IMPACT OF GLAZED BALCONIES ON THE ENERGY EFFICIENCY OF RESIDENTIAL BUILDINGS: THE CASE OF COASTAL REGION; SAIDA

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This thesis work is dedicated to my husband, Yousef,
And my baby soon to be born Malek.

Aldo Leopold wrote:
“Conservation is a state of harmony between men and land.”

Abstract

This research project aims to study the effect of glazed balconies on energy consumed on cooling, balcony typologies, and adjacent spaces. The research focuses on the case of seafronts and specifically Saida's coastal zone: "Corniche El Baher" area. Glazed balconies are a spontaneous chaotic trend that allows users to benefit from and occupy balcony spaces in all seasons. This trend has many impacts on the indoor thermal comfort and energy consumed in the glazed spaces.

Drawing upon previous energy consumption research, particularly in the summer months in residential buildings in Lebanon and focusing on the coastal zones and buildings overlooking the sea on the west, was helpful in identifying the relation between energy consumption and glazing. The adopted methodology identified the balcony typologies found in "Corniche El Baher" area overlooking the west through site observation and note takings. Building modeling and energy simulations were implemented on several case studies in order to estimate the energy consumed on cooling in the glazed balconies and adjacent spaces of different balcony typologies. Three case studies were modeled representing the three balcony typologies; balcony surrounded by 1 wall, 2 walls, and 3 walls. Three scenarios for each model were simulated; balcony, glazed balcony, and glazed balcony having the wall separating the adjacent space from the balcony removed.

The recordings indicated high-energy consumption in glazed spaces of all models, but difference in performance. The balcony surrounded by 1 wall having the wall separating the balcony from the adjacent space removed recorded the highest cooling demand. Amongst all spaces adjacent to the balconies in the three scenarios, the space adjacent to the unglazed balcony recorded the highest cooling usage. The most efficient adjacent space is when the balcony is glazed. The glazed balcony forms a buffer zone separating the adjacent spaces from the outdoor environment that decreases the heat transfer through the glazed balcony.

The thesis presented projections where parameters such as: replacing glazing type by low-e, installing shading devices on 2/3 of the windows, changing the orientation of the balconies, and decreasing the window-to-wall ratio to 30%.

There was a clear improvement in all scenarios' energy consumption when shading devices were added to the glazed balconies models causing the energy consumed in the spaces to decrease. It is hoped that this thesis will contribute significantly to the the performance improvement of the current balcony glazing trend in Lebanon. The "Corniche El Baher" area will be set as a sample for seafronts in Lebanon having similar characteristics.

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1. Introduction

1.1 Background

The need for energy consumption and production is constantly growing in several sectors. The building sector accounts for almost 40% of the total global energy consumed (Clerici, 2013). The energy consumed in the building sector corresponds to the energy used in the form of electricity to maintain occupants' thermal comfort inside buildings. A significant portion of the energy used globally is consumed on heating and cooling systems in the buildings (up-to 37%) (Energy, 2012; Japan, 2010; Department, 2016). Attempts to reduce energy usage on cooling and heating in the building sector have been a challenge. Several countries made policies and regulations in order to reduce and control the energy consumed in buildings. Countries have tried to implement and adapt; energy conservation guidelines, building energy regulations, building codes, and awareness on building energy conservation issues, and to encourage the construction of energy efficient buildings (Hui, 2002; Janda, 2009).

Building envelopes have a major role in controlling the consumption of energy used inside buildings for heating and cooling to maintain indoor thermal comfort. In order to achieve a comfortable indoor temperature, the selection of material of the building envelope should be focused on, since it directly affect the heat transferred through the building envelope (Natephra, Yabuki, & Fukuda, 2018).

Several studies indicated that the main material in the building envelope that has the highest impact on the energy consumption is glazing (Azmy & Elghamry, 2018).

Glazed envelopes account for about 36% of the cooling load. They are considered the most important functional elements as they have direct impact on the thermal behavior of the building, hence, the amount of energy consumed within (Haase & Amato , 2006; Al-Hosany & Khalifah, 2002; Azmy & Elghamry, 2018).

In Lebanon, energy consumed in residential building exceeds commercial and industrial facilities. Residential buildings occupy up-to 47% of the total energy usage in Lebanon, out of which space cooling dominates other uses (Assaad, Habchi, Ghali, & Ghaddar, 2018; Yassine B. , Ghali, Ghaddar, Srour, & Chehab, 2012; Yathreb, 2016).

Therefore, it is crucial to study the major contributor to the high-energy usage on space cooling in residential buildings.

Since glazing is a brittle component in the building envelope that has direct impact on the energy consumption and space cooling, the thesis will focus on this building material in Lebanon (Kumar & Raheja, 2016).

Glazing in buildings is observed in the form of curtain wall system, windows, and glazed balconies. The existence of each glazing type in buildings depends on the cost and building type. In Lebanon, curtain wall systems exist mostly in office buildings in the form of glazed façades. Currently, there is a trend of increasing the use of glazing in balconies in residential buildings.

Glazed balconies are currently a spontaneous chaotic trend that allows the closure of balconies by glazing in order to benefit from the balcony space legally. Glazed balconies allow users to benefit from the space in all seasons and enlarge the occupied spaces. Moreover, glazing the balcony allows the space to be exploited and occupied, especially in small apartments. This is because there is an increase in the construction of multistory residential buildings and small affordable housing in the cities- due to the growing demand for people to live near their working spaces and the urban land price and construction costs(Kuamar, Ganesh, A.S, & Ramancharla, 2009; Credit Libanais Annual Report, 2017). The dense urban fabric in the cities deprived the users from privacy in balconies, since apartments are overlooking each other; therefore, glazed balconies provide privacy to the users but also isolation from the neighborhood (Jokhadar & Jabi, 2019).

Glazed balconies in residential buildings will be the focus of the thesis in order to study the impact of glazed balconies on space cooling.

However, there is a gap in the literature concerning the different balcony typologies and the performance of each. Therefore, the thesis will focus on glazed balconies in different balcony typologies to be indicated.

The performance of glazing is affected by the climate and the orientation placed in. The performance of glazing in winter is different from the summer months, and the performance of glazing in the western elevation is different from the northern, eastern, and southern. Climate and orientation affect the glazing through the different range of solar radiation and heat gains. In Lebanon, the western orientation records the highest cooling demand in the buildings due to the high solar radiation accounted. The western elevation, if adjusted, can achieve a decrease in the energy consumption and space cooling in the apartments.

Briefly, since cooling records the highest energy usage in the summer months, and the western elevation is proved to have high impact on energy consumption, the thesis will limit the focus on glazed balconies in residential building in the coastal zone of Lebanon overlooking the western orientation in Saida sea front focusing on the cooling demand.

Saida city accommodates a large population- upto 100,000 people , encounters economic, and construction growth. The context will serve as a sample to the sea fronts in Lebanon located in the same climatic region and overlooking the western orientation. If an in-depth study was conducted, 80% reduction on energy consumption for the use of cooling and heating can be obtained (Mirrahimi, et al., 2016).

1.2 Aims, Objectives, and Methodologies

The thesis will answer the following research questions;

What is the impact of glazed balconies on energy consumed on cooling?

What is the impact of the balcony typology on energy performance of glazed balconies?

What is the impact of glazed balconies on the energy performance of adjacent spaces?

By following these objectives:

- To identify factors that affect thermal comfort
- To estimate impact of glazing on indoor thermal comfort
- To survey the types of glazed balconies
- To estimate energy consumed on cooling in glazed balconies
- To estimate the effect of glazed balconies on the adjacent spaces' cooling demand
- To estimate the effect of balcony types on space cooling
- To modify several parameters that can improve efficiency of glazed balconies

Each objective will be addressed through different methods; whether based on secondary data in the literature review or based on experimental and primary data. The site observation and note taking methodology will be implemented in order to identify the different balcony types found in the context chosen. Building modeling and energy simulation will be used in order to estimate the energy consumed on cooling in the spaces by designing a model using several architectural software; Revit, Insight 360, Energy Plus, and Green Building Studio.

1.3 Thesis Structure

The first chapter is a general introductory chapter that explains the structure, aims and objectives, research question and the methodology employed. Chapter 2 provides a critical review on the existing literature on glazing and glazed balconies by identifying their impact on energy consumption and thermal comfort. Chapter 3 is dedicated to the understanding of the selected site where the simulations were done. Chapter 4 describes the theoretical approaches to research methodologies that will assess in framing the implemented methodology. Chapter 5 elaborates on the implemented methodology and empirical work done on the specified area. Chapter 6 is devoted to the analysis of the findings and data collection from the undertaken empirical analysis. Chapter 7 starts with the conclusion to the thesis with possible projections towards achieving efficient performance and energy reduction.

2. Literature Review

2.1 Introduction

This chapter will acknowledge previous work done on similar topic of the thesis. The literature will help frame the methodologies to be implemented and shed light on the gaps if found in the previous studies. The first section will define the thermal comfort that affects the occupants' comfort inside buildings. Several factors affecting the thermal comfort will be explored, focusing on the measurable factors that have to do with architects. The effect of thermal comfort on energy consumed, especially on the building sector is discussed in the second section, focusing on the main factors that increases the energy consumption in residential units. The third section discusses the important factor that affects energy consumption; Building envelope. All the building components will be elaborated upon focusing on glazed balconies phenomena, and mainly glazing; the most brittle component in the envelope.

2.2 Occupants' Comfort Inside Buildings; Thermal Comfort

Thermal comfort is a term that defines the comfort of an environment, whether in buildings or outside, determined by norms and expectations of individuals (Nicol & Roaf, 2017). The comfort field was firstly introduced in the 20th century. It defined the need for heating, ventilation, and air conditioning systems (HVAC) in order to allow engineers to target and calculate the sizing of the HVAC plants implemented in a building. Engineers needed measurable and physical factors to ensure thermal balance between occupants and the environment (Farnham, Emura, & Mizuno, 2015; Nicol & Roaf, 2017; Chappells & Shove, 2005).

Thermal comfort is when users adapt to the environment they are occupying, in relation to the location, climate, and building performance (Quang, Knibbs, Dear, & Morawska, 2014). The adaptation occurs when heat exchange underwent between the body and the environment to allow occupants maintain comfort. This heat exchange happened through convection, conduction, radiation, and evaporation (ASHRAE, 2004).

There are several factors that affect the human comfort, where some were measurable and can be quantified, and some were not, such as the metabolic rate. The measurable parameters that influenced the building sector in general, and on the glazing in specific, are our concern in which the methodology can build upon. The measurable factors that affected the building envelope are; air temperature, air velocity, radiant temperature, and relative humidity. Whereas personal factors are: the activity level, metabolic rate, and clothing insulation of the user (Simion, Socaciu, & Unguresan, 2016).

ASHRAE defined thermal comfort of buildings “as the state of mind that expresses satisfaction with the surrounding environment “ (ASHRAE, 2004). Meaning, in order to achieve thermal comfort inside a building, the following parameters must be controlled: air temperature (heat loss and heat gain), mean radiant temperature, relative humidity, air velocity, ventilation, infiltration, occupants, thermal transmittance, area and quality of glazing, and internal and external temperature. In order to maintain a balance, the relationship between the occupants and the indoor environment must be controlled without human effort (ASHRAE, 2004; Pernigotto, Tarantini, & Gasparella, 2017).

Unfortunately, maintaining thermal comfort is not attained without relying on HVAC systems. Up to 40% of the global energy consumption is accounted from the building sector, which also contributed to over 30% of the total CO_2 emissions (Almarzouq, 2019; Azmy & Elghamry, 2018). Thus, most of the energy consumed is used to achieve thermal comfort by operating HVAC.

The growing demand for a better thermal comfort in buildings resulted in the increase of HVAC installations, and thus energy consumption. This concern led researches to improve the building performance, and mainly; the building envelope, the windows and glazing systems in particular, since they have major impact on energy consumed (Govindaraju & Tang, 2013; Costa, Keane, & Corry, 2013; Huang & Chung, 2013). The thesis will focus on the important factors that affect the thermal comfort in the building component. The focus to maintain thermal comfort will directly address the energy consumed. Addressing the energy consumed will help decrease energy bills, heating, and cooling demands by maintaining comfort with minimal energy consumption (Akbeiber, 2016; Assaad, Habchi, Ghali, & Ghaddar, 2018; Azmy & Elghamry, 2018).

2.3 Energy Consumption

Energy consumption is increasing annually. In 2015, a survey indicated that the global energy demand and CO_2 emissions have grown by 49% and 43% annually respectively (Andelkovic, Mujan, & Dakic, 2016). The contribution of the building sector on this demand exceeds other sectors; industrial and transportation. This was due to several reasons, such as growth in population, increase of time spent indoors, and the demand for comfort levels inside buildings (Apte & Wu, 2012). The increasing demand raised concerns on the supply depletion, and exhaustion of the used natural resources (oil, fuel, andcooling many more). Therefore, reducing energy consumed in the building sector, and designing energy efficient buildings has become the international researchers' concern (Perez-Lombard, 2008; Akbeiber, 2016; Andelkovic, Mujan, & Dakic, 2016).

Energy consumed in buildings can be affected by several factors. Several studies attempted to understand the major contributors on energy demand in buildings (Yu, Fung, Haghighatt, Yoshino, & Morofsky, 2011; Natephra, Yabuki, & Fukuda, 2018). The factors that influence the total building energy consumption can be summed up to seven factors. Climatic characteristics: concerned with the outdoor air temperature, solar radiation, wind velocity, air humidity, shading, and long wave radiation. The climatic characteristics affect the heat transfer within the walls and envelope of the building and thus affect the building energy balance (Moser & Koschenz, 2001). Building-related characteristics: concerned with the type, area, location, and orientation of building. User-related characteristics: user presence and occupancy of buildings excluding the social and economic factors (Ali, 2013). Building services system and operation: that includes space cooling and heating, and the hot water supply. Social and economic factors that are concerned with the educational level of the users. Finally, building occupants' behavior and activities, and the indoor environmental quality (Yu, Fung, Haghighatt, Yoshino, & Morofsky, 2011; Natephra, Yabuki, & Fukuda, 2018).

In the early design stages, understanding the solar radiation, wind speed, orientation, and other climatic data obtained from the context, assisted to choose the most appropriate energy saving strategy to be implemented in the design phase. The design stage also provided opportunities for designers to integrate design alternative strategies that best achieved energy efficient buildings. The structures, building materials, and building envelope are explored at the early stage (Jalaei & Jrade, 2014; Mourshed, Kelliher, & Keane, 2000).

By implementing energy efficient strategies, usage of the HVAC systems could be reduced, especially that cooling and heating systems are considered major energy consumers in residential buildings. In response to this issue, there was growing consensus in the building and design communities about reducing energy demand by quantifying the performance of building's components at the design stage (Natephra, Yabuki, & Fukuda, 2018).

Achieving energy efficient strategies in buildings also relied on how the occupants behaved and interacted in the building. (Owens & Driffill, 2008) Occupants' behavior activities indoors had a major influence on the energy consumed inside a building (Hong, Yan , D'Oca, & Chen, 2017). The cooling system is directly affected by the residents' occupation and density inside a building. As the density of occupants inside the building increases, the usage for the cooling and heating system increases (Yuan, Ruan, Yang, Feng, & Li, 2016).

However, although several factors have direct contribution on energy consumption in buildings, the building envelope still determined a large part of HVAC usage in buildings (42%) (Natephra, Yabuki, & Fukuda, 2018; Guerra, Itard, & Visscher, 2009). For this reason, the thesis will focus on energy consumed in buildings in the form of building envelope and its components.

2.4 Building Envelope

The building envelope is the enclosure system of the building that separates the interior of the building from the exterior. It acts as a closure; both aesthetic, structural, and environmental, and indicates distribution of functions from the facade (Grosso & Basso, 2010). The building envelope is a system that affects the energy efficiency of buildings (Egwunatum, Joseph-Akwara, & Akaigwe, 2016). The thermal properties of the building envelope's material have a direct impact on the amount of operational energy required by the buildings for cooling and heating systems (Noori & Hwaish, 2015; Sadineni, Madala, & Boehm, 2011; Chan & Chow, 2014).

Building envelopes and facades are mainly static, although the climatic characteristics have variable parameters. The building envelope acts as a thermal barrier through which the thermal energy is transferred. By minimizing the heat transfer through the building envelope, the need of energy used for heating and cooling can be reduced considerably. The envelope affects the thermal performance of the interior spaces and yet controls the demand of the habitants hereby act as an environmental moderator (Sadineni, Madala, & Boehm, 2011; Wang, Beltran, & Kim, 2012).

The thermal barrier acts as a boundary for heat flow. The air barrier acts as a protective and air-resistant material that controls air leakage through the building envelope. To maintain comfortable indoor conditions, the building envelope must provide a good thermal barrier and prevent heat losses and gains (Kruger & Seville, 2012). For this reason, if the heat transfer from the building envelope to the interior spaces is increased, the amount of energy used in order to achieve and compensate the internal comfort is increased, noting that 60% of the total energy consumed in a building is for space heating and cooling (H, Ghaffarianhoseini, Raahemifar, & Tookey, 2016; Oral & Yilmaz, 2003).

In order to achieve indoor comfort, the thermal performance of the building should be quantified. The choice of the building envelope's material reduces cooling and heating loads due to the indoor thermal comfort regulations with respect to the climatic conditions (Noori & Hwaish, 2015). Hence, by designing the building envelope parameters with respect to the orientation, shape, walls, fenestrations, shading device, roof, and the climate of the context, the HVAC load can be reduced in the buildings. This leads to the decrease in the energy consumed for heating and cooling (Oral & Yilmaz, 2003).

The main components of the building envelope that has major effect on the energy consumption are mainly the components with the bigger area and contact with the environment. Walls, roofs, and glazing are materials that affect the building operational energy performance and demand. The effect of the envelope component in the cooling demand depends on the thermal transmittance and conductivity of the materials used. Thermal transmittance (U-value) is the rate of heat transfer through the material. The lower the U-value, the higher the insulation. The higher the U-value, the higher the thermal and heat transmittance (Chowdhury, 2019). Thermal conductivity is the measure of the ability of the material to conduct heat. The higher the thermal conductivity, the higher the efficiency to conduct heat (steel), and vice versa (such as Styrofoam) (Asdrubali, D'Alessandro, & Schiavoni, 2015; Trgala, 2019). When the material has high U-value and low conductivity, energy consumed is controlled and decreased (Asdrubali & Baldinelli, 2011; Vollaro, et al., 2015).

Walls have the largest surface of the façade; they represent the largest environment direct interaction. The thermal transmittance and thermal conductivity of the wall has a major effect on the cooling demand (Visser & Yeretzian, 2013; Luo, 2019). For example, lightning the wall color creates a reflection for the heat, and rough wall surface reduces heat absorption thus reducing the cooling load (Visser & Yeretzian, 2013; Lin, Zhou, Yang, & Chun-Qing, 2018).

The roof of the building has the highest direct solar radiation on a surface. Therefore, the roof has high impact on the cooling demand. The lower the insulation of the roof surface material, the higher solar absorption and heat transfer, the higher the cooling demand. Lightning the roof color can create a time lag by delaying the solar absorption and heat transfer for up-to 2 hours (Visser & Yeretzian, 2013; Alhuwayil, 2019).

Scholars proposed several strategies to minimize heat gain through the envelope. Such strategies include enhancing the design of the building in terms of placement, position, and orientation of material (Noori & Hwaish, 2015; Sadineni, Madala, & Boehm, 2011). Choosing appropriate building materials that are suitable to the climate of the context is another strategy (Haase & Amato , 2006; Al-Hosany & Khalifah, 2002; Azmy & Elghamry, 2018). Moreover, considering shading devices on the glazing, enhancing the surrounding microclimate, and finally selecting an optimum building orientation and area of windows can achieve efficient energy reduction. Combining the appropriate choice of materials of envelops, is one strategy that can lower the thermal impact, minimize solar heat transmission, and help architects achieve high-energy efficiency in buildings (Noori & Hwaish, 2015; Sadineni, Madala, & Boehm, 2011).

Research indicated that the main component of the envelope that has an effect on the energy demand is the glazing: its orientation, area, type, ratio, and characteristics (Hilliaho, Köliö, Pakkala, Lahdensivu, & Vinha, 2016). Glazed envelopes account for about 36% of the cooling loads and are considered the most important functional elements. Glazed envelops have direct impact on the thermal performance of the building, thus the amount of energy consumed within the envelope (Haase & Amato , 2006; Al-Hosany & Khalifah, 2002; Azmy & Elghamry, 2018). Having glazing accounted for major energy demand contributor; the thesis will focus on this component.

Glazing facades in residential buildings in Lebanon is found in the form of glazed balconies, rather than curtain walls. Thus, the thesis will focus on the glazing component in the glazed balconies phenomena, in order to address an existing typology.

2.4.1 Glazing

This section elaborate on previous studies done on glazing with respect to energy consumption and efficiency. The studies underwent several variables that affect energy efficiency such as, the glazing type and thickness, window-to-wall ratio, orientation of glazing, and shading on glazing. Several terms were defined and introduced in order to further focus on the aim of the thesis. Thermal transmittance and emissivity were defined to allow correct evaluation of glazing type. The literature will shed light on most efficient glazing types and variables that affect energy consumption in order to focus upon in the simulations of the designed models.

2.4.1.1 Glazing; Thickness and Type

Glazing is the most brittle material in the building envelope that has direct relation with the outdoor environment. It is a weak component, regarding energy performance, due to its direct solar gain through transparency (Alwetaishi M. , 2019). Consequently, glazing is of prime importance for affecting the indoor thermal comfort and controlling energy demand in buildings (Alwetaishi M. , 2019). Architects and engineers should be aware of its consequences on the indoor comfort and energy performance, especially in hot climatic regions (Kim, Yoon, & Lee, 2017).

Glazing is responsible for heat losses and gains. Thus, glazing has major influence on the energy consumed through thermal transmittance (U-value) and emissivity (Roberto, Mazuroski, Abadie, & Mendes, 2011; Tsikaloudaki, Laskos, & Theodosiou, 2012). Thermal transmittance is the rate of transfer of heat through matter. Emissivity is the measure of effectiveness in emitting energy as thermal radiation (Escudier & Atkins, 2019).

Thermal transmittance along with emissivity are two main factors that have direct impact on solar radiation transfer.

The thermal characteristics of glazing have an impact on the energy consumed and are directly affected by the glazing type used; single glazing, double glazing, or low-e glazing. The lower the thermal transmittance, the lower heat gains, and the lower energy consumed on cooling. Accordingly, low-e (low emissivity) glazing has the lowest U-value amongst double and single glazing (Yang & Chow, 2018; Almarzouq, 2019).

However, very low thermal transmittance reduces the daylight accessibility and thus increases the use of artificial lighting (very low emissivity) (Yang & Chow, 2018; Almarzouq, 2019).

When considering the thermal transmittance of glazing types, it is crucial to focus on the thickness of the glazing used and its effect on the thermal transmittance, heat loss and gain (Tavares, Perdigao, & Bastos, 2017; Li & Malcom, 2010). The glazing thickness can vary from 3mm to 12mm (Tavares, Perdigao, & Bastos, 2017; Li & Malcom, 2010).

	Glazing type	SF [%]	U [W/ m^2.C°]	τ [%]	Thickness [mm]
Type 1	Simple glazing	0.83	5.8	0.87	4
Type 2	Double glazing classic	0.75	3.3	0.81	4(6)4
Type 3	Double solar control glazing Air	0.47	2.8	0.41	6 (12) 6
Type 4	Double solar control glazing Air	0.12	2.3	0.07	6 (12) 6
Type 5	Double glazing (Reinforced Thermal Insulation) and solar control Air	0.08	1.4	0.07	6 (16) 6
Type 6	Double glazing (Reinforced Thermal Insulation) and solar control Argon 85 %	0.37	1.2	0.40	6 (16) 6
Type 7	Double glazing (Reinforced Thermal Insulation) and solar control Argon 85 %	0.08	1.2	0.07	6 (16) 6
Type 8	Double glazing (Reinforced Thermal Insulation) and solar control Argon 85 %	0.17	1.1	0.18	6 (16) 6
Type 9	Double glazing (Reinforced Thermal Insulation) and solar control Argon 85 %	0.08	1.1	0.07	6 (16) 6

Figure 2.4.1. Effects of the thickness of glazing. Source: (Mebarki, Djakab, Karim El Hassar, & El Amine Slimani, 2018)

Figure 2.4.1 indicates the effect of the glazing thickness on the insulation and thermal transmittance (U-value). According to Figure 2.4.1, the thicker the glazing, the more the insulation from solar radiation can be obtained. The less the solar radiation in the interior space, the more the stabilization of the indoor temperature. The thickness also helps maintain indoor stability in cold climates and reduces heat losses (Ozel, 2019; Alhuwayil, 2019).

Determining the thickness of the glazing depends on the sizing and area of the opening (Figure2.4.2). As the area of the glazing and height of building increases, the thickness of the glazing should increase. Comprehensively, as the thickness of the glazing increases, the price and its weight also increase (Almarzouq, 2019; Djamila, 2017; Perina, Sevcikova, Redek, & Marcela, 2016).

Window area (sq.m.)		0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0
Window thickness (mm)	Up to 6 floors	3.0	3.0	4.0	4.0	5.0	5.0	5.5	5.5	6.5	6.5
	More than 6 floors	3.0	4.0	4.0	4.0	6.5	7.0	7.0	8.0	8.0	8.0

Figure2.4.2.Thickness of glazing in relation with sizing and area, Source: [1]

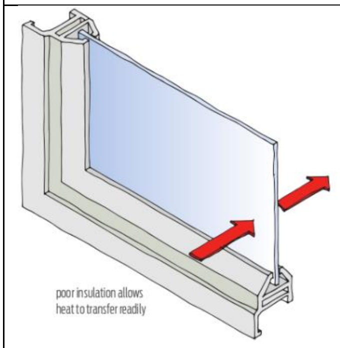
Another factor that affects the energy consumption and performance of the glazing is the glazing type. Each glazing type has a different thermal transmittance and emissivity coefficients that transfers solar radiation. The solar radiation transferred coefficient is different in single pane, double, or a selective coating in induced glazing (Msnuela, Anna, Salvatore, & Antonio, 2016).

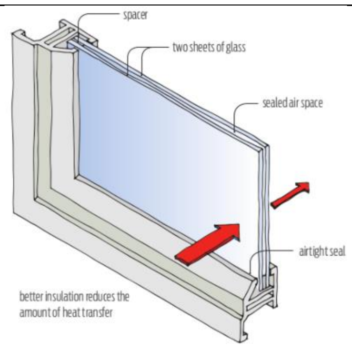
Amongst glazing types, single glazing has the highest transmittance coefficient which leads to high heat exchange, especially in hot climates (Zhou, Hu, & Du, 2013; Zdenek, Sevcikova, fabian, Halirova, & Rykalova, 2016). Yet, single glazing is inefficient in reducing heat exchange that occurs across the glazing system. A study was undertaken in the hot climate of KSA (Kingdom of Saudi Arabia) examined the effect of a 6mm glazing in several institutional buildings (Alwetaishi M. , 2019; Cinzia, Linda, & Elisa, 2012). Simulations underwent, and the findings revealed excessive heat gain and high thermal conductivity coefficient. The excessive heat gain resulted in high energy consumed on cooling (Nicola & Inger, 2016; Tavares, Gaspar, Martins, & Frontini, 2014).

Installing double layered glass (double-glazing) can ensure higher insulation than the single clear glazing (Table 2.4.1). The distance between the glasses reduced heat transfer since it has low thermal conductivity (Nicola & Inger, 2016; Tavares, Gaspar, Martins, & Frontini, 2014).

[1] https://alcon.co.il/all-about-glass/

Several studies for energy efficient glazing has been carried out. The findings concluded that most of the glazing involving low-e (low emissivity) are considered the most efficient and can achieve up to 20% of total energy reduction (Alwetaishi M. , 2019; Ozel, 2019; ISO & FDIS, 2003). Adding coating to the glazing blocks deviates radiation that causes heat gain and allows high visibility (Roberto, Mazuroski, Abadie, & Mendes, 2011). A very common efficient coating is the spectrally selective coating, which has been developed in many studies. The coating was proved to reduce heat energy exchange by 55% compared to double glazing (Table 2.4.1) (Kim, Yoon, & Lee, 2017). However, the cost also differs in each glazing type, having the spectrally selective coating significantly increase the initial cost (Roberto, Mazuroski, Abadie, & Mendes, 2011). Triple glazing is an efficient glazing type that ensured energy consumption reduction, but the implementation required extreme climate conditions due to its increased initial cost (Msnuela, Anna, Salvatore, & Antonio, 2016).

<table>
<tr><th>Single Glazing</th><th>Double Glazing</th><th>Spectrally Selective Coating</th></tr>
<tr>
<td>


High transmittance
Excessive heat gain
High thermal conductivity coefficient
High solar penetration (Alwetaishi, 2019)
</td>
<td>


Ensure higher insulation
Lower Transmittance
Less cooling demand and heat exchange
</td>
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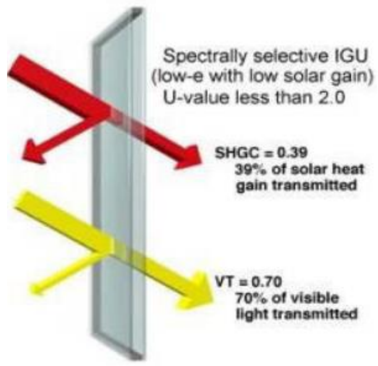

Blocks infrared radiation that causes heat gain
Reduces heat energy exchange by 55% compared to double-glazing. (Kim, Yoon, & Lee, 2017; Alwetaishi, 2019)
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</table>

Table 2.4.1.Table indicating several types of glazing and their properties

Scholars examined the influence of glazing in relation to energy saving in several residential buildings through simulations. It was found that the application of low emissivity (low-E) glazing would lead to a reduction in cooling electricity usage by up to 4.2%, and double clear glazing by up to 3.7% (Almarzouq, 2019; Yang & Chow, 2018; Ozel, 2019). The achievable saving would depend on orientation and climate (Islam & Alam, 2017; Manzan & Padovan, 2015).

The glazing type does not only affect the energy consumed for cooling, but also impacts the penetration of natural light in the building. Scholars agree that single clear glass allowed high solar penetration, but also high levels of heat gain (Ozel, 2019). This means that energy consumed in artificial lighting is decreased, whereas energy consumed in cooling is increased. In contrast, tinted glass plates allow less sunlight penetration and decreased cooling usage (Zdenek, Sevcikova, fabian, Halirova, & Rykalova, 2016; Yang & Chow, 2018). Meanwhile, the reflective glass plates that acts as a mirror has minimum visibility and natural sunlight penetration, but less heat gain.

In conclusion, each type of glazing performs differently according to the climate situated in. Glazing type installed in hot climatic zones performed differently than glazing installed in cold climatic zones. Using glazing that compensated between reducing artificial lighting and reducing direct solar radiation could cause a reduction in the annual cooling by 16% (Alwetaishi M. , 2019). Moreover, the glazing decision must consider the context and climate placed in, in order to choose the most suitable type, and to focus on the window-to-wall ratio and orientation of the openings in the building design.

2.4.1.2 Window to Wall Ratio and Orientation of Glazing

Window-to-wall ratio and the orientation of the glazing, in respect to where they are placed, are main factors to be considered before installing glazing. The energy efficiency of glazing is different in different orientations, and the energy performance of glazing is different in different window-to-wall ratios. According to the context and climate, glazing is responsible for up to 25% of heat loss and excessive heat gain depending on the sizing of the glazing, orientation, and window to-wall ratio (Alwetaishi M. , 2019).

Window-to-wall ratio is the value that corresponds to the window area and that of the wall area (façade). As the window-to-wall area increases, the natural lighting increases in the room; thus, artificial lighting decreases. However, the increase in the window-to-wall ratio affects the thermal comfort of the interior spaces and energy consumption. As the window-to-wall ratio increases, the total energy consumption increases and vice versa, especially in the eastern and western orientation. The northern façade is mostly affected by the window ratio unlike the southern façade where window-to-wall ratio has the least influence (Tavares, Perdigao, & Bastos, 2017; Kim, Yoon, & Lee, 2017; Tavares, Gaspar, Martins, & Frontini, 2014).

According to several studies, the minimum efficient window-to-wall ratio that results in minimum energy demand ranges between 30 and 45%. Other studies suggested that having 15% window-to-wall ratio resulted in best energy demand (Hassouneh, Alshboul, & Al-Salamyeh, 2010; Zhou, Hu, & Du, 2013; Yu, Fung, Haghighat, Yoshino, & Morofsky, 2011; Yang, et al., 2015). However, window-to-wall ratios perform differently in different climates. The minimum window-to-wall ratio is not efficient in cold climates since high solar penetration is needed in order to heat the area. The larger the window area, the larger the cooling demand, and the lower the heating demand in cold climates. In hot climates, glazing on the eastern and western facades can perform efficiently with a sizing of 25% to reduce excessive heat gain. In cold climates, on the other hand, south facades can maximize heat gain and thus reduce heating demand (Hassouneh, Alshboul, & Al-Salamyeh, 2010; Zhou, Hu, & Du, 2013; Yu, Fung, Haghighat, Yoshino, & Morofsky, 2011; Yang, et al., 2015).

Window-to-wall ratio is directly affected by the orientation of the installation and the climate of the building. In cold climates, installing large glazing façades can reduce heating demand, while in hot climates; large facades can cause excessive heat gain and thus high cooling demand. The choice of ratio and orientation should be linked to the climate and context of the building in order to design the most efficient glazing placement. Studies recommend considering the placement of glazing and sizing in order to prevent high-energy bills (Zhou, Hu, & Du, 2013; Yu, Fung, Haghighat, Yoshino, & Morofsky, 2011; Yang, et al., 2015).

In order to control and minimize heat transfer through glazing, the window-to-wall ratio of the envelope must not exceed 18% (Xu, Feng, Chi, Liu, & Duo, 2018). In the southern façade, window-to-wall ratio should not exceed 10%. On the northern façade -which has the lowest radiations of all the facades- enlarging the glazing ratio does not affect the heat transfer. Whereas, glazing should preferably be reduced on the western, eastern, and southern façades (Visser & Yeretzian, 2013; Iwaro & Mwasha, 2010).

2.4.1.3 Shading and Glazing

Shading the glazing in all its means and technologies proved to reduce efficiently direct solar radiation. Shading the openings has an important role in affecting the energy efficiency of the interior spaces. Shading, whether movable or static, has been proved to decrease the total energy consumption of the residential units (Islam & Alam, 2017).

The shades influence the energy consumption by decreasing the solar radiation on the glazing transmitted to the interior spaces. Installing shading devices on windows can reduce temperature by 1.5 degrees and energy consumption by 8% from the base model (Tkaczyk, Mauring, & Kull, 2015). However, the effectiveness of the shading differs from one orientation to another and from different climatic regions (Samanta, Saha, Biswas, & Dutta, 2014). Scholars agreed that the reduction in energy consumption by using shading, especially regarding cooling in all orientations, is similar to the reduction in energy when applying high cost optimized glazing. The decrease in space cooling upon the addition of shading can reach up-to 7% (Samanta, Saha, Biswas, & Dutta, 2014; Manzan & Padovan, 2015; Islam & Alam, 2017).

Similar to other factors that affect glazing, orientation and climate are main factors that affect the placement of the shading and the energy bill. In hot climate, the installation of glazing has a high effect on the cooling demand by decreasing the direct solar radiation, unlike in cold climates.

2.4.1.4 Conclusion

In conclusion, several factors should be considered when choosing the glazing type to be inserted in the facades depending on the sizing of glazing, orientation overlooking, context placed in, and most importantly climate of the area. In climates similar to the climate of Lebanon, where energy is mainly consumed on cooling, emissivity and transmittance should be considered in order to control the heat exchange between the environments. Therefore, a minimum thickness can cause high heat exchange, and a single glazing can cause high cooling demand. The glazing type preference should be suitable to the climate. Architects should also be aware of the different performances of the glazing placements, sizing, and orientation. In existing buildings, the placement of shading devices along with replacing the glazing type can efficiently decrease the energy consumption.

2.4.2 Balconies

Balconies are important architectural features that are part of the building envelope. They have several effects on the sociability and connectivity of the neighborhood, and on the indoor thermal quality (Ai Z. , Mak, Niu, & Li, 2011).

Since the 1920s, balconies played a major role in the housing design. This enabled people living in the upper floors to enjoy sunlight and air. It allowed apartments to being visually connected to, while physically separated from, the street and neighborhood (Lin J.-A. , 2015).

The Lebanese rules and regulations mandated that architects include a balcony in every apartment. A minimum of 20% the area of the floor should be occupied by balconies.

Not only do the balconies have a social and urban impact, but they also have an environmental impact on the indoor spaces. The balconies contribute in improving natural ventilation and air quality indoors. This contribution is due to the effect of the wind distribution on the envelope by directing the wind both indoor and outdoor, which maintains indoor thermal comfort by providing shading and thus decreases heat gain in the apartments (Ai Z. , Mak, Niu, & Li, 2011).

However, several countries are enclosing the balconies and changing the appearance of the buildings. In Taiwan, at the first glance, the balconies may be invisible as most have been glazed; it is as if balconies were unwanted by apartment owners (Omrani, Garcia-Hansen, Capra, & Drogemuller, 2017). This trend for low-cost architectural modification crosses economic class boundaries (Saleh, 2015). Although the act of enclosing balconies has a positive influence (e.g. active user participation), yet the negative influence urban aesthetics and climate control is major (Posht, Kohneh, Khosro, & Seyed Majid, 2017).

2.4.3 Glazed Balconies

Enclosing the balcony by glazing have several purposes and corresponds to several consequences. This act has a direct effect on the building’s envelope appearance, interior spaces, and thermal comfort. The trending phenomena of enclosing balconies are an international act that allowed its users to benefit from the interior spaces in all seasons. The trend allowed contractors and designers to design the houses accordingly. They considered the balcony as a continuation to the adjacent space or other livable spaces separating them by glass doors. Since the balcony space is glazed, it served as an extra room. For contractors, the space is considered a profitable area that can be promoted as a space for extension. For users, glazed balconies were considered additional spaces that could be transformed into useful interior spaces (Lin J.-A. , 2015; Grudzinska, 2016; Liu, 2006).

This low cost modification phenomenon can be observed in small apartments aiming to enlarge the space, or in luxurious apartments aiming to benefit from all spaces of the house (Perina, Sevcikova, Redek, & Marcela, 2016).

Glazed balconies help reduce transparency especially in dense urban cities. It can also help in reducing noise if the location was on a traffic road and maintain privacy. However, this act can also cause social isolation. Balconies were used to communicate with the outdoor and overlook the neighborhood. Upon enclosing this space, it resulted in having apartments that are introverted with no interaction with the neighborhood and streets (Lin J.-A. , 2015; Grudzinska, 2016; Liu, 2006).

Enclosing balconies change the building envelope's appearance and thus its performance. The thermal performance of the building is affected by its materials. If the materials change, the performance consequently changes. The addition of glazing on the balcony affected the thermal properties of the apartments by 5 degrees warmer than the outdoor temperature (Perina, Sevcikova, Redek, & Marcela, 2016; Hilliaho, Nordquist, Wallenten, Abdul Hamid, & Lahdensivu, 2016)**.**

Glazed balconies perform differently in different climatic zones. In cold climates, as the outdoor temperature decreases, the temperature inside the glazed balcony increases. This is because solar radiation heats the area**,** especially on the north and south façade. The northern and southern façade allow glazed balconies to function as a buffer zone that controls heat loss during the winter and protect from solar radiation in the summer season as shadings (Paek, 2014; Ghabra, Rodrigues, & Oldfield, 2017; Hilliaho, Köliö, Pakkala, Lahdensivu, & Vinha, 2016). However, this buffer zone can result in the increase of humidity by 60%, and the formation of molds in the structures of the glazed balconies (Zdenek, Sevcikova, fabian, Halirova, & Rykalova, 2016).

In hot climates and summer seasons, the glazed balconies are not recommended especially in the west façade where it causes the highest annual energy consumption (Azmy & Elghamry, 2018; Ge, McClung, & Zhang, 2013). This is because solar radiation warms up the glazed balcony very rapidly and causes greatest temperature difference between the space and the outdoor (Hilliaho, Köliö, Pakkala, Lahdensivu, & Vinha, 2016)**.**

Whereas a balcony serves as a passive cooling device, the greenhouse effect of an glazed balcony results in substantial heat gains and thus necessitates mechanical cooling in which energy consumption for cooling can reach up to 200% increase (Jergensen & Hendriksen, 2004; Tavares, Perdigao, & Bastos, 2017; Hilliaho, Nordquist, Wallenten, Abdul Hamid, & Lahdensivu, 2016). In the case of buffer zone creation, the wall separating the balcony from the interior is not removed whereby the balcony is a glazed interior space but is still separated from interior spaces (Perina, Sevcikova, Redek, & Marcela, 2016).

The glazed balcony phenomena are the focus of the thesis since it affects the energy bill, especially on cooling in the Lebanese context. There is a gap in the literature in the different performances of the glazed balconies in different scenarios when the wall separating the balcony from the adjacent space is removed. The thesis will focus on the thermal performance of both cases: when the wall is not removed and when the wall is removed, in order to examine the efficiency and energy consumption of both.

2.5 Conclusion

In this chapter, several studies were acknowledged regarding the thermal performance of glazed balconies and several variables affecting it. In the glazed balcony, the types of glazing used in a specific context affect the thermal performance of the building. In the Lebanese coastal zone, single glazing is not recommended since it has a very high thermal transmittance, and thus high cooling demand. Moreover, the thickness of the glazing should not be very thin to avoid overheating and direct solar penetration. Nevertheless, before considering the glazing type, the position of the glazing (orientation), sizing (wall-to-window ratio), and placement of shading should be considered in the early stages. In Lebanon, high window-to-wall ratio especially on the western façade causes excessive cooling demand and high-energy bills. However, the placement of shading can help decrease this demand in all orientations.

In conclusion, several measures would have to be considered in order to provide thermal comfort in the interior spaces and decrease energy consumed. The literature framed the methodology and scope of sampling. The chapters assisted in the choice of variables and scenarios to be implemented that has an impact on the glazed balconies and can be applied in the specified context. Gaps in the literature were elaborated in order to further focus upon in the specified context. It was noticed that the balcony typologies and their effect on the energy consumption were not studied in previous research (balcony structures; cantilevered, 2 wall structure, and 3 wall structure). The thesis will focus on this gap by addressing the objectives of the thesis through case study modeling.

3. The Coastal Region: Saida's Sea Front in South Lebanon

3.1 Introduction

This chapter will introduce the selected area of Study. Saida city will be explored in its geographic, economic, urban, and population fields, focusing on its sea front area, "Corniche El Baher". Upon setting the sample area, it is hereby essential to analyze its climate due to its influence on the performance of buildings within the selected zone. The climate of an area directly affects the energy consumed in buildings through the material used in the building envelope. Therefore, the building envelope's existing condition in the selected area will be reviewed to build further the model based on its thermal characteristics. Exploring the selected area and its buildings will help build an accurate model and obtain factual estimations.

3.2 Climatic Factors

Lebanon has four regions based on the temperature and climatic factors. The climatic factors are essential when considering energy efficiency since they have direct impact on the thermal comfort and energy consumed (UNDP.a, 2005; UNDP.b, 2005).

The four climatic zones in Lebanon are as follows: The first zone is the Coastal Zone, which has less than 1000-degree days (UNDP.a, 2005; UNDP.b, 2005). Zone 2 is the Mid-Mountain zone and it has up to 2000-degree days. Zone 3, which is the High-Mountain zone, has more than 2000 degree-days. Finally, zone 4 is the Inland zone that has up to 2000-degree days (Figure 3.2.1) (UNDP.a, 2005; UNDP.b, 2005; Sabsaby & Omar, 2015).

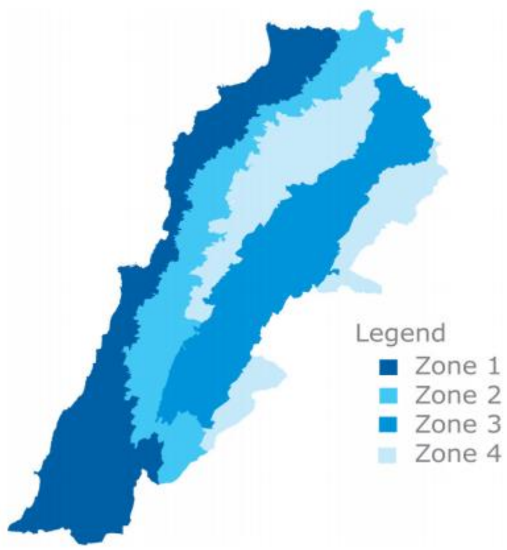


Figure 3.2.1. Climatic Zones of Lebanon, Source**:** (Harkous, Fardoun, & Biwole, 2017)

The Lebanese Coastal Zone is defined by having an altitude of 0-800m. According to the Council for Development and Reconstruction (CDR), the Lebanese coastal zone consists of Beirut, first ring, second ring, Jbeil, North, and the South. The first ring represents the area between Damour and Khaldeh, and the second ring represents the area between Jounieh, Bikfaya, and Broummana (DAR & IAURIF, 2005).

Beirut, first ring, and second ring consist of economic, cultural, and political centers of Lebanon. It is the coastal line where the commercial, financial, transport, industry, tourism, government administration, and headquarters of political authorities and diplomatic councils are based. Jbeil is known for its various activities, trades, historical, and touristic algorithm. On the other hand, agricultural and natural activities take place in the North and part of the South (from Saida to Nakkoura), allowing Saida in particular to consist of residential and economic coastal line. The coastal line of Saida consists of medium to low wage residential buildings ageing from the 70s. This typology is redundant in the Lebanese coast, and thus focusing on this area will allow the thesis to represent a greater percentage of existing buildings (DAR & IAURIF, 2005).

Saida, similar to the Lebanese sea fronts, is located in the Lebanese Coastal Zone. The coastal zone has a mean annual temperature that varies between 12.50 C° during winter and 26.8 C° during summer (Yeretzian, 2006; Shaban & Houhou, 2015). The variation of temperature between day and night is mild ranging between 6.80 C° (winter) and 8.20 C° (summer) (CDR, 2004). The coldest month of the year is January while the hottest month is August (Yeretzian, 2006; Shaban & Houhou, 2015).

The relative humidity along the Lebanese Coastal Zone is mainly constant and oscillates around 70 percent (CDR, 2004). Similar to the coastal cities of Lebanon, Saida city has a mild climate with rainy winters and hot - humid summers. In fact, by analyzing the temperature data for all the months in one year, it became evident that although the weather varies, it remains characterized by the existence of a short cold season and a relatively lengthy hot season (Yeretzian, 2006; Shaban & Houhou, 2015).

According to UNDP, the seafronts of Lebanon belong to the same climatic region (UNDP.a, 2005; UNDP.b, 2005). This allow Saida’s seafront to represent seafronts having similar building characteristics (UNDP.a, 2005; UNDP.b, 2005). The climatic factor is an essential factor to be considered when exploring thermal comfort and energy consumption. The climate of an area has direct impact on the building envelope, material used, and thermal transmittance, thus energy consumed within the building.

3.3 Geographic Location

Prominent cities such as Jbeil, Beirut, Tripoli and Tyre are located within the Lebanese coast. These cities are occupied by 75% of the total country's population. The coast represents a narrow strip that stretches for about 210 km (kilometer) along the Mediterranean Sea with a width of 0-210 m (meters) (Figure 3.3.1). Most of the industrial, commercial and financial activities in the country are centered along this coast (Shaban & Houhou, 2015; Lavallo, Darwich, Telesca, & Shaban, 2013; SDATL, 2005).

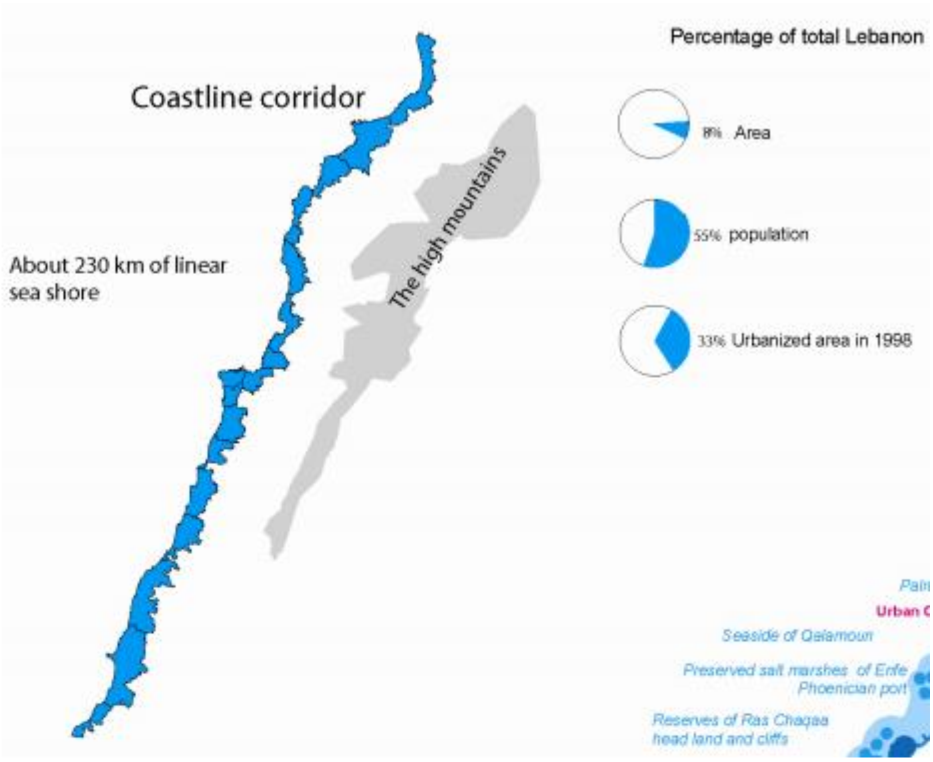


Figure 3.3.1. The Coastline of Lebanon, Source: (CDL, 2004)

The city of Saida is located 40 km to the south of the capital of Lebanon, Beirut. It is accessible to Beirut and South region by a highway connecting the regions together. Saida consists of three cadastral zones: the historical core, the Dekerman, and the Wastani (CDL, 2004). Due to the central location, and ease of connectivity to the neighboring regions of Saida, the city has grown rapidly in many terms: economic, demographic, and construction (Nahas & Yahya, 2001). Along the coastal zone of Saida, directly facing the Mediterranean Sea, "Corniche El Baher" represents the main road that connects the city with the south and north region. It also crosses the three cadastral zones.

The thesis will focus on "Corniche El Baher" area that is the sea front of the city. The area demonstrates an example for the country's sea fronts having the same climatic region and similar building characteristics and typologies. The sea fronts in Lebanon ha buildings overlooking the west orientation. These buildings have increased ratio of glazing to overlook the sea (Figure 3.3.2).

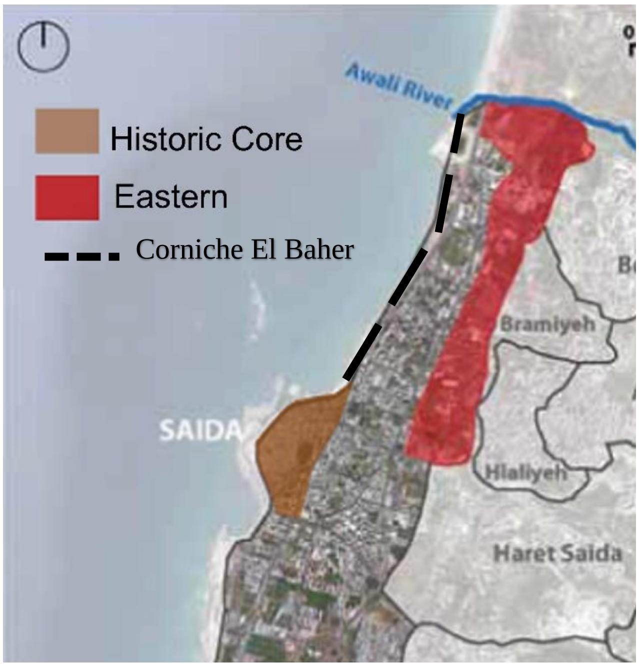


Figure 3.3.2. "Corniche El Baher" Area. Source: (Masri, 2018)

“Corniche El Baher” area consists of contemporary and old buildings having commercial services on the ground floors. Some buildings date back to 1970s. Figure 3.3.3, Figure 3.3.4, and Figure 3.3.5 represent some of the buildings observed that are located on the “Corniche El Baher” area during the observation. It is noted that glazing in these residential buildings along the sea front is intensely observed according to Figure 3.3.3, Figure 3.3.4, and Figure 3.3.5.

Figure 3.3.3. " Corniche El Baher" area. Source: Author

Figure 3.3.4. Glazed second and third floor in "Corniche El Baher" area. Source: Author

Figure 3.3.5. Glazed third floor in "Corniche El Baher" area. Source: Author

The empirical data collected in “Corniche El Baher” will allow identification of the existing glazed balconies in the area for further analysis and case study modeling.

3.4 Economic, Urban, and Population Growth

Saida has been currently witnessing several economic, urban, and population growths. Since the area is located on a main transit axis that connects the South region with Beirut, the city witnessed several demographic modifications. The economic growth that the area witnessed affected the urban and population density (Faour & Mhawej, Mapping Urban Transitions in the Greater Beirut Area Using, 2014).

Saida has been regarded as an economical center of the South region due to its developed commercial status by having several trades and businesses. Moreover, the historical and touristic sites located by the sea boosted the city's economy (SDATL, 2005).

The economic, touristic, and geographic location of the city affected the urban and population growth. The ease of accessibility to the South and the capital, and the affordable pricing of apartments, led to the increase in the construction industry. Since the 1980s, the residential building sector affected the loss of 50% of agricultural areas and led to the expansion of the city to the Awali River- north of the city. This expansion was due to the residential boom after the Israeli withdrawal in 2002 (SDATL, 2005; Asmar & Taki, 2014; Masri, 2018).

The urban growth was accompanied by population growth.

The coastal zone is occupied by 75% of the Lebanese total population distributed between Beirut, Tripoli, and Saida (Asmar & Taki, 2014). Saida is within the South and Nabatiyeh region where it is estimated to witness a population growth increase of 37.93% by 2030 (SDATL, 2005) (Figure 3.4.1). According to Figure 3.4.2, Saida is estimated to reach 100,611 population in 2040.

	Population in 1997	**Population in 2030**	**Growth %**
Beirut and Mount Lebanon	1,910,896	2,310,000	21.22
North and Akkar	807,204	1,140,000	41.18
South and Nabatiyeh	747,477	1,040,000	37.93
Beqaa and Baalbeck-Hermel	539,448	740,000	38.90
LEBANON	**4,005,025**	**5,230,000**	**30.79**

Figure 3.4.1. Estimated Population Growth. Source: (SDATL, 2005)`

Table 19. Population projections for the city of Saida

Year	1995	2000	2010	2020	2030	2040
Population	63,365	72,869	86,597	94,752	99,610	100,611

Figure 3.4.2. Estimated population growth for the city of Saida. Source: (CDR, 2004)

The economic, urban, and population growth are factors that affected the dynamicity of the "Corniche El Baher" area especially that it represents the sea front of the city.

These factors are also affected by the climate of the context. The climate of the coast allowed the city to be occupied and visited in all seasons thus allowing it to prosper.

3.5 Building Envelope's Condition in Saida

The city's climate -among Lebanese coastal cities- favors implementing energy efficient strategies to allow reduce energy consumed on cooling. However, the current condition of the residential building envelope in the city lack application of sustainable strategies and does not benefit from the favorable climate of the city. The building envelope's insulation- if found- is limited to the roof. In addition, the building envelope's tightness does not provide protection against external agents such as rain and wind. There is water migration inside the walls by capillarity, uncoated facades, and abundance of shading systems and glare protection. Moreover, windows are not properly oriented; their orientation is to the west to overlook the sea. They often lack airtightness and water tightness, hence infiltrations of outside air that causes thermal losses, air draughts, and entrance of external dust and noise. Finally, the building envelopes are often unfit to adapt with the local climate in terms of: orientation, standardized construction, and use of materials in spite of the Lebanese climatic zones (Chedid & Ghajar, 2004; Chedid, Chaaban, & Salameh, 2001; Mattar, Chehab, Chaaban, Ghaddar, & Chedid, 2001). This results in the use of HVAC equipment- split units are used in the residential units to provide cooling and heating to compensate the discomfort (Assaad, Habchi, Ghali, & Ghaddar, 2018).

Thermal characteristics of envelope component

Component	Description	U-Value (W/(m^2 K)
Roof	Reinforced concrete	2.96
Walls	Plaster–Hollow blocks-plaster	3.22
Windows	Aluminum frame single pane	5.41
Slabs	Reinforced Concrete	2.96

Figure 3.5.1. Thermal Characteristics of Building Envelopes in Lebanon, Source: (Tibi, Ghaddar, & Ghali, 2012)

Figure 3.5.1 represents the thermal characteristics often used in the buildings. According to Figure 3.5.1, the thermal value of the materials of the building envelope allow high thermal transmittance, thus the building envelope and glazing type used does not provide thermal comfort. Based on the energy simulation studies, the cooling load is higher than the heating load in Lebanon (Samarji, Jouni, & Karaki, 2012).

In addition, the construction of small, affordable apartments and the leisure to overlook the sea on the west orientation, lead contractors to use balconies as interior spaces and glaze them, unaware of the effect of glazed balconies and glazing on the comfort of the spaces. This is also related to the building rules and regulations and percentage fo exploitation of the building.The mentioned factors affect the indoor comfort of the occupants and thermal comfort in relation to the context of Saida.

The building envelope is the major factor that affects the energy usage in buildings- having the direct impact on the environment. The thermal characteristics of the materials chosen should be considered to avoid high-energy bills and thermal discomfort inside the spaces.

3.6 Conclusion

The data collected in “Corniche El Baher” area will help continue the empirical work. The characteristics of the study area will be noted and inserted in the modeled case study. Upon in-depth study on the focus area, the data collected will allow accuracy in results in the case study in the following implemented methodology. The gathered data will allow accurate assessment on the glazed and adjacent spaces in the seafront case.

4. Methodology

4.1 Introduction

This chapter acknowledges the methodologies used in previous studies to frame the methodology of the thesis and build upon it. The following sections will explore several methods used by researchers implemented on similar subjects to further inspire and decide on methods to implement in the thesis. The choice will be in accordance to several limitations, such as time, season, and other factors to be discussed.

The sections will help indicate the strengths and weakness of each method used for the detection and identification of a phenomena and trend (glazed balconies and balcony typologies) in a specified area by using site observational methodology. Moreover, building modeling and energy simulation method will be presented for estimating the energy consumed in the glazed balconies. The introduced methods will target the aim of the thesis and shed light on the limitations and accuracy of the methods used in previous studies in order to allow data collection.

4.2 Site Observation and Note Taking

This section presents the site observation and note taking method by acknowledging previous studies that implemented this method. The method will allow identifying and detecting the balcony typologies existing in “Corniche El Baher” area.

Detection methods for a building characteristic or a site differ from one case to another depending on the focus of the selected and addressed subject. Site selection for locating and positioning a specific project, requires the use of specific tools, such as the Geographic Information System (GIS). The GIS is a tool that allows landscape modelling and three-dimensional analysis of sites in order to choose the suitable one (Hemandez, 2014; Aydin, 2013). However, the selection of a site in an identified area to detect a specific building characteristics requires a different tool. Observational methodology and note taking is a method that researchers implement when detecting and identifying phenomena in a specified area (Nicholls, Quach, Von Elm, Asgtrid, & David, 2015).

Observational methodology is a scientific data collection method of qualitative nature (depending on the focus of observation). It is considered one of the most fundamental methods whether an observation of physical static movement, or a social and behavioral phenomenon (Ponterotto, 2006). The method can be used in several aspects: participant observation, fieldwork, field research, and ethnography (Gibbs, Kealy, Willis, & Green, 2007). The method requires the qualitative observer to use all his senses to evaluate and record the observations noted. It is a simple and common method for data collection, that does not require technical knowledge (Marshall, Cardon, Poddar, & R, 2013).

The site observation and note taking methodology is useful for framing hypothesis by observing a phenomenon or act continuously. It is considered an accurate method, since the participant can immediately observe the accuracy of detection rather than in other methods that requires analyzing the data such as interviews or questionnaires (Jamshed, 2014).

However, this method has several limitations to be considered. If an observer is detecting a current occurrence, the occurrence may not be open to the observer neither can happen when the observer is at hand (Aagaard & Matthiesen, 2016). In the architecture field, researchers use this method in order to record and locate a specific phenomenon in buildings, site selection, or to analyze and record physical damage of a building (Lis & Sekret, 2016).

The observation and note taking method will be used to detect the balcony typologies found in “Corniche El baher” area to be further studied. The method will allow indicating the existence of balcony enclosure phenomena in “Corniche El Baher” area and identifying the different balcony typologies found. The phenomena to be observed is of physical and static phenomena, that does not require the occurrence of a certain act. Therefore, the balcony typologies to be observed does not depend on the reliability and conception of a specific understanding neither the observer can be bias in such case (Jain, et al., 2015; Urquhart, 2015). Accordingly, the limitations of this method do not affect the field observation to be done. Observing and identifying the existence of the phenomena and existing balcony structures, allows the data collection and case study modeling.

4.3 Building Modeling and Energy Simulation

Several tools and methods can be used to estimate the energy consumed in a building, where each has its limitations and concerns. Measuring the energy consumed can be obtained by using both manual recording and simulation software for calibration, or by using energy simulation software only.

Energy simulation software are reliable programs that allow to design, analyze, and estimate the energy consumed in models in a specified location, orientation, and climate (Fasi & Budaiwi, 2015). Several effective energy simulation software are currently used by researchers such as; Design Builder, DOE-2, Ecotect, Energy Plus, Green Building Studio, Insight 360, and many more, where the simulations recorded successful energy calculation assumptions (Fasi & Budaiwi, 2015; Azmy & Elghamry, 2018; Makitalo, Hilliaho, & Lahdensivu, 2015).

The Energy Plus and Green Building Studio are software used to estimate and quantify energy used for heating, cooling, and other HVAC electric usages in buildings. Scholars were able to prove the credibility and accuracy of the software due to its reliability of its results compared to ASHRAE 1052-RP Toolkit (Andelkovic, Mujan, & Dakic, 2016).

In order to simulate the model and develop energy results using the simulation software, several steps must be followed. First, the model must be designed in an architectural drawing aided software such as AutoCAD or Revit. Revit and AutoCAD are different software that have different compatibilities and capacities. Both software can acquire architectural drawings, but Revit can perform energy analysis through plugins. Since Green Building Studio, Insight 360, and Energy Plus are plug in software in Revit, the use of Revit for modeling will be compatible for further energy analysis. Moreover, Revit is an architectural drawing tool that is familiar to architects and designers in order to use energy plugins for energy simulations.

Several similar researches aiming to estimate energy consumed on cooling in a specific space used the mentioned energy software for calibration, but firstly the models where designed on Revit (Figure 4.3.1). Figure 4.3.1 is an example of a building designed on Revit in order to further simulate the building by using energy plugins of Revit (Azmy & Elghamry, 2018; Kim, Zadeh, Staub, Forese, & Cavka, 2016; Goia, 2016).

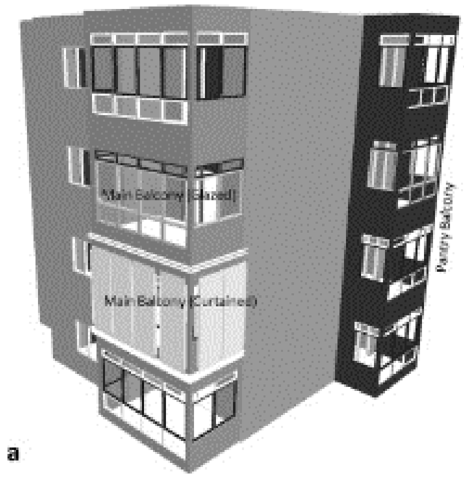


Figure 4.3.1.Case study designed on Revit to allow energy estimations. Source: (Saleh, 2015)

In order to get accurate results, the identification of the location must be inserted in the software used. Moreover, data has to be collected concerning the materials' used in the specified location in order to insert their properties and characteristics (Figure 4.3.2) such as: the thermal properties of glazing, plaster, hollow block, slabs, roofs, the existence of any insulating material, and window to wall ratio. Moreover, the glazing used in the area has to be specified, whether single, double, tinted, or low-e through data collection (Fasi & Budaiwi, 2015; Azmy & Elghamry, 2018; Makitalo, Hilliaho, & Lahdensivu, 2015).

Component	**Description**	***U*-Value (W/(m^2 K)**
Roof	Reinforced concrete	2.96
Walls	Plaster–Hollow blocks-plaster	3.22
Windows	Aluminum frame single pane	5.41
Slabs	Reinforced Concrete	2.96

Figure 4.3.2.Thermal Characteristic of Envelope Component, Source: (Tibi, Ghaddar, & Ghali, 2012)

After the insertion of all the material characteristics in the software, an estimate range of internal loads and appliances are counted in. Identifying the occupied hours in the building allows estimating the operation hours of the HVAC systems used (Figure 4.3.3). The occupied hours allow to identify whenever the spaces are heated or cooled in the specified season (Tibi, Ghaddar, & Ghali, 2012; Yassine B. , Ghali, Ghaddar, Srour, & Chehab, 2012).

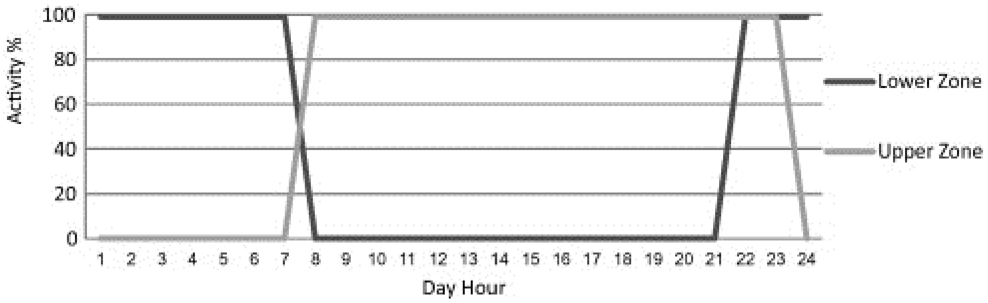


Figure 4.3.3. Mechanical System Operation, Source: (Tibi, Ghaddar, & Ghali, 2012)

Before starting the energy simulation, the weather station has to be identified along with the location for further accuracy of results (Figure 4.3.4).

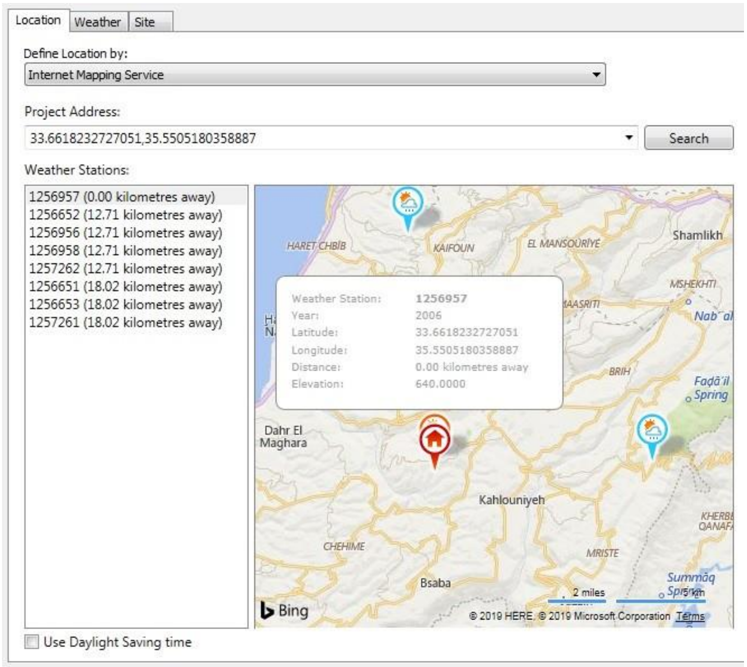


Figure 4.3.4. Weather Station and Location. Source: Author

Finally, the model can be generated and analyzed. The simulation of the base model can show recordings for annual energy consumed, whether for heating and cooling loads, or other specified HVAC system used (Figure 4.3.5). The recordings can be obtained by using Revit plugins; Energy Plus, Green Building Studio, and Insight 360 (Fasi & Budaiwi, 2015; Azmy & Elghamry, 2018; Makitalo, Hilliaho, & Lahdensivu, 2015).

Usage	Electric energy consumption breakdown	
	Reported in literature (%)	Base case model (%)
Appliances	22	17
Lights	6	4
Water Heating	22	19
HVAC System	50	60

Figure 4.3.5. Energy Consumption Comparative analysis result. Source: (Tibi, Ghaddar, & Ghali, 2012)

Whereas, using both methods for energy estimation: manual recordings, and simulation software, requires specifying an existing building in a specified area in which the data collection will undergo. The identified building must include all the variables and scenarios the researcher focuses on. Moreover, the climate and season must be specified, whether throughout the year, month, season, or day. Upon the chosen period, the space of focus is manually monitored. The temperature, humidity, wind velocity are recorded through several site visits. The recordings are then inserted in a simulation software to be calibrated in which results will be included (Figure 4.3.6) (Fasi & Budaiwi, 2015; Makitalo, Hilliaho, & Lahdensivu, 2015; Saleh, 2015).

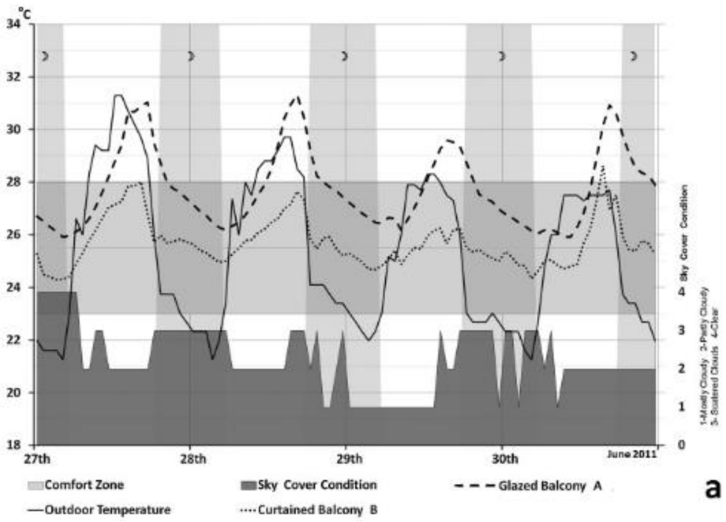


Figure 4.3.6.Results of Base Model Simulation, Source: (Saleh, 2015)

Both methods can be applied and give relatively similar results, but each method has a limitation. Using manual recording then energy simulation software can be time consuming and confined in a certain period, season, or climate. Since the thesis is concerned with the cooling load in the summer season –since most of the energy consumed in Lebanon is on cooling- therefore, I cannot manually record the findings in a specified building due to time limitation (Haase & Amato , 2006; Al-Hosany & Khalifah, 2002; Azmy & Elghamry, 2018). Moreover, the thesis will focus on several scenarios of balcony enclosure and balcony typologies where the scenarios will be compared and analyzed; this will make it difficult to specify an existing building that includes all the variables identified.

Using the building simulation software in the thesis will be an applicable and suitable tool for energy consumption estimation that allows the flexibility of identifying the season, location, and several scenarios to be simulated and analyzed.

4.4 Conclusion

The acknowledged methodologies inspired further thesis work and data collection and framed the methodology to be implemented. By following the site observation and note taking method, the detection of the balcony structures and balcony enclosure in “Corniche El Baher” area can be obtained. The observation method will allow developing models that include the different building characteristics observed. In addition, using the energy simulation software compatible with Revit will allow the energy estimation, and thus the objectives of the thesis can be answered and analyzed.

5. The Model

5.1 Introduction

This chapter presents the methodologies implemented to obtain the results required. The chapter introduces the procedure and preliminary outcome of each method used, emphasizing on the limitations that affected the research and field experience that influenced the work. The first section presents the site observation and note-taking method undertook in order to identify the balcony typologies found in “Corniche El Baher” area and allocate the existence of balcony enclosure which allows the development of different models. The second section thoroughly describes the steps, tools, and methods used to estimate the energy consumed in the developed models. The simulation presented in this chapter is a representative and repetitive model to all balcony typology models and scenarios. The detailed procedure done on each model and scenario studied will be referred to in the appendix to avoid repetition in the chapter.

5.2 Balcony Type Selection

Following the research done on glazed balconies and their effect on energy consumption, a gap in the literature is found. The balcony type and structure are not studied in accordance to thermal performance, therefore the performance of different balcony typologies cannot be indicated and thus has to be simulated. In order to simulate balcony typologies, the balcony structures found in the area must be identified. To identify the balcony types in “Corniche El Baher” area, site observation and note taking methodology shall be held.

There are three different balcony typologies to observe and identify in Saida; balcony surrounded by 1 wall (cantilevered), balcony surrounded by 2 walls, and balcony surrounded by 3 walls (loggia) having an average area of 10 m^2 (Figure 5.2.1, Figure 5.2.2, and Figure 5.2.3 respectively).

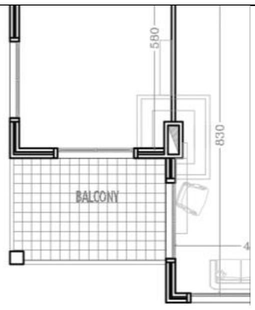


Figure 5.2.1. Presentation of balcony surrounded by 2 walls. Source: Author

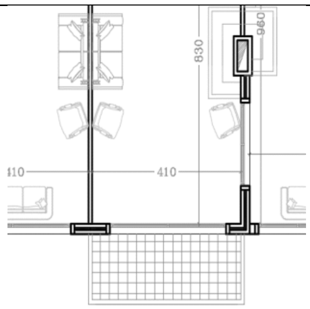


Figure 5.2.2. Presentation of balcony surrounded by 1 wall. Source: Author

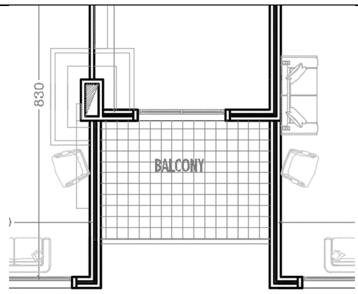


Figure 5.2.3. Presentation of balcony surrounded by 3 walls. Source: Author

The site observation method allows locating and identifying which of the balcony structures is found in “Corniche El Baher” area. The site observation starts from “Sidon Sea Castle” to “Saida Football Stadium”, disregarding the historical core from the observation according to the lack of the phenomenon in the historical buildings (Figure 5.2.4). Figure 5.2.4 highlights the track where the fieldwork takes place.

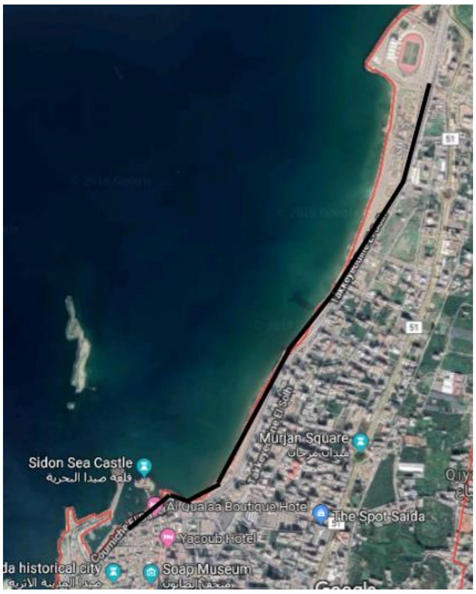


Figure 5.2.4. Observational path in “Corniche El Baher”. Source: Google map; November 5, 2020

The site observation occurred on Wednesday, October 30, 2019 at 12.30pm, for a duration of approximately 4 hours, by car and foot. Several stops and pictures are taken when balcony enclosure is observed.

During the site observation, the abundance of the glazed balconies phenomena is significantly observed in every building overlooking the west orientation in the area. The three different balcony typologies are observed along “Corniche El Baher” area (Figure 5.2.5, Figure 5.2.6, Figure 5.2.7, Figure 5.2.8, Figure 5.2.9, Figure 5.2.10, Figure 5.2.11, Figure 5.2.12, Figure 5.2.13, and Figure 5.2.14). The figures below are taken during the observation. Each figure indicates the detection of a different balcony typology: surrounded by 1 wall, 2 walls, and 3 walls, and glazed balcony phenomena in the area. Moreover, the figures indicate the chaos and inconsistency of the glazing trend in the same building: balconies are not glazed in all floors, rather by the choice of the user.

 Figure 5.2.5.Balcony observed surrounded by 1 wall, Source: Author	 Figure 5.2.6. Balconies observed surrounded by 1 wall and 2 walls, Source: Author
 Figure 5.2.7. Balconies observed surrounded by 1 wall and 3 walls , Source: Author	 Figure 5.2.8.Balcony observed surrounded by 1 wall, Source: Author
 Figure 5.2.9. Balcony observed surrounded by 2 walls, Source: Author	 Figure 5.2.10. Balconies observed surrounded by 3 walls and 2 walls, Source: Author

Figure 5.2.11.Balconies observed surrounded by 2 walls, Source: Author

Figure 5.2.12. Balconies observed surrounded by 2 walls, Source: Author

Figure 5.2.13. Balconies observed surrounded by 2 walls and 3 walls, Source: Author

Figure 5.2.14. Balconies observed surrounded by 2 walls and 3 walls, Source: Author

Following the observation and allocation of the three balcony types and existence of balcony enclosure in “Corniche El Baher” area, the case study can be developed and simulated including all three scenarios observed.

5.3 Model Simulation

In this section, the three models are designed, according to the data collected from the observation done on the balcony typologies found in “Corniche El Baher” area. In addition, the data collected on the building envelope and material characteristics are inserted in the simulation. The building modeling and energy simulation software used is presented to allow the extraction of accurate energy estimations. The three balcony types found in the area are described and summarized in a table where each model is referred to in the Appendix.

Each model presents a balcony type undergoes three scenarios; each scenario represents a variable in the glazed balcony: when the balcony is not glazed, when the balcony is glazed, and when the balcony is glazed and the wall separating the balcony from the adjacent space is removed. The detailed simulation description for each model and scenario is referred to in the appendix. Outcomes of the models and scenarios are presented in a table form in order to analyze the recorded data in the analysis chapter.

In “Corniche El Baher” area, the buildings have their main elevation orientated towards the west, overlooking the pleasant view of the sea and date back to the 70s. Accordingly, most of the buildings are horizontally placed along the seafront having a glazed western façade.

A similar building typology is modeled on Revit (2020). A typical plan is designed, having balconies and main façade overlooking the west orientation.

Revit 2020 is used to design three models- representing the three different balcony types- Energy Plus is an energy engine of Revit that is used to create energy models, and export heating and cooling reports for each space (room) of the model. Insight360 and Green Building Studio (GBS) are also Autodesk software and plugins on Revit, where the model designed on Revit is energy analyzed on both Insight 360 and GBS that will allow estimating the cooling loads per month on the total model.

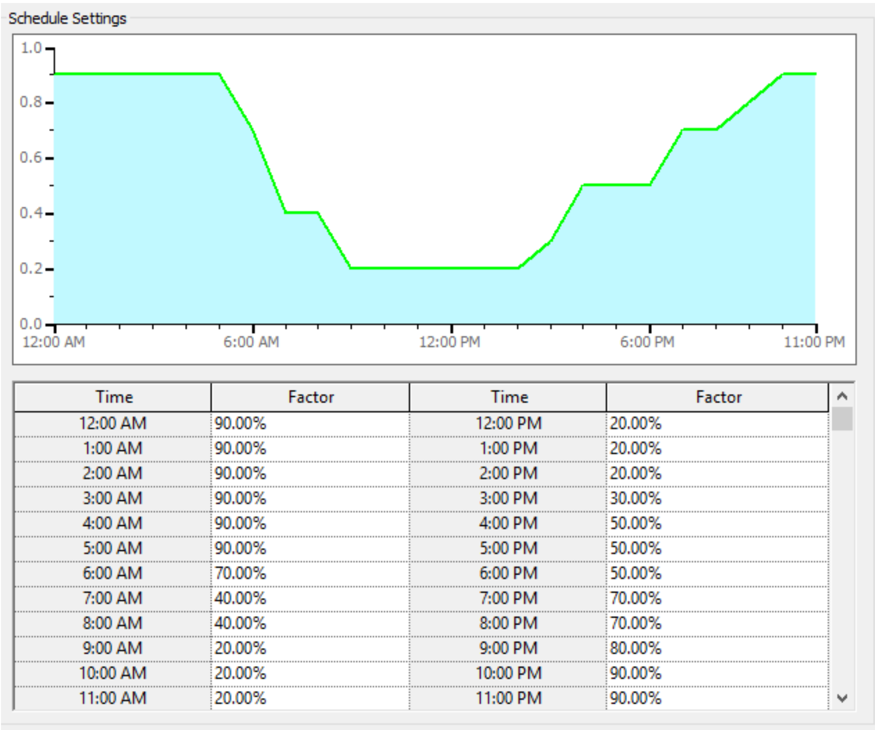
Several parameters are considered when designing the models that affect the energy consumed according to the literature review. The orientation is the first parameter. Since the focus of the thesis is the glazed balconies overlooking the west orientation, the typical plan have balconies overlooking the west. Nevertheless, since the placement of balconies might be in the corners of the building (depending on the balcony type) then, north-west and south-west orientations also have to be considered.

Moreover, the thermal properties of the materials inserted in the model are similar to the properties of materials used in the area (the properties that are usually used on the coast of Lebanon) (Figure 5.3.1): reinforced concrete roofs and slabs, walls consisting of plaster and hollow blocks, and aluminum single pane glazing (Azmy & Elghamry, 2018; Annan, Ghaddar, & Ghali, 2014; Assaad, Habchi, Ghali, & Ghaddar, 2018). All the materials mentioned have relatively high U-value (Figure 5.3.1) (Azmy & Elghamry, 2018; Annan, Ghaddar, & Ghali, 2014; Assaad, Habchi, Ghali, & Ghaddar, 2018).

Component	Description	U-Value (W/(m² K)
Roof	Reinforced concrete	2.96
Walls	Plaster–Hollow blocks-plaster	3.22
Windows	Aluminum frame single pane	5.41
Slabs	Reinforced Concrete	2.96

Figure 5.3.1. Thermal properties of materials used, Source: (Saleh, 2015)

The glazing type used in the buildings –and inserted in the model- is the single glazing (6mm single pane) that has a low cost and a very high U-value (U= 5.88 W/m^{2}k). Moreover, the occupation of the residential units is also identified to give further accuracy of the operable HVAC systems (Figure 5.3.2).



Time	Factor	Time	Factor
12:00 AM	90.00%	12:00 PM	20.00%
1:00 AM	90.00%	1:00 PM	20.00%
2:00 AM	90.00%	2:00 PM	20.00%
3:00 AM	90.00%	3:00 PM	30.00%
4:00 AM	90.00%	4:00 PM	50.00%
5:00 AM	90.00%	5:00 PM	50.00%
6:00 AM	70.00%	6:00 PM	50.00%
7:00 AM	40.00%	7:00 PM	70.00%
8:00 AM	40.00%	8:00 PM	70.00%
9:00 AM	20.00%	9:00 PM	80.00%
10:00 AM	20.00%	10:00 PM	90.00%
11:00 AM	20.00%	11:00 PM	90.00%

Figure 5.3.2. Home occupancy; Source: Author

The location is identified: “Corniche El Baher” area, and the weather station is chosen. According to Figure 5.3.3, when indicating the location (“Corniche El Baher” area), two weather stations are observed, one near Joun area, and one in Jiyeh area. However, knowing that Jiyeh is located along the coast similarly to Saida city and 17km to the North of Saida, therefore Jiyeh weather station was chosen. Joun is relatively higher in altitude than Saida, and therefore using the weather station will not give accurate results (Figure 5.3.3).

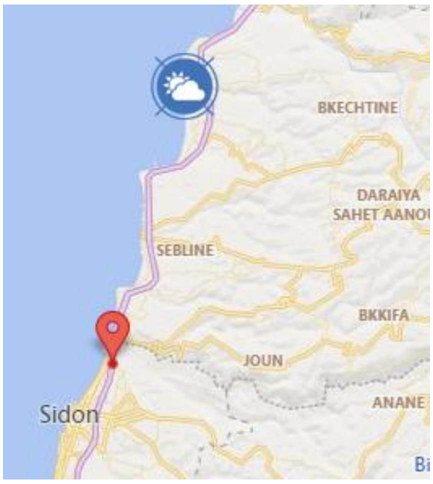


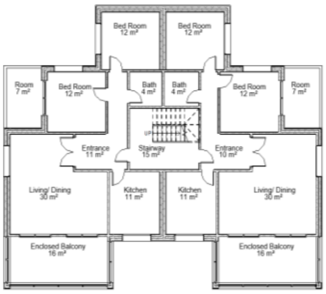
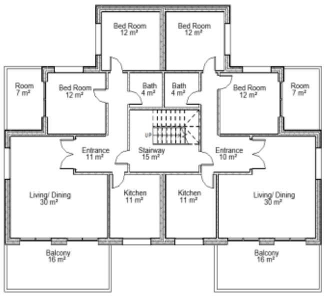
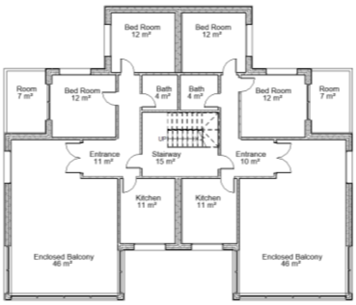
Figure 5.3.3. Location and weather station, Source: Insight360

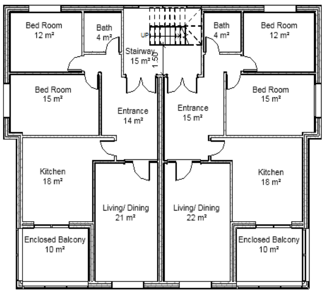
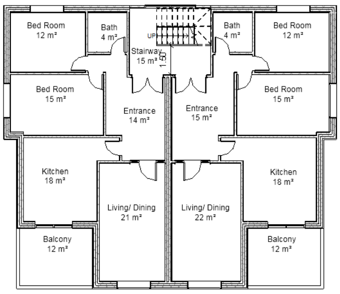
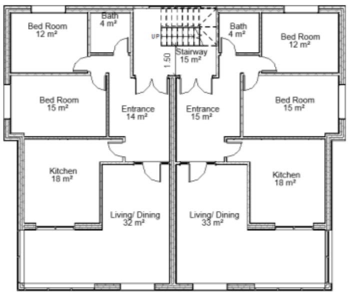
Moreover, to analyze the plan through the energy plugins mentioned, room tags are added, and spaces are identified. For accuracy of estimations, each space (room) of the plan is identified by specifying the building type and occupation of each (balcony, bathroom, bedroom, kitchen, etc…).

Following the completion of the modeling and insertion of all characteristics, the model is energy simulated. The energy model is created, generated, and optimized, in Revit, where the analysis is available in Insight 360 and GBS. The report for heating and cooling generated by Energy Plus plugin in Revit is exported, where the cooling demand for each space in the model is specified. By generating the energy model, energy analysis of the model is viewed and extracted by visiting Insight 360 website and GBS website. Insight 360 and GBS shows detailed energy analysis on the model and is easily extracted. GBS allows extracting cooling demand for each month of the year, as previously justified, the thesis will focus on the cooling demand in the summer months. The cooling demand is recorded for the balcony the space adjacent to the balcony, in order to record the impact of glazing on the balcony and adjacent spaces. The parameters will result in having 3 models with 3 scenarios each, which are analyzed and assessed. The outcomes are extracted from the energy software and inserted in Excel to create tables and charts for the ease of analyzing and presenting the data.

Table 5.3.1 presents the plan of each model and scenario designed, indicating the monthly cooling, and heating demand (KWh) in the glazed and adjacent spaces (living) in the summer months. These demands are allocated to the south-west orientation, since the south-west and north-west shows similar results having south-west slightly higher. The results of the north-west orientation of each model is found in the relevant appendix for each case. The following table summarizes the outcomes induced.

The table refers to the codes representing each model for further usage (symbol). Moreover, further details are found in the appendix referred to each model.

BALCONY STRUCTURE	NAME	PLAN		COOLING (Kwh)	HEATING (Kwh)	SYMBOL	APPENDICE
SURROUNDED BY 1 WALL - B1W	Glazed - 100		GLAZED	1819	949	**B1W-100**	Appendix B
			ADJACENT	2026	696		
	BALCONY-200		GLAZED			**B1W-200**	Appendix A
			ADJACENT	2070	701		
	Glazed Without Wall-300		GLAZED	1823	922	**B1W-300**	Appendix C
			ADJACENT	2006	683		

<table>
<tr><td rowspan="6">SURROUNDED BY 2 WALLS-B2W</td><td rowspan="2">Glazed - 100</td><td rowspan="2"></td><td>GLAZED</td><td>1340</td><td>755</td><td rowspan="2">B2W-100</td><td rowspan="2">Appendix C
Appendix</td></tr>
<tr><td>ADJACENT</td><td>1432</td><td>513</td></tr>
<tr><td rowspan="2">BALCONY-200</td><td rowspan="2"></td><td>GLAZED</td><td></td><td></td><td rowspan="2">B2W-200</td><td rowspan="2">Appendix D</td></tr>
<tr><td>ADJACENT</td><td>1429</td><td>519</td></tr>
<tr><td rowspan="2">Glazed Without Wall-300</td><td rowspan="2"></td><td>GLAZED</td><td>1469</td><td>760</td><td rowspan="2">B2W-300</td><td rowspan="2">Appendix I</td></tr>
<tr><td>ADJACENT</td><td>776</td><td>272</td></tr>
</table>

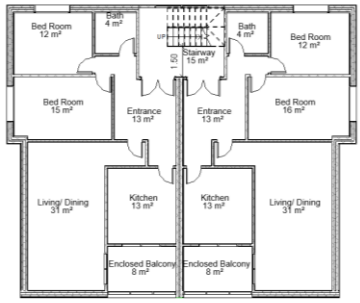
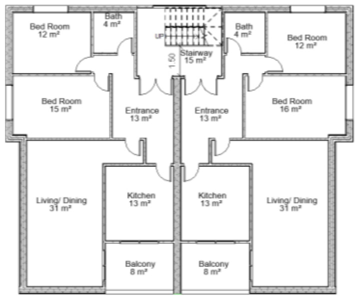
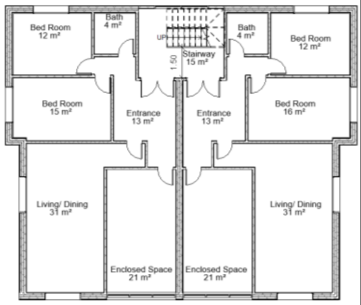
SURROUNDED BY 3 WALLS-B3W	Glazed - 100		GLAZED	1084	436	**B3W-100**	Appendix G
			ADJACENT	767	198		
	BALCONY-200		GLAZED			**B3W-200**	Appendix F
			ADJACENT	2065	857		
	Glazed Without Wall-300		GLAZED	895	356	**B3W-300**	Appendix C Appendix H
			ADJACENT	846	229		

Table 5.3.1. Heating and cooling demand for the glazed and adjacent spaces in the models per peak month, Source: Author

The outcomes mentioned in the table; monthly heating and cooling demand (KWh) in glazed balconies and adjacent spaces are further discussed in the following chapter.

In addition, GBS allows to modify certain parameters in the model and compare the cost and energy consumed between the base run (result of the model) and an alternative run (results of the model with modified parameters).According to the results obtained from Insight360 , parameters such as window-wall-ratio, orientation of glazing, glazing type, and shading (that shows influence on the energy consumed according to the literature) are modified in GBS inorder to simultaneously identify the impact of each on the energy consumed.

The performance of both: the base and alternative models are compared and adjusted to obtain an efficient performance. Table 5.3.2 indicates the models' annual cost and energy consumption (Kwh) for the scenarios 100 and 300: when the balcony is glazed, and when the balcony is glazed and interior wall is removed . The table indicates the annual energy consumption and cost when adjustments on glazing type, shading , orientation, and window-to- wall ratio are obtained. The parameters modified include reducing the window-to-wall ratio to 30%, rotating the building and balconies to the north orientation, replacing the 6mm single pane glazing with low-e double glazing, and placing shading on 2/3 of the windows. The results recorded in Table 5.3.2 are extracted from GBS to the scenarios when the balcony is glazed (100), and when the balcony is glazed in the interior wall is removed (300), disregarding the scenario of the unglazed balcony.

MODEL		BASE RUN		WWR		ORIENTATION		GLAZING		SHADING		APPENDICE
		COST	KWH	COST	KWH	COST	KWH	COST	KWH	COST	KWH	
B1W	100	$4,352	38293	$ 4,257	37857	$ 4,170	36777	$ 4,232	37774	$3,963	34726	Appendix B
	300	$4,451	40064	$ 4,335	39312	$ 4,319	38955	$ 4,336	39682	$4,044	36316	Appendix C
B2W	100	$4,321	42084	$ 4,772	46416	$ 4,096	40166	$ 4,165	41042	$3,978	38948	Appendix E
	300	$4,303	42716	$ 4,345	43270	$ 4,135	40949	$ 4,146	41683	$3,980	39659	Appendix I
B3W	100	$4,576	43564	$ 4,562	44073	$ 4,224	40616	$ 4,600	44242	$4,232	40412	Appendix G
	300	$4,461	43169	$ 4,405	42584	$ 4,209	40975	$ 4,329	42250	$4,126	39959	Appendix H

Table 5.3.2. Annual energy consumption and energy cost of the base run and alternative runs, Source: Author

The methodology presented is repeated similarly for all the models and scenarios simulated, where it is referred to in the appendix. The outcomes recorded allow assess the performance of glazed balconies and adjacent spaces. According to the previous studies, the methods implemented for the energy simulations ensures accurate estimations for the energy consumed, thus able to answer the aim of the thesis.

5.4 Conclusion

The methodologies implemented allows framing the case study in “Corniche El Baher” area. The observation done on the selected area, allows data collection on the focus area and identification of balcony types and balcony enclosures found. The energy modeling and simulation attains outcomes that are further inserted into Excel to create tables and charts for analysis. The results of the models assess the impact of the glazed balcony on the cooling demand in the space that is analyzed.

6. Analysis

6.1 Introduction

This chapter analyses the recorded data from the building modeling and energy simulations done on the observed types of balconies in “Corniche El Baher” area in Saida. The sample balconies simulated each have an average area of 10 m^2. In this chapter, the gathered data was divided according to the scenarios of the balcony types; balcony, glazed balcony, glazed balcony with wall removal. Each scenario will be analyzed in each balcony type, where the scenarios will be compared among each balcony type. The first section will describe, analyze, and compare the recorded data on the balcony scenario in the three different balcony types; surrounded by 1 wall, 2 walls, and 3 walls. The second section will further focus on the scenario when the balcony is glazed in each balcony type. The following section will analyze the scenario when the balcony is glazed and the wall separating the interior from the balcony is removed. Each scenario will undergo adjustments in several parameters to reduce the impact of glazing on the cooling demand. The scenarios of the different models will be further analyzed, discussed, and compared focusing on the energy usage and the effect of the glazed balcony on the adjacent space and glazed space. Noting that the cooling and heating demand recorded from the simulations is the result of the HVAC equipment used in the residential units which is the heat pump (mini split wall-deco unit) with alternator compressor.

The recordings are summarized and presented in tables, charts, and figures, where the results are referred to in the related or appendices.

6.2 Balcony Models Simulation Analysis

This section analyzes and compares the recordings of space cooling and energy usage in each balcony type: B1W, B2W, and B3W. The scenarios include unglazed balconies analysis (B1W-200, B2W-200, and B3W-200), to allow comparing the adjacent spaces of the glazed scenarios to the balcony scenarios. Therefore, the focus will be on the impact of balcony types on the cooling demand- since there is no glazing on the balconies. It is essential to focus on the impact of balcony type on the cooling demand. However, there is a gap in the literature review on the impact of different types of balconies on the energy consumption (2.4.2).

Chart 6.2.1, Chart 6.2.2, and Chart 6.2.3 indicate the annual energy usage in each month in the three models located in “Corniche El Baher” area; B1W-200, B2W-200, and B3W-200. The simulations were exported from GBS and arranged in Excel in order to obtain and compare the charts.

According to the charts below, all models showed highest energy usage in the summer months: June, July, and August, exceeding other months' energy usage.

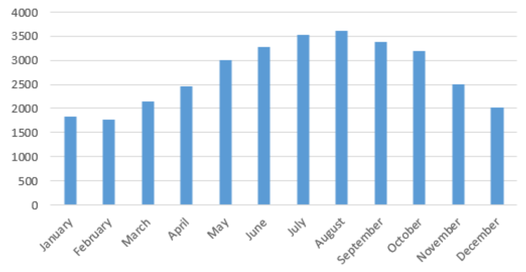


Chart 6.2.1.Energy usage per month in model having balcony surrounded by 1 wall mode (KWh), Source: Author

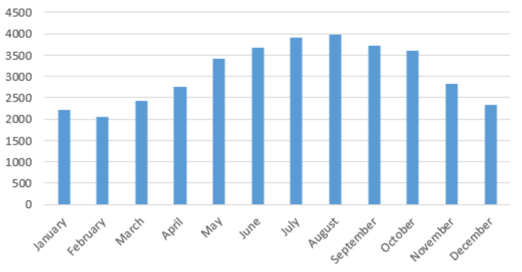


Chart 6.2.2.Energy usage per month in model having balcony surrounded by 2 walls model (KWh), Source: Author

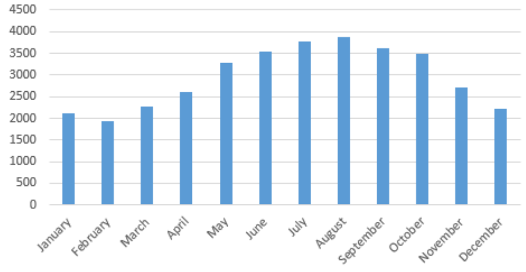


Chart 6.2.3.Energy usage per month in model having balcony surrounded by 3 walls model (KWh), Source: Author

Among the total energy usage in the summer months indicated in the previous charts, most of this energy is used on space cooling (Chart 6.2.4, Chart 6.2.5, and
Chart 6.2.6).
Chart 6.2.4, Chart 6.2.5, and
Chart 6.2.6 indicate the percentage of the annual electric energy use in the three models of the three balcony structures, B1W, B2W, and B3W respectively.
All models showed high percentage of usage of space cooling compared to other electric uses. The space cooling in the simulated models recorded up-to 30% of the total energy consumed that is the highest electric energy used amongst all.

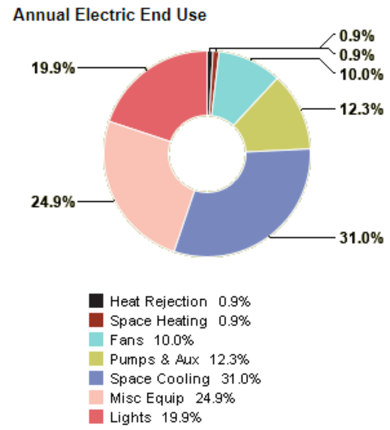


Chart 6.2.4.Energy usage per equipment in model having balcony surrounded by 1 wall, Source: Author, GBS

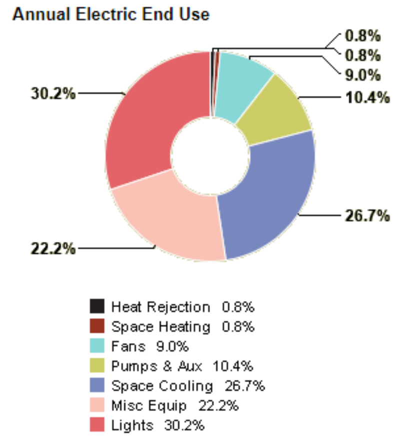


Chart 6.2.5. Energy usage per equipment in model having balcony surrounded by 2 walls, Source: Author, GBS

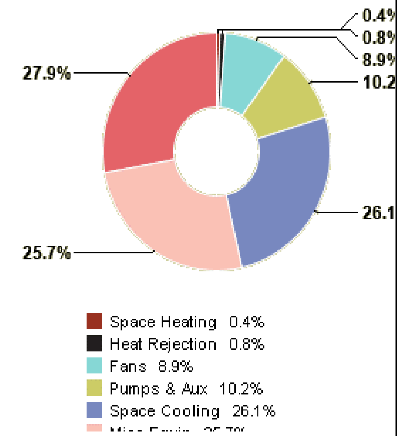


Chart 6.2.6.Energy usage per equipment in model having balcony surrounded by 3 walls, Source: Author, GBS

The gathered data corroborates with the literature review which states that in Lebanon, energy used for space cooling dominates other uses, especially during the summer months, where cooling consumes up-to 36% of the total energy in Lebanon (Haase & Amato , 2006; Al-Hosany & Khalifah, 2002; Azmy & Elghamry, 2018)

This indicates that most of the residential buildings in Lebanon are not built upon the climate of the context, since Lebanon belongs to zone 2A; hot humid climatic zone (ASHRAE, 2004). The climatic zone ensures relatively hot climate, thus requires efficient building material and design to reduce the cooling demand. Accordingly, architects, and contractors should design and choose material based on the climate of the context in order to control energy consumption. Based on Chart 6.2.4, Chart 6.2.5, and

Chart 6.2.6, thebalcony surrounded by 1 wall structure shows the highest percentage of space cooling compared to other models. Whereas, the balcony surrounded by 2 walls, and 3 walls structure have similar space cooling percentages.

This result is affected by several variables. Firstly, since the most prominent difference in the three models is the balcony structure, then the balcony type is an important factor that affects energy consumption.

The exposure of the envelope to the environment and the different shading offered by the balcony in the different balcony types is different. The balcony surrounded by 1 wall has the highest space cooling demand (31%), since balcony surrounded by 1 wall has the highest interaction and exposure with the environment compared to other balcony types and provides the least shading to the adjacent spaces. This can also be explained by the slight difference (0.6%) between the percentages of space cooling between the balconies surrounded by 2 walls (26.7%), which is slightly higher than the balcony surrounded by 3 walls (26.1%).

The higher the building envelope exposure to the outdoor environment, the lower the thermal comfort inside the spaces, the highest the energy consumed; and specifically, cooling demand, and vice versa. This is based on several parameters; U-value of material used, orientation of building and material, and other climatic aspects.

On the other hand, according to Chart 6.2.4, Chart 6.2.5, and

Chart 6.2.6 the energy used on heating in the models is minimal. The highest heating demand recorded is 0.9%, which is relatively a very low demand compared to other electric equipment used (Chart 6.2.4, Chart 6.2.5, and

Chart 6.2.6).

This result confirms the observation that buildings in the area are suitable for winter months rather than summer months, although it is a hot-humid area and should be the opposite.

Moreover, the energy used on space cooling in the models differed in each month depending on the temperature of the location. Chart 6.2.7, Chart 6.2.8, and Chart 6.2.9 indicate the annual space cooling in each month in the three models; B1W, B2W, and B3W respectively (KWh).

According to the simulations done, months June, July, and August recorded the highest space cooling demand (Chart 6.2.7, Chart 6.2.8, and Chart 6.2.9), having the month August record the highest energy usage on cooling.

Similar to the previous energy simulations, the balcony surrounded by 1 wall exceeded the models for energy consumed on cooling in August: 1483.9 KWh per 10m^2, which is the balcony area, and 148.39KWh per m^2 (Table 6.2.1).

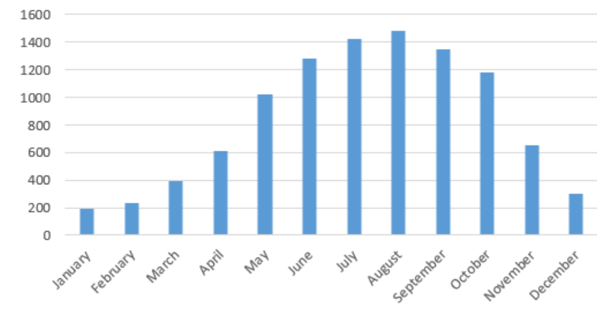


Chart 6.2.7.Energy used on cooling per month in balcony surrounded by 1 wall model (KWh) , Source: Author, GBS Simulation

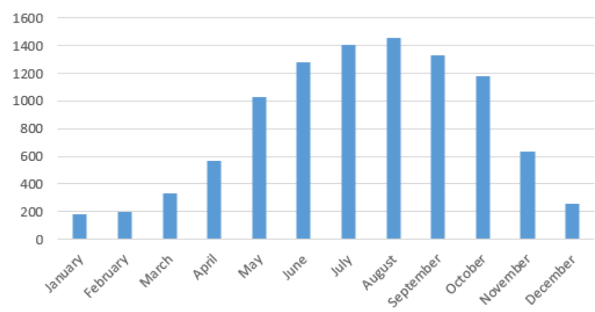


Chart 6.2.8.Energy used on cooling per month in balcony surrounded by 2 walls model (KWh), Source: Author, GBS Simulation

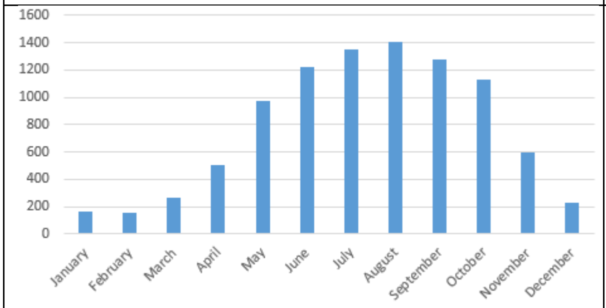


Chart 6.2.9.Energy used on cooling per month in balcony surrounded by 3 walls model (KWh), Source: Author, GBS Simulation

	Months	KWh
B1W	June	1283.47
	July	1421.13
	August	1483.9
B2W	June	1279.53
	July	1403.85
	August	1456.58
B3W	June	1219.25
	July	1350.4
	August	1409.47

Table 6.2.1.Cooling loads in months June, July, and August for the 3 simulated models; balcony surrounded by 1 wall, 2 walls, and 3 walls, Source: Author

The cooling demand is increased according to the temperature of the context in those months (Saida; Corniche El-Baher) (Figure 6.2.1). Figure 6.2.1 represents the annual temperature (C) in “Corniche El Baher” area in each month.

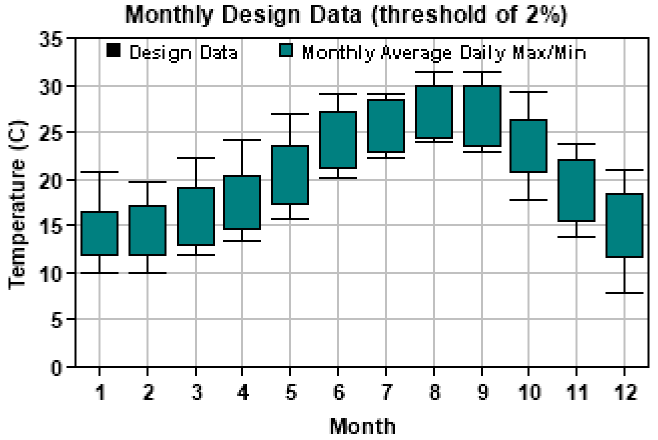


Figure 6.2.1. Monthly Temperature in Saida; Coastal Zone, Source: Author, GBS Simulation

As the temperature increases, the space cooling demand increases. The increase in operating space cooling is to obtain indoor thermal comfort, and compensate the heat exchange through the building envelope, especially through glazing. Figure 6.2.1 indicates the monthly temperature in “Corniche el Baher” area having August the highest temperature. In the summer months, the coastal zone of Lebanon, seafront of Saida, the temperature reaches a maximum of 32°c and a minimum of 21°c (Figure 6.2.1). The summer months in Saida are accompanied by high direct, diffused, and global solar radiation (Chart 6.2.10, Chart 6.2.11, and Chart 6.2.12) that results in overheating. This explains the high cooling demand in the models especially that the models (balconies) are placed horizontally facing the western elevation and overlooking the sea. The western elevation have the highest solar radiation amongst all in Lebanon (Ge, McClung, & Zhang, 2013; Azmy & Elghamry, 2018). The spaces overlooking the west orientation will result in high operational usages in the summer months, especially if not shaded.

The high solar radiation in summer months on the western elevation can cause greenhouse effect in glazed space causing indoor thermal discomfort.

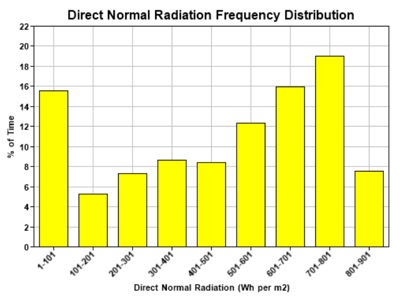


Chart 6.2.10.Direct normal solar radiation in Corniche Baher; Saida, Source: Author, GBS Simulation

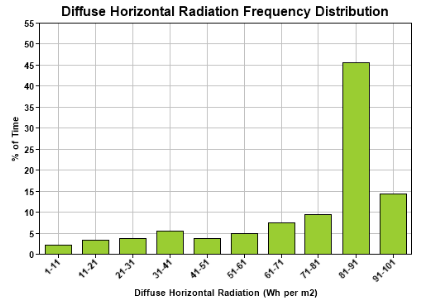


Chart 6.2.11.Defused horizontal solar radiation in Corniche Baher; Saida, Source: Author, GBS Simulation

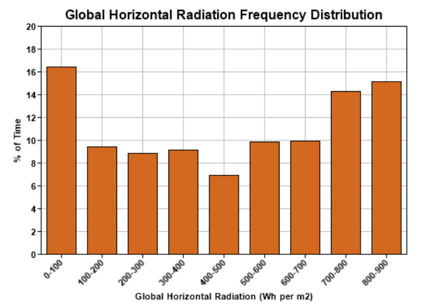


Chart 6.2.12.Global Horizontal solar radiation in Corniche Baher; Saida, Source: Author, GBS Simulation

Having B1W model with highest exposure allows direct solar radiation to penetrate in the spaces resulting in heat gains, thus resulting in higher cooling demand.

Moreover, Chart 6.2.13 represents the difference in the operational cooling demand in the models in the orientations north-west and south-west. The chart indicated that the orientation south-west has higher cooling usage than north-west, since the southern orientation records higher solar radiation that the north.

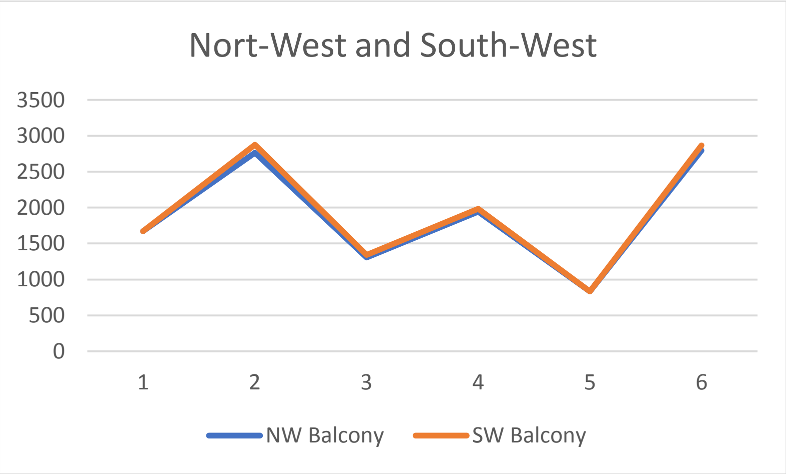


Chart 6.2.13. Cooling demand in the North-West orientation VS South-West orientation (KWh), Source: Author

Since this section is analyzing the results of the scenarios in the models with unglazed balconies, then it is necessary to analyze the cooling demand in the adjacent spaces of the balconies rather than the balconies itself, since the balcony is an open space.

Analyzing the cooling demand in the adjacent space will assess the impact of shading (from the balconies), and the impact of the different balcony types on the space cooling. Analyzing the adjacent spaces of the balconies that are not glazed can serve as a benchmark to compare further balcony enclosures and simulations.

Chart 6.2.14 Indicates the cooling demand in the balcony and adjacent spaces on the 3 models in the north-west and south-west orientations.

According to Chart 6.2.14, it is observed that the highest cooling demand was recorded in the adjacent space in B1W. This is explained by having the balcony type providing the most environmental exposure, and the least balcony shading to the interior space. Moreover, the position of the balcony and the adjacent spaces are on the opposing corners of north-west and south-west having a high direct solar radiation (Appendix A).

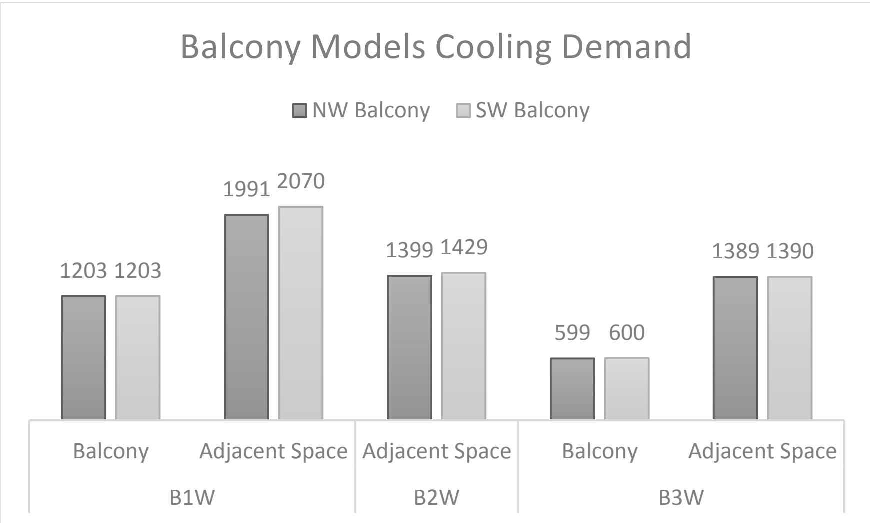


Chart 6.2.14. Cooling demand in KWh for the balcony and adjacent space for each model, Source: Author

The cooling in the adjacent spaces in B2W and B3W indicate lower results respectively (Chart 6.2.14).

The cooling demand in B2W and B3W was decreased down to half of the adjacent spaces in B1W. This is due to, the shading, the balcony type is providing to the adjacent spaces; the higher the shading, the lower the demand and vice versa.

The mentioned simulations are done on the balcony models that are not yet glazed. Therefore, the simulation indicates the impact of the balcony structures on the cooling and energy demand on the adjacent spaces (since the balconies are an open space). The balcony surrounded by 1 wall recorded the highest demand in the adjacent space amongst all, having highest exposure and least shading for the interior spaces.

The recordings will allow us to compare the impact of glazing (when balconies are glazed in further sections) on the energy demand in comparison to the natural state of design (balcony not glazed).

6.3 Glazed Balcony Models Simulation Analysis

In this section, the recordings of the glazed balconies in each model will be described and analyzed. The annual space cooling and heating recordings of balcony surrounded by 1 wall (B1W), 2 walls (B2W), and 3 walls (B3W) models will be discussed respectively. Moreover, the cooling and heating demand in the glazed and adjacent spaces will be discussed and analyzed, emphasizing on the impact of glazing on the balcony space and adjacent space(s). Alternatives will be projected where several parameters in the models will undergo modifications in order to decrease energy consumption. Finally, the models' recordings will be compared indicating the difference in performance of glazing in each balcony type.

6.3.1 Models Simulation Analysis

This section will analyze the recoding of the glazed balcony in the models B1W-100, B2W-100, and B3W-100. The analysis will include the annual total cooling and heating demand in the model, and the energy consumed specifically in the glazed balcony and adjacent space. The heating and cooling demand will be discussed focusing on the impact of glazing on the glazed balcony and adjacent space. Table 6.3.1 summarizes the energy consumption in the three models; further details on each model will be found and referred to in the Appendices (Appendix J, Appendix K, and Appendix L).

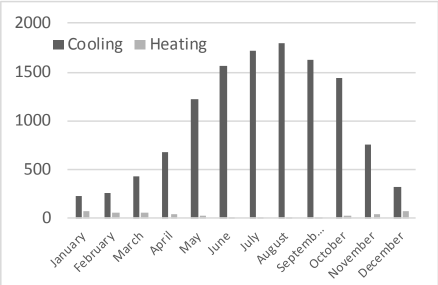
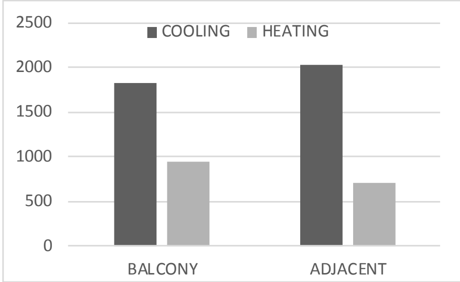
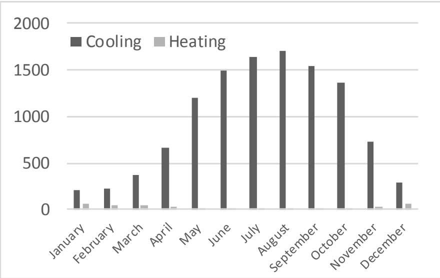
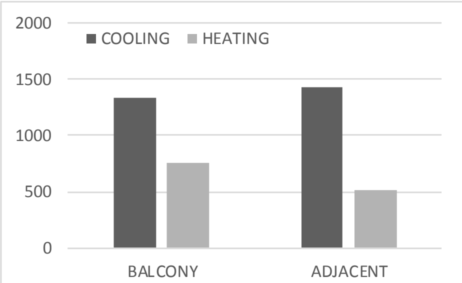
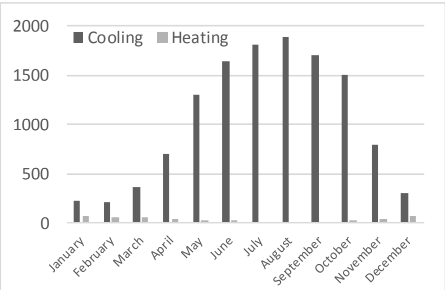
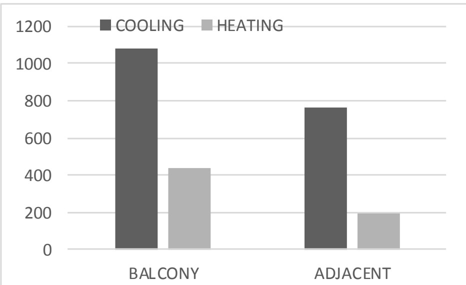
BALCONY STRUCTURE	ANNUAL SPACE COOLING VS HEATING (KWH)	COOLING DEMAND FOR GLAZED BALCONY AND ADJACENT SPACE (KWH)		COOLING (Kwh)	HEATING (Kwh)	APPENDICE
1 WALL-B1W-100			BALCONY	1819	949	Appendix J
			ADJACENT	2026	696	
2 WALLS-B2W-100			BALCONY	1340	755	Appendix K
			ADJACENT	1432	513	
3 WALLS-B3W-100			BALCONY	1084	436	Appendix L
			ADJACENT	767	198	

Table 6.3.1.Annual cooling and heating demand of the three balcony structures, and the heating and cooling demand in the glazed balcony and adjacent space, Source: Author

The results of the energy simulation done on B1W-100 model showed high annual cooling demand in the summer months (June, July, and August). According to Table 6.3.1 the space cooling for the model recorded highest demand in the month of August (1792.9 Kwh). This demand - excluding other electric equipment used- is higher than the US standard set for the whole apartment (860 KWh) by 2 times (Bimenyimana, Osarumwense Asemota, Ihirwe, & Li, 2018; Stoy & Kytzia, 2006).

Similar to the previous model, the B2W-100 model indicated high-energy usage in summer months (Table 6.3.1). However, when observing the recordings of the heating demand versus the cooling demand, it is noted that the heating demand is almost minimal compared to the cooling. This ensures that the material used in the apartments, and the U-value used in Saida, Corniche El Baher area, is not specifically suitable for the climate of the context. The thermal characteristics of the material used perform efficiently in the cold months rather than in the hot months.

B3W-100 model showed that the building material and balcony enclosure are efficient in the cold months rather than in the summer months since there is a significant variation between the annual cooling and heating demand having the cooling demand in the summer months more than 1800KWh (Table 6.3.1).

Amongst the annual space cooling and heating recorded, the glazed balcony recorded a significant share. Table 6.3.1 includes the cooling and heating demand for the glazed balcony and the adjacent space to the glazed balcony (living space) to maintain comfortable interior spaces in the south-west orientation. Both orientations; the north-west and south-west have similar electric demands, having the south-west slightly higher. The south-west is mentioned in the table while the north-west will be available in the appendix (Appendix J).

According to Table 6.3.1, the glazed balcony in B1W-100 consumes a peak of 1819 KWh per area of balcony (181.9 KWh/m^2) on cooling in summer months in order to achieve indoor comfort. Whereas, the heating demand needed in the winter months recorded a maximum of 1318 KWh (131.8 KWh/m^2) (Appendix B and Appendix J).

The cooling and heating demand of the glazed balcony are relatively high, compared to the US standards. This is due to several parameters; glazing type and balcony type. The glazing type in the models is single glazing 6mm pane, which has a very high U-value, and thus results in excessive heat transfer.

The high U-value of the glazing type allows heat transfer in summer months resulting in heat gains in the glazed balcony. In winter, the U-value of the glazing type allows the transfer of heat from the interior space to the outdoor. Both heating and cooling demands is increased in the glazed and adjacent spaces to improve indoor quality and compensate the discomfort resulting from the heat transfer. Moreover, the balcony type; B1W-100, imposes large area of glazing due to its exposure from 3 elevations thus insulation is minimal in the area.

Whereas in winter, and during daytime, the direct solar radiation from three exposed elevations allows direct solar radiation to penetrate in the glazed space and heat the area without operating any electric system for few hours. According to Appendix B and Appendix J, the total heating demand in the residential unit (not only in the glazed space) accounts for 1.1% of the total electric demand, which corroborates with the literature that states the efficiency of glazing in cold climatic regions during daytime.

In the model B2W-100, the Table 6.3.1 indicates the cooling demand in the summer months in the glazed balcony and adjacent space in the south-west orientation. The table indicates that the adjacent spaces (living) recorded slightly higher cooling demand than the glazed balcony. This is due to the area of cooling operation. The area of the adjacent space is larger than the area of the glazed balcony. Whereas the heating in the adjacent space is, lower than the glazed space due to the formation of a buffer zone in the glazed space. The buffer zone reduces the heat exchange from the glazed space to the outdoor. Accordingly, the results of B2W-100 corroborates with the literature review that clearly states that the glazed spaces when separated from the interior spaces, allow reduction in the heating demand. Both recordings; the glazed balcony and adjacent space, are significantly higher than the US standard.

In B3W-100 model, according to Appendix L the cooling demand in the glazed balcony in both orientations north-west and south-west has similar results. The living area adjacent to the glazed balcony shows lower cooling recording (1066 KWh) than the glazed balcony (1506 KWh) (Table 6.3.1) whereas the heating demand indicates the opposite, having minimal heating demand in the adjacent space. This is due to the reason mentioned in the previous model (buffer zone formation), and having the spaces surrounded from three elevation, with only one elevation with glazing.

The collected data of the model's recordings are further analyzed and compared along with other scenarios in order to discuss the impact of the glazing on the glazed spaces, and adjacent spaces. Several parameters are presented in order to reduce the consumption of the spaces in the models.

6.3.2 Alternative Scenario Simulations

In order to reduce the electric demand in the models, the following section presents the creation of several scenarios for each model having adjusted parameters. The parameters adjusted directly affect the energy consumed in the glazed spaces, and especially cooling, according to the literature. The modified parameters are; changing the orientation of glazing, decreasing the window-to-wall ratio, installing shading on glazing, and replacing the glazing type. Each scenario will undergo modifications in the mentioned scenarios by which will be compared to the base model in order to identify the efficient parameter that enables cooling reduction in the glazed spaces. The initial cost of the parameters implemented will not be considered, since they are not the focus of the thesis and will be suggested for further studies.

The scenarios were created according to the charts from the Insight 360 (Appendix B, Appendix E, and Appendix G) and designed in GBS. The results from GBS are arranged in the form of table exported from Excel in order to compare easily the results.

6.3.2.1 Alternative Scenarios of Model B1W-100

The following scenario examines the modified parameters in the model B1W-100.

Table 6.3.2 indicates the annual reduction in cost and KWh of the parameters adjusted on GBS compared to the base run of the model B1W-100. Noting the cost per KWh in Lebanon is 0.09 USD.

When the window-to-wall ratio was reduced to 30% on the west and southern elevations, there was a slight decrease in the energy consumed and cost (95 USD annually). The table shows that when the model is rotated 90°; when the balconies are placed on the North elevation rather than on the western, the energy usage was reduced by 1516 KWh and cost was reduced by 182 USD annually. When the single pane 6mm glazing was replaced by a low-e glazing for hot climate, the reduction was 120 USD and 519 KWh annually.

All the mentioned modifications; glazing, orientation, and window-to-wall modification did not make a recognizable reduction on the cost neither energy consumed. Moreover, the price of replacing the glazing type with low-e is more than the savings in 30 years (3600 USD).

When the shading devices are placed on glazing to cover 2/3 of the window, there was a reduction of 3570 KWh and 389 USD annually, almost 12000 USD in 30 years. However, installing shading devices will affect the view, thus movable shadings can be implemented, but this will also increase the initial cost.

BALCONY TYPE	MODEL	BASE RUN		WWR		ORIENTATION		GLAZING		SHADING		
		COST	KWH	COST	KWH	COST	KWH	COST	KWH	COST	KWH	
B1W	100	$ 4,352	38293	$ 4,257	37857	$ 4,170	36777	$ 4,232	37774	$ 3,963	34726	B1W-100
REDUCTION				1.13%		4%		1.30%		9.30%		

Table 6.3.2. Percentage of reduction of each modification in relation to the base run, Source: Author

Briefly, according to Table 6.3.2, the highest reduction occurred when the shading was inserted on 2/3 of the glazing. Reducing the solar radiation by shading installation recorded efficient results than replacing the glazing type.

However, since the examined phenomenon is in an existing building, and the possibility to decrease window-to-wall ratio or orientation of the building is not possible, then Figure 6.3.1 shows the result of the scenario when both the glazing and shading are modified. Shading and glazing are the only modifications amongst the mentioned that can be implemented in any existing building.

1 Base Run	
Energy, Carbon and Cost Summary	
Annual Energy Cost	$4,352
Lifecycle Cost	$59,275
Annual CO_2 Emissions	
Electric	0.0 Mg
Onsite Fuel	5.1 Mg
Large SUV Equivalent	0.5 SUVs / Year
Annual Energy	
Energy Use Intensity (EUI)	1,029 MJ / m² / year
Electric	38,293 kWh
Fuel	101,800 MJ
Annual Peak Demand	8.9 kW
Lifecycle Energy	
Electric	1,148,796 kW
Fuel	3,054,012 MJ
Assumptions	

2 Design Alternative	
Estimated Energy & Cost Summary	
Annual Energy Cost	$3,888
Lifecycle Cost	$52,959
Annual CO_2 Emissions	
Electric	0.0 Mg
Onsite Fuel	4.3 Mg
Large SUV Equivalent	0.4 SUVs / Year
Annual Energy	
Energy Use Intensity (EUI)	1,029 MJ / m² / year
Electric	34,514 kWh
Fuel	87,146 MJ
Annual Peak Demand	8.0 kW
Lifecycle Energy	
Electric	1,035,418 kW
Fuel	2,614,378 MJ
Assumptions	

Figure 6.3.1. Modification of Shading and Glazing VS Base run, Source: Author

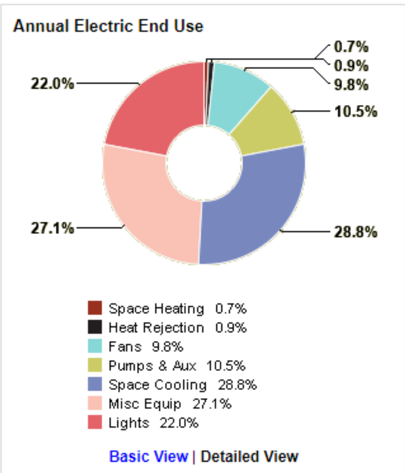


Figure 6.3.2. Cooling for Shading and Glazing, Source: Author

The scenario proves that when the shading is installed on 2/3 the window and glazing type is replaced by low-e, a reduction of up to 470 USD annually (2800 KWh annually), 14000 USD lifecycle reduction (30year) can be attained (Figure 6.3.1), with a reduction of cooling demand (28.8% instead of 31.4%) (Figure 6.3.2). However, the initial cost of implementing the mentioned strategies is a factor that should be considered in further research.

6.3.2.2 Alternative Scenarios of Model B2W-100

The following scenario examines the modified parameters in the model B2W-100. The results are obtained from GBS and inserted to Excel in order to create clear visuals for analysis. Table 6.3.3 indicates the annual reduction in cost and KWh of the parameters adjusted on GBS compared to the base run of the model B2W-100.

The base model consumes 42084 KWh; 4321 USD annually. According to Table 6.3.3, decreasing the window-to-wall ratio to 30% was not efficient since it led to an increase in the cooling demand; this is because some of the elevations already had less than 30%. When rotating the building, having the main façade overlooking the north elevation, a decrease of 5.3% occurred (4092 USD). Moreover, when the single pane clear 6mm glazing was replaced by low-e glazing, a decrease of up-to 3.6% was conducted (4165 USD) (Table 6.3.3).

Shading 2/3 of the windows led to a decrease of up-to 8% (3978 USD) (Table 6.3.3).

BALCONY TYPE	MODEL	BASE RUN		WWR		ORIENTATION		GLAZING		SHADING		
		COST	KWH	COST	KWH	COST	KWH	COST	KWH	COST	KWH	
B2W	100	$ 4,321	42084	$ 4,772	46416	$ 4,096	40166	$ 4,165	41042	$ 3,978	38948	B2W-100
REDUCTION				110.00%		5%		2.50%		7.45%		

Table 6.3.3.Percentage of reduction per parameter in relation to the base run, Source: Author

According to Table 6.3.3, amongst all the modifications done on the model, the shading showed the highest efficiency and energy reduction (7.45%).

However, since as mentioned in the previous section, the only applicable parameters to existing buildings is placing shading and replacing the glazing type, therefore, a scenario including both parameters is done.

1 Base Run	
Energy, Carbon and Cost Summary	
Annual Energy Cost	$4,321
Lifecycle Cost	$58,856
Annual CO_2 Emissions	
Electric	0.0 Mg
Onsite Fuel	2.5 Mg
Large SUV Equivalent	0.2 SUVs / Year
Annual Energy	
Energy Use Intensity (EUI)	882 MJ / m² / year
Electric	42,084 kWh
Fuel	49,744 MJ
Annual Peak Demand	8.4 kW
Lifecycle Energy	
Electric	1,262,534 kW
Fuel	1,492,308 MJ
Assumptions	

2 Design Alternative	
Estimated Energy & Cost Summary	
Annual Energy Cost	$3,890
Lifecycle Cost	$52,982
Annual CO_2 Emissions	
Electric	0.0 Mg
Onsite Fuel	1.9 Mg
Large SUV Equivalent	0.2 SUVs / Year
Annual Energy	
Energy Use Intensity (EUI)	882 MJ / m² / year
Electric	38,475 kWh
Fuel	37,312 MJ
Annual Peak Demand	7.5 kW
Lifecycle Energy	
Electric	1,154,243 kW
Fuel	1,119,368 MJ
Assumptions	

Figure 6.3.3. Shading and Glazing, Source: Author

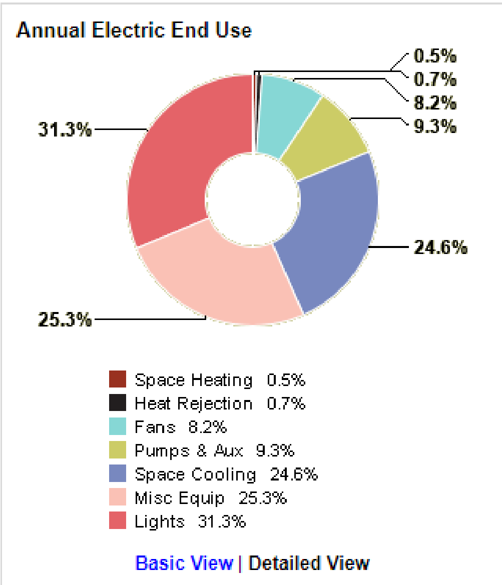


Figure 6.3.4. Cooling decrease when shading and glazing are changed, Source: Author

The mentioned scenario led to a decrease of up-to 10% from the annual cost and energy consumption (Figure 6.3.3). The cooling demand in the model decreased from 27.2% to 24.6% (Figure 6.3.4).

6.3.2.3 Alternative Scenarios of Model B3W-100

The last scenario examines the modified parameters in the model B3W-100. Table 6.3.4 indicates the annual reduction in cost and KWh of the parameters adjusted on GBS compared to the base run of the model B3W-100.

In order to decrease the high cooling demand, several scenarios where created; placing shading on 2/3 of the window, replacing the glazing with low-e, rotating the building 90°, and reducing the window-to-wall ratio to 30%.

According to Table 6.3.4, the results of the scenarios showed that the most efficient parameters where placing shading devices (a decrease of 7.2 %), and changing the orientation of the building by placing the glazed balconies to the north elevation (a decrease of 7 %). Whereas adjusting the orientation and replacing the glazing type, tended to increase the energy consumed by 1% (Table 6.3.4).

BALCONY TYPE	MODEL	BASE RUN COST	BASE RUN KWH	WWR COST	WWR KWH	ORIENTATION COST	ORIENTATION KWH	GLAZING COST	GLAZING KWH	SHADING COST	SHADING KWH	
B3W	100	$ 4,576	43564	$ 4,562	44073	$ 4,224	40616	$ 4,600	44242	$ 4,232	40412	B3W-100
REDUCTION				101%		7%		101%		7.20%		

Table 6.3.4. Percentage of several parameters in relation to the base run, Source: Author

Concerning the applicable parameters to the existing buildings in the area, inserting shading on the windows is the only applicable parameters amongst the ones mentioned that can be applied.

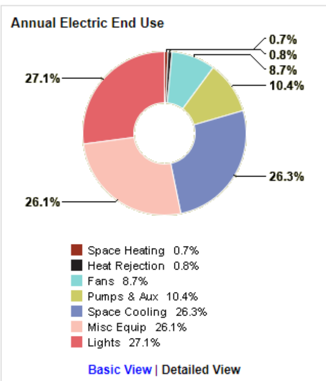


Figure 6.3.5.Space cooling decrease to 26.3%, Source: Author

Placing shading devices to cover 2/3 of the window resulted in the reduction of energy consumed, especially cooling; from 28.4% to 26.3% (Figure 6.6.81).

6.3.2.4 Conclusion

When having a glazing in a balcony surrounded by 1 wall structure (B1W-100), the glazed space will perform efficiently in winter creating a greenhouse effect, however, the space is energy consuming in summer. The most efficient modification to reduce the cooling demand in an existing building is not only to replace the single pane glazing with a low-e, but also to shade 2/3 of the openings to prevent solar heat gain. However, if in the design phase, placing the glazing on the northern façade rather than the western can help prevent heat gain and thus cooling demand. In the balcony surrounded by 2 walls (B2W-100), the glazed balcony imposed minimal heating demand, especially during the day time, compared to the cooling demand in the summer months. The cooling demand in the glazed and adjacent space exceeded the US standard for energy consumption. In B1W-300, the model showed high-energy usage especially on cooling. However, the model indicated opposing results concerning the alternative parameters. When the glazing is changed to low-e, the reduction in energy consumption did not occur. The only efficient and applicable parameter was the placement of shading. The results of the glazed balconies in the three models will be further compared and analyzed in order to derive the impact of glazed balconies on the adjacent space, the impact of glazed balconies on cooling, and the impact of balcony type on the cooling demand and energy usage.

6.3.3 Comparing results of the 3 models glazed balconies

The three models having glazed balconies where simulated and separately analyzed in the previous sections. This section will compare and analyze the results of the glazed balcony models in order to deduce the performance of each with respect to different balcony types.

Chart 6.3.1 indicates the cooling demand for the glazed balconies and adjacent spaces in the 3 models in orientations north-west and south-west.

Amongst all models, B1W recorded the highest cooling demand, then B2W and B3W respectively (Chart 6.3.1).

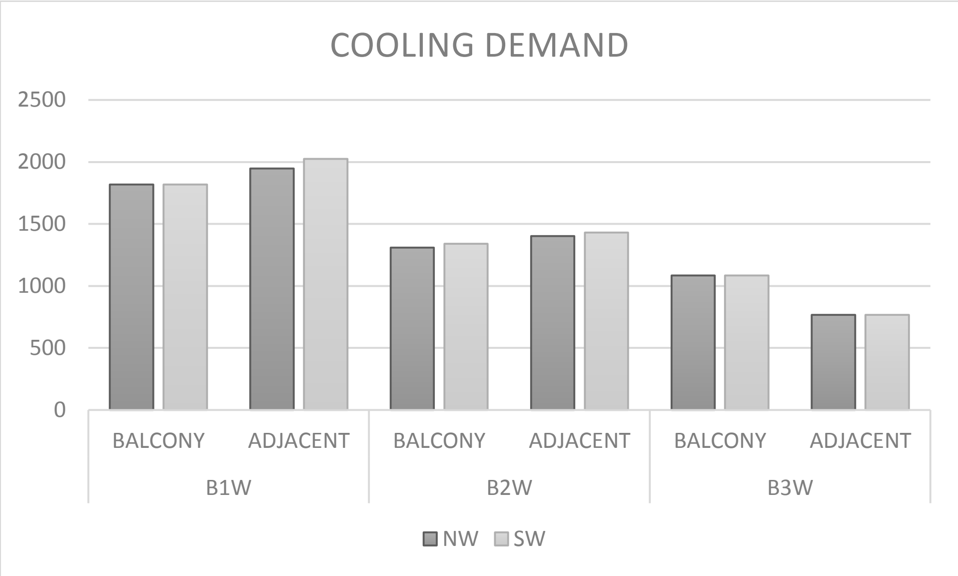


Chart 6.3.1. Cooling demand in glazed balconies and adjacent spaces of the three models, Source: Author

Model B1W has 3 glazed elevations and one wall, and according to Figure 5.3.1, the U-value of the wall used in “Corniche El Baher” area is lower than the U-value of the single pane glazing used. Therefore, the more the walls surrounding the glazed balcony the higher the insulation provided. As the glazing and exposure to direct solar radiation increases, the energy consumed increases, and vice versa- similar to models 2 and 3, that respectively have lower energy consumption than model 1.

The demand in the space adjacent to the balcony space varies. In models B1W and B2W, the cooling operated in the space adjacent to the balcony is higher than the cooling operated in the glazed balcony. This is due to several reasons that are further discussed, noting that the area of the adjacent space is higher than the area of the balcony. Moreover, B3W recorded operated cooling in the adjacent space less than the operated cooling in the balcony space. This is due to the insulation provided by the 3 surrounding walls and the position of the adjacent space prevents direct solar radiation. Moreover, the shading provided from the balcony structure decreases heat gains through solar penetration.

Similarly, the heating demand has records of 949KWh in the cantilevered balcony B1W, and decreases in the other models B2W and B3W respectively (Chart 6.3.2).

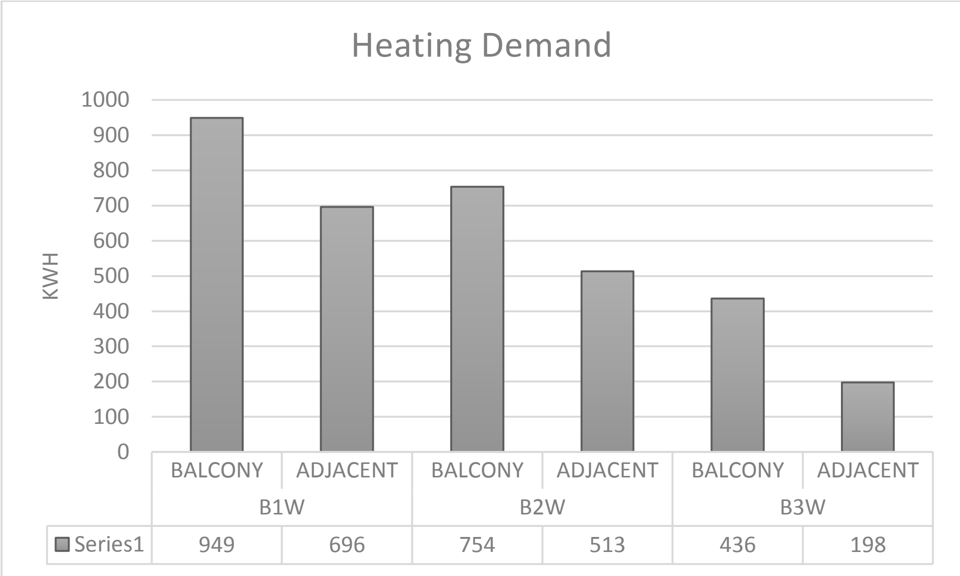


Chart 6.3.2.Heating demand in glazed balconies and adjacent spaces of the three models, Source: Author

The electric usage in the models is affected by several variables. The area of glazing proved to cause an increase in the electric usage; cooling demand. The balcony type and type of glazing directly affect the energy consumed on cooling in the glazed balcony and adjacent spaces.

6.3.4 Conclusion

Briefly, the first model (cantilevered balcony) recorded the highest cooling and heating demand amongst all models. When the three models underwent several changes in order to decrease the energy usage, each responded differently to the same variable. The first and second model resulted in an efficient decrease in energy usage when the glazing is replaced by low-e, and 2/3 of the windows were shaded; a decrease in cost of up-to 10%. The third model didn't perform efficiently when glazing and shading were adjusted together, since adjusting the glazing resulted in an increase in the energy consumed, thus by adjusting the shading only the cost of energy used is decreased by 7.2%.

6.4 Glazed Balcony with Wall Removal Models Analysis

In this section, the recordings of the glazed balconies where the wall separating the balcony from the interior space is removed will be presented and analyzed.

The annual space cooling and heating recordings of the three balcony structures will be discussed respectively. Moreover, the cooling and heating demand in the enlarged glazed spaces will be discussed and analyzed, focusing on the impact of glazing on the enlarged space. Alternatives will be presented where several parameters in the models will undergo modifications in order to decrease energy consumption. Finally, the models' results will be compared indicating the difference in performance of each balcony type.

6.4.1 Models Simulation Analysis

This section will analyze the recoding of the glazed balcony in the models having balcony surrounded by 1 wall, 2 walls, and 3 walls in the scenario when the balcony is glazed and the wall separating the balcony from the adjacent space is removed (B1W-300, B2W-300, AND B3W-300). The analysis will include the total energy consumed in the model, and the energy consumed specifically in the glazed enlarged space. In this scenario, the cooling demand will be analyzed as the sum of the glazed balcony and interior space since they are one enlarged space that demands energy usage. Table 6.4.1 indicates the annual space cooling and heating in the balcony structures models, and the sum of cooling and heating in the enlarged space. The enlarged space in the table is orientated towards the south-west since the results of north-west and south-west are similar with a slight difference. However further details on the models is referred to in the appendix (Appendix M, Appendix N, and Appendix O).

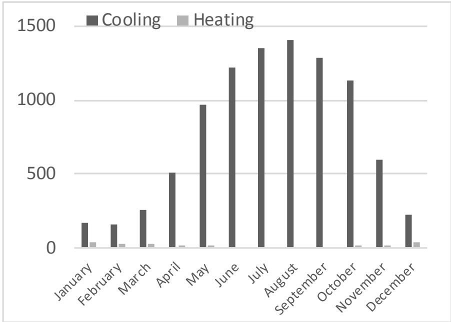
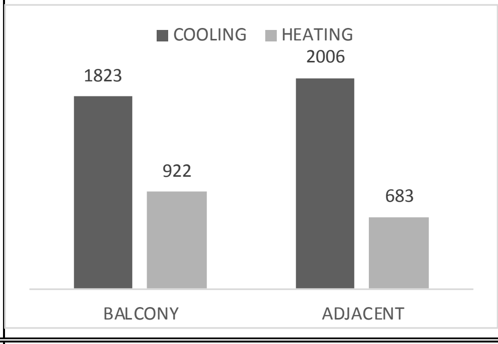
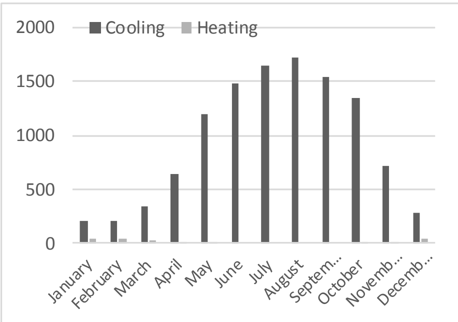
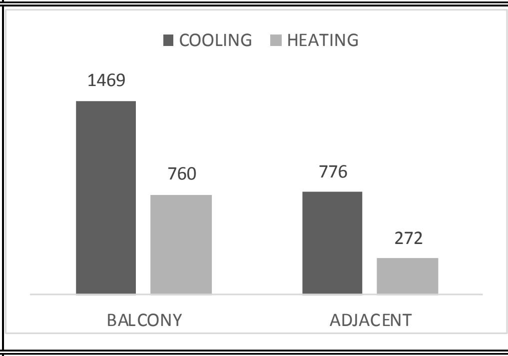
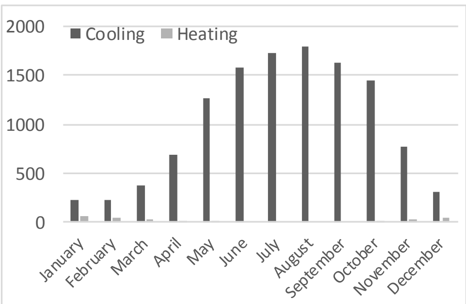
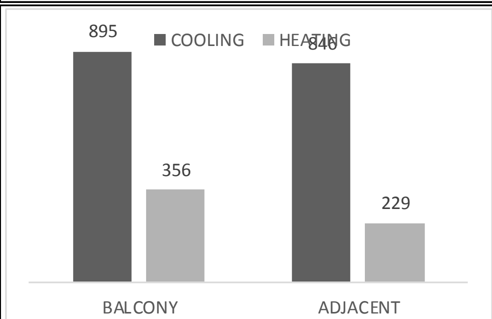
<table>
<tr><th>BALCONY STRUCT</th><th>ANNUAL SPACE COOLING VS HEATING (KWH)</th><th>COOLING DEMAND FOR GLAZED BALCONY AND ADJACENT SPACE (KWH)</th><th></th><th>COOLING (Kwh)</th><th>HEATING (Kwh)</th><th>APPENDICE</th></tr>
<tr><td>1 WALL-B1W-300</td><td>
</td><td>
</td><td>BALCONY
ADJACENT</td><td>3829</td><td>1605</td><td>Appendix J Appendix M</td></tr>
<tr><td>2 WALLS-B2W-300</td><td>
</td><td>
</td><td>BALCONY
ADJACENT</td><td>2245</td><td>1032</td><td>Appendix N</td></tr>
<tr><td>3 WALLS-B3W-300</td><td>
</td><td>
</td><td>BALCONY
ADJACENT</td><td>1741</td><td>585</td><td>Appendix JAppendix O</td></tr>
</table>

Table 6.4.1. Annual cooling and heating demand of the three balcony structures, and the heating and cooling demand in the glazed enlarged space, Source: Author

In B1W-300 model, there is a wide variation between the energy usage per month on cooling and on heating. According to Table 6.4.1 annual space cooling is extremely higher than heating. The space cooling usage recorded a maximum of 1400 KWh, whereas the maximum heating recorded was 40 KWh. The high cooling usage is because of the exposure given by the balcony structure that allows direct solar radiation. Moreover, the cooling will have to be provided for a large area (glazed balcony and living), unlike previous models.

In the model having a glazed balcony surrounded by 2 walls (B2W-300), the space cooling exceeded 1500 KWh in the summer months, whereas in winter, the heating demand reached up-to 50 KWh.

In the model having a glazed balcony surrounded by 3 walls (B3W-300), similarly, the cooling demand is by far higher than the heating demand, this corresponds to the thermal properties of material used and design of buildings.

In the three reviewed models, all models showed similar results having very high cooling demand in the whole model with respect to space heating. This explains that beyond the balcony structure and glazing type used, the U-value of the building material used in "Corniche El Baher" area is not suitable for the climate neither provide insulation from the climatic factors.

In the enlarged spaces; glazed balcony and adjacent space, the electric demand recorded high space cooling usage.

The cooling provided in the enlarged space in B1W-300 records a sum of 3829KWh in the peak summer months (according to Table 6.4.1 and Appendix M). The demand is 4 times above the US monthly standard (860 KWh) of the residential model (Bimenyimana, Osarumwense Asemota, Ihirwe, & Li, 2018; Stoy & Kytzia, 2006).

In B2W-300, the cooling usage in the enlarged space reached up-to 3700 KWh in the summer months (Table 6.4.1 and Appendix N). This cooling demand is extremely high compared to US standards and costs up-to to 333$ per month. This cost is spent only cooling the enlarged space.

In B3W-300, the cooling demand in the enlarged space recorded 1741 KWh, costing 156$ per month in order to achieve indoor comfort in the glazed space.

The described results of the models simulated recorded high-energy usage in the enlarged space. This is due to several variables, and mainly the increased area of space for cooling operation. Moreover, the cooling demand is also affected by several parameters to be modified in the following section in order to decrease the energy usage.

6.4.2 Alternative Scenario Analysis

Similar to the previous models, the scenarios B1W-300, B2W-300, and B3W-300 will undergo several modifications in several parameters in order to reduce the cooling usage in the enlarged space, focusing on glazing related parameters.

In order to reduce the electric demand in the models, the following section presents the creation of several scenarios for each model having adjusted parameters. The parameters adjusted directly affect the energy consumed in the glazed spaces, and especially cooling, according to the literature. The modified parameters are; changing the orientation of glazing, decreasing the window-to-wall ratio, installing shading on glazing, and replacing the glazing type. Each scenario will undergo modifications in the mentioned scenarios by which will be compared to the base model in order to identify the efficient parameter that enables cooling reduction in the glazed spaces.

The scenarios were created according to the charts from the Insight 360 (Appendix B, Appendix E, and Appendix G) and designed in GBS. The results from GBS are arranged in the form of table exported from Excel in order to compare easily the results.

6.4.2.1 Alternative Scenarios of Model B1W-300

In order to decrease the energy usage especially on cooling, the parameters; orientation, shading, glazing, and window-to-wall ratio are modified and simulated for B1W-300 model. Table 6.4.2 summarized the reduction occurred upon modifying the mentioned parameters in terms of cost and Kwh reduction. Modifying the, orientation, glazing, and window to wall ratio, recorded similar results; a decrease by 3%, 1%, and 2% respectively (Table 6.4.2).

Whereas, shading 2/3 of the windows decreased the energy usage by 9.3% (Table 6.4.2).

According to Table 6.4.2, the most efficient parameter that allowed significant reduction on energy usage was the placement of shading. However, replacing the glazing by low-e recorded the minimum decrease (1%).

BALCONY TYPE	MODEL	BASE RUN		WWR		ORIENTATION		GLAZING		SHADING		
		COST	KWH	COST	KWH	COST	KWH	COST	KWH	COST	KWH	
B1W	300	$ 4,451	40064	$ 4,335	39312	$ 4,319	38955	$ 4,336	39682	$ 4,044	36316	B1W-300
REDUCTION				2%		3%		1%		9.30%		

Table 6.4.2. Percentage of reduction with respect to the base run, Source: Author

Chart 6.4.1 and Chart 6.4.2 indicate the difference in the space cooling percentage in each the base run and the model when the shading is placed.

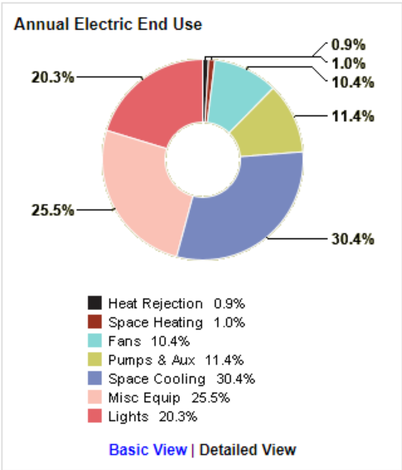


Chart 6.4.1. Annual Electric End Use in Base Run , Source: Author

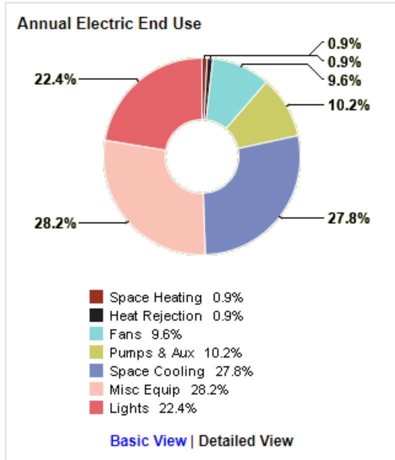


Chart 6.4.2. Annual Electric End Use in Alternative (Shading) , Source: Author

Adjusting the shading only, achieved a decrease in the annual cooling demand by 2.6% (Chart 6.4.1 and Chart 6.4.2).

In conclusion, the model showed high-energy usage and space cooling referring to the enlarged space that needs cooling and the direct contact with the environment that result in excessive heat gain in the summer months. Shading 2/3rd of the windows is the most efficient low cost and applicable method to be applied on existing buildings. The recordings will be further compared to other models in order to deduce the efficient and inefficient model.

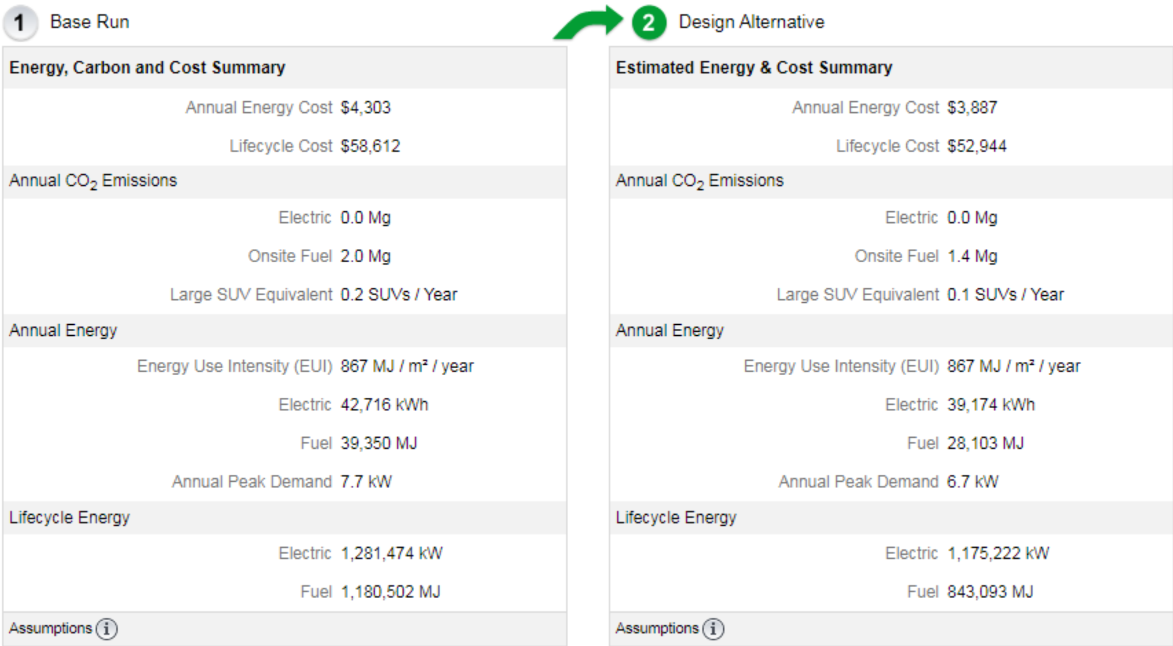
6.4.2.2 Alternative Scenarios of Model B2W-300

In the model B2W-300, Table 6.4.3 illustrates the modified parameters and the percentage of reduction of each with respect to the base model. Shading, glazing, and rotation decreased the energy demand by 7%, 2.4%, and 4% respectively (Table 6.4.3). However, changing the window-to wall ratio to 30% relatively did not make any reduction, rather slightly increased the demand 1% (Table 6.4.3).

According to Table 6.4.3, the most efficient parameter was the placement of shading, followed by the adjustment of orientation to the north rather than the west, and then the glazing.

MODEL	BASE RUN		WWR		ORIENTATION		GLAZING		SHADING		#NAME?
	COST	KWH	COST	KWH	COST	KWH	COST	KWH	COST	KWH	
300	$ 4,303	42716	$ 4,345	43270	$ 4,135	40949	$ 4,146	41683	$ 3,980	39659	B2W-300
			101%		4%		2%		7.00%		

Table 6.4.3.Reduction percentage with respect to the base run of several parameters, Source: Author



1 Base Run		2 Design Alternative	
Energy, Carbon and Cost Summary		**Estimated Energy & Cost Summary**	
Annual Energy Cost	$4,303	Annual Energy Cost	$3,887
Lifecycle Cost	$58,612	Lifecycle Cost	$52,944
Annual CO_2 Emissions		Annual CO_2 Emissions	
Electric	0.0 Mg	Electric	0.0 Mg
Onsite Fuel	2.0 Mg	Onsite Fuel	1.4 Mg
Large SUV Equivalent	0.2 SUVs / Year	Large SUV Equivalent	0.1 SUVs / Year
Annual Energy		Annual Energy	
Energy Use Intensity (EUI)	867 MJ / m² / year	Energy Use Intensity (EUI)	867 MJ / m² / year
Electric	42,716 kWh	Electric	39,174 kWh
Fuel	39,350 MJ	Fuel	28,103 MJ
Annual Peak Demand	7.7 kW	Annual Peak Demand	6.7 kW
Lifecycle Energy		Lifecycle Energy	
Electric	1,281,474 kW	Electric	1,175,222 kW
Fuel	1,180,502 MJ	Fuel	843,093 MJ
Assumptions		Assumptions	

Figure 6.4.1.Adjustment of shading and glazing VS Base run, Source: Author

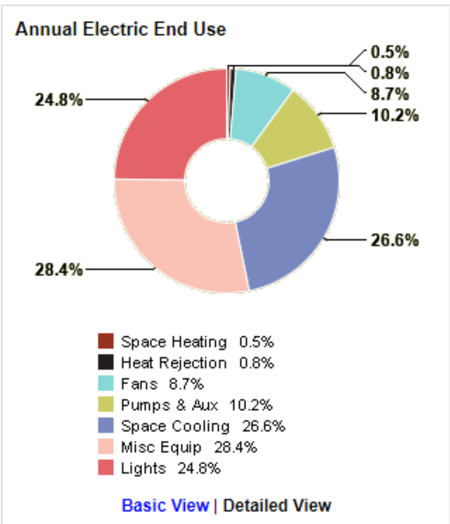


Chart 6.4.3. Base run electric use, Source: Author

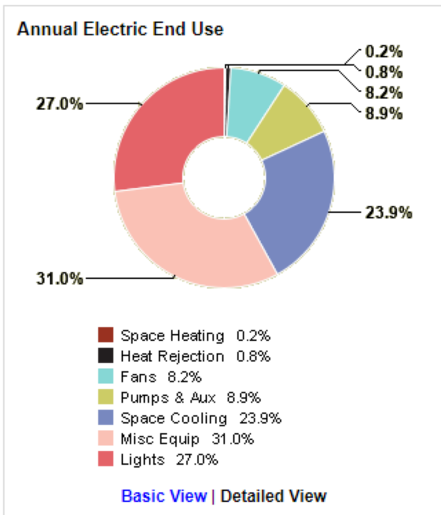


Chart 6.4.4.Alternative model electric use, Source: Author

Adjusting the glazing and placing shades on the windows together, achieved a reduction of up-to 10%, and a reduction in the cooling demand from 26.6% to 23.9% Figure 6.4.1, Chart 6.4.3, and Chart 6.4.4).

In conclusion, the model underwent several readings of recordings in terms of cooling and heating in the space model and in the glazed space. Several parameters were modified in order to obtain the efficient parameter. Shading and glazing adjustment prove reduction in energy consumption can be obtained in existing buildings.

6.4.2.3 Alternative Scenarios of Model B3W-300

Similar to previous models, variables where modified in order to decrease energy intake. Table 6.4.4 indicate the shading, glazing, orientation, and window-to-wall ratio parameters respectively compared to the base run.

Table 6.4.4 indicates that the most efficient variable is the shading- it decreased the energy demand by 7.5% (Table 6.4.4).

BALCONY TYPE	MODEL	BASE RUN		WWR		ORIENTATION		GLAZING		SHADING		
		COST	KWH	COST	KWH	COST	KWH	COST	KWH	COST	KWH	
B3W	300	$ 4,461	43169	$ 4,405	42584	$ 4,209	40975	$ 4,329	42250	$ 4,126	39959	B3W-300
REDUCTION				1%		5%		2%		7.50%		

Table 6.4.4.Reduction percentage of several parameters with respect to the base run, Source: Author

However, when adjusting shading and glazing, since they are variables that can be adjusted in an existing building, a decrease of 9% was achieved (Figure 6.4.2) and a decrease of 2.6% specifically on the cooling demand (Chart 6.4.5 and Chart 6.4.6).

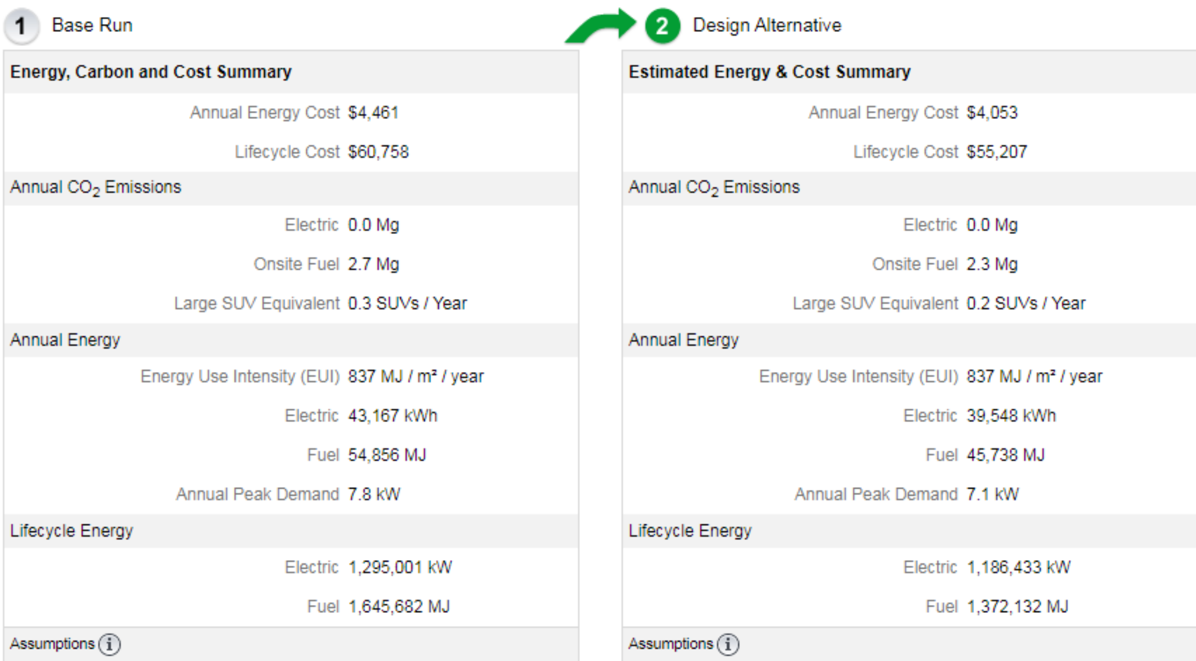


Figure 6.4.2.Shading and glazing adjustment VS Base run, Source: Author

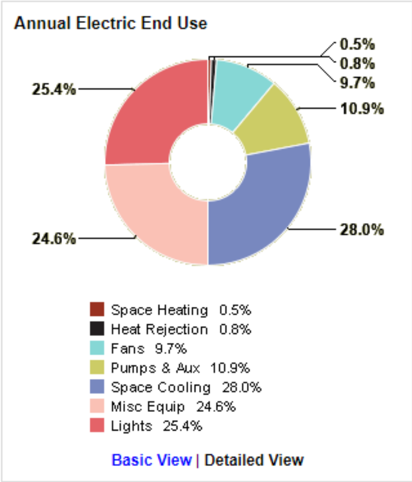


Chart 6.4.5.Base run electric end use, Source: Author

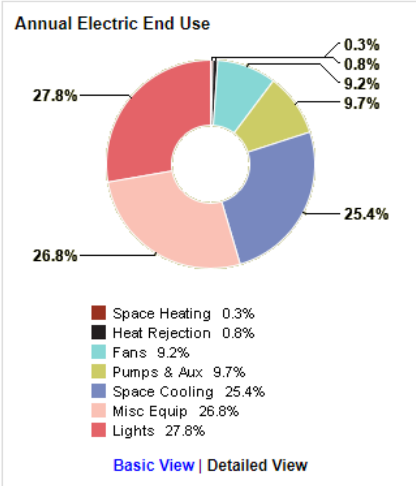


Chart 6.4.6. Alternative electric end use, Source: Author

In conclusion, similar to the previous models, the balcony surrounded by 3 walls recorded high energy usage and high cooling usage, whereas the heating was minimal. The model was mostly respondent to the shading coefficient. Moreover, when glazing and shading were adjusted together, the reduction was recorded per energy use and per cooling specifically.

6.4.2.4 Conclusion

The three balcony type models underwent similar adjustment to several parameters. The aim of the modified parameters is to decrease cooling demand and energy usage resulting from the glazing in the glazed balconies. Each parameter performed differently in each balcony type. However, shading the 2/3rd of the glazing located on the western elevation was a common efficient parameter that recorded reduction in the cooling demand of all three models.

6.4.3 Comparing all results

In the three models studied in the previous sections, the space cooling for the whole models exceeded the US standards, since all scenarios recorded higher than 860 KWh monthly in the summer months; according to the US Energy Information Administration (Chart 6.4.7) (Bimenyimana, Osarumwense Asemota, Ihirwe, & Li, 2018; Stoy & Kytzia, 2006).

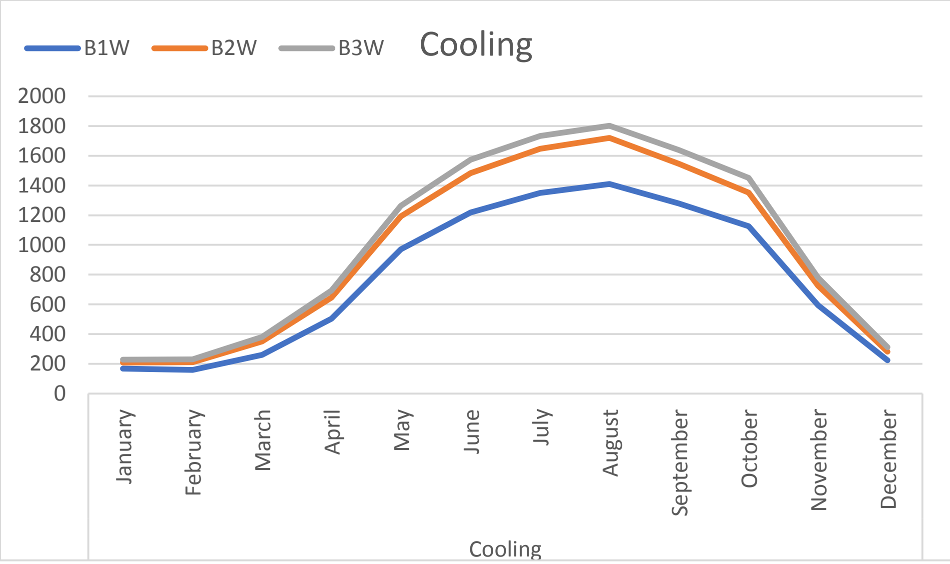


Chart 6.4.7. Space cooling for the three models (KWh), Source: Author

In the glazed spaces of the models; glazed balcony and the adjacent enlarged space, the cooling demand varied in each balcony type, by which some have higher cooling demand in adjacent space rather than in the glazed balcony and others vice versa.

Chart 6.4.8 indicates the cooling demand in the glazed spaces in the three models; B1W, B2W, and B3W.

In the summer months, the cooling demand of both spaces (glazed balcony and adjacent space) recorded highest demand for B1W (3829 KWh monthly in summer), and least cooling demand for B3W (1741 KWh) (Chart 6.4.8). The glazed spaces are using energy for cooling 4 times more than the US standard for the whole residential apartment.

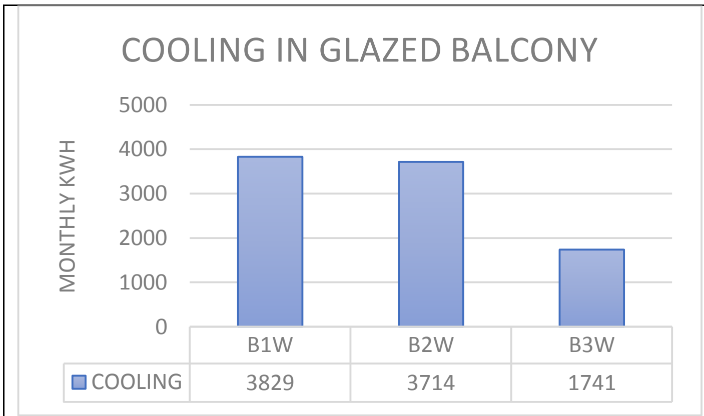


Chart 6.4.8. Cooling demand for glazed balcony and adjacent space, Source: Author

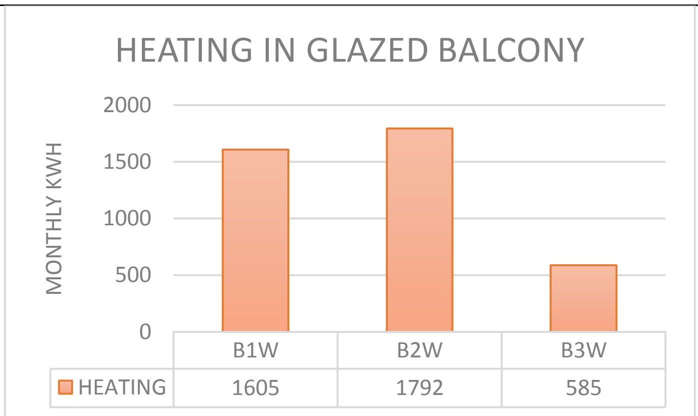


Chart 6.4.9. Heating demand for glazed balcony and adjacent space, Source: Author

Chart 6.4.9 indicates the heating demand for the glazed spaces in the three models. The chart indicates that the heating demand in the glazed spaces is relatively lower than the cooling by up to 2 times in the peak winter months.

This indicates that glazed spaces are efficient in the winter months more than in the summer months, especially the balcony surrounded by 3 walls structure (585 KWh), this is due to many reasons (Chart 6.4.9). Firstly, the thermal properties of the glazing used transmits heat and solar radiation which forms green-house effect in the glazed space; it is useful in the winter months in daytime but will cause excessive heat gain in the summer months and thus the increase of the cooling demand. Although it decreases the heating usage in winter months, it helps in the formation of molds in the structure and high humidity, which affects the structure.

Moreover, the cooling and heating demands are affected by the areas operated. As the area of the space increases, the energy usage increases in order to cover and achieve thermal comfort in all the space. This explains the high-energy usage in the three models compared to other scenarios (when the living area is not enlarged).

When modifying the parameters mentioned in the scenarios in order to decrease the energy demand, each model performed differently with each parameter, noting that the cost of implementation is disregarded in the thesis. Table 6.4.5 indicates the efficient parameters in each model. The most efficient and common parameter amongst all is the placement of the shading.

When placing shades on 2/3rd of the windows, all the models recorded high saving energy demand, unlike other parameters. This parameter also affects the direct vision and view to the outside. Adjusting the window-to-wall ratio in the models did not affect the energy use, and in some models, it slightly increased the demand. However, changing the rotation of the building by rotating the glazed spaces from west to north in these specific models did not have the highest efficient impact on the energy unlike the previous models.

Shading and replacing the single pane glazing by double low-e glazing efficiently reduced the demand and cost in all the models (Table 6.4.5). Nevertheless, when replacing the glazing alone without the placement of the shading, the decrease did not exceed the 2% on the total annual energy usage of the models.

	BASE/ year	ALT/ year	Cost Decrease	Cooling Decrease	Adjusted
B1W	$4,451	$4,044	407	2.60%	Shading
B2W	$4,303	$3,887	416	2.70%	Shading and Glazing
B3W	$4,461	$4,053	408	2.60%	Shading and Glazing

Table 6.4.5.Annual energy use in the base model and alternative model, Source: Author

Figure 6.4.3 indicates the reduced cost of energy usage per year in the three models when adjustments are applied. The most respondent model to the adjustments applied is the balcony surrounded by 2 walls model. The reduction was 416$ annually, 12480$ per 30 years disregarding the initial cost of implementation.

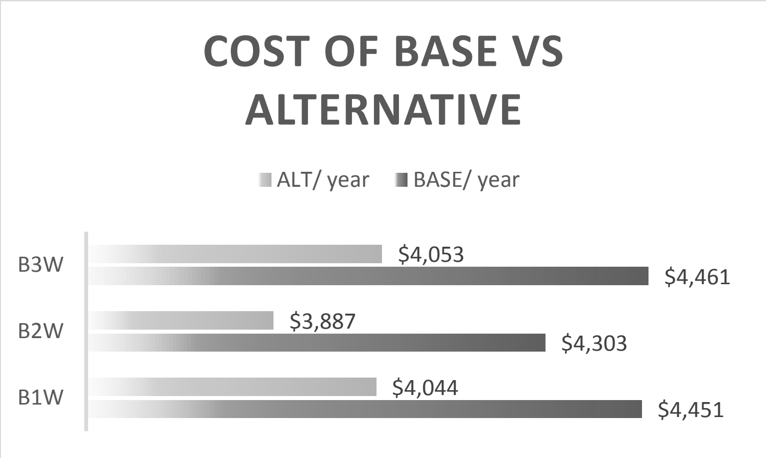


Figure 6.4.3.Annual energy use in the base model and alternative model, Source: Author

The models in this section were compared to each other indicating the most efficient and respondent model to the varied parameters. All models showed high recordings, even higher than previous models due to the increase in the area of cooled and heated spaces. The results of the models will be discussed and analyzed in order to answer the research question and aim of thesis.

6.4.4 Conclusion

This section described and analyzed thoroughly the results of enlarged glazed space in models B1W, B2W, and B3W. All models recorded high space cooling usage in the models, and especially in the enlarged spaces. The models underwent several modifications in the parameters in order to reduce the cooling usage, most of the models responded to the glazing and shading parameters that allowed a reduction of up-to 2.7% on cooling in the models. The recorded results will be further compared, analyzed and discussed amongst each other to deduce the impact of glazing and balcony type on cooling in the glazed spaces and adjacent spaces.

6.5 Discussion and Analysis

In the previous sections, all three models with three scenarios each were simulated, and results were praised. Accordingly, results will be further discussed. The following section will analyze and compare the results of cooling and energy usage in all balcony spaces of the three model. The second section will analyze the results of the previous models concerning the impact of glazed balconies on the adjacent spaces. The last section will provide projections that are capable in reducing the energy consumed on cooling in the spaces.

6.5.1 Balcony Space Analysis

This section will compare and analyze the cooling demand for the balcony space scenario in all the models; balcony surrounded by 1 wall, 2 walls, and 3 walls, when the balcony is glazed, and when the interior wall is removed, and the balcony space. The balcony spaces simulated are facing the sea with no shading or adjacent building affecting their performance. However, this scenario- amongst several scenarios- can be simulated in future studies to study the impact of adjacent buildings on the glazed balconies.

Chart 6.5.1 and Chart 6.5.2 indicate the cooling and heating demands in the balcony spaces. Firstly, balcony having a 1 wall structure (cantilevered) recorded highest cooling and heating demand in all scenarios. This is due to the exposure from 3 elevations, and the thermal characteristic of the glazing found in the 3 elevations allows poor insulation and excessive heat gain in the western elevation on the coast.

In contrary, balcony surrounded by 3 walls; having only 1 elevation overlooking the west, recorded the least cooling and heating demand.

The energy use and cost for cooling and heating in balcony surrounded by 1 wall and 2 walls structure each can reach up-to 2.3 times the energy usage of cooling and heating in the balcony surrounded by 3 walls per month.

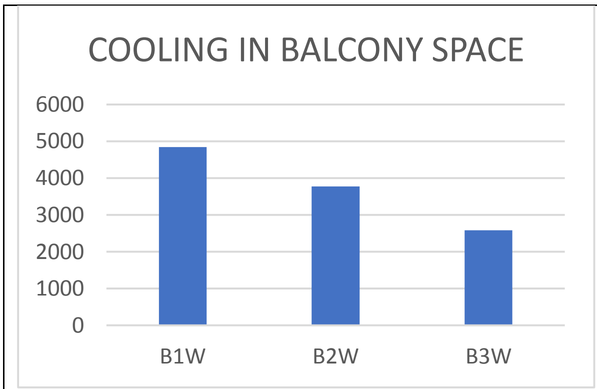


Chart 6.5.1. Cooling demand for the balcony space in the three balcony types (KWh), Source: Author

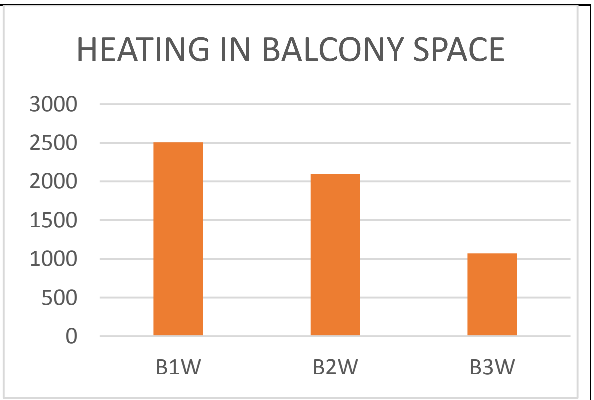


Chart 6.5.2.Heating demand for the balcony space in the three balcony types (KWh), Source: Author

Moreover, Chart 6.5.3 and Chart 6.5.4 indicated that the cooling and heating demands when the balcony is glazed (100) and when the balcony is glazed and adjacent space is enlarged

(300), recorded relatively high demand compared to when the balcony is not glazed (200) in all models.

The cost of the energy demand in the glazed and enlarged space models (100 and 300) is 1.5 times the energy demand of the balcony models per month.

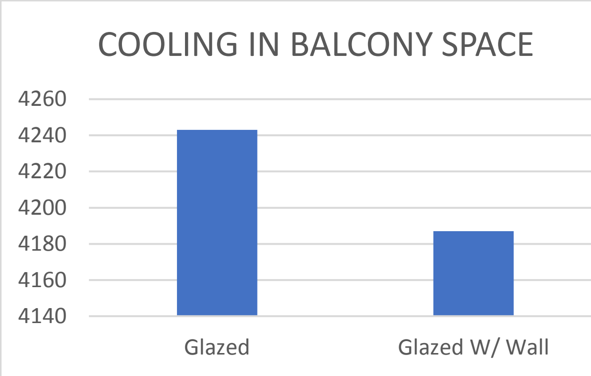


Chart 6.5.3.Cooling demand for the balcony space in the three scenarios of different balcony types (KWh), Source: Author

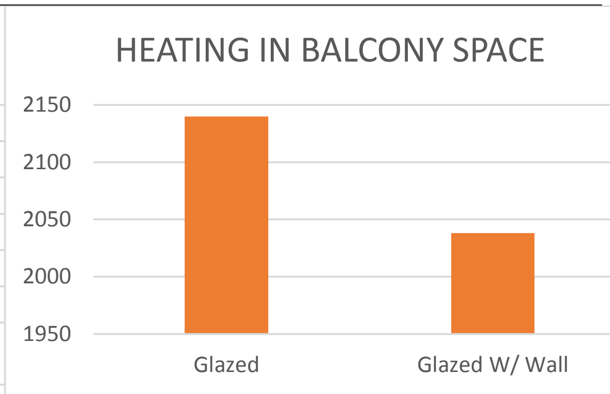


Chart 6.5.4. Heating demand for the balcony space in the three scenarios of different balcony types (KWh), Source: Author

Accordingly, the models with the highest cooling demand are when the scenarios have a balcony with 1 wall structure and when the balcony is glazed, and the adjacent space is enlarged.

Chart 6.5.5 indicated the cooling demand for the 3 scenarios; balcony, glazed balcony, and glazed balcony with enlarged space, in the three balcony structures B1W, B2W and B3W. The chart aims to compare the scenarios (100, 200, and 300) with respect to the balcony types (B1W, B2W, and B3W). The cantilevered balcony model having enlarged glazed balcony recorded the highest cooling demand amongst all per month (B1W-300: 1469KWh). The mentioned recording is 1.7 times greater than the US cooling demand standard for the whole apartment (860 KW per month) (Bimenyimana, Osarumwense Asemota, Ihirwe, & Li, 2018; Stoy & Kytzia, 2006).

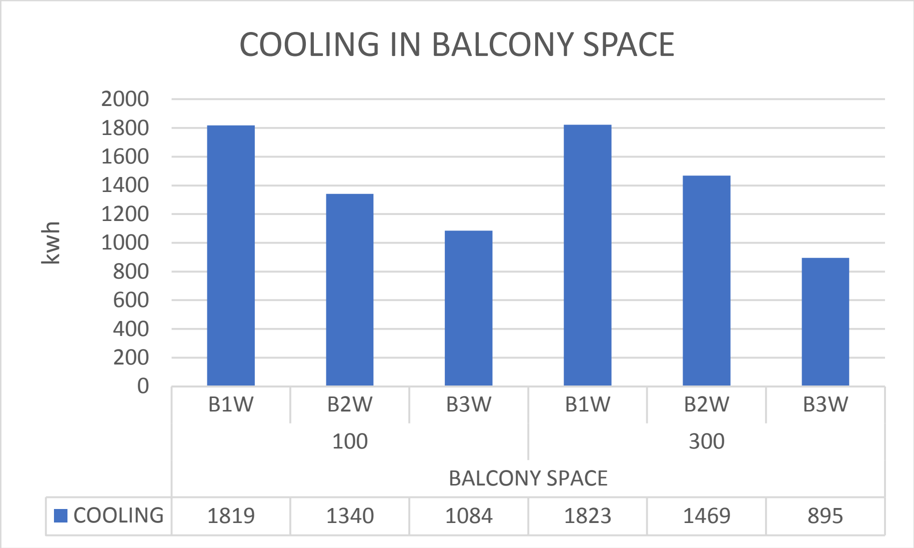
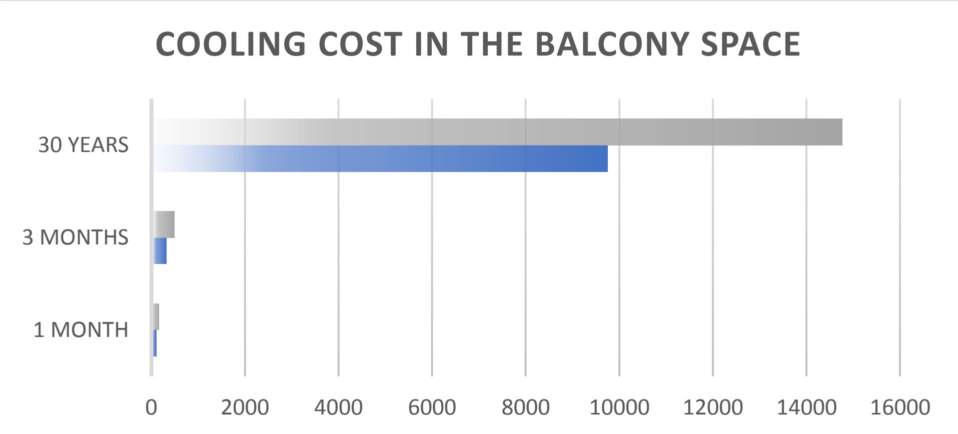


Chart 6.5.5.Cooling demand to all balcony spaces in the 3 models in the three scenarios, Source: Author

Moreover, model B1W-100, showed similar results to B1W-300. Noting that the only difference between scenarios 100 and 300 is the wall removal; scenario 300 is almost double the area of 100 whereas scenario 100 only include the cooling in the glazed balcony.

This explains that the impact of the cooling demand is not the enlarged space (the bigger the area that needs to be cooled the more the cooling demand), but the glazing area and balcony type. Having bigger glazing ratio; 3 elevations, led to the increase in the demand compared to other models. Since the only difference between B1W-100 and B1W-200 is the glazing on the balcony, thus the glazing can lead to a significant increase in cooling in the interior spaces. The mentioned data corroborates with the literature that clearly states the relation of glazing with the increase in energy consumed (2.4.1).

By comparing the scenario B1W-300 with the same balcony structure but without the balcony enclosure B1W-200, an increase of 151% in cooling demand and energy cost in the balcony space, having a difference of up-to 5000 USD in 30 years only in the balcony space.



	1 MONTH	3 MONTHS	30 YEARS
B1W 300	164.07	492.21	14766.35
B1W 200	108.27	324.87	9746

Chart 6.5.6.The difference in cost (USD) between the scenarios B1W-300 and B1W-200 in 1 month, summer season (3months), and 30 years, Source: Author

In conclusion, the balcony spaces in the models simulated proved the relation of glazing ratio and area on the cooling demand and declined the relation of the operated area of space with cooling demand. Therefore, the balcony surrounded by 1 wall recorded the highest demand amongst all due to the highest glazing ratio in the western orientation.

6.5.2 Adjacent Space Analysis

The following section will compare and analyze the cooling demand for the space adjacent to the balcony in all scenarios in order to identify the effect of the glazing trend on the energy usage in the adjacent space.

Chart 6.5.7 and Chart 6.5.8 indicate the total cooling and heating demand respectively to the space adjacent to the glazed balcony in the 3 balcony types; balcony surrounded by 1 wall, 2 walls, and 3 walls, in order to indicate the impact of balcony type on the adjacent space. According to Chart 6.5.7 and Chart 6.5.8, the cooling and heating demand in the adjacent space is at its highest in the cantilevered balcony structure (B1W). Having a space adjacent to a cantilevered balcony can consume up-to 1.7 times on cooling than the balcony surrounded by 2 walls, and up-to 1.6 times than the balcony surrounded by 3 walls. The higher the glazing area, the higher the effect not only on the glazed space but on the adjacent space too.

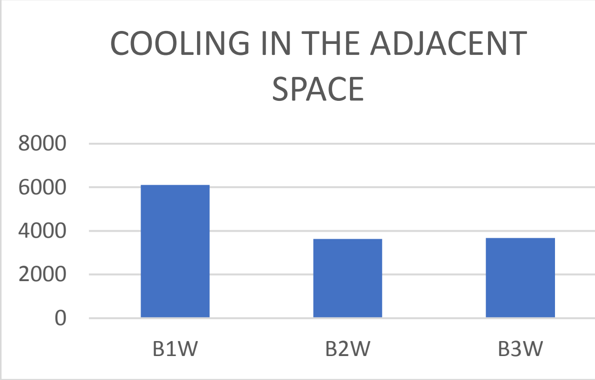


Chart 6.5.7.Cooling demand in the space adjacent to the glazed balcony in the three balcony types, Source: Author

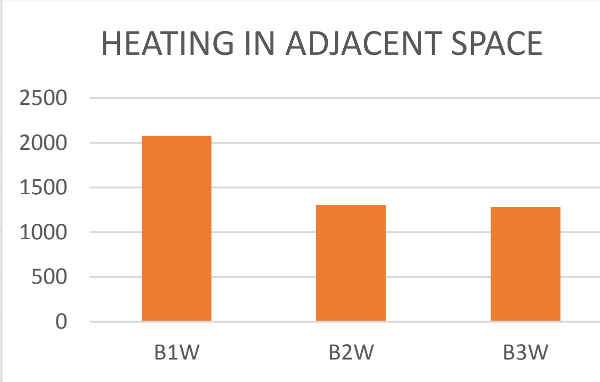


Chart 6.5.8. Heating demand in the space adjacent to the glazed balcony in the three balcony types, Source: Author

However, Chart 6.5.9 and Chart 6.5.10 indicate the total cooling and heating demands respectively of the different scenarios 100, 200, and 300, in order to indicate the impact of scenarios on the cooling demand, and the impact of the glazed balcony on the adjacent spaces. The highest space cooling and heating of the adjacent spaces are when the balcony is not glazed (scenarios 200: B1W-200, B2W-200, and B3W-200), secondly when the balcony is glazed (scenarios 100: B1W-100, B2W-100, and B3W-100), and finally, the least demand is when the balcony is glazed, and the space is enlarged (scenarios 300: B1W-300, B2W-300, and B3W-300).

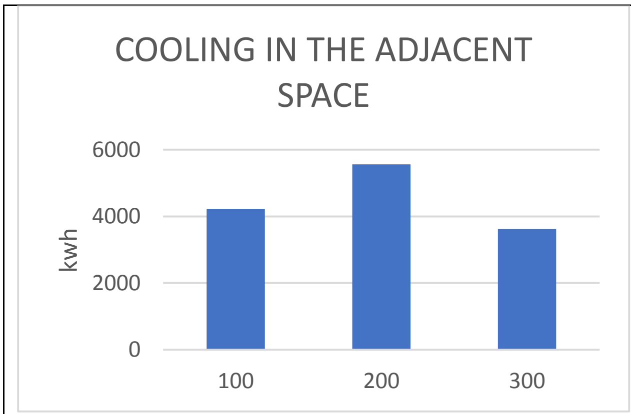


Chart 6.5.9.Cooling demand in the space adjacent to the glazed balcony in the three scenarios, Source: Author

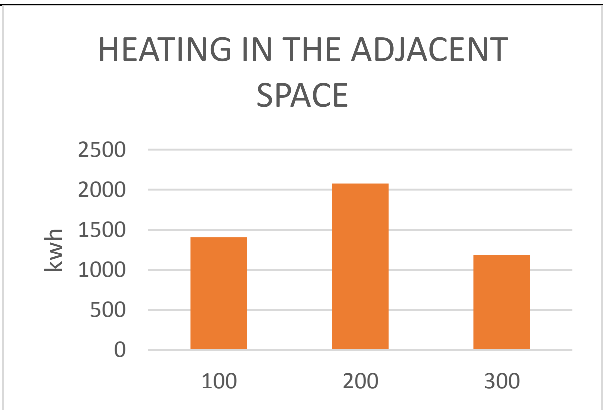
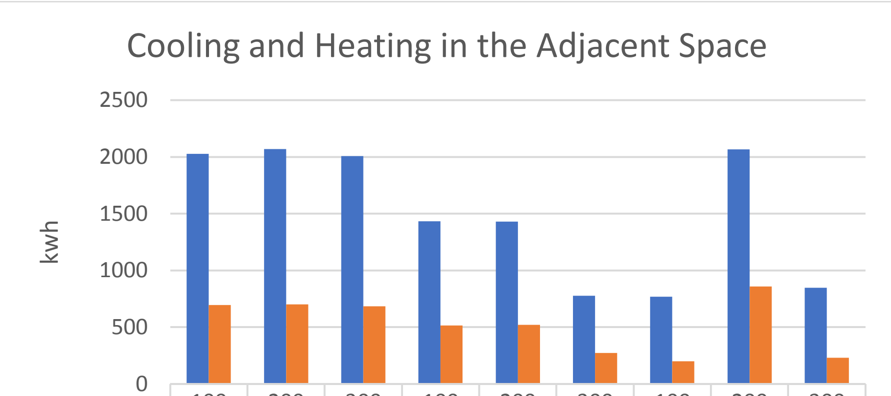


Chart 6.5.10.Heating demand in the space adjacent to the glazed balcony in the three scenarios, Source: Author

This indicates the difference in the performance and effect of the different glazing scenarios on the adjacent space.

A glazed balcony can perform efficiently when it is separated from the adjacent space. When the glazed balcony is separated from the adjacent space, a buffer zone between the outdoor environment and the adjacent space is formed. This buffer zone allows minimum heat exchange between the outdoor and the adjacent space in the summer and winter. In summer, it minimizes the direct solar radiation and direct heat exchange, and accordingly reduces cooling demand by 1.3 times from when the balcony is not glazed. In winter, it creates a greenhouse effect and reduces the heating demand in the adjacent space by 1.3 times from when the balcony is not glazed.

The glazed balcony in both scenarios 100 and 300 proved to decrease the cooling demand in the adjacent space compared to when the balcony is not glazed.



	B1W			B2W			B3W		
	100	200	300	100	200	300	100	200	300
COOLING	2026	2070	2006	1432	1429	776	767	2065	846
HEATING	696	701	683	513	519	272	198	857	229

Chart 6.5.11. Cooling and heating demand in all models, Source: Author

Chart 6.5.11 indicates that the cantilevered model having a balcony that is not glazed (B1W-200) recorded the highest cooling demand amongst all models; 2070 KWh which is 2.4 times higher than the accepted US standard calculated for the whole residential apartment per month (860 KWh) (Bimenyimana, Osarumwense Asemota, Ihirwe, & Li, 2018; Stoy & Kytzia, 2006). This is because there is no buffer zone that separates the excess heat from the interior space like other scenarios having glazed balconies.

To elaborate on the impact of glazed balcony on the adjacent space, Chart 6.5.12 indicates the difference between the cooling cost of B1W-200 with B3W-100; balcony VS glazed balcony on the impact of adjacent space. The comparison is between the highest cooling demand VS lowest cooling demand in the adjacent space. B1W-200 recorded an increase of 10554 USD in 30 years in the cantilevered balcony than the other model.

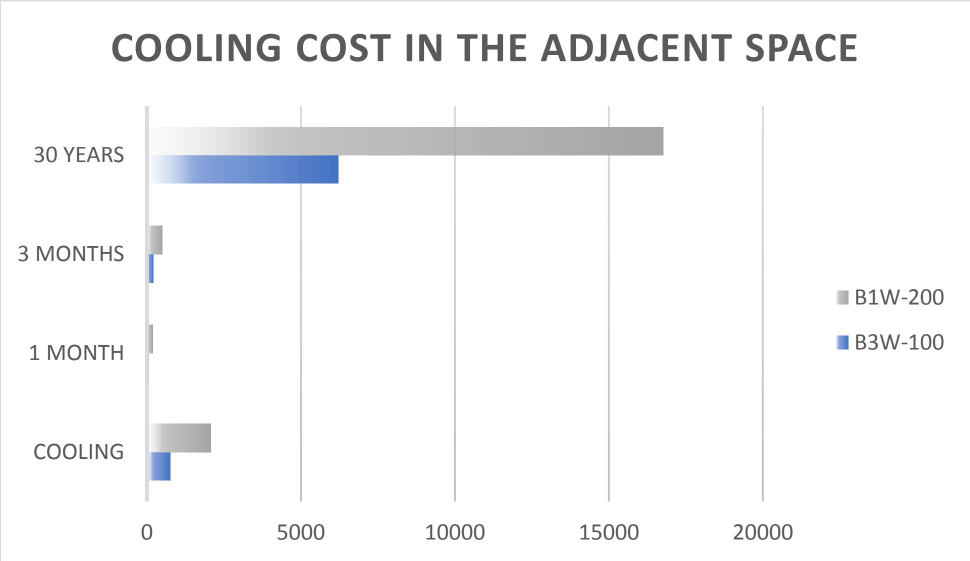


Chart 6.5.12.Difference in cost (USD) between the scenarios B1W-200 and B3W-100 in 1 month, summer season (3months), and 30 years in the adjacent space, Source: Author

When comparing B1W-200 with B1W-300 (Chart 6.5.13), minimal reduction was recorded; 519USD in 30 years. This proves that not only the glazing type affects the cooling in the adjacent space, but the balcony type and glazing area is the most important factors.

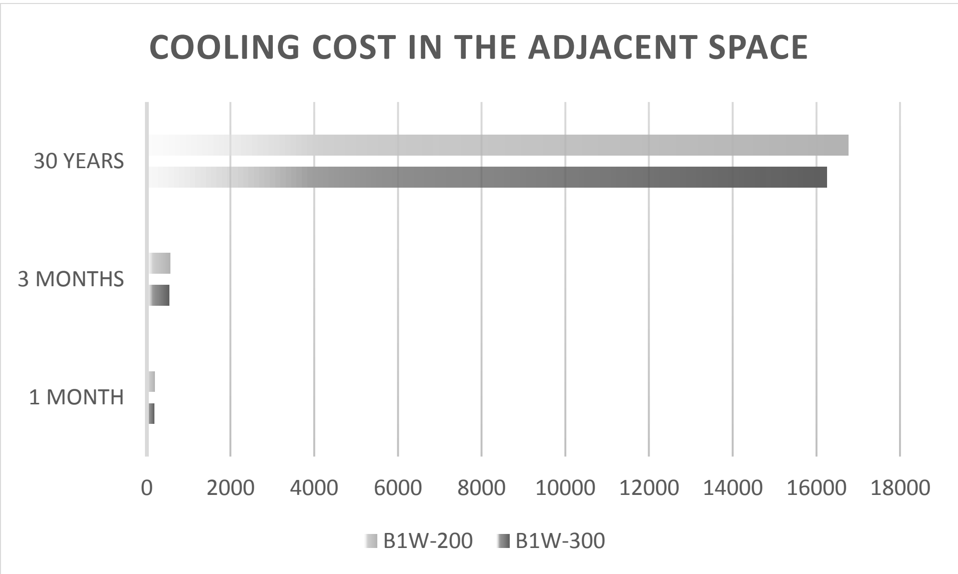


Chart 6.5.13.Difference in cost (USD) between the scenarios B1W-300 and B1W-200 in 1 month, summer season (3months), and 30 years in the adjacent space, Source: Author

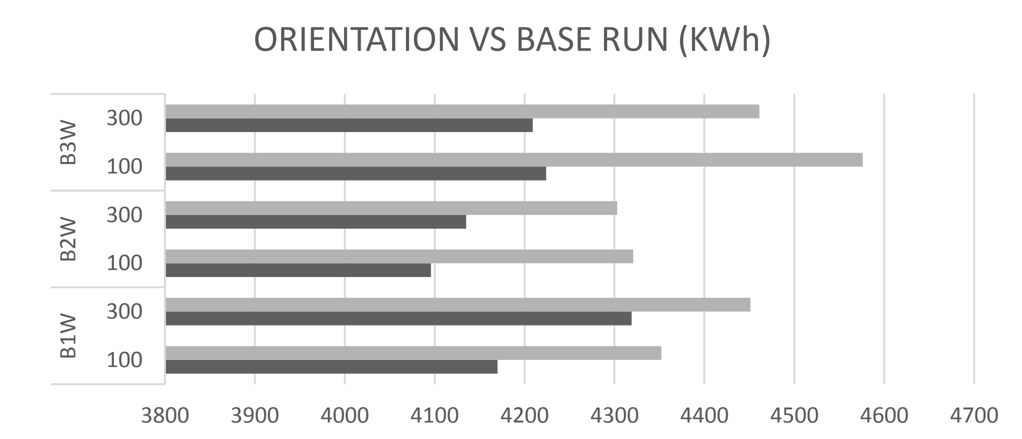
The glazing showed effective and efficient recording on the adjacent spaces to the glazed balconies. Having a glazed balcony and separated from the interior is the most efficient method that reduces heating and cooling usage in all months.

6.5.3 Alternative Adjustment Analysis

The simulated models and scenarios recorded high-energy usage, therefore, parameters were modified and adjusted in order to compare with the base models and identify the efficient parameter.

The scenarios underwent several parameters that were found efficient in the literature review. Firstly, the orientation of the glazing was adjusted. According to the charts exported from Insight360, rotating the building 90 degrees; orienting the glazed balconies facing the north rather than the west, can reduce the energy consumed. This is because the western elevation has the highest solar radiation amongst the day and especially in the summer months.

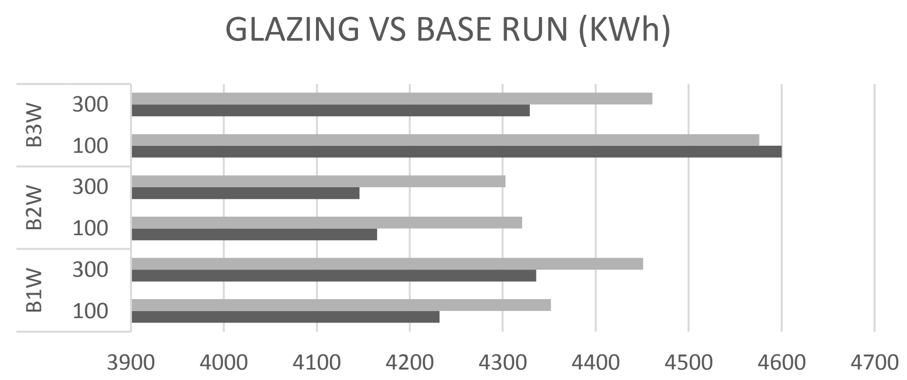
Chart 6.5.14 indicates the reduced ratio between the north orientation and the west orientation. All models showed significant reduction having the most respondent scenario is B3W-100 with a reduction of 352 KWh per year compared to the base model of B3W-100 when the balconies are oriented to the west.



	B1W		B2W		B3W	
	100	300	100	300	100	300
BASE RUN	4352	4451	4321	4303	4576	4461
ROTATION	4170	4319	4096	4135	4224	4209

Chart 6.5.14.The reduction occurred when changing the orientation of the models with respect to the base model per (KWh), Source: Author

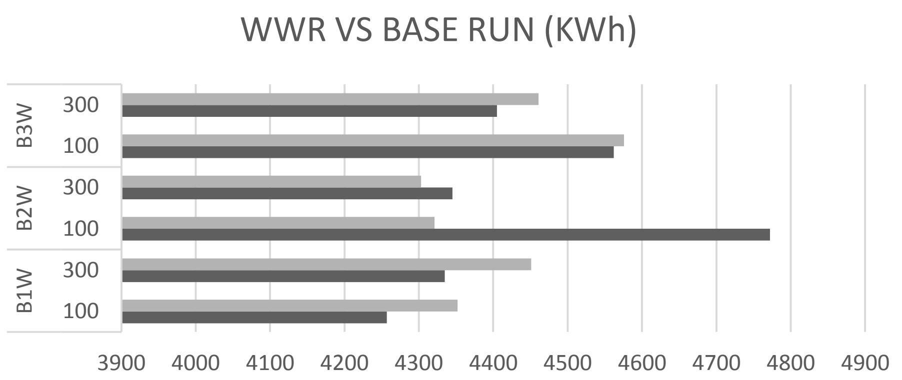
The second parameter tested is replacing the single 6mm single pane glazing with low-e hot climate glazing. The low-e glazing has a lower U-value than the glazing used in the area. Therefore, adjusting the glazing can decrease the heat exchange and thermal bridging between the exterior and the glazed balcony space. According to Chart 6.5.15, the scenario that highly responded to the glazing replacement is B2W-300 with a reduction of 157 KWh compared to the base model.



	B1W		B2W		B3W	
	100	300	100	300	100	300
BASE RUN	4352	4451	4321	4303	4576	4461
GLAZING	4232	4336	4165	4146	4600	4329

Chart 6.5.15. The reduction occurred when replacing the glazing of the models with respect to the base model per (KWh), Source: Author

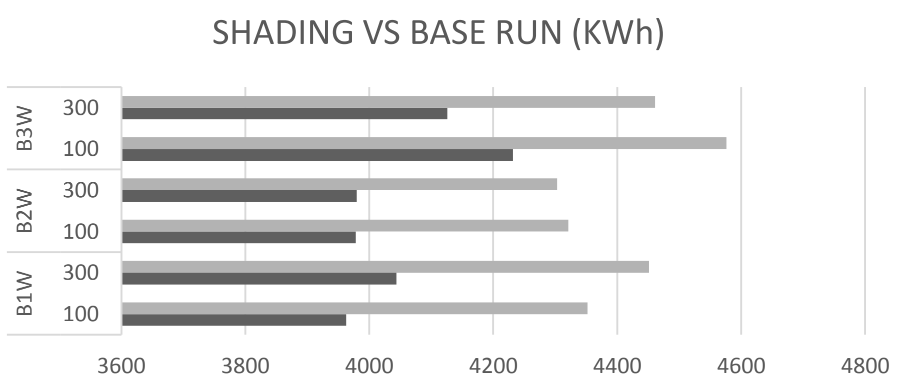
The parameter window-to-wall ratio was also tested, knowing the importance of glazing ratio on energy consumed. The window-to-wall ratio was reduced to 30% in the western elevation rather than having the elevation fully glazed. However, according to Chart 6.5.16, minimal reduction occurred in this parameter, having B1W-300 the most respondent to the reduction (116KWh). This explains that the ratio of glazing does not affect the energy consumed in the glazed spaces.



	B1W		B2W		B3W	
	100	300	100	300	100	300
BASE RUN	4352	4451	4321	4303	4576	4461
WWR	4257	4335	4772	4345	4562	4405

Chart 6.5.16.The reduction occurred when adjusting the window-to-wall ratio of the models with respect to the base model per (KWh) , Source: Author

The final parameter adjusted that showed importance in reduction of energy in the literature review was the installation of the shading. The models underwent installing shading on 2/3rd of the windows in the western elevation in all the scenarios. Chart 6.5.17 indicated the annual reduction of energy consumed between the modified models and the base model. The reduction in KWh occurred in all models, having B1W-300 the most respondent model to reduction amongst all (a reduction of 407 KWh).



	B1W		B2W		B3W	
	100	300	100	300	100	300
BASE RUN	4352	4451	4321	4303	4576	4461
SHADING	3963	4044	3978	3980	4232	4126

Chart 6.5.17. The reduction occurred when placing the shading on the models with respect to the base model per (KWh), Source: Author

The models responded differently to each parameter adjusted. Nevertheless, according to Chart 6.5.18, the most efficient parameter that obtained the highest annual energy reduction in all scenarios of the 3 models is the placement of shading. Shading recorded the highest reduction amongst all parameters, then glazing, orientation, and window-to wall ratio respectively. However, shading installation and glazing replacement are two parameters that can be modified in existing buildings in the studied area.

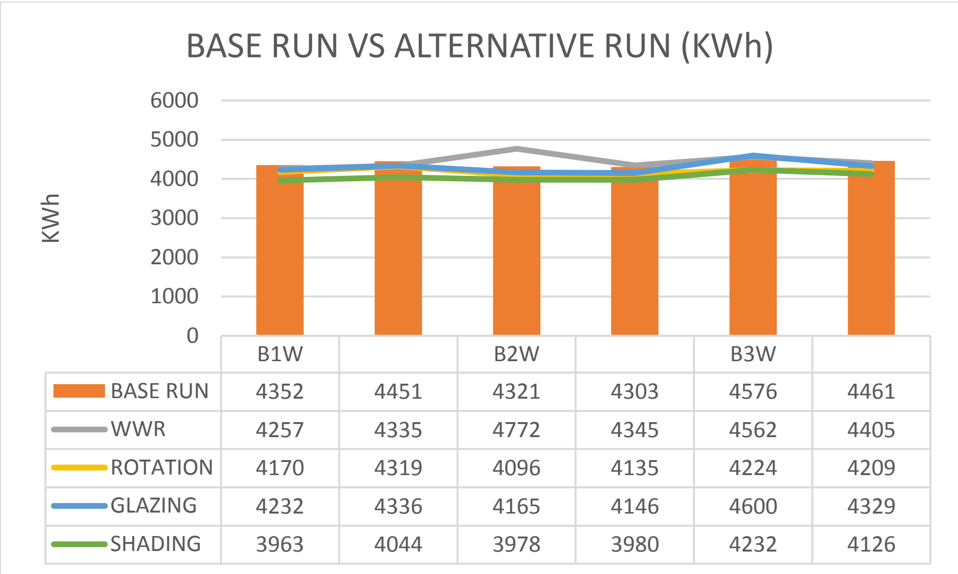
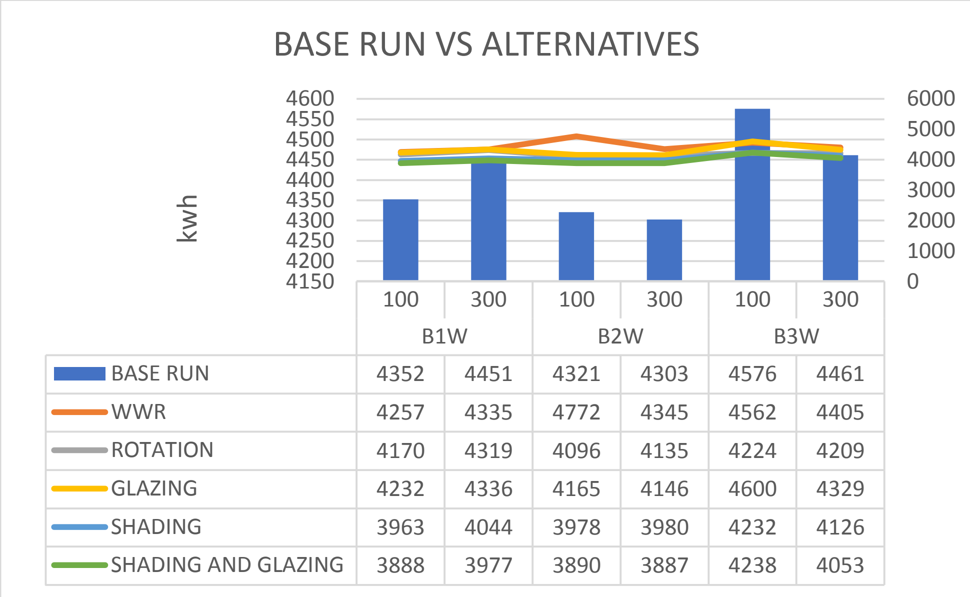


Chart 6.5.18. Annual reduction of several parameters in relation to the base model (KWh), Source: Author

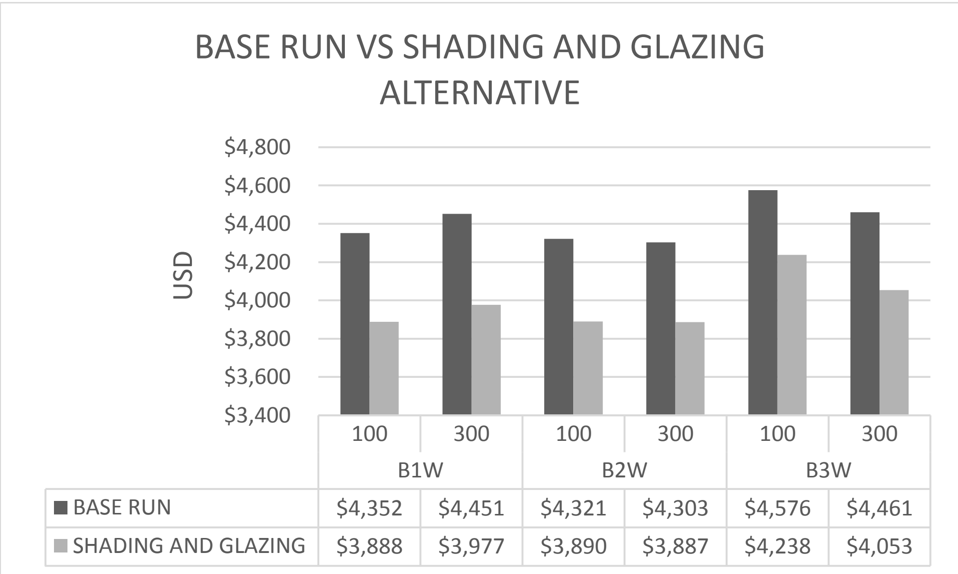
When applying shading on 2/3rd of the windows, and changing the glazing type to low-e, Chart 6.5.19 recorded the highest reduction occurred. The adjustment of shading and glazing proved efficient and highest reduction in cost and energy consumed in all the models.



	B1W		B2W		B3W	
	100	300	100	300	100	300
BASE RUN	4352	4451	4321	4303	4576	4461
WWR	4257	4335	4772	4345	4562	4405
ROTATION	4170	4319	4096	4135	4224	4209
GLAZING	4232	4336	4165	4146	4600	4329
SHADING	3963	4044	3978	3980	4232	4126
SHADING AND GLAZING	3888	3977	3890	3887	4238	4053

Chart 6.5.19. Annual reduction of shading and glazing together in compared to other parameters (KWh), Source: Author

According to Chart 6.5.20, the simulated parameters; shading and glazing recorded significant reduction in the cost; up-to 500 USD annually, 15000 USD per 30 years.



	B1W		B2W		B3W	
	100	300	100	300	100	300
BASE RUN	$4,352	$4,451	$4,321	$4,303	$4,576	$4,461
SHADING AND GLAZING	$3,888	$3,977	$3,890	$3,887	$4,238	$4,053

Chart 6.5.20.Annual reduction in the glazed scenarios when adjusting the shading and glazing (KWh), Source: Author

Adjusting the shading and glazing type proved to reduce up-to 10% annually in terms of cost and energy consumption.

In conclusion, many alternatives can be projected in order to reduce the energy consumption in the glazed spaces. Placing shading devices and replacing the glazing type is one method. However, the shading is a wide technology that has several concepts and characteristics; whether movable, static, horizontal, and vertical. Therefore, considering several types of shading in the future work on glazed balconies in the coast of Lebanon would be interesting. Nevertheless, architects and contractors should be aware of the impact of glazing in several aspects in the building (glazing type, window-to-wall ratio, and orientation) in order to design efficient buildings that abide by the climate of context rather than introducing alternatives to the building.

6.6 Conclusion

The glazed balconies perform differently in each scenario. By examining the three models and the three developed scenarios, it is noted that the balcony type and glazing area has a major impact on the energy consumed on cooling in the spaces. As the glazing area and exposure to the environment ratio increases, the need for cooling increases. This explains why the balcony surrounded by 1 wall recorded the highest cooling demand in the summer months. Although the glazed balcony resulted in high energy usage, when separated from the adjacent space it performs efficiently. The glazed balcony when separated from the adjacent living spaces creates a buffer zone and thus reduces the usage of cooling in the summer months in the adjacent space, whereas the glazed balcony records high-energy usage.

The glazed balcony improves the performance of the adjacent spaces more than when the balcony is not glazed (1.3 times less). Moreover, the material of the glazing used in the buildings should be suitable for the climate put in. The U-value of the material used should be considered in the early phases in order to decrease the heat exchange and improve the thermal comfort.

Briefly, the spontaneous trend of glazed balconies directly affects the cooling demand depending on the interior wall separation and balcony type. If to reduce the cooling demand, the placement of shading and low-e glazing can efficiently decrease down to 10% of the annual cooling demand -from the heat pump (mini split wall-deco unit) with alternator compressor- disregarding the initial cost of implementation.

7. Projections and Conclusions

This chapter summarizes the findings and offers projections for the glazed balconies in the "Corniche El Baher" area of the Lebanese coastal zone and Lebanese sea fronts. It seeks to answer the research questions raised in the thesis that could be set as a benchmark for the sea fronts of Lebanon with similar characteristics. Several methodologies were implemented in order to understand the impact of glazing on the cooling demand, the impact of the balcony type on glazed balconies, and the impact of glazed balconies on the adjacent space. The research type applied in the thesis is verifying by simulation. In order to answer the research questions, several simulations underwent using architectural software that estimate energy consumed.

Upon the simulations underwent, it was clear that the chaotic trend of glazed balconies performs differently depending on the climate, orientation, balcony type, and glazing type.

Through the recordings of the simulations and data analysis, it is indicated that the building material used in the "Corniche El Baher" area is not applicable for the climate of the area. The material allows excessive heat gains in the residential buildings due to the high U-value material, mainly glazing. Moreover, the orientation of the placement and area of glazing does not favor the indoor thermal comfort. These factors result in excessive electric operation, especially cooling to compensate the discomfort resulting from the glazing.

In the glazed balconies, the balcony type and area of glazing exposure directly affect the energy consumed on cooling. The glazed cantilevered balcony proved to record the highest cooling demand amongst all balconies. The less the walls surrounding the balcony structure, the higher the energy consumed on cooling.

The simulations also proved that there is no direct relation between the operational cooling and the area of the space need to be cooled. This is because when the interior wall separating the balcony from the adjacent space is removed, the cooling demand did not increase, whereas when the area of the glazing increased, the cooling demand increased.

However, the space adjacent to the glazed balcony consumes less cooling demand that the space adjacent to a balcony. This explains the formation of the buffer zone between the adjacent space and glazed balcony that decreases the heat transfer to the interior spaces. When comparing the three scenarios: balcony, glazed balcony, and glazed balcony with wall removal, the highest cooling consumed is in the adjacent space to the balcony.

The thesis indicated the importance of the effect of the balcony type on the cooling demand, which is minimal in the literature review and elaborated on the local spontaneous glazing trend.

Several projections and alternatives were introduced in order to decrease the energy consumed in existing buildings by which the instalment of shading recorded the highest decrease.

However, the shading technology was not elaborated in the thesis due to the focus of the thesis. It would be interesting for further future work to experiment the effect of different shading technologies on the glazed balconies and cooling demand. Moreover, the initial cost of the installed shading devices compared to the cost in reduction of cooling could also be researched, in addition to the impact of shading on the vision to the outside.

Moreover, the thesis only focused on the glazing material of the glazed balcony disregarding the glazing frame. The frame of the glazing directly affects the heat transfer in the interior space that would also be suggested as a further research study.

This research proved the impact of glazed balconies and indicated the efficient and inefficient scenarios by simulation and validation.

The thesis can be used as a benchmark that assesses the impact of glazed balconies in the sea fronts having similar climate characteristics and facing the western orientation.

Bibliography

(2017). Credit Libaais Annual Report.

Aagaard, J., & Matthiesen, N. (2016). Methods of Materiality: Participant Observation and Qualitative Research in Psychology. *Qualitative Research in Psychology, 13*(1), 33-46.

Ai, Z., Mak, C., Niu, J., & Li, Z. (2011). Effect of balconies on thermal comfort in wind-induced, naturally ventilated low-rise buildings. *Building Services Engineering Research and Technology*, 277-292.

Ai, Z., Mak, C., Niu, J., Li, Z., & Zhou, Q. (2010). Effect of balconies on the ventilation performance of lowrise buildings. *Indoor and Built Ennvironment*.

Akbeiber, H. (2016). A review on phase change material for sustainable passive cooling in building envelopes. *Renewable and Sustainable Energy*, 1470-1497.

Al-Hosany, & Khalifah, N. (2002). Sustainable facade design and virtue in incarceration architecture :the case of prison buildings in Abu Dhabi.

Alhuwayil, W. K. (2019). Impact of external shading strategy on energy performance of multi-story hotel building in hot-humid climate. *Energy, 169*, 1166-1174. doi:10.1016/j.energy.2018.12.069

Ali, M. (2013). *Factors of Sustainability Assessment.* doi:https://doi.org/10.1016/C2012-0-02851-7

Almarzouq, A. (2019). Effects of glazing design and infiltration rate on energy consumption and thermal comfort in residential buildings. *Thermal Science, 23*(5), 2951-2960. doi:10.2298/TSCI170910073A

Alwetaishi, M. (2015). Human Thermal Comfort and Building Performance of Schools in Hot and Humid Climate with a Particular Reference to Saudi Arabia. *Jeddah Nottingham University*.

Alwetaishi, M. (2019). Impact of glazing to wall ratio in various climatic regions: A case study. *Journal of King Saud University- Engineering Sciences, 31*(1), 6-18.

Andelkovic, A., Mujan, I., & Dakic, S. (2016). Experimental val-idation of a EnergyPlus model: Application of a multi-storey natu-rally ventilated double skin façade. *Energy and Buildings*, 27-36.

Annan, G., Ghaddar, N., & Ghali, K. (2014). Natural ventilation in Beirut residential buildings for Extended Comfort Hours. *International Journal of Sustainable Energy*, 996-1013.

Apte, M., & Wu, X. (2012). Ventilation, temperature, and HVAC characteristics in small and medium commercial buildings in California. *Indoor Air, 22*(4), 309-320.

Armstrong, R. (2012). Living architecture: how synthetic biology can remake our cities and reshape our lives.

Asdrubali, F., & Baldinelli, G. (2011). Thermal transmittance measurements with the hot box method: calibration, experimental procedures, and uncertainty analyses of three different approaches. *Energy and Buildings, 43*(7), 1618-1626.

Asdrubali, F., D'Alessandro, F., & Schiavoni, S. (2015). A Review of Unconventional Sustainable Building Insulation Materials. *Sustainable Material and Technology, 4*, 1-17.

ASHRAE. (2004). Thermal environmental conditions for human occupancy. *American Society of Heating, Refrigerating and Air-Conditioning Engineers*.

Asmar, J.-P. E., & Taki, A. (2014). Sustainable rehabilitation of the built environment in Lebanon. *Sustainable Cities and Society, 10*, 22-38. doi:10.1016/j.scs.2013.04.004

Assaad, D. A., Habchi, C., Ghali, K., & Ghaddar, N. (2018). Simplified model for thermal comfort, IAQ and energy savings in rooms conditioned by displacement ventilation aided with transient personalized ventilation. *Energy Conversion and Management*, 203-217.

Aydin, N. Y. (2013). GIS-based site selection methodology for hybrid renewable energy systems: A case study from western Turkey. *Energy Conversion and Management, 70*, 90-106. doi:10.1016/j.enconman.2013.02.004

Azmy, N. Y., & Elghamry, R. (2018). Effect of the Window Position in the Building Envelope on Energy Consumption.

Azmy, N., & Elghamry, R. (2018). Effect of the Window Position in the Building Envelope on Energy Consumption. *International Journal of Engineering & Technology, 7*(10).

Baty, J. (2005). Energy Efficient Solution. *Concrete Concepts*, 20-23.

Beesley, P. (2006). Responsive architectures: subtle technologies . *Riverside Architectural Press*.

Bimenyimana, S., Osarumwense Asemota, G., Ihirwe, P., & Li, L. (2018). Clustering Residential Electricity Consumption: A Case Study. *International Conference on electronics and electrical engineering technology* (pp. 44-51). Tianjin China: Association for Computing Machinery.

Bokel, R. (2007). The effect of window position and window size on the energy demand for heating, coolingm and electric lighting. *Building Simulation, 10*.

Bsat, A., & Ghaddar, N. (1998). Energy conservation of residential buildings in Beirut.

Chan, A., & Chow, T. (2014). Calculation of overall thermal transfer value (OTTV) for commercial buildings constructed with naturally ventilated double skin façade in subtropical Hong Kong. *Energy and Building*, 14-21.

Chappells, H., & Shove, E. (2005). Debating the Future of Comfort : Enironmental Sustainablity, Energy Consumption, and the Indoor Environment. *Building Research and Environment, 33*(1), 32-40.

Chedid, R. B., & Ghajar, R. (2004). Assessment of Energy Efficiency Option in the Building Sector of Lebanon. *Energy Policy*, 647-655.

Chedid, R., Chaaban, F., & Salameh, S. (2001). Policy analysis of greenhouse gas emissions: The case of the Lebanese electricity sector. *Energy Conversion and Management*, 373-392.

Chowdhury, D. (2019). Thermal performance evaluation of traditional walls and roof used in tropical climate using guarded hot box. *Construction and Building Material, 218,* 73-89. doi:10.1016/j.conbuildmat.2019.05.032

Cinzia, B., Linda, B., & Elisa, M. (2012). Application of artificial neural network to predict thermal transmittance of wooden windows. *Applied Energy, 98,* 425-432.

Clerici, A. (2013). *Worl Energy Recources Survey.* London: World Energy Council .

Costa, A., Keane, M., & Corry, E. (2013). Building operation and energy performance: monitoring, analysis and optimization toolkit. *Applied Energy, 101,* 310-316.

Countries: Lebanon . (2019, May 17). Retrieved from World Population Review: http://worldpopulationreview.com/countries/lebanon-population/cities/

Cui, D., Mak, C., & Niu, J. (2013). Effect of balconies and upper-lower vents on ventilation and indoor air quality in a wind-induced, naturally ventilated building. *Building Services Engineering Research and Technology*.

Department, E. a. (2016). *Hong Kong Energy End-Use Data.*

Djamila, H. (2017). Indoor thermal comfort predictions: Selected issues and trends. *Renewable and Sustainable Energy Reviews*, 569-580.

Du, J., Chan, M., Pan , D., Shang, L., & Deng, S. (2016). The impacts of daytime external envelope heat gain/storage on the nighttime cooling load and the related mitigation measures in a bedroom in the subtropics. *Energy and Buildings*, 70-81.

Eftekhari, M. (1998). Natural ventilation: Impact of Wall Material and Windows on Thermal Comfort. *Building Services Engineering Research and Technology 19*, 43-47.

Egwunatum, S., Joseph-Akwara, E., & Akaigwe, R. (2016). Optimizing energy consumption in building designs using Building Information Model (BIM). *Slovak Journal of Civil Engineering*, 19-28.

ElDallal, N., & Florentine, V. (2017). A climate responsive urban design tool: a platform to improve energy efficiency in a dry hot climate. *International Journal of Sustainable Energy*.

El-Katiri, L., & Fattou, B. (2015). Lebanon's Gas Trading Options. *The Lebanese Centerfor Policy Studies*.

Energy, U. D. (2012). *Buildings Energy Data Book.*

Escudier, M., & Atkins, T. (2019). A Dictionary of Mechanical Engineering (2 ed. *Oxford University Press*.

Fallahi, A., Haghighat, F., & Elsadi, H. (2010). Energy performance assessment of double-skin façade with thermal mass.

Faour, G. (2015). Evaluating Urban Expansion Using Remotely-Sensed Data in Lebanon. *Lebanese Science Journal, 16*(1), 23-32.

Faour, G., & Mhawej, M. (2014). Mapping Urban Transitions in the Greater Beirut Area Using. *Land*, *3*, 941-956.

Farnham, C., Emura, K., & Mizuno, T. (2015). Evaluation of cooling effects: Outdoor mist fan. *Building Research and Information, 43*(3), 334-345.

Fasi, M. A., & Budaiwi, I. M. (2015). Energy performance of windows in office buildings considering daylight integration and visual comfort in hot climates. *Energy and Buildings, 108*, 307-316. doi:10.1016/j.enbuild.2015.09.024

Ge, H., McClung, V., & Zhang, S. (2013). Impact of balcony thermal bridges on the overall thermal performance of multi-unit residential buildings: A case study.

Ghabra, N., Rodrigues, L., & Oldfield, P. (2017). The impact of the building envelope on the energy efficiency of residential tall buildings in Saudi Arabia. *International Journal of Low-Carbon Technologies*.

Ghaddar, N., & Bsat, A. (1998). Energy Conservation of Residential Buildings in Beirut. *Fuel and Energy Abstracts*.

Gibbs, L., Kealy, M., Willis, K., & Green, J. (2007). What Have Sampling and Data Collection got to do With Good Qualitative Research? *Australian and New Zealand Journal of Public Health, 31*(6), 540-544.

Goia, F. (2016). Search for the optimal window-to-wall ratio office buildings in different European climates and the implications on total energy saving potential. *Solar Energy, 132*, 467-492.

Govindaraju, V., & Tang, C. (2013). The dynamic links between CO2 emissions, economic growth and coal consumption in China and India. *Applied Energy, 104*, 310-318.

Grosso, A. E., & Basso, P. (2010). Adaptive Skin Structures.

Grudzinska, M. (2016). Glazed balconies as passive greenhouse systems – Potential of their use in Poland. *Building Services Engineering Research and Technology*, 555-572.

Guerra, O., Itard, L., & Visscher, H. (2009). The effect of occupancy and building characteristics on energy use for space and water heating in Dutch residential stock. *Energy and Buildings*, 1223-1232.

H, O., Ghaffarianhoseini, A., Raahemifar, K., & Tookey, J. (2016). Application of Passive Wall Systems for Emproving the Energy Efficiency in Buildings ; A comprehensive Review. *Renew Sustain Energy*, 1252-1263.

Haase, M., & Amato , A. (2006). Sustainable Facade Design for Zero Energy Buildings in the Tropics. *The 23rd Conference on Passive and Low Energy Architecture, Geneva, Switzerland*.

Haddad, E., Farajallah, N., Camargo, M., R, L., & F, V. (2014). Climate change in Lebanon: higherorder regional impacts from agriculture. *The Region*, 9-24.

Haddad, R., Richani, S., & Levesque, C. (2012). Public Beirut.

Hassouneh, K., Alshboul, A., & Al-Salamyeh, A. (2010). Influence of windows on the energy balance of apartment buildings in Amman. *Energy Conversion and Management, 51*(8), 1583-1591.

Hatzaki, M., Giannakopoulos, M., Hadjinicolaou, C., & Kostopoulou, E. (2010). Information sheet on observed climate indicators for the CIRCE urban case studies: Beirut, Lebanon.

Hemandez, J. (2014). Assessment of the visual impact made on the landscape by new buildings: a methodology for site selection. *Landscape and Urban Planning*, *68*(1), 15-28. doi:10.1016/S0169-2046(03)00116-6

Hilliaho, K., Köliö, A., Pakkala, T., Lahdensivu, J., & Vinha, J. (2016). Effects of added glazing on balcony indoor temperatures: Field Measurements. *Energy and Buildings*.

Hilliaho, K., Lahdensivu, J., & Vinha, J. (2015). Glazed space thermal simulation with IDA-ICE 4.6.1 software—suitability analysis with case study. *Energy and Buildings, 89*, 132-141. doi:10.1016/j.enbuild.2014.12.041

Hilliaho, K., Makitalo, E., & Lahdensivu, J. (2015). Energy saving potential of glazed space: Sensitivity analysis. *Energy and Buildings, 99*, 87-97.

Hilliaho, K., Nordquist, B., Wallenten, P., Abdul Hamid, A., & Lahdensivu, J. (2016). Energy saving and indoor climate effects of an added glazed facade to a brick wall building: Case study.

Hong, T., Yan , D., D'Oca, S., & Chen, C. (2017). Ten questions concerning occupant behavior in buildings: the big picture. *Building ad Environment*, 518-530.

Houri, A., & Ibhrami-Korfali, S. (2005). Residential Energy Consumption Patterns: The Case of Lebanon. *International Journal of Energy Research 29*, 755-766.

Huang, Y., & Chung, T. (2013). Study on the performance of energy-efficient retrofitting measures on commercial building external walls in cooling-dominated cities. *Applied Energy, 103*, 97-108.

Hui, S. (2002). Using performance-based approach in building energy standards and codes. 52-61.

Hussein, M., Barlet, A., & Semidor, C. (2010). SocioEnvironmental Dimensions of Private Outdoor Spaces in Contemporary Palestinian Housing. *Open House International*, 67-76.

Hwang, R.-L. (2011). Building Envelope Regulations on Thermal Comfort in Glass Facade Buildings and Energy Savung Potential for PMV- Based Comfort Control. *Building and Environment*, 824-834.

Islam, M. A., & Alam, J. (2017). Effect of external shading and window glazing on energy consumption of buildings in Bangladesh. *Advances in Building Energy Research, 11*(2), 180-192.

ISO, & FDIS. (2003). Thermal performances of windows, doors and shading devices—detailed calculations.

Iwaro, J., & Mwasha, A. (2010). A Review of Building Energy Regulation and Policy for Energy Conservation in Developing Countries.

Jain, S., Edgar, D., Bothe, J., Newman, H., Annmaree, W., Bint, B., . . . Harris, J. (2015). Reflection on observation: A qualitative study using practice development methods to explore the experience of being a hand hygiene auditor in Australia. *American Journal of Infection Control, 43*(12), 1310-1315.

Jalaei, F., & Jrade, A. (2014). An automated BIM model to conceptually design, analyze, simulate, and assess sustainable building projects. *Hindawi*, 1-21.

Jamshed, S. (2014). Qualitative Research Method-Interviewing and Observation. *Journal of Basic and Clinical Pharmacy, 5*(4), 87-88.

Janda, K. (2009). Worldwide status of energy standards for buildings: a 2009 update. 485-491.

Japan, T. E. (2010). *Energy Conservation in Modern Office Buildings.*

Jergensen, O. B., & Hendriksen, O. (2004). GLAZED BALCONIES AND SUN SPACES – ENERGY SAVERS OR ENERGY WASTERS ?

Jokhadar, A. A., & Jabi, W. (2019). Spatial reasoning as a syntactic method for programming socio-spatial parametric grammar for vertical residential buildings. *Architectural Science Review, 63*(2), 135-153.

Jonsson, T., Pinson, P., & Madsen, H. (2010). On the market impactof wind energy forecasts. *Energy Economics, 32*(2), 313-320.

Kaloustian, N., & Diab, Y. (2015). Effects of Urbanization on the Urban Heat Island in Beirut. Manuscript submitted for publication.

Karlsson, F. (2007). Measured and predicted energy demand of a low energy building: important aspects when using building energy simulation. *Building Services Engineering Research and Technology, 28*(3), 223.

Kim, S., Zadeh, P., Staub, S., Forese, T., & Cavka, B. (2016). Assessment of the impact of window size, position and orientation on building energy load. *Procedia Engineering, 145*, 1424-1431.

Kim, S.-C., Yoon, J.-H., & Lee, H.-M. (2017). Comparative Experimental Study on Heating snd Cooling Energy Performance of Spectrally Selective Glazing. *145*, 78-89. doi:10.1016/j.solener.2016.11.028

Koohsari, A., Fayaz, R., & Kari, B. (2015). The Influence of Window Dimensions and Location on Residential Building Energy Consumption by Integrating Thermal and Lighting Analysis in a Mild and Humid Climate. *BRIS Journal of Advances in Science and Technology, 3*, 187-194.

Kruger, A., & Seville, C. (2012). Green Building: Principles and Practices in Residential Construction.

Kuamar, H. V., Ganesh, M., A.S, S., & Ramancharla, P. (2009). MODIFIED ANALYSIS OF MULTI STORIED RESIDENTIAL BUILDINGS. *MCMCT 2008.* Melmaruvathur Tamil Nadu.

Kumar, G., & Raheja, G. (2016). Design Determinants of Building Envelope for Sustainable Built Environment: A Review. *International Journal of Built Environment and Sustainability, 3*(10), 111-118.

Lahn, G., & Stevens, P. (2011). Burning Oil to Keep Cool: the Hidden Energy Crisis in Saudi Arabia. *The Royal Institute of International Affairs*.

Lavallo, M., Darwich, a., Telesca, L., & Shaban, A. (2013). Investigating the time dynamics of monthly rainfall time series observed in northern Lebanon by means of the detrended fluctuation analysis and the Fisher-Shannon method. *Acta Geophys*, 1538-1555.

Levin, H., & Cruz, A. (1996). Building Ecology: Relation of Building to Environmental and Societal Issues.

Li, H., & Malcom, L. (2010). Measurement of thermal performance of building envelope - a comparison of some international legislation. 108-121.

Li, H., Gao, Y., Zhao, G., & Jing, Y. (2013). Impact of Window-Wall Ratio on Air Conditioning Energy Consumption under Different Residential Using Modes in Guangzhou. *Applied Mechanics and Materials, 316*, 1123-1127.

Lin, J.-A. (2015). Enclosed Balconies: Complicity Between Builders and Users Of Taipei Walkups. *Open House International*, 11-16.

Lin, J.-A. (2015). Enclosed Balconies: Complocity Between Builder and User of Taipei Walkups. *open House International, 40*(3), 11-16.

Lin, Y., Zhou, S., Yang, W., & Chun-Qing, L. (2018). Design Optimization Considering Variable Thermal Mass, Insulation, Absorptance of Solar Radiation, and Glazing Ratio Using a Prediction Model and Genetic Algorithm. *Sustainability, 10*(2), 336. doi:DOI:10.3390/su10020336

Lis, P., & Sekret, R. (2016). Energy Effectiveness of Buildings-Selected Issues. *Building Research & Information, 44*(8).

Liu, K. (2006). A Study on the Thermo-comfortability of a Bedroom -Influenced By Varied Openings and Multi-layer Exterior wall.

Loutzenhiser, P., Manz, H., Moosberger, S., & Maxwell, G. (2009). An empirical validation of window solar gain models and the associated interactions. *48*(1), 85-95.

Luo, Y. (2019). Active building envelope systems toward renewable and sustainable energy. *Renewable and Sustianable Energy Reviews, 104*, 470-491. doi:10.1016/j.rser.2019.01.005

Maalouf, A., & El-Fadel, M. (2019). Life Cycle Assessment for Solid Waste Managemnet in Lebanon: Economic Implications of Carbon Edit. *Waste Management and Research, 37*(1), 14-26.

Makitalo, E., Hilliaho, K., & Lahdensivu, J. (2015). Energy saving potential of glazed space: Sensitivity analysis. *Energy and Buildings, 99*, 87-97.

Manzan, M., & Padovan, R. (2015). Multi-criteria energy and day-lighting optimization for an office with fixed and moveable shading devices. *Advances in Building Energy Research, 9*, 238*252.

Marshall, B., Cardon, P., Poddar, A., & R, F. R. (2013). Does Sample size matter in qualitative research? *Journal of Computor Information Systems, 54*(1), 11-22.

Masri, S. S. (2018). Integrating youth in city planning: Developing a participatory tool toward a child-friendly vision of Eastern Wastani – Saida. *Alexandria Engineering Journal, 57*(2), 897-909.

Mattar, T., Chehab, S., Chaaban, F., Ghaddar, N., & Chedid, R. (2001). Assessment of energy efficiency measures: The case of the Lebanese energy sector. *International Journal of Energy Research*, 355-374.

Mebarki, C., Djakab, E., Karim El Hassar, S., & El Amine Slimani, M. (2018). Impact of glazing type and orientation on the optimum dimension of windows for office room in hot climate. *Journal of Architectural Environment and Structural Engineering Research, 1*(1), 10-15.

Mirrahimi, S., Mohamed, M., Haw, L., Ibrahim, N., Yusoff, W., & Aflaki, A. (2016). The effect of building envelope on the thermal comfort and energy saving for high-rise buildings in hot–humid climate. *Renewable and Sustainable Energy Reviews*, 1508-1519.

Monroe, K. (2016). *The Insecure City : Space, Power, and Mobility in Beirut.* New Jursey: New Brunswick, New Jursey: Rutgers University Press.

Mortada, S. (2018). *The First Energy Indicators Report of the Republic of Lebanon.* Lebanese Republic Ministry of Energy and Water.

Moser, A., & Koschenz, M. (2001). Industrial Ventilation Design Guidebook. *Mechanical Engineering CIME, 123*(8).

Mourshed, M., Kelliher, D., & Keane, M. (2000). Green architecture: the need for climate analysis and thermal simulation during early stages of design. *Global Built Environement*, 12-20.

Msnuela, F., Anna, C., Salvatore, E., & Antonio, D. (2016). AIN-Ag based low-emission sputtered coatings for high visible transmittance window. *Surface Coating Technology, 295*, 2-7.

Nahas, C., & Yahya, M. (2001). Sidon. In C. Nahas, *Cultural Heritage Report* (pp. 197-237). Beirut.

Natephra, W., Yabuki, N., & Fukuda, T. (2018). Optimizing the evaluation of building envelope design for thermal performance using a BIM-based overall thermal transfer value calculation. *Building and Environment*, 128-145.

Nicholls, S., Quach, P., Von Elm, E., Asgtrid, M., & David. (2015). The REporting of Studies Conducted Using Observational Routinely-Collected Health Data Statement: Methods for Arriving at Consensus and Developing Reporting Guidelines. *PLoS One*, *10*(5). doi:10.1371/journal.pone.0125620

Nicol, F., & Roaf, S. (2017). Rethinking Thermal Comfort. *Building Research and Information*, *45*(7), 711-716.

Nicola, L., & Inger, A. (2016). Aerogel vs. argon insulation in windows: a greenhouse gas emissions analysis. *Building and Environment, 101*, 64-76.

Noori, A., & Hwaish, A. (2015). Impact of heat exchange on building envelope in the hot climates. 47-57.

Omrani, S., Garcia-Hansen, V., Capra, B., & Drogemuller, R. (2017). On the effect of provision of balconies on natural ventilation and thermal comfort in high-rise residential buildings. *Building and Environment*, 504-516.

Oral, K., & Yilmaz, Z. (2003). Building form for cold climatic zones related to building envelope from heating energy conservation point of view. *Energy Build*, 383-388.

Owens, S., & Driffill, L. (2008). How to change attitudes and behaviours in the context of energy. *Energy Policies*, 4412-4418.

Ozel, M. (2019). Influence of glazing area on optimum thickness of insulation for different wall orientations. *Applied thermal engineering, 147*, 770-780. doi:10.1016/j.applthermaleng.2018.10.089

Paek, J. (2014). Environmental Performance of Adaptive Building Envelope Design: Urban Housing in Seoul, Korea.

Pathirana, S., Rodrigo, A., & Halwatura, R. (2019). Effect of building shape, orientation, window to wall ratios and zones on energy efficiency and thermal comfort of naturally ventilated houses in tropical climate. *International Journal of Energy and Environmental Engineering*, 107-120.

Perez-Lombard, L. (2008). A Review on Buildings Energy Consumption Information. *Energy and Buildings, 40*(3), 394-398. doi:10.1016/j.enbuild.2007.03.007

Perina, Z., Sevcikova, H., Redek, H., & Marcela, R. (2016). The Impact of Blacony Glazing on the Selected Building Envelope. *Applied Mechanics and Materials,* 315-322.

Pernigotto, g., Tarantini, M., & Gasparella, A. (2017). *A Co-Citation Analysis on the Thermal Comfort and Productivity Aspects in Production and Office Buildings.*

Pitts, A., & Gao, Y. (2014). Design of Dwellings and Interior Family Space in China: Understanding the History of Change and Opportunities for Improved Sustainability Practices. *Buildings, 4*(6), 823-848.

Ponterotto, J. (2006). Brief Note on the Origins, Evolution, and Meaning of the Qualitative Research. *The Qualitative Report, 11*(3).

Posht, R., Kohneh, A., Khosro, D., & Seyed Majid, M. (2017). The Effect of Balcony to Enhance Natural Ventilation in Local Houses in Mazandaran Province. *Journal of History, Culture & Art Research,* 894-918.

Quang, T., Knibbs, L., Dear, R., & Morawska, L. (2014). *Co-optimisation of Indoor Environment Quality and Energy Consumption within Urban Office Buildings.*

Roberto, F., Mazuroski, W., Abadie, M., & Mendes, M. (2011). Capacitive Effect on the Heat Transfer through Building Glazing System. *Applied Energy, 88,* 4310-4319.

Sabsaby, Y., & Omar, O. (2015). Thermal Comfort in Lebanese Residential unit case studies: A coastal region in Lebanon.

Sadineni, S., Madala, S., & Boehm, F. (2011). Passive building energy savings: a review of building envelope components. 3617-3631.

Sadineni, S., Madala, S., & Boehm, R. (2011). Passive Building Energy Savings: A Review of Building Envelope Components. *Renew Sustain Energy,* 3617-3631.

Saleh, P. (2015). Thermal Performance of Glazed Balconies Within Heavy Weigh/Thermal Mass Buildings in Beirut , Lebanon's Hot Climate.

Samanta, A., Saha, S., Biswas, J., & Dutta, A. (2014). Evaluation of Impact of Shading Devices on Energy Consumption of Buildings in Tropical Regions. *Journal of Energy Resources Technology, 136*(2).

Samarji, T., Jouni, A., & Karaki, A. (2012). Net zero energy buildings: Application in Lebanon on a typical residential building.

SDATL. (2005). *National Physical Master Plan of the Lebanese Territory.* DAR-IAURIF.

Selkowitz, S., Aschehoug, O., & Lee, E. (2003). Advanced interactive facades – critical elements for future green buildings?

Serghides, D., & Georgakis, C. (2012). The Building Envelope of Mediterranean Houses: Optimization of Mass and Insulation. *Journal of Building Physics,* 83-98.

Shaban, A., & Houhou, R. (2015). Drought or humidity oscillations? The case of coastal zone of Lebanon. *Journal of Hydrology*, 1768-1775.

Simion, M., Socaciu, L., & Unguresan, P. (2016). Factors which influence the thermal comfort. *Sustainable Solutions for Energy and Environment* , 472-480.

Stoy, C., & Kytzia, S. (2006). Benchmarking electricity consumption. *Construction Management and Economics, 24*(10), 1083-1089. doi:10.1080/01446190600799414

Szokolay, S. (2004). Introduction to Architectural Science: the Basis of Sustainable Design. *Architectural Press, Oxford*.

Tavares, M., Perdigao, H., & Bastos, J. (2017). The glazing area in residential buildings in temperate climate: The thermal-energetic performance of housing units in Lisbon. *Energy and Buildings, 140,* 280-294.

Tavares, P., Gaspar, A., Martins, A., & Frontini, F. (2014). Evaluation of electrochromic windows impact in the energy performance of buildings in Mediterranean climates. *Energy Pollution, 67,* 68-81.

Tibi, G., Ghaddar, N., & Ghali, K. (2012). Sustainable design guidelines for detached housing in the Lebanese inland region. *International Journal of Sustainable Built Evironment, 1*(2), 177-193.

Tkaczyk, A. H., Mauring, T., & Kull, T. (2015). Energy balance calculation of window glazing’s in the northern latitudes using long-term measured climatic data. *Energy Conversion and Management, 89,* 896-906.

Trgala, K. (2019). Energy performance of five different building envelope structures using a modified Guarded Hot Box apparatus;Comparative analysis. *Energy and Buildings, 195,* 116-125. doi:10.1016/j.enbuild.2019.04.036

Tsichritzis, L., & Yannas, S. (2015). The Glazing of Balconies as a Retrofitting Solution for Reducing the Heating Loas of the Adjacent Room in Athens. *PLEA Architecture in Revolution.* Bologna.

Tsikaloudaki, K., Laskos, T., & Theodosiou, D. (2012). Assessing Cooling Energy Performance of Windows for Office Buildings in the Mediterranean Zone. *Energy Building, 49*, 192-19.

UNDP.a. (2005). Climate and Comfort: Passive Design Strategies for Lebanon.

UNDP.b. (2005). Passive Climate and Comfort Design Strategies for Lebanon.

Urquhart, C. (2015). Observation Research Techniques. *Journal of EAHIL, 11*(3), 29-31.

Visser, F., & Yeretzian, A. (2013). Energy Efficient Guidelines.

Vollaro, R., Guattari, C., Evangelisti, L., Battista, G., Carnielo, E., & Gori, P. (2015). Building energy performance analysis: a case study. *Energy and Buildings, 87,* 87-94.

Wang, J., Beltran, L., & Kim, J. (2012). Static to kinetic: a review of acclimated kinetic building envelopes.

Wincent, J., Bogatyreva, O., Bogatyrev, N., Bowyer, N., & Pahl, K. (2006). Biomimetics: Its Practice and Theory.

Xu, X., Feng, G., Chi, D., Liu, M., & Duo, B. (2018). Optimization of Performance Parameter Design and Energy Use Prediction for Nearly Zero Energy Buildings. *Energies, 11*(12), 2-23. doi:http://dx.doi.org.neptune.ndu.edu.lb:2048/10.3390/en11123252

Yang, Q., Liu, M., Chang, S., Mmereki, D., Daniel, H., & Uzzal, M. (2015). Impact Analysis of Window-Wall Ratio on Heating and Cooling Energy Consumption of Residential Buildings in Hot Summer and Cold Winter Zone in China. *Engineering*.

Yang, Y., & Chow, C. L. (2018). Transient temperature fields and thermal stress fields in glazing of different thicknesses exposed to heat radiation. *Contruction and Building Materials, 193*, 589.

Yassin, N. (2012). Beirut. *Cities*, 64-73.

Yassin, N. (2012). Beirut. *Cities, 29*(1), 64-73.

Yassine, B., Ghali, K., Ghaddar, N., Srour, I., & Chehab, G. (2012). A Numerical Modeling Approach to Evaluate Energy-Efficient Mechanical Ventilation Strategy. *Energy and Buildings*, 618-630.

Yassine, B., Ghali, k., Ghaddar, N., Srour, I., & Chehab, G. (2014). Effectiveness of Earth Tube Heat Exchanger System Coupled to a Space Model in Achieving Thermal Comfort in Rural Areas. *International Journal of Susainable Energy,* 567-586.

Yathreb, S. (2016). Analysis of a Residential Building Energy Consumption as Base Model in Tripoli, Lebanon. *International Journal of Energy Production and Management, 1*(4), 359-370.

Yeretzian, A. (2006). A Building Ecology Index for Residential Buildings in Beirut .

Yu, Z., Fung, B., Haghighat, F., Yoshino, H., & Morofsky, E. (2011). A systematic procedure to study the influence of occupant behavior on building energy consumption. *Energy and Buildings, 43*(6), 1409-1417. doi:10.1016/j.enbuild.2011.02.002

Yu, Z., Fung, B., Haghighatt, F., Yoshino, H., & Morofsky, E. (2011). A systematic procedure to study the influences of occupant behavior on building energy consumption. *Energy and Buildings, 43*(6), 1409-1417. doi:10.1016/j.enbuild.2011.02.002

Yu, Z., Zhang, W., & Fang, T. (2013). Impact of building orientation and window-wall ratio on the office building energy consumption. *Applied Mechanics and Materials, 409,* 606-611.

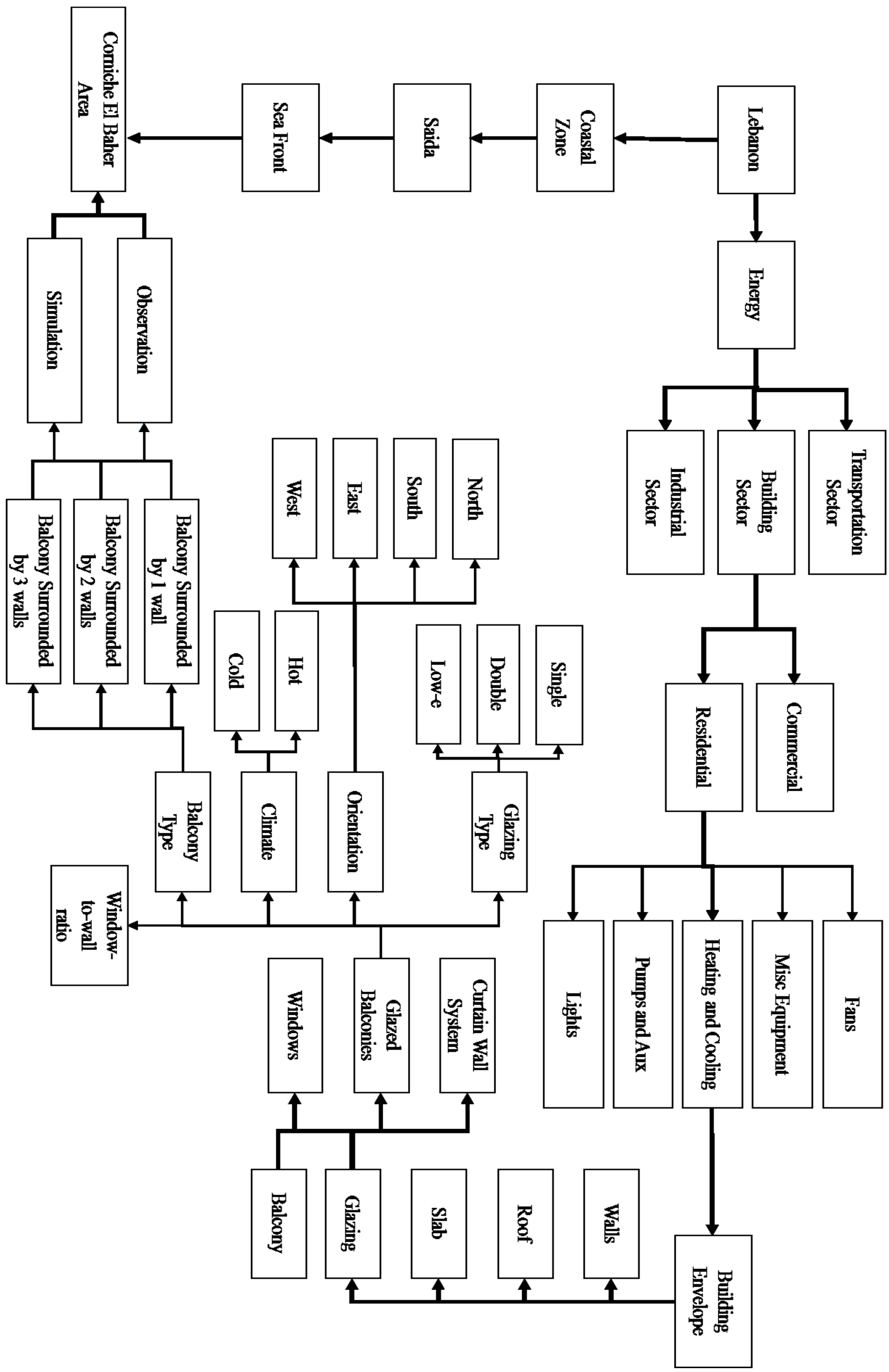
Yuan, L., Ruan, Y., Yang, G., Feng, F., & Li, Z. (2016). Analysis of factors influencing the energy consumption of government office buildings in Qingdao. *Energy Procedia*, 263-268.

Zdenek, P., Sevcikova, H., fabian, R., Halirova, M., & Rykalova, E. (2016). The Impact of Balcony Glazing on the Selected Building Envelope. *Applied Mechanics and Materials* , 315-322.

Zein, A. E., Tewtel-Salem, M., & Nehma, G. (2004). A Time-Series Analysis of Mortality and Air Temperature in Greater Beirut. *Science of the Total Environment,* 71-80.

Zhou, Z., Hu, S., & Du, T. (2013). Study on determination of best window-wall ratio of office building in cold area. *Applied Mechanics and Materials, 261*, 606-611.

Thesis Framework



Appendix A Balcony Model B1W-200

In the following method, three models will be designed and simulated, having similar plans but each with a different balcony structure (surrounded by 1 wall, 2 walls, and 3 walls). Moreover, each model of the three models will undergo several variables to be simulated; when the balcony is glazed, when the balcony is glazed and the wall separating the balcony from the adjacent space is removed, and when the balcony is not glazed. All three models with their 3 variables undergo similar steps. Therefore, in this section 1 model will be explored as a sample to other models (other models will be mentioned in the appendence).

The buildings observed in “Corniche El Baher” area belong to the 70s era, where most of the buildings are not high-end or highly finished and constructed. The buildings in the specified area have their main elevation orientated to the west, to overlook the sea. Accordingly, most of the buildings are horizontally placed on the street having a glazed western façade.

According to the mentioned data, a similar building typology will be modeled on Revit (2020). A typical plan will be designed, having balconies and horizontal façade overlooking the west orientation.

Revit 2020 was used to design each model, since Revit is an architecture software that allows architects to design plans, and 3Ds. Revit has the plugin feature that allows energy analysis. Energy Plus is an energy engine of Revit which will be used to create energy models, and export heating and cooling report for each space of the model. Insight360 and Green Building Studio (GBS) are also Autodesk software and plugins on Revit, by which the model designed on Revit is energy analyzed on both Insight 360 and Green Building Studio which will further estimate cooling loads per month on the total model.

The orientation will be the first variable, since the focus of the thesis is the glazed balconies overlooking the west orientation. However, the balconies are not only overlooking the west, but also the north-west, and south-west (since they are placed at the corners).

These two orientations will be taken into consideration for each scenario- balcony structure. Moreover, the cooling demand will be the focus, thus only summer months will be considered during the analysis. Finally, the simulations will also consider the cooling demand when the balcony is not closed, when the balcony is closed and the interior wall is removed, and when the balcony is closed and the interior wall is not removed. When studying the cooling demands in the mentioned variable, it is a necessity to also include the cooling demand for the room adjacent to the balcony in order to record the impact of the glazed balcony on the adjacent spaces.

The variables mentioned will result in having 3 models where each have 3 scenarios, in which they will be analyzed and assessed. The preliminary outcomes will be proposed in order to insert the data into Excel to create tables and charts for the ease of analyzing the data.

The following is a sample of a repetitive method done on all three models.

A typical plan was designed on Revit having a balcony structure surrounded by only 1 wall (Figure 1). The balcony was located on the west orientation. The plan was designed according to the building typology, orientation, and appearance of the buildings found in the observation.

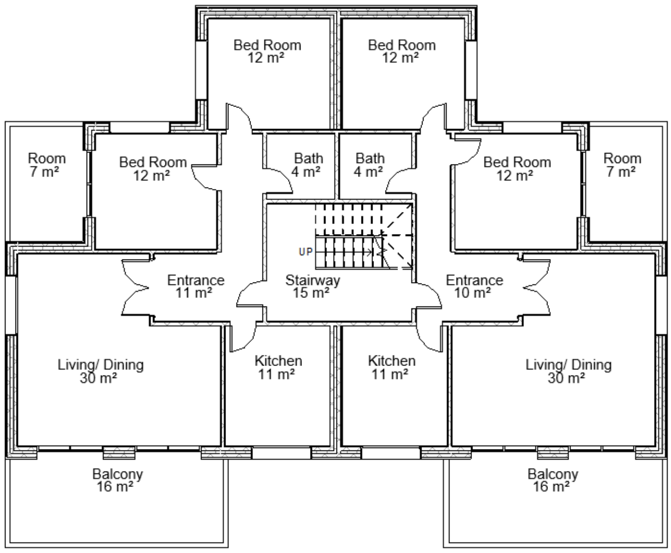


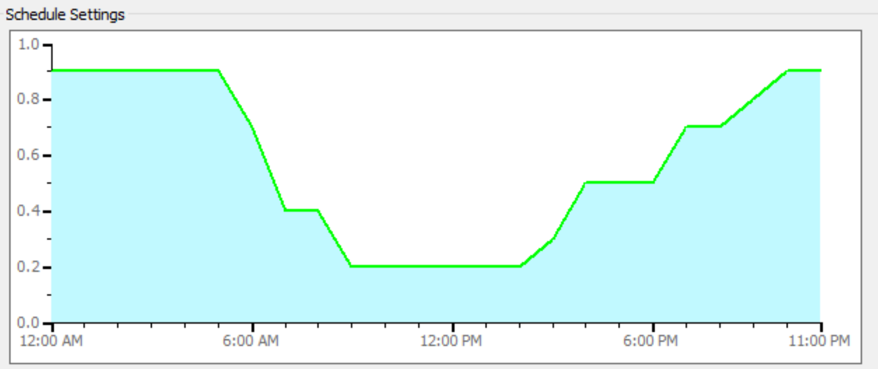
Figure 1.Typical plan to be used for simulations for balcony structure surrounded by 1 wall overlooking the west orientation, Source: Author

The thermal properties of the materials used in the model are similar to the properties used in the area (the properties that are usually used on the coast of Lebanon) (Figure 5.3.12) (Azmy & Elghamry, 2018; Annan, Ghaddar, & Ghali, 2014; Assaad, Habchi, Ghali, & Ghaddar, 2018).

Component	Description	U-Value (W/(m² K)
Roof	Reinforced concrete	2.96
Walls	Plaster–Hollow blocks-plaster	3.22
Windows	Aluminum frame single pane	5.41
Slabs	Reinforced Concrete	2.96

Figure 2.Thermal properties of materials used in the area, Source: Author

The glazing used in the buildings is the single glazing (6mm single pane) that has a cheap price and a very high U-value. (U= 5.88 W/m^{2}k). Moreover, the occupation of the apartment will also have to be identified to give further accuracy (Figure 5.3.23).



Time	Factor	Time	Factor
12:00 AM	90.00%	12:00 PM	20.00%
1:00 AM	90.00%	1:00 PM	20.00%
2:00 AM	90.00%	2:00 PM	20.00%
3:00 AM	90.00%	3:00 PM	30.00%
4:00 AM	90.00%	4:00 PM	50.00%
5:00 AM	90.00%	5:00 PM	50.00%
6:00 AM	70.00%	6:00 PM	50.00%
7:00 AM	40.00%	7:00 PM	70.00%
8:00 AM	40.00%	8:00 PM	70.00%
9:00 AM	20.00%	9:00 PM	80.00%
10:00 AM	20.00%	10:00 PM	90.00%
11:00 AM	20.00%	11:00 PM	90.00%

Figure 6.6.1.Home occupancy, Source: Author

The location was inserted; "Corniche El Baher Area", and the weather station was chosen. According to the location indicated, two weather stations where observed, one near Joun area, and one in Jiyeh area, but knowing that Jiyeh is on the coast and similar to Saida city, therefore Jiyeh weather station was chosen. Joun is relatively higher than Saida, and therefore using the weather station will not give accurate results (Figure **5.3.3**4).

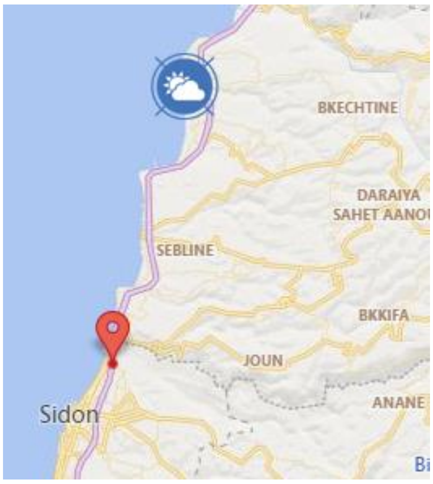


Figure 6.6.2.Location and weather station are identified, Source: Author

The mentioned data will be similar for all models to be analyzed. The typical plan for this balcony structure will undergo several simulations for several variables to estimate the cooling load; balcony, glazed balcony, and glazed balcony with wall removed. The following sections will explore each scenario for the first model and mention the preliminary outcomes of each without analyzing them.

For the first simulation of this balcony structure, the typical plan designed in Revit was used (Figure 1), true north was projected having the balconies overlooking the west orientation.

In order to analyze the plan through energy software mentioned, room tags should be added to the spaces and spaces should be identified. Each space of the plan is identified by specifying the building type of each with the occupation, balcony, bathroom, bedroom, kitchen, etc… The occupation was inserted in the field of home occupancy.

Now that the model is ready for energy simulation, the energy model is created, generated, and optimized, by which the analysis will result in Insight 360 and GBS (Figure 6.6.3).

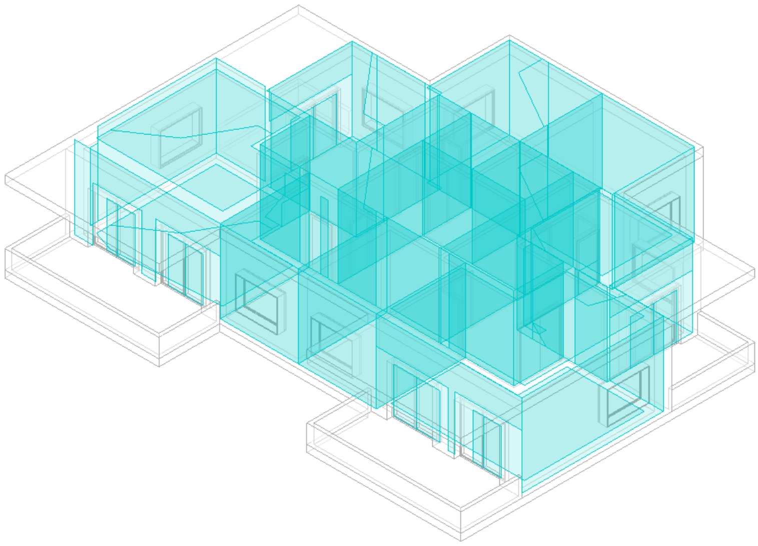


Figure 6.6.3. Energy model is created, Source: Author

Moreover, the report and schedule for heating and cooling generated by Energy Plus plugin in Revit can be exported, which shows the cooling demand for each space in the apartments.

By generating the energy model, energy analysis of the model can be viewed and extracted by visiting Insight 360 website, and GBS website. Insight 360 and GBS will show detailed energy analysis on the model, and be easily extracted (Figure 6.6.4). GBS can allow to extract cooling demand for each month of the year.

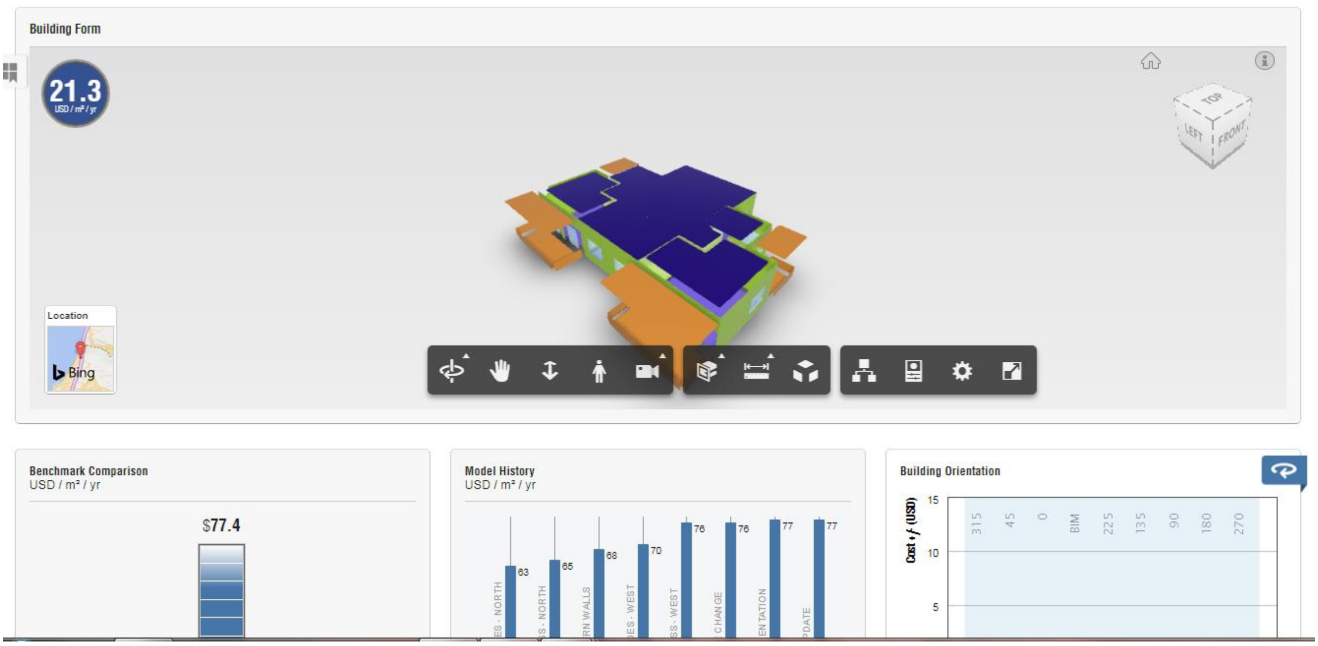


Figure 6.6.4.Insight360 project homepage, Source: Author, GBS

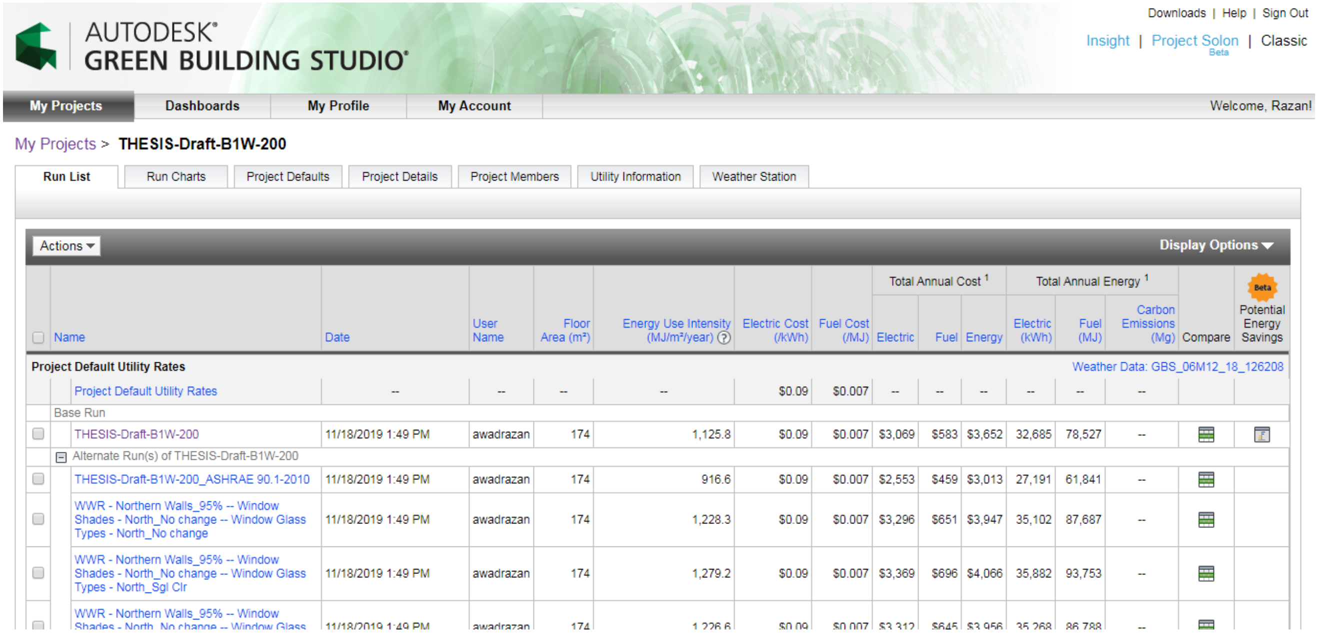


Figure 6.6.5. GBS project homepage, Source: Author, GBS

In addition, GBS allows to modify certain variables and compare the cost between the base run (results of the model) with an alternative run (results of modified variables) (Figure 6.6.5). After the accessibility of Insight 360, GBS, and Energy plus, it is possible to go through the result, arranging the data, and start analyzing.

The preliminary outcomes are the results extracted from Energy Plus, Insight 360, and GBS. As mentioned, the focus is on the balcony and the adjacent room, taking into consideration the spaces on the north-west and spaces on south-west. Table 1 indicates the cooling load for the balcony space located on the north-west orientation, resulting in 1672 Watts. Table 2 indicates the cooling demand for the living space that is adjacent to the balcony space on the north-west orientation, having 2766 Watts.

Space Summary - 44 Balcony NW

Back to summary of spaces

Input Data	
Area (m²)	16
Volume (m³)	50.09
Wall Area (m²)	42
Roof Area (m²)	18
Door Area (m²)	0
Partition Area (m²)	0
Window Area (m²)	9
Skylight Area (m²)	0
Lighting Load (W)	185
Power Load (W)	253
Number of People	1
Sensible Heat Gain / Person (W)	73
Latent Heat Gain / Person (W)	59
Infiltration Airflow (L/s)	16.3
Space Type	Balcony
Calculated Results	
Peak Cooling Total Load (W)	**1,672**
Peak Cooling Sensible Load (W)	1,536
Peak Cooling Latent Load (W)	136
Peak Cooling Airflow (L/s)	106.5
Peak Heating Load (W)	**885**
Peak Heating Airflow (L/s)	370.3

Table 1.Cooling Load report for balcony space located on the North-West orientation, Source: Author, REVIT

Space Summary - 40 Space

Back to summary of spaces

Input Data	
Area (m²)	30
Volume (m³)	95.98
Wall Area (m²)	22
Roof Area (m²)	33
Door Area (m²)	4
Partition Area (m²)	0
Window Area (m²)	11
Skylight Area (m²)	0
Lighting Load (W)	355
Power Load (W)	484
Number of People	2
Sensible Heat Gain / Person (W)	73
Latent Heat Gain / Person (W)	59
Infiltration Airflow (L/s)	8.3
Space Type	Living/ Dining
Calculated Results	
Peak Cooling Total Load (W)	**2,766**
Peak Cooling Sensible Load (W)	2,662
Peak Cooling Latent Load (W)	104
Peak Cooling Airflow (L/s)	176.2
Peak Heating Load (W)	**974**
Peak Heating Airflow (L/s)	477.1

Table 2. Cooling Load report for space adjacent to balcony located on the North-West orientation, Source: Author, REVIT

Table 3 indicates the cooling load for the balcony space located on the south-west orientation, resulting in 1672 Watts. Table 4 indicates the cooling demand for the living space that is adjacent to the balcony space on the south-west orientation, having 2876 Watts.

Space Summary - 52 Balcony SW

Back to summary of spaces

Input Data	
Area (m²)	16
Volume (m³)	50.09
Wall Area (m²)	42
Roof Area (m²)	18
Door Area (m²)	0
Partition Area (m²)	0
Window Area (m²)	9
Skylight Area (m²)	0
Lighting Load (W)	185
Power Load (W)	253
Number of People	1
Sensible Heat Gain / Person (W)	73
Latent Heat Gain / Person (W)	59
Infiltration Airflow (L/s)	16.3
Space Type	Balcony
Calculated Results	
Peak Cooling Total Load (W)	**1,672**
Peak Cooling Sensible Load (W)	1,535
Peak Cooling Latent Load (W)	136
Peak Cooling Airflow (L/s)	106.5
Peak Heating Load (W)	**885**
Peak Heating Airflow (L/s)	370.3

Table 3. Cooling Load report for balcony space located on the South-West orientation, Source: Author, REVIT

Space Summary - 49 Space

Back to summary of spaces

Input Data	
Area (m²)	30
Volume (m³)	95.98
Wall Area (m²)	22
Roof Area (m²)	33
Door Area (m²)	4
Partition Area (m²)	0
Window Area (m²)	11
Skylight Area (m²)	0
Lighting Load (W)	355
Power Load (W)	484
Number of People	2
Sensible Heat Gain / Person (W)	73
Latent Heat Gain / Person (W)	59
Infiltration Airflow (L/s)	8.3
Space Type	Living/ Dining
Calculated Results	
Peak Cooling Total Load (W)	**2,876**
Peak Cooling Sensible Load (W)	2,772
Peak Cooling Latent Load (W)	104
Peak Cooling Airflow (L/s)	183.2
Peak Heating Load (W)	**974**
Peak Heating Airflow (L/s)	477.1

Table 4.Cooling Load report for space adjacent to balcony located on the South-West orientation, Source: Author, REVIT

Insight360 obtains several energy results by which only the thesis concerned where selected to be further analyzed in the thesis. The first scenario (balcony) in the first model type (surrounded by 1 wall) has a mean cost of 21 USD per m^2 annually (Figure 6.6.6).

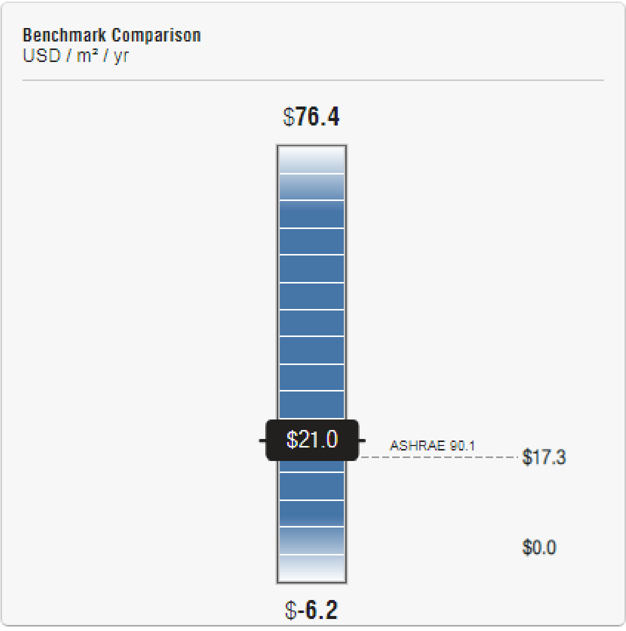


Figure 6.6.6. Benchmark comparison between model and ASHRAE 20.1 and ASHAE 2030, Source: Author, INSIGHT360

The following figures (Figure 6.6.7, Figure 6.6.8, Figure 6.6.9, and Figure 6.6.10) from Insight360 indicate several modifications and factors that have direct impact on energy consumed in the scenario.

Figure 6.6.7 indicates the impact of orientation of the building, and mainly the balcony position, with respect to energy consumed, illustrating several modifications of orientation. Figure 6.6.8 shows the different glazing types used in the model and how the energy consumed is affected.

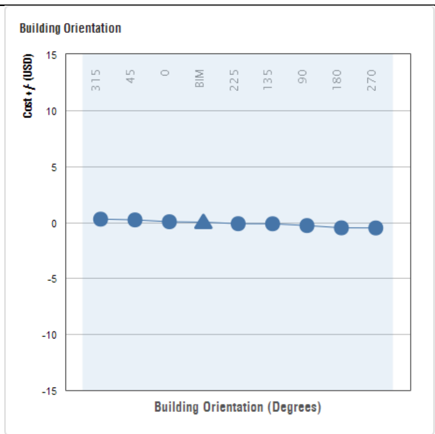


Figure 6.6.7. Building orientation chart indicating orientation adjustments that reduces the cost /m2, Source: Author, INSIGHT360

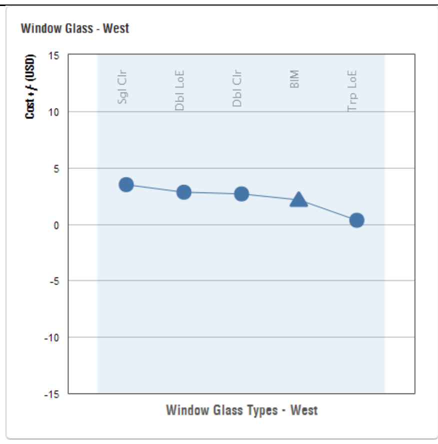


Figure 6.6.8. Chart indicating glazing types and their effect on cost consumed on energy, Source: Author, INSIGHT360

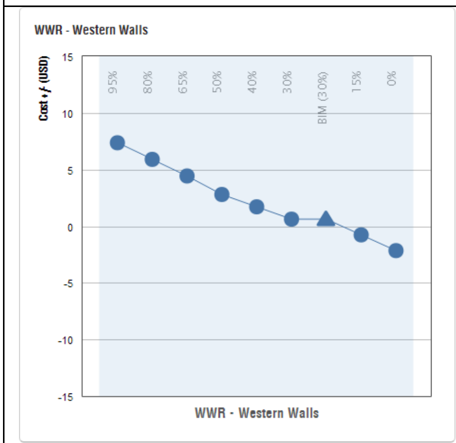


Figure 6.6.9. Chart indicating difference in energy consumption when window to wall ratio is reduced (on the western facade) , Source: Author, INSIGHT360

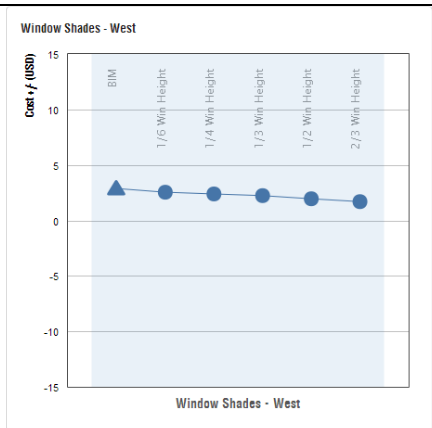


Figure 6.6.10. Chart indicating window shading and their effect on energy consumption, Source: Author, INSIGHT360

Moreover, GBS was used to extract cooling loads per month for the whole apartment. Chart 6.6.1, Chart 6.6.2, and Chart 6.6.3 represent the cooling demand (kWh) in the summer months; June, July, and August, respectively.

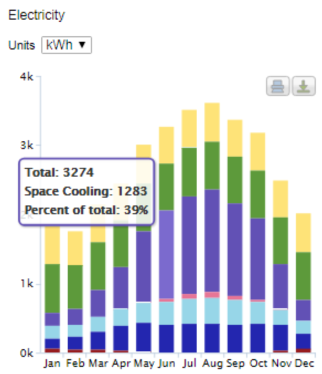


Chart 6.6.1. Cooling load in June, Source: Author, INSIGHT360

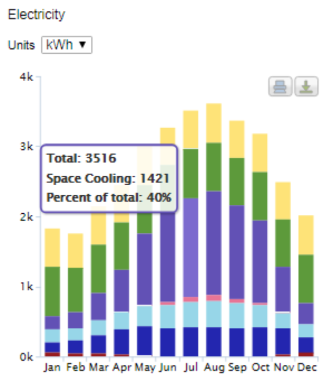


Chart 6.6.2. Cooling load in July, Source: Author, INSIGHT360

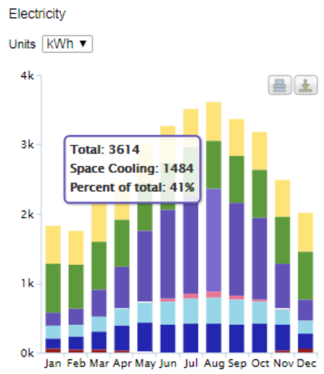


Chart 6.6.3. Cooling load in August, Source: Author,

According to the charts resulting from Insight360 (Figure 6.6.7, Figure 6.6.8, Figure 6.6.9, and Figure 6.6.10) , variables such as window-wall-ratio, orientation, glazing type, and shading, can be modified in GBS inorder to impact the performance of the enclosure and result in reduction of enery consumption. The performancfe of both the base run and alternative run can be compared and modified to get the best result.

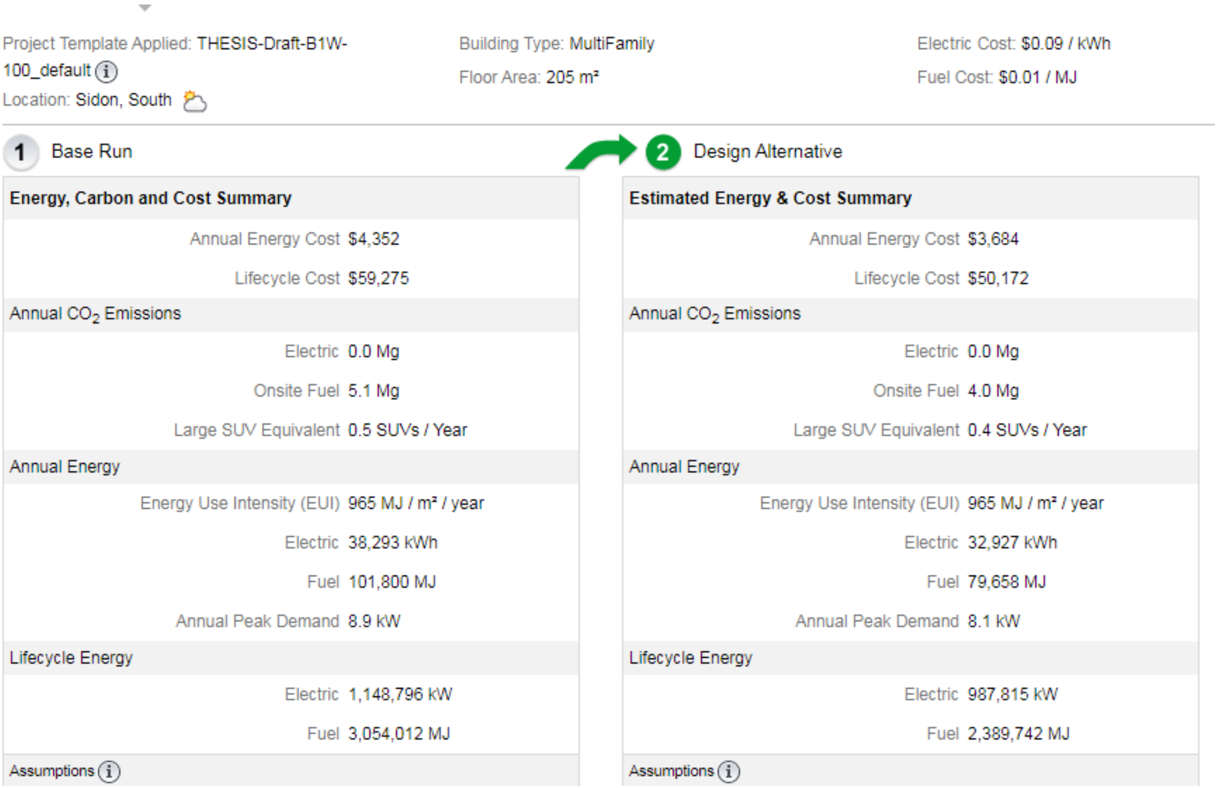


Figure 6.6.11. Figure extracted from GBS indicating the ability to design alternatives and compare with base run, Source: Author, GBS

After finishing the first scenario in the first model, the results can now be inserted in excel, and tables and charts can be excluded. Moreover, the other scenarios can be designed and simulated similarly to the first scenario.

Appendix B Glazed Balcony Model; B1W-100

The second simulation for the first model – balcony structure surrounded by 1 wall- is when the balcony is closed and glazed. The plan used for this simulation is the same typical used for the first simulation, but the balcony is glazed.

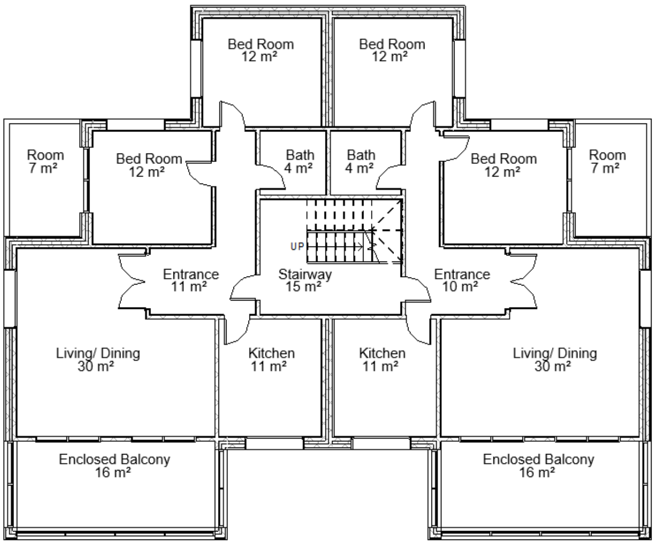


Figure 6.6.12. Plan used for second simulation having glazed balconies overlooking the west orientation, Source: Author

Figure 6.6.12 was designed on Revit, similarly to the first simulation true north was projected having balconies overlooking the west, the thermal properties of the material used were inserted. Room tags, spaces, building type, and occupancy where indicated. Location and weather station were also inserted.

The model will be energy simulated, so energy model is created, generated, and optimized.

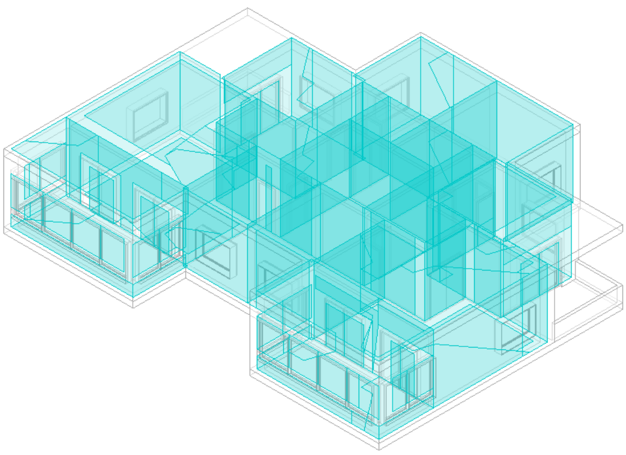


Figure 6.6.13. Energy model for glazed balcony without wall removal is created, Source: Author

When the energy model is created, results can be obtained from Energy Plus, Insight 360, and Green Building Studio.

The heating and cooling report indicated the cooling demand for the specified spaces; the glazed balcony and the adjacent space in the south-west and north-west orientation. Table 5 and Table 6 indicate the cooling demand for the glazed balcony (2527 W) and the living space adjacent to the glazed balcony (2705 W) respectively on the north-west orientation.

Space Summary - 44 EB NW

Back to summary of spaces

Input Data	
Area (m²)	16
Volume (m³)	49.92
Wall Area (m²)	43
Roof Area (m²)	18
Door Area (m²)	0
Partition Area (m²)	0
Window Area (m²)	28
Skylight Area (m²)	0
Lighting Load (W)	185
Power Load (W)	252
Number of People	1
Sensible Heat Gain / Person (W)	73
Latent Heat Gain / Person (W)	59
Infiltration Airflow (L/s)	16.7
Space Type	Enclosed Balcony
Calculated Results	
Peak Cooling Total Load (W)	**2,527**
Peak Cooling Sensible Load (W)	2,417
Peak Cooling Latent Load (W)	110
Peak Cooling Airflow (L/s)	135.4
Peak Heating Load (W)	**1,318**
Peak Heating Airflow (L/s)	125.4

Table 5. Cooling Demand for glazed balcony on the North-west orientation, Source: Author, REVIT

Space Summary - 40 Space

Back to summary of spaces

Input Data	
Area (m²)	30
Volume (m³)	95.09
Wall Area (m²)	21
Roof Area (m²)	32
Door Area (m²)	4
Partition Area (m²)	0
Window Area (m²)	11
Skylight Area (m²)	0
Lighting Load (W)	352
Power Load (W)	480
Number of People	2
Sensible Heat Gain / Person (W)	73
Latent Heat Gain / Person (W)	59
Infiltration Airflow (L/s)	8.1
Space Type	Living/ Dining
Calculated Results	
Peak Cooling Total Load (W)	**2,705**
Peak Cooling Sensible Load (W)	2,617
Peak Cooling Latent Load (W)	89
Peak Cooling Airflow (L/s)	144.9
Peak Heating Load (W)	**967**
Peak Heating Airflow (L/s)	117.2

Table 6. Cooling Demand for adjacent space to the glazed balcony on the North-west orientation, Source: Author, REVIT

The south-west orientation resulted 2527W for cooling in the glazed balcony (Table 7), and 2705 W in the living area (Table 8).

Space Summary - 52 EB NW

Back to summary of spaces

Input Data	
Area (m²)	16
Volume (m³)	49.92
Wall Area (m²)	43
Roof Area (m²)	18
Door Area (m²)	0
Partition Area (m²)	0
Window Area (m²)	28
Skylight Area (m²)	0
Lighting Load (W)	185
Power Load (W)	252
Number of People	1
Sensible Heat Gain / Person (W)	73
Latent Heat Gain / Person (W)	59
Infiltration Airflow (L/s)	16.7
Space Type	Enclosed Balcony
Calculated Results	
Peak Cooling Total Load (W)	**2,527**
Peak Cooling Sensible Load (W)	2,417
Peak Cooling Latent Load (W)	110
Peak Cooling Airflow (L/s)	135.4
Peak Heating Load (W)	**1,318**
Peak Heating Airflow (L/s)	125.4

Table 7. Cooling Demand for glazed balcony on the South-west orientation, Source: Author, REVIT

Space Summary - 40 Space

Back to summary of spaces

Input Data	
Area (m²)	30
Volume (m³)	95.09
Wall Area (m²)	21
Roof Area (m²)	32
Door Area (m²)	4
Partition Area (m²)	0
Window Area (m²)	11
Skylight Area (m²)	0
Lighting Load (W)	352
Power Load (W)	480
Number of People	2
Sensible Heat Gain / Person (W)	73
Latent Heat Gain / Person (W)	59
Infiltration Airflow (L/s)	8.1
Space Type	Living/ Dining
Calculated Results	
Peak Cooling Total Load (W)	**2,705**
Peak Cooling Sensible Load (W)	2,617
Peak Cooling Latent Load (W)	89
Peak Cooling Airflow (L/s)	144.9
Peak Heating Load (W)	**967**
Peak Heating Airflow (L/s)	117.2

Table 8. Cooling Demand for adjacent space to the glazed balcony on the south -west orientation, Source: Author, REVIT

Similar to the first scenario, Inisght360 compares the cost per m2 of the model and compares it with ASHRAE 90.1 as a benchmark (Figure 6.6.14), showing the difference between the 2.

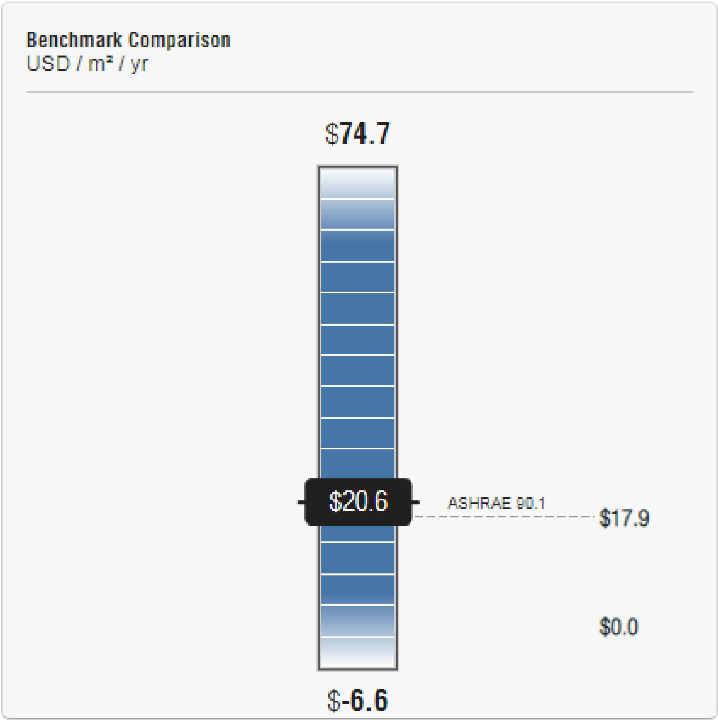


Figure 6.6.14. Benchmark comparison between model and ASHRAE 20.1 and ASHAE 2030, Source: Author, INSIGHT360

The following figures (Figure 6.6.15, Figure 6.6.16, Figure 6.6.17, and Figure 6.6.18) are conducted from Insight360 that shows several modifications and factors that have direct impact on energy consumed in the scenario and benchmark comparison.

Figure 6.6.15 indicates the impact of orientation of the building, and mainly the balcony position, with respect to energy consumed, showing how the consumption changes when the orientation is modified. Figure 6.6.16 shows the different glazing types used in the model and how the energy consumed is affected for each glazing type.

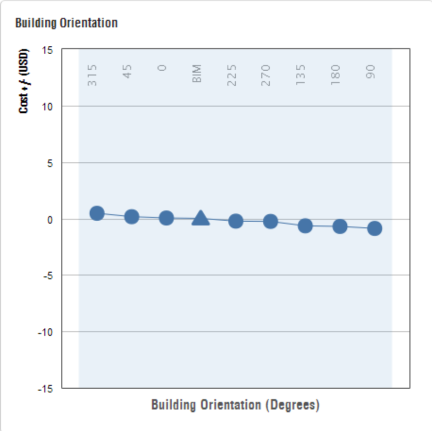


Figure 6.6.15. Building orientation chart indicating orientation adjustments that reduces the cost /m2, Source: Author, INSIGHT360

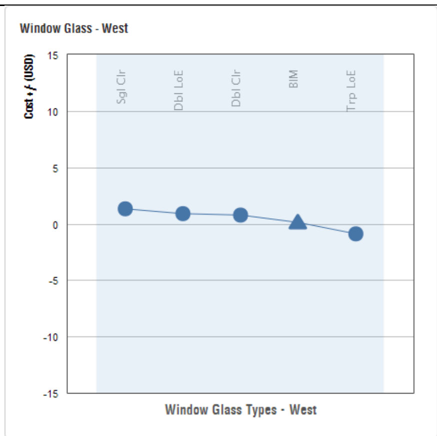


Figure 6.6.16. Chart indicating glazing types and their effect on cost consumed on energy, Source: Author, INSIGHT360

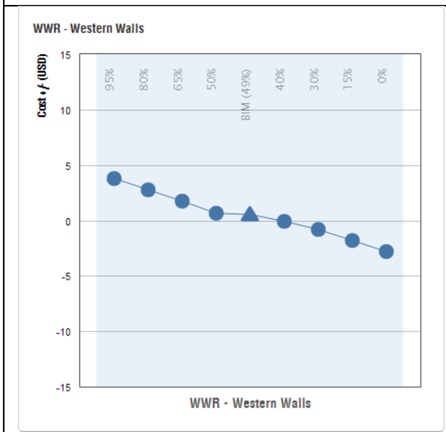


Figure 6.6.17. Chart indicating difference in energy consumption when window to wall ratio is reduced (on the western facade) , Source: Author, INSIGHT360

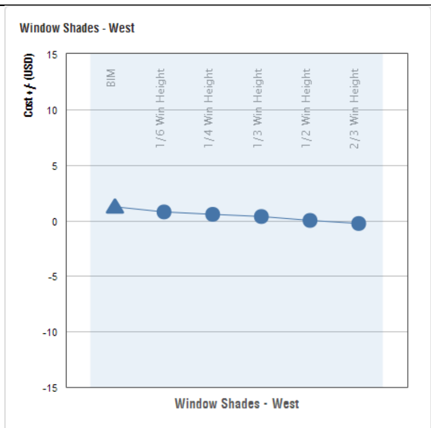


Figure 6.6.18. Chart indicating window shading and their effect on energy consumption, Source: Author, INSIGHT360

Finally, Chart 6.6.4, Chart 6.6.5, and Chart 6.6.6 are extracted from Green Building Studio indicating the space cooling demand for the model in months June, July, and August respectively.

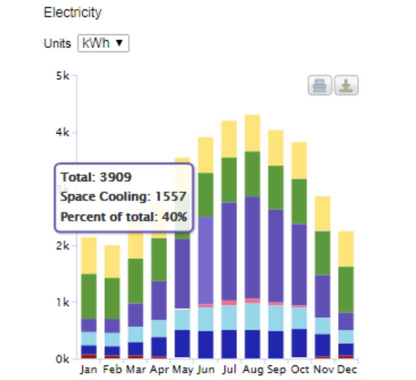


Chart 6.6.4. Cooling load in June, Source: Author, GBS

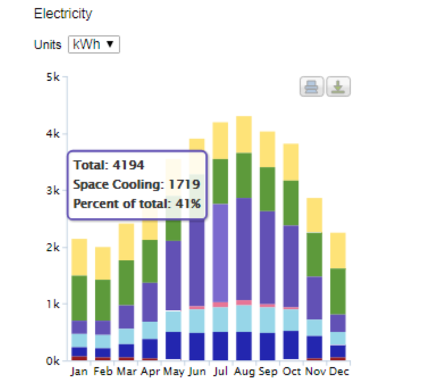


Chart 6.6.5. Cooling load in July, Source: Author, GBS

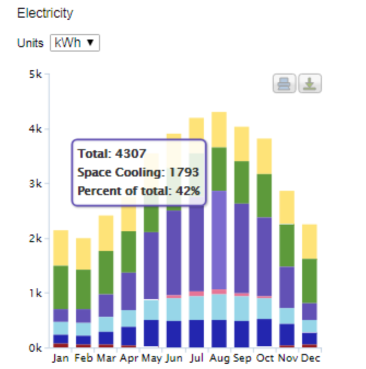


Chart 6.6.6. Cooling load in August, Source: Author, GBS

Appendix C Glazed Balcony with Wall Removal Simulation; B1W-300

The third simulation for the first model – balcony structure surrounded by 1 wall- is when the balcony is closed and glazed, and the wall (glazed door) separating the balcony from the interior is removed, creating a large living space. The plan used for this simulation is the same typical used for the first, and second simulation, but the wall is removed.

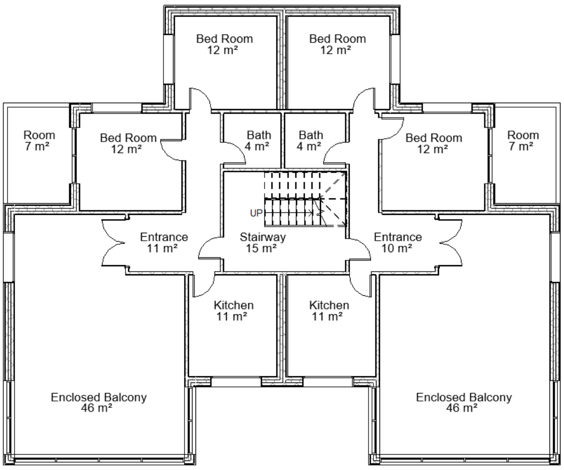


Figure 6.6.19. Plan used for third simulation having glazed balconies overlooking the west orientation and enlarged livable space, Source: Author

Figure 6.6.19 was designed on Revit, similarly to the previous simulations true north was projected having balconies overlooking the west, the thermal properties of the material used were inserted. Room tags, spaces, building type, and occupancy where indicated. Location and weather station were also chosen. The model will be energy simulated, so energy model is created, generated, and optimized (Figure 6.6.20).

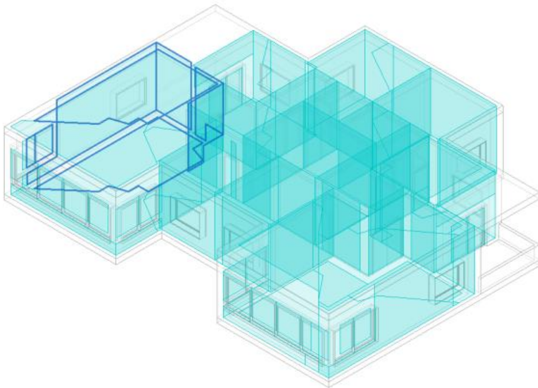


Figure 6.6.20. Energy model for glazed balcony when wall is removed, Source: Author

Now that the energy model is created, results can be obtained from Energy Plus, Insight 360, and Green Building Studio.

The heating and cooling report indicated the cooling demand for the specified spaces; the glazed balcony space and the adjacent space that is open to it; living and dining, in the south-west and north-west orientation. Table 9 and Table 10 indicate the cooling demand for the glazed balcony (2532 W) and the living space adjacent to the glazed balcony (2678 W) respectively on the north-west orientation.

Space Summary - 44 EB NW

Back to summary of spaces

Input Data	
Area (m²)	16
Volume (m³)	52.61
Wall Area (m²)	43
Roof Area (m²)	19
Door Area (m²)	0
Partition Area (m²)	0
Window Area (m²)	20
Skylight Area (m²)	0
Lighting Load (W)	195
Power Load (W)	265
Number of People	1
Sensible Heat Gain / Person (W)	73
Latent Heat Gain / Person (W)	59
Infiltration Airflow (L/s)	16.5
Space Type	Enclosed Balcony (1W)
Calculated Results	
Peak Cooling Total Load (W)	**2,532**
Peak Cooling Sensible Load (W)	2,422
Peak Cooling Latent Load (W)	111
Peak Cooling Airflow (L/s)	135.6
Peak Heating Load (W)	**1,281**
Peak Heating Airflow (L/s)	123.7

Table 9. Cooling Demand for glazed balcony on the North-west orientation, Source: Author, REVIT

Space Summary - 55 LIVING NW

Back to summary of spaces

Input Data	
Area (m²)	30
Volume (m³)	95.09
Wall Area (m²)	21
Roof Area (m²)	32
Door Area (m²)	4
Partition Area (m²)	0
Window Area (m²)	3
Skylight Area (m²)	0
Lighting Load (W)	352
Power Load (W)	480
Number of People	2
Sensible Heat Gain / Person (W)	73
Latent Heat Gain / Person (W)	59
Infiltration Airflow (L/s)	8.1
Space Type	Living/ Dining
Calculated Results	
Peak Cooling Total Load (W)	**2,678**
Peak Cooling Sensible Load (W)	2,590
Peak Cooling Latent Load (W)	88
Peak Cooling Airflow (L/s)	143.4
Peak Heating Load (W)	**949**
Peak Heating Airflow (L/s)	115.9

Table 10. Cooling Demand for adjacent space to the glazed balcony on the North-west orientation, Source: Author, REVIT

The south-west orientation resulted 2532 W for cooling in the glazed balcony (Table 11), and 2786 W in the living area (Table 12).

Space Summary - 52 EB NW

Back to summary of spaces

Input Data	
Area (m²)	16
Volume (m³)	52.61
Wall Area (m²)	43
Roof Area (m²)	19
Door Area (m²)	0
Partition Area (m²)	0
Window Area (m²)	20
Skylight Area (m²)	0
Lighting Load (W)	195
Power Load (W)	265
Number of People	1
Sensible Heat Gain / Person (W)	73
Latent Heat Gain / Person (W)	59
Infiltration Airflow (L/s)	16.5
Space Type	Enclosed Balcony (1W)
Calculated Results	
Peak Cooling Total Load (W)	**2,532**
Peak Cooling Sensible Load (W)	2,421
Peak Cooling Latent Load (W)	111
Peak Cooling Airflow (L/s)	135.6
Peak Heating Load (W)	**1,281**
Peak Heating Airflow (L/s)	123.7

Table 11. Cooling Demand for glazed balcony on the South-west orientation, Source: Author, REVIT

Space Summary - 56 LIVING SW

Back to summary of spaces

Input Data	
Area (m²)	30
Volume (m³)	95.09
Wall Area (m²)	21
Roof Area (m²)	32
Door Area (m²)	4
Partition Area (m²)	0
Window Area (m²)	3
Skylight Area (m²)	0
Lighting Load (W)	352
Power Load (W)	480
Number of People	2
Sensible Heat Gain / Person (W)	73
Latent Heat Gain / Person (W)	59
Infiltration Airflow (L/s)	8.1
Space Type	Living/ Dining
Calculated Results	
Peak Cooling Total Load (W)	**2,786**
Peak Cooling Sensible Load (W)	2,698
Peak Cooling Latent Load (W)	88
Peak Cooling Airflow (L/s)	149.2
Peak Heating Load (W)	**949**
Peak Heating Airflow (L/s)	115.9

Table 12. Cooling Demand for adjacent space to the glazed balcony on the south -west orientation, Source: Author, REVIT

Similar to the previous scenarios, Inisght360 showed that the model has a 19.8 USD for every m^2 annually, which is above the ASHRAE benchmark. (Figure 6.6.21)

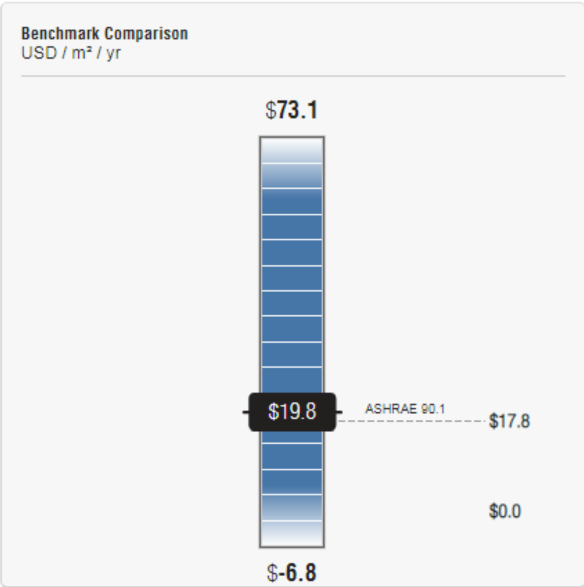


Figure 6.6.21. Benchmark comparison between model and ASHRAE 20.1 and ASHAE 2030, Source: Author, INISGHT360

The following figures (Figure 6.6.22, Figure 6.6.23, Figure 6.6.24, and Figure 6.6.25) are conducted from Insight360 that shows several modifications and factors that have direct impact on energy consumed in the scenario and benchmark comparison.

Figure 6.6.22 indicates the impact of orientation of the building, and mainly the balcony position, with respect to energy consumed, showing how the consumption changes when the orientation is modified. Figure 6.6.23 shows the different glazing types used in the model and how the energy consumed is affected for each glazing type.

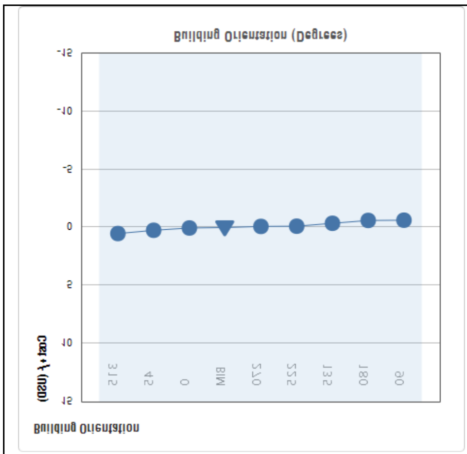


Figure 6.6.22. Building orientation chart indicating orientation adjustments that reduces the cost /m2, Source: Author, INSIGHT360

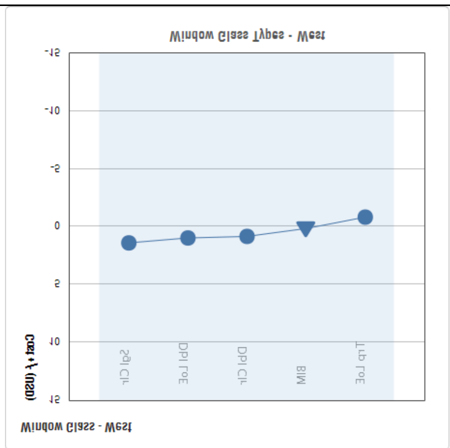


Figure 6.6.23. Chart indicating glazing types and their effect on cost consumed on energy, Source: Author, INSIGHT360

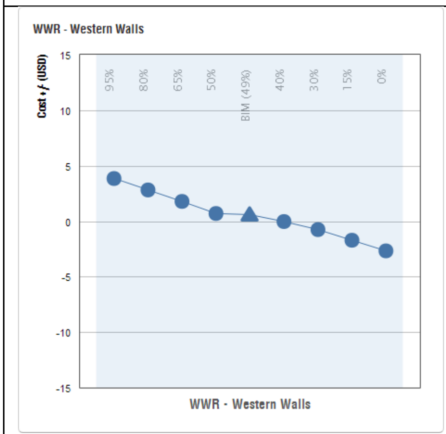


Figure 6.6.24. Chart indicating difference in energy consumption when window to wall ratio is reduced (on the western facade) , Source: Author, INSIGHT360

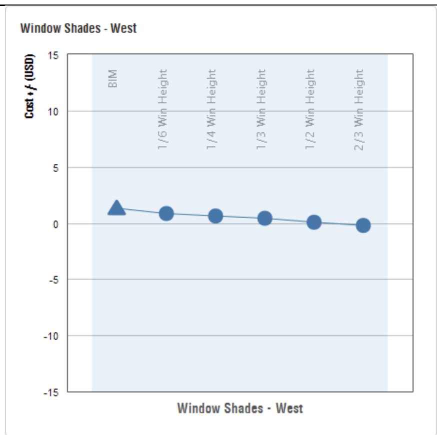


Figure 6.6.25. Chart indicating window shading and their effect on energy consumption, Source: Author, INSIGHT360

Finally, Chart 6.6.7, Chart 6.6.8, and Chart 6.6.9 are extracted from Green Building Studio indicating the space cooling demand for the model in months June, July, and August respectively.

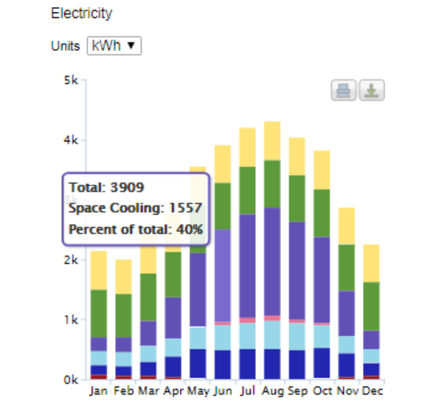


Chart 6.6.7. Cooling load in June, Source: Author

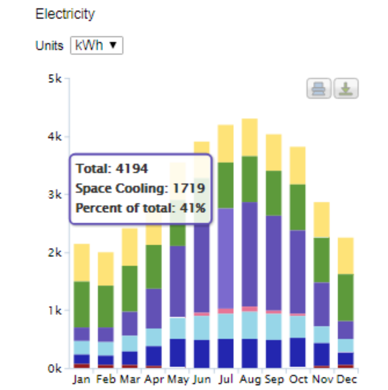


Chart 6.6.8. Cooling load in July, Source: Author

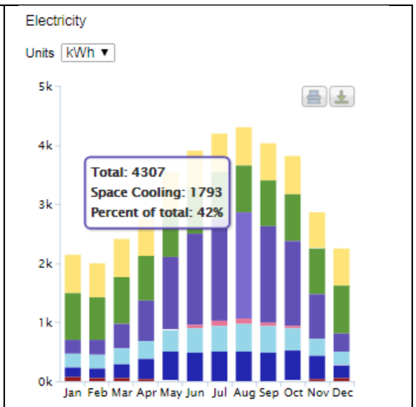


Chart 6.6.9. Cooling load in August, Source: Author

Appendix D Balcony Simulation; B2W-200

The second model is also designed on REVIT using the same plan as the first model with some modifications in order to design a balcony surrounded by 2 walls (Figure 1). The model will then be simulated into 3 scenarios where each scenario will examine several variables to estimate the cooling load; balcony, glazed balcony without removal of interior wall, and glazed balcony without the removal, having all balconies to be examined overlooking the west orientation.

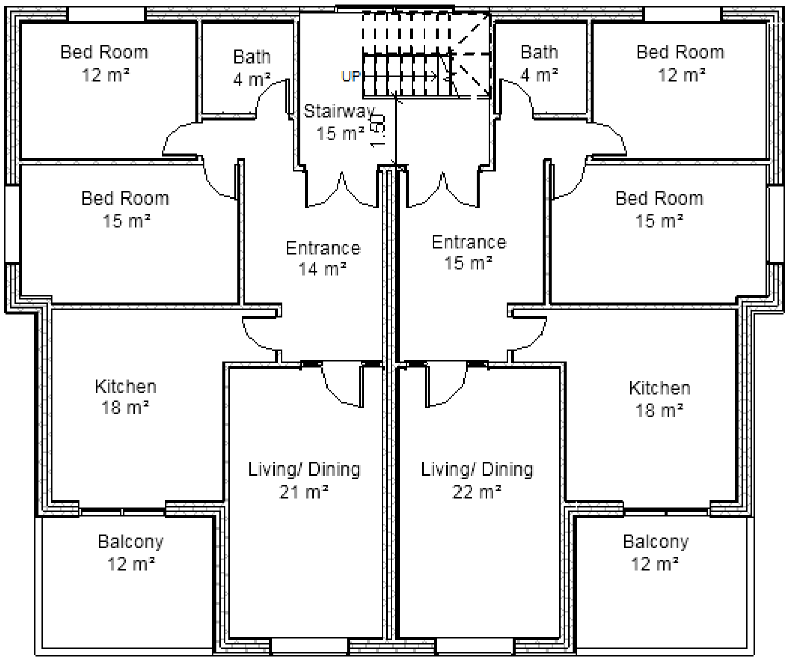


Figure 6.6.26. Typical plan to be used for simulations for balcony structure surrounded by 2 walls overlooking the west orientation, Source: Author

For the first simulation of this structure, the plan was projected to true north having the balconies overlook the west orientation. The materials inserted in the model are the same material used in the area, where their thermal properties are inserted similar to the previous model; roof, walls, window frames, glazing type, and slabs.

Room tags, spaces, building type, room type, and occupation where identified.

For further accurate estimation, the location was identified – "Corniche El Baher Area"- and the weather station closest to the focus area was chosen. Now that the model is ready for energy simulation, the energy model is created, generated, and optimized, by which the analysis will result in Insight 360 and Green Building Studio.

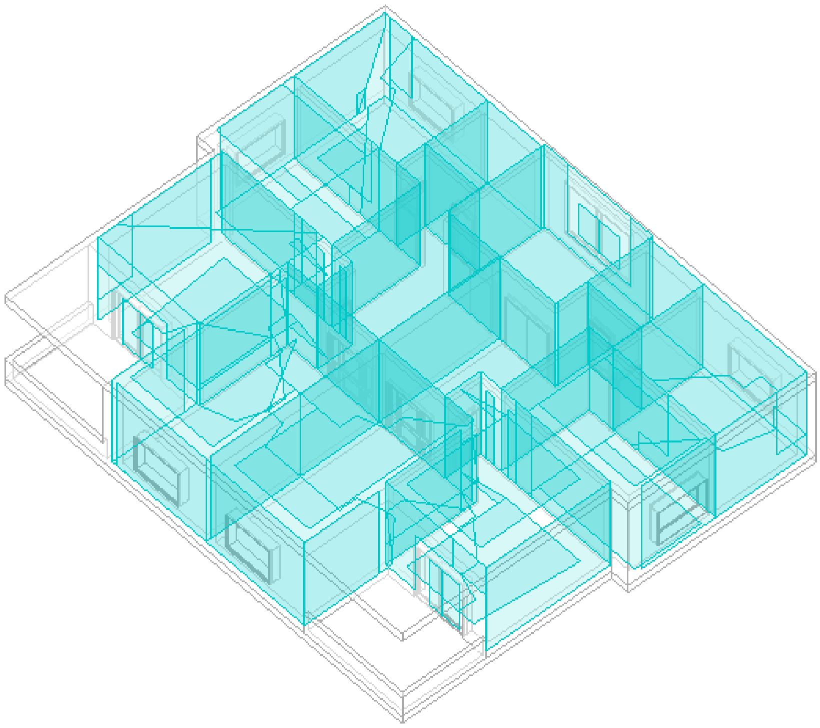


Figure 6.6.27. Energy model is created, Source: Author

Moreover, the report and schedule for heating and cooling generated by Energy Plus plugin in Revit can be exported, which shows the cooling demand for each space in the apartments.

The preliminary outcomes of the second model's first scenario are the results of the heating and cooling report, Insight 360, and Green Building Studio. Table 13 indicates the cooling load for the balcony space located on the north-west orientation, resulting in 1308 Watts. Table 14 indicates the cooling demand for the living space that is adjacent to the balcony space on the north-west orientation, having 1944 Watts.

Space Summary - 18 Balcony NW

Back to summary of spaces

Input Data	
Area (m²)	12
Volume (m³)	37.04
Wall Area (m²)	33
Roof Area (m²)	13
Door Area (m²)	0
Partition Area (m²)	0
Window Area (m²)	4
Skylight Area (m²)	0
Lighting Load (W)	137
Power Load (W)	187
Number of People	1
Sensible Heat Gain / Person (W)	73
Latent Heat Gain / Person (W)	59
Infiltration Airflow (L/s)	12.9
Space Type	Balcony
Calculated Results	
Peak Cooling Total Load (W)	**1,308**
Peak Cooling Sensible Load (W)	1,233
Peak Cooling Latent Load (W)	75
Peak Cooling Airflow (L/s)	61.9
Peak Heating Load (W)	**817**
Peak Heating Airflow (L/s)	60.3

Table 13. Cooling Load report for balcony space located on the North-West orientation, Source: Author, REVIT

Space Summary - 16 Space

Back to summary of spaces

Input Data	
Area (m²)	18
Volume (m³)	57.46
Wall Area (m²)	23
Roof Area (m²)	20
Door Area (m²)	2
Partition Area (m²)	0
Window Area (m²)	4
Skylight Area (m²)	0
Lighting Load (W)	213
Power Load (W)	290
Number of People	1
Sensible Heat Gain / Person (W)	73
Latent Heat Gain / Person (W)	59
Infiltration Airflow (L/s)	8.9
Space Type	Kitchen
Calculated Results	
Peak Cooling Total Load (W)	**1,944**
Peak Cooling Sensible Load (W)	1,876
Peak Cooling Latent Load (W)	68
Peak Cooling Airflow (L/s)	92.0
Peak Heating Load (W)	**721**
Peak Heating Airflow (L/s)	61.2

Table 14. Cooling Load report for space adjacent to balcony located on the North-West orientation, Source: Author, REVIT

Table 15 indicates the cooling load for the balcony space located on the south-west orientation, resulting in 1341 Watts. Table 16 indicates the cooling demand for the living space that is adjacent to the balcony space on the south-west orientation, having 1985 Watts.

Space Summary - 25 Balcony SW

Back to summary of spaces

Input Data	
Area (m^2)	12
Volume (m^3)	37.04
Wall Area (m^2)	33
Roof Area (m^2)	13
Door Area (m^2)	0
Partition Area (m^2)	0
Window Area (m^2)	4
Skylight Area (m^2)	0
Lighting Load (W)	137
Power Load (W)	187
Number of People	1
Sensible Heat Gain / Person (W)	73
Latent Heat Gain / Person (W)	59
Infiltration Airflow (L/s)	12.7
Space Type	Balcony
Calculated Results	
Peak Cooling Total Load (W)	**1,341**
Peak Cooling Sensible Load (W)	1,267
Peak Cooling Latent Load (W)	74
Peak Cooling Airflow (L/s)	63.5
Peak Heating Load (W)	**811**
Peak Heating Airflow (L/s)	59.9

Table 15. Cooling Load report for balcony space located on the South-West orientation, Source: Author, REVIT

Space Summary - 23 Space

Back to summary of spaces

Input Data	
Area (m²)	18
Volume (m³)	57.46
Wall Area (m²)	23
Roof Area (m²)	20
Door Area (m²)	2
Partition Area (m²)	0
Window Area (m²)	4
Skylight Area (m²)	0
Lighting Load (W)	213
Power Load (W)	290
Number of People	1
Sensible Heat Gain / Person (W)	73
Latent Heat Gain / Person (W)	59
Infiltration Airflow (L/s)	8.9
Space Type	Kitchen
Calculated Results	
Peak Cooling Total Load (W)	**1,985**
Peak Cooling Sensible Load (W)	1,917
Peak Cooling Latent Load (W)	68
Peak Cooling Airflow (L/s)	94.0
Peak Heating Load (W)	**721**
Peak Heating Airflow (L/s)	61.2

Table 16. Cooling Load report for space adjacent to balcony located on the South-West orientation, Source: Author, REVIT

Insight360 obtains several energy results by which only the thesis concerned where selected to be further analyzed in the thesis. The first scenario (balcony) in the second model type (surrounded by 2 walls) has a mean cost of 20 USD per m^2 annually (Figure 6.6.28).

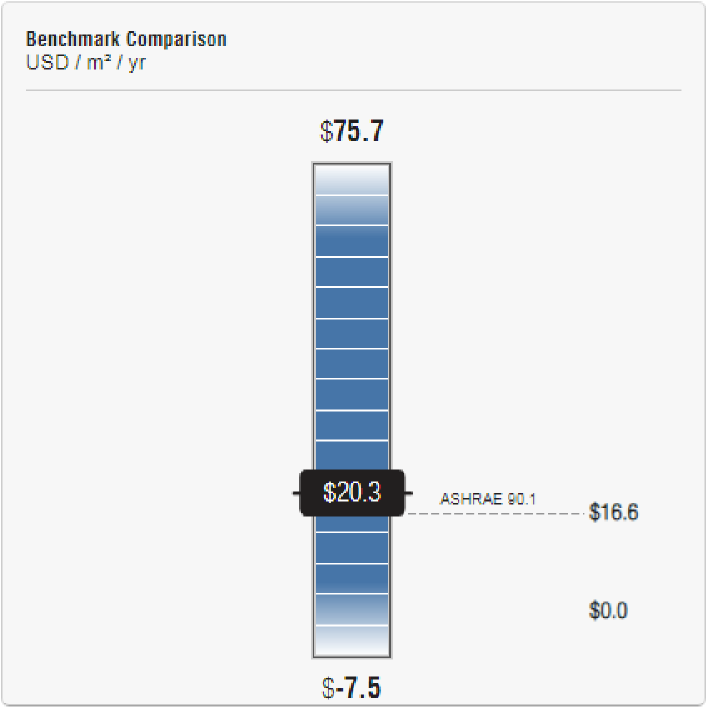


Figure 6.6.28. Benchmark comparison between model and ASHRAE 20.1 and ASHAE 2030, Source: Author, INSIGHT360

The following figures (Figure 6.6.29, Figure 6.6.30, Figure 6.6.31, and Figure 6.6.32) from Insight360 indicate several modifications and factors that have direct impact on energy consumed in the scenario.

Figure 6.6.29 indicates the impact of orientation of the building, and mainly the balcony position, with respect to energy consumed, illustrating several modifications of orientation. Figure 6.6.30 shows the different glazing types used in the model and how the energy consumed is affected.

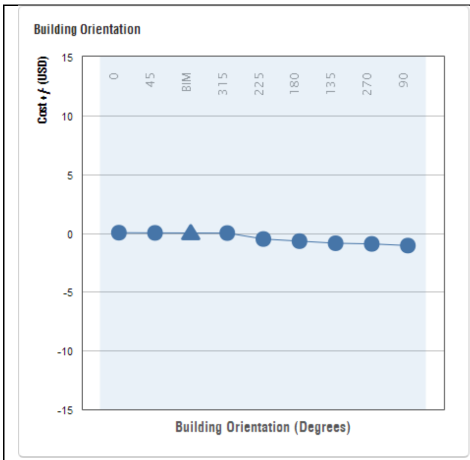


Figure 6.6.29. Building orientation chart indicating orientation adjustments that reduces the cost /m2, Source: Author

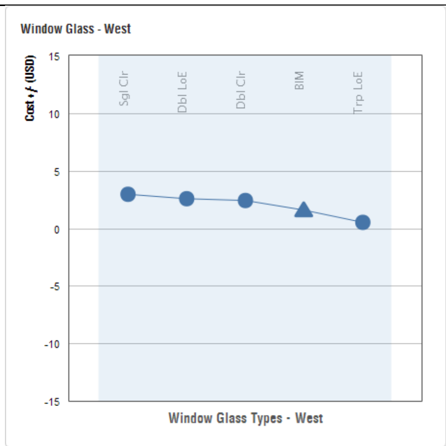


Figure 6.6.30. Chart indicating glazing types and their effect on cost consumed on energy, Source: Author

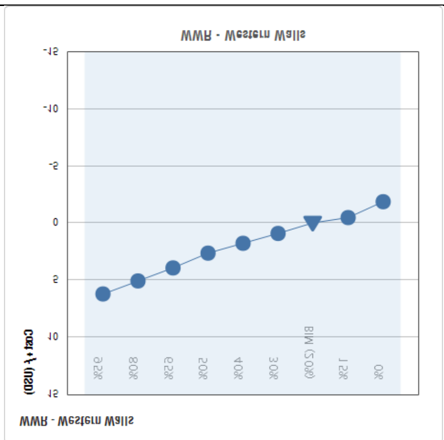


Figure 6.6.31. Chart indicating difference in energy consumption when window to wall ratio is reduced (on the western facade) , Source: Author

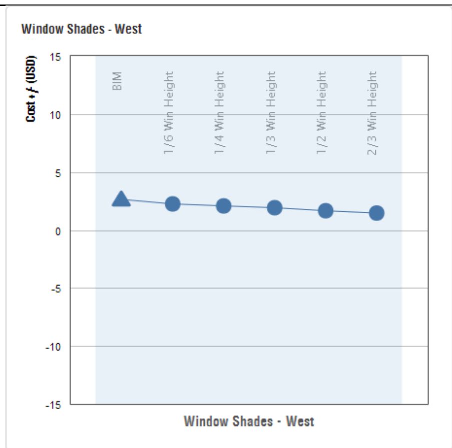


Figure 6.6.32. Chart indicating window shading and their effect on energy consumption, Source: Author

Moreover, Green Building Studio was used to extract cooling loads per month for the whole apartment. Chart 6.6.10, Chart 6.6.11, and Chart 6.6.12 represent the cooling demand (kWh) in the summer months; June, July, and August, respectively.

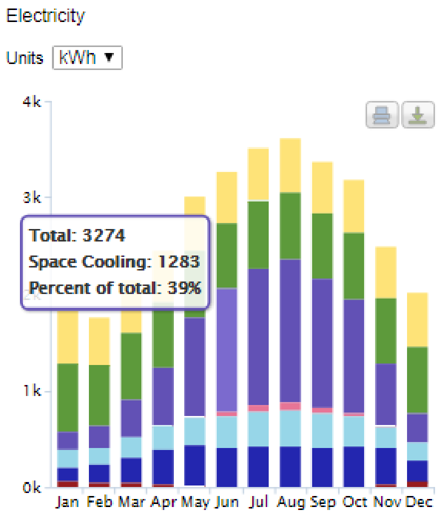


Chart 6.6.10. Cooling load in June, Source: Author

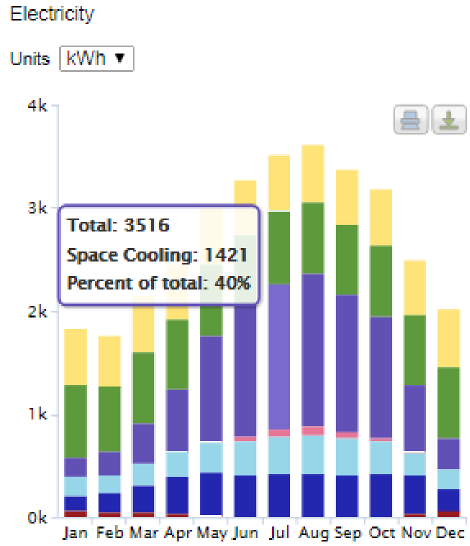


Chart 6.6.11. Cooling load in July, Source: Author

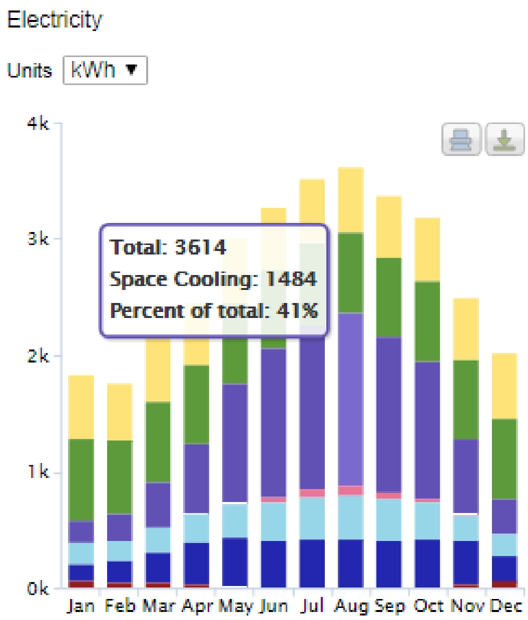


Chart 6.6.12. Cooling load in August, Source: Author

Appendix E Glazed Balcony Simulation; B2W-100

The second simulation for the second model is when the balcony is closed and glazed, and the wall (glazed door) separating the balcony from the interior is not removed. The plan used for this simulation is the same typical used for the first simulation (Figure), but the balcony is glazed.

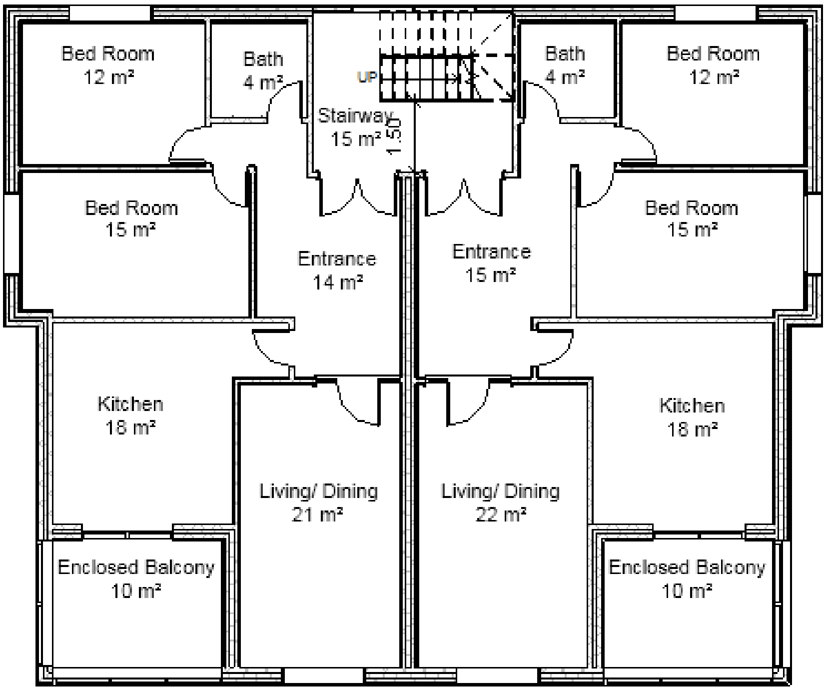


Figure 6.6.33. Plan used for second simulation having glazed balconies overlooking the west orientation, Source: Author

Figure 6.6.33 was designed on Revit, similar to previous simulations, all setting and modifications are applied to get accurate energy estimation for the selected area. The model will be energy simulated, so energy model is created, generated, and optimized (Figure 6.6.34).

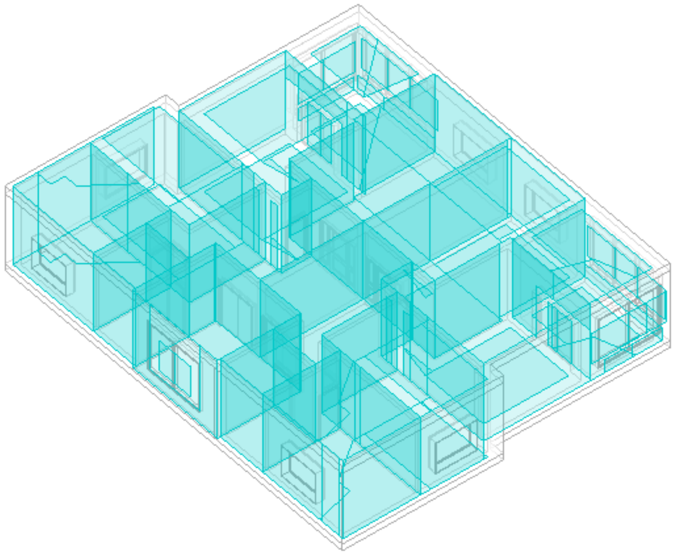


Figure 6.6.34. Energy model for glazed balcony without wall removal is created, Source: Author

When the energy model is created, results can be obtained from Energy Plus, Insight 360, and Green Building Studio.

The heating and cooling report indicated the cooling demand for the specified spaces; the glazed balcony and the adjacent space in the south-west and north-west orientation. Table 17 and Table 18 indicate the cooling demand for the glazed balcony (1818 W) and the living space adjacent to the glazed balcony (1948 W) respectively on the north-west orientation.

Space Summary - 18 EB NW

Back to summary of spaces

Input Data	
Area (m²)	10
Volume (m³)	32.21
Wall Area (m²)	32
Roof Area (m²)	12
Door Area (m²)	0
Partition Area (m²)	0
Window Area (m²)	18
Skylight Area (m²)	0
Lighting Load (W)	119
Power Load (W)	163
Number of People	1
Sensible Heat Gain / Person (W)	73
Latent Heat Gain / Person (W)	59
Infiltration Airflow (L/s)	12.4
Space Type	Enclosed Balcony (2W)
Calculated Results	
Peak Cooling Total Load (W)	**1,818**
Peak Cooling Sensible Load (W)	1,738
Peak Cooling Latent Load (W)	80
Peak Cooling Airflow (L/s)	92.8
Peak Heating Load (W)	**1,048**
Peak Heating Airflow (L/s)	96.5

Table 17. Cooling Demand for glazed balcony on the North-west orientation, Source: Author

Space Summary - 16 Space

Back to summary of spaces

Input Data	
Area (m²)	18
Volume (m³)	57.46
Wall Area (m²)	23
Roof Area (m²)	20
Door Area (m²)	2
Partition Area (m²)	0
Window Area (m²)	4
Skylight Area (m²)	0
Lighting Load (W)	213
Power Load (W)	290
Number of People	1
Sensible Heat Gain / Person (W)	73
Latent Heat Gain / Person (W)	59
Infiltration Airflow (L/s)	8.9
Space Type	Kitchen
Calculated Results	
Peak Cooling Total Load (W)	**1,948**
Peak Cooling Sensible Load (W)	1,873
Peak Cooling Latent Load (W)	74
Peak Cooling Airflow (L/s)	99.5
Peak Heating Load (W)	**713**
Peak Heating Airflow (L/s)	81.0

Table 18. Cooling Demand for adjacent space to the glazed balcony on the North-west orientation, Source: Author

The south-west orientation resulted 1862 W for cooling in the glazed balcony (Table 19), and 1989 W in the living area (Table 20).

Space Summary - 25 EB SW

Back to summary of spaces

Input Data	
Area (m²)	10
Volume (m³)	32.21
Wall Area (m²)	32
Roof Area (m²)	12
Door Area (m²)	0
Partition Area (m²)	0
Window Area (m²)	18
Skylight Area (m²)	0
Lighting Load (W)	119
Power Load (W)	163
Number of People	1
Sensible Heat Gain / Person (W)	73
Latent Heat Gain / Person (W)	59
Infiltration Airflow (L/s)	12.4
Space Type	Enclosed Balcony (2W)
Calculated Results	
Peak Cooling Total Load (W)	**1,862**
Peak Cooling Sensible Load (W)	1,783
Peak Cooling Latent Load (W)	80
Peak Cooling Airflow (L/s)	95.1
Peak Heating Load (W)	**1,049**
Peak Heating Airflow (L/s)	96.6

Table 19. Cooling Demand for glazed balcony on the South-west orientation, Source: Author

Space Summary - 23 Space

Back to summary of spaces

Input Data	
Area (m²)	18
Volume (m³)	57.46
Wall Area (m²)	23
Roof Area (m²)	20
Door Area (m²)	2
Partition Area (m²)	0
Window Area (m²)	4
Skylight Area (m²)	0
Lighting Load (W)	213
Power Load (W)	290
Number of People	1
Sensible Heat Gain / Person (W)	73
Latent Heat Gain / Person (W)	59
Infiltration Airflow (L/s)	8.9
Space Type	Kitchen
Calculated Results	
Peak Cooling Total Load (W)	**1,989**
Peak Cooling Sensible Load (W)	1,915
Peak Cooling Latent Load (W)	74
Peak Cooling Airflow (L/s)	101.6
Peak Heating Load (W)	**713**
Peak Heating Airflow (L/s)	81.0

Table 20. Cooling Demand for adjacent space to the glazed balcony on the south -west orientation, Source: Author

Figure 6.6.35 is derived from Insight 360, indicating that the second scenario of the second model has a 19.4 USD cost for every m^2 annually, and compares it with ASHRAE benchmark.

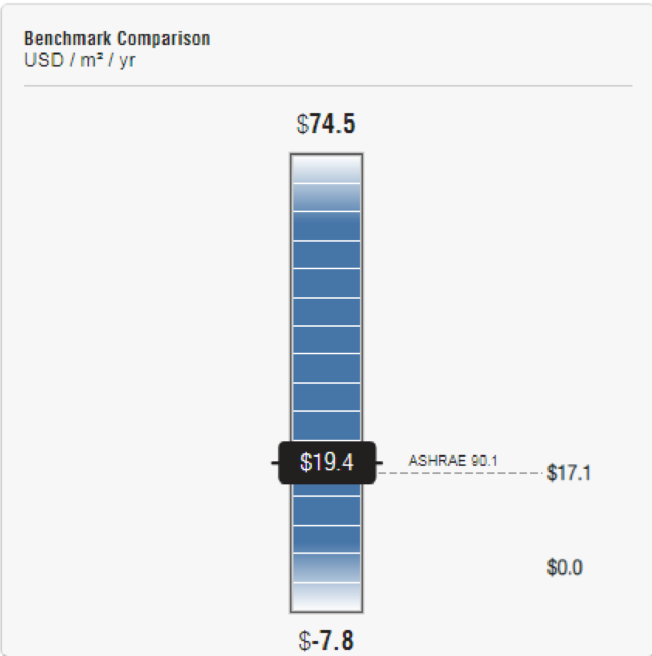


Figure 6.6.35. Benchmark comparison between model and ASHRAE 20.1 and ASHAE 2030, Source: Author

The following figures (Figure 6.6.36, Figure 6.6.37, Figure 6.6.38, and Figure 6.6.39) are conducted from Insight360 that shows several modifications and factors that have direct impact on energy consumed in the scenario and benchmark comparison.

Figure 6.6.36 indicates the impact of orientation of the building, and mainly the balcony position, with respect to energy consumed, showing how the consumption changes when the orientation is modified. Figure 6.6.37 shows the different glazing types used in the model and how the energy consumed is affected for each glazing type.

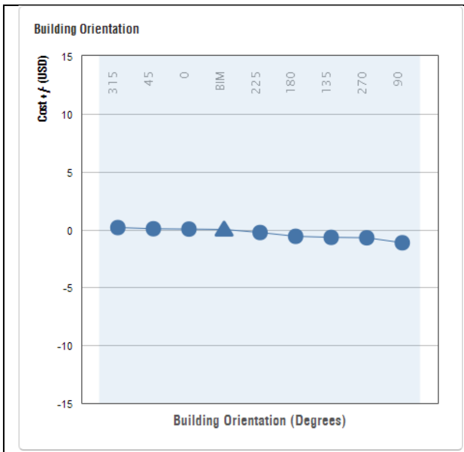


Figure 6.6.36. Building orientation chart indicating orientation adjustments that reduces the cost /m2, Source: Author

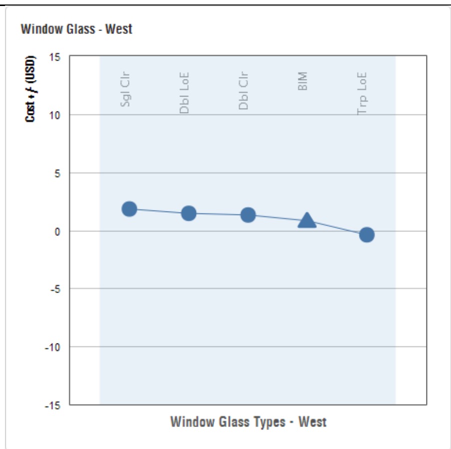


Figure 6.6.37. Chart indicating glazing types and their effect on cost consumed on energy, Source: Author

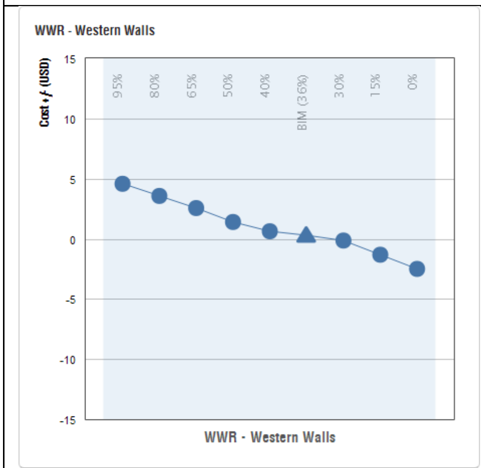


Figure 6.6.38. Chart indicating difference in energy consumption when window to wall ratio is reduced (on the western facade) , Source: Author

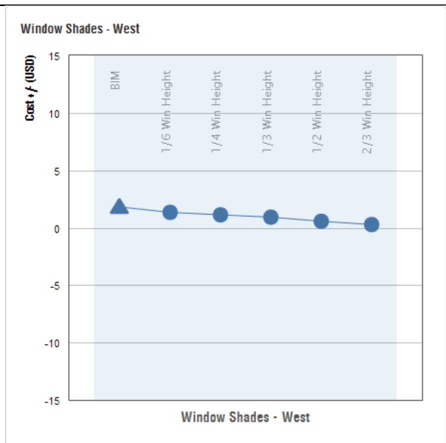


Figure 6.6.39. Chart indicating window shading and their effect on energy consumption, Source: Author

Finally, Chart 6.6.13, Chart 6.6.14, and Chart 6.6.15 are extracted from Green Building Studio indicating the space cooling demand for the model in months June, July, and August respectively.

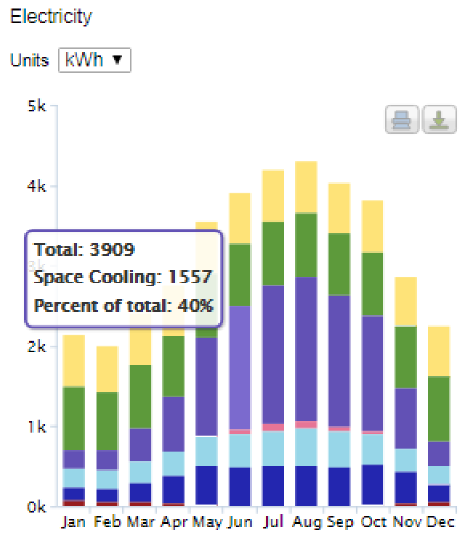


Chart 6.6.13. Cooling load in June, Source: Author

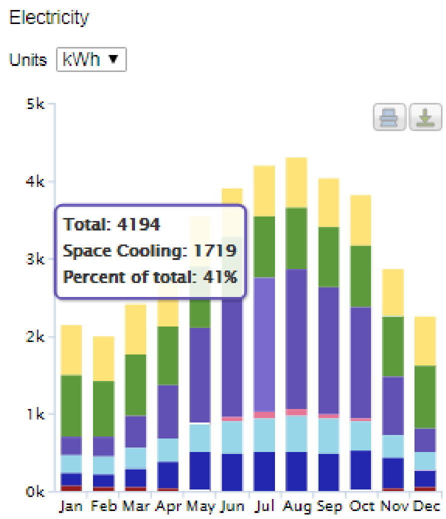


Chart 6.6.14. Cooling load in July, Source: Author

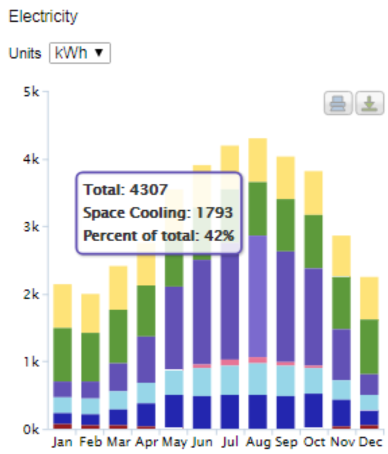


Chart 6.6.15. Cooling load in August, Source: Author

Appendix F Balcony Surrounded by Three Walls Structure; B3W-200

The third and final model is also designed on REVIT using the same plan as the first model with some modifications in order to design a balcony surrounded by 3 walls (Figure). The model will also undergo 3 scenarios, similar to the previous model.

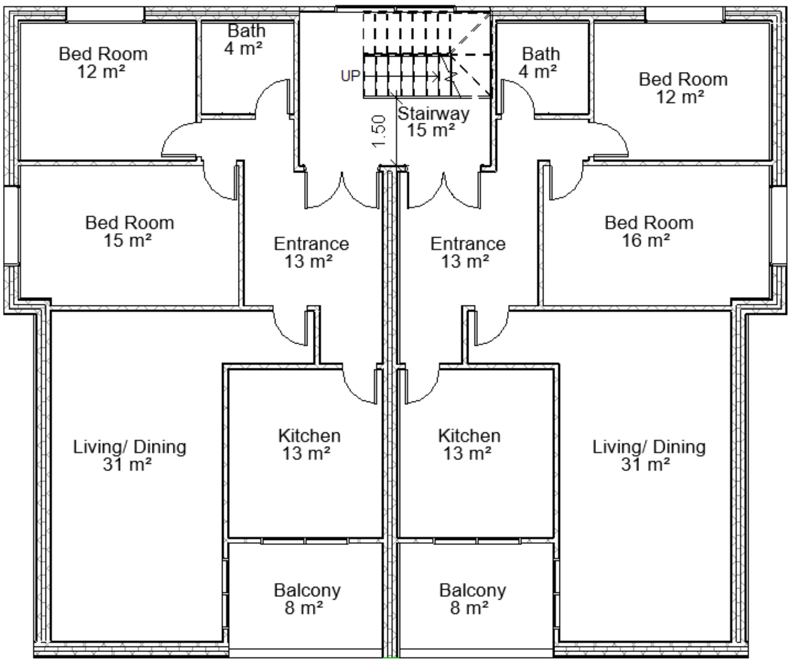


Figure 6.6.40. Typical plan to be used for simulations for balcony structure surrounded by 3 walls overlooking the west orientation, Source: Author

For the first simulation of this structure, the plan was projected to true north having the balconies overlook the west orientation. All modifications are done as previous models. Energy model is created (Figure 6.6.41).

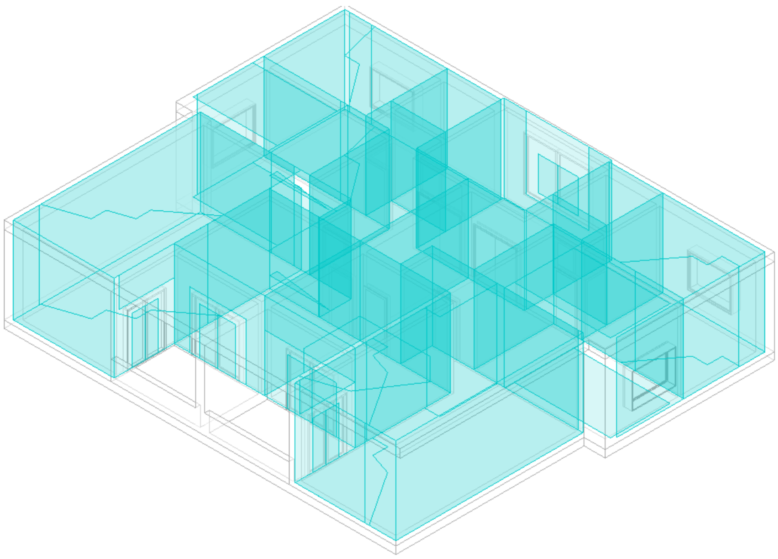


Figure 6.6.41. Energy model is created, Source: Author

Moreover, the report and schedule for heating and cooling generated by Energy Plus plugin in Revit can be exported, which shows the cooling demand for each space in the apartments.

The preliminary outcomes of the third model's first scenario are the results of the heating and cooling report, Insight 360, and Green Building Studio. Table 21 indicates the cooling load for the balcony space located on the north-west orientation, resulting in 832 Watts. Table 22 indicates the cooling demand for the living space that is adjacent to the balcony space on the north-west orientation, having 2796 Watts.

Space Summary - 29 WEST BALCONY

Back to summary of spaces

Input Data	
Area (m²)	8
Volume (m³)	26.18
Wall Area (m²)	13
Roof Area (m²)	9
Door Area (m²)	0
Partition Area (m²)	0
Window Area (m²)	8
Skylight Area (m²)	0
Lighting Load (W)	97
Power Load (W)	132
Number of People	1
Sensible Heat Gain / Person (W)	73
Latent Heat Gain / Person (W)	59
Infiltration Airflow (L/s)	5.2
Space Type	WEST BALCONY
Calculated Results	
Peak Cooling Total Load (W)	**832**
Peak Cooling Sensible Load (W)	792
Peak Cooling Latent Load (W)	40
Peak Cooling Airflow (L/s)	43.2
Peak Heating Load (W)	**390**
Peak Heating Airflow (L/s)	42.2

Table 21. Cooling Load report for balcony space located on the North-West orientation, Source: Author

Space Summary - 16 Space

Back to summary of spaces

Input Data	
Area (m²)	31
Volume (m³)	98.86
Wall Area (m²)	42
Roof Area (m²)	34
Door Area (m²)	2
Partition Area (m²)	0
Window Area (m²)	3
Skylight Area (m²)	0
Lighting Load (W)	366
Power Load (W)	180
Number of People	4
Sensible Heat Gain / Person (W)	73
Latent Heat Gain / Person (W)	45
Infiltration Airflow (L/s)	16.1
Space Type	Living Quarters -
Calculated Results	
Peak Cooling Total Load (W)	**2,796**
Peak Cooling Sensible Load (W)	2,643
Peak Cooling Latent Load (W)	153
Peak Cooling Airflow (L/s)	145.4
Peak Heating Load (W)	**1,191**
Peak Heating Airflow (L/s)	121.9

Table 22. Cooling Load report for space adjacent to balcony located on the North-West orientation, Source: Author

Table 23 indicates the cooling load for the balcony space located on the south-west orientation, resulting in 832 Watts. Table 24 indicates the cooling demand for the living space that is adjacent to the balcony space on the south-west orientation, having 2869 Watts.

Space Summary - 29 WEST BALCONY

Back to summary of spaces

Input Data	
Area (m²)	8
Volume (m³)	26.18
Wall Area (m²)	13
Roof Area (m²)	9
Door Area (m²)	0
Partition Area (m²)	0
Window Area (m²)	8
Skylight Area (m²)	0
Lighting Load (W)	97
Power Load (W)	132
Number of People	1
Sensible Heat Gain / Person (W)	73
Latent Heat Gain / Person (W)	59
Infiltration Airflow (L/s)	5.2
Space Type	WEST BALCONY
Calculated Results	
Peak Cooling Total Load (W)	**832**
Peak Cooling Sensible Load (W)	792
Peak Cooling Latent Load (W)	40
Peak Cooling Airflow (L/s)	43.2
Peak Heating Load (W)	**390**
Peak Heating Airflow (L/s)	42.2

Table 23. Cooling Load report for balcony space located on the South-West orientation, Source: Author

Space Summary - 33 Space

Back to summary of spaces

Input Data	
Area (m²)	31
Volume (m³)	98.86
Wall Area (m²)	42
Roof Area (m²)	34
Door Area (m²)	2
Partition Area (m²)	0
Window Area (m²)	3
Skylight Area (m²)	0
Lighting Load (W)	366
Power Load (W)	180
Number of People	4
Sensible Heat Gain / Person (W)	73
Latent Heat Gain / Person (W)	45
Infiltration Airflow (L/s)	16.1
Space Type	Living Quarters - [
Calculated Results	
Peak Cooling Total Load (W)	**2,869**
Peak Cooling Sensible Load (W)	2,716
Peak Cooling Latent Load (W)	153
Peak Cooling Airflow (L/s)	149.1
Peak Heating Load (W)	**1,191**
Peak Heating Airflow (L/s)	121.9

Table 24. Cooling Load report for space adjacent to balcony located on the South-West orientation, Source: Author

Insight360 obtains several energy results by which only the thesis concerned where selected to be further analyzed in the thesis. The first scenario (balcony) in the third model type (surrounded by 3 walls) has a mean cost of 19.6 USD per m^2 annually (Figure 6.6.42).

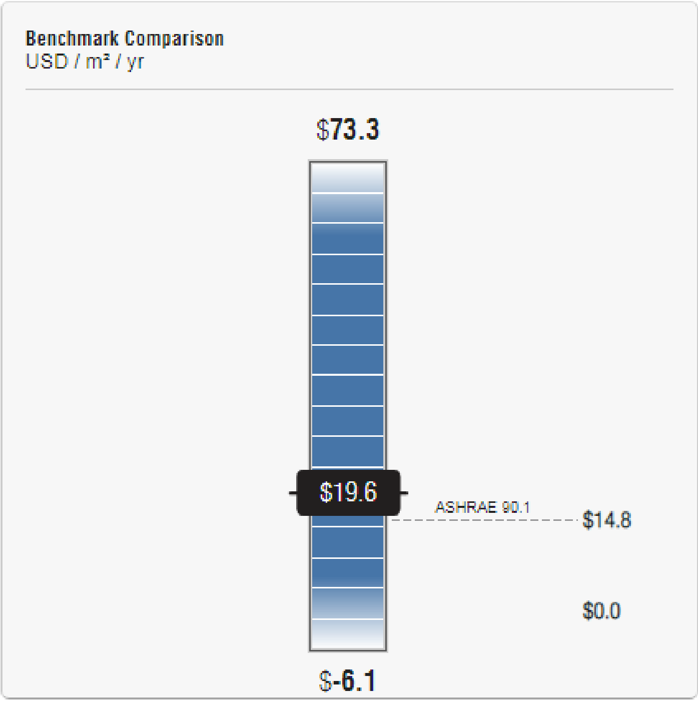


Figure 6.6.42. Benchmark comparison between model and ASHRAE 20.1 and ASHAE 2030, Source: Author

The following figures: Figure 6.6.43, Figure 6.6.44, Figure 6.6.45, and Figure 6.6.46, from Insight360 indicate several modifications and factors that have direct impact on energy consumed in the scenario.

Figure 6.6.43 indicates the impact of orientation of the building, and mainly the balcony position, with respect to energy consumed, illustrating several modifications of orientation. Figure 6.6.44 shows the different glazing types used in the model and how the energy consumed is affected.

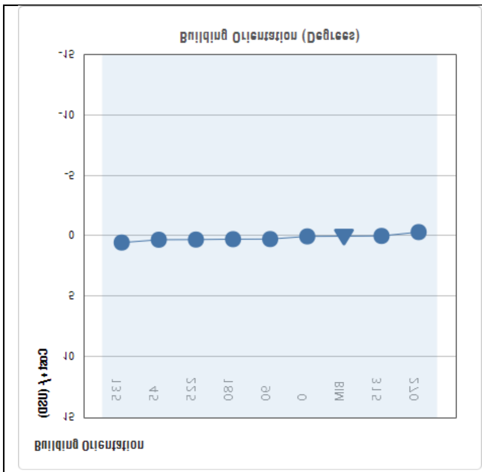


Figure 6.6.43. Building orientation chart indicating orientation adjustments that reduces the cost /m2, Source: Author

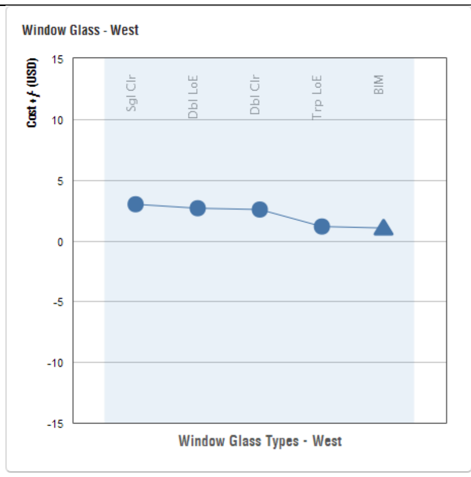


Figure 6.6.44. Chart indicating glazing types and their effect on cost consumed on energy, Source: Author

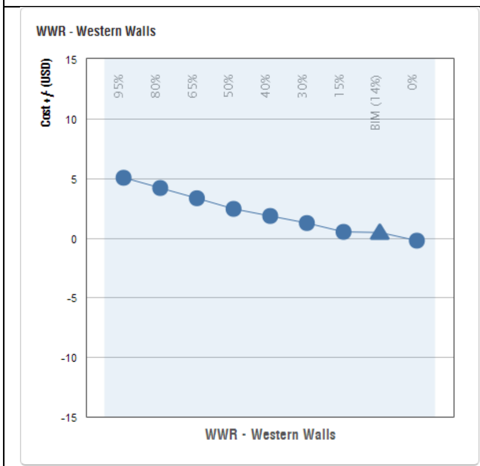


Figure 6.6.45. Chart indicating difference in energy consumption when window to wall ratio is reduced (on the western facade) , Source: Author

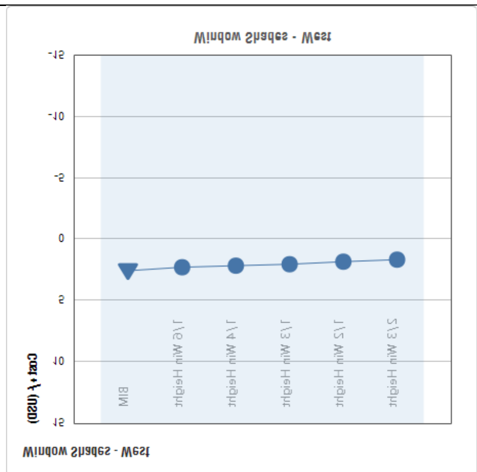


Figure 6.6.46. Chart indicating window shading and their effect on energy consumption, Source: Author

Moreover, Green Building Studio was used to extract cooling loads per month for the whole apartment. Chart 6.6.16, Chart 6.6.17, and Chart 6.6.18 represent the cooling demand (kWh) in the summer months; June, July, and August, respectively.

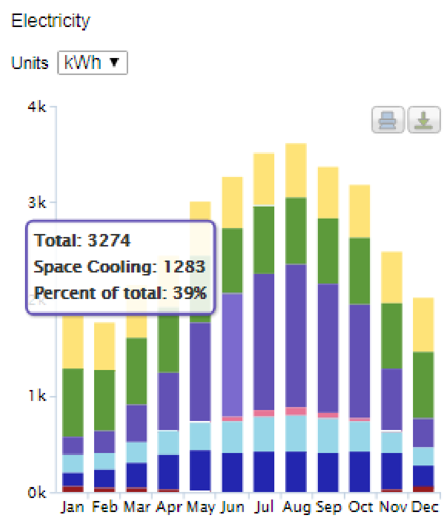


Chart 6.6.16. Cooling load in June, Source: Author

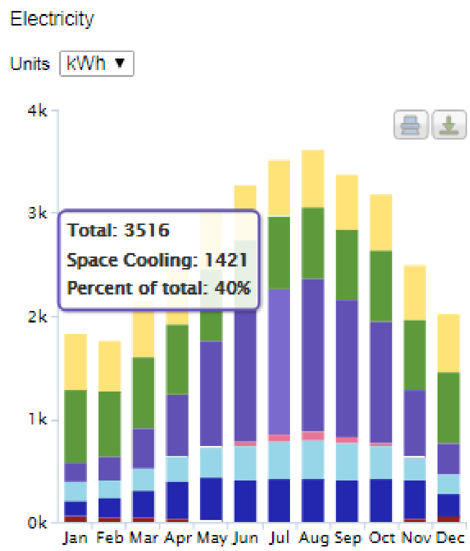


Chart 6.6.17. Cooling load in July, Source: Author

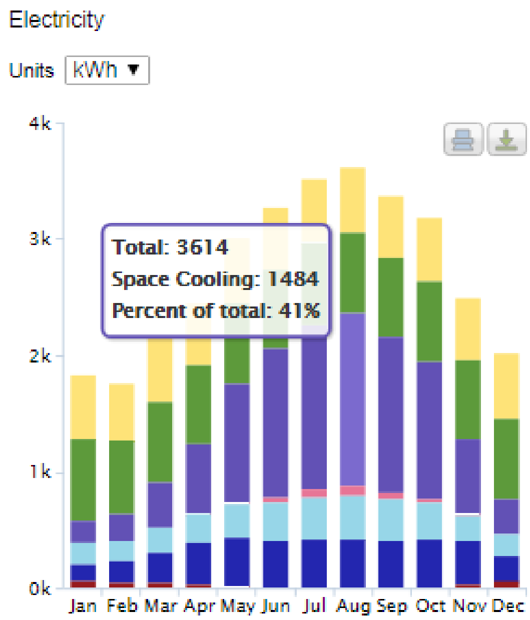


Chart 6.6.18. Cooling load in August, Source: Author

Appendix G Glazed Balcony Simulation; B3W-100

The second simulation for the third model is when the balcony is closed and glazed, and the wall (glazed door) separating the balcony from the interior is not removed. The plan used for this simulation is the same typical used for the first simulation, but the balcony is glazed (Figure 6.6.47).

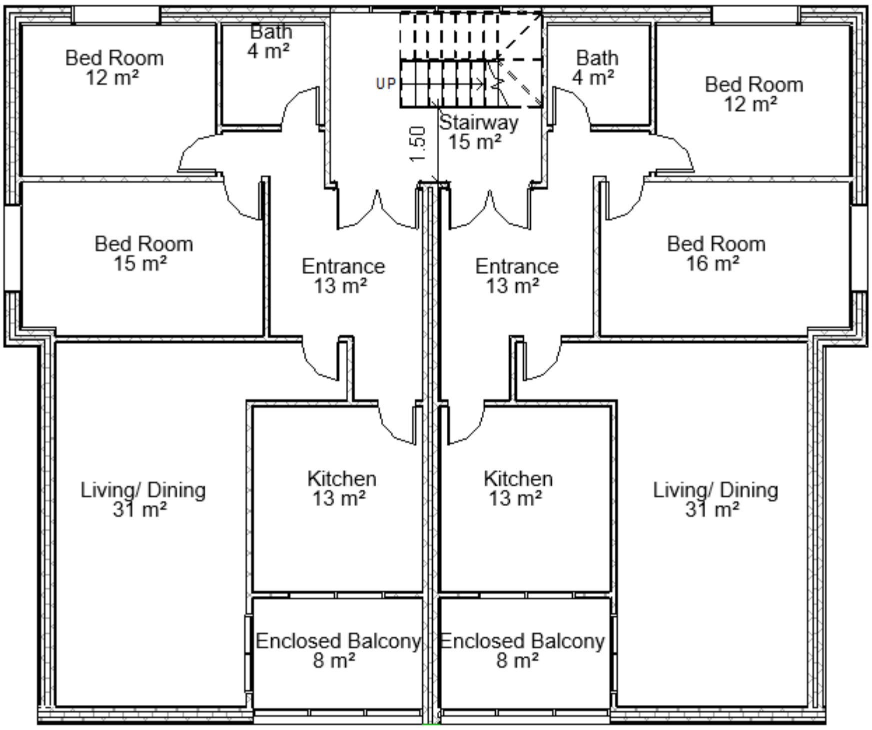


Figure 6.6.47. Plan used for second simulation having glazed balconies overlooking the west orientation, Source: Author

Figure 6.6.47 was designed on Revit, similar to previous simulations, all setting and modifications are applied to get accurate energy estimation for the selected area. Energy model is created (Figure 6.6.48).

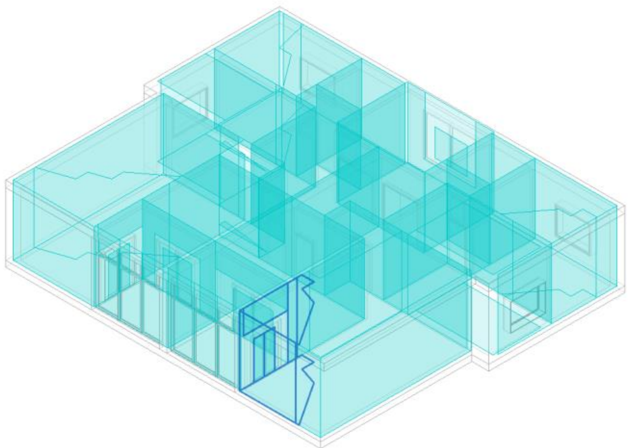


Figure 6.6.48. Energy model for glazed balcony without wall removal is created, Source: Author

When the energy model is created, results can be obtained from Energy Plus, Insight 360, and Green Building Studio.

The heating and cooling report indicated the cooling demand for the specified spaces; the glazed balcony and the adjacent space in the south-west and north-west orientation. Table 25 and Table 26 indicate the cooling demand for the glazed balcony (1506 W) and the living space adjacent to the glazed balcony (1066 W) respectively on the north-west orientation.

Space Summary - 29 EB W With Wall

Back to summary of spaces

Input Data	
Area (m²)	8
Volume (m³)	25.51
Wall Area (m²)	13
Roof Area (m²)	9
Door Area (m²)	0
Partition Area (m²)	0
Window Area (m²)	19
Skylight Area (m²)	0
Lighting Load (W)	94
Power Load (W)	129
Number of People	1
Sensible Heat Gain / Person (W)	73
Latent Heat Gain / Person (W)	59
Infiltration Airflow (L/s)	5.1
Space Type	West Enclosed I
Calculated Results	
Peak Cooling Total Load (W)	**1,506**
Peak Cooling Sensible Load (W)	1,471
Peak Cooling Latent Load (W)	35
Peak Cooling Airflow (L/s)	73.5
Peak Heating Load (W)	**606**
Peak Heating Airflow (L/s)	44.0

Table 25. Cooling Demand for glazed balcony on the North-west orientation, Source: Author

Space Summary - 31 Space

Back to summary of spaces

Input Data	
Area (m²)	13
Volume (m³)	41.44
Wall Area (m²)	0
Roof Area (m²)	14
Door Area (m²)	2
Partition Area (m²)	0
Window Area (m²)	4
Skylight Area (m²)	0
Lighting Load (W)	153
Power Load (W)	209
Number of People	1
Sensible Heat Gain / Person (W)	73
Latent Heat Gain / Person (W)	59
Infiltration Airflow (L/s)	0.0
Space Type	Kitchen
Calculated Results	
Peak Cooling Total Load (W)	**1,066**
Peak Cooling Sensible Load (W)	1,045
Peak Cooling Latent Load (W)	20
Peak Cooling Airflow (L/s)	52.0
Peak Heating Load (W)	**276**
Peak Heating Airflow (L/s)	29.9

Table 26. Cooling Demand for adjacent space to the glazed balcony on the North-west orientation, Source: Author

The south-west orientation resulted 1506 W for cooling in the glazed balcony (Table 27), and 1066 W in the living area (Table 28).

Space Summary - 29 EB W With Wall

Back to summary of spaces

Input Data	
Area (m²)	8
Volume (m³)	25.51
Wall Area (m²)	13
Roof Area (m²)	9
Door Area (m²)	0
Partition Area (m²)	0
Window Area (m²)	19
Skylight Area (m²)	0
Lighting Load (W)	94
Power Load (W)	129
Number of People	1
Sensible Heat Gain / Person (W)	73
Latent Heat Gain / Person (W)	59
Infiltration Airflow (L/s)	5.1
Space Type	West Enclosed I
Calculated Results	
Peak Cooling Total Load (W)	**1,506**
Peak Cooling Sensible Load (W)	1,471
Peak Cooling Latent Load (W)	35
Peak Cooling Airflow (L/s)	73.5
Peak Heating Load (W)	**606**
Peak Heating Airflow (L/s)	44.0

Table 27. Cooling Demand for glazed balcony on the South-west orientation, Source: Author

Space Summary - 36 Space

Back to summary of spaces

Input Data	
Area (m²)	13
Volume (m³)	41.44
Wall Area (m²)	0
Roof Area (m²)	14
Door Area (m²)	2
Partition Area (m²)	0
Window Area (m²)	4
Skylight Area (m²)	0
Lighting Load (W)	153
Power Load (W)	209
Number of People	1
Sensible Heat Gain / Person (W)	73
Latent Heat Gain / Person (W)	59
Infiltration Airflow (L/s)	0.0
Space Type	Kitchen
Calculated Results	
Peak Cooling Total Load (W)	**1,066**
Peak Cooling Sensible Load (W)	1,045
Peak Cooling Latent Load (W)	20
Peak Cooling Airflow (L/s)	52.0
Peak Heating Load (W)	**276**
Peak Heating Airflow (L/s)	29.9

Table 28. Cooling Demand for adjacent space to the glazed balcony on the south -west orientation, Source: Author

Figure 6.6.49 is derived from Insight 360, indicating that the second scenario of the second model has a 18.7 USD cost for every m^2 annually, and compares it with ASHRAE benchmark.

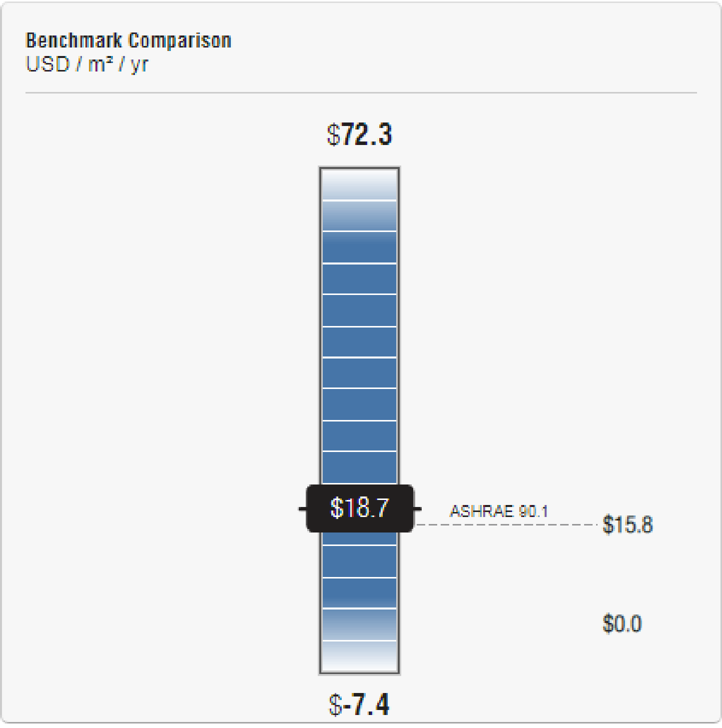


Figure 6.6.49. Benchmark comparison between model and ASHRAE 20.1 and ASHAE 2030, Source: Author

The following figures (Figure 6.6.50, Figure 6.6.51, Figure 6.6.52, and Figure 6.6.53) are conducted from Insight360 that shows several modifications and factors that have direct impact on energy consumed in the scenario and benchmark comparison.

Figure 6.6.50 indicates the impact of orientation of the building, and mainly the balcony position, with respect to energy consumed, showing how the consumption changes when the orientation is modified. Figure 6.6.51 shows the different glazing types used in the model and how the energy consumed is affected for each glazing type.

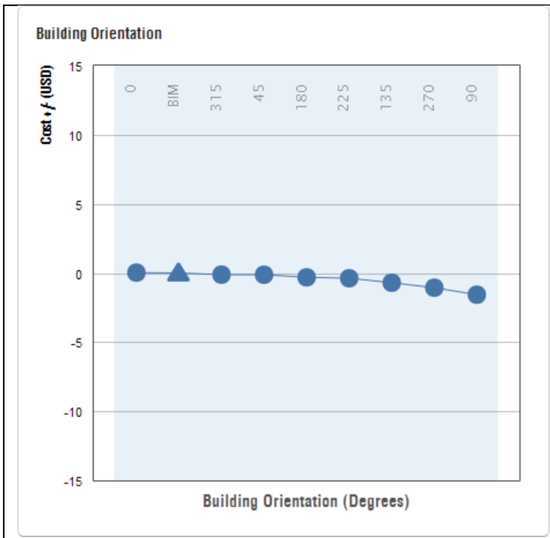


Figure 6.6.50. Building orientation chart indicating orientation adjustments that reduces the cost /m2, Source: Author

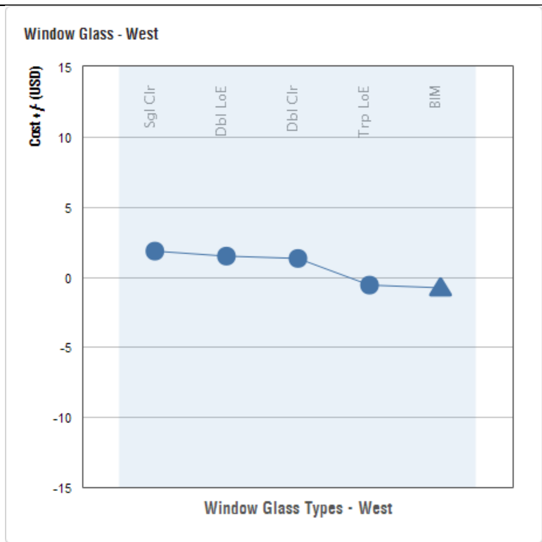


Figure 6.6.51. Chart indicating glazing types and their effect on cost consumed on energy, Source: Author

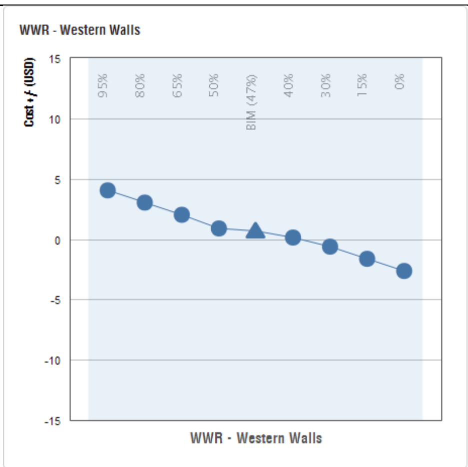


Figure 6.6.52. Chart indicating difference in energy consumption when window to wall ratio is reduced (on the western facade) , Source: Author

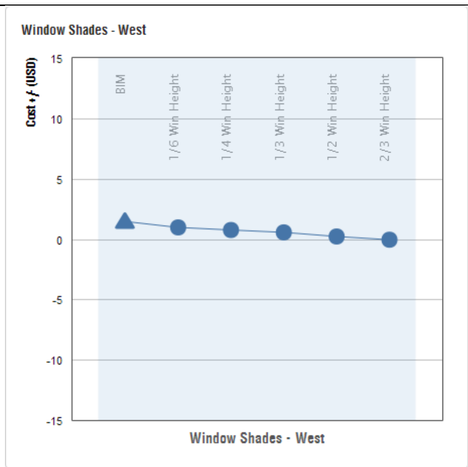


Figure 6.6.53. Chart indicating window shading and their effect on energy consumption, Source: Author

Finally, Chart 6.6.19, Chart 6.6.20, and Chart 6.6.21 are extracted from Green Building Studio indicating the space cooling demand for the model in months June, July, and August respectively.

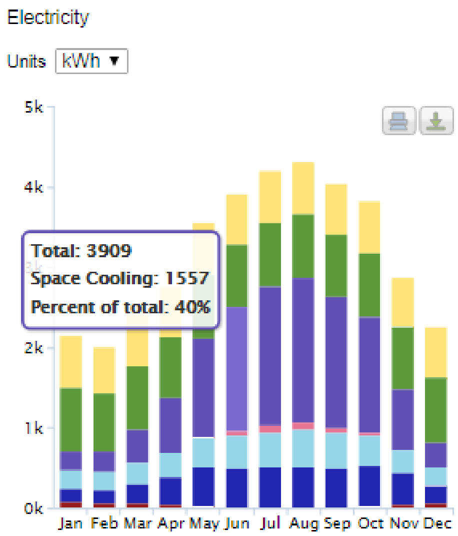


Chart 6.6.19. Cooling load in June, Source: Author

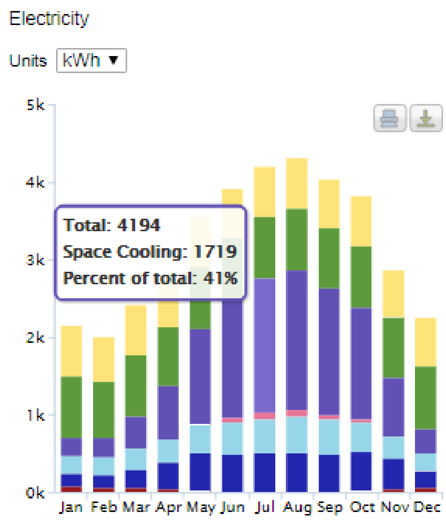


Chart 6.6.20. Cooling load in July, Source: Author

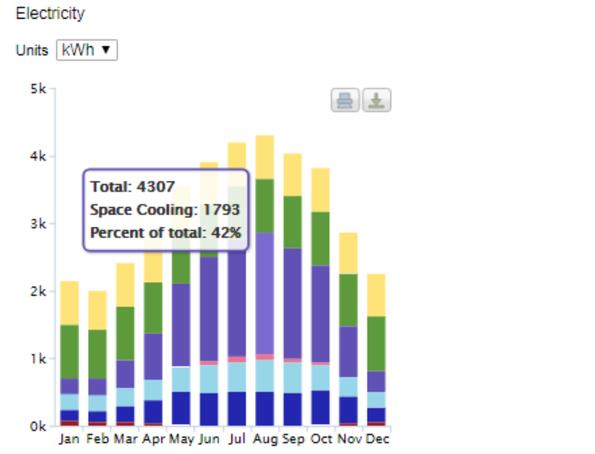


Chart 6.6.21. Cooling load in August, Source: Author

Appendix H Glazed Balcony with Wall Removal Simulation; B3W-300

The third simulation for the third model is when the balcony is closed and glazed, and the wall (glazed door) separating the balcony from the interior is removed, creating a large living space. Figure 6.6.54 is the plan used for this simulation.

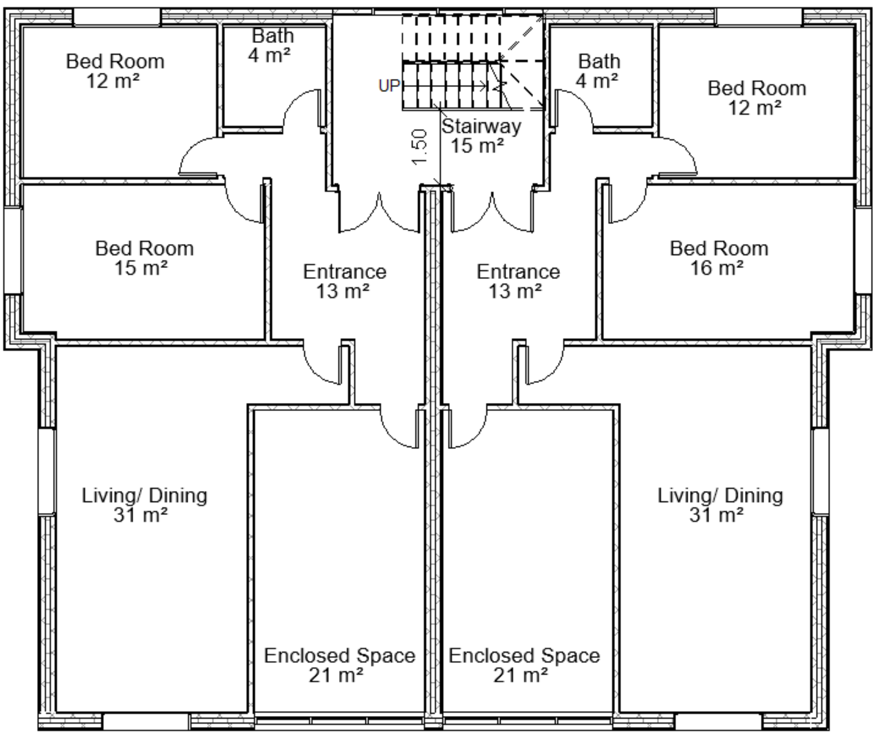


Figure 6.6.54. Plan used for third simulation having glazed balconies overlooking the west orientation and enlarged livable space, Source: Author

Figure 6.6.54 was designed on Revit, the model will be energy simulated, so energy model is created, generated, and optimized (Figure 6.6.55).

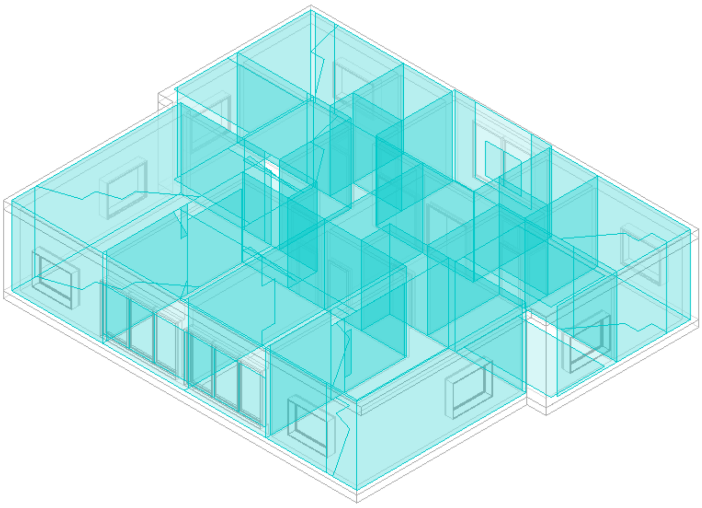


Figure 6.6.55. Energy model for glazed balcony when wall is removed, Source: Author

Now that the energy model is created, results can be obtained from Energy Plus, Insight 360, and Green Building Studio.

The heating and cooling report indicated the cooling demand for the specified spaces; the glazed balcony space and the adjacent space that is open to it; living and dining, in the south-west and north-west orientation. Table 29 and Table 30 indicate the cooling demand for the glazed balcony (1243 W) and the living space adjacent to the glazed balcony (1176W) respectively on the north-west orientation.

Space Summary - 29 WEST BALCONY

Back to summary of spaces

Input Data	
Area (m^2)	7
Volume (m^3)	23.25
Wall Area (m^2)	13
Roof Area (m^2)	9
Door Area (m^2)	0
Partition Area (m^2)	0
Window Area (m^2)	7
Skylight Area (m^2)	0
Lighting Load (W)	86
Power Load (W)	117
Number of People	1
Sensible Heat Gain / Person (W)	73
Latent Heat Gain / Person (W)	59
Infiltration Airflow (L/s)	5.1
Space Type	WEST BALCONY
Calculated Results	
Peak Cooling Total Load (W)	**1,243**
Peak Cooling Sensible Load (W)	1,206
Peak Cooling Latent Load (W)	37
Peak Cooling Airflow (L/s)	65.5
Peak Heating Load (W)	**495**
Peak Heating Airflow (L/s)	49.0

Table 29. Cooling Demand for glazed balcony on the North-west orientation, Source: Author

Back to summary of spaces

Input Data	
Area (m^2)	14
Volume (m^3)	43.92
Wall Area (m^2)	0
Roof Area (m^2)	15
Door Area (m^2)	2
Partition Area (m^2)	0
Window Area (m^2)	0
Skylight Area (m^2)	0
Lighting Load (W)	163
Power Load (W)	80
Number of People	2
Sensible Heat Gain / Person (W)	73
Latent Heat Gain / Person (W)	45
Infiltration Airflow (L/s)	0.0
Space Type	Living Quarters -
Calculated Results	
Peak Cooling Total Load (W)	**1,176**
Peak Cooling Sensible Load (W)	1,145
Peak Cooling Latent Load (W)	31
Peak Cooling Airflow (L/s)	62.0
Peak Heating Load (W)	**319**
Peak Heating Airflow (L/s)	41.5

Table 30. Cooling Demand for adjacent space to the glazed balcony on the North-west orientation, Source: Author

The south-west orientation resulted 1243 W for cooling in the glazed balcony (Table 31), and 1176 W in the living area (Table 32).

Space Summary - 29 WEST BALCONY

Back to summary of spaces

Input Data	
Area (m²)	7
Volume (m³)	23.25
Wall Area (m²)	13
Roof Area (m²)	9
Door Area (m²)	0
Partition Area (m²)	0
Window Area (m²)	7
Skylight Area (m²)	0
Lighting Load (W)	86
Power Load (W)	117
Number of People	1
Sensible Heat Gain / Person (W)	73
Latent Heat Gain / Person (W)	59
Infiltration Airflow (L/s)	5.1
Space Type	WEST BALCONY
Calculated Results	
Peak Cooling Total Load (W)	**1,243**
Peak Cooling Sensible Load (W)	1,206
Peak Cooling Latent Load (W)	37
Peak Cooling Airflow (L/s)	65.5
Peak Heating Load (W)	**495**
Peak Heating Airflow (L/s)	49.0

Table 31. Cooling Demand for glazed balcony on the South-west orientation, Source: Author

Back to summary of spaces

Input Data	
Area (m²)	14
Volume (m³)	43.92
Wall Area (m²)	0
Roof Area (m²)	15
Door Area (m²)	2
Partition Area (m²)	0
Window Area (m²)	0
Skylight Area (m²)	0
Lighting Load (W)	163
Power Load (W)	80
Number of People	2
Sensible Heat Gain / Person (W)	73
Latent Heat Gain / Person (W)	45
Infiltration Airflow (L/s)	0.0
Space Type	Living Quarters -
Calculated Results	
Peak Cooling Total Load (W)	**1,176**
Peak Cooling Sensible Load (W)	1,145
Peak Cooling Latent Load (W)	31
Peak Cooling Airflow (L/s)	62.0
Peak Heating Load (W)	**319**
Peak Heating Airflow (L/s)	41.5

Table 32. Cooling Demand for adjacent space to the glazed balcony on the south -west orientation, Source: Author

Inisght360 showed that the model has a 18.7 USD for every m[2] annually, which is above the ASHRAE benchmark (Figure 6.6.56).

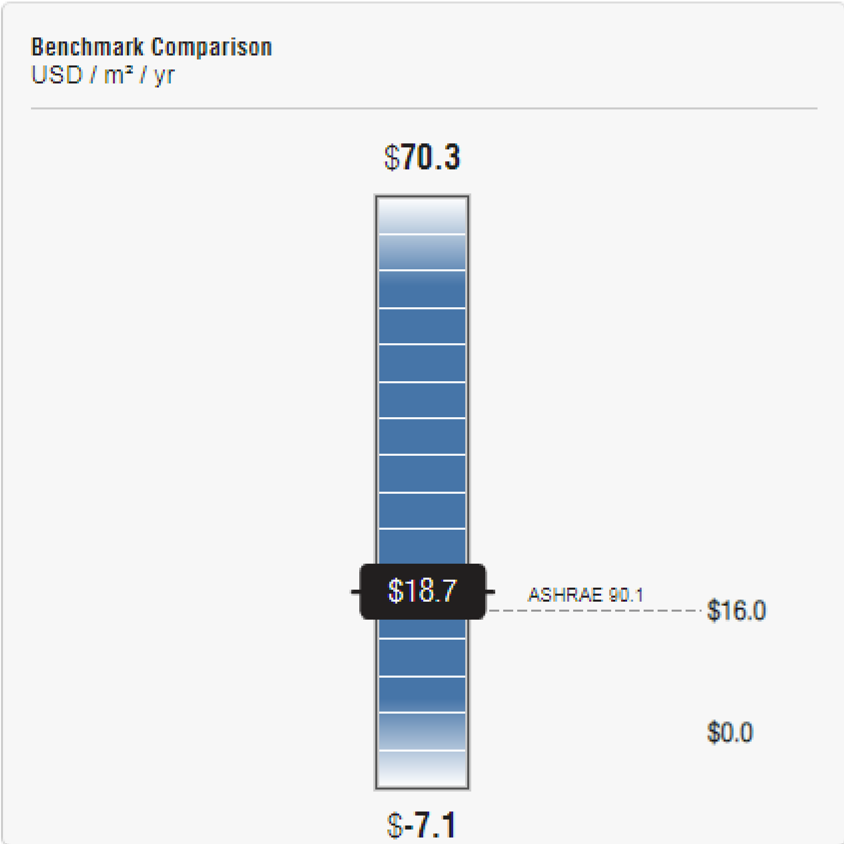


Figure 6.6.56. Benchmark comparison between model and ASHRAE 20.1 and ASHAE 2030, Source: Author

Appendix I Glazed Balcony with Wall Removal Simulation; B2W-300

The third simulation for the second model is when the balcony is closed and glazed, and the wall (glazed door) separating the balcony from the interior is removed, creating a large living space. The plan used for this simulation is the same typical used for the first, and second simulation but the wall is removed (Figure 6.6.57).

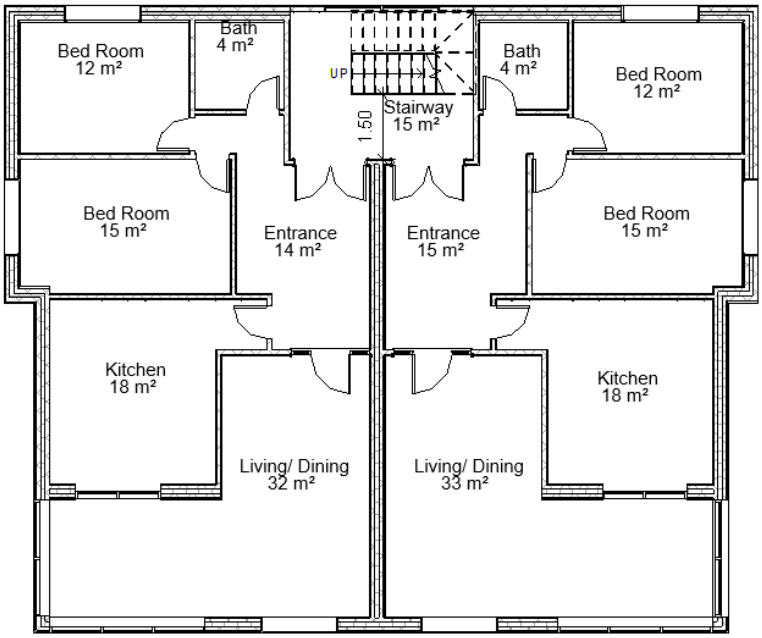


Figure 6.6.57. Plan used for third simulation having glazed balconies overlooking the west orientation and enlarged livable space, Source: Author

Figure 6.6.57 was designed on Revit, the model will be energy simulated, so energy model is created, generated, and optimized (Figure 6.6.58).

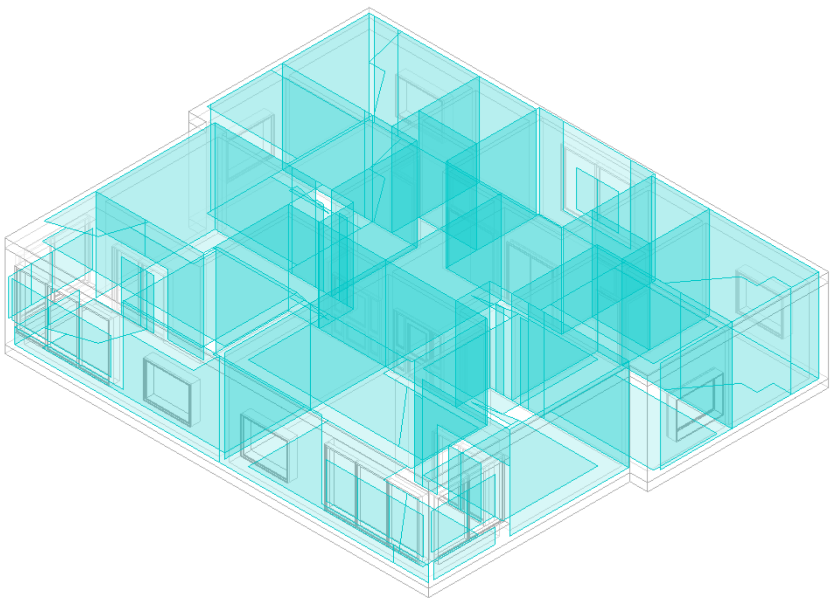


Figure 6.6.58. Energy model for glazed balcony when wall is removed, Source: Author

Now that the energy model is created, results can be obtained from Energy Plus, Insight 360, and Green Building Studio.

The heating and cooling report indicated the cooling demand for the specified spaces; the glazed balcony space and the adjacent space that is open to it; living and dining, in the south-west and north-west orientation. Table 33 and Table 34 indicate the cooling demand for the glazed balcony (4025 W) and the living space adjacent to the glazed balcony (1026 W) respectively on the north-west orientation.

Space Summary - 29 EB NW Without wall

Back to summary of spaces

Input Data	
Area (m²)	20
Volume (m³)	65.44
Wall Area (m²)	46
Roof Area (m²)	23
Door Area (m²)	0
Partition Area (m²)	0
Window Area (m²)	20
Skylight Area (m²)	0
Lighting Load (W)	242
Power Load (W)	330
Number of People	2
Sensible Heat Gain / Person (W)	73
Latent Heat Gain / Person (W)	59
Infiltration Airflow (L/s)	17.6
Space Type	Enclosed Balcony (2W)
Calculated Results	
Peak Cooling Total Load (W)	**4,025**
Peak Cooling Sensible Load (W)	3,588
Peak Cooling Latent Load (W)	436
Peak Cooling Airflow (L/s)	186.6
Peak Heating Load (W)	**2,088**
Peak Heating Airflow (L/s)	142.5

Table 33. Cooling Demand for glazed balcony on the North-west orientation, Source: Author

Space Summary - 31 LIVING NW

Back to summary of spaces

Input Data	
Area (m²)	12
Volume (m³)	37.25
Wall Area (m²)	0
Roof Area (m²)	13
Door Area (m²)	6
Partition Area (m²)	0
Window Area (m²)	0
Skylight Area (m²)	0
Lighting Load (W)	138
Power Load (W)	188
Number of People	1
Sensible Heat Gain / Person (W)	73
Latent Heat Gain / Person (W)	59
Infiltration Airflow (L/s)	0.0
Space Type	LIVING DINING
Calculated Results	
Peak Cooling Total Load (W)	**1,026**
Peak Cooling Sensible Load (W)	1,008
Peak Cooling Latent Load (W)	18
Peak Cooling Airflow (L/s)	47.6
Peak Heating Load (W)	**363**
Peak Heating Airflow (L/s)	33.3

Table 34. Cooling Demand for adjacent space to the glazed balcony on the North-west orientation, Source: Author

The south-west orientation resulted 4081 W for cooling in the glazed balcony (Table 35), and 1079 W in the living area (Table 36).

Space Summary - 30 Space

Back to summary of spaces

Input Data	
Area (m²)	21
Volume (m³)	67.00
Wall Area (m²)	46
Roof Area (m²)	24
Door Area (m²)	0
Partition Area (m²)	0
Window Area (m²)	21
Skylight Area (m²)	0
Lighting Load (W)	248
Power Load (W)	338
Number of People	2
Sensible Heat Gain / Person (W)	73
Latent Heat Gain / Person (W)	59
Infiltration Airflow (L/s)	17.9
Space Type	Enclosed Balcony (2W)
Calculated Results	
Peak Cooling Total Load (W)	**4,081**
Peak Cooling Sensible Load (W)	3,639
Peak Cooling Latent Load (W)	443
Peak Cooling Airflow (L/s)	189.2
Peak Heating Load (W)	**2,111**
Peak Heating Airflow (L/s)	144.4

Table 35. Cooling Demand for glazed balcony on the South-west orientation, Source: Author

Space Summary - 32 LIVING SW

Back to summary of spaces

Input Data	
Area (m²)	12
Volume (m³)	39.20
Wall Area (m²)	0
Roof Area (m²)	13
Door Area (m²)	6
Partition Area (m²)	0
Window Area (m²)	0
Skylight Area (m²)	0
Lighting Load (W)	119
Power Load (W)	40
Number of People	2
Sensible Heat Gain / Person (W)	73
Latent Heat Gain / Person (W)	59
Infiltration Airflow (L/s)	0.0
Space Type	Restrooms
Calculated Results	
Peak Cooling Total Load (W)	**1,079**
Peak Cooling Sensible Load (W)	1,011
Peak Cooling Latent Load (W)	68
Peak Cooling Airflow (L/s)	50.0
Peak Heating Load (W)	**378**
Peak Heating Airflow (L/s)	34.9

Table 36. Cooling Demand for adjacent space to the glazed balcony on the south -west orientation, Source: Author

Inisght360 showed that the model has a 19.3 USD for every m^2 annually, which is above the ASHRAE benchmark. (Figure6.6.59)

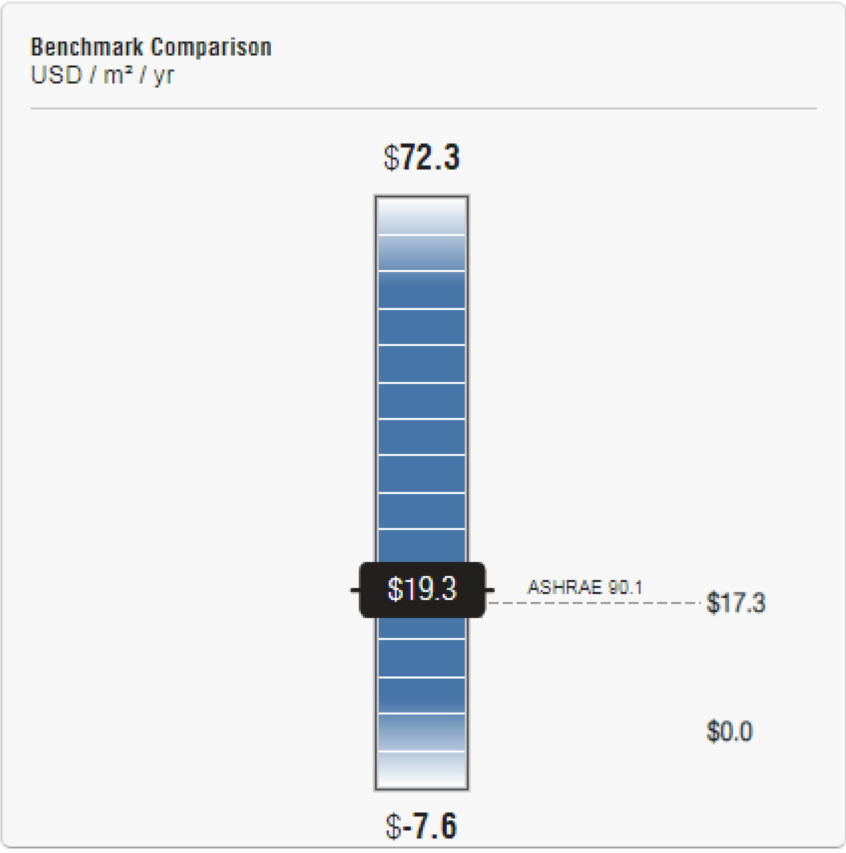


Figure6.6.59. Benchmark comparison between model and ASHRAE 20.1 and ASHAE 2030, Source: Author

The following figures (Figure 6.6.60, Figure 6.6.61, Figure 6.6.62, and Figure 6.6.63) are conducted from Insight360 that shows several modifications and factors that have direct impact on energy consumed in the scenario and benchmark comparison.

Figure 6.6.60 indicates the impact of orientation of the building, and mainly the balcony position, with respect to energy consumed, showing how the consumption changes when the orientation is modified. Figure 6.6.61 shows the different glazing types used in the model and how the energy consumed is affected for each glazing type.

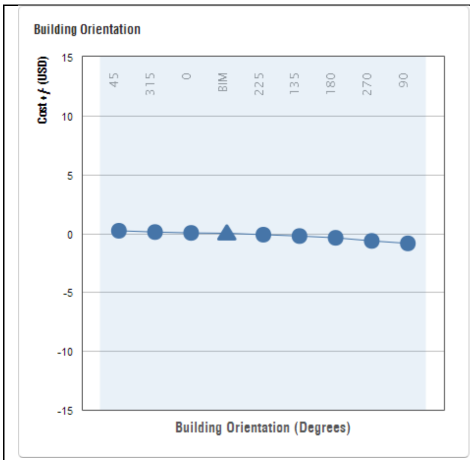


Figure 6.6.60. Building orientation chart indicating orientation adjustments that reduces the cost /m2, Source: Author

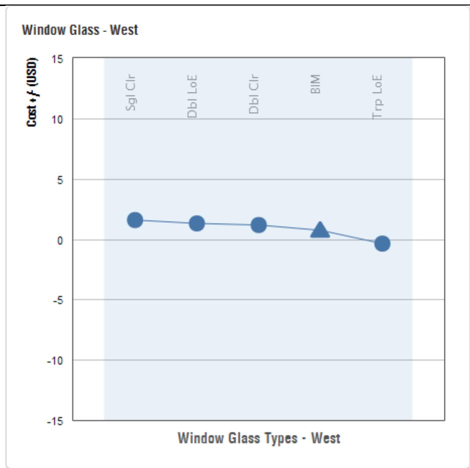


Figure 6.6.61. Chart indicating glazing types and their effect on cost consumed on energy, Source: Author

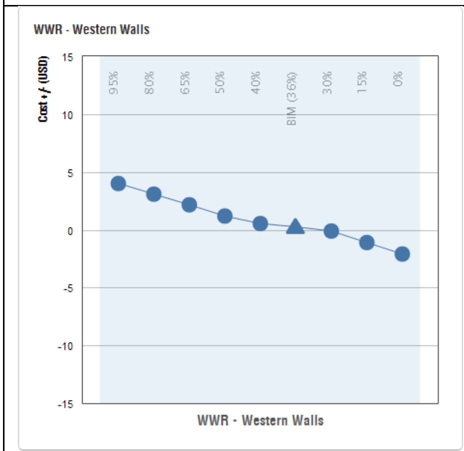


Figure 6.6.62. Chart indicating difference in energy consumption when window to wall ratio is reduced (on the western facade) , Source: Author

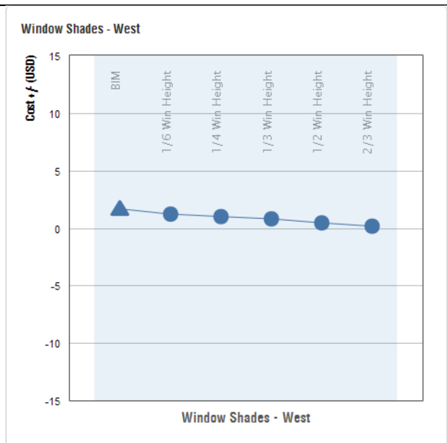


Figure 6.6.63. Chart indicating window shading and their effect on energy consumption, Source: Author

Finally, Chart 6.6.22, Chart 6.6.23, and Chart 6.6.24 are extracted from Green Building Studio indicating the space cooling demand for the model in months June, July, and August respectively.

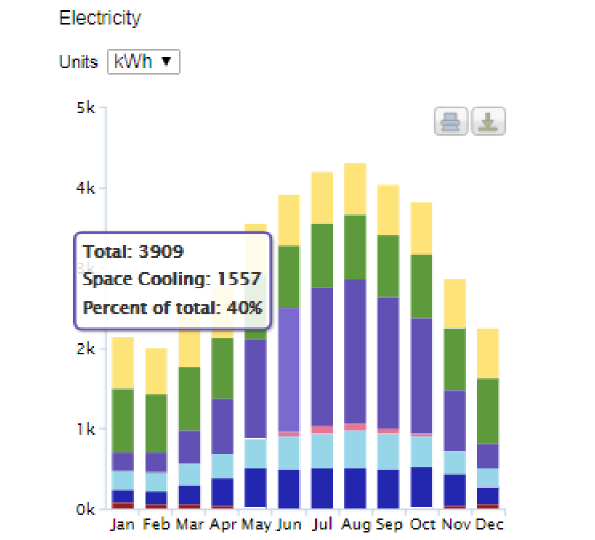


Chart 6.6.22. Cooling load in June, Source: Author

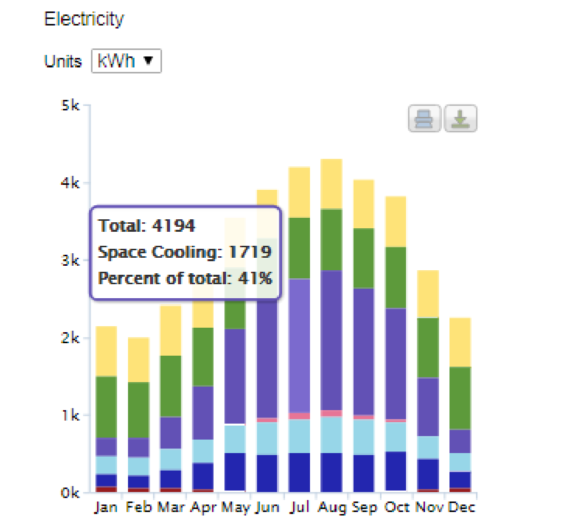


Chart 6.6.23. Cooling load in July, Source: Author

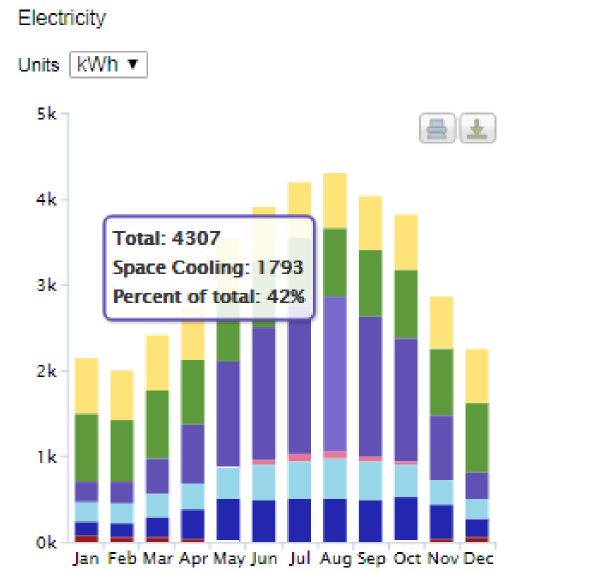


Chart 6.6.24. Cooling load in August, Source: Author, Source: Author

Appendix J B1W-100 Glazed Balcony Surrounded by 1 Wall

The following section will analyze the recoding of the glazed balcony in the model having balcony surrounded by 1 wall. The analysis will include the total energy consumed in the model, and the energy consumed specifically in the glazed balcony and adjacent space.

Moreover, several modified parameters will be discussed in order to maintain energy reduction and comfort in the spaces.

The results of the energy simulation done on the glazed balcony surrounded by 1 wall model showed high cooling demand in the summer months (June, July, and August). Chart 6.6.25 indicates the space cooling for the whole apartment in the model. The space cooling for the balcony surrounded by 1 wall model recorded high demand in the month of August (1792.9 Kwh). This demand -the cooling demand excluding other equipment used- is higher than the US standard for the whole apartment 860 KWh by 2 times (Bimenyimana, Osarumwense Asemota, Ihirwe, & Li, 2018; Stoy & Kytzia, 2006).

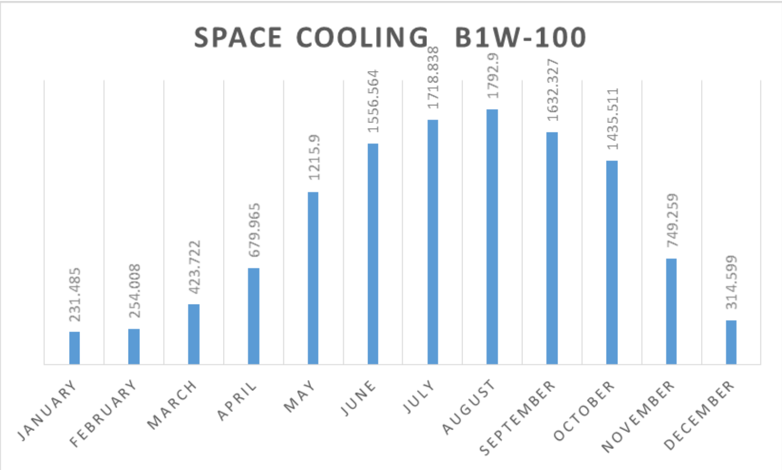


Chart 6.6.25. Chart indicating cooling demand per month (KWh) , Source: Author

Amongst the space cooling demand recorded from Chart 6.6.25, the glazed balcony recorded a significant share. Chart 6.6.26 indicates the cooling demand for the glazed spaces only and the space adjacent (living space) to maintain a comfort indoor. Both orientation; the north-west and south-west have similar cooling demand, having the south-west slightly higher (Chart 6.6.26).

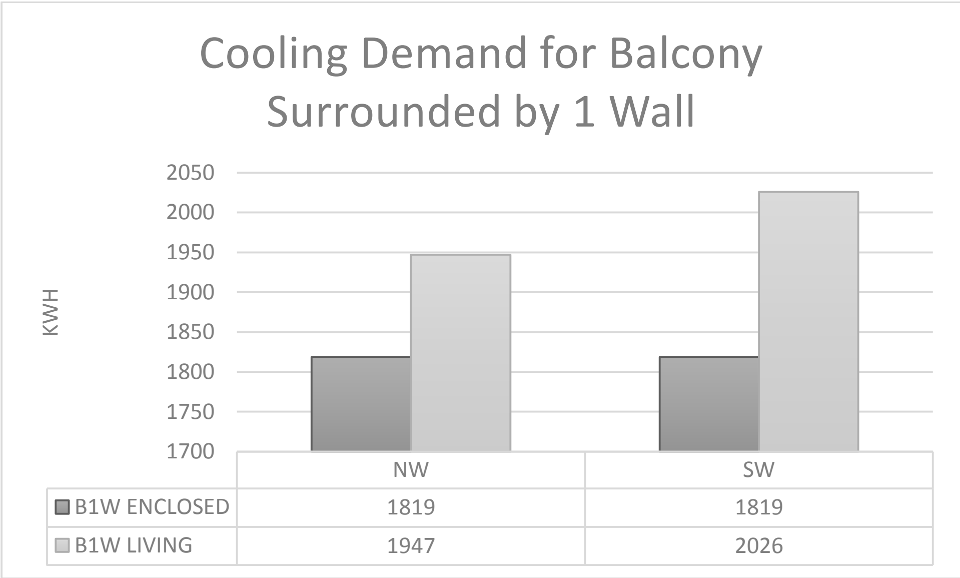


Chart 6.6.26.Chart indicating the cooling demand in south-west and north-west orientation, Source: Author

The glazed balconies need a peak of 1819 KWh cooling in summer months in order to achieve indoor comfort (Chart 6.6.26). Whereas, the heating demand needed in the winter months is a maximum of 1318 KWh (Appendix B). The cooling and heating demand of the glazed balcony are relatively high compared to the standard. This is due to several parameters; glazing type and balcony type. The glazing type in the model is single glazing 6mm pane which has a very high U-value and thus results in excessive heat gain in the summer and heat transfer. The glazing type allows heat transfer in summer resulting in high temperature in the glazed balcony, and allows heat in the interior space to transfer to the outdoor in the winter, thus both demand will be increased to improve indoor quality and comfort. Moreover, the balcony type has a high exposure from three elevation and thus does not provide a barrier or insulation to the outdoor. Accordingly, the model has a result of 4352 USD annual electric usage of which the cooling demand accounts for 31.4% of the total energy usage (Figure 6.6.64).

However, during day time, in winter months, and there is direct solar radiation on the glazed balcony, the area is heated rapidly and allows comfort for few hours during the day without heating demand. According to Figure 6.6.64, the heating accounts for 1.1% of the total electric demand which corroborates with the literature that states the impact of glazing in cold climates.

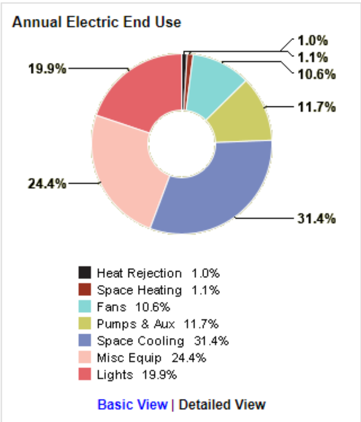
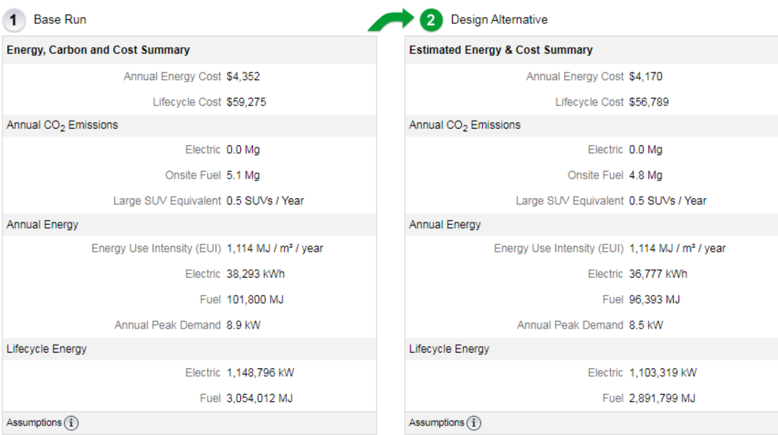


Figure 6.6.64. Annual Electric energy Use for Balcony surrounded by 1 wall model having glazed balconies, Source: Author

Accordingly, in order to reduce the cooling demand, several scenarios where tested by which parameters where modified in order to analyze how the variables are affecting the cooling demand in the spaces and achieve efficient results. Scenarios where created according to the Insight 360 charts (Appendix B). In order to examine the impact on each orientation, glazing, window-to-wall ratio, and shading on the energy consumed and annual energy cost, each variable is compared with the base run of the results of the model to achieve reduction on cooling and energy consumption.

Figure 6.6.65 shows when the model is rotated 90°; when the balconies are placed on the North elevation rather than on the western. The energy usage was reduced by 1516 Kwh and cost was reduced by 182 USD annually.

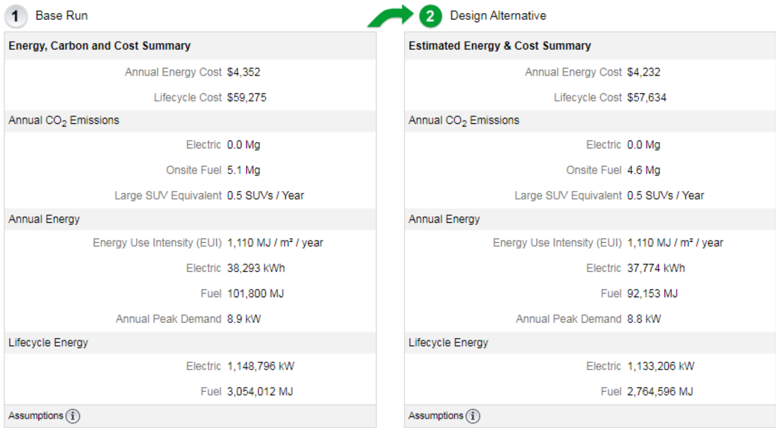


1 Base Run		2 Design Alternative	
Energy, Carbon and Cost Summary		**Estimated Energy & Cost Summary**	
Annual Energy Cost	$4,352	Annual Energy Cost	$4,170
Lifecycle Cost	$59,275	Lifecycle Cost	$56,789
Annual CO_2 Emissions		Annual CO_2 Emissions	
Electric	0.0 Mg	Electric	0.0 Mg
Onsite Fuel	5.1 Mg	Onsite Fuel	4.8 Mg
Large SUV Equivalent	0.5 SUVs / Year	Large SUV Equivalent	0.5 SUVs / Year
Annual Energy		Annual Energy	
Energy Use Intensity (EUI)	1,114 MJ / m² / year	Energy Use Intensity (EUI)	1,114 MJ / m² / year
Electric	38,293 kWh	Electric	36,777 kWh
Fuel	101,800 MJ	Fuel	96,393 MJ
Annual Peak Demand	8.9 kW	Annual Peak Demand	8.5 kW
Lifecycle Energy		Lifecycle Energy	
Electric	1,148,796 kW	Electric	1,103,319 kW
Fuel	3,054,012 MJ	Fuel	2,891,799 MJ
Assumptions		Assumptions	

Figure 6.6.65. Modified orientation VS Base run, Source: Author

When the single pane 6mm glazing was replaced by a low-e glazing for hot climate, the reduction was 120 USD and 519 KWh annually. Both mentioned modifications; glazing, and orientation, did not make a recognizable impact on the cost neither energy consumed.

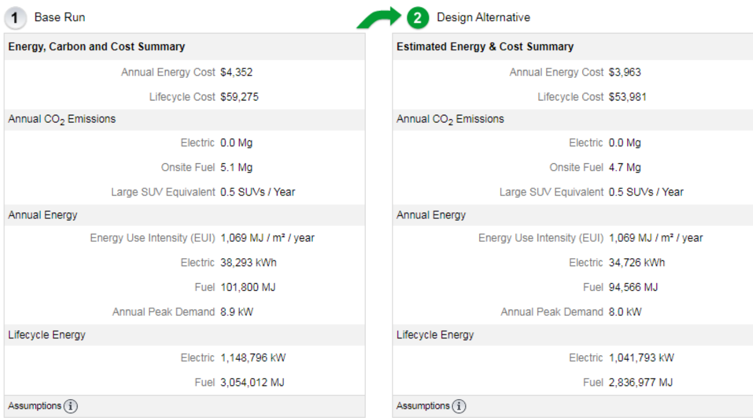
Moreover, the price of replacing the glazing type with low-e is more than the savings in 30 years (3600 USD) (Figure 6.6.66).



	1 Base Run	2 Design Alternative
	Energy, Carbon and Cost Summary	**Estimated Energy & Cost Summary**
Annual Energy Cost	$4,352	$4,232
Lifecycle Cost	$59,275	$57,634
Annual CO_2 Emissions		
Electric	0.0 Mg	0.0 Mg
Onsite Fuel	5.1 Mg	4.6 Mg
Large SUV Equivalent	0.5 SUVs / Year	0.5 SUVs / Year
Annual Energy		
Energy Use Intensity (EUI)	1,110 MJ / m² / year	1,110 MJ / m² / year
Electric	38,293 kWh	37,774 kWh
Fuel	101,800 MJ	92,153 MJ
Annual Peak Demand	8.9 kW	8.8 kW
Lifecycle Energy		
Electric	1,148,796 kW	1,133,206 kW
Fuel	3,054,012 MJ	2,764,596 MJ
Assumptions		

Figure 6.6.66. Modified glazing type VS Base run, Source: Author

When the shading devices are put on windows to cover 2/3 of the window, there was a reduction in coast by 389 USD annually, almost 12000 USD in 30 years (Figure 6.6.67). But, when the window-to-wall ratio was reduced to 30% on the west and southern elevations, there was a slight decrease in the energy consumed (95 USD annually) (Figure 6.6.68).



	1 Base Run	2 Design Alternative
	Energy, Carbon and Cost Summary	**Estimated Energy & Cost Summary**
Annual Energy Cost	$4,352	$3,963
Lifecycle Cost	$59,275	$53,981
Annual CO_2 Emissions		
Electric	0.0 Mg	0.0 Mg
Onsite Fuel	5.1 Mg	4.7 Mg
Large SUV Equivalent	0.5 SUVs / Year	0.5 SUVs / Year
Annual Energy		
Energy Use Intensity (EUI)	1,069 MJ / m² / year	1,069 MJ / m² / year
Electric	38,293 kWh	34,726 kWh
Fuel	101,800 MJ	94,566 MJ
Annual Peak Demand	8.9 kW	8.0 kW
Lifecycle Energy		
Electric	1,148,796 kW	1,041,793 kW
Fuel	3,054,012 MJ	2,836,977 MJ
Assumptions		

Figure 6.6.67. Shade Modification VS Base run, Source: Author

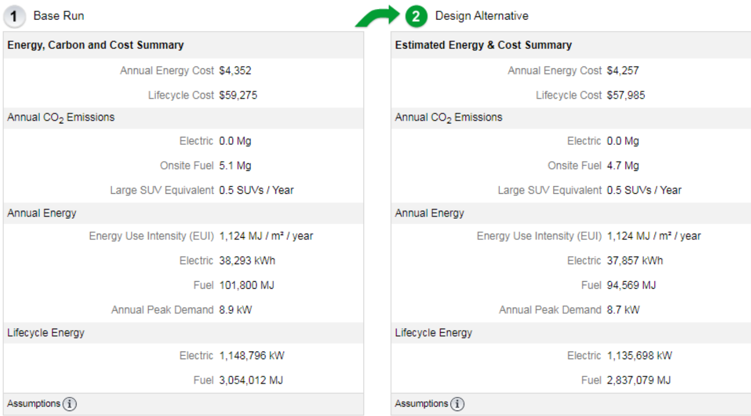


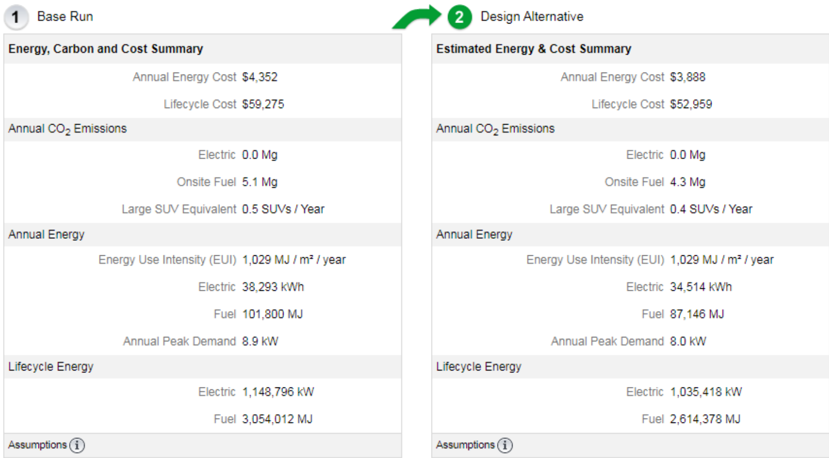
Figure 6.6.68. WWR modification VS Base run, Source: Author

Briefly, according to Table 37, the highest reduction occurred when the shading was inserted on 2/3 of the glazing. Reducing the solar radiation by shading recorded efficient results that replacing the glazing type.

BALCONY TYPE	MODEL	BASE RUN		WWR		ORIENTATION		GLAZING		SHADING		
		COST	KWH	COST	KWH	COST	KWH	COST	KWH	COST	KWH	
B1W	100	$ 4,352	38293	$ 4,257	37857	$ 4,170	36777	$ 4,232	37774	$ 3,963	34726	B1 W-100
REDUCTION				1.13%		4%		1.30%		9.30%		

Table 37. Table indicating percentage of reduction of each modification in relation to the base run, Source: Author

However, since the examined phenomenon is in an existing building, and the possibility to decrease window-to-wall ratio or orientation of the building is not possible, then Figure 6.3.1 shows the result of the scenario when both the glazing and shading are modified. Shading and glazing are the only modifications that can be implemented in any existing building. The scenario proves that when the shading is 2/3 the window and glazing type is low-e, a reduction of up to 470 USD annually, 14000 USD lifecycle reduction (30year) can be attained (Figure 6.6.69), with a reduction of cooling demand (28.8% instead of 31.4%) (Figure 6.6.70).



1 Base Run

Energy, Carbon and Cost Summary	
Annual Energy Cost	$4,352
Lifecycle Cost	$59,275
Annual CO_2 Emissions	
Electric	0.0 Mg
Onsite Fuel	5.1 Mg
Large SUV Equivalent	0.5 SUVs / Year
Annual Energy	
Energy Use Intensity (EUI)	1,029 MJ / m² / year
Electric	38,293 kWh
Fuel	101,800 MJ
Annual Peak Demand	8.9 kW
Lifecycle Energy	
Electric	1,148,796 kW
Fuel	3,054,012 MJ
Assumptions	

2 Design Alternative

Estimated Energy & Cost Summary	
Annual Energy Cost	$3,888
Lifecycle Cost	$52,959
Annual CO_2 Emissions	
Electric	0.0 Mg
Onsite Fuel	4.3 Mg
Large SUV Equivalent	0.4 SUVs / Year
Annual Energy	
Energy Use Intensity (EUI)	1,029 MJ / m² / year
Electric	34,514 kWh
Fuel	87,146 MJ
Annual Peak Demand	8.0 kW
Lifecycle Energy	
Electric	1,035,418 kW
Fuel	2,614,378 MJ
Assumptions	

Figure 6.6.69. Modification of Shading and Glazing VS Base run, Source: Author

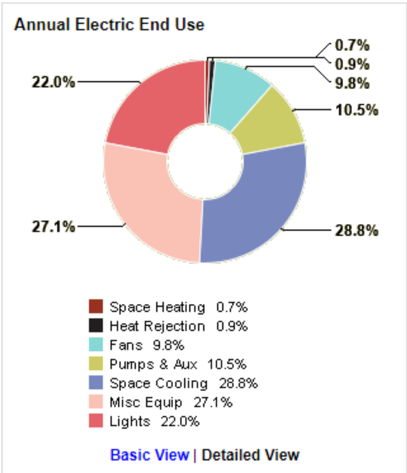


Figure 6.6.70. Cooling for Shading and Glazing, Source: Author

When having a glazed balcony in a balcony surrounded by 1 wall structure, the glazed space will perform efficiently in winter creating a greenhouse effect, however, it is very energy consuming in summer. The most efficient modification to reduce the cooling demand in an existing building is to not only replace the single pane glazing with a low-e, but also shade the openings to 2/3 to prevent solar gain. However, if in the design phase, placing the glazing on the northern façade rather than the western can help prevent heat gain and thus cooling demand.

Appendix K B2W-100 Glazed Balcony Surrounded by 2 Wall

This section will analyze the results of the glazed balcony and adjacent space in model having balcony surrounded by 2 walls. The heating and cooling demand will be discussed focusing on the impact of glazing on the glazed balcony space. Moreover, modifications will be projected emphasizing on the most efficient parameter.

Similar to the previous model, the balcony surrounded by 2 wall model indicated high energy usage in summer months. However, when observing the recordings of the heating demand versus the cooling demand (Chart 6.6.27), it is noted that the heating demand is almost minimal compared to the cooling. This ensures that the material used in the apartments, and the U-value used in Saida, Corniche El Baher area, is not specifically suitable for the climate of the context. The thermal characteristics of the material used perform efficiently in the cold months rather than in the hot months.

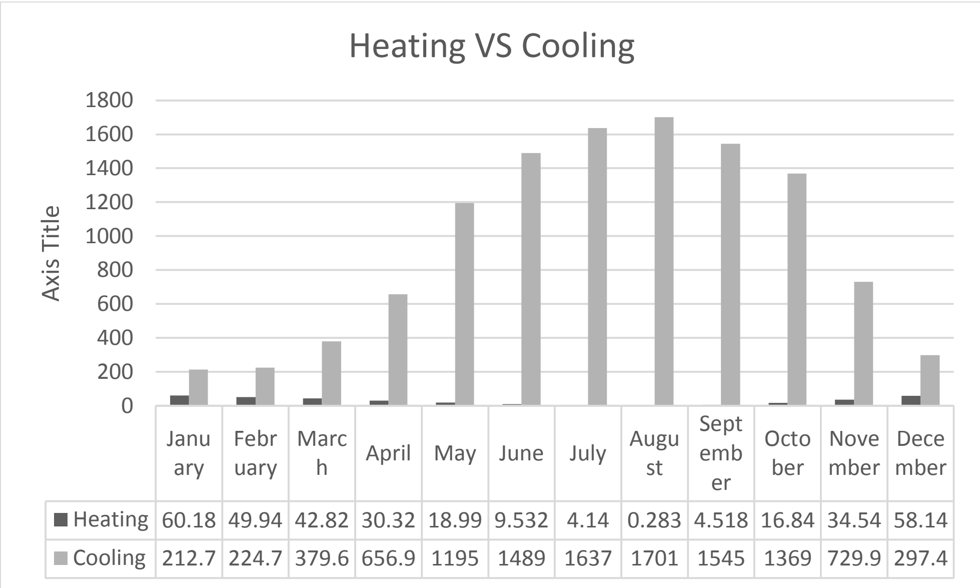


Chart 6.6.27.Annual heating demand VS cooling in the model, Source: Author

Chart 6.6.28 indicates the cooling demand per month in summer in the glazed balcony and adjacent space in the north-west and south-west orientations. The graph indicates a higher recordings in the south-west orientation than the north-west similar to the previous model. This corroborates with the literature that states the higher energy demand in the southern and western orientations.

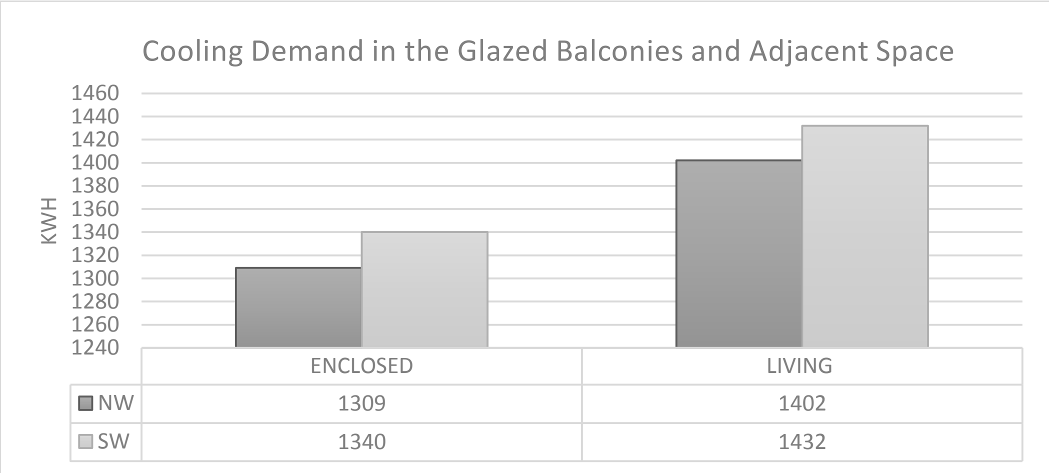


Chart 6.6.28.Cooling demand for the glazed balcony and the adjacent space in the north-west and south-west orientation , Source: Author

In the south-west and north-west orientation, the adjacent spaces (living) recorded higher cooling demand than the glazed balcony (Chart 6.6.28). Although both recordings; the glazed balcony and adjacent space are significantly higher than the US standard.

This collected data will be further analyzed and compared with the model having no balcony enclosure to discuss the impact of the glazing on the glazed spaces, and also the impact of glazed spaces on the adjacent spaces.

According to the high energy demand induced from the graphs, several scenarios were done with modifications in several parameters in order to compare with the base model and analyze the most efficient parameter.

The base model consumes 42084 KWh; 4321 USD annually. According to Figure 6.6.71, when rotating the building, having the main façade overlooking the north elevation, a decrease of 5.3% occurred (4092 USD).

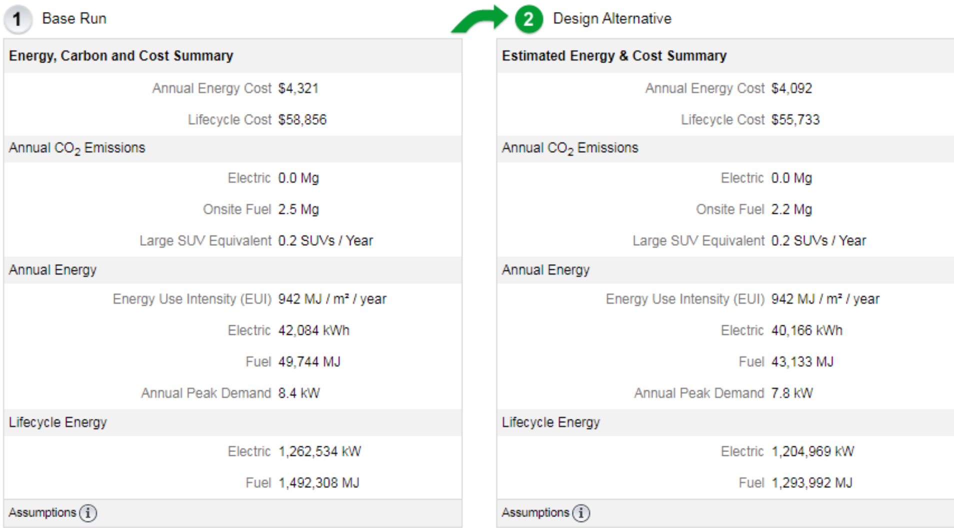


Figure 6.6.71. Rotation modification VS Base run, North orientation VS West orientation, Source: Author

Moreover, when the single pane clear 6mm glazing was replaced by low-e glazing, a decrease of up-to 3.6% was conducted (4165 USD) (Figure 6.6.72).

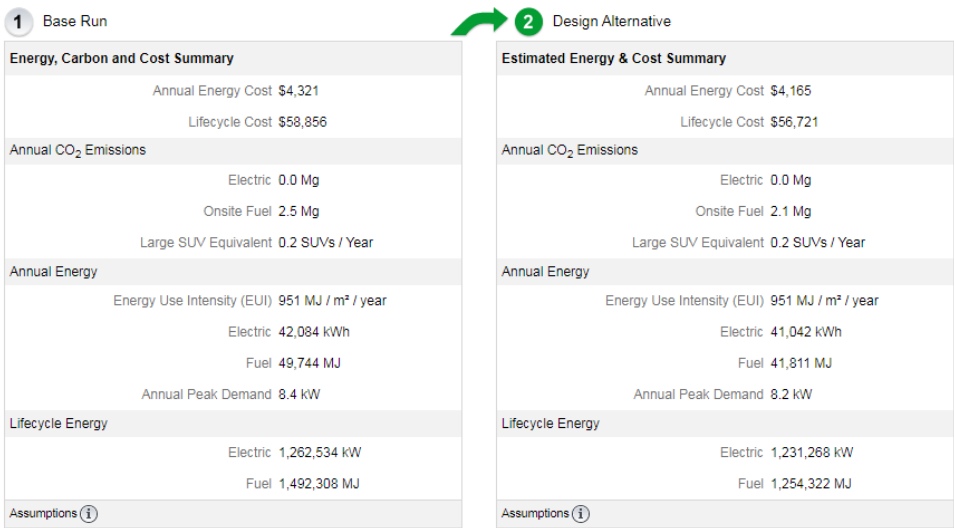


Figure 6.6.72. Glazing modification VS Base run, Source: Author

Shading 2/3 of the windows led to a decrease of up-to 8% (3978 USD) (Figure 6.6.73). Whereas, decreasing the window-to-wall ratio to 30% was not efficient since it led to an increase in the cooling demand, since some of the elevations already had less than 30% (Figure 6.6.74).

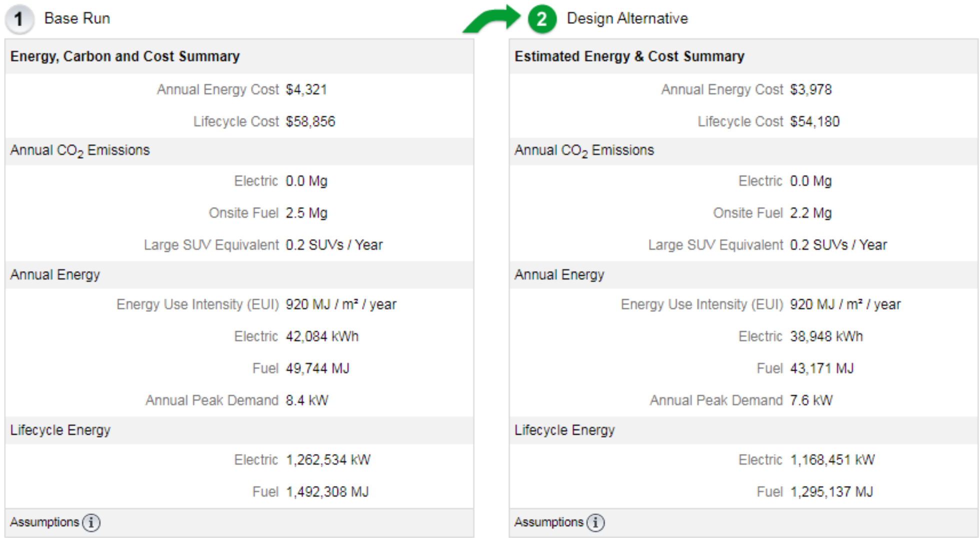


Figure 6.6.73. Shading modification VS Base run, Source: Author

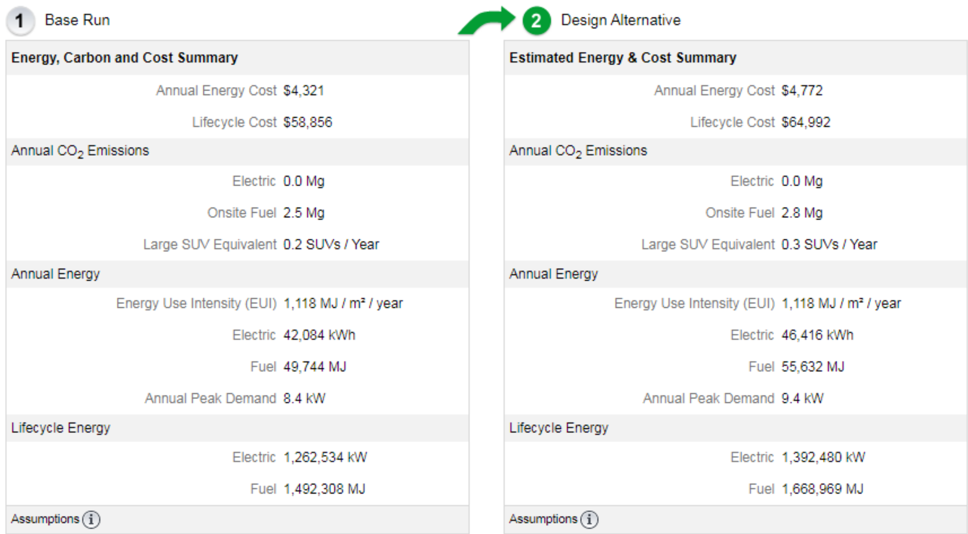


Figure 6.6.74.WWR modification VS Base run, Source: Author

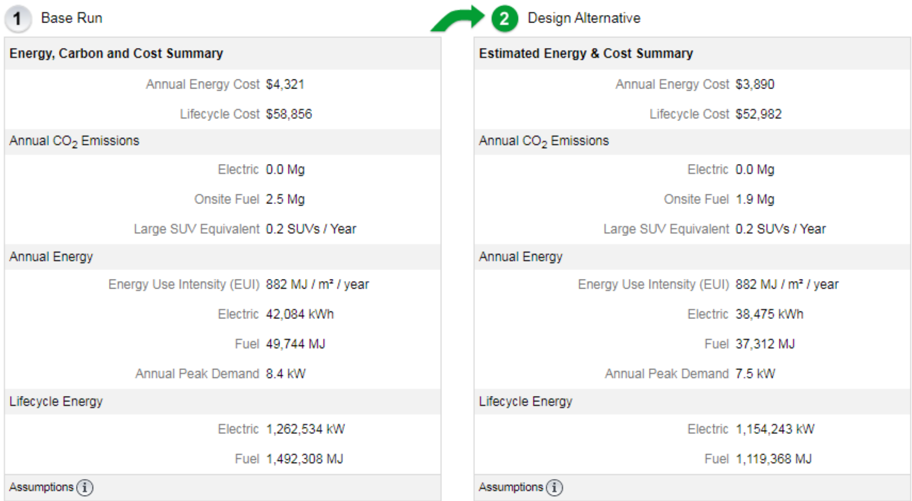
BALCONY TYPE	MODEL	BASE RUN COST	BASE RUN KWH	WWR COST	WWR KWH	ORIENTATION COST	ORIENTATION KWH	GLAZING COST	GLAZING KWH	SHADING COST	SHADING KWH	
B2W	100	$ 4,321	42084	$ 4,772	46416	$ 4,096	40166	$ 4,165	41042	$ 3,978	38948	B2 1
REDUCTION				110.00%		5%		2.50%		7.45%		

Table 38.Table indicating percentage of reduction per parameter in relation to the base run, Source: Author

According to Table 38, amongst all the modifications done on the model, the shading showed the highest efficiency and energy reduction (7.45%).

However, since as mentioned in the previous section, the only applicable parameters to existing buildings is placing shading and replacing the glazing type, therefore, a scenario including both parameters is done.

The mentioned scenario led to a decrease of up-to 10% from the annual cost and energy consumption (Figure 6.6.75). The cooling demand in the model decreased from 27.2% to 24.6% (Figure 6.6.76).



	1 Base Run	2 Design Alternative
	Energy, Carbon and Cost Summary	**Estimated Energy & Cost Summary**
Annual Energy Cost	$4,321	$3,890
Lifecycle Cost	$58,856	$52,982
Annual CO_2 Emissions		
Electric	0.0 Mg	0.0 Mg
Onsite Fuel	2.5 Mg	1.9 Mg
Large SUV Equivalent	0.2 SUVs / Year	0.2 SUVs / Year
Annual Energy		
Energy Use Intensity (EUI)	882 MJ / m² / year	882 MJ / m² / year
Electric	42,084 kWh	38,475 kWh
Fuel	49,744 MJ	37,312 MJ
Annual Peak Demand	8.4 kW	7.5 kW
Lifecycle Energy		
Electric	1,262,534 kW	1,154,243 kW
Fuel	1,492,308 MJ	1,119,368 MJ
Assumptions		

Figure 6.6.75. Shading and Glazing, Source: Author

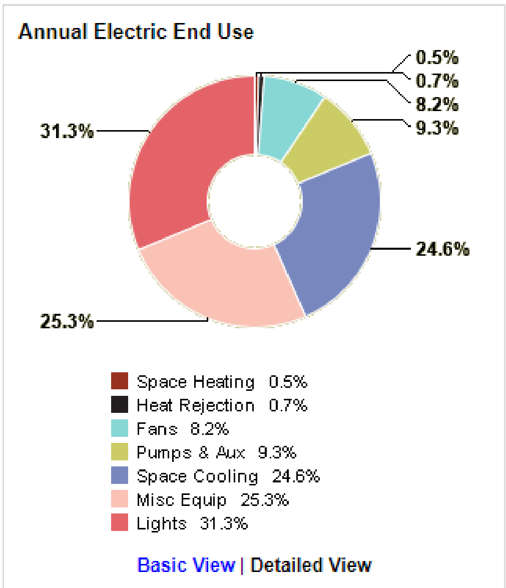


Figure 6.6.76. Cooling decrease when shading and glazing are changed, Source: Author

In the balcony surrounded by 2 walls, the glazed balcony imposed minimal to heating demand, especially during the day time, compared to the cooling demand in the summer months. The cooling demand in the glazed balcony and adjacent space exceeded the US standard for energy consumption. The results of the glazed balcony surrounded by 2 walls will be further compared to other models in order to derive the impact of glazed balconies on the adjacent space, the impact of glazed balconies on cooling, and the impact of balcony type on the cooling demand and energy usage.

Appendix L B3W-100 Glazed Balcony Surrounded by 3 Walls

The following section will analyze the impact of glazing on the balcony surrounded by 3 walls model. The cooling and heating demand of the glazed balcony and adjacent space will be discussed. Scenarios indicating several modifications in order to decrease the energy consumption will be presented and compared to the base run.

The last scenario of the first model is when the balcony is glazed in a 3 wall surrounded balcony structure (loggia). Similar to the previous sections, the building material and balcony enclosure assured that the performance in the cold months is better than in the summer months (**Error! eference source not found.**Chart 6.6.29), especially that the cooling demand in the summer months is more than 1800KWh (Chart 6.6.30).

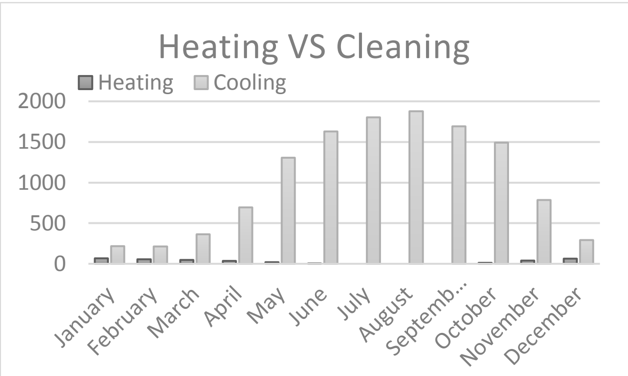


Chart 6.6.29.Graph indicating cooling demand VS heating in the balcony surrounded by 3 wall structure, Source: Author

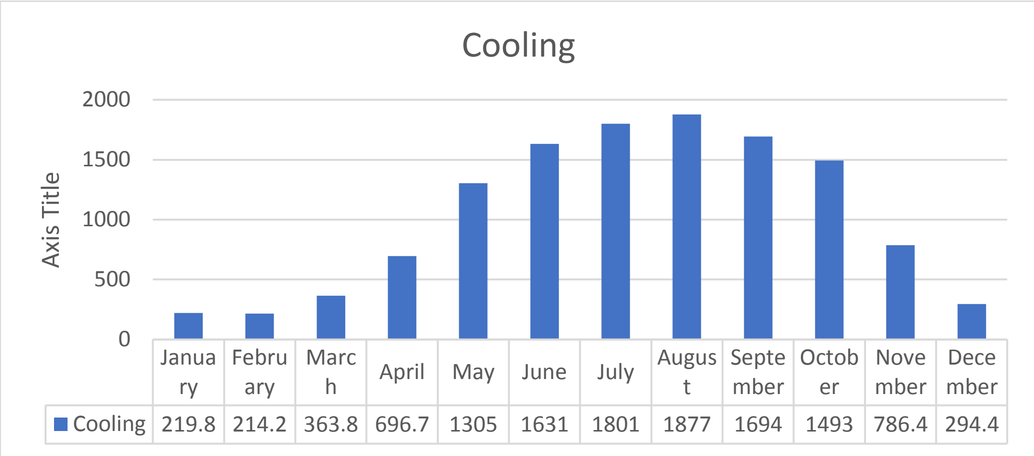


Chart 6.6.30.Cooling demand per month (KWh) , Source: Author

According to Chart 6.6.31 the cooling demand in the glazed balcony in both orientations north-west and south-west has similar results. The living area adjacent to the glazed balcony shows a lower cooling recording (1066 KWh) than the glazed balcony (1506 KWh) (Chart 6.6.31).

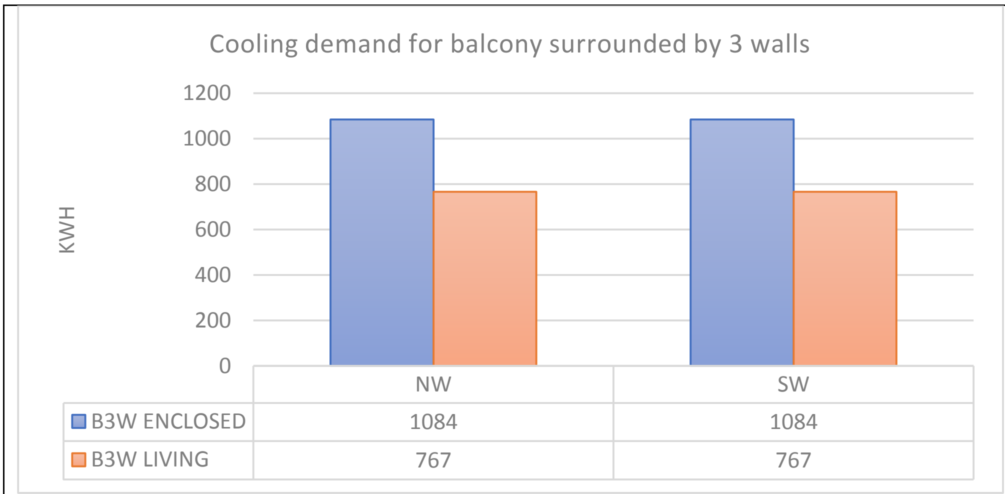


Chart 6.6.31.cooling demand for glazed balcony surrounded by 3 walls, Source: Author

In order to decrease the high cooling demand, several scenarios where created; placing shading on 2/3 of the window, replacing the glazing with low-e, rotating the building 90°, and reducing the window-to-wall ratio to 30% (Figure 6.6.77, Figure 6.6.78, Figure 6.6.79, and Figure 6.6.80).

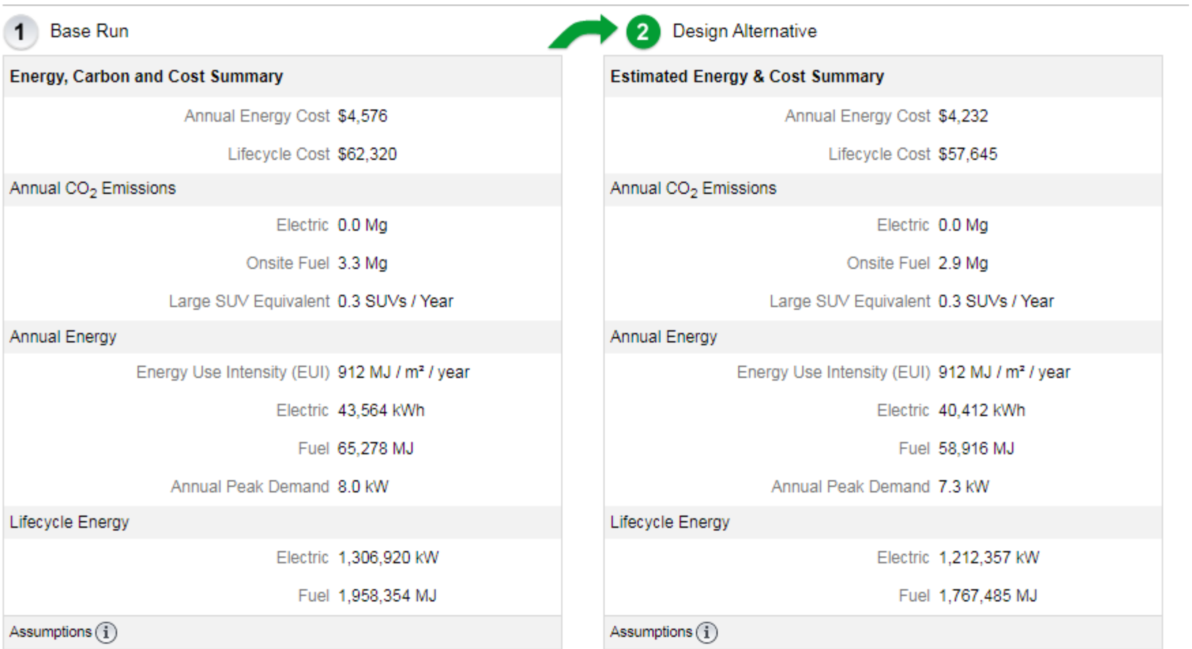


Figure 6.6.77. Shading Placement VS Base Run, Source: Author

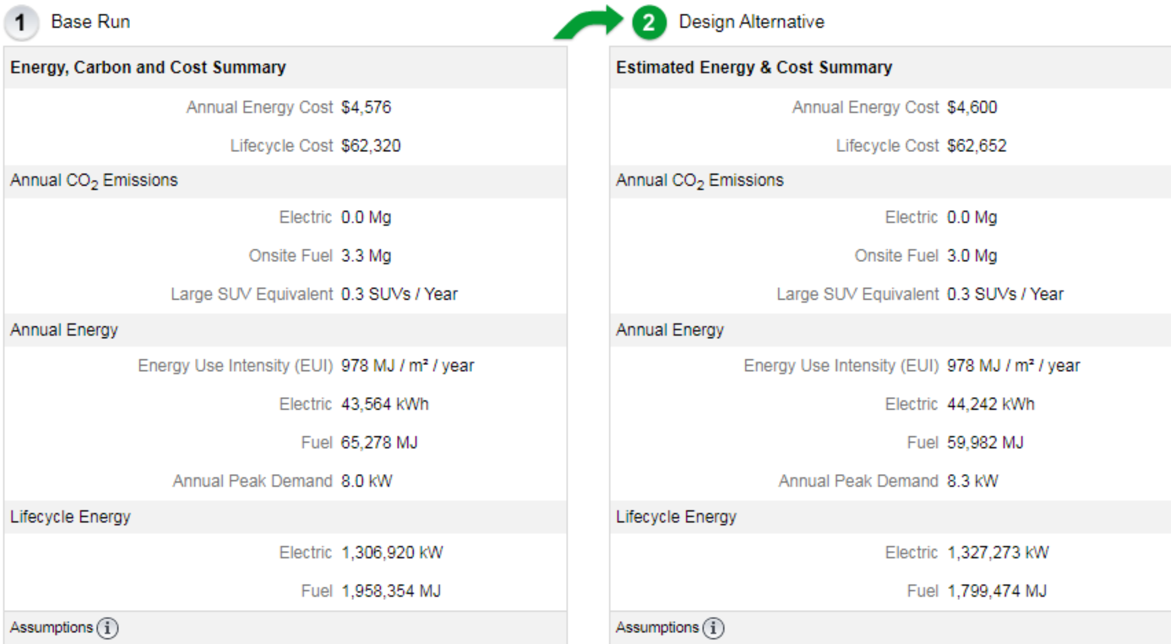


Figure 6.6.78. Glazing modification VS Base run, Source: Author

	1 Base Run	2 Design Alternative
	Energy, Carbon and Cost Summary	**Estimated Energy & Cost Summary**
Annual Energy Cost	$4,576	$4,224
Lifecycle Cost	$62,320	$57,526
Annual CO_2 Emissions		
Electric	0.0 Mg	0.0 Mg
Onsite Fuel	3.3 Mg	2.8 Mg
Large SUV Equivalent	0.3 SUVs / Year	0.3 SUVs / Year
Annual Energy		
Energy Use Intensity (EUI)	898 MJ / m² / year	898 MJ / m² / year
Electric	43,564 kWh	40,616 kWh
Fuel	65,278 MJ	55,158 MJ
Annual Peak Demand	8.0 kW	7.2 kW
Lifecycle Energy		
Electric	1,306,920 kW	1,218,474 kW
Fuel	1,958,354 MJ	1,654,752 MJ
Assumptions		

Figure 6.6.79.Orientation adjustment VS Base run, Source: Author

	1 Base Run	2 Design Alternative
	Energy, Carbon and Cost Summary	**Estimated Energy & Cost Summary**
Annual Energy Cost	$4,576	$4,562
Lifecycle Cost	$62,320	$62,141
Annual CO_2 Emissions		
Electric	0.0 Mg	0.0 Mg
Onsite Fuel	3.3 Mg	2.8 Mg
Large SUV Equivalent	0.3 SUVs / Year	0.3 SUVs / Year
Annual Energy		
Energy Use Intensity (EUI)	962 MJ / m² / year	962 MJ / m² / year
Electric	43,564 kWh	44,073 kWh
Fuel	65,278 MJ	57,073 MJ
Annual Peak Demand	8.0 kW	7.7 kW
Lifecycle Energy		
Electric	1,306,920 kW	1,322,181 kW
Fuel	1,958,354 MJ	1,712,179 MJ
Assumptions		

Figure 6.6.80.WWR adjustment VS Base run, Source: Author

The results of the scenarios showed that the most efficient parameters where placing shading devices (a decrease of 7.2 %), and changing the orientation of the building by placing the glazed balconies to the north elevation (a decrease of 7 %). Whereas adjusting the orientation and replacing the glazing type, tended to increase the energy consumed by 1% (according to Table 39).

BALCONY TYPE	MODEL	BASE RUN		WWR		ORIENTATION		GLAZING		SHADING		
		COST	KWH	COST	KWH	COST	KWH	COST	KWH	COST	KWH	
B3W	100	$ 4,576	43564	$ 4,562	44073	$ 4,224	40616	$ 4,600	44242	$ 4,232	40412	B3 W-100
REDUCTION				101%		7%		101%		7.20%		

Table 39. Table indicating the percentage of several parameters in relation to the base run, Source: Author

Concerning the applicable parameters to the existing buildings in the area, inserting shading on the windows is the only applicable parameters amongst the ones mentioned that can be applied. Placing shading devices to cover 2/3 of the window resulted in the reduction of energy consumed, especially cooling; from 28.4% to 26.3% (Figure 6.6.81).

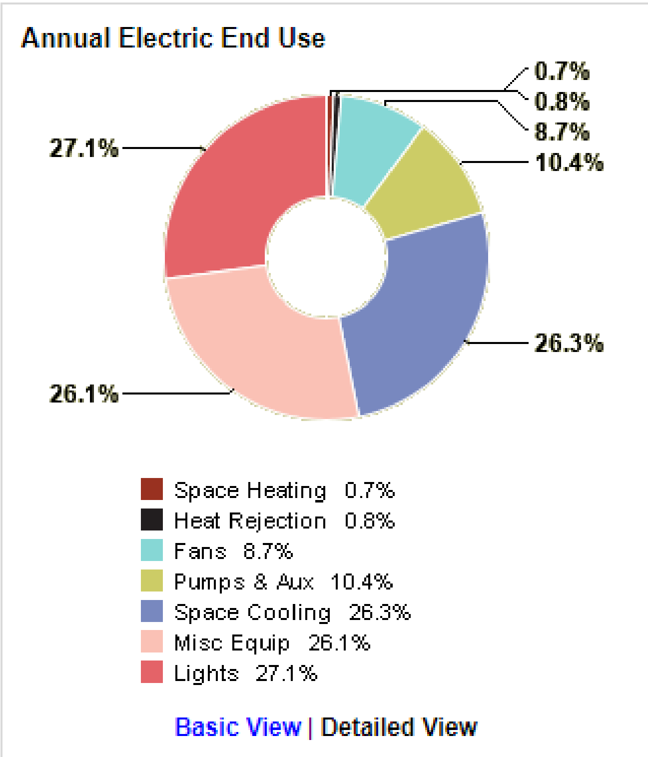


Figure 6.6.81.Space cooling decrease to 26.3%, Source: Author

In conclusion, similar to the previous models, the scenario showed high energy usage especially on cooling. However, the scenario indicated opposing results concerning the alternative parameters. When the glazing is changed to low-e, the reduction in energy consumption didn't occur. The only efficient and applicable parameter was the shading. This scenario will be compared to other models, in order to further target the thesis objectives and answer the research questions.

Appendix M B1W-300 Glazed Balcony Surrounded by 1 Wall Model

The following section presents the reading and analysis of the scenario having glazed balcony surrounded by 1 wall and the interior wall is removed. In this scenario, the cooling demand will be analyzed as the sum of the glazed balcony and interior space since they are one enlarged space that demands energy usage. The section will pass upon the cooling and energy usage in the model, and project several modifications in order to reduce energy consumption.

In this model, the simulation of total energy usage per month indicated a high range between space cooling and heating, having space cooling extremely higher than heating according to Chart 6.6.32 and Chart 6.6.33. The space cooling usage recorded a maximum of 1400 KWh, whereas the maximum heating recorded was 40 KWh. The high cooling usage is because of the exposure given by the balcony type which provides high direct solar radiation. Moreover, the cooling will have to be provided for a large area (glazed balcony and living), unlike previous models.

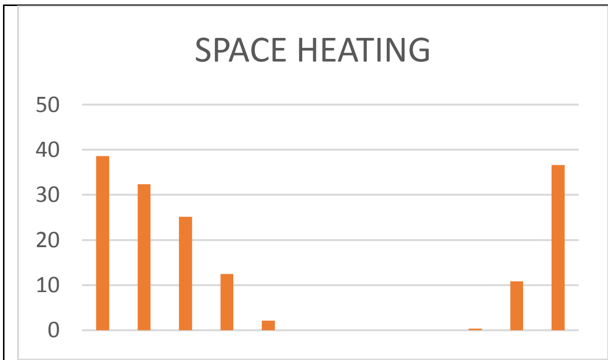


Chart 6.6.32.Graph indicating space heating per month, Source: Author

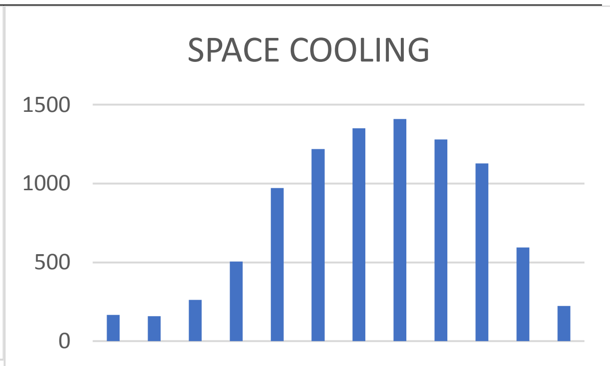


Chart 6.6.33.Graph indicating space cooling per month, Source: Author

The cooling provided in the enlarged space; glazed balcony and living, records a sum of 3829KWh in the peak summer months (according to Table 40 and Chart 6.6.34). The demand is 4 times above the US monthly standard (860 KWh) of the whole residential model (Bimenyimana, Osarumwense Asemota, Ihirwe, & Li, 2018; Stoy & Kytzia, 2006).

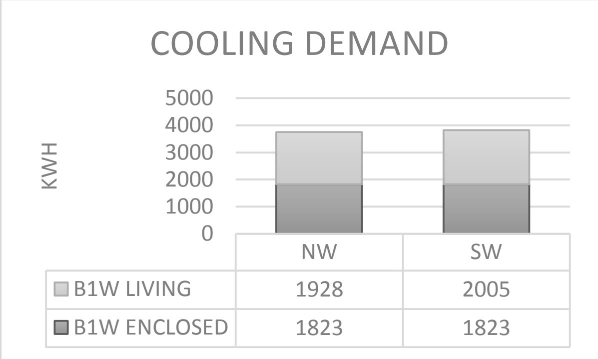


Chart 6.6.34. Chart indicating the cooling demand in the glazed balcony and adjacent space in the north-west and south-west orientations, Source: Author

		NW	SW
B1W	ENCLOSED	1823	1823
	LIVING	1928	2006
		3751	3829

Table 40. Table indicating the cooling demand for the glazed balcony and adjacent space, Source: Author

The north-west and south-west orientations showed similar results with a slight increase in the cooling demand in the south-west orientation, this is because of the heat gains induced from the direct solar radiation from the west and south (Table 40).

In order to decrease the energy usage especially on cooling, the parameters; orientation, shading, glazing, and window-to-wall ratio are simulated. Modifying the, orientation, glazing, and window to wall ratio, recorded similar results; a decrease by 3%, 1%, and 2% respectively (Figure 6.6.82, Figure 6.6.83, and Figure 6.6.85).

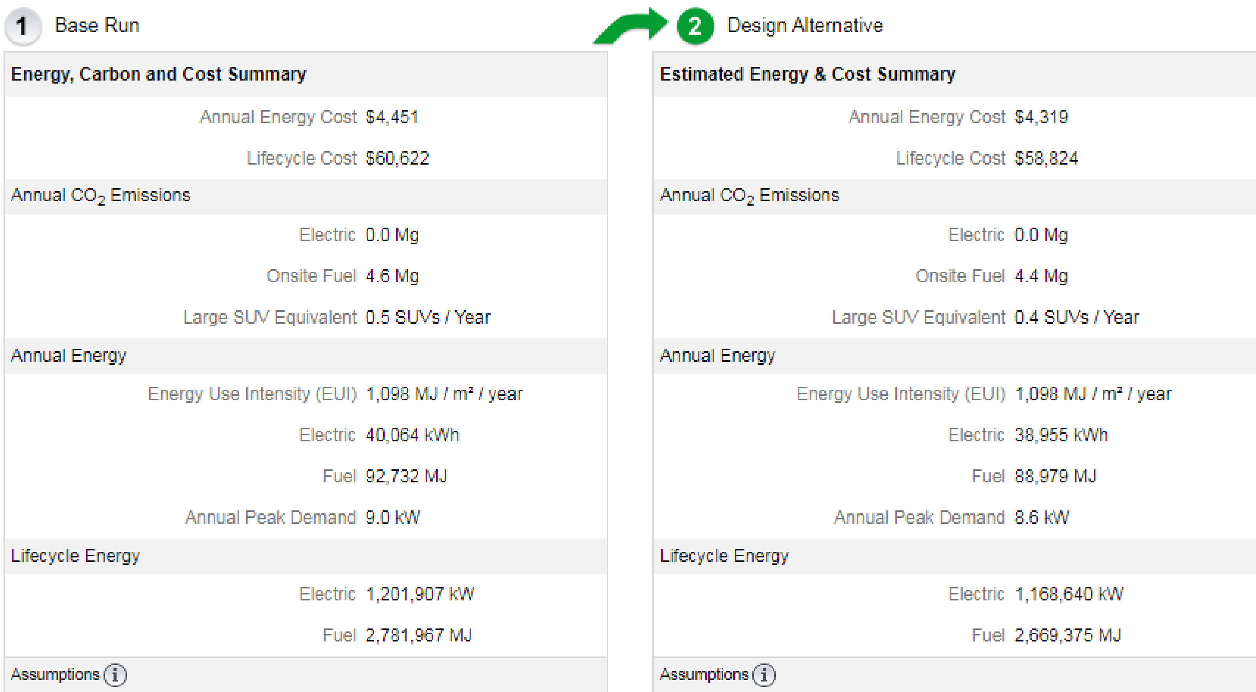


Figure 6.6.82.North Orientation VS Base run, Source: Author

	1 Base Run: Energy, Carbon and Cost Summary	2 Design Alternative: Estimated Energy & Cost Summary
Annual Energy Cost	$4,451	$4,336
Lifecycle Cost	$60,622	$59,051
Annual CO_2 Emissions		
Electric	0.0 Mg	0.0 Mg
Onsite Fuel	4.6 Mg	4.1 Mg
Large SUV Equivalent	0.5 SUVs / Year	0.4 SUVs / Year
Annual Energy		
Energy Use Intensity (EUI)	1,077 MJ / m² / year	1,077 MJ / m² / year
Electric	40,064 kWh	39,682 kWh
Fuel	92,732 MJ	82,033 MJ
Annual Peak Demand	9.0 kW	8.9 kW
Lifecycle Energy		
Electric	1,201,907 kW	1,190,469 kW
Fuel	2,781,967 MJ	2,460,995 MJ
Assumptions		

Figure 6.6.83.Glazing adjustment VS Base run, Source: Author

	1 Base Run: Energy, Carbon and Cost Summary	2 Design Alternative: Estimated Energy & Cost Summary
Annual Energy Cost	$4,451	$4,044
Lifecycle Cost	$60,622	$55,074
Annual CO_2 Emissions		
Electric	0.0 Mg	0.0 Mg
Onsite Fuel	4.6 Mg	4.3 Mg
Large SUV Equivalent	0.5 SUVs / Year	0.4 SUVs / Year
Annual Energy		
Energy Use Intensity (EUI)	1,035 MJ / m² / year	1,035 MJ / m² / year
Electric	40,064 kWh	36,316 kWh
Fuel	92,732 MJ	85,281 MJ
Annual Peak Demand	9.0 kW	8.1 kW
Lifecycle Energy		
Electric	1,201,907 kW	1,089,470 kW
Fuel	2,781,967 MJ	2,558,439 MJ
Assumptions		

Figure 6.6.84.Shading placement VS Base run, Source: Author

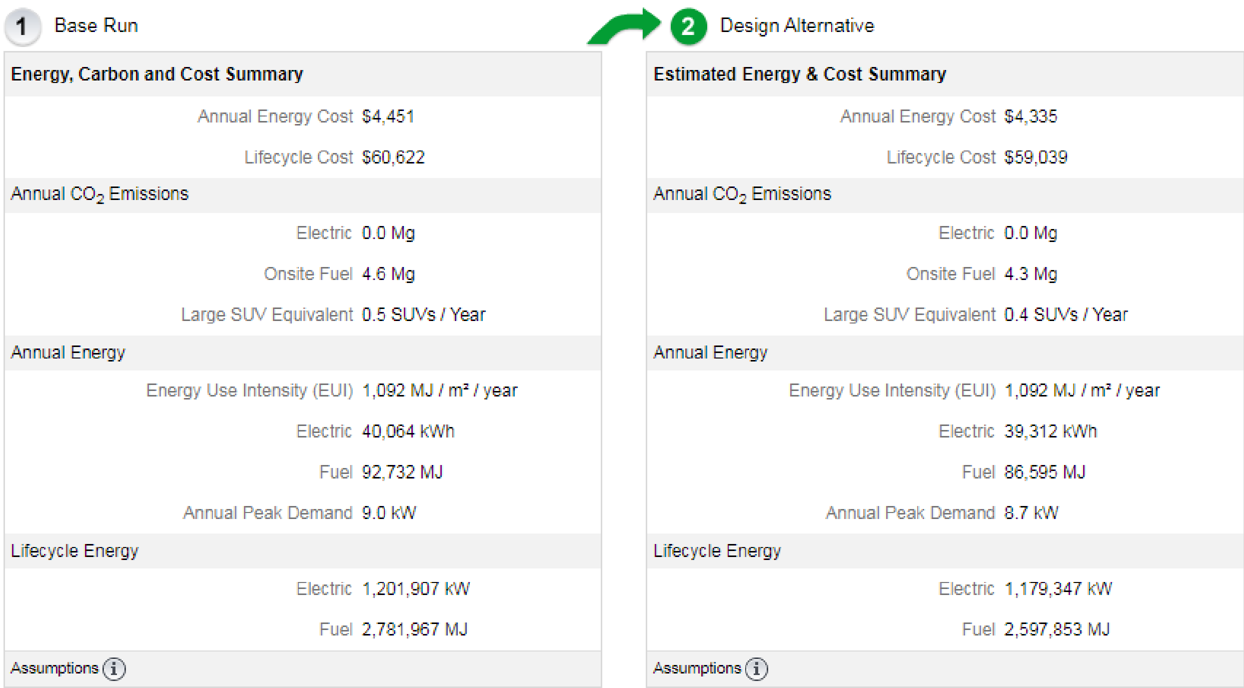


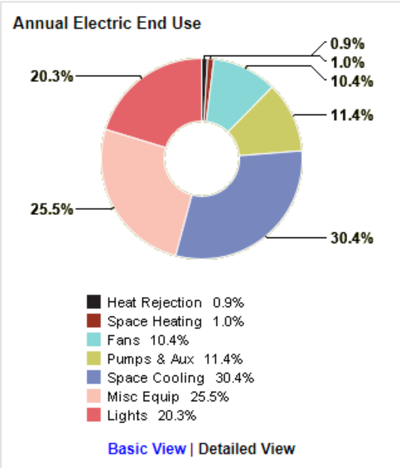
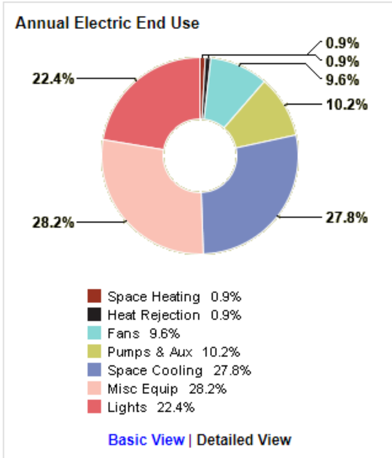
Figure 6.6.85.WWR adjustment VS Base run, Source: Author

Whereas, shading 2/3 of the windows decreased the energy usage by 9.3% (Figure 6.6.84). According to Table 41, the most efficient parameter that allowed significant reduction on energy usage was the placement of shading. However, replacing the glazing by low-e recorded the minimum decrease (1%).

BALCONY TYPE	MODEL	BASE RUN		WWR		ORIENTATION		GLAZING		SHADING		
		COST	KWH	COST	KWH	COST	KWH	COST	KWH	COST	KWH	
B1W	300	$ 4,451	40064	$ 4,335	39312	$ 4,319	38955	$ 4,336	39682	$ 4,044	36316	B1W-300
REDUCTION				2%		3%		1%		9.30%		

Table 41.Table indicating the percentage of reduction with respect to the base run, Source: Author

Chart 6.6.35 and Chart 6.6.36indicate the difference in the space cooling percentage in each the base run and the model when the shading is placed. Adjusting the shading only, achieved a decrease in the annual cooling demand by 2.6% (Chart 6.6.35 and Chart 6.6.36).

 Chart 6.6.35. Annual Electric End Use in Base Run , Source: Author	 Chart 6.6.36. Annual Electric End Use in Alternative (Shading) , Source: Author

In conclusion, the model showed high energy usage and space cooling referring to the enlarged space that needs cooling and the direct contact with the environment that result in excessive heat gain in the summer months. Shading 2/3rd of the windows is the most efficient low cost and applicable method to be applied on existing buildings. The recordings will be further compared to other models in order to deduce the efficient and inefficient model.

Appendix N B2W-300 Glazed Balcony Surrounded by 2 Walls Model

The following section presents and analyzes the recording of the model having a balcony surrounded with 2 walls and enlarged glazed space. The energy usage, space cooling and heating of the space area discussed, focusing on the cooling demand in the balcony enclosure. Chart 6.6.37 and Chart 6.6.38 indicate the space cooling and heating in the model per month (KWh).

In the model having a glazed balcony surrounded by 2 walls, the space cooling exceeded 1500 KWh in the summer months, whereas in the winter it reached up-to 50 KWh (Chart 6.6.37 and Chart 6.6.38).

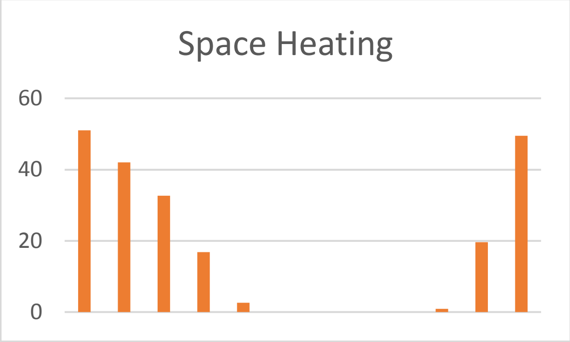


Chart 6.6.37.Space Heating for model having glazed balcony surrounded by 2 walls, Source: Author

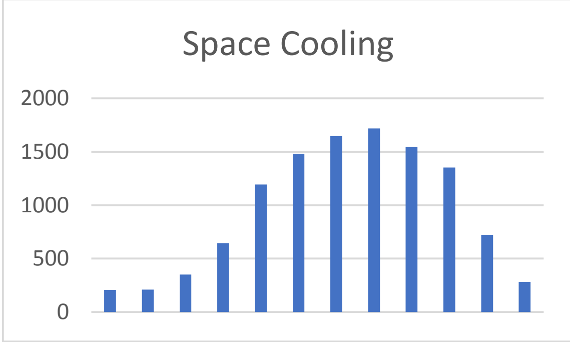


Chart 6.6.38.Space Cooling for model having glazed balcony surrounded by 2 walls, Source: Author

Specifically in the glazed space; glazed balcony and living area, the cooling demand reached up-to 3700 KWh in the summer months (Table 42 and Chart 6.6.39). This cooling demand is extremely high compared to US standards and costs up-to to 333$ per month. This cost is spent only cooling the glazed and living area having 0.09 USD / kWh.

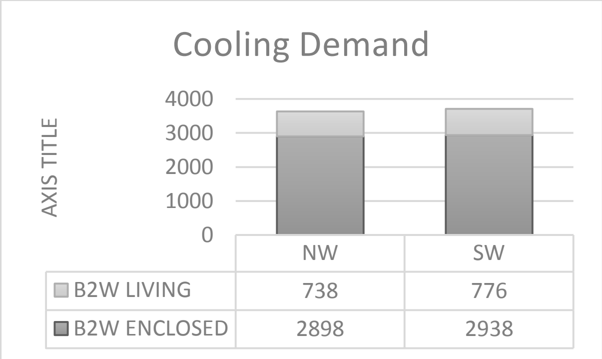


Chart 6.6.39. Chart indicating cooling demand, Source: Author

		NW	SW
B2W	ENCLOSED	2898	2938
	LIVING	738	776
		3636	3714

Table 42. Cooling demand in glazed space and living area, Source: Author

In order to reduce this cost, similar to the methods applied on the previous scenarios, several variables were modified in order to identify the most efficient parameter that can reduce the cost on space cooling. Shading, glazing, and rotation decreased the energy demand by 7%, 2.4%, and 4% respectively (Figure 6.6.86, Figure 6.6.87, and Figure 6.6.88). However, changing the window-to wall ratio to 30% relatively didn't make any reduction, rather slightly increased the demand 1% (Figure 6.6.89).

	1 Base Run	2 Design Alternative
	Energy, Carbon and Cost Summary	**Estimated Energy & Cost Summary**
Annual Energy Cost	$4,303	$3,980
Lifecycle Cost	$58,612	$54,212
Annual CO_2 Emissions		
Electric	0.0 Mg	0.0 Mg
Onsite Fuel	2.0 Mg	1.7 Mg
Large SUV Equivalent	0.2 SUVs / Year	0.2 SUVs / Year
Annual Energy		
Energy Use Intensity (EUI)	908 MJ / m² / year	908 MJ / m² / year
Electric	42,716 kWh	39,659 kWh
Fuel	39,350 MJ	34,499 MJ
Annual Peak Demand	7.7 kW	6.9 kW
Lifecycle Energy		
Electric	1,281,474 kW	1,189,777 kW
Fuel	1,180,502 MJ	1,034,962 MJ
Assumptions		

Figure 6.6.86.Placement of shading VS Base run, Source: Author

	1 Base Run	2 Design Alternative
	Energy, Carbon and Cost Summary	**Estimated Energy & Cost Summary**
Annual Energy Cost	$4,303	$4,146
Lifecycle Cost	$58,612	$56,474
Annual CO_2 Emissions		
Electric	0.0 Mg	0.0 Mg
Onsite Fuel	2.0 Mg	1.6 Mg
Large SUV Equivalent	0.2 SUVs / Year	0.2 SUVs / Year
Annual Energy		
Energy Use Intensity (EUI)	929 MJ / m² / year	929 MJ / m² / year
Electric	42,716 kWh	41,683 kWh
Fuel	39,350 MJ	31,285 MJ
Annual Peak Demand	7.7 kW	7.4 kW
Lifecycle Energy		
Electric	1,281,474 kW	1,250,478 kW
Fuel	1,180,502 MJ	938,540 MJ
Assumptions		

Figure 6.6.87.Replacement of glazing VS Base run, Source: Author

1 Base Run

Energy, Carbon and Cost Summary	
Annual Energy Cost	$4,303
Lifecycle Cost	$58,612
Annual CO_2 Emissions	
Electric	0.0 Mg
Onsite Fuel	2.0 Mg
Large SUV Equivalent	0.2 SUVs / Year
Annual Energy	
Energy Use Intensity (EUI)	955 MJ / m² / year
Electric	42,716 kWh
Fuel	39,350 MJ
Annual Peak Demand	7.7 kW
Lifecycle Energy	
Electric	1,281,474 kW
Fuel	1,180,502 MJ
Assumptions (i)	

2 Design Alternative

Estimated Energy & Cost Summary	
Annual Energy Cost	$4,135
Lifecycle Cost	$56,319
Annual CO_2 Emissions	
Electric	0.0 Mg
Onsite Fuel	1.9 Mg
Large SUV Equivalent	0.2 SUVs / Year
Annual Energy	
Energy Use Intensity (EUI)	955 MJ / m² / year
Electric	40,949 kWh
Fuel	39,018 MJ
Annual Peak Demand	7.1 kW
Lifecycle Energy	
Electric	1,228,484 kW
Fuel	1,170,529 MJ
Assumptions (i)	

Figure 6.6.88.Modified orientation VS Base run, Source: Author

1 Base Run

Energy, Carbon and Cost Summary	
Annual Energy Cost	$4,303
Lifecycle Cost	$58,612
Annual CO_2 Emissions	
Electric	0.0 Mg
Onsite Fuel	2.0 Mg
Large SUV Equivalent	0.2 SUVs / Year
Annual Energy	
Energy Use Intensity (EUI)	992 MJ / m² / year
Electric	42,716 kWh
Fuel	39,350 MJ
Annual Peak Demand	7.7 kW
Lifecycle Energy	
Electric	1,281,474 kW
Fuel	1,180,502 MJ
Assumptions (i)	

2 Design Alternative

Estimated Energy & Cost Summary	
Annual Energy Cost	$4,345
Lifecycle Cost	$59,173
Annual CO_2 Emissions	
Electric	0.0 Mg
Onsite Fuel	1.9 Mg
Large SUV Equivalent	0.2 SUVs / Year
Annual Energy	
Energy Use Intensity (EUI)	992 MJ / m² / year
Electric	43,270 kWh
Fuel	37,895 MJ
Annual Peak Demand	7.9 kW
Lifecycle Energy	
Electric	1,298,099 kW
Fuel	1,136,846 MJ
Assumptions (i)	

Figure 6.6.89.Modified WWR VS Base run, Source: Author

According to Table 43, the most efficient parameter was the placement of shading, followed by the adjustment of orientation to the north rather than the west, and then the glazing.

MODEL	BASE RUN		WWR		ORIENTATION		GLAZING		SHADING		#NAME?
	COST	KWH	COST	KWH	COST	KWH	COST	KWH	COST	KWH	
300	$ 4,303	42716	$ 4,345	43270	$ 4,135	40949	$ 4,146	41683	$ 3,980	39659	B2W-300
			101%		4%		2%		7.00%		

Table 43.Table indicating the reduction percentage with respect to the base run of several parameters, Source: Author

Adjusting the glazing and placing shades on the windows together, achieved a reduction of up-to 10%, and a reduction in the cooling demand from 26.6% to 23.9% (Figure 6.6.90, Chart 6.6.40, and Chart 6.6.41).

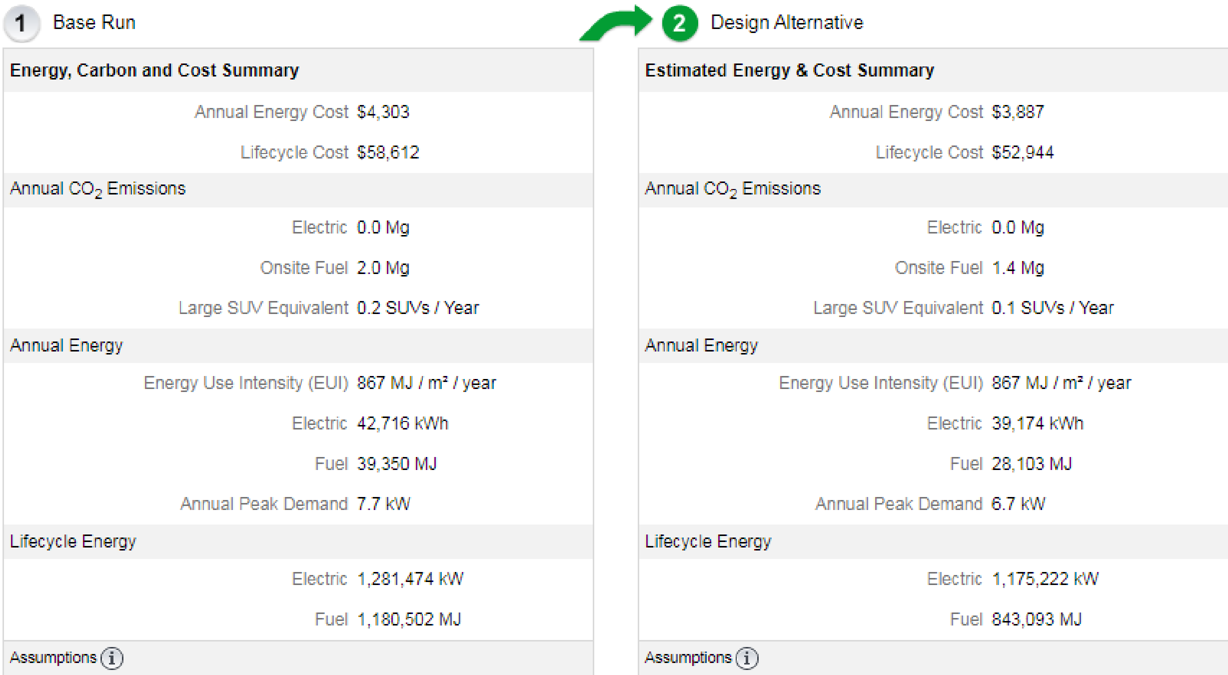


Figure 6.6.90.Adjustment of shading and glazing VS Base run, Source: Author

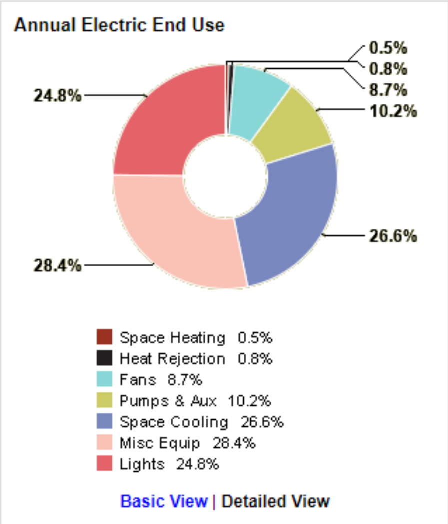
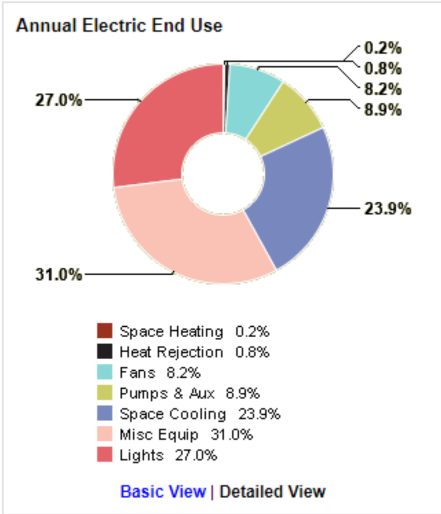
	

Chart 6.6.40. Base run electric use, Source: Author	Chart 6.6.41.Alternative model electric use, Source: Author

In conclusion, the model underwent several reading of recordings in terms of cooling and heating in the space model and in the glazed space. Several parameters were modified in order to obtain the efficient parameter. Shading and glazing showed reduced recordings and can be obtained in existing buildings.

Appendix O B3W-300 Glazed Balcony Surrounded by 3 Walls Model

In the model having an glazed balcony surrounded by 3 walls, similarly, the cooling demand is by far higher than the heating demand, this corresponds to the thermal properties of material used and design of buildings (Chart 6.6.42 and Chart 6.6.43).

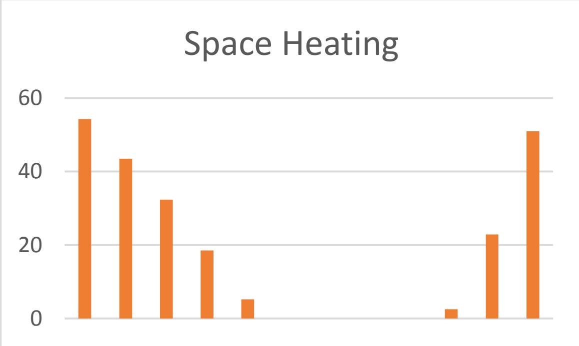


Chart 6.6.42.Space Heating for model having glazed balcony surrounded by 3 walls, Source: Author

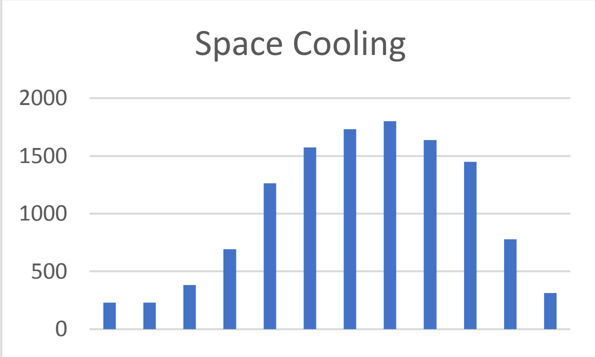


Chart 6.6.43.Space Heating for model having glazed balcony surrounded by 3 walls, Source: Author

The cooling demand in the glazed balcony in the north-west and south-west orientation is similar having an energy usage of 1741 KWh, costing 156$ per month in order to achieve indoor comfort in the glazed space.

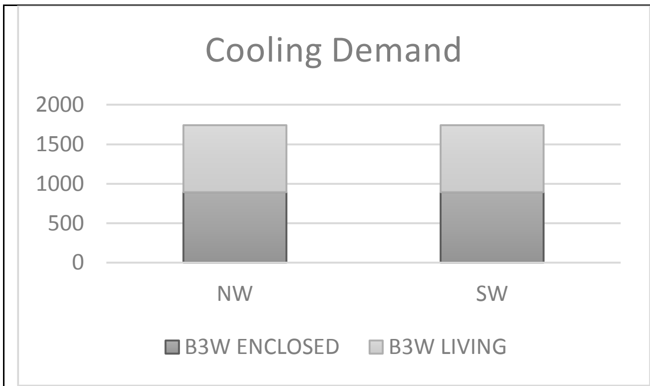
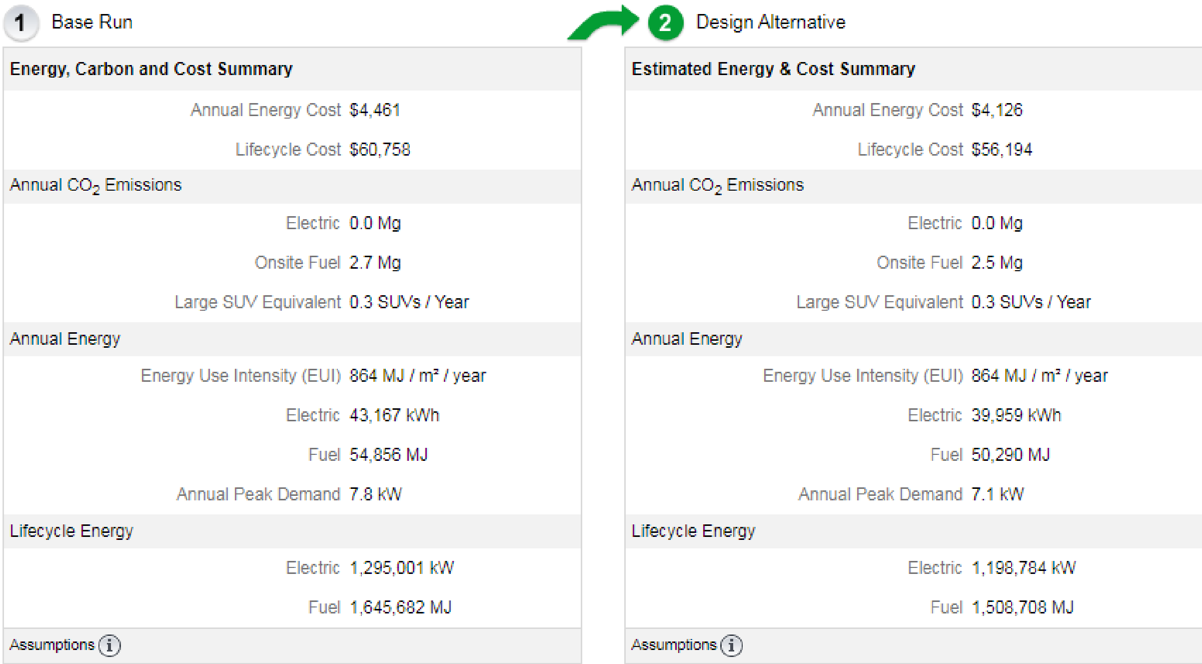


Chart 6.6.44. Cooling demand in glazed space, Source: Author

		NW	SW
B3W	ENCLOSED	895	895
	LIVING	846	846
		1741	1741

Table 44. table indicating cooling demand in glazed space, Source: Author

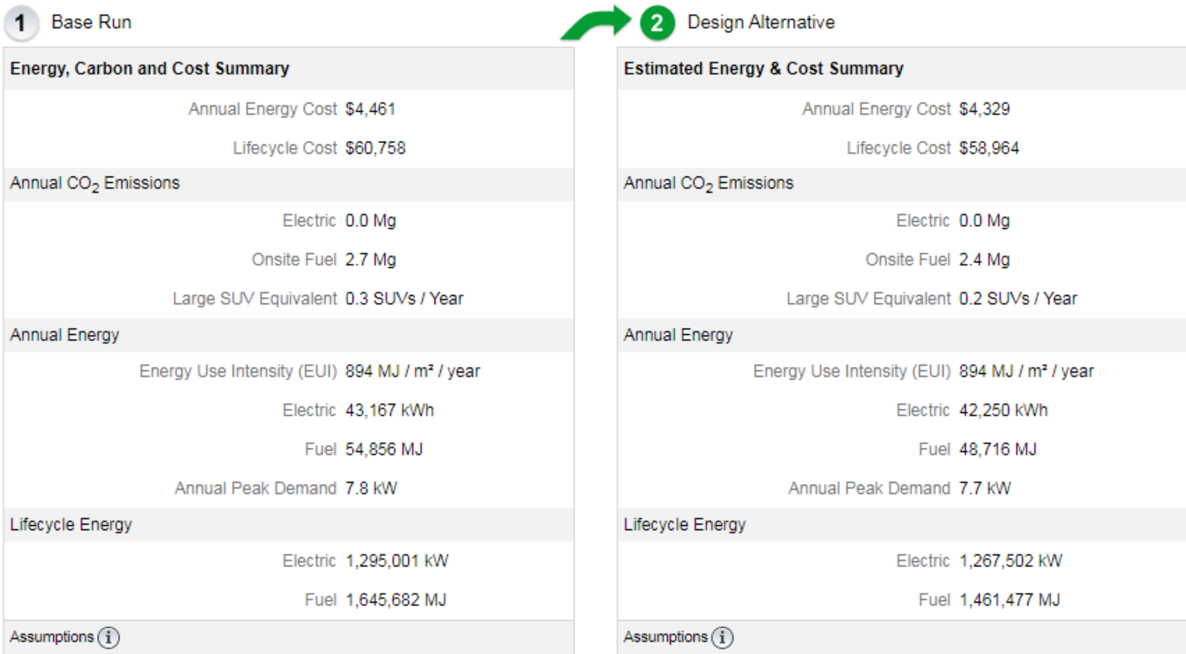
Similar to previous models, variables where modified in order to decrease energy intake. Figure 6.6.91, Figure 6.6.92, Figure 6.6.93, and Figure 6.6.94 indicate the shading, glazing, orientation, and window-to-wall ratio parameters respectively compared to the base run.



1 Base Run	
Energy, Carbon and Cost Summary	
Annual Energy Cost	$4,461
Lifecycle Cost	$60,758
Annual CO_2 Emissions	
Electric	0.0 Mg
Onsite Fuel	2.7 Mg
Large SUV Equivalent	0.3 SUVs / Year
Annual Energy	
Energy Use Intensity (EUI)	864 MJ / m² / year
Electric	43,167 kWh
Fuel	54,856 MJ
Annual Peak Demand	7.8 kW
Lifecycle Energy	
Electric	1,295,001 kW
Fuel	1,645,682 MJ
Assumptions	

2 Design Alternative	
Estimated Energy & Cost Summary	
Annual Energy Cost	$4,126
Lifecycle Cost	$56,194
Annual CO_2 Emissions	
Electric	0.0 Mg
Onsite Fuel	2.5 Mg
Large SUV Equivalent	0.3 SUVs / Year
Annual Energy	
Energy Use Intensity (EUI)	864 MJ / m² / year
Electric	39,959 kWh
Fuel	50,290 MJ
Annual Peak Demand	7.1 kW
Lifecycle Energy	
Electric	1,198,784 kW
Fuel	1,508,708 MJ
Assumptions	

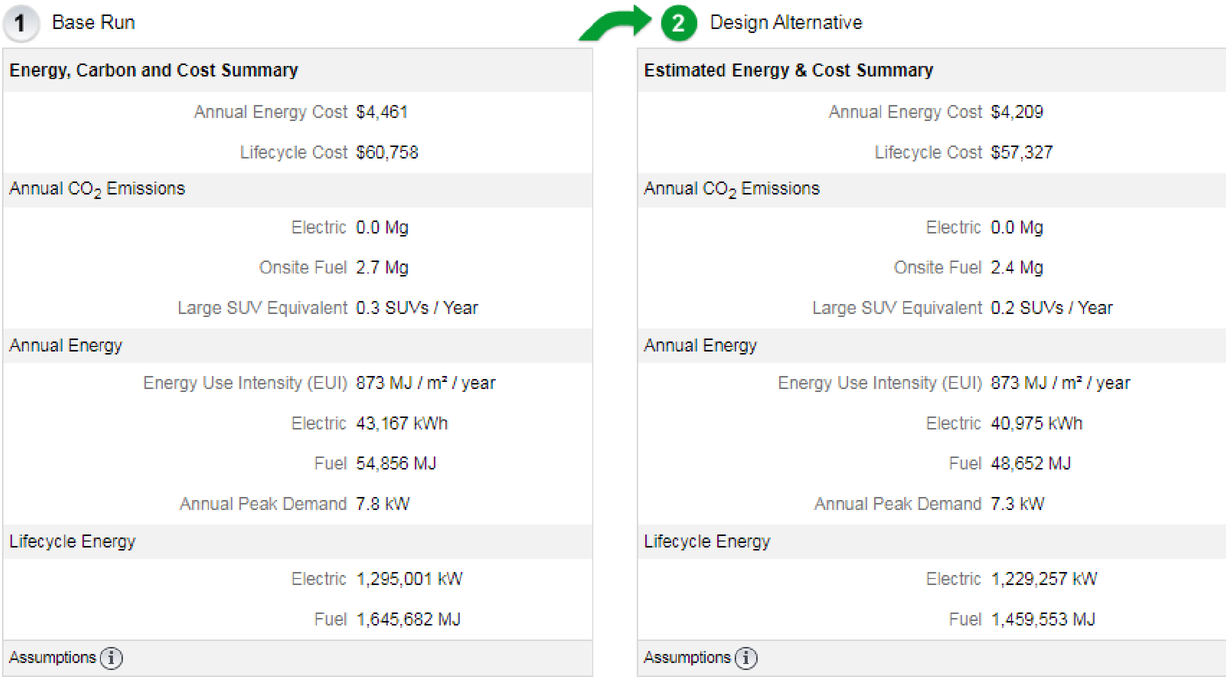
Figure 6.6.91.Shading Placement VS Base run, Source: Author



1 Base Run	
Energy, Carbon and Cost Summary	
Annual Energy Cost	$4,461
Lifecycle Cost	$60,758
Annual CO_2 Emissions	
Electric	0.0 Mg
Onsite Fuel	2.7 Mg
Large SUV Equivalent	0.3 SUVs / Year
Annual Energy	
Energy Use Intensity (EUI)	894 MJ / m² / year
Electric	43,167 kWh
Fuel	54,856 MJ
Annual Peak Demand	7.8 kW
Lifecycle Energy	
Electric	1,295,001 kW
Fuel	1,645,682 MJ
Assumptions	

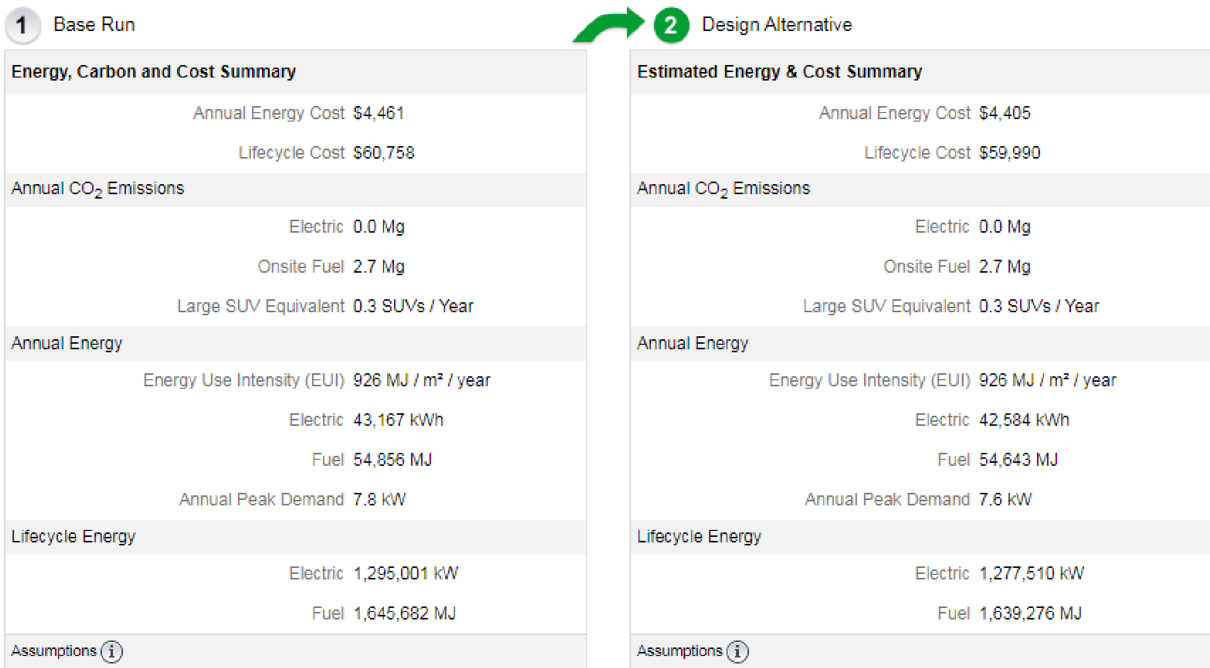
2 Design Alternative	
Estimated Energy & Cost Summary	
Annual Energy Cost	$4,329
Lifecycle Cost	$58,964
Annual CO_2 Emissions	
Electric	0.0 Mg
Onsite Fuel	2.4 Mg
Large SUV Equivalent	0.2 SUVs / Year
Annual Energy	
Energy Use Intensity (EUI)	894 MJ / m² / year
Electric	42,250 kWh
Fuel	48,716 MJ
Annual Peak Demand	7.7 kW
Lifecycle Energy	
Electric	1,267,502 kW
Fuel	1,461,477 MJ
Assumptions	

Figure 6.6.92.Glazing replacement VS Base run, Source: Author



	1 Base Run	2 Design Alternative
	Energy, Carbon and Cost Summary	**Estimated Energy & Cost Summary**
Annual Energy Cost	$4,461	$4,209
Lifecycle Cost	$60,758	$57,327
Annual CO_2 Emissions		
Electric	0.0 Mg	0.0 Mg
Onsite Fuel	2.7 Mg	2.4 Mg
Large SUV Equivalent	0.3 SUVs / Year	0.2 SUVs / Year
Annual Energy		
Energy Use Intensity (EUI)	873 MJ / m² / year	873 MJ / m² / year
Electric	43,167 kWh	40,975 kWh
Fuel	54,856 MJ	48,652 MJ
Annual Peak Demand	7.8 kW	7.3 kW
Lifecycle Energy		
Electric	1,295,001 kW	1,229,257 kW
Fuel	1,645,682 MJ	1,459,553 MJ
Assumptions		

Figure 6.6.93.Rotation adjustment VS Base run, Source: Author



	1 Base Run	2 Design Alternative
	Energy, Carbon and Cost Summary	**Estimated Energy & Cost Summary**
Annual Energy Cost	$4,461	$4,405
Lifecycle Cost	$60,758	$59,990
Annual CO_2 Emissions		
Electric	0.0 Mg	0.0 Mg
Onsite Fuel	2.7 Mg	2.7 Mg
Large SUV Equivalent	0.3 SUVs / Year	0.3 SUVs / Year
Annual Energy		
Energy Use Intensity (EUI)	926 MJ / m² / year	926 MJ / m² / year
Electric	43,167 kWh	42,584 kWh
Fuel	54,856 MJ	54,643 MJ
Annual Peak Demand	7.8 kW	7.6 kW
Lifecycle Energy		
Electric	1,295,001 kW	1,277,510 kW
Fuel	1,645,682 MJ	1,639,276 MJ
Assumptions		

Figure 6.6.94.WWR adjustment VS Base run, Source: Author

Table 45 shows that the most efficient variable was shading, which decreased the energy demand by 7.5% (Figure 6.6.91).

BALCONY TYPE	MODEL	BASE RUN		WWR		ORIENTATION		GLAZING		SHADING		
		COST	KWH	COST	KWH	COST	KWH	COST	KWH	COST	KWH	
B3W	300	$ 4,461	43169	$ 4,405	42584	$ 4,209	40975	$ 4,329	42250	$ 4,126	39959	B3 W-300
REDUCTION				1%		5%		2%		7.50%		

Table 45.Table indicating reduction percentage of several parameters with respect to the base run, Source: Author

However, when adjusting shading and glazing, since they are variables that can be adjusted in an existing building, a decrease of 9% was achieved (Figure 6.6.95) and a decrease of 2.6% specifically on the cooling demand (Chart 6.6.45 and Chart 6.6.46).

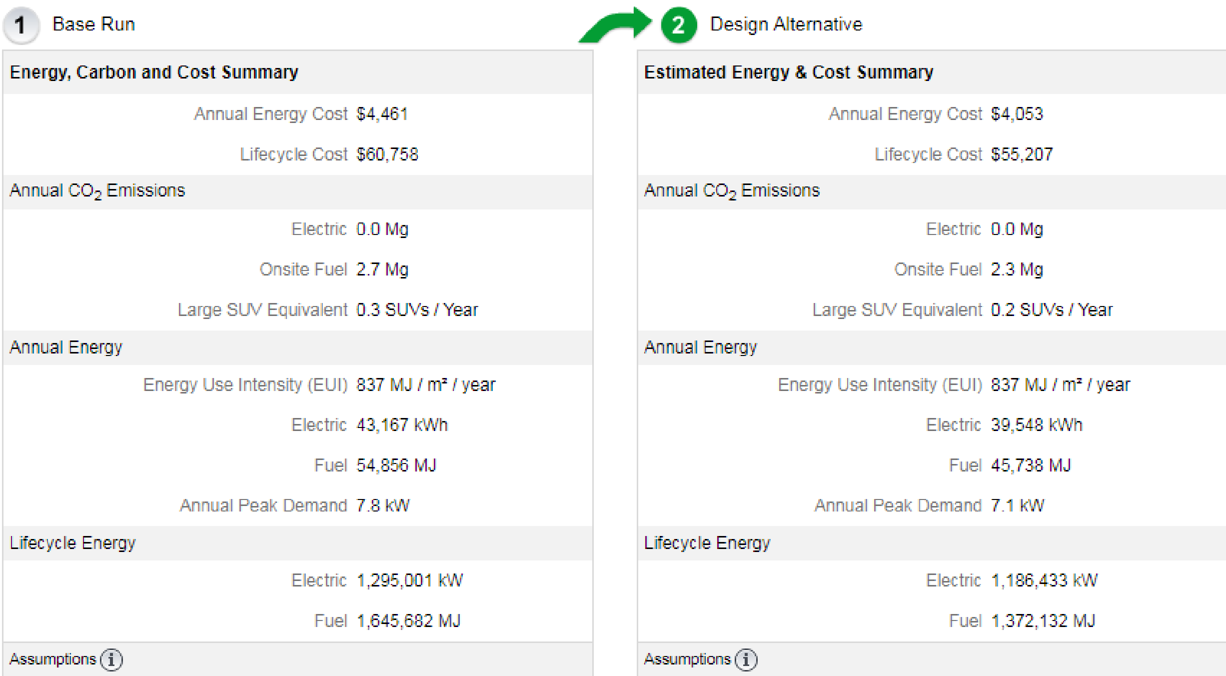


Figure 6.6.95.Shading and glazing adjustment VS Base run, Source: Author

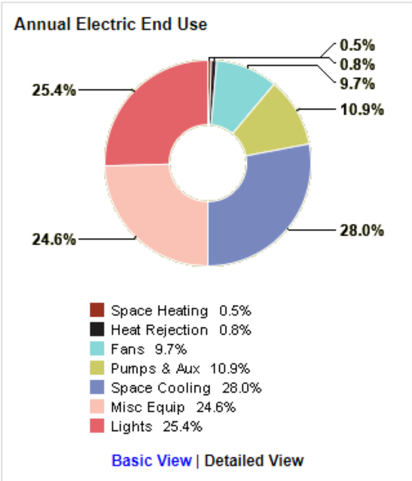


Chart 6.6.45.Base run electric end use, Source: Author

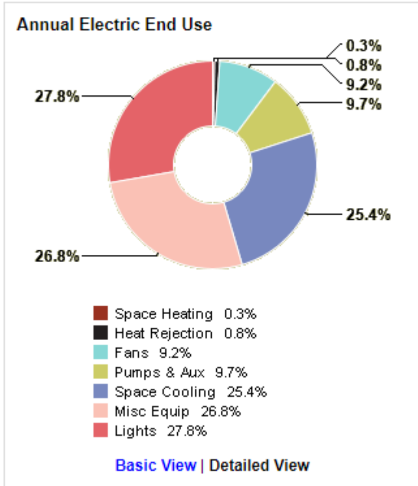


Chart 6.6.46. Alternative electric end use, Source: Author

In conclusion, similar to the previous models, the balcony surrounded by 3 walls recorded high energy usage and high cooling usage, whereas the heating was minimal. The model was mostly respondent to the shading coefficient. Moreover, when glazing and shading were adjusted together, the reduction was recorded per energy use and per cooling specifically.

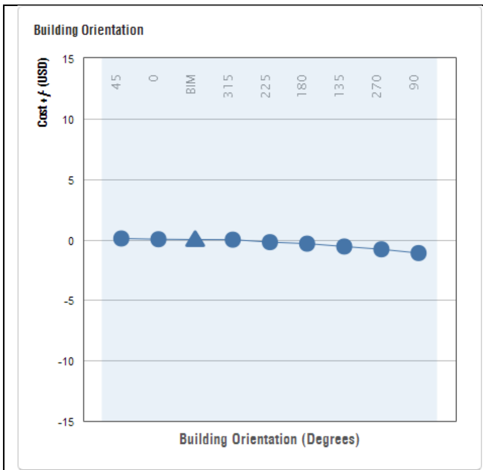


Figure 6.6.96. Building orientation chart indicating orientation adjustments that reduces the cost /m2, Source: Author

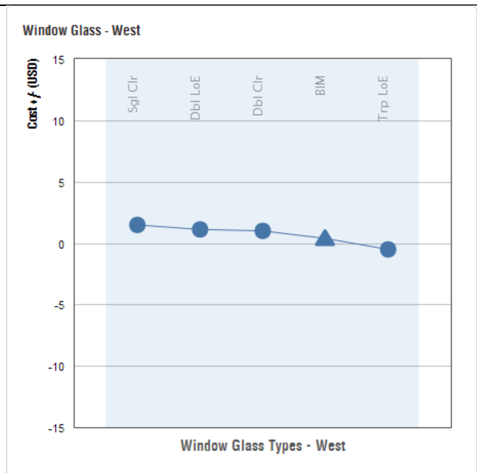


Figure 6.6.97. Chart indicating glazing types and their effect on cost consumed on energy, Source: Author

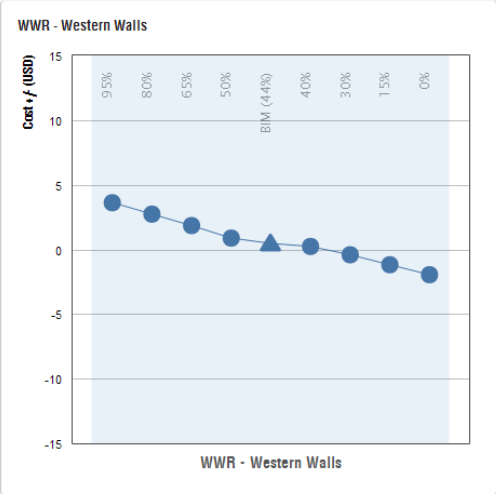


Figure 6.6.98. Chart indicating difference in energy consumption when window to wall ratio is reduced (on the western facade) , Source: Author

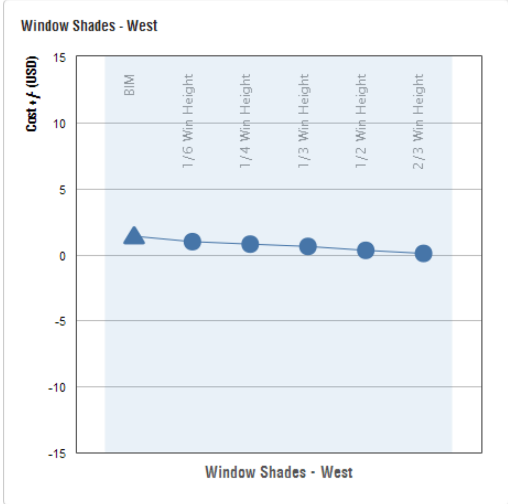


Figure 6.6.99. Chart indicating window shading and their effect on energy consumption, Source: Author

Finally, Chart 6.6.47, Chart 6.6.48, and Chart 6.6.49 are extracted from Green Building Studio indicating the space cooling demand for the model in months June, July, and August respectively.

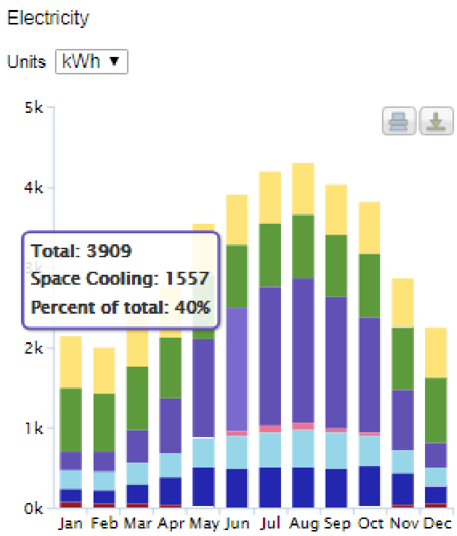


Chart 6.6.47. Cooling load in June, Source: Author

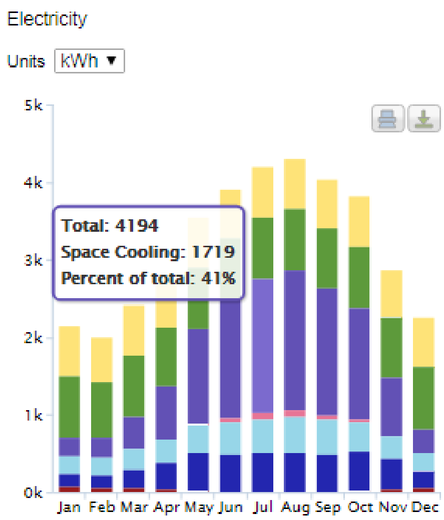


Chart 6.6.48. Cooling load in July, Source: Author

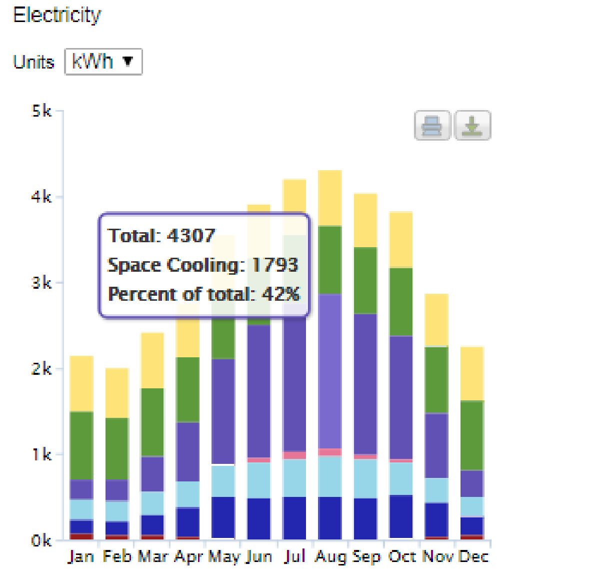


Chart 6.6.49. Cooling load in August, Source: Author