enhance the thermal passive comfort in residential and commercial buildings' interior spaces.

The difference in cooling loads between single-pane and double-pane windows in air-conditioned areas is significant. When compared to single-pane windows, double-glass windows with lower emission coatings and shading devices reduce cooling loads more effectively. The selection of window type and design is critical in building design and energy efficiency, and the use of double glass windows with lower coatings and shading devices can significantly lower cooling loads and advance interior environmental conditions. Different varieties of glazing glass result in varying cooling loads.

This thesis examines the impact of single-pane and double-glazing glass with similar orientation, size, and shading coefficient on solar gain and cooling load. This thesis is mostly an experimental evaluation of the cooling load variations between single- and double-glazing glass.

1.2 Statement of Problem

AC systems are vital for creating relaxed indoor environments, but they consume substantial energy. Windows, as a crucial component of building envelopes, significantly influences the cooling load.

In an era where environmental consciousness and energy conservation are paramount, architects, engineers, and researchers grapple with the challenge of creating sustainable and comfortable indoor environments. Buildings, as significant energy consumers, play a pivotal role in this endeavor. Among the various components that impact energy consumption, glazing specifically the choice between single-pane and double-glazing glass holds immense promise.

The type of glass used in windows has a major influence on the cooling burden in air-conditioned environments. Single-pane and double-glazing glass have different thermal characteristics, which affect heat gain and loss. However, there is a lack of actual evidence comparing the cooling load differences between these two varieties of glass. However, limited empirical data is comparing their cooling load variations. This thesis seeks to address the following questions:

- How does the cooling load differ between single-pane glass and double-glazing glass?

This thesis aims to measure the thermal efficiency of every variety of glass and pinpoint the particular circumstances in which each type displays a different cooling load profile.

- What factors contribute to the observed variations?

The purpose of this thesis is to clarify the fundamental processes that underlie the variations in thermal performance between the two varieties of glass. The cooling load profiles may be shaped by elements including window orientation, shading devices, and surrounding circumstances.

- Can specific window designs mitigate cooling load fluctuations?

This thesis looks into whether window design changes could lessen the effect of fluctuations in cooling load. Low-e coatings, shading mechanisms, or electrochromic glass, for example, may reduce variations in the cooling demand and enhance overall energy efficiency. It attempts to provide a thorough understanding of the cooling load differences between single-pane and double-glazing glass, as well as the variables influencing these changes, by addressing these concerns. The results will have a main influence on energy efficiency which will help to shape the creation of more potent methods for lowering cooling loads and enhancing indoor air quality.

1.3 Objectives

1.3.1 General objective

- To study the variation in cooling load between single-pane glass and double-glazing glass in an- air-conditioned space

1.3.2 Specific objectives

- To estimate the required capacity of the cooling load
- To understand about the energy saving through the appropriate selection of glass
- To calculate the payback period of double-glazing glass

1.4 Significance of AC system

This system is designed to create an indoor temperature environment that is comfortable enough for humans to work or the system to operate. Its basic objective is to control the ambient environment components like temperature, humidity, airflow, and air filtering. The major advantages of using an HVAC system are as follows:

- It works to maintain temperature and humidity which provides the comfort zone ensuring that we neither freeze nor sweat.
- It maintains a healthy environment in the prevention of mold which thrives in warm and damp areas.
- It helps in industrialization and commercialization by providing a necessary artificial environment for storage.

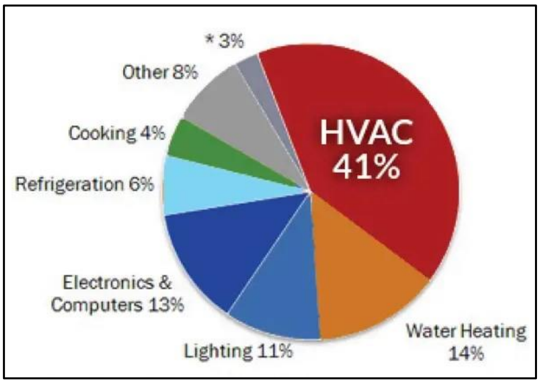

Figure 1.1: Energy Consumption in Residential Area

1.5 Role of Glass in AC System

The Air Conditioning system's performance, interior comfort, and energy saving are all significantly impacted by the glass in windows. Because window glass affects air leakage, insulation, and heat transmission, HVAC systems' energy usage is directly impacted by the type of glass used in windows. Based on the references given, the following are important details on how glass in windows affects the HVAC system.

- Energy Efficiency: Windows with lower emission coatings, double or triple glazing, and insulating gas between panes are examples of energy-efficient windows that significantly lessen heating and cooling loads. By minimizing heat transmission through the glass, these windows contribute to a decrease in energy loss through windows and an increase in total energy efficiency.

- Insulation and Heat Transfer: The insulation that windows provide is affected by the properties of the glass used such as its U-Factor, correction factor, radiation coefficient, and Solar Heat Gain Coefficient (SHGC). Better insulation, which lessens heat transmission through the glass and increases energy efficiency, is indicated by lower U-factor ratings. Furthermore, gases injected between the panes, such as argon or krypton, improve insulation and prevent heat transmission, resulting in reduced energy use and increased comfort. (Yousuf Alhendal, 2019, febrauary)

- Comfort and Air Leakage: Well-sealed windows with energy-efficient glass help stop air leaks, preserving indoor temperature stability and lessening the strain on HVAC systems. As a result, residents experience greater comfort and use less energy for heating and cooling.

- UV Protection and Longevity: Low-e coatings and other coatings on energy-efficient glass block harmful UV rays, extending the life of interior furniture. These coatings contribute to the year-round maintenance of a comfortable interior atmosphere and reduce energy expenses by minimizing the quantity of UV and infrared light that passes through the glass. (Vegiza, 2018)

CHAPTER TWO
LITERATURE REVIEW

The building orientation and glass descriptions can influence the amount of heat losses and gains inside space which is ultimately reflected in the overall need for energy for heating and cooling purposes. The more efficient glass the more saving of energy and money. Energy-efficient glass is the ideal choice for both residential and commercial buildings to improve the air condition system and indoor comfort of the building. This will reduce the electricity consumption for the AC system. On the other hand, choosing the better glass improves the natural lighting which causes to reduce energy for artificial lighting. It is estimated that energy consumption savings can be saved up to 40% in the case of efficient glass installed. (Eiman, May,2019)

A combination of higher technology and efficient glass can alter the energy use of the building. When designed and managed well, this combination can reduce energy use. This includes behavioral changes in energy saving such as switching off lights during the daytime, maximizing energy use, reducing energy wastage, and conducting energy audits. (The_Future_of_Cooling., 2018)

It is discovered that using double-glazing low emissivity glass in a Penang, Malaysia, high-rise residential structure considerably lowers the annual cooling demand by 5.8%. When compared to conventional single-glazed windows, the double-glazed low-emissivity glass exhibits better thermal performance, which is responsible for the decrease in cooling load. Double-glazed low-emissivity glass significantly reduces the cooling demand; in the building under study, this reduction in cooling load was 5.8% annually. A more sustainable built environment and significant energy savings result from this decrease in the cooling load. (Fadzil, 2012)

The study shows the influence of glazing on energy utilization during heat transfer. The energy-proficiency of buildings improves if the overall heat transfer factor of the window reduces. To decline the load summer, the overall heat transfer factor of the window must be very minimal. According to the Kuwait building laws, in a building with a window glass area is 15% of the total area wall 15%, the glasses used should have a thermal coefficient lower than 1.0 W/m^2K. (Helena, 2002)

One of the approaches of lowering conductive heat transfer through glass is increasing shading effects by installing curtains. Small work like reducing air gaps around the curtain and installing solar shading devices will improve the performance of building energy consumption by 10%. (Peter Lyons, 2013)

A study showing the various window-glazing technologies, including single-pane, double-pane, and triple-pane configurations discusses U-values, low-emissivity coatings, and insulating materials between glass panes. It spotlights the improvements in window expertise that can be observed from static and dynamic windowpane. Static windows or the traditional ones include inactive technologies that further can improve heat and optical window performance such as tinted glazing, low-E glazing, self-cleaning glazing, anti-reflective glass, and insulated glass. Meanwhile, dynamic, or active windows contain technologies that use core interaction of materials to adjust or change to external conditions. These include electrochromic glazing, photovoltaic glazing, thermochromic glazing, gas chromic glazing, and liquid crystal glazing. (Saffa Rifat, 05 December 2019)

The impact of the shading effect is studied in Darwin, Australia, and suggested the best shading device. The analysis shows that level fins managed to around 5% cut in the cooling load of the building. In compare, enhancing a difference to the design angles and size intensified the savings to around 9%. The extensions were more proficient than the fins, adding 8.2% energy savings, and the cooling cut were increased to 16.5% with variations in dimensions parameter. (Aiman Mohammed, 23 March 2022)

This chose of the ideal cooling systems is based on updraft execution and power savings for the climatic conditions of Chennai. The results indicate the efficacy of the combined system in maintaining the desired thermal comfort levels and reducing the cooling loads by around 36%. (S. Karthick, 30 September 2022)

(Aguilar-Santana, Feb 2020) Research indicates that double-glazed windows, including two glass panes divided by an air or gas pocket, provide better insulation than single-pane windows. As a result of the thermal barrier created by the space between the panes, there is a 50% decrease in heat loss through the window's components as opposed to single glazing. With a payback period of 8.75 years, reflective glass in double-glazed windows has been found to save up to 72.9% of energy usage, especially in hot and dry conditions. Furthermore, double-glazed windows are 2.5 times more effective at reducing heat gain than single-glazed windows due to the introduction of an air gap between the glass panes, which dramatically lowers the heat transfer rate and reduces heat acquisition by approximately 50–67% in warm climates.

ASHRAE Cooling load Calculation Sheet

The ASHRAE Cooling load Calculation Sheet is a valuable tool that is used in the field of HVAC. The ASHRAE Cooling load Calculation Sheet assists engineers and designers in determining load requirements for a building or space. It plays a crucial role in selecting appropriate HVAC equipment and designing efficient systems. The sheet includes various parameters related to the building, such as floor area, ceiling height, and thermal conditions. It considers factors like occupancy, ventilation, INFILTERATION, and lighting. (Jani, 2019, March)

CLTD

This method is applied to calculate cooling load. It uses comparable temperature difference for determining heat gain across the walls. The formula to determine the ratio of heat transfer from external air to inner air is:

$$Heat\ Transfer = Coefficient\ of\ heat\ transfer \times Area \times (CLTD)c \qquad 1$$

Where,

(CLTD)c = corrected cooling load temperature difference (^{o}F)

CHAPTER THREE
RESEARCH METHODOLOGY

3.1 Framework of Study

Methodology explains the drafting process of the thesis. It covers the steps and procedures used in the completion of the thesis. Furthermore, it shows the source of information, data collection, and ideology differentiation which is collected and used to prepare this research.

The primary source of data includes the data collected by the researcher directly at the site or area of study. To analyze the cooling load, all the data are collected directly from the study site. To study the building design and orientation, the plan and layout of the building are studied. The collected data from the site itself are proven to a crucial information for the qualitative presentation of the thesis.

Secondary sources of data include information collected from various websites, articles, books, and journals related to cooling load calculation and the use of various types of glass in reducing cooling load. Especially, the data regarding standard conditions from ISHRAE and ASHRAE are mostly used. These data were analyzed further to understand the variation in cooling load when single-pane glass and double-glazed glass are used under the same conditions. Analysis of variation further helped to conduct cost analysis and payback period.

The combined data and information from both the primary and secondary sources are used to govern the cooling load. The total Cooling load was calculated for the Months of June and July. To make data more precise, each month's load is calculated at three different times of day @12PM, @2PM, and @4PM for both Single and Double glaze glass. Out of Which, the maximum load was taken for the reference for the further calculation of load.

The changes in the AC load are finally interpreted in terms of financial feasibility to meet the objective of the thesis.

3.2 Study Design

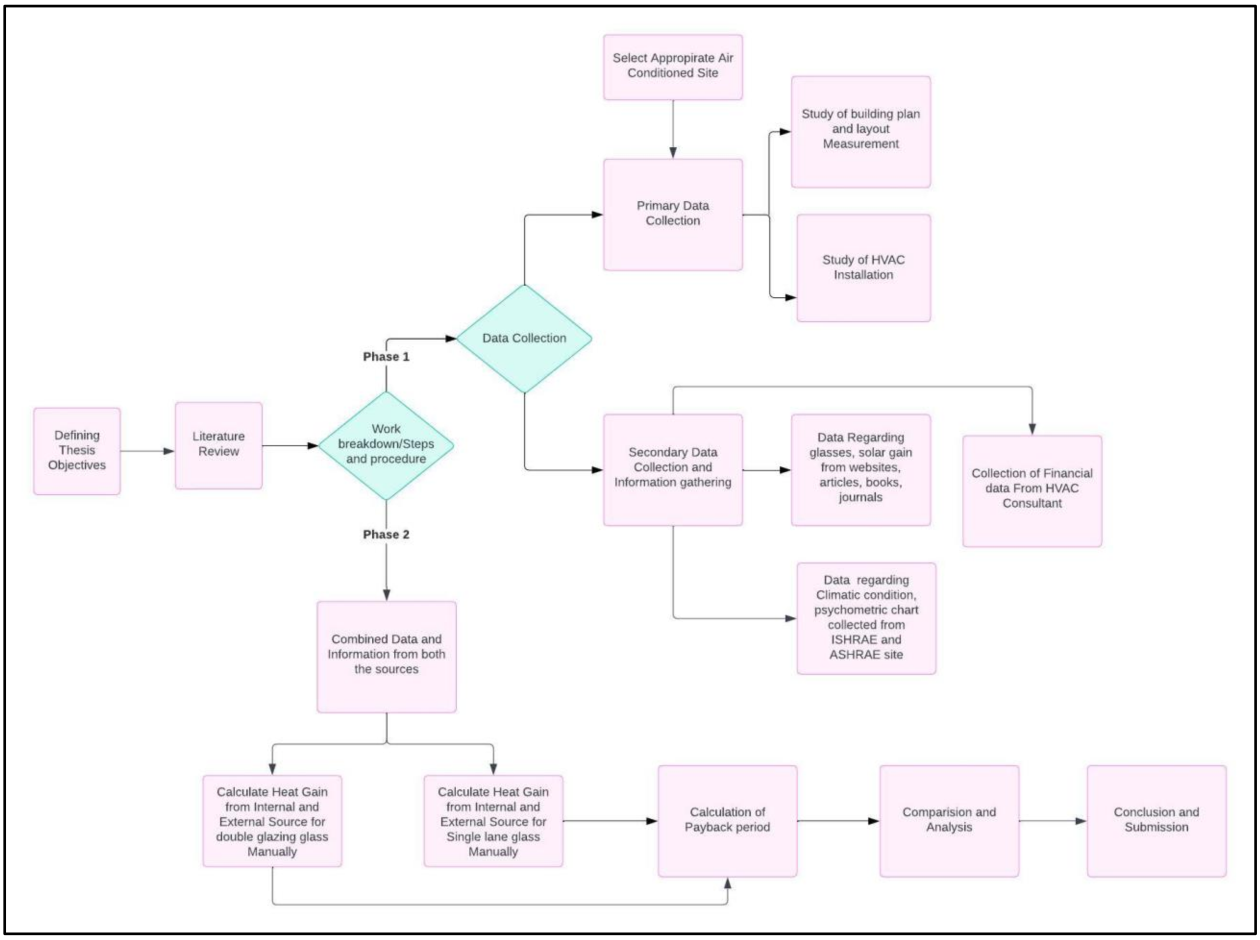

Figure 3.1:Frame Chart of Study

3.3 Basic Information

For the comparison of variations caused in cooling load due to single and double glaze glass, an air-conditioned space is considered. Before analyzing the study, some of the basic information like its orientation, weather conditions, spacing, layout, building materials, etc. is collected. This information is further proven as a base in the calculation of cooling load.

3.3.1 Location and Structure of AC-Space

The space considered in this study is located at Pulchowk, Lalitpur, Nepal. It is on the third floor of a building. The building stands at the latitude of 27.67º N and longitude of 85.33º E at an altitude of 1324 m above sea level. The dimension layout of the building is, 60×50×10 ft.

3.3.2 Climate Condition

Lalitpur has a Sub-tropical climate, generally warm, mild, and temperate. The summer is much rainier than winter. During monsoon (July-September), it receives high rainfall. The coldest month is January with a minimum of 35°F and June is the hottest with a maximum of 90°F.

Table 3.1: Dry bulb temperature every month (in °F)

	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Max. Temp. (°F)	65.4	69.8	77	82.4	86	89.6	87.8	86	82.4	78.8	73.4	68
Min. Temp.(°F)	37.4	41	48.2	55.4	60.8	68	68	68	66.2	57.2	46.4	39.2
Relative Humidity	73%	69%	57%	54%	72%	85%	92%	91%	88%	80%	75%	76%

(Weather, 2024)

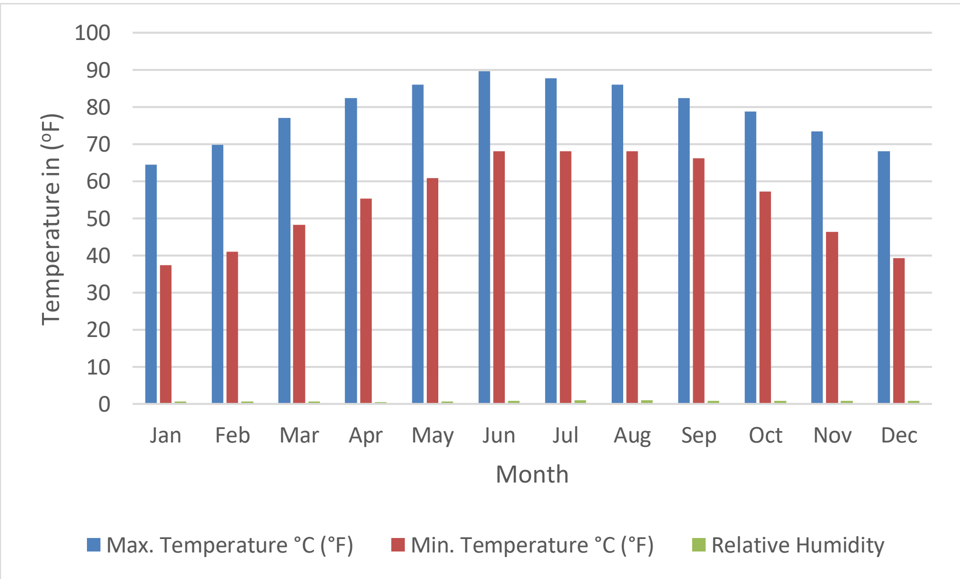

Figure 3.2: Temperature Variation Chart

3.3.3 Conditioned Space and Comfort Space

In the cooling process heat waves need to be controlled at inside space to bring the indoor environment at human comfort conditions of 72-75ºF DB and RH of 50%-60% by the conditioning process, such heat is called air-conditioned load. This is a standard human comfort zone.

The external thermal parameters are referenced from published data of the National Oceanic and Atmospheric Administration (NOAA). The peak summer is in June where DBT is 90ºF and Relative humidity is 73%. Similarly, for July the maximum DBT is 88ºF and Relative humidity is 81%.

1. Human Comfort Condition:

    Indoor Design Condition (Ti): 75 ºF

    Relative Humidity: 50%

2. Outdoor Design Condition at Peak

    Outside room temperature (To): 90 ºF

    Relative Humidity: 73 %

3.4 Cooling Load Components

The heat needed to be eliminated from space in order to achieve desired DB temperature of 72-75ºF and RH of 50%-60% by mechanical intervention equipment is known conditioned load.

The load components contributing in increment room heat are:

a. Conduction through walls, glass, and Ceiling
b. Radiation through glass
c. Lighting
d. Equipment
e. People
f. INFILTERATION
g. Ventilation

3.4.1 Conduction Through Wall

The heat gains through walls via conduction is calculated from the following equation:

$$Q = U \times A \times (CLTD)c \qquad 2$$

Where,

Q= Net room of heat gain through walls in Btu/hr

U= Overall heat transfer coefficient of wall

(CLTD)c= cooling load temperature difference including correction factor, °F

The CLTD is difference in temperature that is responsible for heat-storing effect. These CLTD values need correction according to the latitude and structure design. The corrected CLTD is calculated as:

$$(CLTD)c = \{(CLTD + LM) \times K + (78 - tR) + (to - 85)\} \qquad 3$$

Where,

LM = Latitude correction for the month

K= Correction for color of surface (K=1 for dark color wall)

t_R= room temperature, °F

t_o = Outside temperature, °F

The CLTD for calculating the cooling load for Group B walls is taken from Table 2,

Table 3.2: CLTD Correction for Wall

Wall Facing Direction Wise														
Solar Time Hour														
Hour	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
N	12	10	8	7	5	4	3	4	5	6	7	9	11	13
E	14	12	10	8	6	5	6	11	18	26	33	36	38	37
S	15	12	10	8	8	5	4	3	4	5	9	13	19	24
W	25	21	17	14	12	9	7	6	6	6	7	9	11	14

Hour	15	16	17	18	19	20	21	22	23	24	Hr of Max CLTD	Min. CLTD	Max.CLTD	Diff. CLTD
N	15	17	19	20	21	23	20	18	16	14	20	3	22	19
NE	26	26	26	26	25	24	22	19	17	15	16	4	26	22
E	36	34	33	32	30	28	25	22	20	17	13	5	38	33
Hour	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**Hr of Max CLTD**	**Min. CLTD**	**Max.CLTD**	**Diff. CLTD**
SE	37	36	34	33	31	28	26	23	20	17	15	5	37	32
S	29	32	34	33	31	29	26	23	20	17	17	3	34	31
SW	24	32	38	43	45	44	40	35	30	26	19	5	45	40
W	20	27	36	43	49	49	45	40	34	29	20	6	49	43
NW	16	20	26	32	37	38	36	32	28	24	20	5	38	33

(ISHRAE handbook)

The Table below shows the group wall and its heat transfer coefficient:

Table 3.3: Group of Wall with respective U-Value

Group No.	Description of Wall	U-value Btu/(hr.ft2.F)
D	4-in. Block	0.319
C	4-in. Concrete	0.585
E	4-in. Common Brick+ 4 in concrete block	0.358

(ISHRAE handbook)

Table 3.4: Latitude correction for CLTD month-wise and direction-wise

Lat	Month	N	S	E/W
24^o	Dec	-5	13	-7
	Jan/Nov	-4	13	-6

	Feb/Oct	-4	10	-3
	Mar/Sept	-3	4	-1
	Apr/Aug	-2	-3	-1
	May/Jul	1	-6	0
	Jun	3	-6	0

(ISHRAE handbook)

3.4.2 Conduction Through Glass

The heat gains through glass via conduction is calculated from the following equation:

$$Q = U \times A \times (CLTD)c \qquad 4$$

Where,

Q= Net room of heat gain through glass in Btu/hr

U= Overall heat transfer coefficient of glass

(CLTD)c= Corrected cooling load temperature difference, °F

The CLTD is the temperature variance that is accountable for the heat re-storing effect. These CLTD values need correction according to the latitude and structure design. The corrected CLTD is calculated as:

$$(CLTD)c = CLTD + (78 - tR) + (to - 85) \qquad 5$$

Table 3.5: CLTD for conduction through glass for conduction

Hour	2	4	6	8	10	12	14	16	18	20	22	24
CLTD	0	-2	-2	0	4	9	13	14	12	8	4	2

3.4.3 Radiation Through Glass

Solar radiation varies according to the glass type, daytime hour, orientation, and shading. The net heat gain through radiation via glass is given by,

$$Q = SHGF \times A \times SC \times CLF \qquad 6$$

Where,

SHGF= Solar heat gain factor calculated in Btu/hr-ft^2

An area of glass exposed in the Sun (ft^2)

SC= Coefficient of Shading

CLF = Cooling Load Factor for Glass

The maximum SHGF for the single glass used here is considered in the table below:

Table 3.6: Solar Gain Heat Factor Table

Latitude	Month	N	S	E/W
24°F	Jan	27	227	190
	Feb	30	192	220
	Mar	34	137	234
	Apr	37	75	228
	May	43	46	218
	Jun	55	43	212
	Jul	45	46	213
	Aug	38	72	220
	Sep	35	134	222
	Oct	31	187	211
	Nov	27	224	187
	Dec	26	237	180

(ISHRAE handbook)

The Coefficient of Shading for glass with interior shadowing is given in the table below.

Table 3.7: Shading Coefficient for single and double glass with interior shading

Type of Glass	SC
Single Clear	0.91
Double Glass	0.55

(ISHRAE handbook)

The CLF for glass combined with interior shielding for medium construction exterior wall is given in Table 3.8:

Table 3.8: CLF for glass including effect of interior shading

		Time of Day		
Direction	**Room Construction**	12 PM	2 PM	4 PM
N	Medium	0.89	0.86	0.75

S			0.83	0.68	0.5
E			0.27	0.22	0.2
W			0.17	0.53	0.82

3.4.4 Gain Through Lighting

The equation to calculate the heat gain from light is;

$$Q = 3.4 \times W \times CLF \qquad 7$$

Where,

Q= Net heat accumulated due to light, Btu/hr

W= Capacity of light, watts

CLF= Cooling load factor for lighting

Table 3.9: Lighting Load of Different Rooms

Types of rooms	**Lighting power W/m^2**
Workshop	20
Medium Library	14
Office	11
Conference room	12
Dining room	10
Laboratory	14
Restroom	10
Classroom	16

3.4.5 Gain From People

The heat accumulated in space due to people is comprised of two types of heat, one is sensible heat and other is latent heat. This heat gain is calculated by,

$$Qs = qs \times N \times CLF \qquad 7$$

$$Ql = ql \times N \qquad 8$$

Where,

Qs= Sensible heat accumulated

Ql= Latent heat accumulated

N= number of occupant

3.4.6 Gain from Equipment

The heat gain from electric devices or equipment is directly calculated from the manufacturer catalog. For this thesis, a constant load of 2500 Btu/hr is taken into consideration.

3.4.7 Gain from Ventilation

The sensible and latent heat of outside air, which is brought into a room, is higher than that of a room's air. The extra added heat then becomes a part of the refrigeration load. So, the sensible and latent heat gain due to ventilation is calculated as:

Total sensible heat gain (Qs)=

$$1.1 \times CFM \times TC \tag{9}$$

Total latent heat gain (Q_L)=

$$0.68 \times CFM \times (Wo - Wi) \tag{10}$$

Where,

TC= Total changes in temperature

CFM= Total rate of Air Ventilation, ft^3/min

W_o-W_i = Variation in humidity ratio, gr/lb

Table 3.10: Ventilation Requirement for Occupant

	Required Ventilation Air per Person	
Residential	**Minimum**	**Recommendation**
Living Areas, Bedroom	5	7-10
Kitchen, Bathroom	20	30-50
Commercial		
Hotels Motels	7	7-15

Café	30	30-35
Office	10	10-15

3.4.8 Gain from INFILTERATION

This is heating gain from the outdoor air that enters through the cracks or the operable part of a window panel. It is also calculated the same as ventilation,

$$Qs = 1.1 \times CFM \times TC \quad (11)$$

$$Ql = 0.68 \times CFM \times (Wo - Wi) \quad (12)$$

Where,

Where,

TC= Total changes in temperature

CFM= Total rate of Air Ventilation, ft^3/min

W_o-W_i = Variation in humidity ratio, gr/lb

CHAPTER FOUR

CALCULATION AND ANALYSIS

4.1 Calculations of Heat Gain

4.1.1 Heat gain through walls

From Data Collection, It was found that a major portion of the walls on three sides was covered by glass.

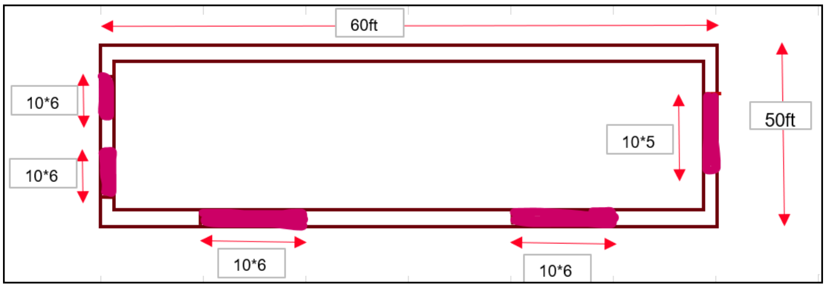

Figure 4.1: Layout of Structure

The outer walls consist of combinations 8in. block with ½ in. sand aggregate plaster finish on the interior.

Individual Resistance found from Annex K,

Inside air (R_1) = 0.68

Block (R_2) = 1.72

Plaster (R_3) = 0.09

Outside air (R_4) = 0.17

Therefore, Overall Heat transfer Coefficient (R),

$$R = \frac{1}{0.68+1.72+0.09+0.17}$$

R= 0.358 Btu/(hr-ft^2°F)

Table 4.1: Area of a wall of AC-Spaced

Direction	Wall's Area (Sq Ft)
North	600
South	480

East	500
West	338
Total	**600**

Cooling load Calculation of Heat gain Through Wall using equation (1) and ASHRAE Cooling load Calculation Sheet.

E.g,

$Q= U \times A \times (CLTD)_c$

$= 0.35 \times 600 \times 9$

= 1890 Btu/hr

Table 4.2: Calculation sheet for heat gain through walls

Room Type: Office								
Climate data	Pulchowk, Lalitpur							
Month	July		**Group B Wall**	**CLTD**	**CLTD cor**	**Glass**	**CLTD**	**CLTD cor**
Temperature	**Max**	**Min**	N	8	15		14	20
	86	70	S	11	11			
RH %	81		E	19	25			
			W	15	22			
COOLING LOAD CALCULATION								
DESIGN CONDITION		DB F	WB F	RH %	W			
OUTDOOR		88	80	81	145			
INDOOR		75	65	50	78			
				AREA				
				Gross	Net Area			
WALL	N		0.35	600	600	9	**1890**	
	S		0.35	600	480	12	**2016**	
	E		0.35	500	500	22	**3850**	
	W		0.35	500	338	14	**1656**	
Total							**9412**	

(Pita, 1981)

4.1.2 Heat Gain through Glass by Conductance

Cooling load Calculation of Heat gain Through Wall using equation (1) and ASHRAE Cooling load Calculation Sheet. The sheet below shows calculations for Single pane glass with a U-value of 0.94.

E.g,

$Q= U\times A\times (CLTD)_c$

$= 0.94\times 120\times 14$

= 1579 Btu/hr

a. Single pane glass

Table 4.3: Calculation sheet for heat gain through Single Glass

Location: Pulchowk								
Project: Thesis								
Building Type: Commercial								
Room Type: Office								
Climate data	Pulchowk, Lalitpur							
Month	July		**Group B Wall**	**CLTD**	**CLTD cor**	**Glass**	**CLTD**	**CLTD cor**
Temperature	**Max**	**Min**	N	8	15		14	20
	86	70	S	11	11			
RH %	81		E	19	25			
			W	15	22			
COOLING LOAD CALCULATION								
DESIGN PARAMETER		DB (^{O}F)	WB (^{O}F)	RH %	W			
OUTSIDE		88	80	81	145			
INSIDE		75	65	50	78			
				AREA				
CONDUCTION	**DIR**	**COL**	**U**	**GROSS**	**NET**	**CLTD/cor**	**RSHG**	

(GLASS)	N	CL	0.94		0	14	0	
	S	CL	0.94		120	14	1579	
	E	CL	0.94		50	14	658	
	W	CL	0.94		120	14	1579	
	Sum						3816	

Cooling load Calculation of Heat gain Through Wall using equation (1) and ASHRAE Cooling load Calculation Sheet. The sheet below shows calculations for Single pane glass with a U-value of 0.61. (Pita, 1981)

b. Double glazed glass

Now, if the windows in the cooling space are replaced by double-glazing glass, keeping every other variable constant, it would show variation in the heat gain.

E.g,

$Q = U \times A \times (CLTD)_c$

$= 0.61 \times 120 \times 13$

$= 952$ Btu/hr

Table 4.4: Calculation sheet for heat gain through Double Glaze Glass

Location: Pulchowk								
Project: Thesis								
Building Type: Commercial								
Room Type: Office								
Climate data	Pulchowk, Lalitpur							
Month	July		**Group B Wall**	**CLTD**	**CLTD cor**	**Glass**	**CLTD**	**CLTD cor**
Temperature	**Max**	**Min**	N	9	16		13	19
	88	73	S	12	12			
RH %	73		E	22	28			
			W	14	21			
COOLING LOAD CALCULATION								

DESIGN PARAMETER		DB F	WB F	RH %	W			
OUTSIDE		88	80	81	144			
INSIDE		75	65	50	78			
				AREA				
CONDUCTION	**DIR**	**COL**	**U**	**GROSS**	**NET**	**CLTD/cor**	**RSHG**	
(GLASS)	N	CL	0.61		0	13	0	
	S	CL	0.61		120	13	952	
	E	CL	0.61		50	13	397	
	W	CL	0.61		120	13	952	

4.1.3 Heat Gain through Glass by Radiation

Cooling load Calculation of heat gain through the wall via radiation is calculated using equation (6) and the ASHRAE Cooling load Calculation Sheet. The sheet below shows calculations for Single pane glass with a solar constant of 0.91.

a. Single pane glass

$Q = SHGF \times A \times SC \times CLF$

$= 46 \times 120 \times 0.91 \times 0.68$

$= 3416$ Btu/hr

Table 4.5: Calculation sheet for heat gain by radiation through a single glass

Location: Pulchowk								
Project: Thesis								
Building Type:Commercial								
Room Type: Office								
Climate data	Pulchowk, Lalitpur							
Month	July		**Group B Wall**	**CLTD**	**CLTD cor**	**Glass**	**CLTD**	**CLTD cor**
Temperature	**Max**	**Min**	N	9	16		13	19
	88	73	S	12	12			
RH %	73		E	22	28			
			W	14	21			
COOLING LOAD CALCULATION								

DESIGN PARAMETER		DB F	WB F	RH %	W			
OUTSIDE		88	80	81	144			
INDOOR		75	65	50	78			
				AREA				
SOLAR	DIR	Sh	SHGF	A	SC	CLF		
(GLASS)	N		45	0	0.91	0.86	0	
	S		46	120	0.91	0.68	3416	
	E		213	50	0.91	0.22	2132	
	W		213	120	0.91	0.53	12328	

b. Double Glaze Glass

Now, if the windows in the cooling space are replaced by double-glazing glass, keeping every other variable constant, it would show variation in the heat gain. The sheet below shows calculations for Single pane glass with a solar constant of 0.55.

Table 4.6: Calculation sheet for heat gain by radiation through double glass

Location: Pulchowk								
Project: Thesis								
Building Type: Commercial								
Room Type: Office								
Climate data	Pulchowk, Lalitpur							
Month	July		**Group B Wall**	**CLTD**	**CLTD cor**	**Glass**	**CLTD**	**CLTD cor**
Temperature	**Max**	**Min**	N	9	16		13	19
	88	73	S	12	12			
RH %	73		E	22	28			
			W	14	21			
COOLING LOAD CALCULATION								
DESIGN PARAMETER		DB F	WB F	RH %	W			
OUTSIDE		88	80	81	144			
INSIDE		75	65	50	78			
				AREA				
SOLAR	DIR	Sh	SHGF	A	SC	CLF		
(GLASS)	N		45	0	0.55	0.86	0	

	S		46	120	0.55	0.68	2064	
	E		213	50	0.55	0.22	1289	
	W		213	120	0.55	0.53	7451	

4.1.4 Heat gain due to INFILTERATION

Total fresh air in the room (CFM/person) = 15 CFM/person

Total no of people/occupancy = 50 persons

Total fresh air needed due to occupancy = No of occupancy × CFM/person

$$= 15 \times 50 = 750 \text{ CFM}$$

The sheet below shows calculations for INFILTERATION using equations (11) and (12)

Table 4.7: Calculation sheet for heat gain by INFILTERATION

Location: Pulchowk								
Project: Thesis								
Building Type: Commercial								
Room Type: Office								
Climate data	Pulchowk, Lalitpur							
Month	July		**Group B Wall**	**CLTD**	**CLTD cor**	**Glass**	**CLTD**	**CLTD cor**
Temperature	**Max**	**Min**	N	8	15		14	20
	86	70	S	11	11			
RH %	81		E	19	25			
			W	15	22			
COOLING LOAD CALCULATION								
DESIGN CONDITION		DB F	WB F	RH %	W			
OUTDOOR		88	80	81	145			
INDOOR		75	65	50	78			
INFILTERATION	1.1	×	200	CFM ×	15	TC	3300	

	0.68	×	200	CFM ×	130	gr/lb		17680

4.1.5 Heat gain due to Ventilation.

Heat accumulated due to ventilation is calculated using equation (3.9) and (3.10) and is summarized in the Cooling load calculation sheet:

Table 4.8: Calculation sheet for heat gain by Ventilation

Location: Pulchowk								
Project: Thesis								
Building Type: Commercial								
Room Type: Office								
Climate data	Pulchowk, Lalitpur							
Month	July							
Temperature	**Max**	**Min**						
	86	70						
RH %	81							
COOLING LOAD CALCULATION								
DESIGN PARAMETER		DB F	WB F	RH %	W			
OUTSIDE		88	80	81	145			
INSIDE		75	65	50	78			
VENTILATION	1.1	×	750	CFM ×	13	TC	10725	
	0.68	×	750	CFM ×	67	gr/lb		34170
Total								44895

4.1.6 Heat gain from Occupant.

The heat gain from people is comprised of two types of heat, one is sensible heat and other is latent heat. This heat gain is calculated by equation (7) and (8)

Sensible heat gain per person = 240 Btu/hr (as per ISHRAE Standard)

Latent heat gain per person = 120 Btu/hr (as per ISHRAE standard)

∴Total sensible heat (Q_S) = 250×50=125000 Btu/hr

∴Total latent heat (Q_L) = 200×50 = 10000 Btu/hr

Total Heat Gain from Occupant**: 22500 Btu/hr**

Table 4.9: Calculation sheet for heat gain from occupant

Location: Pulchowk								
Project: Thesis								
Building Type: Commercial								
Room Type: Office								
Climate data	Pulchowk, Lalitpur							
Month	July							
Temperature	**Max**	**Min**						
	86	70						
RH %	81							
COOLING LOAD CALCULATION								
DESIGN PARAMETER		DB F	WB F	RH %	W			
OUTSIDE		88	80	81	145			
INSIDE		75	65	50	78			
PEOPLE	250	SHG ×	**50**	N ×	1	CLF ×	12500	
	200	LHG ×	**50**	N				10000
Total								22500

4.2 Calculation Sheet for Single-Pane Glass

The above procedure is followed to calculate the cooling load. Since, in Lalitpur, the peak month of cooling load is June and July, the cooling load required in these months is calculated. To make data more precise, the cooling load is calculated at three different hours @12pm, @2pm and @4pm.

Table 4.10: Calculation sheet @4pm in June for Single pane glass

Location: Pulchowk								
Project: Thesis								
Building Type: Commercial								
Room Type: Office								
Climate data	Pulchowk, Lalitpur							
Month	June		**Group B Wall**	**CLTD**	**CLTD cor**	**Glass**	**CLTD**	**CLTD cor**
Temperature	**Max**	**Min**	N	8	15		14	20
	88	70	S	11	11			
RH %	73		E	19	25			
			W	15	22			
COOLING LOAD CALCULATION								
DESIGN PARAMETER			WB F	RH %	W			
OUTSIDE		88	82	73	161			
INSIDE		75	65	50	78			
				AREA				
CONDUCTION	**DIR**	**COL**	**U**	**GROSS**	**NET**	**CLTD/cor**	**RSHG**	
(GLASS)	N	CL	0.94		0	14	0	
	S	CL	0.94		120	14	1579	
	E	CL	0.94		50	14	658	
	W	CL	0.94		120	14	1579	
WALL	N		0.35	600	600	9	1890	
	S		0.35	600	480	12	2016	
	E		0.35	500	500	22	3850	

	W		0.35	500	338	14	1656	
CEILING			0.4		3000	14	16800	
FLOOR								
PARTITION								
DOOR				42				
SOLAR	DIR	Sh	SHGF	A	SC	CLF		
(GLASS)	N		55	0	0.91	0.75	0	
	S		43	120	0.91	0.35	1643	
	E		212	50	0.91	0.17	1640	
	W		212	120	0.91	0.82	18983	
								Latent gain
LIGHT	50	W ×	3.14		1	CLF ×	196.25	
PEOPLE	250	SHG ×	**50**	N ×	1	CLF ×	12500	
	200	LHG ×	**50**	N				10000
EQUIPMENT							2500	
INFILTERATION	1.1	×	200	CFM ×	15	CT	3300	
	0.68	×	200	CFM ×	83	gr/lb		11288
VENTILATION	1.1	×	750	CFM ×	13	TC	10725	
	0.68	×	750	CFM ×	83	gr/lb		42330
						TOTAL	81516	63618
						SUBTOTAL	145134	

						GRAND TOTAL	152391.1809	
						TOTAL TR =	13	
						Grand Total [TR]	**12.70**	

4.3 Calculation Sheet for Double Glaze Glass

Table 4.11: Calculation sheet @4pm in June for Double glazed glass

Location: Pulchowk								
Project: Thesis								
Building Type: Commercial								
Room Type: Office								
Climate data	Pulchowk, Lalitpur							
Month	June		**Group B Wall**	**CLTD**	**CLTD cor**	**Glass**	**CLTD**	**CLTD cor**
Temperature	**Max**	**Min**	N	8	15		14	20
	88	70	S	11	11			
RH %	73		E	19	25			
			W	15	22			
COOLING LOAD CALCULATION								
DESIGN PARAMETER		DB F	WB F	RH %	W			
OUTSIDE		88	82	73	161			
INSIDE		75	65	50	78			
				AREA				
CONDUCTION	**DIR**	**COL**	**U**	**GROSS**	**NET**	**CLTD/cor**	**RSHG**	
(GLASS)	N	CL	0.61		0	14	0	
	S	CL	0.61		120	14	1025	
	E	CL	0.61		50	14	427	

	W	CL	0.61		120	14	1025	
WALL	N		0.35	600	600	9	1890	
	S		0.35	600	480	12	2016	
	E		0.35	500	500	22	3850	
	W		0.35	500	338	14	1656	
CEILING			0.4		3000	14	16800	
FLOOR								
PARTITION								
DOOR				42				
SOLAR	DIR	Sh	SHGF	A	SC	CLF		
(GLASS)	N		55	0	0.55	0.75	0	
	S		43	120	0.55	0.35	993	
	E		212	50	0.55	0.17	991	
	W		212	120	0.55	0.82	11473	
								Latent gain
LIGHT	50	W ×	3.14		1	CLF ×	196.25	
PEOPLE	250	SHG ×	**50**	N	1	CLF ×	12500	
	200	LHG ×	**50**	N				10000
EQUIPMENT							2500	
INFILTERATION	1.1	×	200	CFM	15	TC	3300	
	0.68	×	200	CFM	83	gr/lb		11288
VENTILATION	1.1	×	750	CFM	13	TC	10725	
	0.68	×	750	CFM	83	gr/lb		42330
						TOTAL	71368	63618

						SUBTOTAL	134986	
						GRAND TOTAL	141735.1845	
						TOTAL TR =	12	
						Grand Total [TR]	**11.81**	

4.4 Comparison Analysis in Cooling Load

From the calculation sheet, the cooling load at 4 pm in June for the single pane glass is found to be 12.7TR and for the double glaze glass, it is found to be 11.81TR. Annex B contains a calculation sheet to calculate the total cooling load for June and July at 12 PM, 2 PM, and 4 PM.

From **Annex A to Annex J,**

Table 4.11: Comparison Analysis of Heat Gain in Single Pane and Double Glaze Glass for June and July at 12 PM, 2 PM, and 4 PM.

Table 4.12: Summary Sheet for Total Cooling Load for June and July at different time

	June			**July**		
Hour	**12**	**2**	**4**	**12**	**2**	**4**
Single Glass	10.98	12.59	**12.7**	10.5	11.62	11.79
Double Glass	10.34	11.88	**11.81**	9.84	10.9	10.91
Difference in TR	0.64	0.71	**0.89**	0.66	0.72	0.88

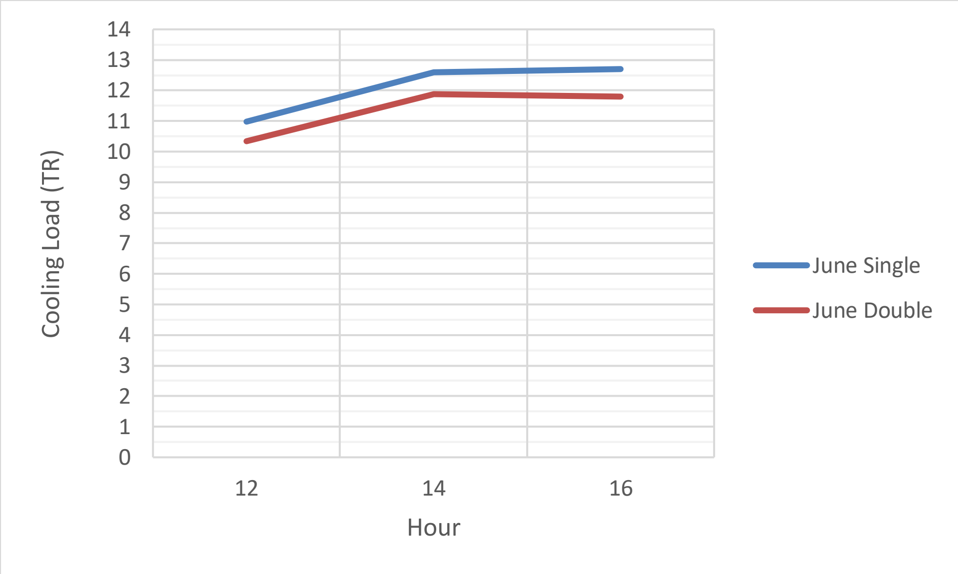

Figure 4.2: Load Variation in June

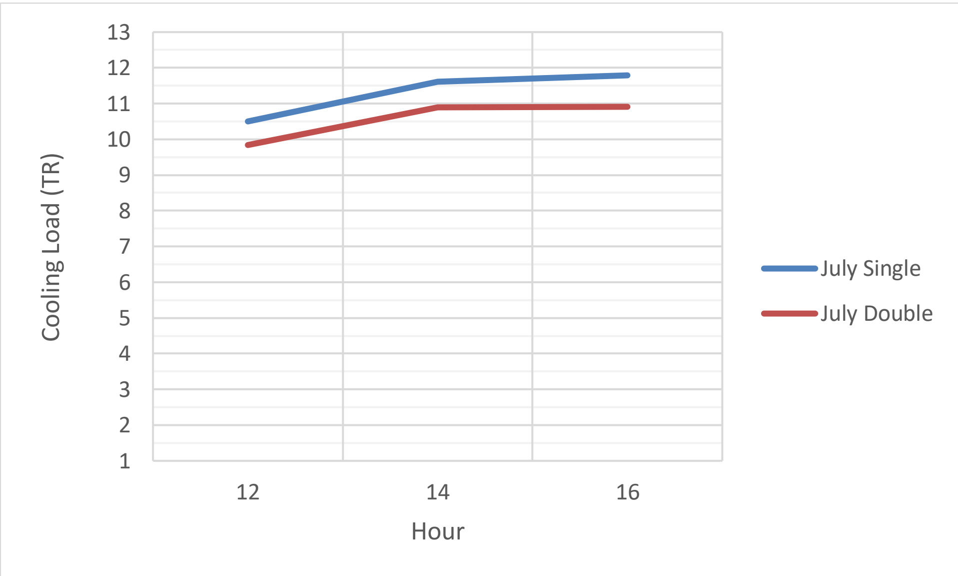

Figure 4.3: Load Variation in July

Since the greatest value of the cooling load is in June at 4 PM, further calculations are done considering these values.

4.5 Financial Analysis

Double glazing glass reduces the air conditioning load thus saving the total energy consumption by installing air conditioners of less capacity. It is calculated from the result that there is a need for 13 TR capacity of AC for single glaze glass and similarly, 12 TR of AC is needed in case of double glaze glass.

4.5.1 Installation Cost of Single Glass

a. Cost of Outdoor and Indoor Units

The cooling load was found to be around 13TR when a single glaze glass was installed in the window. The total cost of installation of AC includes the cost of an outdoor unit and an indoor unit. The standard market cost is considered when calculating the equipment cost and other accessories that come along with it. Table 24 shows the prices of units required for the installation of 13 TR AC Units.

Table 4.13: Cost of AC-Equipment for 13TR

SN.	Units	Cost (in Rs.)
1	Outdoor unit	650000
2	Indoor unit	770000
3	Joint kit	56000
4	Remote Control	56000
5	Copper Piping with installation	30000
6	Control Plant	40000
7	Drain Pipe	15000
8	Installation of ODU	25000
9	Installation of IDU	28000
10	Testing and Commission	20000
11	Sub-Total	**Rs. 16,90,000**

b. Piping price

Similarly, the pipes and ducts in the AC units contribute a lot to overall pricing. There are pipes of different diameters required for connecting indoor and outdoor units. Table 25 shows the standard pipe required in AC installation along with prices and overall cost.

Table 4.14: Cost of Pipes required in the installation of AC.

Piping Prices					
S.N.	Diameter	Required(in feet)	Req. in meter	Cost Per Meter (Rs.)	
1	6mm	90	27.44	800	21951
2	9mm	35	10.67	900	9603
3	12mm	90	27.44	1200	32926

4	15mm	30	9.15	1600	14634
5	19mm	25	7.62	2200	16768
Sub-Total					**95884**
Cost of Units	From table 24				**1690000**
Total					**Rs. 17,85,884**

c. Cost of Glass

According to the market standard, single-pane glass costs around 700 per square foot of area including the installation. The total area of glass in the AC space is 290 square feet.

Therefore,

The total Installation cost of single-pane glass is,

= 290× Rs. 700

=Rs. 2,03,000

Table 4.15: Cost of installation of Single glass

Investment on glass			
Glass	Area	Price per sq. feet	Total
Single	290	700	Rs. 203000

d. Operation Cost of 13TR of AC Unit

The operation cost of AC includes the day-to-day electrical consumption cost. It contributes to the huge lump of money when calculated annually. The rated power for 13 TR is found to be around 11kw from a catalog of Mitsubishi. Considering the power rating of AC unit to be 0.6 efficient operating 10 hrs. a day: (citymulti_catalogue, 2016)

Power Consumption= 11×0.6×10

= 66kWh

Per month =66×30

= 1980kWh

Considering, the unit cost of electricity to be Rs.11/kWh,

Total electrical Consumption per month: = 11× 1980

= Rs. 21,780 per month

Table 4.16: Operational Cost Calculation

S.N.	AC	13	TR
1	Power Input	11	
2	Power Rating	0.6	
3	Operating hrs	10	hrs/day
4	Per day	66	kWh
5	per month	1980	Rs.
6	per unit	11	
	Total Cost	21780	
	Total Electricity Cost Per year	Rs. 261360	

From the above calculations, when single pane glass is installed in the window, there is a requirement of 13TR of AC unit. The total cost of installation of glass and AC unit including operational cost can be summarized in Table 4.17 which shows the total cost to be around 22 lakh and 50 thousand.

Table 4.17: Overall total yearly cost for single glass and 13TR AC including operation.

Summary	
Total Investment in AC	1785884
Total Investment in Glass	203000
Total yearly consumption of electricity	261360
Total	**Rs. 22,50,244**

4.5.2 Installation of Double-glazing glass

a. Cost of Outdoor and Indoor Units

The cooling load was found to be around 12TR when double glaze glass was installed in the window. The total cost of installation of AC includes the cost of the outdoor unit and indoor unit. The standard market cost is considered when calculating the equipment cost and other accessories that come along with it. Table 24 shows the prices of units required for installation of 12 TR AC Units.

Table 4.18: Cost of AC-Equipment for 12TR

Sn.	Units	Price
1	Outdoor unit	550000
2	Indoor unit	770000
3	Joint kit	56000
4	Remote Control	56000
5	Copper Piping with installation	30000
6	Control Panel	40000
7	Drainpipe	15000
9	Installation of ODU	25000
10	Installation of IDU	28000
11	Testing and Commission	20000
	Sub-Total	1590000
From Table 4.14	Piping Price	95884
Total		**Rs. 16,85,884**

b. Piping price

The total cost of pipes and ducts is almost similar for the 13TR and 12TR AC units. Table 4.14 shows the standard pipe required for AC installation along with prices and overall cost.

c. Cost of Glass

According to the market standard, single-pane glass costs around 700 per square foot of area including the installation. The total area of glass in the AC space is 290 square feet.

Therefore,

The total Installation cost of single-pane glass is,

= 290×Rs. 1200

=Rs. 3,48,000

Table 4.19: Cost of installation of Double glass

Investment on glass			
Glass	Area	Price per sq. feet	Total
Double	290	1200	Rs. 3,48,000

d. Operation Cost of 12TR of AC Unit

The operation cost of AC includes the day-to-day electrical consumption cost. It contributes to the huge lump of money when calculated annually. The rated power for 12 TR is found to be around 10kw from a catalog of Mitsubishi. Considering the power rating of AC unit to be 0.6 efficient operating 10 hrs a day: (citymulti_catalogue, 2016)

Power Consumption= 10×0.6×10

= 60kWh

Per month =66×30

= 1800kWh

Considering, the unit cost of electricity to be Rs.11/kWh,

Total electrical Consumption per month: = 11×1800

= Rs. 19,800 per month

Table 4.20: Operational cost calculation of 12TR

AC	12	TR
Power Input	10	
Power Rating	0.6	
Operating hrs	10	hrs/day
Per day	60	kWh
per month	1800	
per unit	11	
Total Cost per Month	19800	
Cost per year	**Rs. 2,37,600**	

From the above calculations, when double pane glass is installed in the window, there is a requirement of 12TR of AC unit. The total cost of installation of glass and AC unit including operational cost can be summarized in Table 4.21 which shows the total cost to be around 21 lakh and 26 thousand.

Table 4.21: Overall total yearly cost for double glass and 12TR AC including operation.

Summary	
Total Investment in AC	1685884

Total Investment in Glass	203000
Total yearly consumption of electricity	237600
Total	**Rs. 21,26,484**

4.5.3 Calculation of Payback Period

It costs less to the installation of single-pane glass in windows, but it comes along with increased costs in AC units. Also, the double glaze glass is expensive in installation but it saves money in the installation of lesser capacity of AC unit and ultimately saves yearly consumption of energy.

Therefore, when double glaze glass is used instead of single pane glass from Table 26 and Table 30:

Total Increased cost in the installation of glass = Rs. 1,45,000

But there will be cost reduction in installation of AC unit. Therefore, from Table 4.20 and Table 4.21

Total Decreased cost in the installation of lesser capacity AC unit: = Rs. 1,00,000

From the increased cost of the installation of glass and the decreased cost installation of of an AC unit, it can be summarized that, in the beginning,

Net increased cost during installation = Rs.1,45,000- Rs. 1,00,000

= Rs. 45,000

Now, the annual consumption of electricity when single glass is used in a window would be more as there is a higher capacity of AC unit is installed. Similarly, the cost of electricity would be less in the case of double-glazed glass as there would be AC units of lesser capacity.

So Annual savings in electricity consumption from Table 4.20 and Table 4.21;

Total Annual Saving = Rs. 2,61,360 - Rs. 2,37,600

= Rs. 23,760

Also, there will be savings in the yearly maintenance of AC units. Around Rs. 2000 is saved in maintenance cost of AC.

Table 4.22: Summary of Net Cost Analysis

Total Extra Expenses in Installing Double Glass	1,45,000
Saving in Installation of HVAC	1,00,000
So, the Total Overall initial investment	45,000
Saving in Operation and Maintenance	2,000
Saving in electricity Consumption	23,760
Total Saving yearly	Rs. 25,760

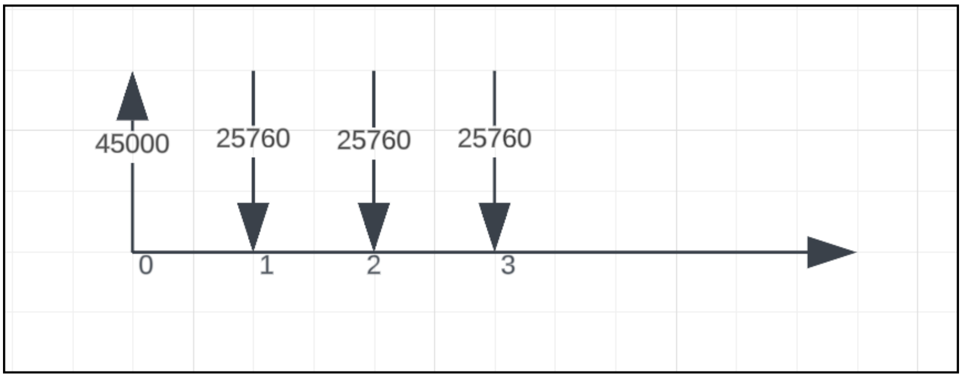

Figure 4.4: Cashflow Diagram

Table 4.23: Cashflow Table

Year	**Outflow**	**Inflow**	**CF**
0	-45,000		
1		**25,760**	**-19,240**
2		**25,760**	**6,520**
3		25,760	32,280
4		25,760	58,040
5		25,760	83,800
6		25,760	1,09,560

The payback period is 1 year 8 months.

4.5.4 Result and Discussion

The total Cooling load is calculated for space by considering single-pane glass and double-pane glass. It is calculated using the ASHRAE Cooling load Calculation Sheet for more accuracy. The load is calculated for June and July at 12 PM, 2 PM, and 4 PM. The detailed information and calculation sheet for different hours are summarized in ANNEX B.

The summary of the calculations is as follows:

Table 4.24: Summary Table of Required TR

S.N.	**Type of Glass**	**Required TR of AC(From Cooling load Calculation Sheet)**
1	Single Pane Glass	13 TR
2	Double Glaze Glass	12 TR

The result shows that the total cooling load for the building while using single pane glass is almost 13 TR and when double glaze glass is used the cooling load seemed to reduce to 12 TR. This shows that just by changing the window glass (single and double glaze) with different solar gain constants the cooling load varies by 8%. The payback period is calculated as 1 year and 8 months which means the project is technically and financially feasible. In the long term, this difference can be proven crucial in energy saving of air conditioning.

CHAPTER FIVE
CONCLUSION

5.1 Conclusion

The research determined the difference in total cooling when single-pane glass is replaced by a double-glazed window in an air-conditioned space. The result shows that the overall cooling load decreased by around 10% when double-glazed glass was used in windows. Based on the calculation sheet, it is observed that the capacity of AC required in the case of a single glaze window is around 13TR. But keeping other variables constant only replacing single glass with double glaze AC load decreased. So, the result shows total AC required in the case of double-glazed glass is around 12TR.

The results showed using double-glaze glass in place of single-pane glass in windows would considerably reduce the solar energy that appears the structures, and therefore, reduce the heat gain due to solar energy through buildings. Then power utilization by the air-conditioning system is degraded directly. When using better glass, led to more energy efficiency in air-conditioned buildings. For this particular case study, the double-glazing glass is found to be more than 10% energy efficient in terms of air-conditioned energy load.

Windows occupies around 20%-30% of the total area of the building which is exposed to solar radiation. In earlier days, it was considered only for the aesthetic looks but nowadays it is considered a great way to energy efficiency. It is a major area of a building that has direct contact with heat gain and loss. Therefore, a better selection of windows leads towards energy-saving and energy-efficient building. This ultimately reduces the energy consumption in the HVAC sector.

5.2 Recommendations

Energy-efficient glass in windows can be proven a great way to reduce the energy used in air conditioning. Air conditioning energy covers a major portion of total energy consumed and demand has been increasing with the increase in urbanization and industrialization. This is a technically feasible idea to ensure energy savings in huge amounts. So, it is recommended that the use of double-glazed glass should be prioritized and practiced for the long-term sustainability of energy saving. Also, double-glazed glass is the best method for sound insulation. In the crowded urbanization from being energy efficient to sound insulator use of double-glazed glass should be considered.

The study is limited to the analysis between two different types of glass. With the advancement of technology, several types of energy-efficient glass can be used in the window to lower the energy consumption by the AC unit. Glasses when coated with metal oxides reduce heat absorption and emissivity. This type of glass also improves the thermal comfort. Also, laminated glass, Borosilicate glass, electro-chromium glass, and Tempered glass are used in windows. These glasses' efficiency comes along with the prices.

Also, three-layered glasses are more efficient in extreme conditions. The selection of these glasses depends on thermal conditions and project finance. Further analysis can elaborate more on the cooling load varies along different types of glasses. The simple concept of selecting more energy-efficient glasses can be a huge step in energy saving.

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ANNEX A: COOLING LOAD CALCULATION SHEET SINGLE GLASS JUNE AT 12 PM

Location: Pulchowk								
Project: Thesis								
Building Type: Commercial								
Room Type: Office								
Climate data	Pulchowk, Lalitpur							
Month	June 12 PM		**Group B Wall**	**CLTD**	**CLTD cor**	**Glass**	**CLTD**	**CLTD cor**
Temperature	**Max**	**Min**	N	8	15		9	15
	88	63	S	11	11			
RH %	85		E	19	25			
			W	15	22			
COOLING LOAD CALCULATION								
DESIGN PARAMETER		DB F	WB F	RH %	W			
OUTSIDE		88	81	73	147			
INSIDE		75	65	50	78			
				AREA				
CONDUCTION	**DIR**	**COL**	**U**	**GROSS**	**NET**	**CLTD/cor**	**RSHG**	
(GLASS)	N	CL	0.94		0	9	0	
	S	CL	0.94		120	9	1015	
	E	CL	0.94		50	9	423	

	W	CL	0.94		120	9	1015	
WALL	N		0.35	600	600	15	3150	
	S		0.35	600	480	11	1848	
	E		0.35	500	500	25	4375	
	W		0.35	500	338	22	2603	
CEILING			0.4		3000	14	16800	
FLOOR								
PARTITION								
DOOR				42				
SOLAR	DIR	Sh	SHGF	A	SC	CLF		
(GLASS)	N		55	0	0.91	0.89	0	
	S		43	120	0.91	0.83	3897	
	E		212	50	0.91	0.27	2604	
	W		212	120	0.91	0.17	3936	
								Latent gain
LIGHT	50	W ×	3.14		1	CLF ×	196.25	
PEOPLE	250	SHG ×	**50**	N ×	1	CLF ×	12500	
	200	LHG ×	**50**	N				10000

EQUIPMENT							2500	
INFILTERATION	1.1	×	200	CFM	15	Air Change	3300	
	0.68	×	200	CFM	69	gr/lb		9384
VENTILATION	1.1	×	750	CFM ×	13	Air Change	10725	
	0.68	×	750	CFM ×	69	gr/lb		35190
						TOTAL	70888	54574
						SUBTOTAL	125462	
						GRAND TOTAL	131734.6653	
						TOTAL TR =	11	
						Grand Total [TR]	**10.98**	

ANNEX B: COOLING LOAD CALCULATION SHEET DOUBLE GLASS JUNE AT 12 PM

Location: Pulchowk								
Project: Thesis								
Building Type: Commercial								
Room Type: Office								
Climate data	Pulchowk, Lalitpur							
Month	June		**Group B Wall**	**CLTD**	**CLTD cor**	**Glass**	**CLTD**	**CLTD cor**
Temperature	**Max**	**Min**	N	8	15		9	15
	88	63	S	11	11			
RH %	85		E	19	25			
			W	15	22			
COOLING LOAD CALCULATION								
DESIGN PARAMETER		DB F	WB F	RH %	W			
OUTSIDE		88	81	73	147			
INSIDE		75	65	50	78			
				AREA				
CONDUCTION	**DIR**	**COL**	**U**	**GROSS**	**NET**	**CLTD/cor**	**RSHG**	
(GLASS)	N	CL	0.61		0	9	0	
	S	CL	0.61		120	9	659	
	E	CL	0.61		50	9	275	
	W	CL	0.61		120	9	659	
WALL	N		0.35	600	600	15	3150	
	S		0.35	600	480	11	1848	
	E		0.35	500	500	25	4375	
	W		0.35	500	338	22	2603	
CEILING			0.4		3000	14	16800	
FLOOR								

PARTITION								
DOOR				42				
SOLAR	DIR	Sh	SHGF	A	SC	CLF		
(GLASS)	N		55	0	0.35	0.89	0	
	S		43	120	0.35	0.83	1499	
	E		212	50	0.35	0.27	1002	
	W		212	120	0.35	0.17	1514	
								Latent gain
LIGHT	50	W ×	3.14		1	CLF ×	196.25	
PEOPLE	250	SHG ×	**50**	N ×	1	CLF ×	12500	
	200	LHG ×	**50**	N				10000
EQUIPMENT							2500	
INFILTERATION	1.1	×	200	CFM	15	Air Changes	3300	
	0.68	×	200	CFM	69	gr/lb		9384
VENTILATION	1.1	×	750	CFM	13	Air Changes	10725	
	0.68	×	750	CFM	69	gr/lb		35190
						TOTAL	63603	54574
						SUBTOTAL	118177	
						GRAND TOTAL	124086.1755	
						TOTAL TR =	10	
						Grand Total [TR]	**10.34**	

ANNEX C: COOLING LOAD CALCULATION SHEET SINGLE GLASS JUNE AT 4 PM

Location: Pulchowk								
Project: Thesis								
Building Type: Commercial								
Room Type: Office								
Climate data	Pulchowk, Lalitpur							
Month	June		**Group B Wall**	**CLTD**	**CLTD cor**	**Glass**	**CLTD**	**CLTD cor**
Temperature	**Max**	**Min**	N	8	15		14	20
	88	70	S	11	11			
RH %	73		E	19	25			
			W	15	22			
COOLING LOAD CALCULATION								
DESIGN PARAMETER			WB F	RH %	W			
OUTSIDE		88	82	73	161			
INSIDE		75	65	50	78			
				AREA				
CONDUCTION	**DIR**	**COL**	**U**	**GROSS**	**NET**	**CLTD/cor**	**RSHG**	
(GLASS)	N	CL	0.94		0	14	0	
	S	CL	0.94		120	14	1579	
	E	CL	0.94		50	14	658	
	W	CL	0.94		120	14	1579	
WALL	N		0.35	600	600	9	1890	
	S		0.35	600	480	12	2016	
	E		0.35	500	500	22	3850	
	W		0.35	500	338	14	1656	
CEILING			0.4		3000	14	16800	
FLOOR								
PARTITION								

DOOR				42				
SOLAR	DIR	Sh	SHGF	A	SC	CLF		
(GLASS)	N		55	0	0.91	0.75	0	
	S		43	120	0.91	0.35	1643	
	E		212	50	0.91	0.17	1640	
	W		212	120	0.91	0.82	18983	
								Latent gain
LIGHT	50	W ×	3.14		1	CLF ×	196.25	
PEOPLE	250	SHG ×	**50**	N ×	1	CLF ×	12500	
	200	LHG ×	**50**	N				10000
EQUIPMENT							2500	
INFILTERATION	1.1	×	200	CFM	15	Air Changes	3300	
	0.68	×	200	CFM	83	gr/lb		11288
VENTILATION	1.1	×	750	CFM	13	Air Changes	10725	
	0.68	×	750	CFM	83	gr/lb		42330
						TOTAL	81516	63618
						SUBTOTAL	145134	
						GRAND TOTAL	152391.1809	
						TOTAL TR =	13	
						Grand Total [TR]	**12.70**	

ANNEX D: COOLING LOAD CALCULATION SHEET DOUBLE GLASS JUNE AT 4 PM

Location: Pulchowk								
Project: Thesis								
Building Type: Commercial								
Room Type: Office								
Climate data	Pulchowk, Lalitpur							
Month	June		**Group B Wall**	**CLTD**	**CLTD cor**	**Glass**	**CLTD**	**CLTD cor**
Temperature	**Max**	**Min**	N	8	15		14	20
	88	70	S	11	11			
RH %	73		E	19	25			
			W	15	22			
COOLING LOAD CALCULATION								
DESIGN PARAMETER		DB F	WB F	RH %	W			
OUTSIDE		88	82	73	161			
INSIDE		75	65	50	78			
				AREA				
CONDUCTION	**DIR**	**COL**	**U**	**GROSS**	**NET**	**CLTD/cor**	**RSHG**	
(GLASS)	N	CL	0.61		0	14	0	
	S	CL	0.61		120	14	1025	
	E	CL	0.61		50	14	427	
	W	CL	0.61		120	14	1025	
WALL	N		0.35	600	600	9	1890	
	S		0.35	600	480	12	2016	
	E		0.35	500	500	22	3850	
	W		0.35	500	338	14	1656	
CEILING			0.4		3000	14	16800	
FLOOR								
PARTITION								

DOOR				42				
SOLAR	DIR	Sh	SHGF	A	SC	CLF		
(GLASS)	N		55	0	0.55	0.75	0	
	S		43	120	0.55	0.35	993	
	E		212	50	0.55	0.17	991	
	W		212	120	0.55	0.82	11473	
								Latent gain
LIGHT	50	W ×	3.14		1	CLF ×	196.25	
PEOPLE	250	SHG ×	**50**	N ×	1	CLF ×	12500	
	200	LHG ×	**50**	N				10000
EQUIPMENT							2500	
INFILTERA TION	1.1	×	200	CFM	15	Air Changes	3300	
	0.68	×	200	CFM	83	gr/lb		11288
VENTILATI ON	1.1	×	750	CFM	13	Air Changes	10725	
	0.68	×	750	CFM	83	gr/lb		42330
						TOTAL	71368	63618
						SUBTOTAL	134986	
						GRAND TOTAL	141735.1 845	
						TOTAL TR =	12	
						Grand Total [TR]	**11.81**	

ANNEX E: COOLING LOAD CALCULATION SHEET SINGLE GLASS JULY AT 12 PM

Location: Pulchowk								
Project: Thesis								
Building Type: Commercial								
Room Type: Office								
Climate data	Pulchowk, Lalitpur							
Month	July		**Group B Wall**	**CLTD**	**CLTD cor**	**Glass**	**CLTD**	**CLTD cor**
Temperature	**Max**	**Min**	N	8	12		9	12
	88	60	S	11	8			
RH %	81		E	19	22			
			W	15	19			
COOLING LOAD CALCULATION								
DESIGN PARAMETER		DB F	WB F	RH %	W			
OUTSIDE		85	80	81	145			
INSIDE		75	65	50	78			
				AREA				
CONDUCTION	**DIR**	**COL**	**U**	**GROSS**	**NET**	**CLTD/cor**	**RSHG**	
(GLASS)	N	CL	0.94		0	9	0	
	S	CL	0.94		120	9	1015	
	E	CL	0.94		50	9	423	
	W	CL	0.94		120	9	1015	
WALL	N		0.35	600	600	12	2520	
	S		0.35	600	480	8	1344	
	E		0.35	500	500	22	3850	
	W		0.35	500	338	19	2248	
CEILING			0.4		3000	14	16800	
FLOOR								

PARTITION								
DOOR				42				
SOLAR	DIR	Sh	SHGF	A	SC	CLF		
(GLASS)	N		45	0	0.91	0.89	0	
	S		46	120	0.91	0.83	4169	
	E		213	50	0.91	0.27	2617	
	W		213	120	0.91	0.17	3954	
								Latent gain
LIGHT	50	W ×	3.14		1	CLF ×	196.25	
PEOPLE	250	SHG ×	**50**	N ×	1	CLF ×	12500	
	200	LHG ×	**50**	N				10000
EQUIPMENT							2500	
INFILTERATION	1.1	×	200	CFM	15	Air Changes	3300	
	0.68	×	200	CFM	83	gr/lb		9112
VENTILATION	0.68	×	750	CFM	83	gr/lb	8250	
	1.1	×	200	CFM	15	Air Changes		34170
						TOTAL	66701	53282
						SUBTOTAL	119983	
						GRAND TOTAL	125982.6152	
						TOTAL TR =	10	
						Grand Total [TR]	**10.50**	

ANNEX F: COOLING LOAD CALCULATION SHEET DOUBLE GLASS JULY AT 12 PM

Location: Pulchowk								
Project: Thesis								
Building Type: Commercial								
Room Type: Office								
Climate data	Pulchowk, Lalitpur							
Month	July		**Group B Wall**	**CLTD**	**CLTD cor**	**Glass**	**CLTD**	**CLTD cor**
Temperature	**Max**	**Min**	N	8	12		9	12
	88	60	S	11	8			
RH %	81		E	19	22			
			W	15	19			
COOLING LOAD CALCULATION								
DESIGN PARAMETER		DB F	WB F	RH %	W			
OUTSIDE		85	80	81	145			
INSIDE		75	65	50	78			
				AREA				
CONDUCTION	**DIR**	**COL**	**U**	**GROSS**	**NET**	**CLTD/cor**	**RSHG**	
(GLASS)	N	CL	0.61		0	9	0	
	S	CL	0.61		120	9	659	
	E	CL	0.61		50	9	275	
	W	CL	0.61		120	9	659	
WALL	N		0.35	600	600	12	2520	
	S		0.35	600	480	8	1344	
	E		0.35	500	500	22	3850	
	W		0.35	500	338	19	2248	
CEILING			0.4		3000	14	16800	
FLOOR								

PARTITION								
DOOR				42				
SOLAR	DIR	Sh	SHGF	A	SC	CLF		
(GLASS)	N		45	0	0.35	0.89	0	
	S		46	120	0.35	0.83	1604	
	E		213	50	0.35	0.27	1006	
	W		213	120	0.35	0.17	1521	
								Latent gain
LIGHT	50	W ×	3.14		1	CLF ×	196.25	
PEOPLE	250	SHG ×	**50**	N ×	1	CLF ×	12500	
	200	LHG ×	**50**	N				10000
EQUIPMENT							2500	
INFILTERATION	1.1	×	200	CFM	15	Air Changes	3300	
	0.68	×	200	CFM	83	gr/lb		9112
VENTILATION	0.68	×	750	CFM	83	gr/lb	8250	
	1.1	×	200	CFM	15	Air Changes		34170
						TOTAL	59231	53282
						SUBTOTAL	112513	
						GRAND TOTAL	118138.4978	
						TOTAL TR =	10	
						Grand Total [TR]	**9.84**	

ANNEX G: COOLING LOAD CALCULATION SHEET SINGLE GLASS JULY AT 2 PM

Location: Pulchowk								
Project: Thesis								
Building Type: Commercial								
Room Type: Office								
Climate data	Pulchowk, Lalitpur							
Month	July		**Group B Wall**	**CLTD**	**CLTD cor**	**Glass**	**CLTD**	**CLTD cor**
Temperature	**Max**	**Min**	N	9	16		13	19
	88	73	S	12	12			
RH %	73		E	22	28			
			W	14	21			
COOLING LOAD CALCULATION								
DESIGN PARAMETER		DB F	WB F	RH %	W			
OUTSIDE		88	80	81	144			
INSIDE		75	65	50	78			
				AREA				
CONDUCTION	**DIR**	**COL**	**U**	**GROSS**	**NET**	**CLTD/cor**	**RSHG**	
(GLASS)	N	CL	0.94		0	13	0	
	S	CL	0.94		120	13	1466	
	E	CL	0.94		50	13	611	
	W	CL	0.94		120	13	1466	
WALL	N		0.35	600	600	16	3360	
	S		0.35	600	480	12	2016	
	E		0.35	500	500	28	4900	
	W		0.35	500	338	21	2484	
CEILING			0.4		3000	14	16800	
FLOOR								
PARTITION								

DOOR				42				
SOLAR	DIR	Sh	SHGF	A	SC	CLF		
(GLASS)	N		45	0	0.91	0.86	0	
	S		46	120	0.91	0.68	3416	
	E		213	50	0.91	0.22	2132	
	W		213	120	0.91	0.53	12328	
								Latent gain
LIGHT	50	W ×	3.14		1	CLF ×	196.25	
PEOPLE	250	SHG ×	**50**	N ×	1	CLF ×	12500	
	200	LHG ×	**50**	N				10000
EQUIPMENT							2500	
INFILTERATION	1.1	×	200	CFM	15	Air Changes	3300	
	0.68	×	200	CFM	83	gr/lb		8976
VENTILATION	0.68	×	750	CFM	83	gr/lb	10725	
	1.1	×	200	CFM	15	Air Changes		33660
						TOTAL	80201	52636
						SUBTOTAL	132837	
						GRAND TOTAL	139478.6862	
						TOTAL TR =	12	
						Grand Total [TR]	**11.62**	

ANNEX H: COOLING LOAD CALCULATION SHEET DOUBLE GLASS JULY AT 2 PM

Location:Pulchowk								
Project: Thesis								
Building Type:Commercial								
Room Type: Office								
Climate data	Pulchowk, Lalitpur							
Month	July		**Group B Wall**	**CLTD**	**CLTD cor**	**Glass**	**CLTD**	**CLTD cor**
Temperature	**Max**	**Min**	N	9	16		13	19
	88	73	S	12	12			
RH %	73		E	22	28			
			W	14	21			
COOLING LOAD CALCULATION								
DESIGN PARAMETER		DB F	WB F	RH %	W			
OUTSIDE		88	80	81	144			
INSIDE		75	65	50	78			
				AREA				
CONDUCTION	**DIR**	**COL**	**U**	**GROSS**	**NET**	**CLTD/corrr**	**RSHG**	
(GLASS)	N	CL	0.61		0	13	0	
	S	CL	0.61		120	13	952	
	E	CL	0.61		50	13	397	
	W	CL	0.61		120	13	952	
WALL	N		0.35	600	600	16	3360	
	S		0.35	600	480	12	2016	
	E		0.35	500	500	28	4900	
	W		0.35	500	338	21	2484	
CEILING			0.4		3000	14	16800	
FLOOR								
PARTITION								
DOOR				42				

SOLAR	DIR	Sh	SHGF	A	SC	CLF		
(GLASS)	N		45	0	0.55	0.86	0	
	S		46	120	0.55	0.68	2064	
	E		213	50	0.55	0.22	1289	
	W		213	120	0.55	0.53	7451	
								Latent gain
LIGHT	50	W ×	3.14		1	CLF ×	196.25	
PEOPLE	250	SHG ×	**50**	N ×	1	CLF ×	12500	
	200	LHG ×	**50**	N				10000
EQUIPMENT							2500	
INFILTERATION	1.1	×	200	CFM	15	Air Changes	3300	
	0.68	×	200	CFM	83	gr/lb		8976
VENTILATION	0.68	×	750	CFM	83	gr/lb	10725	
	1.1	×	200	CFM	15	Air Changes		33660
						TOTAL	71885	52636
						SUBTOTAL	124521	
						GRAND TOTAL	130747.176	
						TOTAL TR =	11	
						Grand Total [TR]	**10.90**	

ANNEX I: COOLING LOAD CALCULATION SHEET SINGLE GLASS JULY AT 4 PM

Location: Pulchowk								
Project: Thesis								
Building Type: Commercial								
Room Type: Office								
Climate data	Pulchowk, Lalitpur							
Month	July 4 PM		**Group B Wall**	**CLTD**	**CLTD cor**	**Glass**	**CLTD**	**CLTD cor**
Temperature	**Max**	**Min**	N	8	15		14	20
	86	70	S	11	11			
RH %	81		E	19	25			
			W	15	22			
COOLING LOAD CALCULATION								
DESIGN PARAMETER		DB F	WB F	RH %	W			
OUTSIDE		88	80	81	145			
INSIDE		75	65	50	78			
				AREA				
CONDUCTION	**DIR**	**COL**	**U**	**GROSS**	**NET**	**CLTD/cor**	**RSHG**	
(GLASS)	N	CL	0.94		0	14	0	
	S	CL	0.94		120	14	1579	
	E	CL	0.94		50	14	658	
	W	CL	0.94		120	14	1579	
WALL	N		0.35	600	600	9	1890	
	S		0.35	600	480	12	2016	
	E		0.35	500	500	22	3850	
	W		0.35	500	338	14	1656	
CEILING			0.4		3000	14	16800	
FLOOR								

PARTITION								
DOOR				42				
SOLAR	DIR	Sh	SHGF	A	SC	CLF		
(GLASS)	N		55	0	0.91	0.75	0	
	S		43	120	0.91	0.35	1643	
	E		212	50	0.91	0.17	1640	
	W		212	120	0.91	0.82	18983	
								Latent gain
LIGHT	50	W ×	3.14		1	CLF ×	196.25	
PEOPLE	250	SHG ×	**50**	N ×	1	CLF ×	12500	
	200	LHG ×	**50**	N				10000
EQUIPMENT							2500	
INFILTERA TION	1.1	×	200	CFM	15	Air Changes	3300	
	0.68	×	200	CFM	83	gr/lb		9112
VENTILATI ON	0.68	×	750	CFM	83	gr/lb	10725	
	1.1	×	200	CFM	15	Air Changes		34170
						TOTAL	81516	53282
						SUBTOTAL	134798	
						GRAND TOTAL	141538.3809	
						TOTAL TR =	12	
						Grand Total [TR]	**11.79**	

ANNEX J: COOLING LOAD CALCULATION SHEET DOUBLE GLASS JULY AT 4 PM

Location: Pulchowk								
Project: Thesis								
Building Type: Commercial								
Room Type: Office								
Climate data	Pulchowk, Lalitpur							
Month	July		**Group B Wall**	**CLTD**	**CLTD cor**	**Glass**	**CLTD**	**CLTD cor**
Temperature	**Max**	**Min**	N	8	15		14	20
	86	70	S	11	11			
RH %	81		E	19	25			
			W	15	22			
COOLING LOAD CALCULATION								
DESIGN PARAMETER		DB F	WB F	RH %	W			
OUTSIDE		88	80	81	145			
INSIDE		75	65	50	78			
				AREA				
CONDUCTION	**DIR**	**COL**	**U**	**GROSS**	**NET**	**CLTD/cor**	**RSHG**	
(GLASS)	N	CL	0.61		0	14	0	
	S	CL	0.61		120	14	1025	
	E	CL	0.61		50	14	427	
	W	CL	0.61		120	14	1025	
WALL	N		0.35	600	600	9	1890	
	S		0.35	600	480	12	2016	
	E		0.35	500	500	22	3850	
	W		0.35	500	338	14	1656	
CEILING			0.4		3000	14	16800	
FLOOR								

PARTITION								
DOOR				42				
SOLAR	DIR	Sh	SHGF	A	SC	CLF		
(GLASS)	N		55	0	0.55	0.75	0	
	S		43	120	0.55	0.35	993	
	E		212	50	0.55	0.17	991	
	W		212	120	0.55	0.82	11473	
								Latent gain
LIGHT	50	W ×	3.14		1	CLF ×	196.25	
PEOPLE	250	SHG ×	**50**	N ×	1	CLF ×	12500	
	200	LHG ×	**50**	N				10000
EQUIPMENT							2500	
INFILTERATION	1.1	×	200	CFM	15	Air Changes	3300	
	0.68	×	200	CFM	83	gr/lb		9112
VENTILATION	0.68	×	750	CFM	83	gr/lb	10725	
	1.1	×	200	CFM	15	Air Changes		34170
						TOTAL	71368	53282
						SUBTOTAL	124650	
						GRAND TOTAL	130882.3845	
						TOTAL TR =	11	
						Grand Total [TR]	**10.91**	

ANNEX K: THERMAL RESISTANCE

Source: (Aurora, 2009)

Material	**Description**	**Specific heat**	**Thermal conductivity**	**Conductance**
		Measured in (kJ/kg.K)	Measured in (W/m.K)	W/m2.K
Bricks	Regular	0.84	0.77	-
	Face	0.84	1.32	-
Masonry materials	Concrete	0.88	1.73	-
	Plaster cement	0.796	8.65	-
	Hollow clay tiles			
	100 mm	-	-	5.20
	200 mm	-	-	2.33
	300 mm	-	-	
	Hollow concrete block	-	-	
	100 mm	-	-	4.54
	200 mm	-	-	
	300 mm			
Glass	Window	0.84	0.78	-
	Coro silicate	-	1.09	-
Insulating materials	Fiberglass board	0.7	0.038	-

	Core board	1.88	0.038	-
	Mineral or glass wool	0.67	0.038	-
	Magnesia	-	0.067	-
	Asbestos	0.82	0.154	-

ANNEX L: U-FACTOR FOR GLASS

(ISHRAE handbook)

Window type	Overall U-factor	Visible transmittance	SHGC	LSG
Single-pane clear glass	0.81	0.71	0.72	0.99
Double-pane clear glass	0.61	0.63	0.60	1.05
Double-pane bronze-tinted glass	0.60	0.38	0.42	0.90
Double-pane glass with reflective glazing	0.54	0.10	0.17	0.59
Double-pane clear glass with low-e coating	0.46	0.57	0.34	1.68
Double-pane bronze-tinted glass with low-e coating	0.49	0.36	0.39	0.92
Triple-pane clear glass with two low-e layers and low-conductivity frame	0.14	0.34	0.20	1.70
Double-pane argon-filled electrochromic glass (in tinted state)	0.26	0.04	0.09	0.39
Double-pane argon-filled electrochromic glass (in clear state)	0.29	0.62	0.48	1.29

Notes: LSG = light-to-solar-gain ratio; U-factor = heat-transfer value;
SHGC = solar heat gain coefficient.

Source: (ouc.bizenergyadvisor.com/article/windows, 2023)

ANNEX M: TYPICAL LIGHTING LOAD

Description of rooms	**Lighting power W/m^2**
Office room	12
Conference/Meeting/Multipurpose	14
Classroom/Lecture/Training	15
Audience/Seating area	10
Dining area	10
Laboratory	15
Rest room	10
Electrical/mechanical room	16
Workshop	20
Library, reading area	13

(ISHRAE handbook)

To study the variation in cooling load between single-pane glass and double-glazing glass in an- air-conditioned space

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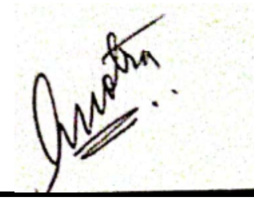

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