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Master of Architecture – Sustainable Design

Assessment of the Setback Regulations' Impact on The Quality of the Indoor Environment and Enhancement Strategies in Bethlehem-Palestine

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Thesis submitted in partial fulfillment of requirements of the degree
Master of Architecture- Sustainable Design

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Assessment of the Setback Regulations' Impact on The Quality of the Indoor Environment and Enhancement Strategies in Bethlehem-Palestine.

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ABSTRACT

Urban context has a significant impact on energy consumption, daylighting intensity, in multi-story residential buildings which represent the largest construction sector in Palestine. The relationship between building blocks and indoor environment performance has become increasingly important. Because the building regulations especially setbacks regulations are the primary regulator of this relationship, this thesis examines the interaction between buildings' performance and setbacks regulations in residential B-Zone in Palestine. The study depends on quantitative and qualitative methods to achieve the research objectives. Simulation results were employed to investigate the impact of current setbacks regulations by using Design Builder software, then discusses alternative strategies for reducing energy consumption for lighting, heating, and cooling activates. Analysis of the most common residential building prototypes was carried out in terms of apartment area, number of floors, common residential spaces and their characteristics and the number of apartments on each floor to help in the assessment and proposing alternative phases.

The simulation work was conducted along two consequent phases; firstly, simulating the current situation of the residential urban context with existing setbacks regulations and their impact on the natural daylight and thermal energy performance, and secondly optimizing these parameters by testing various alternatives. To further examine how the local setback affects the provision of daylighting and energy savings, both urban and building levels parameters were considered. Urban factors include the external blocks and the relations to each other. On the other hand, building level factors like window to wall ratio (WWR) and shading devices were included.

In the assessment phase, the results show that existing setback distances in residential B-Zone are not sufficient to provide an acceptable level of daylighting and to enhance the thermal energy consumption inside residential spaces. In the optimization phase, the study found that, 10m of building separation is the minimum distance to obtain an acceptable level of daylighting and minimize total energy consumption to enhance the building performance. The optimal setback distance was in all cases higher than the current distance and often reached twice the existing distance. At the building level, the optimization process indicated as for windows characteristics, WWR has a significant impact on daylighting availability and on heating energy consumption at regulated setbacks distance. Optimal WWR, especially on lower floors, was higher than WWR in the current housing projects. For example, the optimum WWR for the living room in the north-oriented street was 60%, 40%, 20%, and 20% in the first, second, third, and fourth floors which are higher than the existing ratio of 22.70% on all floors. In addition, shading systems especially outside blind which is used in hot summer is the ideal strategy to be implemented to block direct sunlight in summer to reduce cooling consumption by about 4% to 35% and admit natural daylight and solar radiation in winter in all urban context cases.

تقييم تأثير قوانين الارتدادات على كفاءة البيئة الداخلية واستراتيجيات التحسين في بيت لحم – فلسطين

خلود نايف مناصرة

ملخص

السياق الحضري له تأثير كبير جدا على استهلاك الطاقة والاضاءة الطبيعة في المباني السكنية. حيث أن العلاقة بين كتل المباني المختلفة ضمن السياق الحضري وأداء البيئة الداخلية أصبحت ذات أهمية كبيرة. ونظرا لأن قوانين البناء هي المنظم الرئيسي لهذه العلاقة، فإن هذه الأطروحة تبحث في العلاقة بين أداء المباني وقوانين الارتدادات في المناطق السكنية عالية الكثافة في فلسطين مثل منطقة سكن ب. تعتمد هذه الدراسة على أساليب نوعية وكمية لتحقيق الأهداف المرجوة. نتائج المحاكاة تم توظيفها للتحقق من تأثير قوانين الارتدادات الحالية باستخدام برنامج Design Builder على أداء البيئة الداخلية للمباني السكنية، ثم مناقشة البدائل المقترحة للحد من استهلاك الطاقة اللازمة للإضاءة الصناعية وأحمال التبريد والتدفئة.

تم إجراء عملية المحاكاة على مرحلتين متتاليتين، أولا: محاكاة الوضع الحالي لسيناريوهات السياق الحضري المختلفة لمنطقة سكن ب الخاضعة لقوانين الارتدادات لدراسة تأثيرها على الإضاءة الطبيعية وأداء الطاقة الحرارية داخل الفراغات السكنية. ثانيا: تحسين هذه العوامل عن طريق اقتراح بدائل مختلفة. لدراسة الكيفية التي تؤثر بها قوانين الارتدادات على توافر ضوء النهار الطبيعي وتوفير استهلاك الطاقة، تم الأخذ بعين الاعتبار مجموعة من العوامل والمتغيرات على المستوى الحضري وعلى مستوى تصميم المبنى. تشمل العوامل الحضرية كتل المباني الخارجية وعلاقتها مع بعضها البعض والتي تحكم هذه العلاقة قوانين الارتدادات. ومن ناحية أخرى، تشمل المتغيرات الداخلية على مستوى المبنى مجموعة من العوامل مثل توجيه الفراغات نسبة مساحة النافذة الى مساحة الجدار وكذلك وسائل التظليل الداخلية والخارجية.

توصلت الدراسة في مرحلة التقييم إلى أن مسافات الارتدادات التي تفرضها قوانين البناء والتنظيم الفلسطينية في منطقة سكن ب غير كافية لتوفير مستوى مقبول من ضوء النهار وتعزيز استهلاك الطاقة الحرارية داخل فراغات المباني السكنية. أما فيما يتعلق بالمرحلة الثانية التي تهدف الى الوصول الى حلول مثلى، أثبتت الدراسة أن الإضاءة الطبيعية في الفراغات السكنية تتأثر بشكل كبير بالمباني المجاورة والتظليل الناتج عنها، في حين أنه عندما تكون المسافة الفاصلة بين المبنى والمبنى المجاور 10 م تعتبر مقبولة كحد أدنى في بعض الحالات للحصول على مستوى مقبول من الإضاءة الطبيعية وتقليل استهلاك الطاقة لتعزيز أداء المبنى. حيث كانت المسافة المثلى للارتداد في جميع السيناريوهات الحضرية أعلى من القيمة الفعلية التي تنص عليها قوانين البناء والتي غالبا ما تصل الى ضعف المسافة الحالية، وهذا يؤثر سلبا على نسبة المساحة المبنية للمشاريع السكنية. أما على مستوى تصميم المبنى، فقد أشارت عملية التحسين الى أن الفراغات الجنوبية تتمتع بأفضل سلوك من ناحية استهلاك الأحمال الحرارية أكثر من الفراغات الأخرى، وأن الشمال الشرقي والشمال الغربي هما أسوء توجيه للفراغات السكنية على الإطلاق. أما فيما يتعلق بخصائص النوافذ، فإن عامل نسبة مساحة النافذة الى مساحة الجدار له تأثير كبير على توافر ضوء النهار الطبيعي واستهلاك الطاقة اللازمة للتدفئة في سياق قوانين الارتدادات الحالية. وكانت نسبة مساحة النافذة الى مساحة الجدار في الطوابق السفلية أعلى من النسبة في الطوابق العلوية. على سبيل المثال، كانت النسبة المثلى للنافذة لغرفة المعيشة في حالة الشارع المتجه نحو الشمال 60%و40%و20% و20% في الطوابق الأول والثاني والثالث والرابع على التوالي، وهي أعلى من النسبة المستخدمة حاليا والبالغة 22.70% في جميع الطوابق. وبالإضافة الى ذلك، تعتبر وسائل التظليل وخاصة الستائر الخارجية التي تم استخدامها في أشهر الصيف الحارة بديل مثالي يمكن الاعتماد عليه لحجب أشعة الشمس المباشرة في الصيف والتقليل من أحمال التبريد بحوالي 4%-35% في الفراغات المختلفة ضمن حالات السياق الحضري المقترحة، وفي نفس الوقت تسمح هذه الستائر بدخول ضوء النهار الطبيعي والاشعاع الشمسي في فصل الشتاء.

DECLARATION

I declare that the Master Thesis entitled" Assessment of the Setback Regulations' Impact on The Quality of the Indoor Environment and Enhancement Strategies in Bethlehem-Palestine." is my own original work, and herby certify that unless stated, all work contained within this thesis is my own independent research and has not been submitted for the award of any other degree at any institution, except where due acknowledgement is made in the text.

Student Name………………………………….

Signature:—————————— Date:——————

DEDICATION

To my great parents, great family for all your support, encouragement and love……

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Chapter one

1. Introduction:

1.1. Background:

Urbanization all over the world has many influences on the city structure which led to increase housing densities in urban cities than it used to a long time ago in the traditional settlements. At the same time, the world is also facing multiple environmental, economic and social problems due to climate change, especially in the urban areas. Palestine like the rest of the world, especially developing countries, is highly vulnerable to climate change. Also, the housing sector faces different problems due to the poor economic situation in parallel with the lack of land in comparison to the increase in population density and land prices. According to this, a new urban context has formed of high-density residential zones with high rise buildings was appeared in all Palestinian cities to keep up with the increasing demands for housing units (Barakat, Elkahlout, & Jacoby, 2004; Chapman, Watson, Salazar, Thatcher, & McAlpine, 2017; DOE, 2015; Hui, 2001; Kurraz, 2006; Li, Wong, Tsang, & Cheung, 2006).

Nowadays, the challenge that is facing the residential sector is the ability to provide housing units to support the highly increasing number of populations, while trying to minimize the impact of the built environment on the natural environment and to provide housing units but also to ensure a suitable indoor environment in the residential spaces. Designing housing in confined urban residential areas such as Palestinian cities needs special concern until these challenges are achieved. Rapid population growth and the need for housing, in addition to scarce resources and land and improvement of the living standards led to densify the built environment and rapid increase in the residential sector energy demand which consume about 46% from total energy consumption in Palestine which has affected the thermal balance of urban areas, increase CO_2 emissions, reduce vegetation and open spaces. All these problems are linked to health risks in cities due to the climate change (Abdellatif, 2018; Chapman et al., 2017; R. Chen, Sung, Chang, & Chi, 2013; Ibrahim, Kershaw, Shepherd, & Coley, 2021; Juaidi, Montoya, Ibrik, & Manzano-Agugliaro, 2016). A large proportion of the consumed energy in residential buildings is used for heating, ventilation, and air conditioning (HVAC) and for lighting (Khatib, 2012).

The quality of the indoor environment is a relative measure of comfort perceived by those exposed to interior conditions (Piasecki, Kostyrko, & Pykacz, 2017). It has a significant impact on occupants' behavior, occupants' satisfaction (level of comfort), and on building performance as well (Peretti & Schiavon, 2011), there is a strong relationship between housing indoor conditions and a person's physical and mental health. In other words, adequate housing conditions have demonstrated a strong relationship with good health, productivity and socioeconomic development for residents (Akinyemi, Hadiza, & Salau, 2020).

In general, there are different physical factors that predict the quality of the indoor environment such as the indoor air quality, natural lighting and visual comfort, thermal comfort, ventilation and acoustic comfort, etc. (Mihai & Iordache, 2016; Molina & Yaguana, 2018; Nasir et al., 2011). These indoor environmental factors significantly affect the energy consumption of a building (Almeida, de Freitas, & Delgado, 2015; Heinzerling, Schiavon, Webster, & Arens, 2013). The satisfaction especially with the thermal and visual environment have a significant impact on occupants' health and well-being (Gregg, 2018). When an adequate amount of daylight and solar radiation enter residential buildings, thermal and visual discomfort is eliminated, provide a view to the outdoor environment, minimize energy consumption for electrical lighting and HVAC systems especially in heating period (CLTC, 2018).

From previous studies, the building design and its envelope related parameters such as windows to wall ratio WWR and building envelope materials are not the only factors that have impacts on the quality of the indoor environment. The urban context has a great effect as well (Quan, Economou, Grasl, & Yang, 2014). According to the Yaşar et al. and Hachem et al., the amount of natural daylight and solar radiation reaching to the residential spaces depend on a number of factors such as building orientation, shading from surrounding buildings, building shape and urban context density (Hachem, Athienitis, & Fazio, 2012; Yaşar, Kalfa, Haydaraslan, & Haydaraslan, 2018). Also Jon Gregg in his report about energy performance in terms of daylighting availability and energy consumption in tall buildings which located in high density areas in London stated that to enhance the daylighting availability whilst minimizing the overheating it should take into consideration number of parameters such as space orientation, position on site and shading from surrounding (Gregg, 2018). For this reason, it is very important to take into account the relation between the building and surrounding at the early design stage to provide acceptable levels of daylighting and solar radiation to reduce energy consumption (Sanaieian, Tenpierik, Van Den Linden, Seraj, & Shemrani, 2014; Yaşar et al., 2018).

The relationship between buildings and the surrounding environment has been introduced by researchers since the 19th century (Yaşar et al., 2018). Urban context includes everything in the built environment, not only building elements but can also include all the natural surrounding elements (Alzoubi & Dwairi, 2015). For the purpose of this study, only adjacent buildings and their effect one on the other will be studied so as to elaborate on the effect of urban context on the indoor environment performance. In our context, building regulations had a great effect on the urban context and the way neighboring buildings affect one another. These regulations had been and are still guiding the country's structure and its urban fabric since they highly affect the relationship between buildings and the surrounding environment, as well as other urban elements within the city structure such as streets, open squares and gardens.

This research will focus on these regulations and specifically on building heights regulations and setbacks between buildings, which mainly have an influence on the penetration of direct sunlight which will have an influence on building performance and on the quality of the indoor environment. The building performance will be tested in terms of the level of natural daylight in living spaces and bedrooms, as well as heating and cooling energies consumed in winter and summer seasons.

In Palestine, there exists two different urban contexts that can be studied separately. One is the context in the old towns where compact urban fabric represents the relationship between different building blocks (Ben-Hamouche, 2009). Within this context, building regulations were formed as a result of people's needs, traditions and cultural values. Whereas, the heights of these buildings have ranged from one to maximum two floors (Mansour, 2015). Houses in the traditional urban fabric were highly populated (M Itma, 2014). Second is the urban context away from the city centers where more buildings regulations were formed and used and has led to the current urban context. These building regulations specify the building heights and setback distances based on city master plan and city planning zones. These developed regulations contradict with the social, cultural and political needs of the community and are not compatible with the local environment (Al-Natsha, Yaghi, & Abu-Alia, 1991).

For the previously mentioned reasons, many researches focused on proposing modifications to building level (heights) in the dense residential areas so as to improve the indoor environment quality in terms of improving the penetration of natural daylight and so of improving building thermal performance. Others have focused on enhancing the building envelope, proposing more sustainable building materials, modifying windows to wall ratio, windows location, glazing type, and shading devices so as to overcome the urban context effects. Few studies have studied the effect of urban context on buildings by means of studying the effect of neighboring buildings on an individual building and their impact on the building performance in different parts of the world and in different climatic zones. One of the pioneering studies trying to understand this relationship was the work of Alzoubi and Dwairi (Alzoubi & Dwairi, 2015) which studied the impact of the Jordanian energy efficiency codes on building performance in terms of energy consumption in winter (heating loads). They tested the relationship between setbacks regulation and energy consumption in residential buildings in Amman by testing the effect of these regulations on allowing buildings to be exposed to solar radiation and so to increase thermal comfort in the internal spaces and to increase the dependency on natural solar energy. DEROB-LTH computer energy simulation software was used to test the existing setbacks regulations in integral with surrounding buildings heights. The tested residential building was 200 m^2 area, one story 3 m height, and is oriented to the east-west. Four Different scenarios with varying neighboring building location and height were considered for the purpose of the assessment. The study found that setbacks regulations have had a negative impact on the energy performance especially in winter because the adjacent buildings block the solar energy from touching the building envelope and prevent it from penetrating into the residential spaces. Also, they conclude that so as to minimize heating loads in winter, the neighboring building is preferable to be on the eastern, western, and northern sides to allow solar radiation to reach the reference building from the south (direction of the highest amount of radiation).

Also, Mohamed Saad (Saada, 2016) has examined the impact of the regulated setbacks between buildings in Cairo on the availability of natural daylight to penetrate inside the residential spaces. The testing process has followed two different methodologies. The first one was by changing the windows to wall ratio (WWR) in the sides facing rooms. And the second one was by adding shading elements to prevent excessive solar gains happening as a result of varying window to wall ratio. The case study was modeled by using Grasshopper, the parametric plugin for Rhinoceros 3D, and the daylight analysis was completed using DIVA software. The simulated building was of 12 story height and the regulated setback distance is 3m. The simulation was conducted through 1169 cases (164 in the first phase and 1005 in the second phase). The study showed that each floor and each building orientation should have its own specific design to enhance the daylight distribution inside residential spaces. Also, the regulations should take into consideration the ability to allow daylight to penetrate inside buildings.

On the other hand, in Palestine there are very limited studies that address the impact of the urban context on indoor environmental quality and building performance. Asfour and Alshawaf's study (Asfour & Alshawaf, 2015) aims to determine the relationship between housing density in the hot climate in Gaza and energy performance in residential buildings. This was done based on numerical analysis by using Ecotect simulation software. The simulation process was implemented for 15 cases that represent different housing types in the urban context. The housing unit area (130 m^2), site area (3300 m^2). This study did not address the concept of the setback's regulations, but it studied the urban context in terms of housing density and building heights, thus providing a general perception of the relationship between the building and adjacent buildings. The study found that energy loads are highly affected by site housing density, if housing densities rise, the cooling loads increase simultaneously since increasing density can be considered a restricted passive heat loss from buildings. Thus, compact horizontal housing configurations can perform better in terms of energy efficiency when compared to the vertical buildings' configurations.

1.2. Research Problem and Significance:

Residential urban context issues are one of the greatest challenges facing Palestinian cities both from quantitative and qualitative aspects. The quantitative aspect results from rapid population growth and the increasing needs for housing units, in the same time with limited expansions for the built up areas (low availability of square meter area per capita) due to Israeli policies which forbids the expansion of residential zones in the area called area "C". on the other hand, the qualitative aspect is due to the dense urban context and the decreasing of green and open spaces within residential zones because urban open spaces design and landscaping inside residential areas have been neglected in almost all implemented housing projects which has a negative impact on the indoor environment performance (Al-Sa'ed, 2006). In most housing projects, the landscape and open space around the building are restricted to setback distance, which are mostly neglected areas that are not suitable for any activity, being small and it's often a place to collect waste (see Figure 1.1).

Figure 1.1: Setback distance in residential buildings (from Nablus city).

However, the governmental endeavors to meet the challenges facing housing sector and to improve buildings performance also to address with sustainable and green architecture legislations were confined firstly on non-compulsory guidelines for efficient building design and climate based design criteria which implemented by the Ministry of Local Government (MOLG), secondly on green building guidelines were developed by non-governmental institution which is the Palestine Higher Green Building Council emanating from the Palestinian Engineers Association, which provide general policies as rating system to evaluate the buildings in term of being green or not for all building types in all building phases. It also scores green building design to get a certification using a pointing system that is categorized in main six areas include, site sustainability, energy efficiency, water use efficiency, indoor environment quality, material and resources and innovation and building integrated design. These two types of guidelines were confined non-compulsory to the building scale without taking into account the relationship with surrounding buildings and the impact of the urban context. Furthermore, Palestinian building regulations do not contain articles regulating the relationship between the building and the surrounding environment. They are reproduced from European regulations which are not based on studies about current status and the local environment in Palestinian cities.

In general, a research problem is a specific problem or knowledge gap that the research seeks to find its solutions which is considered the basis for any research. However, the main problem in this research is that there are no studies or regulations and guidelines in Palestine that investigate the impact of the urban context on the housing units quality and indoor environment performance in terms of the availability of natural daylight and thermal energy performance in housing sector especially in multi-story residential buildings, so it is important to assess this relationship between the surrounding environment and existing urban context and the buildings performance with considering an important factor that regulates this relationship between the building and the adjacent buildings, which is the separation distances between building's blocks.

The research Significance comes from the idea that People spend about 80% of their time at home (Foldvary, 2016). Occupants’ exposure to the indoor residential environment is very high. Low natural daylight intensity and poor thermal performance has a significant influence on occupants’ health and satisfaction in the residential spaces. This has caused the increase in demand for non-renewable energy to improve the quality of the indoor environment and the dependence mainly on the artificial lighting and HVAC systems. In Palestine, this has resulted in increasing the dependency on the imported energy sources since Palestine depends on other countries to produce its needs from energy due to the lack of energy resources (Ouda, 2010). 87% of electricity in Palestine is mainly imported from Israel, 1% from Jordan, 3% from Egypt and 9% from Palestinian electric company (Hamed, Flamm, & Azraq, 2012). In addition, about 20-40% savings in the energy consumption could be achieved in the building sector if improving the building energy efficiency (S. Chen, Zhang, Xia, Setunge, & Shi, 2020).

This issue shows the importance of having effective strategies that help to reduce the consumption of non-renewable energy especially in residential buildings that consume about 62% of the total electricity in Palestine (WB, 2016). To reduce the dependency of non-renewable energy; urban context and building design are considered very important parameters that need great attention (Quan et al., 2014). On the other hand, this study aims to contribute to the effectiveness and potential enhancement of the local buildings' codes and regulations for multi-story residential buildings in residential B-Zone especially in terms of building energy efficiency in order to reduce energy consumption while enhancing the quality of the indoor environment.

Urban context has an influence on the building indoor environment through allowing or preventing solar radiations from reaching the building envelope which mainly effect on the intensity of natural lighting and thermal performance, which will affect the total energy consumed in residential buildings (Alzoubi & Dwairi, 2015). Because of this, it is very important to take into account the relationship between buildings and their surrounding environment at the early design stage to reduce energy consumption and provide maximum natural lighting (Sanaieian et al., 2014; Yaşar et al., 2018). On the other hand, the importance of this research appears from the complete absence of studies in Palestine that have evaluated the setbacks and buildings height regulations and their impact on the indoor environment.

1.3. Research Questions and Objectives:

This thesis will study the impact of urban context on indoor environment performance. The main research question is; how does the urban context influence the indoor environment and building performance in residential apartments in selected residential zone (B)?

The indoor environment and the building performance are defined as the overall thermal performance and natural daylight. Thermal performance includes heating and cooling loads. Thus, the main research question can be developed into two sub questions:

1- How does the urban context affect the indoor environment and energy consumption?
2- What are the optimal distances for setbacks for residential zones in Palestine under existing urban context conditions?

As for the research objectives, **one of the main goals** is **to evaluate** the impact of the regulated setback distances on the indoor environment performance in terms of daylighting availability and energy consumption. Another one is **to enhance** the quality of the indoor environment in residential buildings to meet the occupants needs and to reduce thermal energy consumption required to reach comfort by proposed alternative solutions at urban and building levels.

1.4. Research Limits:

This research was valid in multi-story residential buildings which constructed after Palestinian National Authority Period (from 1994) in residential B-Zone (five story building, ground floor is used for local commercial functions, setbacks distances [5m, 4m, 3m from front, back and sides] in the central high-hills especially in Bethlehem city. Also, the research was valid when the target building was located on a 10m width street with specific urban context characteristics for surrounding buildings and urban context topography as mentioned in the next chapters.

1.5. Research Structure:

This thesis consists of seven main chapters. The first chapter introduces this study, defines the research problem, and lays out its objectives, methodology, importance of this study, and finally ends with the thesis structure. The second chapter includes a dense literature review that introduces the reader with all building regulations developed in Palestine in different periods starting from the Islamic civilization period (early times) in general, moving to the Ottoman era in detail since it is the transitional phase between the compact urban fabric in the old cities and current urban fabric. Followed by the British Mandate period. Then the Arab Era Period (Jordanian regulations in West Bank and Egyptian regulations in Gaza Strip), then the Israeli occupation period. Finally, the Palestinian National Authority regulations period. The literature review in chapter three also includes for Palestinian energy status, residential building sector.

The methodology chapter identifies the prototype of the residential building in the selected area depending on the online questionnaire, local cases in Palestine and interviews with occupants. Then a POE survey was conducted to identify the problem in the apartments in multi-story residential buildings in residential B-Zone. Chapter five includes an evaluation tool to study the impact of setbacks regulations on the indoor environment and energy consumption using simulation software.

Chapter six presents the optimization phase on current setbacks and buildings heights regulations based on the results that were obtained in the previous chapter. The optimization is implemented on urban and building scale and then assesses these suggestions by using the simulation program. Finally, Chapter seven discusses the optimization results, concludes the research results and recommends future studies to improve the quality of the building's regulations used in Palestine. The study ends by providing the key references used and some appendices that may be of use to the reader.

Chapter Two

2. Building Regulations in Palestine and the Evolution of the Setbacks Regulations

2.1. Preface:

Historical and archeological studies in Palestine have recorded that the first appearance of human settlement _in the form of housing and buildings_ was found in the eighth century BC in Jericho. Ancient communities constructed shelters using unstable structures to protect them from the outdoor environment such as; wind, rain, cold and excessive heat. Over time, communities have become more stable, requiring permanent communities to be developed to meet the changing conditions. As a result of the growing communities and urban contexts, laws had to be enforced to regulate, manage, control and improve the growing communities (Alsuwaidan, 2004). At the very early human life presence in Palestine, laws were very simple, and it evolved with the growth of civilizations that had been present in this land and was affected by living styles that had emerged. As a result, regulations emerged to regulate the building sector. Since the Greek and Roman civilizations and even the early Islamic State, regulations have evolved in Palestine, where special regulations in the field of construction have appeared and was influenced by the Islamic mentality, which was formed and embraced more during the late Ottoman period and took the character of the regulations as they are today (Tuffaha, 2009).

Building regulations are the main guidelines for the city's urban morphology. When looking at the urban morphology in the Palestinian cities, random urban and architectural scene arise from failure and lack of legislation regulating this community, in addition to the absence of an administrative and supervisory apparatus in the state that has governed the execution of such laws (Tuffaha, 2009). When analyzing the current situation of the Palestinian cities, it was realized that the key explanation for this situation is the political and administrative instability, resulting from the diverse and multiple states that were controlled Palestine, and has led to the multiplicity of laws and legislations applied in the construction sector. Following the fall of the Ottoman Empire, several countries occupied Palestine, creating laws and regulations that reflect their policies and regional political, administrative, and economic interests. Beginning with the British Mandate, then with the Arab era represented by the Hashemite Kingdom of Jordan administration in the West Bank, and Arab Republic of Egypt administration in the Gaza strip. In addition to the Zionist occupation that has established its alleged state over the cities of Palestine in 1948 officially. This continued until 1967, as the Zionist invasion broadened its influence. In the West Bank and Gaza before the Palestinian National Authority arrived in 1994, self-government evolved in parts of Palestine (Kahlot, 2016; Tuffaha, 2009).

To evaluate the regulations currently being used, and to know their effects on the indoor environment, it was important to review all the building regulations especially setbacks regulations applied in Palestine from the Islamic period till the existing regulations which was defined and enforced by the Palestinian National Authority (Tuffaha, 2009).

2.2. *Building Regulations in Islamic Civilization:*

The Islamic armies invaded the Palestinian Holy Land in the year 636 AD after the Battle of Yarmouk in northern Jordan. The Islamic rule was dominant in Palestine until the Ottoman Empire collapsed in 1917 AD and the British Mandate invaded Palestine (Tuffaha, 2009).

Architecture in Islamic cities has been affected by Islamic religion's teachings that focus on meeting the needs of individuals and society (Abu-Lughod, 1987; Qaradaghi, 2014). Islamic architecture has been affected by many changeable natural and cultural factors, resulting in architecture for every time and place (Qaradaghi, 2014; Tuffaha, 2009). At the same time, the Islamic civilization did not ignore the history and achievements of other civilizations that evolved before its evolution. It sought to transform all societies and cultures into a single framework in compliance with Islamic religious rules (AL-Qattan & Qasem, 2016). In other words, Islamic civilization has adapted the classical urban heritage as a response to cultural and social requirements (Correia & Taher, 2015). They retained the Roman towns, exploited the existing buildings and developed them based on the basis of Islamic laws to suit their way of thinking and their religion (Tuffaha, 2009). Figure 2.1 and Figure 2.2 shows Nablus old town master plan, the city quarters were connected by the Romantic streets network while seeking to adjusted privacy levels which is a very essential belief according to the Islam (Correia & Taher, 2015).

Figure 2.1: Roman street network in Nablus city (Correia & Taher, 2015).

Figure 2.2: Islamic city quarters connected to the existing Romanic street in Nablus city (Correia & Taher, 2015).

Among the most important of those laws which were enforced in all stages and circumstances of the Islamic State resulting from the Islamic mentality: The general legal rule of "There Should Be Neither Harming nor Reciprocating Harm". It is considered one of the most important general rules adopted and it was the basis of many laws that emerged from the Prophet's Sunnah and from the Prophet's hadith: "There should be neither harming nor reciprocation harm" narrated by Ibn Majah. It means that harming anyone with any actions is forbidden. A set of laws emerged from this general rule and became the basis for building laws and regulations in Islamic cities that focused on minimizing the damage done by or result from the construction process. These laws include:

2.2.1. *Buildings Height:*

Islam has regulated the height of buildings. It comes from not harming the neighbors, by means of not invading their privacy or preventing them from natural light and natural ventilation. As Muadh bin Jabal's hadith has said " Do you know the rights of the neighbor, you must not build to exclude the breeze from him, unless you have his permission " Narrated by Ibn Adi and al-Kharati (AL-Qadi, 2008; Hakim, 2013). The regulations did not define a specific height for buildings but instead linked it to the principle of preventing harm to citizens. If the extension harms others, by means of blocking fresh air and sunlight, then the governor[1], will prevent this extension (Tuffaha, 2009).

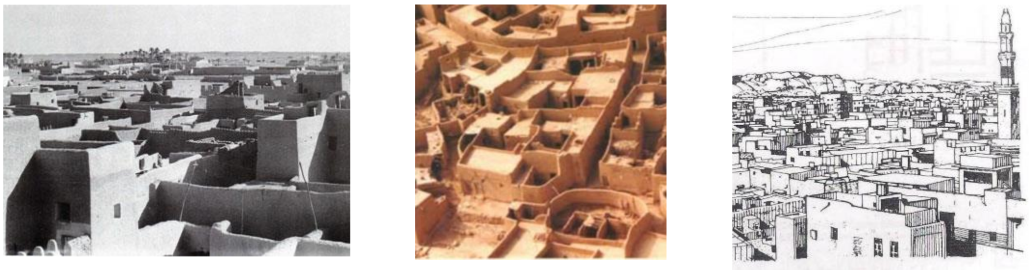


Figure 2.3: The height of buildings in Islamic cities, in Al Hijaz, Saudi Arabia respectively (AL-Qattan & Qasem, 2016; Ben-Hamouche, 2009; Yousef, 2017).

2.2.2. Privacy:

The concept of housing design in the Islamic city's revealed from the principle of providing users' needs, privacy, and comfort. Housing was the main element in the city which permitted the occupants to conduct their daily activities without revealing the privacy of neighbors or their privacy. The Islamic city planning and building design _particularly residential buildings_ were followed by many strategies to achieve the principle of privacy at urban and building scales. At urban scale, privacy was achieved mainly through the morphological pattern of cities which is the **compact organic complex** urban fabric (Ben-Hamouche, 2009; Tuffaha, 2009).

At the building scale, Islamic houses were oriented inward around the central courtyard to improve natural ventilation, natural lighting and thermal comfort due to the lack of external openings (AL-Qattan & Qasem, 2016; Malik & Mujahid, 2016). External windows were constructed higher than the level of the pedestrian sightline, especially at ground floors overlooking the narrow alleys as shown in Figure 2.4 (AL-Qadi, 2008; El-kady, 1998).

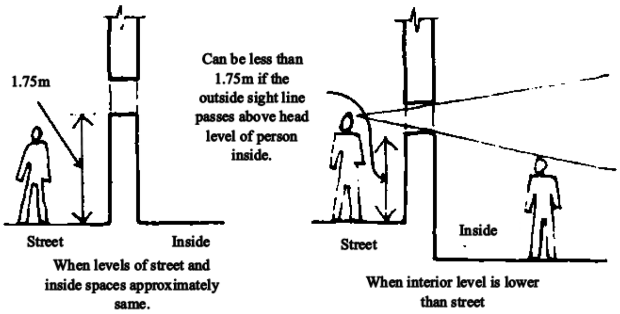


Figure 2.4: Window placement in the Islamic cities.

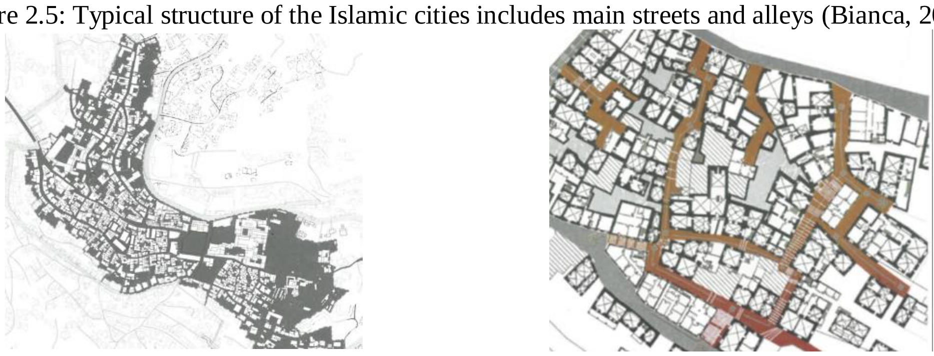
2.2.3. The Concept of Setbacks Distances in the Islamic Cities:

The term “setbacks distance” didn’t exist in the Islamic architecture, especially in the early stages. Traditional Islamic cities were characterized by the compact organic urban fabric (Ben-Hamouche, 2009). The buildings were closely grouped together in order to shade each other and shade nearby alleys. The compact urban fabric minimizes

[1] who is responsible for building permits and for solving problems arising between people.

the external surface area which is exposed to direct solar radiation, thus reducing heat gain through building elements and improving the quality of the indoor environment (Alshaibani, 1996). From this, it is obvious that in the early stages of Islamic civilization, the setbacks distances didn’t exist until the late Ottoman period due to the influence by the western codes and regulations. In the traditional Islamic architecture, the inner courtyard was considered the main element in buildings which provide thermal comfort, natural daylight and natural ventilation. There was no need for spaces between buildings to obtain natural daylight and ventilation because all building spaces were oriented around the courtyard. At that time, streets and alleys were considered a setback distance between buildings since it was the only separation distance between housing blocks, see Figure 2.5.

Figure 2.5: Typical structure of the Islamic cities includes main streets and alleys (Bianca, 2000).



Open Spaces (Alley, street, Courtyard, Housh). Buildings.

Figure 2.6: Old city in Bethlehem (separation distance between buildings) (CCHP, 2014).

The form and geometry of the streets and alleys network (only separation distance in the city) wasn't randomly found in the Islamic cities. Streets were carefully placed depending on their location and uses, as well as depending on the region's climate. There were two main types of streets. One is the public street that anyone can use. It connects the city center and gives access to the different quarters in the city. It is the largest road; it reaches about 60 to 80 cubits in width. Second is the private dead-end alleys which can be used by the owners of the surrounding residential buildings and give access to individual buildings or groups of buildings (Mohammed Itma, 2018). They are narrow, winding and about seven-cubit in their width. The buildings along those roads were no more than one to two floors high which help in providing shade in these alleys, depending on the ratio of building height to street width (Falahat, 2013; Othman, 2006). As for the climate conditions, the streets are winding in shape with closed vistas to act as a temperature regulator (Falahat, 2013). In hot regions, their orientation was perpendicular to the sun's movement from north to south to reduce the exposure of the streets and buildings to the direct solar radiation for long hours. This orientation results in street shading during the day. The streets and buildings orientation also help to receive the north and northwest common winds for long periods, shadows the streets throughout the day helping in lowering their temperature during daylight hours for the longest time possible. In cold areas, the streets were oriented east-west to get as much solar radiation as possible during the day and to block the north and northwest cold winds (Othman, 2006).

Generally, the only distance between buildings in Islamic architecture was the alleys and streets which were carefully studied in terms of their orientation and their width. They emerged as part of dominant laws and regulations which made them an essential and efficient element in achieving thermal comfort in the city as a whole and in buildings specifically.

After reviewing the basic regulations that appeared and were applied in all Islamic cities, the Ottoman Caliphate period will be thoroughly studied due to its substantial impact on the establishment of the regulations in Islamic countries, including Palestine. It's the transitional period between traditional Islamic cities and the beginning of modern architecture with its modern regulations and characteristics.

2.2.4. Building Regulations in the Ottoman Caliphate period 1517-1918, and Appeared of the Setbacks Distances:

The Ottoman Caliphate era started in 1300 AD and it took charge of the Islamic world in 1500 AD, and of Palestine in 1517 AD. Most ancient residential buildings whether in Palestine or in other Islamic countries that still exist today are dated to the Ottoman period, (Abu-Sirieah, 2016). The Ottoman Caliphate era was split into two main stages:

1. The First Stage (The Early Stage of Ottoman Period):

All Islamic cities in that time were structured very similar to the structure dominated during the early stages of the Islamic civilization, since the regulations were emanating from the Islamic law, which did not undergo extreme changes, but maintained its same previous pattern that was dominant from 1517 CE to 1840 CE (Abu-Sirieah, 2016). Some Islamic architectural elements and characteristics were preserved, such as the simplicity in the façade design, the lack of openings and their small size especially at ground floors, and the limited height of the buildings. In addition, extended floors remained below the height of the mosque, as well as residential buildings oriented inwards toward the courtyards without setbacks between buildings (Tuffaha, 2009). The residential buildings remained within the borders of the old cities and their compact urban fabric, consisting of residential neighborhoods and quarters that could be accessed from alleys branched from the main street (Abu-Sirieah, 2016).

2. The Second Stage (from 1840 CE to 1918 CE):

This stage has marked the weakness of the Ottoman Caliphate and the beginning of the Industrial Revolution and the political changes in Europe. The Ottoman Caliphate was affected by the revolution that was mainly affecting the architecture and construction sector, as well as by the modern Western regulations such as British and French regulations and by the abandonment of the Islamic laws in organizing community affairs (Tuffaha, 2009). The construction materials were later replaced by modern types of materials and construction techniques (Abu-Sirieah, 2016). As a result of these new materials and technologies, the city proposed new regulations to regulate the evolving urban environment. The Ottoman Empire in this period copied these regulations from European countries and applied them without taking into consideration whether or not they were appropriate for the local environment and needs of the Islamic cities or not (AL-Qadi, 2008; Tuffaha, 2009). This was the beginning of the transformation of architecture in Islamic cities into European renaissance styles (Tuffaha, 2009). For instance, the urban fabric has changed considerably because of the production of new building materials and building regulations.

Based on the previous information, it was made obvious that the great development of the building regulations between the beginnings of the Islamic civilization and the end of the Ottoman Empire has greatly influenced the design of residential buildings. For example, the buildings' height has increased, **the courtyard** which is the main element in the Islamic residence, disappeared and the houses were opened to the outside environment, and was **replaced by the separation distances (setback distances) between buildings** (Altaie, Al-Ansari, & Knutsson, 2012; Mansour, 2015; Tuffaha, 2009). Each city determined a setback distance that they think might be suitable for ventilation, solar radiation and natural daylight. This stage was a step toward opening the residential buildings to the outside environment by proposing openings (windows) on the external walls. The buildings moved away from the old city boundary to the periphery and then into new neighborhoods. This period was the transitional phase that led to the emergence of a new urban context that was totally different from the compact organic fabric, which necessitated the existence of regulations governing this modern urban context pattern (Abu-Sirieah, 2016).

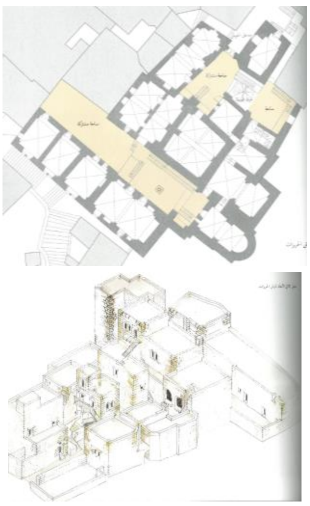


Figure 2.7: Housh building in the first stage of Ottoman era in Bethlehem (CCHP, 2014).

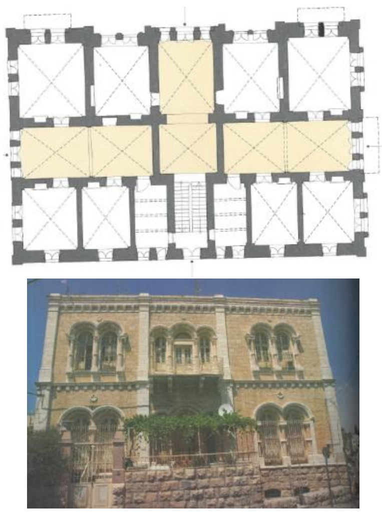


Figure 2.8: The second stage buildings of Ottoman era in Bethlehem (CCHP, 2014).

2.1. Regulations During the British Mandate Period 1917-1948:

After the defeat of the Ottomans in the World War I and the collapse of the Islamic Caliphate, the Arab countries were split, as stated in the 1916 AD Treaty of Sykes-Picot, between the ally countries, Britain and France. Then the modern colonial era began. Palestine was of course no different from the rest of the Arab countries. According to the Sykes-Picot Treaty, it subsequently came under the British military administration from 1917 to 1921, in order to prepare Palestine to become a national home for the Israeli occupation. So as to fulfill the Balfour Declaration officially announced on 2 November 1917 AD, to serve the colonial interests of Britain in the Middle East, and especially in the Arab region (Al-Natsha et al., 1991; Jarbawi & Abdulhadi, 1990; Tuffaha, 2009).

At that time, the regulations were formulated to accommodate the British government 's interests in creating a national home for Israeli occupation. The Ottoman regulations were used in the early stage of the British Mandate (Tuffaha, 2009). In this period, town planning schemes and planning regulations for a number of towns and villages were issued. Also, regional land-use plans for almost all cities were drawn up (Abdulhadi, 1994). The British mandate regional land-use plans classified the land areas into three major zones: development zone; agricultural zone; natural reserve zone. Each zone has its own specific regulations. These regulations determined the type and the function of construction and land use allowed in each zone, the built-up densities, the required set-back distances from existing or proposed roads and size and form of building (Abdulhadi, 1994; Altaie et al., 2012).

The most important regulation implemented in the field of construction and organization, during the British mandate period is the **Cities Planning Act No. (28) in 1936 AD.** This law is considered one of Palestine's most significant regulations for urban planning, which was enacted by the High Commissioner Wakob on 4 May 1936 A.D. It was applied during the British mandate period in the West Bank and Gaza Strip and it's still in use in the Gaza Strip until now. This law includes 42 articles which organize the construction in the Palestinian cities (Kahlot, 2016; Wakob, 1936).

In particular, Cities Planning Act No. 28 included a set of articles that were responsible for issuing the internal regulations and codes. Building committees, construction and city organizations were formed. The main task of these committees was to issue internal regulations and codes in the cities located in their districts, and none of them will be implemented without the High Commissioner 's approval, so as to be published in the Palestinian Official Gazette. Article 12 of the same Act has mentioned that each district committee may appoint the regulations and codes for the urban master planning of all lands located within its district. These regulations and codes include the construction of new streets and highways, paving the current streets and transportation lines, in addition to the appointing construction lines **and setbacks distances, determining land uses**, such as residential or industrial zones, and the allocation of property for airports etc. Likewise, this article authorizes the committees to impose conditions and restrictions regarding the separation distances around buildings, the height and type of buildings that are permitted to be erected in the different zones (Wakob, 1936).

In this period, the typical house with a courtyard disappeared and was replaced by multi-story buildings oriented to the outside environment. The western style of the building was introduced, through the facade design, and from the use of modern construction materials and technologies. These materials were not used before such as cement, iron, which have affected the homogeneity of the traditional Palestinian cities (Altaie et al., 2012; Tuffaha, 2009)

2.2. The period of the Arab Era 1948-1967:

Following the withdrawal of British forces from Palestine on 14 march 1948 AD, the Israeli occupation controlled about 80% of the historical land of Palestine and forced people to move from the areas they occupied to the unoccupied area of Palestine and to neighboring countries (Abdulhadi, 1994; Jarbawi & Abdulhadi, 1990). As for the unoccupied areas of Palestine, the West Bank was under the Jordanian rule and the Gaza Strip was under the Egyptian administration (AL-Wahedey, 2012; Tuffaha, 2009).

New outline plans for the west bank area were generated between 1948 and 1967. They were very similar to mandate plans which were prepared to propose zoning for new areas to be developed. These plans were to regulate roads and setback distances from roads despite building types. At the same time, there was no consideration to applying different regulations for different building zones such as public vs. industrial vs. residential (Abdulhadi, 1994).

The British Cities Planning Law No. (28) in 1936 AD was canceled in 1955 in the West Bank when the Jordanian Cities, Villages and Buildings Planning Law No. 31 in 1955 was promulgated. At the same time, Cities Planning Act No. (28) in 1936 AD was still in use in the Gaza Strip and is still dominant until now (AL-Wahedey, 2012; Halabi, 1997; Tuffaha, 2009).

The most important laws that were issued during the period of Jordanian era in the West Bank are the Cities, Villages and Buildings Planning Act No. 31 in 1955 and Cities, Villages and Buildings Planning Act No. 79 in 1966. The 1955 law includes articles related to the planning of cities, villages, and buildings in general, and its provisions are clearly influenced by the British Act in 1936. This law imposed a **construction line (setbacks)** that may cannot be overridden. No one can build outside such construction boundaries (setbacks line). It was the committee's responsibility to determine the minimum distance that must be left between buildings and between lands boundaries. No one must change or correct the construction lines and setbacks distances based on the decision of the competent committee (Government, 1955; Halabi, 1997).

As for Cities, Villages and Buildings Planning Law No. 79 in 1966 which was abolished in the 1955 law and is still in use until today in the West Bank, with some amendments introduced by the Israeli military in 1967 (Halabi, 1997). This law defined the concept of setback as the distance separating the building boundaries from the land boundaries. Also, this law has given authority to Cities and Villages Planning Department to determine the required distance in the regional and master plans, as well as to impose conditions and restrictions on the height and type of buildings that are allowed to be built in different zones. On the other hand, the planning committees must remove any violations related to the setbacks distance, heights of buildings and the floors number (Government, 1966; Halabi, 1997).

The Jordanian government worked on establishing master plans for Palestinian cities until 1967 in accordance with the provisions of the Jordanian and British regulations, as there were many British regulations and instructions still used after the issuance of the Jordanian law in 1955. These master plans were traditional and did not take into account demographic, social and future developments of the Palestinian population, as these plans did not allow cities to expand their borders to ensure the existence of areas for future expansions (Jarbawi & Abdulhadi, 1990). At this period, buildings shifted rapidly outside the old cities boundaries in horizontal and vertical expansion as a result of the overcrowding in the city centers. This expansion was without relying on urban master plans, which in turns caused randomness. These new neighborhoods outside the old cities' boundaries were characterized by the fact that they include buildings inspired by some western values. Whether by high-rise multi-story buildings, widening openings in façades, construction method and increasing of building height (Tuffaha, 2009).

2.3. The period of Totally Israeli Occupation (1967-1994):

In the 1967, the Zionist occupation authorities have taken over officially what has remained of the historical land of Palestine. Severe restrictions were imposed on the use of lands that remained under Palestinian control (Abdulhadi, 1994; AL-Wahedey, 2012; Jarbawi & Abdulhadi, 1990). Planning policies and regulations followed since 1967 have prevented Palestinian citizens from developing the construction sector to meet housing and physical needs such as population growth, economic and social sectors requirements (Abdulhadi, 1994). The Zionist occupation modified the building and planning regulations used in the West Bank such as Act No. 79 of 1966, which made it lose its substance. Their goal was to help the policy of settlement in controlling the occupied areas. In this way, the Israeli occupation authority was able to restrict Palestinian urban growth in the occupied West Bank on the one hand, and to create appropriate conditions to accelerate the process of Judaization and settlement on the other hand (Jarbawi & Abdulhadi, 1990; Tuffaha, 2009).

As a result of the unjust laws imposed by the Israeli occupation on the Palestinian cities, Palestinian cities were and became overcrowded, tall buildings spread out very close to each other. Apartments within the multi-story apartment building emerged, which could have one or more than one apartment per floor "commercial housing". The apartments have shared the same facilities such as: stairs and parking spaces. The areas of the apartments varied depending on the floor area. These buildings may have commercial spaces at ground floor (Tuffaha, 2009).

2.4. The Palestinian National Authority Period (1994-Present):

From 1994-1995 a new period arose in Palestine, the period of self-government that came after agreements signed between the Palestinian Liberation Organization and the Israeli occupation, and thus the Palestinian National Authority became responsible for security and civil affairs. Because of that, the Palestinian Authority decided to coordinate administration and civil affairs in the Authority's territories according to the laws and regulations they have, beginning with Ottoman law and finishing with Israeli military laws. The Ministry of Local Government took responsibility for the growth and improvement of the civilian conditions of the population and it depended on laws to achieve its duties and responsibilities such as Cities, Villages and Buildings Planning Act No. 79 in 1966 for West Bank and No. 28 in 1936 for Gaza Strip.

Hence, it is important to distinguish between two terms, law or regulation and code. The law is what the legislature approves. The code is an explanation or detail of the law and does not contradict it. It was approved by the Supreme Planning Council within its specified mechanisms. The current Palestinian law is the Provisional Law in 1966 AD No. 79, but the code introduced in Palestine was the Buildings and Organizing Code for Local Authorities No. 5 in 2011 AD (BOC) approved by the Supreme Planning Council and is constantly evolving (Tuffaha, 2009).

In this period, multi-story residential buildings with separation distances between others widely appeared as a result to the Oslo peace agreement which divided the West Bank into three parts and gave the Palestinian Authority the right to control about 40% of the land. Land lots become very limited and expensive, causing high dense residential zones with high rise vertical buildings (M Itma, 2014). This type of residential building evolved mainly in the Palestinian main cities such as Ramallah, Nablus and Hebron (Mohammed Itma, 2018).

2.4.1. The Setbacks Regulations and Residential Zones Classifications:

The term of setback means the separating distance between the building and the plot boundary on which the building is built, or the road line adjacent to the land (Government, 1966). According to the city's master plan and the Buildings and Organizing Code for Local Authorities No. 5 in 2011 AD (BOC), the residential region was divided into different zones and classifications. Each residential zone has its own rules for setbacks, for building heights, as well as for the maximum acceptable built area percentage as shown in the Table 2.1. The existing setback regulation didn't take into consideration neither the height of the building nor the number of floors and its relation with the separation distances. As a result, apartment buildings were very close to each other. These spaces were turned from a small setback area between buildings to a place where waste was collected. In addition to their effect on natural ventilation and lighting in buildings, in addition to privacy (Tuffaha, 2009).

According to the Building regulations and codes in Palestine, residential regions are divided into seven basic zones, in addition to other classifications included in the city's master plan which the local councils will determine their requirements and regulations. (Abu-ALhija, 2019; MOLG, 2011). Current setback regulations do not take such values into consideration. The principle of privacy introduced by Islamic regulations disappeared. This imposes the need for some improper behavior such as using shutters and blinds which was a normal response from the community to protect their privacy. Current regulations and the current governmental policy of housing in Palestine is not based on any scientific studies that took local conditions and occupant's needs into account while generating (Al-Sa'ed, 2006; Tuffaha, 2009).

Table 2.1: Residential zones characteristics according to the Buildings and Organizing Code.

Residential Zone	Building Height (Floors)	Building Height (m)	Setbacks Distances			Maximum Floor Area Percentage %
			Front Setback (m)	Side Setback (m)	Back Setback (m)	
Residential A	5	18	5	4	5	180%
Residential B	5	18	5	3	4	210%
Residential C	5	18	4	3	4	240%
Residential D	5	15	3	3	3	260%
High Residential Buildings	9	30	12	8	8	324%
Villas	3	12	5	5	5	90%
High Residential A	7	25	5	6	6	280%

2.4.2. Current Building Regulations Problems:

After the Ottoman era, various administrations ruled Palestine during the past decades. After the British Mandate, the Jordanian government ruled the West Bank, and Gaza was ruled by the Egyptian government, then in 1948 the state of the Zionist entity was formed over the rest of Palestine. Also, it occupied the West Bank and Gaza in 1967. As a result, this led to the distortion of the legal framework that the successive and contradictory administrations established in their institutional and political orientations, they introduced regulations without regard for the needs and conditions of the Palestinian community (Kahlot, 2016).

One problem associated with the building regulations and codes that are currently being used in Palestine is that they are copied regulations that have been copied and applied to our buildings from different countries that have completely different cultures and are regulated in completely different environments, these regulations were not reviewed or examined. These regulations should also take into account the exceptional political situation in Palestine and be supportive of the resilience of the Palestinian citizens.

Regulations and codes should meet society's needs, it should be part of the community culture and requirements. All regulations that are currently used in Palestine are copied from the British regulations and codes without taking the Islamic regulations and limitations that existed at that time into account. This has produced buildings that are different and don’t comply with any traditional patterns (Tuffaha, 2009). For instance, the cold European atmosphere which affected their needs and access to the sun in their building designs is never sufficient to our countries. These copied regulations largely correspond to the Western environment conditions, which are built upon separation, solitude, and less active social life, which is never consistent with the Islamic way of life. These regulations, in particular the setbacks distances, allow the building to be clustered, primarily in the middle of the land and also separating the rest of the land into strips and longitudinal corridors scattered around the building, and much of the time they stay as empty and as dead spaces that don't have enough sun or ventilation, and they are hard to use in any efficient manner. In addition to, and according to my interview with Mrs. Arwa Abu-Alhija head of Local Government Directorate- Bethlehem who mentioned that the majority of residential buildings in different residential zones at Bethlehem are not compliant with the building regulations and codes, whether in the number of floors, building heights or setbacks distance (Abu-ALhija, 2019; Al Tawayha, 2011; Tuffaha, 2009).

Although the Islamic cities are more suitable to occupant's needs and environmental requirements, it is improper to convert the existing urban context to old patterns that were in the traditional Islamic cities. The idea is to enact regulations that are appropriate to the local environmental characteristics and to meet the citizen's needs similar to regulations in Islamic cities. For example, currently, society needs green and open space around buildings as opposed to the Islamic organic cities, but they have to be thoughtful in order to contribute to the improvement of the indoor environment of buildings as well as the outdoor environment of Palestinian cities.

2.4.3. Addition Building Guidelines Which Also Implemented in Palestine:

In addition to the building regulations and codes used mainly in Palestine, institutions concerned with green building and energy efficiency appeared later, which issued guidelines to apply these concepts in projects that support these ideas such as:

1- Green Buildings Guidelines-State of Palestine:

The Palestinian Green Buildings Guidelines (PGBG) was developed by the Palestine Higher Green Building Council (PHGBC) which is a nongovernmental organization with no legislative authority. In cooperation between the Palestinian Engineers Association and UNDP, this code has emerged to introduce and encourage green buildings in Palestine in order to save the environment and the natural resources from the hazardous construction practices and to lessen the construction overall cost as well as buildings operational cost. It addresses different categories such as: management and implementation strategies, site sustainability, indoor environment quality, resources efficiency and materials, in addition to the innovative techniques integrated within building design (Alsamamra & Said, 2019; PHGBC, 2013).

The guidebook also includes a pointing system to evaluate the candidate buildings as green buildings based on their collection points out of 200 points in in six parts; site sustainability 30 point, energy efficiency 60 point, water use efficiency 50 point, indoor environmental quality 30 point, materials and resources 20 point and innovation and building integrated design 10 points. According to the collection points in these parts, there are four categories of the green buildings classifications, as follows (PHGBC, 2013):

1) Diamond class for buildings that get 160 points and more.
2) Golden class, which is between 140 and 159 points.
3) Silver class is a building that scores between 120 and 139 points.
4) Bronze class for buildings with between 100 and 119 points.

As for indoor environment quality, this guidebook provides general necessary guidance about indoor air quality (IAQ), smoking control, ventilation quality, indoor material emissions, air quality management in the car parking, thermal comfort, artificial lighting frequency, natural daylight and glare, view, sound comfort and safe environment (PHGBC, 2013). These guidelines do not provide solutions and alternatives to solve problems related to the quality of the indoor environment in terms of daylighting and energy consumption for example, whether at building design level or on the surrounding urban context level.

2- Guidelines for Energy Efficient Building Design:

The Ministry of Local Government issued these instructions to deal with the sustainable architecture legislation, which aims mainly to reduce waste of energy by minimizing load consumption, and to develop the Palestinian building systems that considers thermal designs and design with climate considerations so as to ensure thermal satisfaction. The guidebook presents methods for climatic data analysis and provides general information about climatic status for Palestine, common building materials and their characteristics. In addition, it provides general information about different strategies which can enhance the thermal performance inside buildings such as windows design, window size, orientations and shading devices. In addition to building orientation without providing detailed instructions and solutions in respect to the current energy status in Palestine (Alsamamra & Said, 2019; MOLG, 2004).

2.5. Summery:

To summarize, Palestine, like other third world countries, suffered from the disadvantages of indiscriminate construction and non-compliance with building regulations, as the required setbacks and building heights are not adhered to as stipulated in the regulations and codes, in addition to the shortcomings of these regulations because they are reproduced from the countries that differ completely from the nature of the local environment, which makes them unsuitable for use in Palestine as the Islamic regulations were.

Through the successive and diverse periods of the various states and governments that occupied Palestine, each of them has set its own building laws and regulations that neglect the specific conditions of the Palestinian society, its culture, its needs, and requirements, and have worked on destroying all the characteristics of the architectural and urban context that existed from different periods especially from the Islamic State. These regulations intend to serve Mandate interests and the Zionist occupation

Chapter Three

3. Energy Status and Residential Sector in Palestine

3.1. Preface:

This chapter covers the energy situation in Palestine in order to understand its impact on the indoor environment and on the energy consumption needed for heating, cooling and lighting. This was highlighted because the energy demand in Palestine is highly and constantly increasing. The use of heating, cooling and lighting equipment to enhance the performance of the indoor environment and to provide healthy living spaces specifically at residential buildings accounts for a large portion of the household energy consumption in the country. Since living standards have increased globally, space cooling demand has increased by 33% from 2010 to 2018. Similarly, space heating demand consumes about one-third of total global energy demand in buildings (IEA, 2019). In terms of lighting, natural daylight is a key factor in residential spaces for achieving a healthy and comfortable environment for occupants (Mostafa, 2016). It will also discuss the residential building sector in Palestine, common construction materials which are very important in affecting energy consumption and in developing the common residential building design prototypes dominant in the study area.

3.2. Energy Consumption in Palestine:

According to the international energy agency, global energy demand is expected to increase by 40% between the year 2009 and 2030 which equals to 1.3% growth per year (Khatib, 2012). In Palestine in general and in residential buildings in particular, energy demand has been increasing significantly over the last years due to the rapidly growing population (+2.9% per annum) (Lazzeroni et al., 2017). In detail, Palestine is the third fastest-growing population when compared to the other countries in the region over 2000-2012 (Njore, 2016). Energy consumption has increased as a result of the rising living conditions due to the installation of new technologies and equipment that is considered a largest consumer of energy in residential buildings such as HAVC systems. Also, increase in comfort level and comfort expectations in winter and summer in the indoor environment , increased the energy consumption in HVAC systems (Monna et al., 2021; Pérez-Lombard, Ortiz, & Pout, 2008).

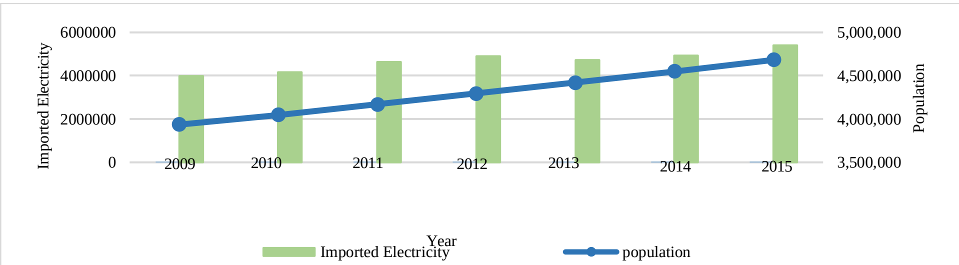


Figure 3.1: Imported Electricity in Palestine and population between 2009-2015 (Jebril & Khatib, 2018).

The energy sector in Palestine is confronted with two significant challenges: the dependency on other countries to provide the country's energy requirements due to the limited domestic resources and the Palestinian citizen pays the highest energy price for the lowest consumption rate compared to the surrounding countries (Alsamamra &

Said, 2019; Juaidi et al., 2016). In fact, Palestine is relying heavily on neighboring countries to meet its energy needs due to scarce natural resources. For example, Palestine imports 100% of its fossil fuel needs from Israel annually (Jebril & Khatib, 2018). Besides, electricity is mainly imported from Israel (Zionist occupation) about 87%, 3% from Egypt, 1% from Jordan, and only 9% from Palestinian electricity companies (Katz & Shafran, 2019; Njore, 2016). The primary energy sources for Palestine illustrated in Figure 3.2 (Alsamamra & Said, 2019; Juaidi et al., 2016; Njore, 2016).

3.2.1. Energy Consumption in Residential Sector:

The residential and commercial sectors are the largest energy consumers by about 58.2% of the total energy followed by transportation sector by 36.5%, the industrial sector consumed 5.5% of the national energy demands. The shares of energy consumption by major sectors are shown in Figure 3.3. With 34%, electricity is the largest portion of the Palestinian energy sources. Furthermore, the household sector is the highest consumer, about 62% of the whole yearly electricity demand in Palestine (Lazzeroni et al., 2017; Njore, 2016).

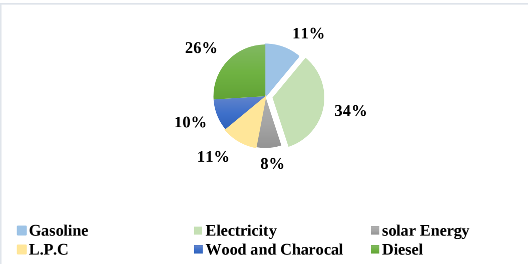


Figure 3.2: Energy sources in Palestine (Njore, 2016).

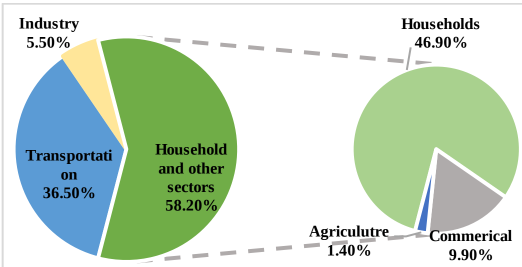


Figure 3.3: Palestine's national energy consumption by sector (Juaidi et al., 2016).

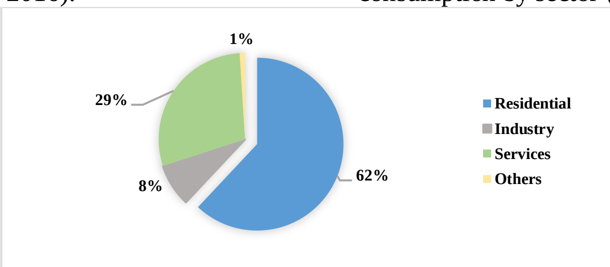


Figure 3.4: Electricity consumption by sectors.

Electricity bills for residential buildings in Palestine reflects household total consumption which is the total consumption of all usages and appliances. According to the Household Energy Survey which was conducted by the Palestinian Central Bureau of Statistics in January 2015 to study the energy consumption behavior, type of energy and devices used by households, the main usage of electricity in residential buildings are air-condition, electric room heater, fridge, lighting and water heating. The main results of the survey indicated that about 52% and 74% of the households in the Middle of the West Bank use electricity for room heating and for water heating respectively. The main findings show that the Middle towns of the West Bank record the highest electricity consumption in January than other regions by 442 kWh, followed by 294kWh in the South of West Bank (see Table 3.1) (PCBS, 2015).

As for air conditioning and lighting, all appliances which were used mainly depend on electricity. A households' energy survey was done by the Palestinian Central

Bureau of Statistics in June 2013 which has indicated that 86.8% of the Palestinian households use cooling appliance that mainly depend on electricity to operate air conditioning split units' and fans (Monna, Juaidi, Abdallah, & Itma, 2020). In which about 18.7%, 45.3% and 80.6% used air conditioning, fixed fan and mobile fan in cooling process respectively (PCBS, 2013). In 2015, the average household electricity consumption was 306 kWh. In 2030, this value is predicted to rise to 545 kWh monthly (Monna et al., 2021; Monna et al., 2020; PCBS, 2015).

Table 3.1:Households behavior in using electricity (PCBS, 2015).

Percentage of Households who are using electricity by Region in Winter, 2015						
Region	**Water Heating (%)**		**Heating (%)**	**Average Household Consumption (kWh)**		
North of West Bank	59.80%		38.30%	272 kWh		
Middle of West Bank	74.20%		52.00%	442 kWh		
South of West Bank	38.30%		30.20%	294 kWh		
West Bank	57.00%		39.80%	328 kWh		
Percentage of Households who are using different types of appliances in cooling in summer, 2013						
Region	**Electricity in cooling**			**Average Household Consumption (kWh)**		
	AC	**Fixed Fan**	**Mobile Fan**	**2010**	**2013**	**Expected 2015**
North of West Bank	27.0%	42.60%	83.90%	252 kWh	259 kWh	267 kWh
Middle of West Bank	24.0%	32.00%	82.30%	294 kWh	305 kWh	318 kWh
South of West Bank	14.8%	16.70%	91.20%	260 kWh	246 kWh	256 kWh
West Bank	22.8%	32.30%	85.30%	250 kWh	260 kWh	273 kWh

According to the electricity company data base, the lowest electricity consumption is obtained in spring and autumn _when room heating and air conditioning appliances are not used. In winter, because of the use of room heaters and water heating appliances the consumption raises to 79GWh. In summer, the consumption reaches 72GWh because of electrical AC appliances. Other usages such as room heaters are mainly dependent on electricity and other alternative sources. Figure 3.5 illustrates that HVAC systems, water heating, electric room heaters, fridge and lighting are the most electricity consuming appliances (Monna et al., 2021; Njore, 2016).

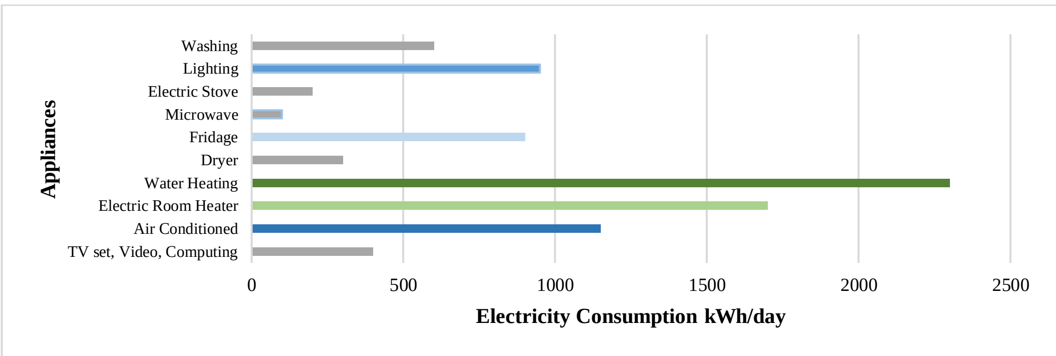


Figure 3.5: Electricity consumption for one standard household (kWh/day) (Njore, 2016).

3.3. Residential Buildings Sector in Palestine:

Since residential buildings are the first consumers of electricity and energy, efforts should be concentrated to make them more energy-efficient, particularly in heating, cooling and lighting sectors. This research intends to evaluate the performance of the indoor environment for typical residential buildings. For this assessment process, the most commonly utilized residential building prototype must be selected. In order to achieve this, this research focuses into the residential building sector in Palestine in a detailed review to form and create a clear image of the current design of residential apartments.

The need for multi-story housing units is increasing in Palestine as a result of the increased population density in comparison to land availability. High population density with low square- meter area per capita. The limitation and high prices of the land lots and the increased demand for housing units is greatly influencing the dominant residential buildings typologies in the different urban context of the Palestinian cities. This demand is due to the Israeli policies that prohibit the Palestinian housing expansion in the areas defined as areas "C" according to the Oslo agreement (Al-Sa'ed, 2006). Besides which, the current residential settlements have different types of housing typologies such as detached houses, attached houses, and the housing units in the compact urban fabric (M Itma, 2014). These housing typologies are highly affected by the surrounding environment. Detached typologies are mostly found in the Palestinian villages and the suburbs areas. Inside cities, multi- family residential apartments typology is widely found, which was produced to solve the problem of land lots affordability and to decrease the costs of dwellings and infrastructure that are mainly found in cities rather than villages. As for the last type, its presence was limited within the boundaries of the old cities walls as compact urban context units (Abdulhadi, 1994; M Itma, 2014).

As mentioned in the chapter 2, the transformation that has occurred in the Palestinian urban context from the compact fabric structure into dispersed settlements suddenly appeared at the beginning of the twentieth century in the second stage of the Ottoman era. Detached houses had started to appear instead of courtyard houses which were built outside the boundaries of the traditional old cities. In the second half of this century, multi-story residential buildings _consisting of two or more stories_ that are mostly constructed from concrete and external stone facades has appeared in the Palestinian cities (Abdulhadi, 1994; Al-Sa'ed, 2006; M Itma, 2014).

After reviewing the statistical data available on housing and establishment reports, it became clear that there is a shift toward the construction of multi-story buildings in the residential buildings sector to improve the efficiency of land use (Al-Sa'ed, 2006). The 2017 census results have shown that about 62.3% of the occupied housing units in Palestine were apartments. This percentage was concentrated in the main governorate in the central high hills zone which includes Jerusalem, Ramallah, Nablus, Bethlehem and Hebron, where this study is mainly concentrated except Nablus. Residential apartments in Palestine constitute approximately 62.30%, 68.50%, 56.40% and 46.40% of the total occupied housing units in Ramallah, Jerusalem, Bethlehem and Hebron respectively, and in total about 33.64% and 61% from the total number of apartment buildings in Palestine and West Bank respectively in 2017 (PCBS, 2018). Most of these buildings are designed in regular shape of square or rectangular. Each floor consists of one or four apartments in most cases of multi-story buildings, and one or more vertical circulation units (staircase) in addition to the elevator. The floors are usually distributed as parking in the basement or ground floors, and residential apartments on the upper floors. (Monna et al., 2020).

From the above, we conclude that multi-story residential buildings that have more than three stories are commonly found in the residential zones of the Palestinian cities and have increased starting from the second half of the last century. The building's layout and areas are highly affected by and follow the boundaries of the dominant setbacks distances which is highly affected by the classification of the different residential zones defined in a master plan to get a maximum build up area. Therefore, central high hills _which is the largest zone containing a very high percentage of apartment buildings in Palestine_ was selected as a location for residential building prototype formation in the next chapter in order to conduct the study on it. At the same time, the central high hills cities share one climate zone which is zone 4. This zone is characterized by hot summers and cold winters and heating dominancy (MOLG, 2004; Monna et al., 2021).

Figure 3.6: Residential zones in Ramallah, Bethlehem, Hebron and Nablus respectively.

3.4. Construction Materials:

Over the years, construction materials have changed from vernacular architecture that used thick stone as a structural material in forming the external walls with backup fill of rubble stones and traditional binders such as lime, mud and gypsum which have had great interaction with the surrounding environment (Alsamamra & Said, 2019; Hadid, 2002). At the beginning of the twentieth century, many changes occurred in the construction sector in Palestine. Those changes were mainly in building construction materials, which has in turn affected the construction methods and techniques. Such as reducing the thicknesses of walls and ceilings, which increases the heat gain and loss in summer and winter (Alsamamra & Said, 2019).

When analyzing contemporary architecture in Palestine, thin concrete walls with external thin cladding stone and low thermal insulation replaced the old stone structural elements (Haddad, 2010). The contemporary construction sector in Palestine depends on local and imported raw materials. Some of these new construction materials were produced locally and widely used in the West Bank mountains such as stone, because of the availability of limestone and sandstone in abundance in Palestine. Most construction equipment and other building materials like cement, steel, aluminum and glass are imported from other countries (Abdulhadi, 1994; Al-Sa'ed, 2006; Hasan, 1999). The main construction materials that are used in contemporary architecture in Palestine especially in residential buildings (Haddad, 2010) are:

- Backup Concrete: is mainly used for structural purposes in columns, slabs, foundations and bearing walls. Also, it is used in hollow blocks which are mainly used as cladding material to the inner side of the external walls and in the internal partitions.
- Stone: it is a common cladding material in all buildings in Palestine.
- Iron Bars: it is also used as a main component within the structural elements such as bearing walls, slabs, columns and foundations. Table 3.2 lists typical wall components for buildings in Palestine and their thermal characteristics.

Table 3.2: Thermal characteristic for building materials (MOLG, 2004).

Building materials	Thermal Conductivity (W/m. ºC)	Density (kg/m3)
Stone	1.70	2250
Concrete	1.75	2300
Cement Block	0.90	1400
Cement Plaster	1.20	2000

It is important for the purpose of this study to determine the common building materials that are used in forming the common building envelope. A set of studies, in addition to results from the Palestinian Central Bureau of statistics, as well as results obtained from the online questionnaire that was directed to engineering offices, were all used to determine the type of envelopes used. The Hasan study presents the most common wall components that are widely used in the urban areas in the West Bank. It consists of 7 cm lime or sand stone followed by 20 cm backup concrete and 3 cm of internal plaster in urban areas. Now, new construction materials used in the construction sector in Palestine like different types of insulation materials.

According to the Salameh master thesis, the main building elements and their characteristics in the West Bank as following (Note: In this part we present the elements that are only used in the simulation process)(Salameh, 2012):

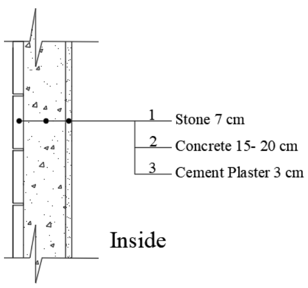


Figure 3.7: Contemporary external wall- type 1.

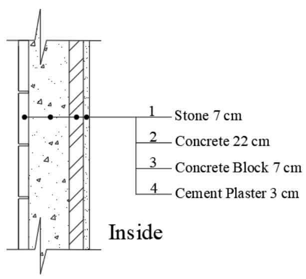


Figure 3.8: Contemporary structural wall- type 2.

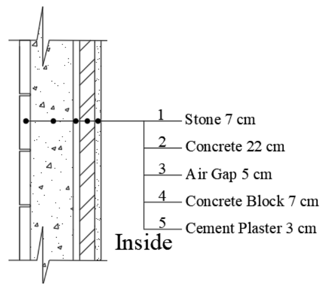


Figure 3.9: Contemporary external wall- type 3 .

3.5. Summery:

As shown in this chapter, about 90% of annual energy consumption in Palestine is imported mainly from Israel and from the surrounding countries. This means that there is a need to reduce energy consumption in almost all sectors, especially the residential sector which consumes about 62% of the total electricity consumption. For Palestine, energy conservation in the residential buildings is considered essential, and building energy efficiency strategies might be one of the most important opportunities to reduce the energy dependency on other countries. This is because the residential buildings sector in Palestine is the largest energy consumer than other sectors since it accounts for 46.90% of the country’s total energy consumption. In particular, lighting and thermal systems are the two largest energy consumers in residential buildings. Therefore, reduction of heating, cooling energy is expected in order to reduce the overall energy consumption of residential buildings. Also, access to sunlight improves building energy performance; effective daylight reduces artificial lighting energy consumption. As well as, sunlight in winter improves solar gain which reduce the amount of heating energy inside spaces. Good building design aims to take advantage of indirect lighting and avoid overheating during the summer period (IEA, 2019). For these reasons, this study focused on these energy consumers who were targeted in energy reduction in the assessment and optimization phases.

Chapter Four

4. Research Methodology

4.1. Preface:

As response to the research questions and objectives, the methodology of the thesis was formed and was divided into four consecutive phases. The **first** phase concentrated on collecting data which is important in the research. Starting by studying the development of all building regulations in Palestine (existing and historical regulation from the Islamic period). Then, reviewing the energy status in Palestine especially in the residential sector and collecting data about residential sector characteristics and the common construction materials in order to be used in identifying the most common prototype of residential buildings in Palestine. Finally, review related available studies that concentrated on enhancing the indoor environment through optimization strategies whether on urban or building scale.

The **second** phase focused on collecting specific data to be used in the formation of residential buildings prototype in Palestine. In this phase, a thorough study was conducted to create a representative model for residential apartments in Palestine especially in residential B-zone to be used in the assessment and optimization phases. In other words, the residential building prototype for this investigation was carefully chosen to reflect the common design of multi-story residential apartments in Palestine. To build the prototype, a systematic approach was created to identify the residential prototype inputs data. These input data were collected from different data sources. In this phase, four steps were conducted to develop the prototype. The first step mainly depended on reviewing the prior literature on common residential buildings typology in Palestine, analyzing construction materials and techniques that were widely used in these buildings. This step also depends on survey reports completed by the Palestinian Central Bureau of Statistics housing and establishments. The second step depends on the analytical study of residential apartments that have been designed and implemented in different West Bank cities, especially on the study context in central high hills.

The third step used in the prototype formation is a quantitative method based on an online survey, which was directed via email to engineering offices in the study area _central high hills_ main cities. It included questions that support the formation of this prototype, such as the common number of apartments on each floor in the vast majority cases, main residential spaces, their dimensions, orientations, also the number of windows inside these spaces, dimensions and their height from the floors, etc. This information played a significant role in the formation of the prototype to achieve the main goal of this research, which is to assess the current status of setback regulations in residential areas and their impact on the quality of the indoor environment in multi-family residential buildings in Palestine. With regard to the third step, the last step was based on open-ended and closed-ended interview questions with residents in residential apartments in residential B-zone in Ad-Doha city as a part of on-site POE questionnaire to confirm the results obtained from the previous steps (see Figure 4.1).

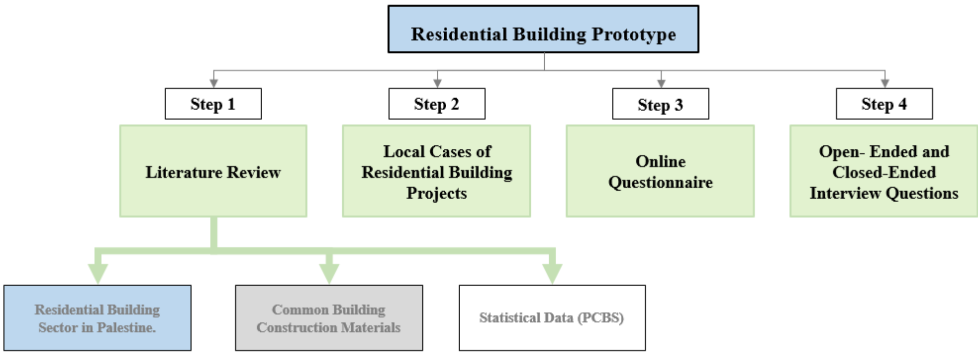


Figure 4.1: Systematic approach in the identifying the residential prototype.

As for the **third** phase in this research which is the core of this study through which the main objective of the thesis is achieved, which is the assessment of the current setback regulations and their impact on the daylighting availability and on energy consumption by using simulation program and post occupancy evaluation survey (POE). All previous studies in the same field have demonstrated the impact of surrounding buildings on the performance of the indoor environment in buildings, but have not addressed a clear generalization or general guidance on the optimum distance between buildings to achieve the best and applicable result to all situations under different climatic and urban context conditions, because each study was based on specific climatic conditions within the common characteristics of the urban context in the study area . So in the case of Palestine, we cannot conclude the impact of the adjacent buildings on the building performance and to know whether the setbacks distance imposed through the Palestinian building regulations is enough to reach an acceptable performance in the indoor environment or not. Because of this, the assessment phase is very important. From the prior literature review, the assessment tools used in the same or similar cases as shown in the table below. The table shows a sample of previous studies about evaluating the performance of buildings in different aspects. Researchers have established several evaluation systems based on tools such as numerical simulation, on site measurements, calculations and Post Occupancy Evaluation Tool (POE).

Table 4.1: Previous studies about using different tools in the assessment studies.

NO.	Article Title	References	Assessment Tool
1	Prediction of Interior Daylight Under Clear Sky Conditions	(Alshaibani, 1996)	-Simulation -On site measurements
2	Impact of Window Parameters on The Building Envelope on The Thermal Comfort, Energy Consumption And Cost and Environment	(Elghamry & Hassan, 2020)	-Simulation -On site measurements
3	Energy Optimization of Building Design For Different Housing Units in Apartment Buildings	(Yao, 2012)	-Simulation
4	Low-Energy Envelope Design of Residential Building in Hot Summer And Cold Winter Zone in China	(Yu, Yang, & Tian, 2008)	-Simulation
5	Parametric Study on Window-Wall Ratio (WWR) for Daylighting Optimization in Multi-Story Residential Buildings: Case Study of an Apartment Complex in Mansoura City, Egypt.	(Yassin, Sheta, & ELWazeer, 2017)	-Simulation
6	Energy Consumption in Buildings: A Correlation for the Influence of Window to Wall Ratio and Window Orientation in Tripoli, Libya	(Alghoul, Rijabo, & Mashena, 2017)	-Simulation
7	Studying the Impact of Orientation, Size, and Glass Material of Windows on Heating and Cooling Energy Demand of the Gaza Strip Buildings	(Muhaisen & Dabboor, 2013)	-Simulation
8	Building Regulations and Its Contribution In Improving Daylight Of A Residential Building in Cairo	(Saada, 2016)	-Simulation
9	Re-assessment of national energy codes in Jordan in terms of energy consumption and solar right in residential buildings	(Alzoubi & Dwairi, 2015)	-Simulation

10	Using simulation tools for optimizing cooling loads and daylighting levels in Egyptian campus buildings	(Samaan, Farag, & Khalil, 2018)	-Simulation
11	Parametric Studies On Building Separation of Daylight Performance In Obstructed Low Cost High Rise Residential Building Through Computer Simulation Techniques In Kuala Lumpur, Malaysia	(Arifin, Abdullah, & Yeap, 2017)	-Simulation
12	A study of the daylighting performance and energy use in heavily obstructed residential buildings via computer simulation techniques	(Li et al., 2006)	-Simulation
13	The influence of exterior obstruction on the integrated evaluation of daylight utilization during initial design stage	(Sun, Li, & Xiao, 2017)	-Simulation
14	Climate-based daylighting analysis for the effects of location, orientation and obstruction	(Munoz, Esquivias, Moreno, Acosta, & Navarro, 2014)	-Simulation
15	Performance assessment of buildings via post-occupancy evaluation: A case study of the building of the architecture and software engineering departments in Salahaddin University-Erbil, Iraq	(Mustafa, 2017)	-POE
16	An evaluation model for indoor environmental quality (IEQ) acceptance in residential buildings	(Lai, Mui, Wong, & Law, 2009)	-POE survey
17	Post Occupancy Evaluation (POE) in Residential Buildings Utilizing BIM and Sensing Devices: Salford Energy House Example	(Ozturk, Arayici, & Coates, 2012)	-POE -On site measurements

In the circumstances of this research and within the context of the urban context in Palestine, it is difficult to use on-site measurements to achieve the thesis primary objective, which is to make an assessment of the regulated setbacks distances imposed by Buildings and Organizing Code for Local Authorities No. 5 in 2011 AD, because of the scarcity of residential buildings that have complied with the distance and height imposed by regulations according to the researcher site visits to residential areas (see Figure 4.2). Then, the **fourth and final** phase focused on enhancing the residential building indoor environment performance in terms of natural daylight intensity and thermal energy consumption in residential spaces at urban and building levels to achieve better building performance. In other words, one of the main objectives of this phase is to identify optimum solutions at both Building and urban levels.

Figure 4.2: Multi-story residential buildings in residential B-Zone.

The main objective of this research is to study the existing setbacks regulations and their impact on building performance in residential apartments in Palestine, to enhance the quality of the indoor environment on urban and building levels. In detail, both qualitative and quantitative approaches and methods have been used to achieve the research goals which are totally different in the data collection and analyzing.

Qualitative approach is concerned with qualitative phenomena, such as those which concern or involve quality or nature to discover how people feel or think on a particular subject or institution using open-ended questions and interviews and collecting data in a non-numerical form. On the other hand, quantitative approach includes closed ended questions and questionnaire in order to transform the collected data into numerical values to carry out statistical analysis (Gelo, Braakmann, & Benetka, 2008; Hesse-Biber & Leavy, 2010).

Different methods were selected for the data gathering, assessment, and optimization of the model. All these methods which were used to obtain the research objectives are divided into quantitative and qualitative methods as show in the Figure 4.3 which summarized the research phases and methodology. This study focuses mainly on the quantitative methods to formulate and create the multi-story residential building prototype especially in residential B-Zone depending. Although, the methodology does not exclude the qualitative tools mainly used to collect data about building regulations in Palestine over the years, and about the common design of residential apartment buildings depending on personal interviews with professionals and residents in residential B-Zone.

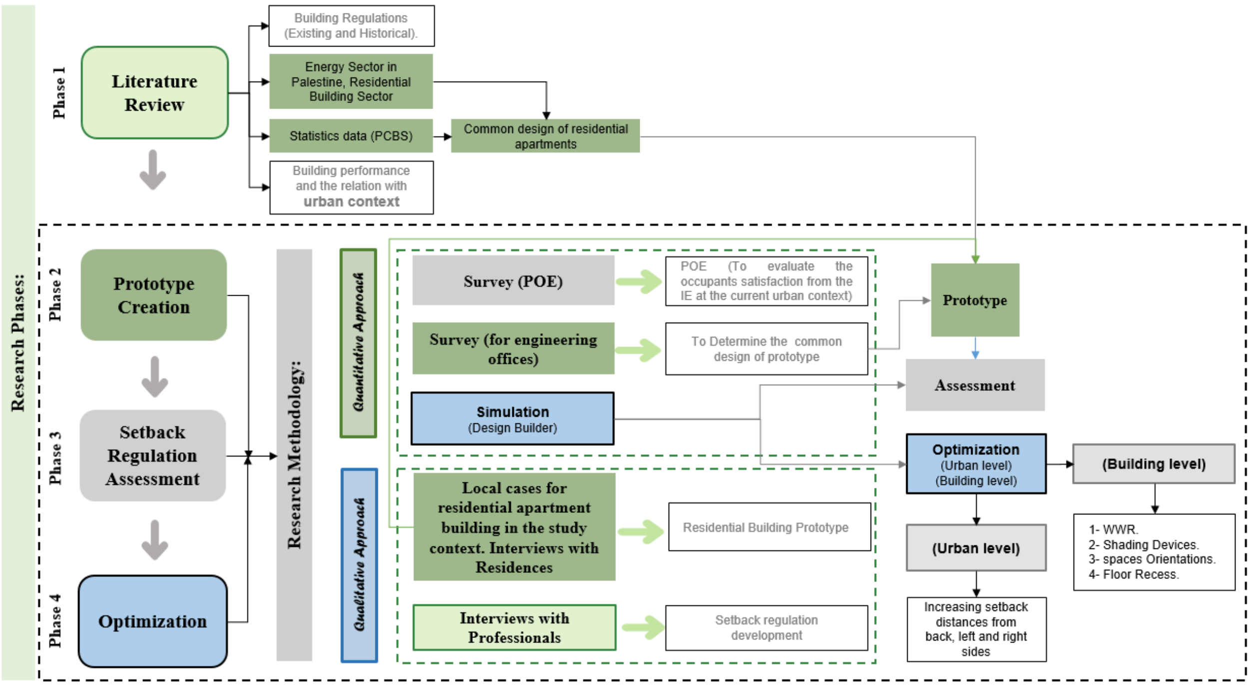


Figure 4.3: Thesis four consecutive phases and research methodology.

4.2. Interviews with Professionals:

Two interviews were conducted in this thesis which investigated the development of the building regulations in Palestine which changed the cities from compact urban fabric in the old towns to the current modern cities especially setbacks and building height regulations. The first one with the teacher at Palestine Polytechnic University, Eng. Yousef Rabei on 23, October 2019 about the development of building regulations in Palestine from Islamic civilization until present regulations.

The second interview was conducted with Arwa Abu-Alhija the head of Local Government Directorate- Bethlehem on 12, November 2019 about the current building regulations and the status of residential buildings in different residential zones and about Violations against building regulations (See Appendix 1A).

4.3. Interviews with Residents:

This is a part of the post occupancy evaluation questionnaire (POE) which is discussed in the research methodology chapter and appendix 1C. This method helps to confirm the results obtained from the literature review and from the online survey about the common design for residential buildings, because it describes the characteristics of real cases for residential apartments. The participants are chosen to represent all cases in the residential B-Zone such as residents of different age groups, gender, building orientation, number of floors, apartment location in the building, etc. The questionnaire includes a part that asks residents to describe the interior design of their residential apartment in terms of the interior spaces inside the apartment in addition to the other parameters that help in the prototype creation.

4.4. Local cases for residential buildings in Palestine:

Architectural drawings of the different multi-story residential building typologies and layout design were studied in order to understand the common trend of the design of these buildings. Residential apartment buildings projects from different Palestinian cities were viewed and analyzed, then the results compared with the results of the questionnaire to formulate the proposed design for the residential building prototype (See Appendix 1B).

4.5. Survey (Residential Building Prototype Development Survey):

This section discusses the concept and the necessity of identifying a prototype for residential apartment and its potential application in Palestine. However, the proposed prototype must represent the typical and common design of residential buildings in Palestine which is used to assess the impact of urban context and setbacks regulations on the indoor environment performance in the central high hills zone. After identifying the Residential building prototype, many approaches can now be conducted such as assessing existing buildings performance under specific conditions, optimizing the common design of residential apartments, developing new codes and standards that enhance the building energy consumption and the quality of the indoor environment in term of availability of natural daylight, natural ventilation, etc.(Ye, Wang, & Zuo, 2018). Hence the importance of formulating a model for residential buildings in Palestine to achieve the research objectives.

An online questionnaire survey was sent to engineering offices in Palestine via e-mail in cooperation with the Palestinian Engineers Association to determine the most common design of residential buildings based on their practical experience in designing apartment buildings in the study context. In Palestine and specifically in the residential buildings sector, there are great similarities in the design and layout of multi-family residential buildings in almost all the Palestinian cities in the West Bank. This is due to the absence of architectural design that takes into consideration the environmental conditions such as specific location and local climate in each climatic zone while focusing to a great extent on social values and needs only. The availability of the common prototype for designing residential buildings in Palestine comes and is seen when investigating the nature and type of apartment buildings found in most Palestinian cities. Based on the observations of many residential projects implemented in cities, it became clear that there are common features between these designs despite the differences in designers, owners, climatic zone, and geographic regions.

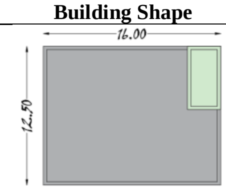
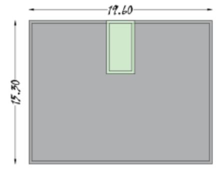
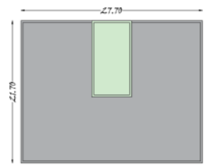
So, for the previously mentioned reason, it became possible to generalize a common design which represents most of the residential apartment buildings in Palestine in general and the design of multi-story residential buildings in residential B-zone in particular. This survey covers more than 100 offices and was distributed on 5th February 2020. Only 30 questionnaires were completed. The aim was to reach a representative sample of at least 100 offices. After two months, the 30 participants took part in the survey. A decision was made to stop the survey due to the low participation rate from the engineering offices. Most of the returned questionnaires were fully completed. Since the prototype reflects the common design of residential apartments, the highest answers percentages are selected as input data.

In the context of the prior literature, minimal studies were conducted in Palestine that submits a proposed design for residential buildings prototype. Hadid's report about “Architectural Styles Survey in Palestinian Territories” mentioned that it was hard to formulate specific residential prototypes in the West Bank because this process needs indoor visits. Also, the study confirmed that the residential prototypes in the cities totally differ from the villages housing prototypes. In cities, the common type was apartment buildings, but in the villages, the single houses or villas were the dominant types of housing units. This report has proposed a typical design for apartment buildings in Palestine according to the author's view (see Figure 4.4) (Hadid, 2002).

Figure 4.4: Residential Building Prototype according to the Hadid report (Hadid, 2002).

Another study was conducted on 11, December 2020 by Monna and others about the potential of energy production from PV installation on residential buildings in four cities in Palestine, which represent the different governorates in the West Bank (North, Central and South) and Gaza Strip. Until this goal is achieved, the most used residential building typologies were selected in the cities that represent north, central and south governorates in Palestine. The results show that the most common residential buildings contain multiple regular forms of square or rectangular shapes, and the apartments in each floor were combined by a staircase. The design of the building form often follows the planning and organizational laws which are provided by the Ministry of Local Government to determine the permitted number of floors, built-up area ratio and the density of the buildings according to the zone’s classifications. According to the available building regulations in the West Bank and Gaza Strip, the residential buildings have been categorized into three main categories: category A, B and C. Category A consists of one or two apartments in each floor with a total of two floors located on land plots with an area of 500–800 m^2. Category B is a building with four-seven floors that contain two or four apartments in each floor located on land plots with an area of 800–1500 m^2. And C consists of a maximum of four floors with one or two apartments in each floor located on land plots with an area of 400–600 m^2 (see Table 4.2). One and three apartments per floor for type B were excluded from the study in the common residential buildings types because these types are not widely used. Also, the study concluded that, the majority of apartments in the Palestinian cities consist of three to four bedrooms and the building contain a parking in the basement or ground floor, and residential apartments on the upper floors (Monna et al., 2020).

Table 4.2: Common types of residential buildings in Palestine.

Building Shape	Number of Apartment /floor	Apartment Area (m^2)	Number of Floors
	1	200	2 (Type A) 4 (Type C)
	2	150	2 (Type A) 4-7 (Type B) 4 (Type C)
	4	150	4-7 (Type B)

As for envelope building materials, the study finds that, the roof is flat concrete slab, and the envelope consist of stone, concrete, hollow concrete block, and plaster. The glass used for the window is single or double glazing with an aluminum frame (Monna et al., 2020).

Monna also conducted a study about energy retrofitting in residential buildings in Palestine which found that, apartment buildings represent the most used typology of residential building in the Palestinian cities. At the same time, a five-story apartment building, with two apartments on each floor is one of the most common types, see (Monna et al., 2021).

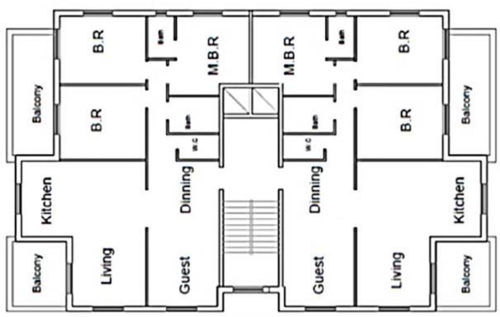


Figure 4.5: One of the representative residential buildings in Palestine (Monna et al., 2021).

The questionnaire was developed by the researcher in order to gather information from expert engineers that are common at designing and implementing residential building projects in Palestine. The researcher determined the questionnaire structure and scope based on the information believed to be important for the development and formation of the multi-story residential buildings prototype according to the literature review (Piotrowska & Borchert, 2017). In order to study the effect of the urban fabric on natural lighting and energy consumption, it is necessary to determine the building characteristics that contribute to the formulation of the prototype, so study the impact on these two parameters. The building design variables include indoor spaces layout, space's function, space dimension (width, length, height), space form, interior partition and orientations. As the different functions have different comfort requirements for thermal comfort and daylighting intensity. Moreover, different spaces layouts and dimensions import different levels of daylight into the building and different lighting distribution. In other words, changing the shape, location and dimension of indoor spaces, the indoor environment performance of the whole building changes (Du, Jansen, Turrin, & van den Dobbelsteen, 2019, 2020, 2021).

Also, the dimensions of the openings and their location are very important in affecting the amount of natural light and solar radiation reaching into the building. On the other hand, these variables include also the characteristics of the building envelopee and the materials used (Du et al., 2020, 2021; Feng, Sha, & Xu, 2016; Huynh, Dias Barkokebas, Al-Hussein, Cruz-Noguez, & Chen, 2021). All these variables affect the performance of the indoor environment in terms of lighting and solar radiation that reaches the residential spaces and it must be determined in the modeling of the base case prototype. According to this, the questionnaire consists of four sections. The first section in the questionnaire has aimed to collect information about the engineering offices characteristics such as the location and the engineering office classifications. The office location has an important relationship in determining the common design of apartment buildings. For example, two apartments on the floor is the common pattern in Bethlehem and Ramallah which is represent one of the most common types of residential buildings in Palestinian cities as mentioned in Monna paper (Monna et al., 2021). When reviewing statistics about housing from Palestinian Central Bureau, the statistics focused on type of housing units, areas, number of rooms, and average of bedrooms in the housing units. On the other hand, there is no information about the number of apartments per floor common in Palestine. Thus, the number of apartments per floor in this study depends on engineering offices survey, POE results and on experience and observations. As for Tulkarm and Nablus, despite the limited responses from these areas, buildings containing three or four apartments are common.

As for engineering office classifications, for example, the consulting offices are considered the most experienced and were resorted to in order to obtain higher credibility in the questionnaire answers, as the experience of the chief engineer in these offices is not less than 12 years, and therefore this experience will be reflected in the answers to the questionnaire.

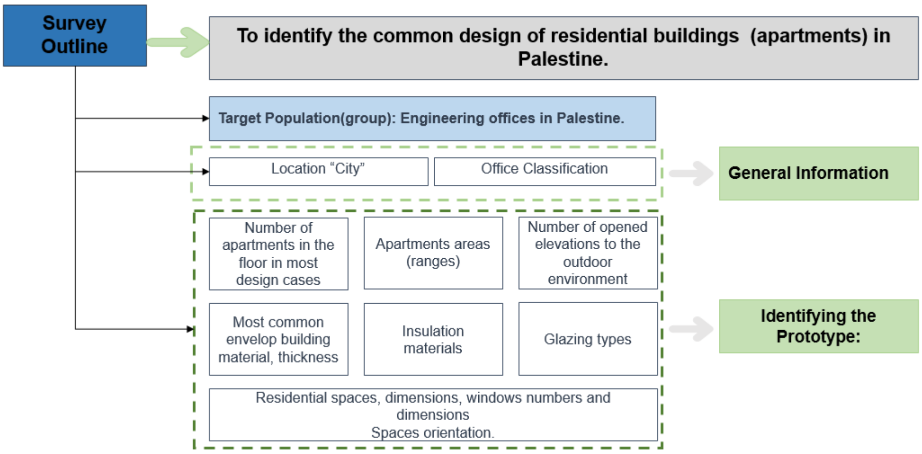


Figure 4.6: Survey general outline.

As for section two, the main objective was to identify the residential building prototype according to the common design standards followed by engineering offices. In the first phase, the general layout of the residential building prototype was created by determining the common number of apartments on each floor in the study context. Also, the average apartment area was investigated in this section by considering several options. Section three collected data which was helped in determining the characteristics of the residential building's envelope includes the building envelope materials that is usually used in the external walls, internal partitions materials and the common glazing type. The last part of this survey is specialized in the characteristics of the internal residential spaces, their dimensions, and windows properties.

After conducting an on-line questionnaire for engineering offices in Palestine, the data were collected and analyzed as outlined in Appendix 1D which was the basis for the creation of the residential building prototype. In addition, POE helped in the prototype development. The results show that most of the evaluated buildings contain two apartments per floor in the residential B-Zone, and therefore each apartment contains at least three external facades that allow natural light and sunlight to enter the building. This has also proved the fact that most of the residential buildings in the region contain two apartments as the office survey results approved, which helped in determining the common prototype of residential buildings in residential B-Zone proposed for the purpose of this thesis. On the other hand, the presence of two apartments per floor gives a better impression of the effect of the surrounding buildings as a main variable parameter without the effect of other parameters. For instance, the effect on the availability of natural lighting and solar radiation is studied, especially in the winter season, as if the building containing three or more apartments in each floor, the number of facades that contain external opening were less than three and thus also contribute to reduce the amount of natural lighting and solar radiation that reaches the building through the urban context and surrounding buildings. The POE survey also asked residents about the ground floor usage in their buildings. The survey intent was not only to assess and evaluate the performance of indoor spaces but also to determine the common residential spaces in each apartment which can help in the prototype creation in this study (See Appendix 1D).

In general, apartments are designed to meet the needs of the Palestinian families. According to the Palestinian Central Bureau of Statistics housing and establishments census survey, final results in 2017, the average area of the housing unit in West Bank is 132.5 m^2. As for Bethlehem governorate, the average area for housing units is 162.1m^2. From the online survey, 42.30% had designed 140-150 m^2 apartments in most cases. The 2017 census report also mentioned that the average number of bedrooms in housing units in Bethlehem is 2.2 (PCBS, 2018).

Once all the required input data has been gathered, the prototype can now be built (see Table 4.3). The residential building proposed prototype design which represents multi-family residential buildings in the residential zones located in central high hills Palestinian cities, especially residential B zone. According to the Buildings and Organizing Code for Local Authorities No. 5 in 2011 AD (BOC), the permitted number of floors are five residential stories in residential Area A and D, and four residential stories in residential B and C which is due to using the ground floor in B and C zones for local commercial functions such as kindergarten, health clinics, Pharmacy, supermarkets, etc. (See Articles 40 and 41 in BOC). These residential areas have different setbacks distance according to the BOC (see Table 2.1). Each floor has two apartments in reference to the results given in the offices-online questionnaire and from POE questionnaire, which showed that most of the residential buildings contain two apartments per floor in the study area. In the same time, four apartments per floor buildings were excluded because this type is not common in the study context as shown in the questionnaire results which can be included in the future research.

Based on the literature, POE and offices survey results, three bedrooms' apartment has been selected as it represents the majority of household units in the Palestinian cities especially in Bethlehem. Also, the total area of each apartment is about 160 m^2, that includes the living room, guest room, kitchen, master bedroom, two children's bedrooms, and bathrooms. In addition, two balconies were provided for each apartment based on the results of the questionnaire and on residential projects in Palestine, which contained two balconies, one of them connected to the master bedroom and the other to the living spaces. The window opening is placed at the center of the walls at 1.04m -1.30m (4-5 stone courses) from the floor with the width of 1.40-1.60 m and the height equal to 1.30m, these characteristics for windows are common in Bethlehem according to the survey, local cases and experience in the local market for apartment buildings design.

Table 4.3: Prototype general characteristics.

	Description	
Total Floor Area	377 m^2	
Apartment Area	148 m^2 +12 m^2 balconies = 160 m^2	
Number of Floors	5 floors (ground floor used as commercial uses and 4 residential floors).	
Floor to Floor Height	3.12 m	
Windows Characteristics		
Glazing Type	Double clear glass	
Windows Dimensions	1.30 m height × (1.50 m or 2.00 m width)	
WWR	Guest Room	19.30 %
	Kitchen	18.90 %, 17.50 %
	Living Room	22.70 %
	Bed Room	17.00 %
	Master Bed Room	15.90 %

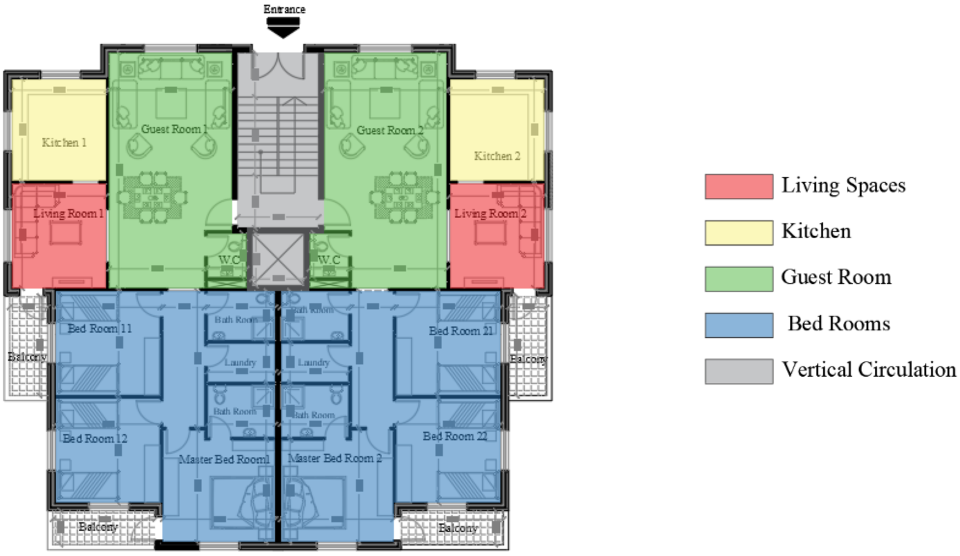
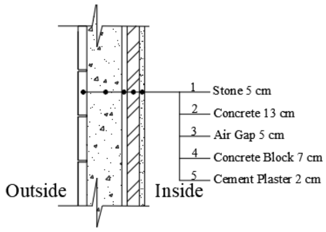
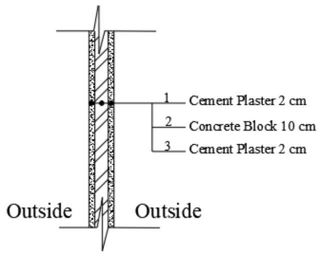
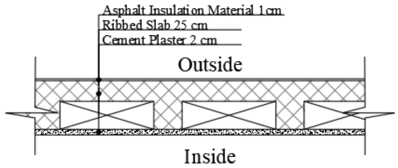
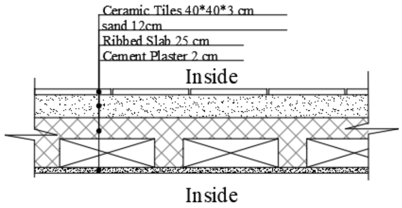


Figure 4.7: Proposed prototype.

The building prototype uses available local construction materials in Palestine and built by common ways of construction. For external walls, 5cm limestone was used in the external cladding with 15 cm backup concrete, then 3 cm air gap and 7 cm cement block covered by 2cm cement plaster from the internal side. Also, double glazing 6mm clear glass for windows. The roof was constructed from 26 cm reinforced concrete with cement block covered by 3 cm cement plaster from inside and insulated by asphalt layer from outside. As for the internal walls, they consist of 10 cm cement blocks covered with a 2 cm cement plaster from both sides (see Table 4.4). Using insulation materials in the external walls is limited in Palestine due to the awareness about its advantages from economic, environmental, and internal comfort aspects (Alsayed & Tayeh, 2019). According to the survey, air gap used widely as an insulation material. Recently, other types of insulation material are commercially available such as Expanded Polystyrene (EPS) and Polyurethane (PUR) (Alsurakji, Abdallah, Assad, & El-Qanni, 2021). The study was based on the use of the air gap but when the Expanded Polystyrene was used there was no impact on the daylighting availability in the internal spaces. At the same time, the total heating consumption decreased by about 35% in the same time with increasing cooling consumption by about 10%.

Table 4.4: Building envelope component characteristics.

Component	Description	Details
External Walls	Concrete Wall with external lime stone cladding. U-value* = 1.93 w/m^2 .k	
Internal Walls	Hollow cement Block 14 cm. U-value = 2.473 w/m^2 .k	

Roof	A ribbed concrete slab 28 cm. U-value = 3.099 w/m^2.k	
Floors	A ribbed concrete slab 42 cm. U-value = 1.877 w/m^2 .k	
Windows	Double clear glass U-value = 2.67 w/m^2 .k	-

*U-value from Design Builder simulation program for each type of construction element.

4.6. Post Occupancy Evaluation (POE):

The researcher considers it is very important to identify and prove that there is a problem at all. One of the best ways to prove that adjacent buildings affect the performance of the indoor environment of the building through assessing the satisfaction of residents with the indoor environment through their experience in their homes within the existing urban context of Palestinian cities. For this reason, this study aims to confirm the research problem from multi-story residential buildings occupants' point of view depending on the post-occupancy evaluation questionnaire (POE). This tool was used to know the residents in residential apartments in the residential B-zone satisfaction with the performance of the apartments within the urban context in which the building is located, in addition to knowing their opinion that the distance between the buildings is sufficient to meet their needs of lighting, solar radiation and private or not. In addition to the problem Identification, POE is very important to evaluate the performance of apartments in multi-story residential buildings in terms of natural lighting and energy consumption.

The POE questionnaire is an effective method to identify the research problem from the occupants' point of view to evaluate the occupant's satisfaction with the indoor environment, thus determining whether there is a problem or not. This method has been relied on in this research to assess the impact of the separation distances between buildings on users' satisfaction with the amount of natural light and solar radiation inside the residential spaces, in addition to providing privacy.

Many researchers have given different definitions to Post Occupancy Evaluation. Post Occupancy Evaluation is defined as "the examination of the effectiveness for human users of occupied designed environments" (Bonde & Ramirez, 2015). It is also a method to evaluate how occupants feel while they are using the space. It is considered an effective diagnostic tool to evaluate the performance of buildings to reduce indoor environmental problems, and then find solutions to improve their performance. POE is based on asking occupants about their needs and experiences in the built environment after they have been occupying the building for some time (Boarin, Besen, & Haarhoff, 2018). By using this tool, we can assess the occupant's satisfaction level in terms of energy use and the indoor environmental quality in terms of many criteria such as thermal comfort, noise, ventilation, lighting, …etc. (Hassin & Azlani, 2018). It was also defined as an assessment of the performance of a building after it becomes occupied which serves as lessons for future buildings (Al Horr et al., 2016; Mastor & Ibrahim, 2010).

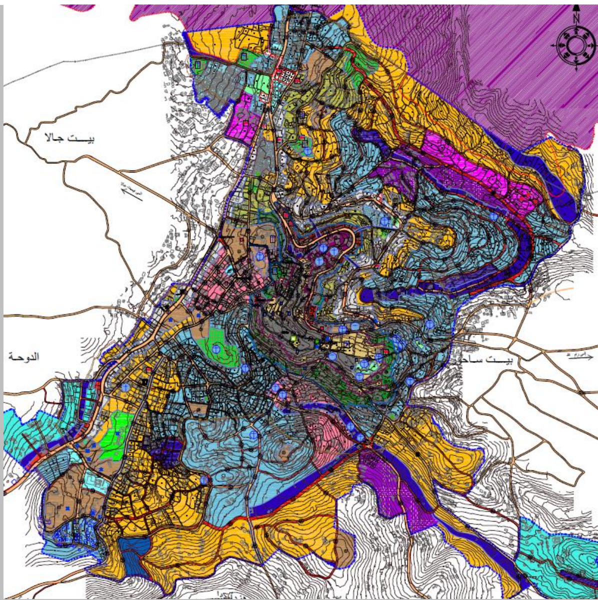
Different methods can be used to conduct a post occupancy evaluation. One is qualitative which includes surveys, questionnaires, interviews as well as observations to evaluate occupant's satisfaction and needs or their behavior (Boarin et al., 2018). Another is quantitative which provides building performance monitoring via electronic devices and simulations to assess the building physics and provide physical measurement such as: air temperatures, humidity and air velocity. For the quantitative approach, before starting the monitoring activity of occupant's satisfaction, it is important to define the indicators to be compared with the actual performance. These indicators can be obtained from many sources, such as requirements in building regulations, and from Standards (Boarin et al., 2018; Deuble & de Dear, 2014; El-Darwish & El-Gendy, 2018). In this study, POE survey was used as a tool to identify a certain problem that is dominant at Palestinian cities urban context in residential B-Zone. Then, simulation software in the assessment phase was used to validate the results obtained from POE.

Generally, POE involves three phases. One **is planning**. Second is conducting and third is applying (Council & Council, 2002). The planning phase is intended to prepare the POE and all the parameters for the assessment will be established. A pilot survey was distributed initially in this phase amongst a sample consist of 15 participants in different ages, gender, academic background, social conditions and different housing conditions (floor location, building c characteristics, urban context characteristics) in order to evaluate the clarity and readability of the survey, so the satisfaction results from this survey were ignored. According to the feedback collected from this pilot survey, many terms were modified and a vocabulary that residents could easily understand was used. Then, the final revision of the POE survey was formulated.

In this phase, the POE was done with the help and cooperation of residents in residential B-zone to evaluate the occupant's satisfaction with the indoor environment, so as to study the impact of setbacks on the building performance from the perspective of the residents. Generally, residential buildings in Palestine reflect real problems of energy consumption and indoor environment performance of the overcrowded residential areas. The main question that this survey planned to answer is "How residential buildings in the current urban context condition perform in terms of regulated setbacks".

An online and on-site survey was developed by the researcher and distributed to residents at a multi-story apartment building in residential B-zone in Ad Doha - Bethlehem. The Bethlehem Governorate is one of central high hills cities which is surrounded by Zionist settlements from all sides, which prevents urban expansion in the governorate. In addition, Area C region, which is the region under full Israeli military and civil control, comprises about 43% of the total land area of the Bethlehem Governorate remaining after the confiscation of large areas for the construction of settlements (ARIJ, 2010b). For these reasons, the construction in Bethlehem is mostly vertical and the buildings are very close to each other due to the scarcity of lands in which construction and urban expansion are not permitted like other Palestinian cities.

According to the Palestinian Central Bureau of Statistics housing and establishments census survey, final results in 2017 statistics showed that, apartments have become more common housing type in Bethlehem especially in urban areas, about 56.4% of occupied housing units are classified as apartments which is apart from multi-story building. Also, the average number of rooms in the Occupied Housing Units in Bethlehem is 3.8 (PCBS, 2018). According to the master plan for the city of Bethlehem that includes classifications of areas and land uses, Residential B- Zone constitutes the highest percentage of Bethlehem's land area, about 21% from the total master plan area (see Figure 4.8, Appendix 1C).



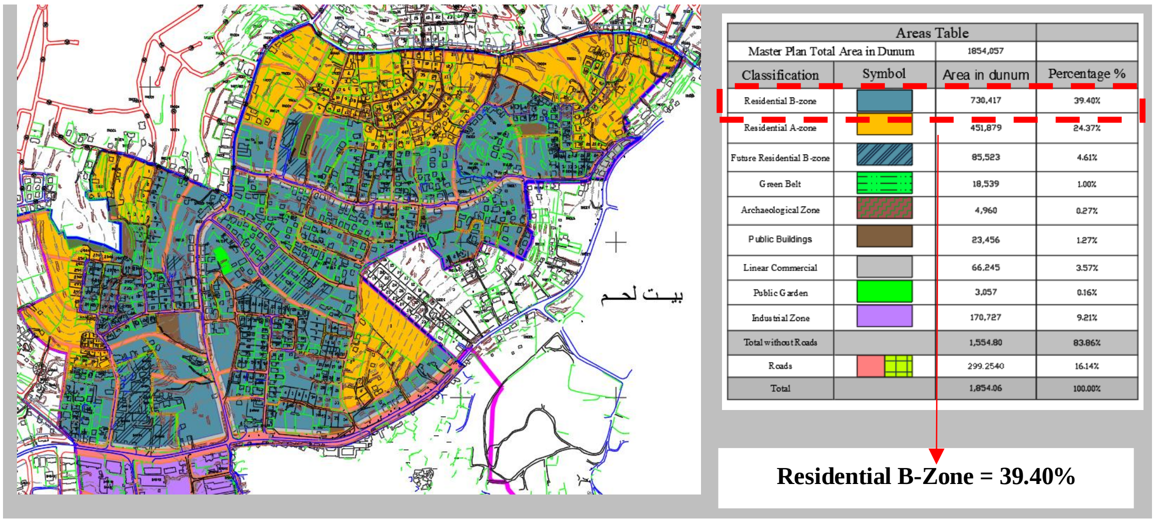
Areas Table			
Master Plan Total Area in Dunum		7,761	
Classification	Symbol	Percentage %	Area in dunum
Residential A		15.24	1,183
Residential B		20.87	1,620
Residential A with special provisions		[illegible]	[illegible]
Villas		4.51	350
High Residential Buildings		2.77	215
Local Services Center		0.73	57
Old City		3.02	234
Tombs		0.37	29
Monastery		1.11	86
Main Center		13.3	243
Tourist area for hotels and recreation		1.79	139
Linear Commercial with special provisions		3.38	262
Open Green Area		4.26	331
Public Garden		0.57	44
Public Facilities		4.56	354
Mixed use with special provisions		0.57	44
Camps		1.20	93
Light Industries		0.45	35
Local commercial and residential within the protection zone		0.73	57
Residential B with special provisions within the protection zone		2.54	197
Mixed use within the protection zone		0.79	61
Total without Roads		86.65	6,725
Roads		13.75	1,036
Total		100	7,761

Residential A		15.24	1,183
Residential B		20.87	1,620

Figure 4.8: Bethlehem Master Plan (B. Municipality, 2019).

For specific, Ad Doha City which is 2.5km west of the Bethlehem City (ARIJ, 2010a), is one of the Palestinian cities that has shown a significant increase in the number of multi-story residential buildings in Residential Area B. Therefore, Ad Doha city was taken as a case study to conduct a post-occupancy evaluation of residents in multi-story residential buildings in residential B- Zone, which is within crowded urban context. The main objective of the survey is to study the resident’s satisfaction in these buildings within the existing urban context, based on the regulated setbacks distances. As shown in the master plan for Ad Doha city, Residential B-Zone ranks first between other land uses and represents 39.40% from the total master plan area.

Figure 4.9: Ad-Doha residential B-Zone urban context.



Areas Table			
Master Plan Total Area in Dunum		1854,057	
Classification	Symbol	Area in dunum	Percentage %
Residential B-zone		730,417	39.40%
Residential A-zone		451,879	24.37%
Future Residential B-zone		85,523	4.61%
Green Belt		18,539	1.00%
Archaeological Zone		4,960	0.27%
Public Buildings		23,456	1.27%
Linear Commercial		66,245	3.57%
Public Garden		3,057	0.16%
Industrial Zone		170,727	9.21%
Total without Roads		1,554.80	83.86%
Roads		299.2540	16.14%
Total		1,854.06	100.00%

Figure 4.10: Ad Doha City Master Plan (A. D. Municipality, 2021).

The main POE studied parameters were daylighting and solar radiation access in the residential spaces. The survey focused on asking questions to the residents about the relationship between the building and surrounding buildings and the possibility of natural daylight and solar radiation for reaching inside the building spaces through the available distances between the buildings in summer and winter. The survey also includes the concept of privacy in residential buildings to find out the reason behind the use of various shading methods such as blinds, and whether they are opened during day time to allow the access of daylighting and solar radiation. Responses to questions and analysis of the answers are mostly based on a multiple-choice structure, with few questions that allow occupants to answer as they see appropriate (open-ended questions). In addition, satisfaction evaluation questions have 7-point scale answers ranging between different values from positive to negative which expresses the extent of the satisfaction with which the user feels (closed questions). The 7-point Likert Scale format was used in the questionnaire to evaluate the occupant's satisfaction where -3 represents very unsatisfied and very bad, -2 represents unsatisfied, -1 represents fairly unsatisfied, 0 represents neutral, +1 represent fairly satisfied, +2 represents satisfied and +3 represents very satisfied and very good.

The survey begins with introductory text that explains the purpose and the main information of the survey. It is consisting mainly of four sections. The first section includes general information about the occupants such as; gender, age and the relationship between the occupants and the apartment, is he a tenant or an owner. The second and third sections include general questions about the apartment, building and about the urban context characteristics which were used in the survey analysis.

The fourth and final section includes questions about occupant's satisfaction in the fields of the accessibility of natural daylight, solar radiation, about separation distances between buildings and privacy. This section has focused mainly on the buildings and the immediate surroundings to achieve the thesis main objective. The privacy questions aim to understand and analyze the behavior of occupants and their needs in relation to natural lighting and solar radiation in connection to the concept of privacy. These questions focused on knowing the reason for using shading elements such as blinds in apartments, when they are used and their impact on the performance of the building. For example, the survey contained a question that needed the user to think and track the time during which the residents open the blinds to make sure that there is no obstacle other than the neighboring buildings that prevent the natural daylight and solar radiation from reaching the apartment.

The second phase is the **conducting phase** which consists of initiating on site data collection, monitoring, managing, analyzing and evaluating data (Council & Council, 2002). In order to select a random sample of multi-story residential buildings in Ad Doha, the residential buildings in the residential B-Zone were counted taking into account excluding all buildings that do not meet the basic conditions, which is that a multi-story residential building must be surrounded by neighboring buildings. As shown in Figure 4.11, the excluded buildings include all non-residential buildings, villas, one to three story residential buildings and buildings without surroundings. Depending on these conditions, the population size is 540 buildings, and according to the online calculator, the sample size is 80 buildings but the available on this study is 78 buildings because there are many unoccupied buildings, in addition to the refusal of many residents to participate in the survey.

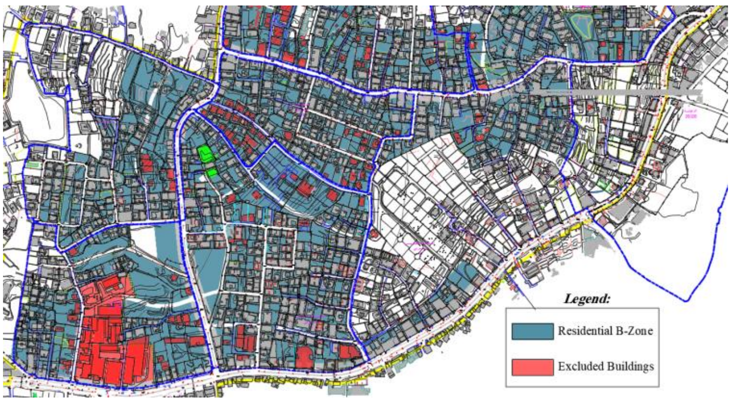


Figure 4.11: Excluded buildings in residential B-Zone.

The POE results developed by using the data collected from 131 occupants from 78 residential buildings which was useful to assess the impact of the urban context on the indoor environment performance. The 78 buildings chosen for the study differ in locations and orientation. The sample are of eight different urban context orientations scenarios. The researcher chose buildings that are located on main streets with eight different orientations that represent the different cases covered by the study which are also surrounded by neighboring buildings only, whether from all sides or at least one side. As for the 131 chosen apartments, the apartments within the same building are chosen on different floors (Ground if used as a residential unit, first, middle whether second or third and roof) in order to study and evaluate the performance of all cases so that the performance of these apartments are compared with each other to determine how the surrounding buildings affect them.

The **applying** phase includes reporting findings, giving recommendations and reviewing outcomes (Council & Council, 2002). According to the POE results, the occupants' sample are all of residence in multi-story apartment buildings in Ad-Doha composed of females and males of different ages with different relationships to the apartment where they live, for example; the number of years and number of hours during the day that they usually in the apartment. All occupants have been using their apartment for at least one complete year. As shown in the appendix 1C, most of the study samples are female which have spent more than 10 years and more than two-third of their day in their apartments. Thus, we conclude that the majority of the study sample has a clear perception of the apartment performance during day hours in different periods of the year, and therefore, their satisfaction or dissatisfaction with the apartment performance and its relationship to the surroundings is based on their long knowledge and experience in the apartment.

The sample included buildings oriented to the north, north-east, east, south-east, south, south-west, west and north-west sides. All these buildings are located in residential B-Zone where the regulations permit the number of the floors to be up to five, including the ground floor. But actually, a large number of buildings in this zone exceed the permissible number of floors.

4.7. Simulation Process:

The building simulation process started after the residential building prototype was identified. Computer simulation and modeling programs were found to be one of the most efficient tools to provide accurate and detailed information regarding building performance especially in terms of building energy consumption and daylighting research. In addition to providing architects with useful information to help optimize their designs to meet the least minimum indoor quality requirements (Samaan et al., 2018). The modeling and parametric numerical simulation was conducted by using Design Builder software v 6.1.0.006 program. It is an effective design and simulation tool for analyzing and understanding the behavior of daylighting and energy consumption. The Design Builder software was chosen due to its ability for developing integrated daylight and thermal simulations in one model without the need for exporting to multiple software. At the same time, the results could be more accurate where the thermal results depend on daylighting performance which has a significant impact on heating and cooling loads consumption.

Design Builder is a graphical user-friendly interface for modeling and exporting files to Energy Plus simulation engine v 8.9.0.001, in addition, it is compatible with Radiance software which is one of the top daylighting simulation engines (Samaan et al., 2018). Also, it is based on using the primitive variable method of the conservation equation (Elghamry & Hassan, 2020). Energy Plus engine based on BLAST and DOE-2 energy simulation programs (Castell & Solé, 2015; Crawley et al., 2004). Radiance engine carried out the simulation steps depending on a series of command line programs. It depends mainly on two methods to run the daylighting simulation process: firstly, used the light-backwards ray tracing method to analyze inter-reflections between both diffuse and specular surfaces. Secondly, it a Monte Carlo method was used to estimate indirect illuminance and the CIE glare index (CGI) to analyze visual comfort (Hassan, 2016).

The simulation model was created for a prototype in one climatic zone in Palestine by using the default weather data file for Jerusalem Airport which is available in the program library. Also, the materials, occupancy, HVAC system and lighting were used from the Design Builder library. Basic information for the chosen climatic zone such as latitude, location was also provided by the Design Builder library.

Complete information was identified into Design Builder software, such as information related to the project location in Palestine (Jerusalem) and building activity (residential, dwelling unit). Except for design variables, it is also necessary to identify the constant parameters used in each case, in order to compare the results from different simulations. Regarding the design variables influencing the building simulations, the following design parameters were kept constant such as residential buildings prototype boundary dimension and form, use of spaces, occupancy schedule in all residential spaces and envelope design such WWR (Guest room: 19.30%, Kitchen 18.90% and 17.50%, Living room 22.70%, Bedrooms:17.00% and master bedroom: 15.90%), materials (including roofs, floors, internal partitions, external walls and glazing type) and size and location of openings for ventilation (1.30m height * 1.50m or 2.00m width in the center of the external room wall). For daylighting simulation settings, the selected sky model is CIE overcast day. The accurate detail template daylighting simulation occurred at a working plane at 0.80 m above the floor level. As for energy performance calculations that were carried out with a monthly, daily and hourly output interval when the simulated building is naturally ventilated. As for the HVAC system, it is assumed full use of radiator heating, boiler hot water and natural ventilation template with 3.0 air change/hr. infiltration rate (Alqadi, Elnokaly, & Sodagar, 2021). Heating and cooling set point temperatures are 20^o C and 24^o C respectively. As for occupancy density, the simulation conducted for default setting for residential occupancy which is 0.0215 people /m^2 (as for apartment area, the total number of family is 3 persons) which it's not the actual occupancy density for the Palestinian family. According to the PCBS in 2017, the average household size in Bethlehem is 4.7 persons and the total area for apartments is about 160 m^2, so the occupancy density is 0.0294 (PCBS, 2018). According to the simulation results, this increasing in the occupancy density increased the heating loads from 0.01%-2% and from 0.05%-1.6% for cooling loads.

Table 4.5: Values of the main parameters of the simulation model.

Parameters	**Value**
Occupancy Schedule	Residential Occ,
Occupancy Density	0.0215 people/m^2.
Heating Set point	20^o C
Heating Schedule	November-April
Cooling Set point	24^o C
Cooling Schedule	May-October
Infiltration	3.0 ac/hr **(see appendix 2A for infiltration rate error)**
Glazing ratio	-
Glazing type and Transmittance	Double clear glass, U-value = 2.67 w/m^2 .k
Shading device	None

To examine the relationship between urban context and residential buildings indoor environment performance in term of daylighting and thermal performance, urban scenarios that represent the existing urban context in the Palestinian cities in residential B-Zone must be identified to start the setback regulations **assessment phase** which followed by the **optimization phase**. Then, the simulation work was processed along two consequent phases; the first phase by simulating base cases models which have without adjacent buildings to find out the effect of the building prototype itself on daylighting and thermal performance inside residential spaces, then to test current setbacks and buildings heights regulations on the previously mentioned factors by comparing the simulation results for base cases with urban context cases which have with adjacent buildings in all directions. The second phase includes optimizing natural daylight and energy performance by testing various solutions at urban and building levels to enhance the quality of the indoor environment depending on many parameters that were found important in the literature review.

From literature review, it could be reported that for the daylighting and thermal energy performance assessment and optimization process in residential buildings, daylighting is often evaluated using one of the daylighting metrics that that have been demonstrated in chapter two while the thermal energy performance evaluation was depending on estimating heating and cooling loads and comparing them to a proposed base case. The simulation process in the two phases focused on the performance of residential spaces such as living spaces, guest rooms and bedrooms while, bathrooms, toilets, storage and laundry were ignored.

4.7.1. Assessment Phase:

Before starting the assessment phase on different urban context scenarios according to the cases which are common in the Palestinian urban context, simulation is conducted for base case scenarios firstly. The main objective in constructing the base case models is to evaluate the impact of adjacent buildings within current setbacks regulations on daylight and energy performance. To do so, the base case models were considered cases without any adjacent buildings from the surrounding directions to use as a measuring unit to quantify changes in daylight availability and energy consumption in the residential spaces when adjacent buildings in all directions surround the target building in the urban context cases.

4.7.1.1.Base Case Model Formulation:

Two aspects were used in forming the base cases morphology; the common design of residential apartment prototype based on the findings presented in the residential building prototype section and the urban context scenarios. The base case models consist of 5 stories with no external obstruction, with 3.12m floor to floor height in the residential floors which are from the first to the fourth floors. The typical floor plan consists of two apartments per floor and was assessed in eight different orientations: North, North-East, East, Southeast, South, Southwest, West and Northwest.

Table 4.6: Base Case Models (Design Builder).

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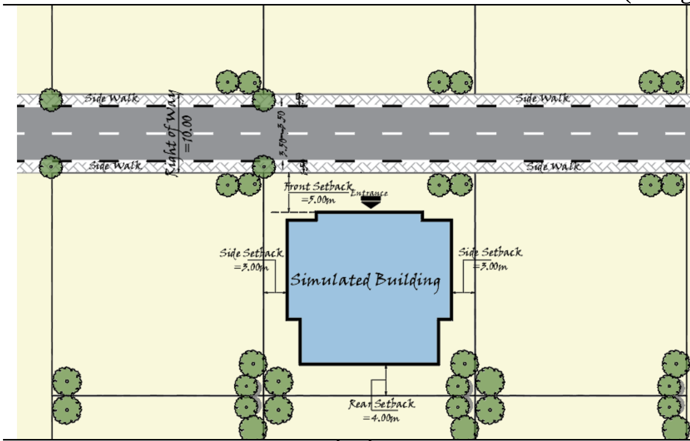
<td>
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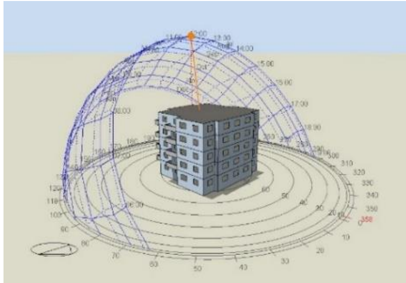
<td>
When the main street oriented to the main eight orientations. Without any adjacent buildings, 21, Jun, 12 PM.</td>
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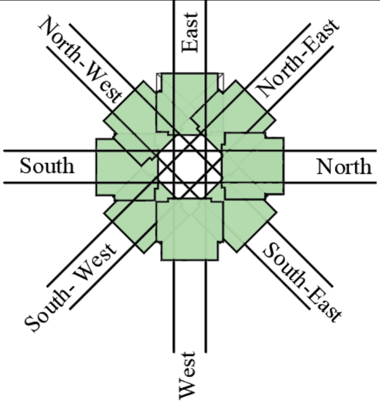
<td>
</td>
<td>The base case residential building without any surrounding buildings. The street orientation in the following cases vary according to the following orientations (North, Northeast, East, Southeast, South, Southwest, West, Northwest).</td>
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</table>

4.7.1.2.Urban Context Scenarios Formulation:

In the Palestinian urban context, many factors are affecting the setbacks distances between buildings and buildings heights as well. So as to study the effect of the previously mentioned factors (imposed from local building regulations) on building performance, all design variables and all urban cases that will be studied are to be identified in the setbacks and buildings height regulations assessment phase, since the proposed optimization process will depend mainly on them.

According to the researcher observations and site visits the urban context scenarios determined according to the three parameters which contribute to the formation of Palestinian cities urban context which include the location and orientation of the main street, site topography and residential zone classification. Among these variables is the **location and orientation of the main street** in comparison to the land (parcel), which plays an important role in determining setbacks distances within residential zones. The Buildings and Organizing Code for Local Authorities No. 5 in 2011 AD confirmed that the street location is the main factor that determines the distance of setback from front, sides, and rear of proposed building. The front setback is the distance between the building and the land lot boundary facing the main street. This distance is usually the largest in all residential zones. Accordingly, also the distances for side and rear setbacks are determined. In addition, there are many cases of multi-story residential buildings in the urban context of Palestinian cities located on more than one street in at least two orientations, but these cases have been neglected because one street is the critical case of lower setback distances. For instance, when a building is located on two streets, the front setback distance is considered to be (the largest distance) from two sides, which gives better performance to the building.

On the other hand, different street orientations affect and play a great role in the internal residential space's orientations and configurations. According to the researcher's observations and analyzing local cases, it is recognized in most residential buildings that the main apartments entrances are towards the main street, which affects the configuration of the indoor residential spaces and its orientation. In other words, the main street orientation determines the orientation of the building and the internal spaces because the customary design in Palestine is based on placing the main entrance of the building on the main street, which contributes to determining the design of the building. The indoor spaces orientations highly affect the daylight penetration and the energy consumption needed so achieve a comfort level. This is due to the change in the sunlight and solar radiation at different orientations and at various times of the day (Burdick, 2011).

After reviewing the street orientation map for Palestine, it is clear that there is an irregularity in the street orientations (see Figure 4.12). Therefore, based on previous studies, the following orientations have been taken into consideration in the regulation's assessment phase; North, Northeast, East, Southeast, South, Southwest, West and Northwest (see Figure 4.12). These orientations are typically used for energy calculation according to the Burdick study(Burdick, 2011). Not only different housing units orientations have a significant impact on the amount of sunlight and solar radiation reaching the indoor spaces, but also buildings windows to wall ratio (WWR) and the shading degree over any site highly affect as well (Burdick, 2011).

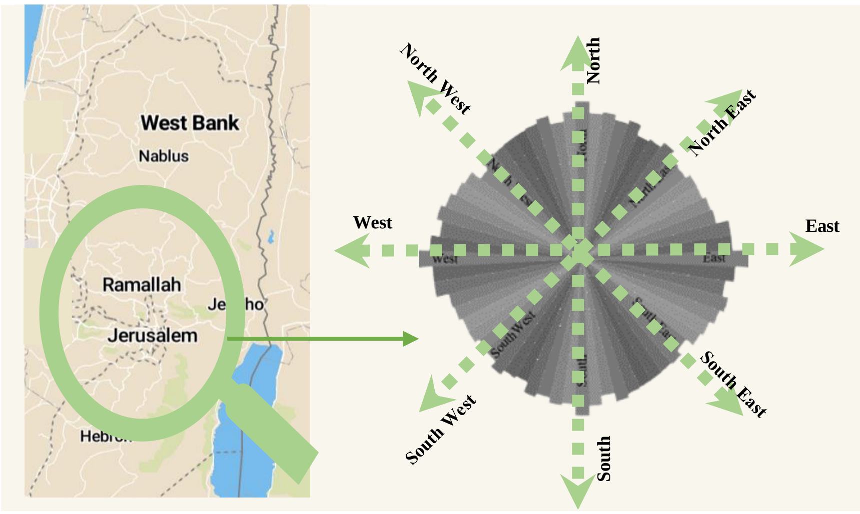


Figure 4.12: Street map direction in Palestine (StreetMap).

In addition to the main street orientation, other parameters were considered in the assessment process**. The second parameter is the site topography**. Where Palestine, especially the in the central high hills region (study area) is characterized by variation in the land's topography which mainly includes; the coastal plain, the central highlands, the Jordan Rift Valley, the trans-Jordanian highlands, the Jordan River, the Sea of Galilee, the Dead Sea and the Mediterranean Sea (see Figure 4.13) (Ighbareyeh, Cano-Ortiz, & Cano, 2014). Natural daylight and energy consumption in the different urban context scenarios were studied and tested. The researcher depends on collecting data through site visits and direct observation of the common topographies in the Palestinian urban context. The urban topography has a significant impact on building performance since it affects the heights of the buildings as well as the shade from one building to the other (Yaşar et al., 2018). However, the Palestinian buildings regulations haven't considered the topography when setbacks and buildings heights regulation were imposed. The proposed site topography depending on the decline of the main street on which the buildings are located, there is therefore a height difference between land plots of about 3 meters based on observations. In detail, each land plot itself is flat, but it differs from neighboring plots in terms of land levels (see Table 4.7). In the existing urban context there are other topography cases which can be determined in future studies.

The final and third parameter is the residential zones classifications. Palestinian cities master plans divide the residential areas into several zones, each of which has its own characteristics and requirements in terms of setback distance, number of floors, and the permissible built-up area. For example, in residential zone-A, the setbacks are greater than residential Zone-B, and therefore the density of built-up areas is less, which contributes to the formation of an urban context different from other residential areas.

Figure 4.13: Topography of the study area in Palestine .

For the purpose of this study and within its scope, the residential building prototype was clearly defined and specifically located in the central highlands and has taken the urban context scenarios within the study context into account, as well as the location and orientation of the main street and the residential zone classification. In the assessment phase, external conditions were proposed as well. The urban context cases were formed in accordance with the regulated setbacks and building heights which are classified in the Buildings and Organizing Code for Local Authorities No. 5 in 2011 AD. Moreover, and to assess the worst-case scenario, the setbacks distances were considered the minimum distance between building boundary and lot boundaries.

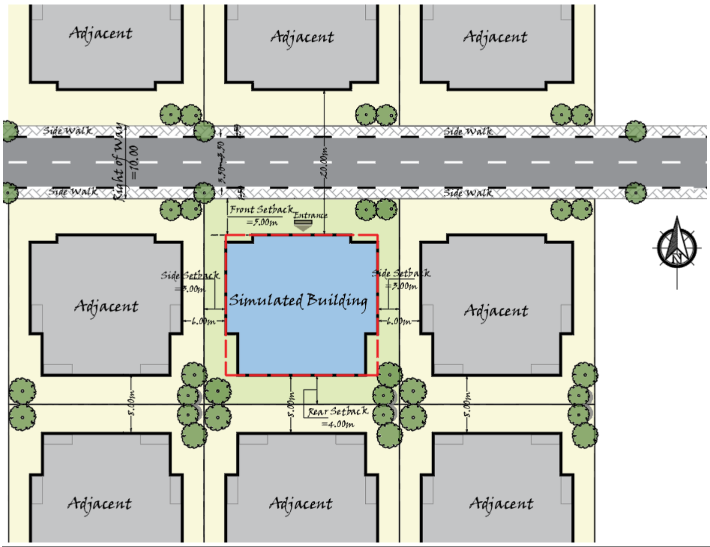
So, the assessment will be conducted through 16 urban context cases. Different street orientations and different adjacent building orientations were considered in the simulation to check their effects on the indoor environment. These cases assum that the building will be facing obstructions (neighboring buildings or topography) from all directions with a setback of 20m, 6m, and 8 m from the front, sides, and rear sides respectively. All adjacent buildings were considered of 5-story height since it is the acceptable building height in the study context "residential B-zone requirements".

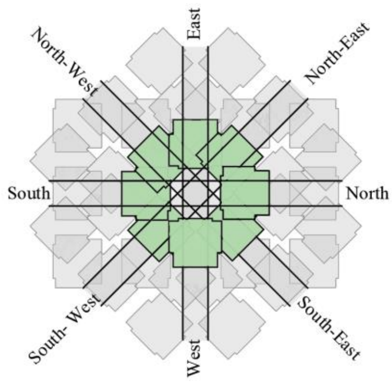
Table 4.7: Urban context scenarios.

Parameter No. 1: Street location and Orientations

Case No.1 (Street oriented to the north), Case No. 2 (Street oriented to the North East), Case No. 3 (Street oriented to the East), Case No.4 (Street oriented to the South East), Case No.5 (Street oriented to the South), Case No.6 (Street oriented to the South West), Case No.7 (Street oriented to the West) and Case No.8 (Street oriented to the North West).

The simulated building was placed on main street with a total width of 10m from front side and away 20 m from front adjacent building, 6m from two sides and 8m from back building in all proposed directions.

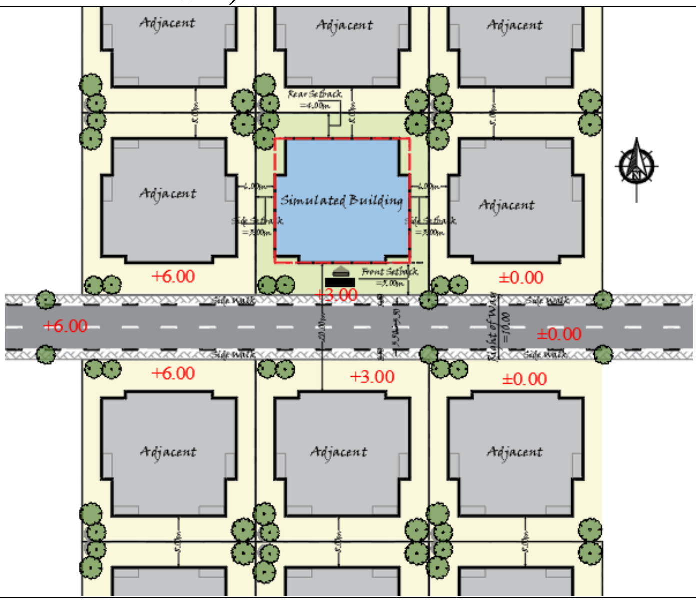




Parameter 2: Site Topography

Cases No.8-16 (Street oriented to the North, North East, East, South East, South, South West, West, North West)

All the previous 8 cases were simulated again while considering a sloped main street which is common in the study context



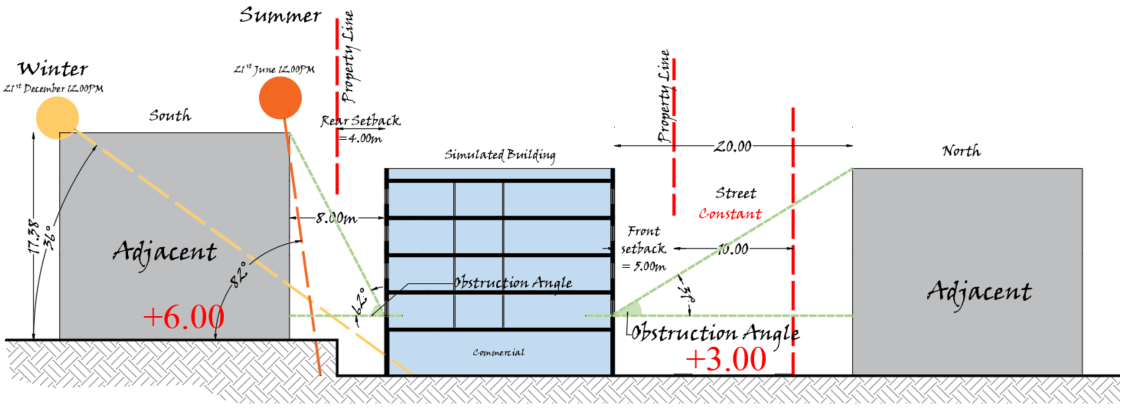


Figure 4.14: Section when the study area slopped (topography in the site north-south).

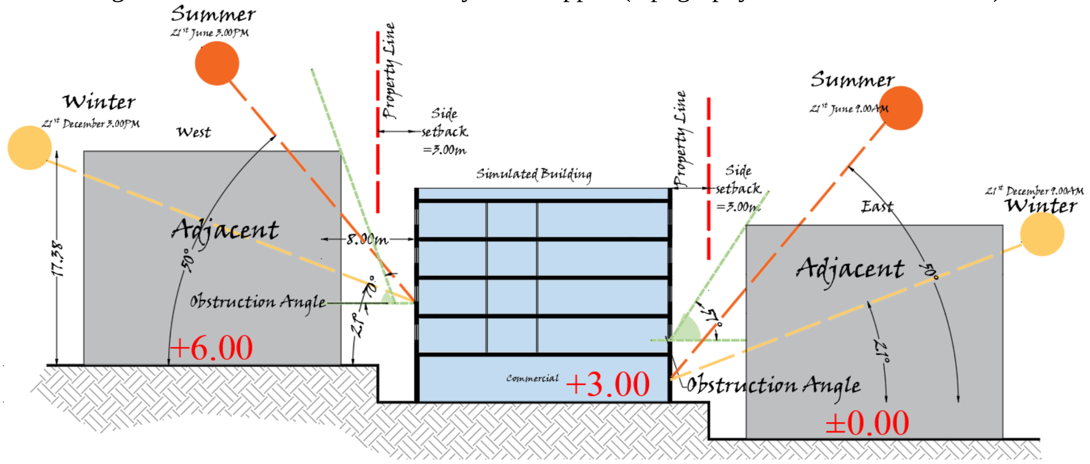


Figure 4.15: Section when the study area slopped (topography in the site east-west).

4.7.2. Optimization Phase:

Parametric simulation and sensitivity analysis methods were used to address the main objective of this thesis which is to optimize and to enhance the indoor environment performance and energy consumption in multi-story residential buildings by exploring the influence of the urban and building scales parameters. Parametric simulation it's a tool for testing unlimited variables to evaluate them and then to choose the best one for the specific design conditions to achieve different solutions and alternatives.

Parametric design process starts by defining all variables and parameters which have to do with the thesis enhancement objective to be tested by taking into account all relevant parameters that may affect the design. Then propose and revise these parameters to identify their relationship to the design conditions in order to determine and choose the best parameters after understanding their effects on the design to generate a wide range of optimum design solutions and alternatives (Hassan, 2016).

In the literature, there are many studies that focus on enhancing daylight availability while reducing energy consumption at urban and building levels in different building types. Thus, these studies propose different parameters to enhance daylighting and energy consumption. While reviewing some of these studies, a number of parameters were concluded that have a significant impact on the building performance as shown in the Table 4.8.

Table 4.8: Building scale parameters to enhance the indoor environment.

Study	Studied Parameters		Building Type
Urban Scale Parameters			
(Alzoubi & Dwairi, 2015)	Setback Distance, Building Height	Energy consumption (Heating Loads)	Residential building
(Saada, 2016)	Setback Distance, Building Height	Daylighting	Residential building
(Arifin et al., 2017)	Building Separation Distance	Daylighting	Residential building
(Li et al., 2006)	Angle of Obstruction (depend on separation distance and building height).	Daylighting Performance and Energy Use	High-Rise Residential Building
(Sun et al., 2017)	Separation Distance and Building Height	Daylighting and Energy consumption	Office Building
(Amer & Attia, 2014)	Reflections of the Outer Facades.	Daylighting	Residential building
(Salvati, Coch, & Morganti, 2017)	Site Coverage of the Building	Energy consumption (Heating and Cooling Loads)	Residential building
Building Scale Parameters			
(G. Kim, Lim, Lim, Schaefer, & Kim, 2012)	External and internal shading devices	Energy consumption (Heating and Cooling)	Residential building
(M. Kim, Leigh, Kim, & Cho, 2015)	External shading device	Cooling loads and daylighting	Residential building
(Samaan et al., 2018)	WWR, shading devices, shading projection, space orientation, glazing types, wall type	Daylighting, Cooling loads	Educational buildings
(Liu & Ning, 2019)	WWR, glazing type, wall type, artificial lighting types	Daylighting, thermal energy consumption	Educational buildings
(Lee, Jung, Park, Lee, & Yoon, 2013)	WWR, glazing type, orientations, climate	Daylighting, thermal energy consumption	Office building
(Saada, 2016)	WWR, shading devices, orientations	Daylighting	Residential building
(S. Chen et al., 2020)	Building Shape, Building Orientation, Building Wall Insulation, Window Glazing, WWR.	Energy Consumption	-
(Li et al., 2006)	Building area ,orientations, window area (WWR), glass type, shading and external obstruction	Daylighting performance and lighting energy consumption	Residential building
(Arifin et al., 2017)	Building area ,orientations, window area (WWR), glass type, shading and external obstruction	Daylighting	Residential building
(Elghamry & Hassan, 2020)	window parameters (shape, design, sizes, position and orientation)	Thermal comfort, energy consumption, cost, and environment effect (CO2 emissions).	Office building
(Shaeri, Habibi, Yaghoubi, & Chokhachian, 2019)	WWR	Total annual energy of cooling, heating, and lighting	Office building
(Gregg, 2018)	Glazing area, window type, glazing location, solar control elements	Daylighting, Overheating	Residential and non-residential buildings

After reviewing above literature, it could be clear that the significant issue for enhancing the building performance firstly occurred by determining a set of linking parameters that affect both the daylighting and thermal energy performance of the residential spaces at the same time by using different evaluation methods such as simulation. Secondly by testing these selected parameters on the proposed prototype within urban context cases to determine the optimum design alternatives. After the parametric study was conducted, the sensitivity analysis method was used to test the effect of selected parameters on the daylighting and energy performance one at a time by changing one variable at a time and keeping other constant, in order to study the impact of each factor separately from the others to completely understand their effect on the building performance (Hassan, 2016).

4.8. Summary:

In this chapter, the methodological steps that were used to achieve the thesis objectives are illustrated. One of the main objectives is to evaluate the impact of regulated setbacks distances on the indoor environment performance. To achieve this, the most common design prototype for multi-story residential buildings in Palestine was formed and modeled according to the different quantitative and qualitative methods. This study concentrates on apartment buildings because they have become more common over the past decade, especially in urban areas, in spite of the traditional preference for detached houses. It is estimated that over 62.3% of the households live in multi-story buildings.

A POE survey was used to understand the problems facing residential apartments in Palestine, also it can be used as an assessment tool. According to the literature review, the most effective method in the assessment process was the simulation tool, which was used to test the impact of setback regulation on the proposed urban context scenarios and compare the results with base cases without adjacent buildings. In addition, the methods used in the optimization phase of building performance were presented, and the parametric simulation with sensitivity analysis to choose the best parameters that enhance the quality of the indoor environment was explained in detail.

Chapter Five

5. Evaluating the Impact of Setbacks Regulations:

5.1. Preface:

Despite the Palestinian government's growing concern about building regulations', it has been also a concern to energy-efficient building design and to the design of green buildings. The impact of these regulations and guidelines on the indoor environmental quality by means of natural daylight availability and thermal energy performance, has not been considered. Meanwhile, these regulations and guidelines provide only general requirements, techniques and treatment methods to improve the quality of the indoor environment in buildings without any concern about the its effectiveness on the local built environment in Palestine under existing building regulations, or providing detailed suggestions to improve the residential building's performance, providing occupants need's and reduce the negative impact on the environment and human. This study will focus on one of these regulations which is "the setbacks between buildings in the residential zones".

In densely constructed residential urban contexts in Palestine, buildings are highly shaded by each other. The setback distances between buildings in this situation remain the only space from which natural daylight and solar radiation penetrates through residential building indoor spaces (Alzoubi & Dwairi, 2015). This demonstrates the necessity of taking setback distances and urban context characteristics into consideration during the design stage to enhance the indoor environmental quality.

This chapter presents a parametric study of using a computational simulation program to evaluate the impact of external obstructions such as local setbacks regulations between buildings on the indoor environment performance. The setbacks regulations impact will be studied and illustrated using a proposed typical residential apartment as a case study. Natural daylight and energy consumption (heating and cooling loads) are the main parameters to be studied in the assessment phase to represent the multi-story residential buildings' behavior under these regulations in different urban context scenarios. The assessment will consider the dual effect of natural daylight and thermal performance of the indoor environment, as the availability of natural daylighting could also be at the same time a risk of excessive solar heat gain, especially during summer. The assessment process went through three phases: first, the residential building prototype was modeled and simulated using Design Builder software as a base case model. Second, different urban context scenarios were generated in comparison to different base case scenarios. Third, the simulation results were compared with the base cases results. Then final results were collected for analysis.

A residential building prototype was modeled and simulated using Design Builder software, it is an effective design tool for analyzing and understanding building performance and the quality of the indoor environment (Samaan et al., 2018). Most energy consumptions in a typical household in Palestinian cities have been identified as domestic hot water, lighting, heating, and cooling appliances. Because of this, those energy consumption uses were targeted in this study for energy reduction and indoor environment enhancement.

5.2. POE Assessment Results:

The results will be used to emphasize and support the research problem in which apartments in multi-story residential buildings in Palestine especially in the residential B-Zone suffers from poor indoor environment in terms of daylighting and energy consumption. As shown in the POE survey results (see appendix 1C), a large number of residential buildings in residential B-Zone in Palestine don't meet the minimum requirements for comfortable indoor environment performance in terms of daylighting and solar radiation. Because of this, it is important to study the current status of residential buildings in residential zones. The results of the POE survey indicated that, for multi-story residential buildings at Palestinian urban context, the surrounding buildings have a negative impact on the overall comfort in the indoor environment in terms of daylighting availability, amount of solar radiation and on occupant's privacy. It became clear and obvious that there is a certain problem facing apartments in the multi-story residential buildings in Palestine as a result of the regulated setback distances. These results about adjacent buildings also indicated that the separation distances between buildings from the occupant's point of view was marked as "not sufficient" performance.

5.3. Assessment Process Cases:

Before starting the assessment phase on different urban context scenarios, simulation is conducted for base case residential models that represent the residential building sector in terms of building size, typologies and types, building occupancy, building materials, and urban context parameters mainly by street orientations. The main objective in constructing the base case models is to evaluate the impact of adjacent buildings within current setbacks regulations on daylight and energy performance. To do so, the **base case models** were considered cases **without any adjacent buildings** from the surrounding directions to use as a measuring unit to quantify changes in daylight availability and energy consumption in the residential spaces when **adjacent buildings in all directions** surround the target building (**urban context cases**). Then, daylighting enhancement and energy savings percentages in the urban context cases were calculated compared to the bases case daylight and thermal energy load results.

As mentioned previously in the methodology chapter, the existing urban context cases in the Palestinian cities' formulation affected by many factors which include the location and orientation of the main street, site topography and residential zone classification. Until the impact of these factors on the indoor environment in residential buildings was confirmed, a simulation of these factors was conducted. The results proved that there is a significant difference between energy consumption for residential spaces at different orientations, however, the proposed optimization process may vary for the same apartment. The simulation results found that there are significant differences between different orientations in heating and cooling loads when the building is surrounded by adjacent buildings in all directions, see Figure 5.1 and Figure

5.2. The minimum heating loads were obtained in the south oriented street cases, while the minimum cooling loads were obtained in the north oriented street case.

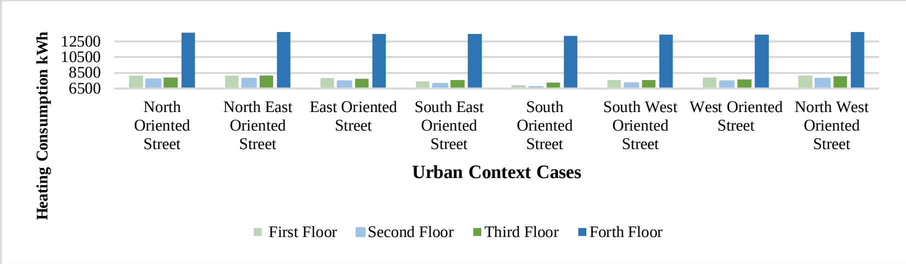


Figure 5.1: Heating loads in different urban cases in kWh.

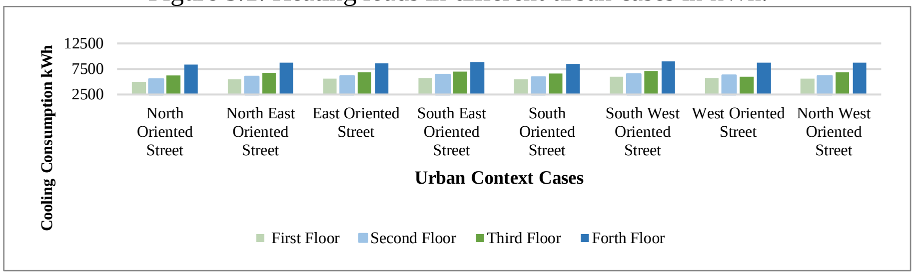


Figure 5.2: Cooling loads in different urban cases in kWh.

As for site topography, the different urban topography has a significant impact on building performance since it affected the reaching of natural daylight and solar radiation to the internal spaces due to the increasing of the building height in the higher lots when the target building surrounded by others with different lots elevation (see Figure 5.3).

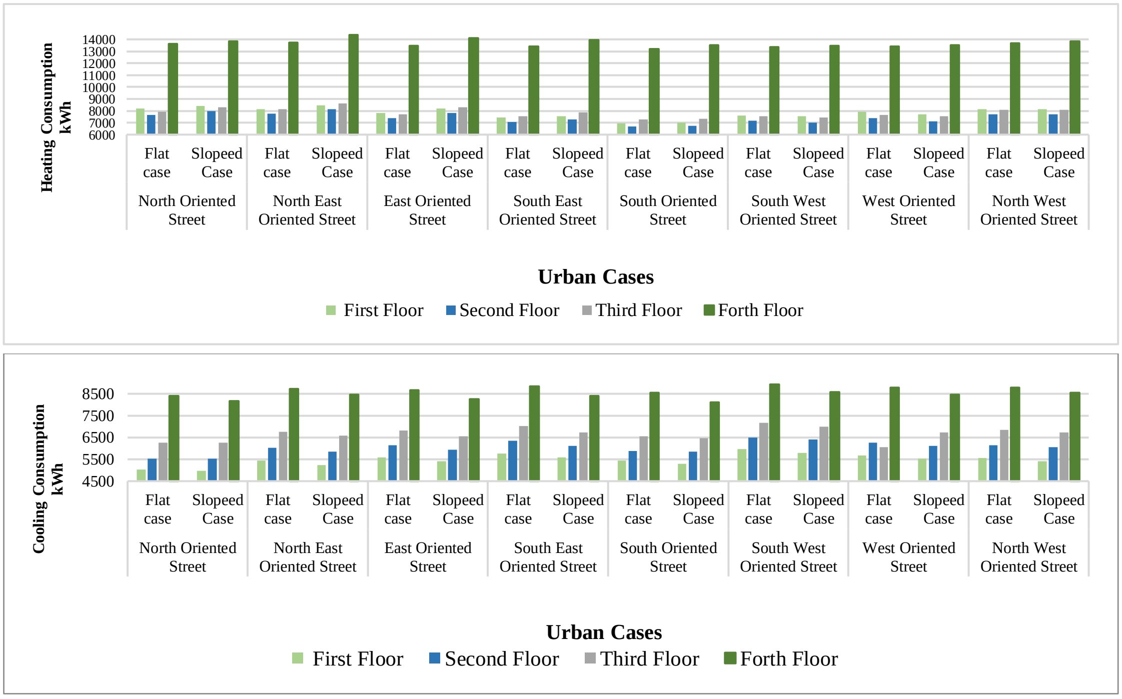


Figure 5.3: Simulation results for the flat urban context cases and sloped to prove the different impact between them .

5.4. Existing Setback Regulation Assessment:

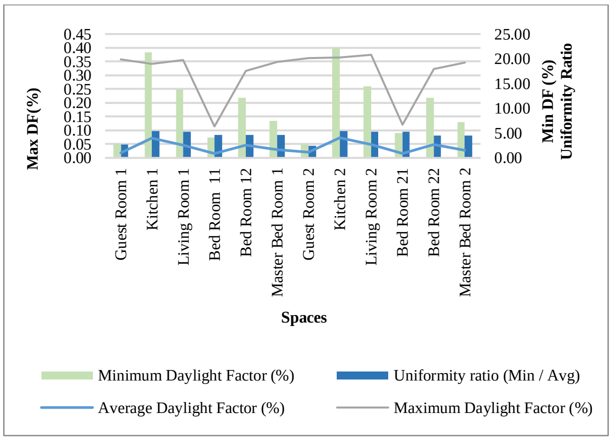
Daylighting and thermal simulations were numerically calculated by using the Design Builder simulation software on all base cases proposed and within different urban context scenarios to study the impact of setbacks distances on the daylight availability and thermal energy performance in living spaces and bedrooms. Daylighting simulation was performed in CIE overcast sky conditions, and the performance for residential spaces was investigated in terms of the average Daylight Factor (DF). According to standards, the acceptable average daylight factor (DF) is at least 1% in bedrooms, 1.5% in living rooms and 2% in kitchens (Li et al., 2006). Thermal performance assessment was conducted in terms of energy consumption in summer and winter (heating and cooling loads). The simulation period starts from 1st of January to 31st December in all cases to determine the required energy in each floor and in each space. In order to estimate total heating and cooling loads in each space, default settings of Design Builder software are used; a naturally ventilated and boiler hot-water option.

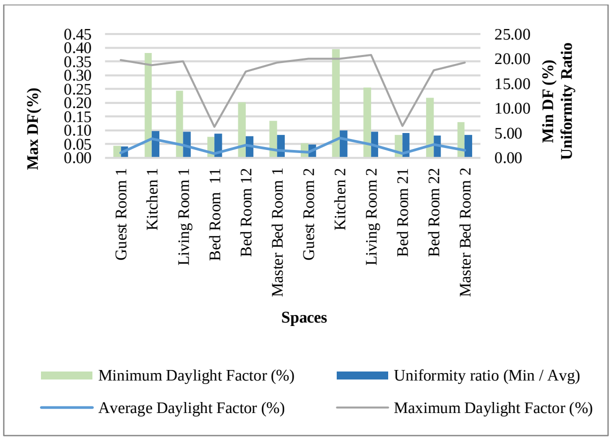
5.4.1. Base Cases Results:

Simulation was done for the eight base cases scenarios without any adjacent buildings in all the previously mentioned street orientations. In these cases, all residential spaces were naturally ventilated. This phase was conducted to analyze the impact of external obstruction buildings on the indoor environment. The simulation of all base cases results shows that the average daylight factor in most of the residential spaces is within an acceptable range which is either equal to or even higher than acceptable standards in first, second, third and fourth floors.

5.4.1.1.North Base Case:

The figures below present the average daylight factor in all residential spaces in each apartment. The results show that living room, kitchen and bed room spaces-12 in apartment 1 that were oriented to the west, north-west and south west sides respectively are located in the acceptable lighting zone with an average daylight factor (DF) more than the 1.5%, 2% and 1% respectively on all floors. Also, in the second apartment living room, kitchen, master bedroom and bedroom spaces-22 that were oriented to the north, east, north-east, south and south-east sides respectively have an average daylight factor more than 1% in bedrooms, 1.5% in living spaces and 2% in the kitchen. On the other hand, the guest room which was oriented to the north in all floors in the apartment No.1 and 2 and bedroom 11 oriented to the west in apartment No.1 in the first and second floors don't meet minimum daylighting requirements and standards. Also, DF in each space is almost constant in all floors with slight differences in some spaces.





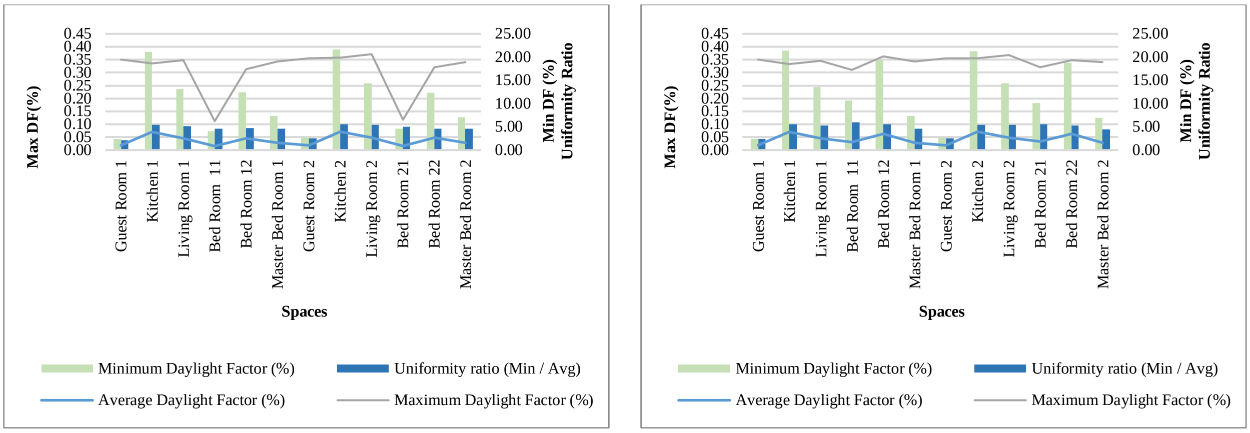
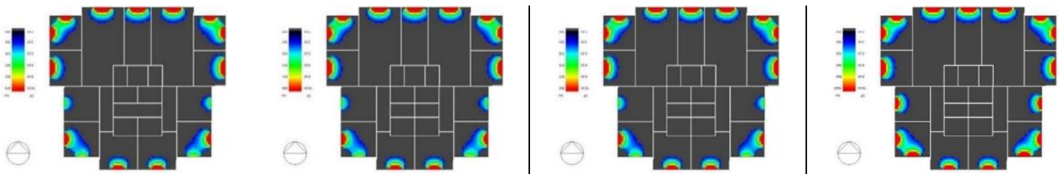


Figure 5.4: Daylighting in residential building , first, second, third and fourth floors (North Base Street Case).

Although the base case is not surrounded by any adjacent buildings, the efficiency and distribution of natural lighting within some of the residential spaces is not sufficient, due to the architectural design of residential buildings in Palestine, which is characterized by the prevalence of deep floor plans.



a. First Floor. b. Second Floor. c. Third Floor. d. Fourth Floor.

Figure 5.5 (a-d): Daylight intensity in North- base case.

As for the thermal energy consumption, Figure 5.6 and Figure 5.7 show the consumption of heating and cooling loads in apartments No.1 and 2, respectively. In this case, when the street is oriented to the north, cooling loads consumption increased when moving to the higher floors because of solar radiation penetration. Unlike heating consumption which has decreased on the second floor and increased on the third and fourth floors due to the heat loss through the building roof. According to the heating consumption, kitchens in apartment 1 and 2 oriented to the north-west and north-east are the worst spaces with the highest consumption. In terms of cooling consumption, living rooms 1 and 2 are the worst on all floors.

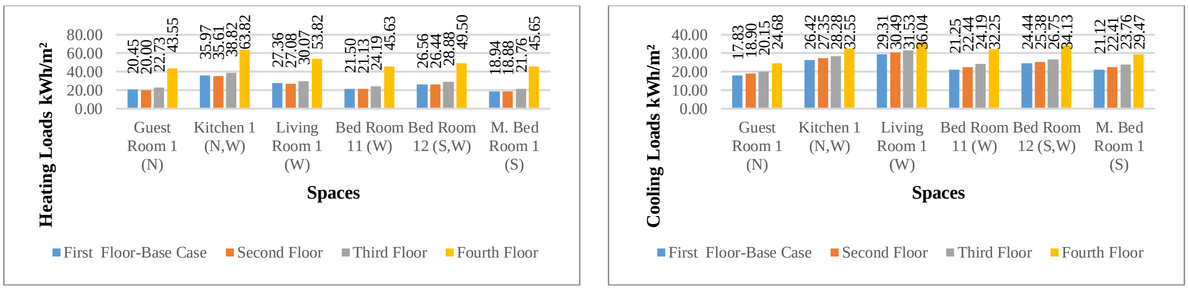


Figure 5.6: Heating and cooling loads consumption for the North base case in apartment No.1.

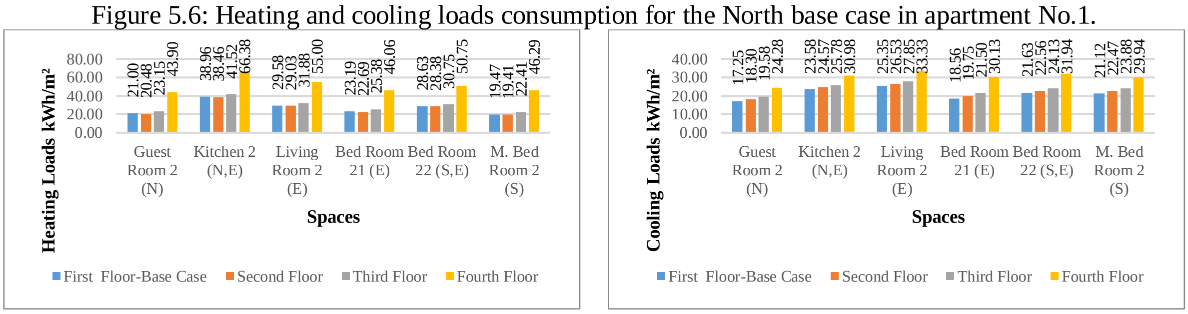


Figure 5.7: Heating and cooling loads consumption for the North base case in apartment No.2.

5.4.1.2.North-East Base Case:

Similarly, the typical residential building that consists of five floors and four residential floors with no external obstruction was assessed as the base case model when the main street was to be oriented to the north- east side. The average daylight factor value was almost constant for each space in all floors as shown in Figure 5.8. The results show that most of residential spaces in different residential floors received acceptable values of DF when the obstruction angles equal 0°. Deeper spaces layout like guest rooms which were oriented to the north eastern side in apartment No.1 and apartment No.2 are the worst spaces in receiving natural daylight because of the source of natural daylight available only in the nearby area on the window.

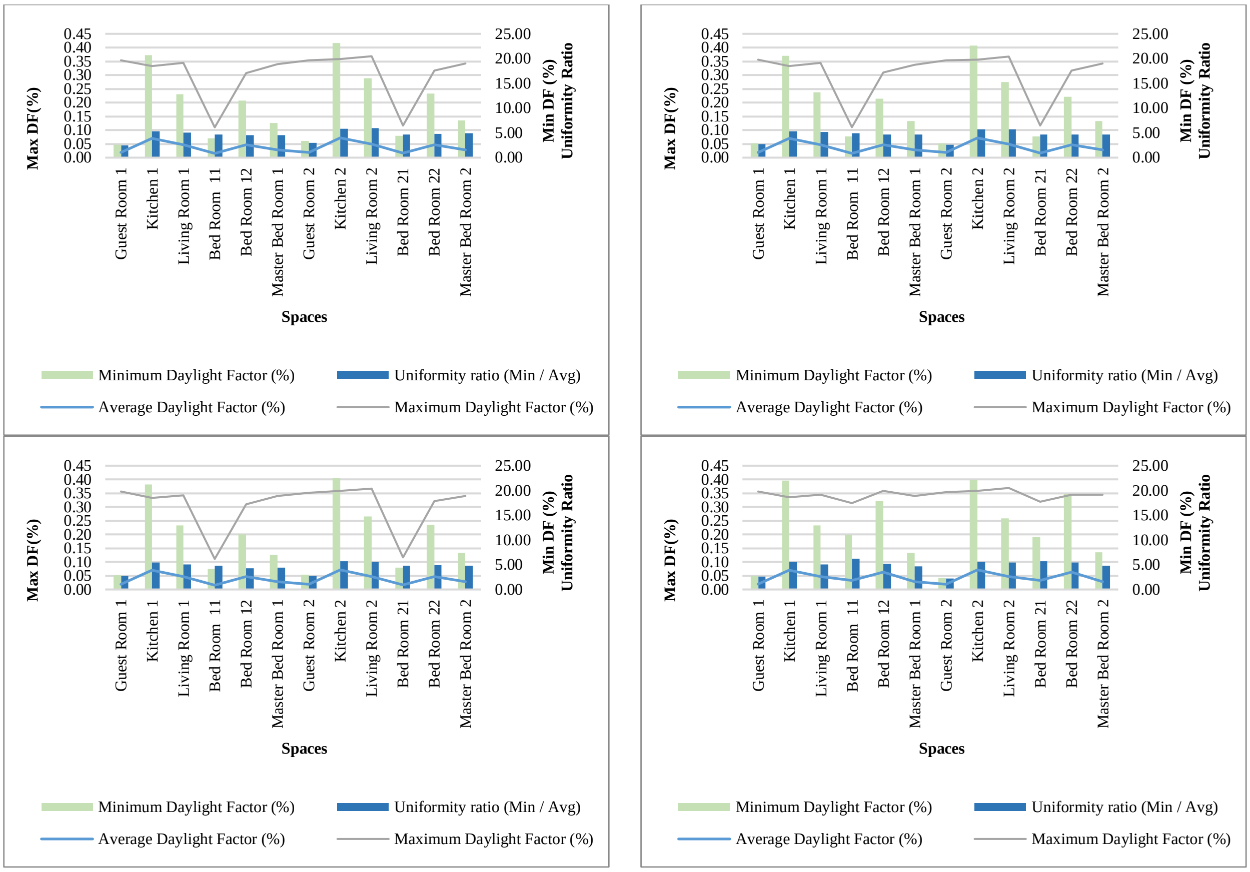


Figure 5.8: Daylighting in residential building , first, second, third and fourth floors (North-East Base Street Case).

In this case, the kitchen in apartment No. 1, which received morning and afternoon solar radiation, and kitchen 2 in apartment No.2, which received sunlight only from morning to before noon, are the worst spaces due to the need for large heating loads' consumption in all floors. This is because North-East and North-West facades received little amount of solar radiation in winter due to the solar path. In summer, bedroom12, master bedroom, and kitchen are the highest consumers of cooling loads in apartment No.1. These spaces received sunlight in the afternoon when its temperature is higher than morning time, thus increasing the heat gain through Southwestern and Northwestern facades. As for apartment No.2, the kitchen is the worst space for heating and cooling loads consumption, see Figure 5.9 and Figure 5.10.

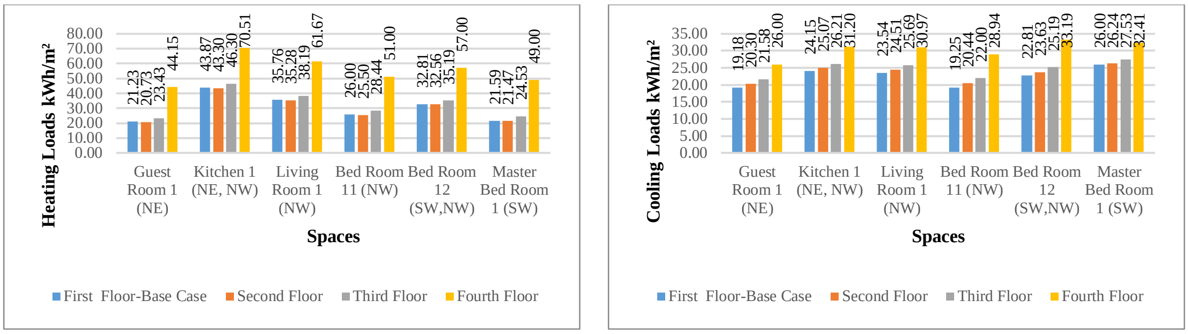


Figure 5.9: Heating and cooling loads consumption for the North-East base case in apartment No.1.

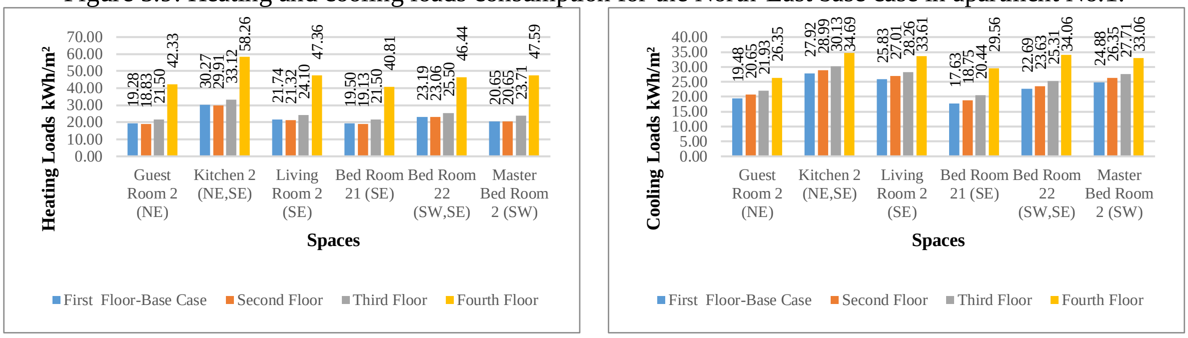


Figure 5.10: Heating and cooling loads consumption for the North-East base case in apartment No.2.

5.4.1.3.East Base Case:

When testing the base case building with the main street oriented to the East, the natural daylight intensity is sufficient in approximately all spaces except bedroom 1 and guest rooms in both apartments 1 and 2. As shown in Figure 5.11, the average DF values in these spaces are equal to or higher than standards.

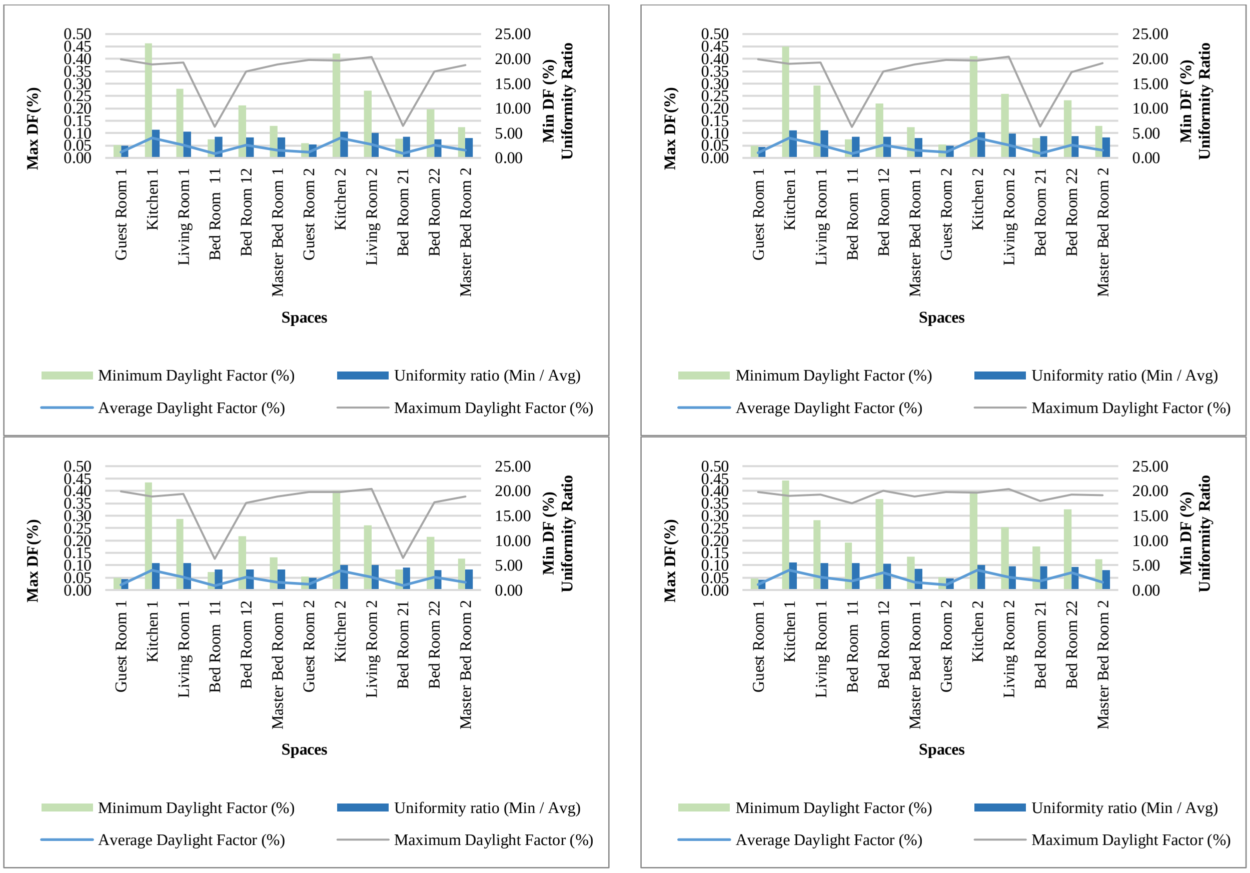


Figure 5.11 : Daylighting in residential building , first, second, third and fourth floors (East Base Street Case).

As for heating and cooling load consumption, in apartment No.1, spaces like guestroom 1 and bedroom 11 are considered the best in heating consumption in comparison with other spaces in apartment No.1 which are oriented to the east direction. On the other hand, only northern rooms consumed the lowest amount of cooling loads in summer. In apartment No.2, southern spaces consumed the lowest amount of heating and cooling loads. Which is because, in winter, they only receive solar radiation at noon when the sun is at low altitude angles, which allows sunlight to penetrate southern spaces. On the contrary, the sun's altitude angles are high on summer days, reducing the heat gain through the building envelope, which reduced the cooling loads required.

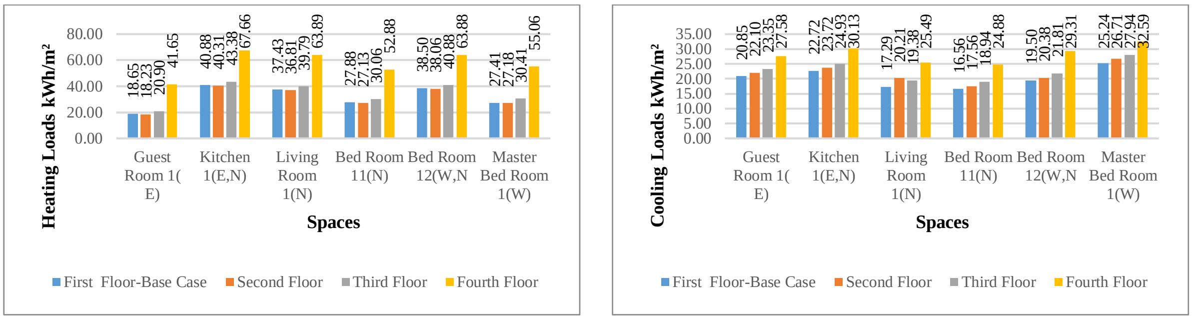


Figure 5.12: Heating and cooling loads consumption for the East base case in apartment No.1.

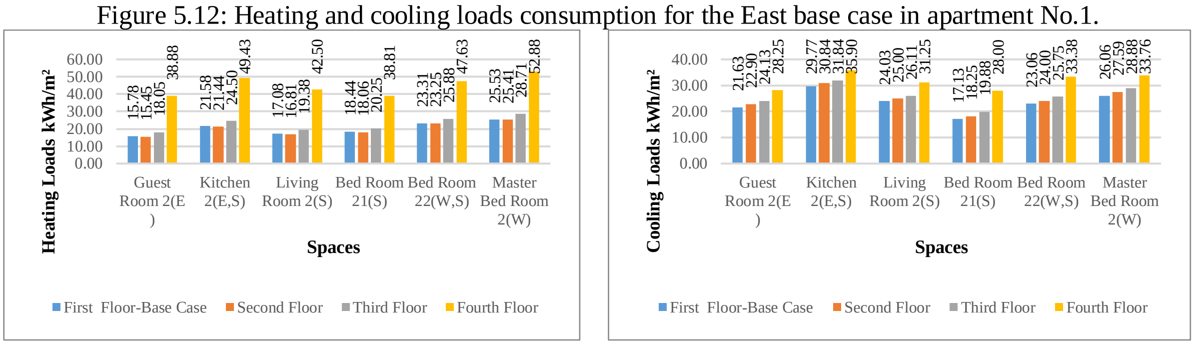
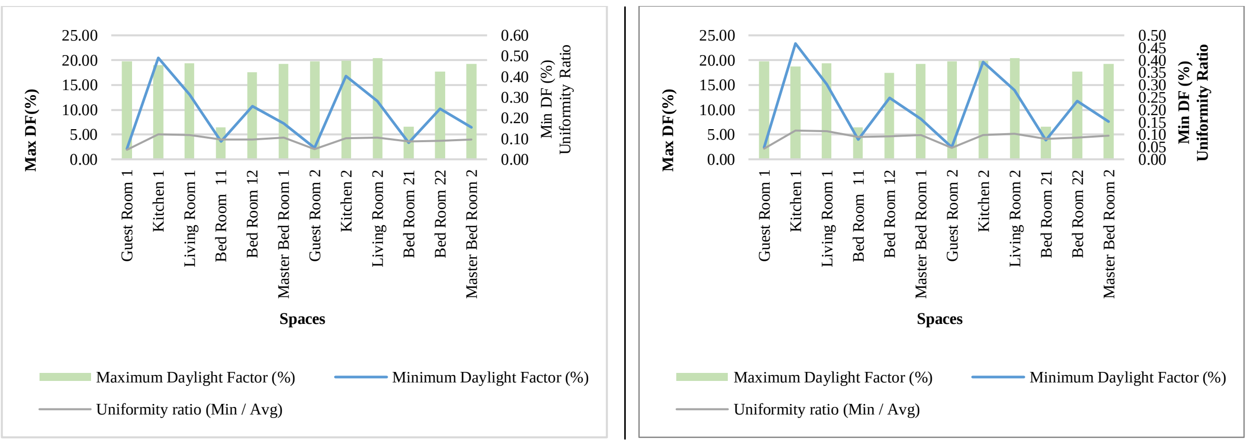


Figure 5.13: Heating and cooling loads consumption for the East base case in apartment No.2.

5.4.1.4.South-East Base Case:

As shown in the daylighting simulation results, kitchen 1, kitchen 2, bedroom 12, and bedroom 22 reflect the best performance in terms of daylighting availability due to the dual aspects of windows in these spaces. On the contrary, guest rooms in apartments No. 1and 2 received the lowest amount of daylight Factor on all floors due to their deep plan and received insufficient natural daylight intensity, especially in areas far from the window.



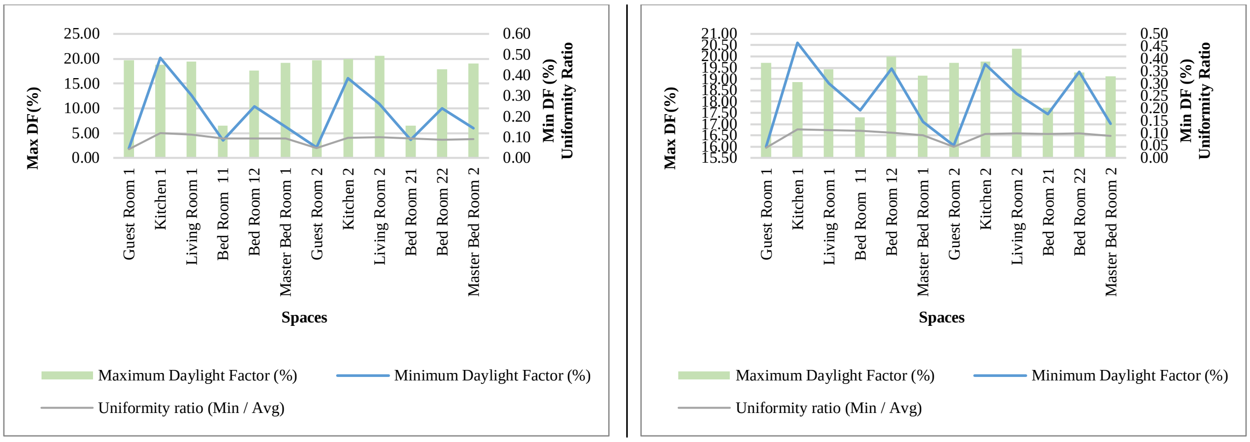


Figure 5.14 : Daylighting in residential building , first, second, third and fourth floors (South-East Base Case).

In apartment No.1, kitchen and bedroom 12 consume the highest amount of heating and cooling load per square meter respectively on all floors. In apartment No.2, the master bedroom, which is oriented to the north-west, is the highest heating load consumer on all floors. Simultaneously, the kitchen, which was oriented to the south-east and south-west, received solar radiation in summer for a long time from morning to afternoon. Thus, it gains a large amount of solar radiation during this period, which increases the cooling loads required to reduce the temperature gained, see Figure 5.15 and Figure 5.16.

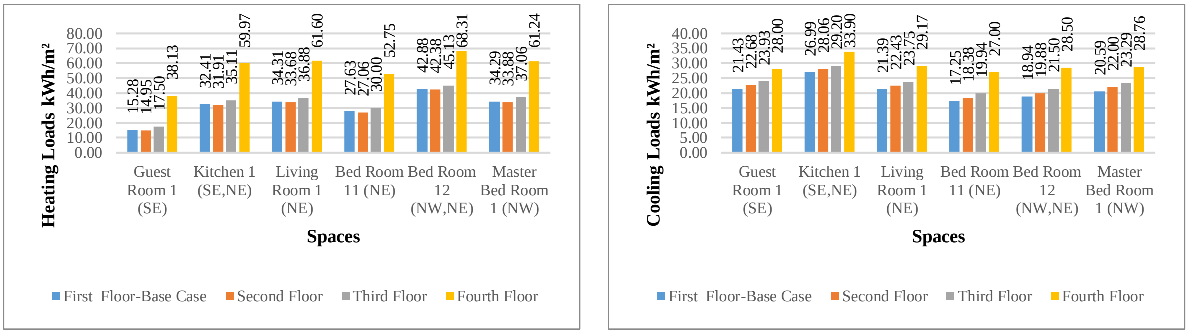


Figure 5.15: Heating and cooling loads consumption for the South-East base case in apartment No.1.

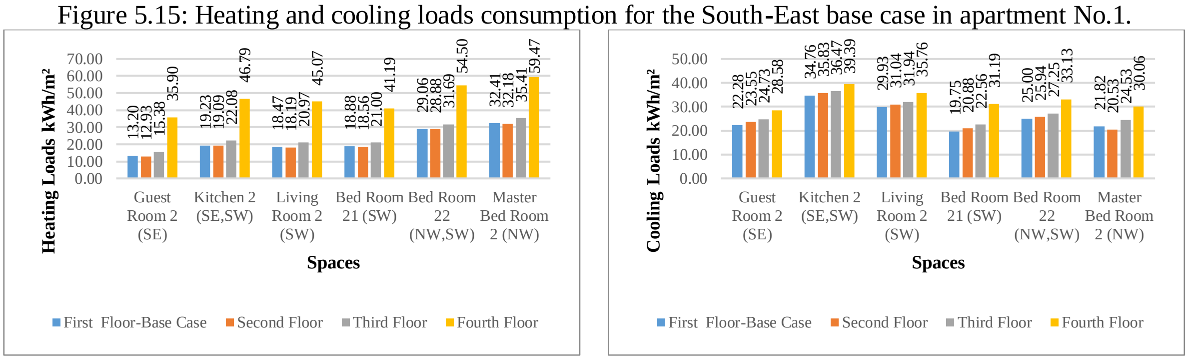


Figure 5.16: Heating and cooling loads consumption for the South-East base case in apartment No.2.

5.4.1.5.South Base Case:

The common design for residential buildings prototype in Palestine succeeds in providing adequate lighting in residential spaces when the building is not surrounded by any external obstacles or neighboring buildings. Where the Daylight Factor (DF) values are higher than 1% in the bedrooms, 1.5% in the living rooms, and more than 2% in the kitchens in apartments No. 1 and 2, as shown in Figure 5.17.

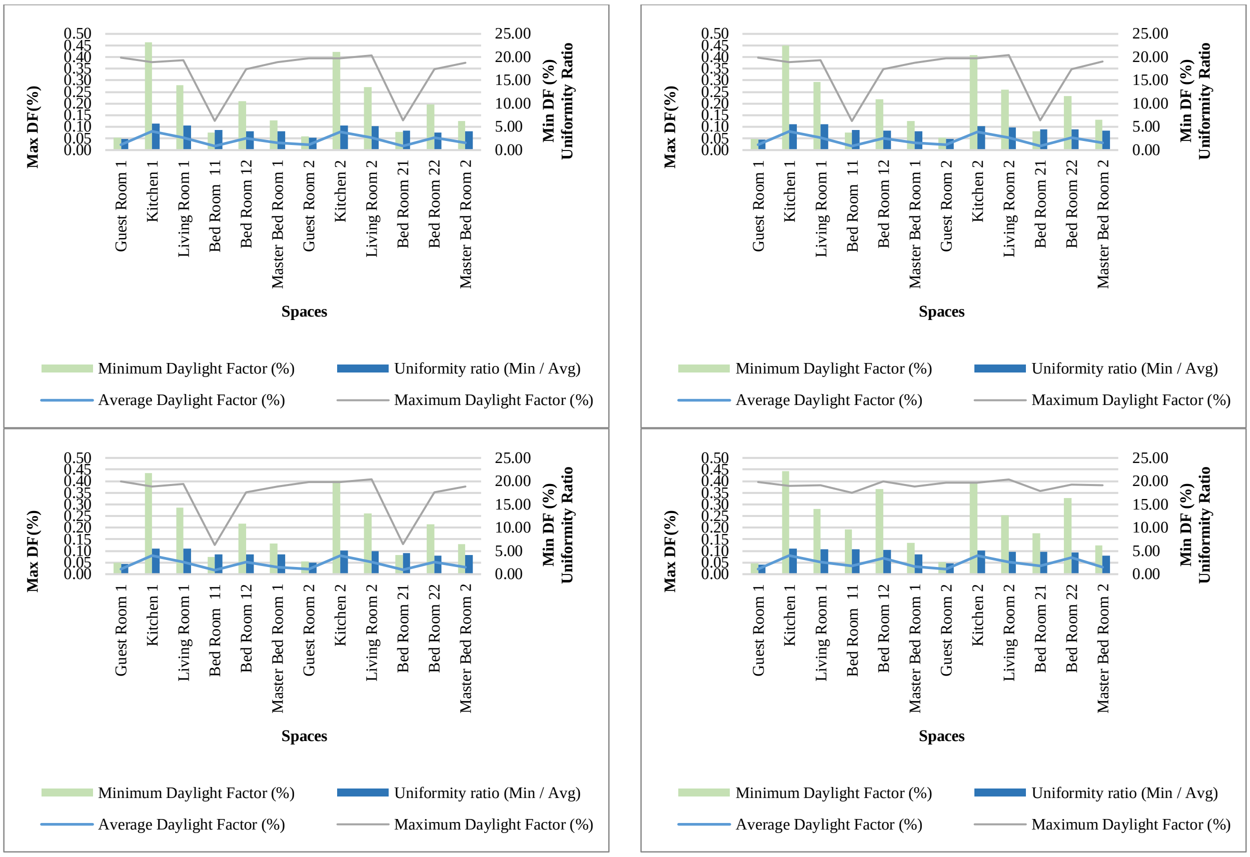


Figure 5.17 : Daylighting in residential building , first, second, third and fourth floors (South Base Street Case).

When analyzing heating consumption, there is a significant increase in consumption on the fourth floor due to heat loss through the building roof. When comparing heating consumption with cooling, the results show that the building consumes more heating than cooling energy, especially on the fourth floor. The guest rooms in apartments 1 and 2, which are oriented towards the south, consume less heating loads than other spaces. But in terms of cooling load consumption, the master bedrooms in apartment1 and 2 consumes the lowest consumption per square meter (see Figure 5.18 and 5.19).

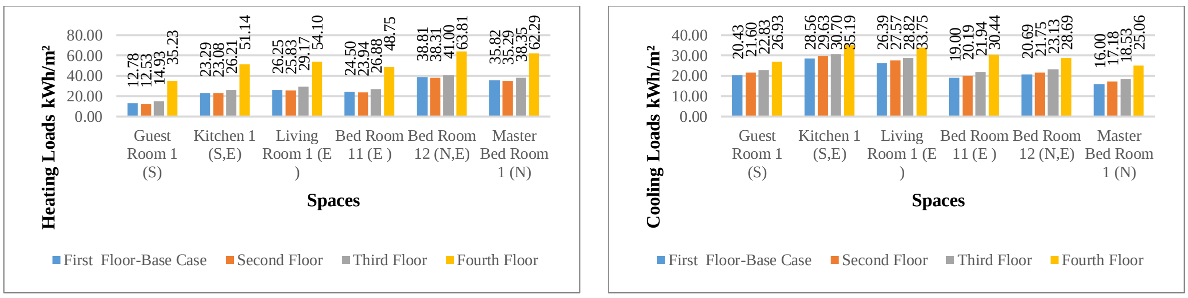


Figure 5.18: Heating and cooling loads consumption for the South base case in apartment No.1.

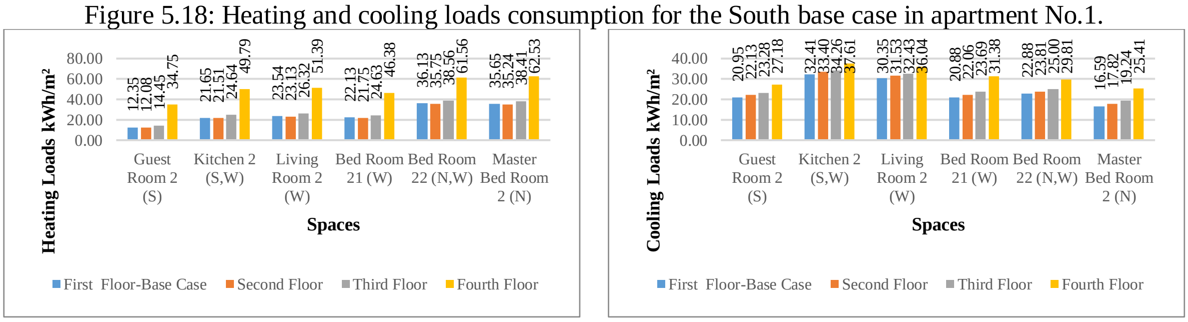


Figure 5.19: Heating and cooling loads consumption for the South base case in apartment No.2.

5.4.1.6.South-West Base Case:

The availability of sufficient daylighting intensity inside residential spaces contributes to reducing the energy consumption required to use artificial lighting during daylight hours to reach the desired day light factor. As noticed in all the previous cases, the surrounding environment which is an external obstacle also affects the amount of daylight penetrates through a space. In addition to other factors, such as building glazing characteristics, internal space layout and window to wall ratio. For example, in this south west base case, although there were no external obstruction from neighboring buildings, the lighting in some of the spaces was insufficient, as shown in Figure 5.20.

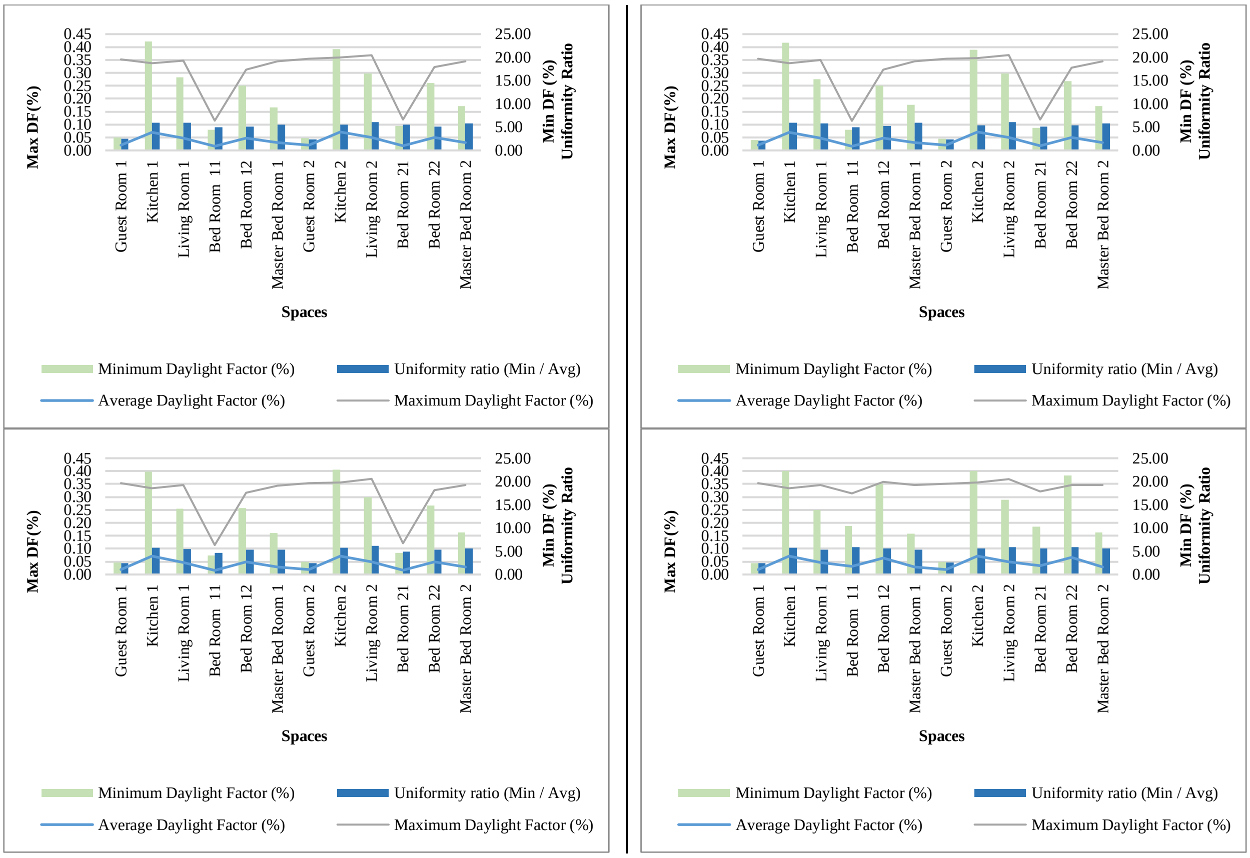


Figure 5.20 : Daylighting in residential building , first, second, third and fourth floors (South-West Base Case).

As for the thermal energy consumption of Apartment No. 1, except for the guest room, the kitchen heating consumption per square meter is less compared to other spaces on the first, second and third floor. On the fourth floor, the consumption of bedroom 11 is the lowest. The same things occurred to the cooling energies, the bedroom11 consumes the lowest energies on the first, second and third floor, but on the fourth floor, the consumption of the master bedroom is the lowest (see Figure 5.21). In Apartment No. 2, bedroom 22 and the kitchen consumed the highest values per square meter of heating and cooling loads respectively on all floors (see Figure 5.22).

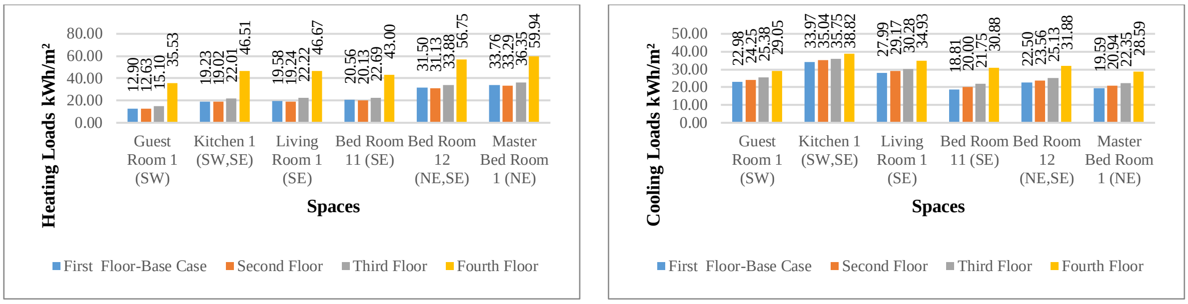


Figure 5.21: Heating and cooling loads consumption for the South-West base case in apartment No.1.

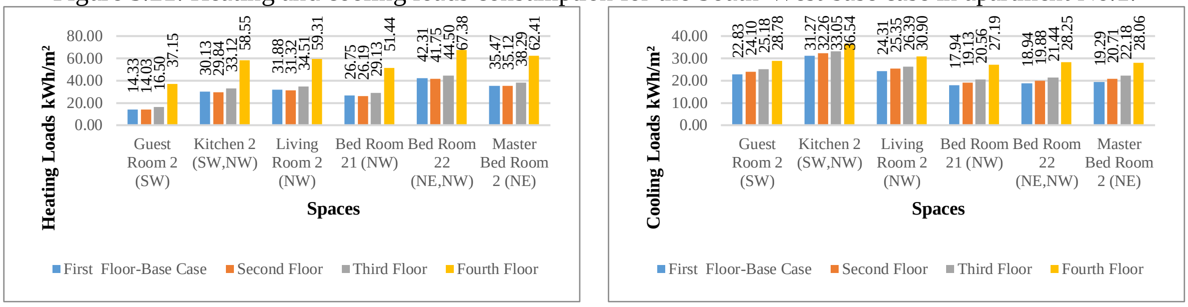


Figure 5.22: Heating and cooling loads consumption for the South-West base case in apartment No.2.

5.4.1.7.West Base Case:

When the main street is oriented to the west, most of the spaces in Apartment No. 1 are facing south. As for the spaces in Apartment No. 2, they are oriented to the north. As presented in Figure 5.23, most of these spaces have an adequate amount of natural daylight, and the average DF values are higher than the required standard values.

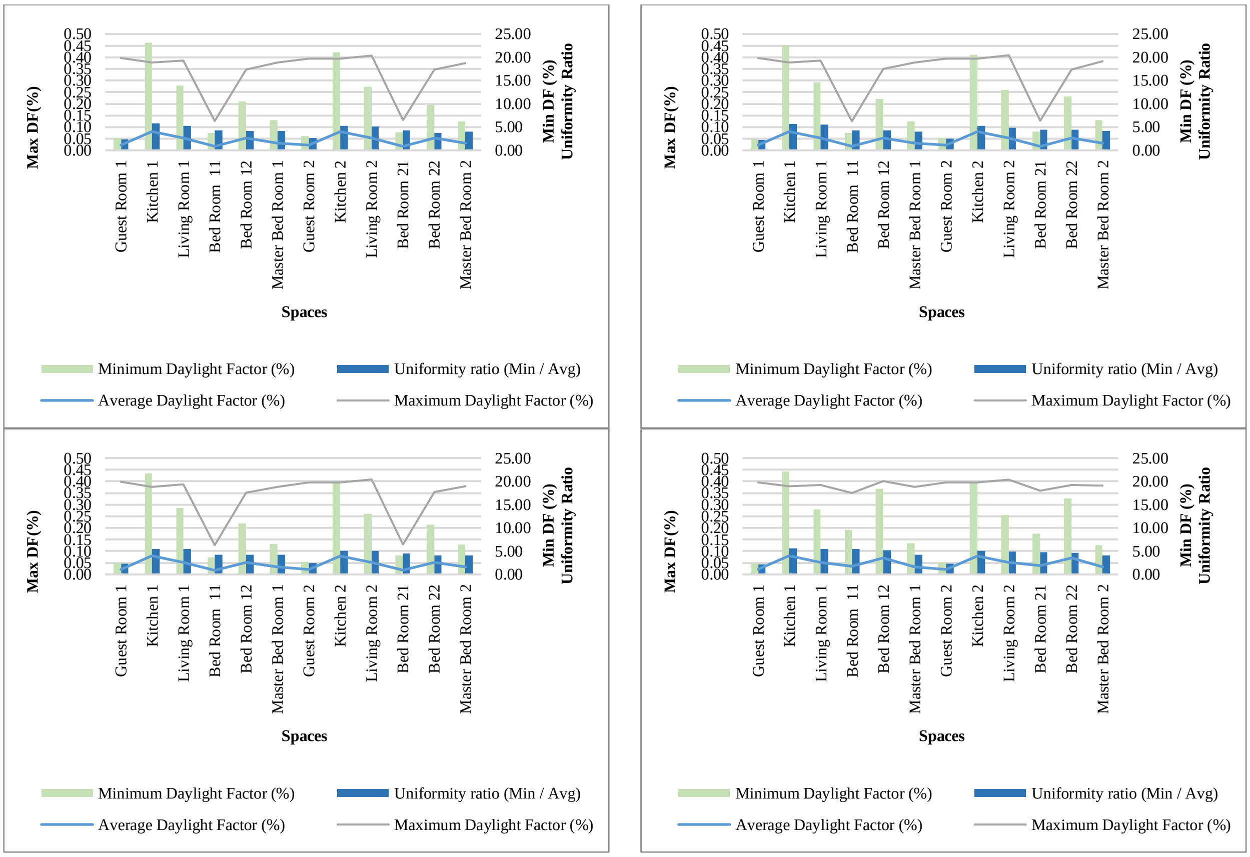


Figure 5.23 : Daylighting in residential building , first, second, third and fourth floors (West Base Street Case).

The living room in apartment No. 1, facing south, consumes the lowest heating loads after the guest room on the first, second, and third floors. In apartment No. 2, bedroom 21, which is oriented to the north, consumes the lowest heating loads per square meter after the guest room. As for cooling loads consumption, bedroom 11 and bedroom 21 in Apartment No. 1 and 2, respectively, consume the lowest values per square meter.

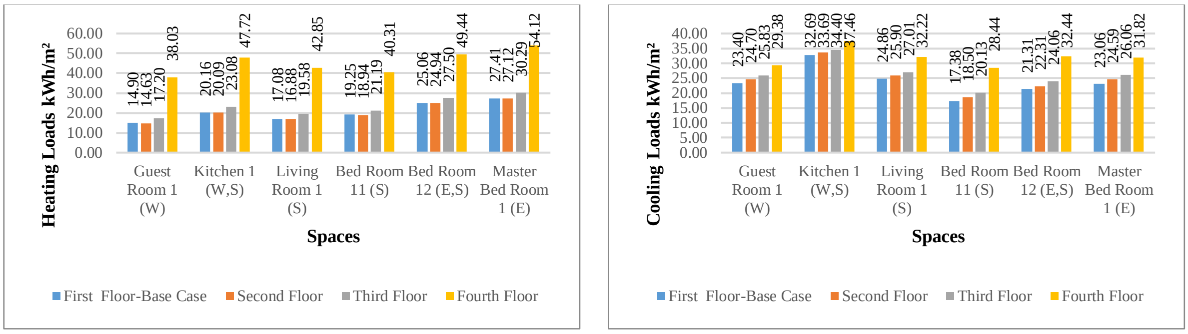


Figure 5.24: Heating and cooling loads consumption for the West base case in apartment No.1.

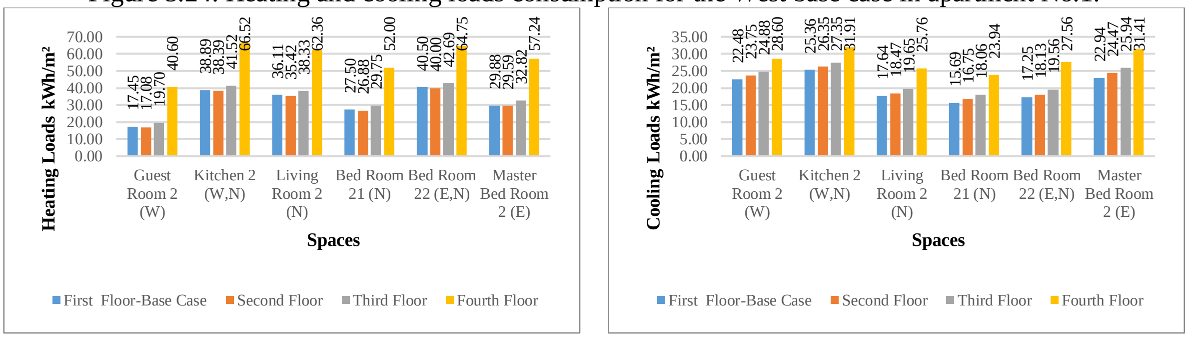
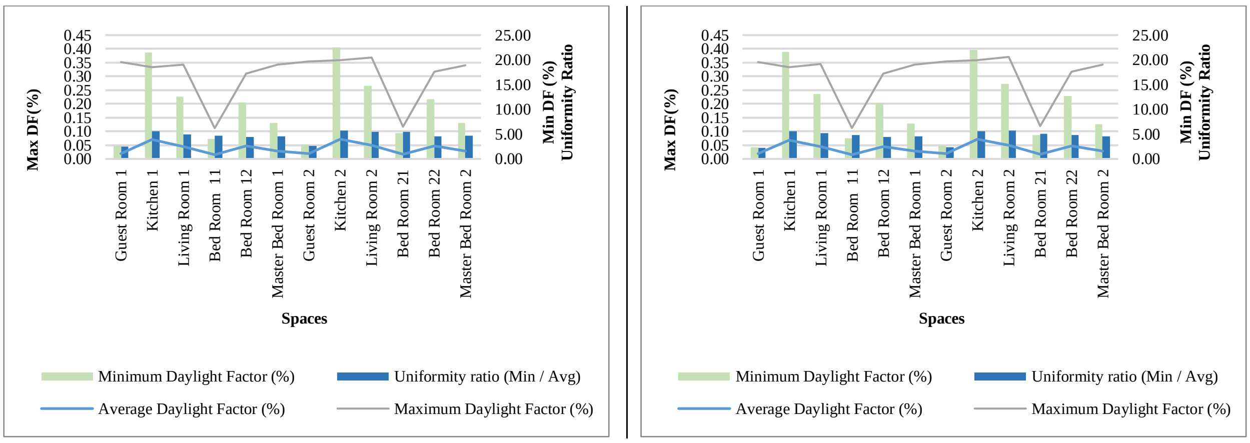


Figure 5.25: Heating and cooling loads consumption for the West base case in apartment No.2.

5.4.1.8.North-West Base Case:

In the north west base case, as in all previous cases, natural daylight in bedroom 11 and bedroom 21 is insufficient due to balconies connected to these rooms that prevent solar radiation and natural daylight from reaching the windows, which reduces the average Daylight Factor values. As for the other spaces, they are located in a comfortable lighting zone on all floors.



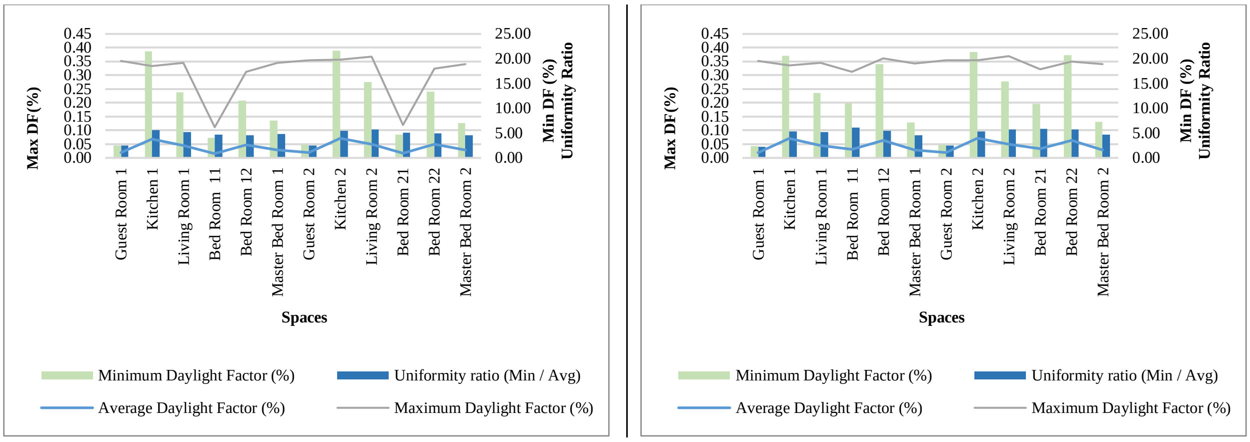


Figure 5.26: Daylighting in residential building , first, second, third and fourth floors (North-West Base Case).

As shown in Figure 5.27, kitchen in apartment No. 1, which oriented to the northwest and southwest consumes the highest cooling and heating loads than other spaces. In Apartment No. 2, the kitchen consumes the highest heating loads per square meter, and the master bedroom consumes the highest cooling loads as shown in Figure 5.28. Also, residential spaces at the ground floors consume less cooling loads than those at the top floors.

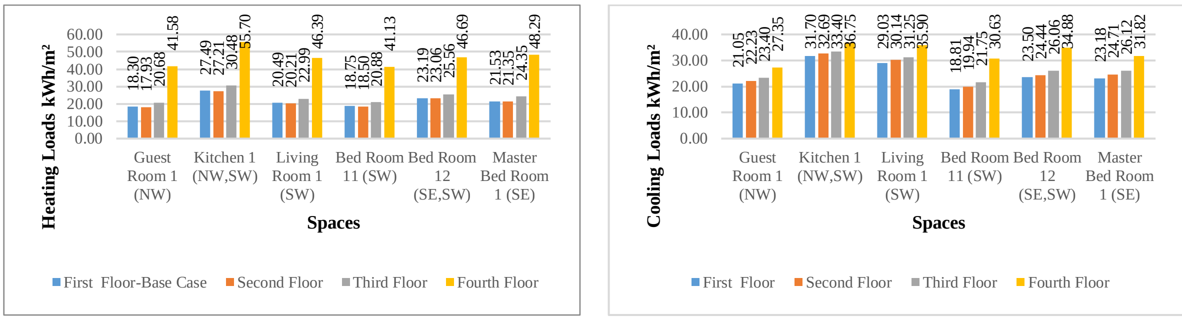


Figure 5.27: Heating and cooling loads consumption for the North-West base case in apartment No.1.

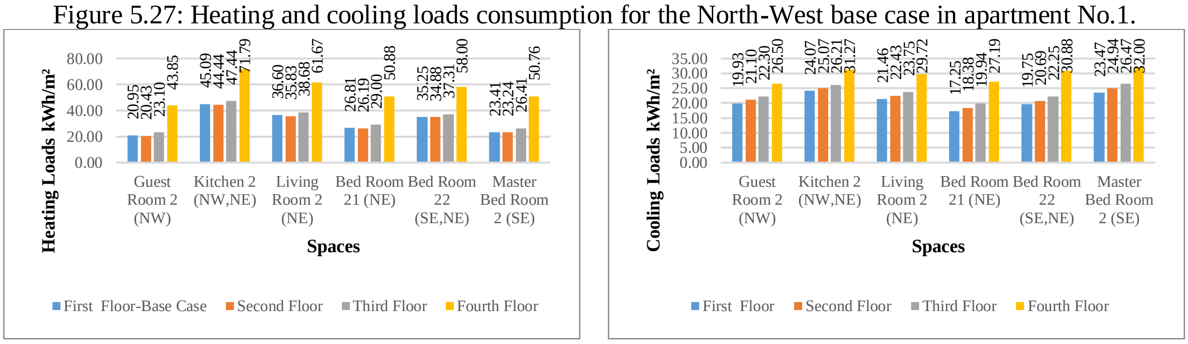


Figure 5.28: Heating and cooling loads consumption for the North-West base case in apartment No.2.

Based on all the previous base cases results, we conclude that most of the spaces in apartments 1 and 2 have sufficient daylight intensity equal to or higher than 1% in bedrooms, 1.5% in living rooms, and 2% in kitchens because there are no external obstructions which prevent sufficient daylighting from reaching residential apartments. As for the guest rooms, bedroom 11 and bedroom 21, they do not receive enough natural daylight due to the design of the building itself by means of its designed deep plan spaces such as guest rooms, as the lighting does not reach the deep areas far from the windows. As for bedrooms 11 and 21, the lack of adequate lighting on the first, second, and third floors is their connection to balconies that act as a shading element that blocks solar radiation and natural daylight.

5.4.2. Urban Context Scenarios Results:

To achieve the research main objective, which is to determine the negative or positive impact of the external obstructions on the indoor environment in multi-story residential buildings in residential B-zone, multi-simulations for different urban context scenarios were conducted to compare their results with the base cases results. A five floor building with adjacent buildings from all directions was established as a model to study the impact of the adjacent buildings on natural daylight and thermal energy performance. The urban context scenarios will be studied in accordance with the existing regulated setbacks in the residential B-zone, as shown in Figure 5.29 and Figure 5.30. In the standard lots, setback distances shall be drawn parallel at right angles from the front, side, and rear property line (see Figure 5.29). For slopped lots, the setbacks are measured perpendicular to the slopped property line without considering the building's outline boundaries form. In this case, the distances between some parts of the building and property line are greater than existing regulated setbacks, so the surrounding external conditions are not the same between the different spaces on the same side; thus, some spaces perform better than others (see Figure 5.30). Therefore, the standard lot was chosen for the purpose of this study since it is considered the critical case.

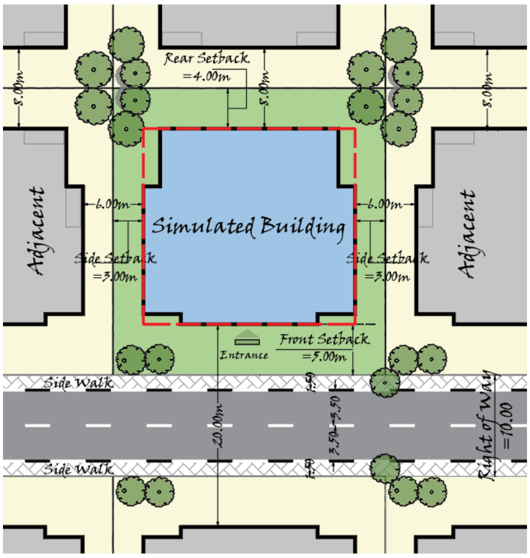


Figure 5.29: Setback Measurement for Standard lot.

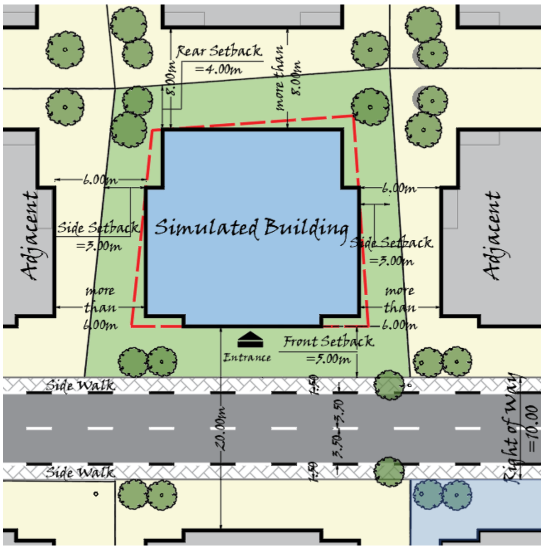


Figure 5.30: Setback Measurement for Slopped lot.

Different research has investigated the impact of the surrounding environment and adjacent buildings on the quality of the indoor environment and on natural daylight availability. Li and Lam studied the effect of external obstruction on the daylight availability in living, dining rooms, and bedrooms of a typical 5-story block under two different cases. The first case was by assuming that the adjacent buildings were the same height. The second case was by considering a 25 story high rise block was surrounding the reference building. The study found that daylighting level in the top floors is generally sufficient in case 1 more than case 2, however, the lower floors in both cases don't meet the minimum requirement of daylight due to the external obstruction at the current separation distance (Li & Lam, 2001).

Others have studied the impact of the surrounding environment and adjacent buildings by focusing on the angle of obstruction in comparison to the simulated building. This angle is defined as the angle between the horizontal line at the window sill level and the line at the highest point of the positive external obstruction building (in some studies from the center of the window)(Sabry, Sherif, Shawky, & Rakha, 2010; Sun et al., 2017). In other words, it is the relation between the distance between two opposite buildings. It can be used to give an indication about the daylighting level inside spaces. It is a tool to measure the impact of external obstruction on the natural daylight in the building. To meet DF requirements for dwelling, angle of obstruction (ɵ) should be between 25° and 45° for the bedrooms and should not be less than 10° for kitchens (Li et al., 2006). In other studies, for housing, obstruction angle should be at maximum 25^{o}. for Mediterranean climate at 35 latitude, the obstruction angle should be 40^{o} (P. Littlefair, 2001).

As shown in Figure 5.31 and Figure 5.32, the angle of obstruction on the first floor regardless to the orientation is higher than standards. This means that the daylight factor inside the first floor spaces is insufficient. Li et al. have used Energy Plus software to study the impact of external obstruction on the daylighting level by calculating angle of obstruction in a typical 51-storty residential building with six units per floor. The study revealed that, the daylight factor values on the lower floors is insufficient and many residential apartments in Hong Kong would have to depend on artificial lighting during daytime period (Li et al., 2006). Munoz et al. found that, daylighting level is affected by different variables such as frontal obstruction, orientation and building location. In open- plan office using Radiance program, the daylighting decreased when the frontal obstruction angle increased (Munoz et al., 2014).

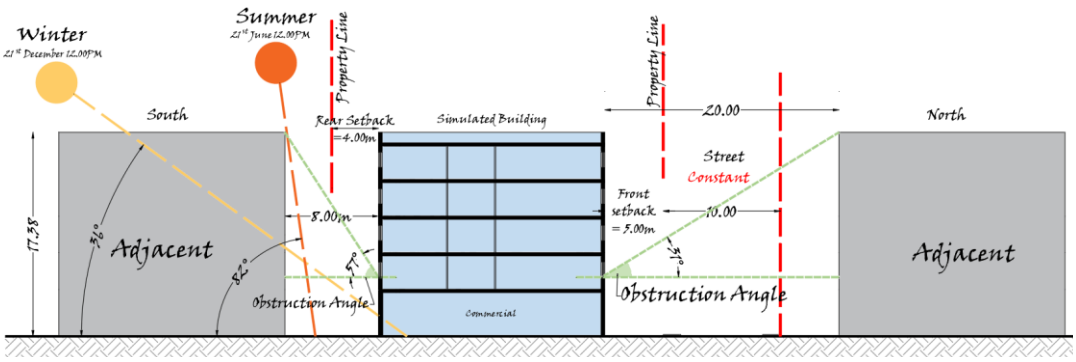


Figure 5.31: Angle of obstruction in the north and south sides.

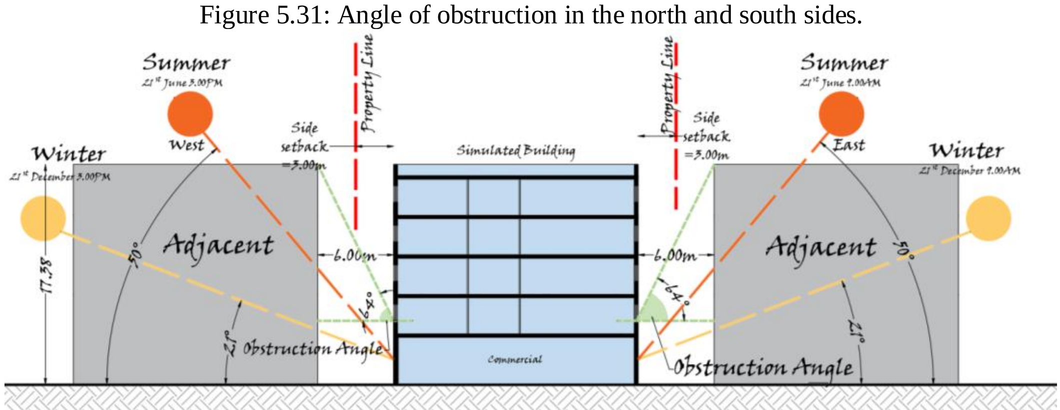


Figure 5.32: Angle of obstruction in the east and west sides.

In the assessment, the differences between urban context cases and base cases in the energy consumption for each floor was analyzed.

5.4.2.1.Street oriented to the North (Case No.1):

For a north oriented street and a maximum setback distance 20 m facing the north direction (front setback distance equals to 5m from land edge + street width 10m). In apartment No.1, the results show that all spaces oriented to the west, north and south did not meet the minimum required DF in the first, second and third floors such as bed room-11, guest room and master bedroom. However, spaces oriented to the west and south west such as the living room and bedroom -12 met DF standards in the fourth floor only. Only the north west oriented kitchen has a DF more than 2% in all floors. Similar results were obtained in apartment No. 2; the majority of spaces didn't meet the minimum daylight factor. In general, the DF was affected by the number of floors and has increased when moving from floor to another.

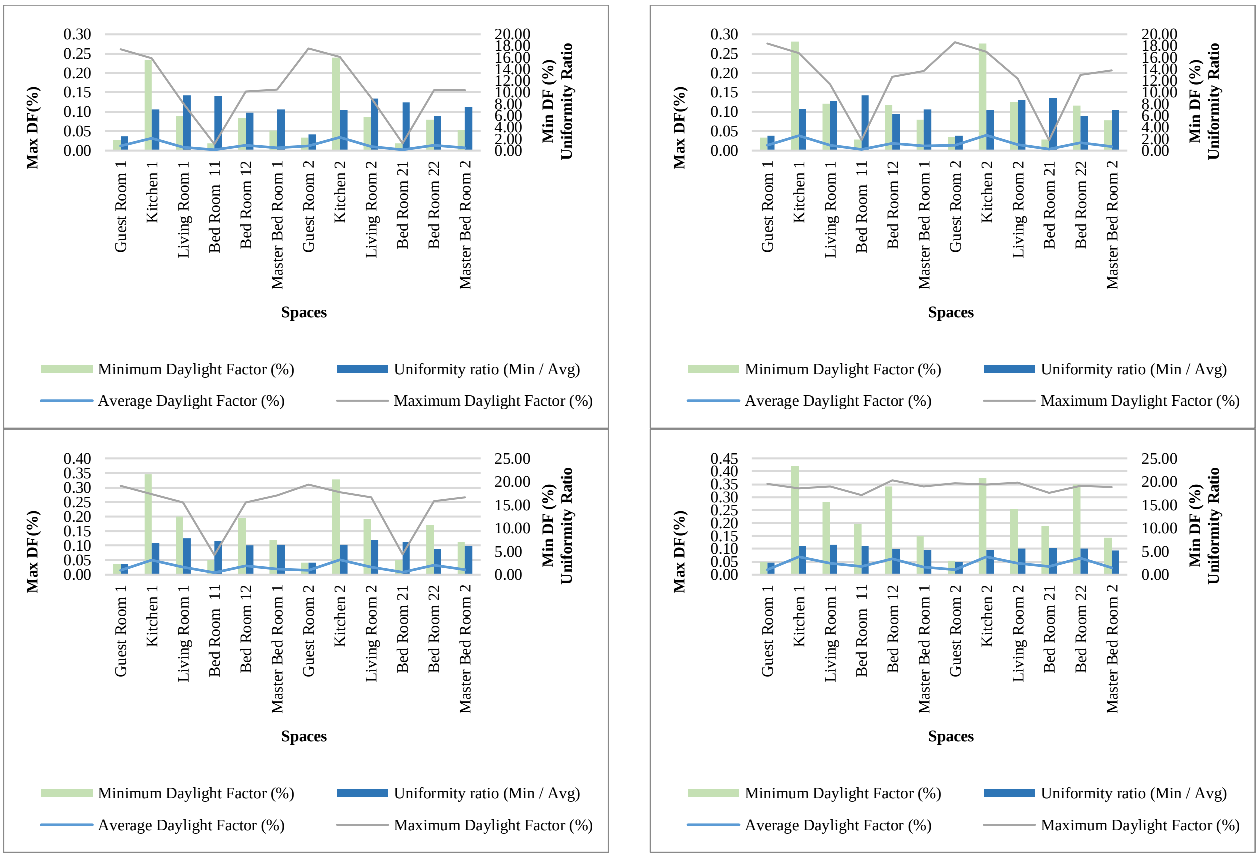
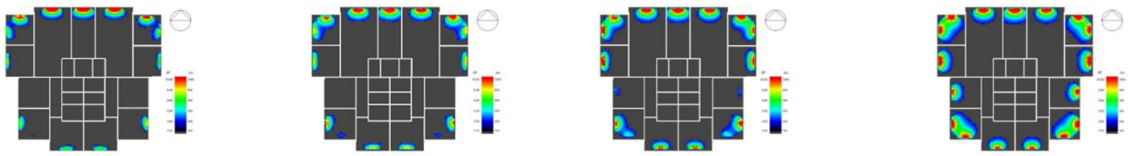


Figure 5.33: Daylighting in residential building , first, second, third and fourth floors (North Street Case).



a. First Floor. b. Second Floor. c. Third Floor. d. Fourth Floor

Figure 5.34 (a-d): Daylight intensity in the prototype- case No. 1.

First floor rooms are the lowest consumers in cooling energy. They consume 15.73 kWh/m^2 which is about 78% less than the consumption per square meter at the fourth floor (28.12 kWh/m^2) and 25.88% less that the base case. This is because case No.1 is surrounded by adjacent buildings that block the summer sun radiation from reaching to the building envelope and thus reduce the amount of solar gain. On the other hand, heating loads has raised 27.28%, 22.79%, 10.89% and 2.85% in the first, second, third and fourth floors respectively when compared to the base case scenarios.

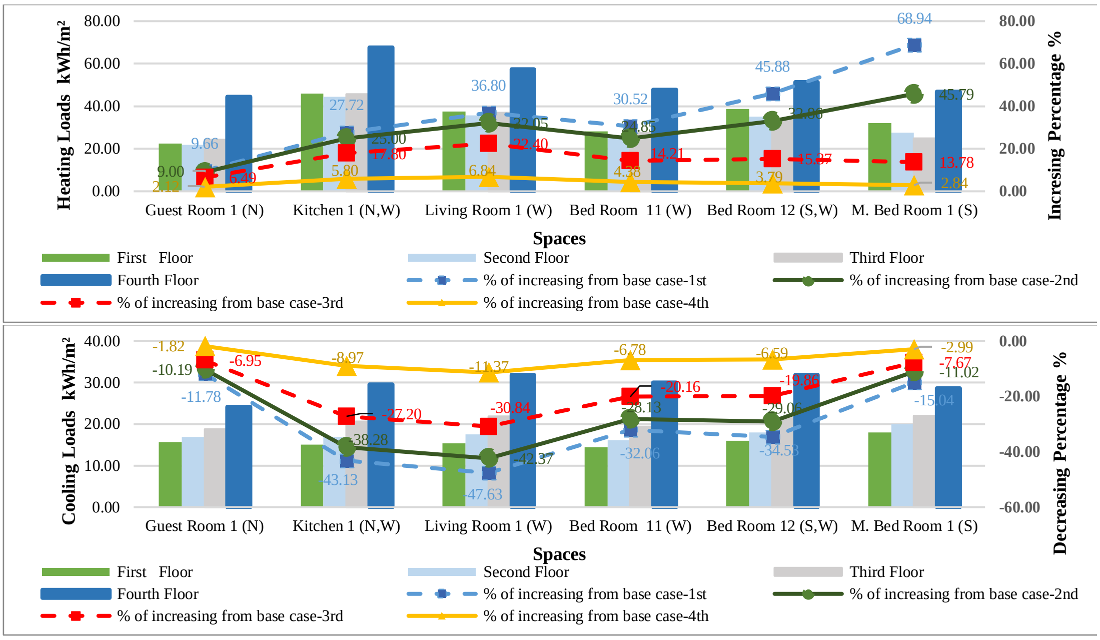


Figure 5.35: Heating and Cooling loads consumption in the North oriented street compared with North base case- Apartment No.1.

As shown in Figure 5.35 and Figure 5.36, south oriented adjacent buildings has caused 68.94% and 64.65% increase of heating loads and 15.04% and 13.37% decrease of cooling load in the master bedroom in apartment No.1 and 2 respectively. The decreasing percentage of cooling loads reached up to 47.00% in the living room in apartment No. 1 on the first floor, and up to 40.00% in the apartment No.2. It was noticed that road width doesn't have any effect on heating loads, be means larger road width didn't affect the heating loads consumption.

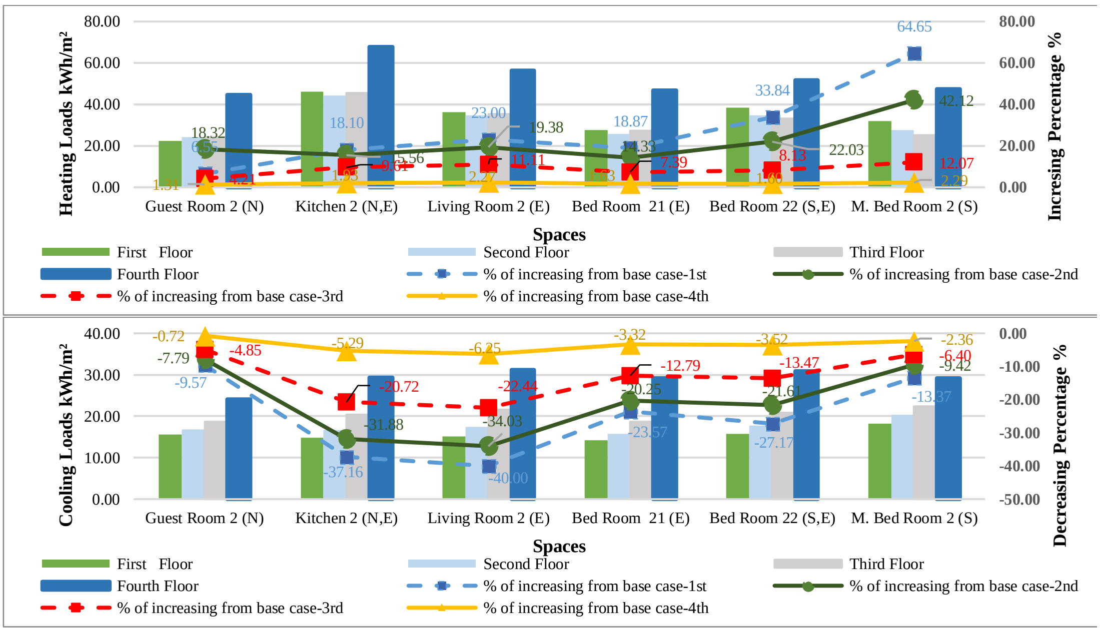


Figure 5.36: Heating and Cooling loads consumption in the North oriented street compared with North base case- Apartment No.2.

5.4.2.2.Street oriented to the North- East (Case No.2):

All results in all urban context cases showed that the daylight factor and the light distribution were the worst at the first floors. For a North-East oriented street, the adjacent buildings have a negative impact on the availability of daylight as well as its distribution especially on the first and second floors. In apartment No.1, the average DF in the first and second floors in bedroom 11, bedroom 12, and master bedroom is lower than 1%, which is the minimum required standard. As for the living room and guest room, adjacent buildings reduced the amount of natural daylight that penetrates through these spaces and decreased the average DF value from 2.5% to 0.6% in the living room on the first floor. Similar results were found at apartment No.2.

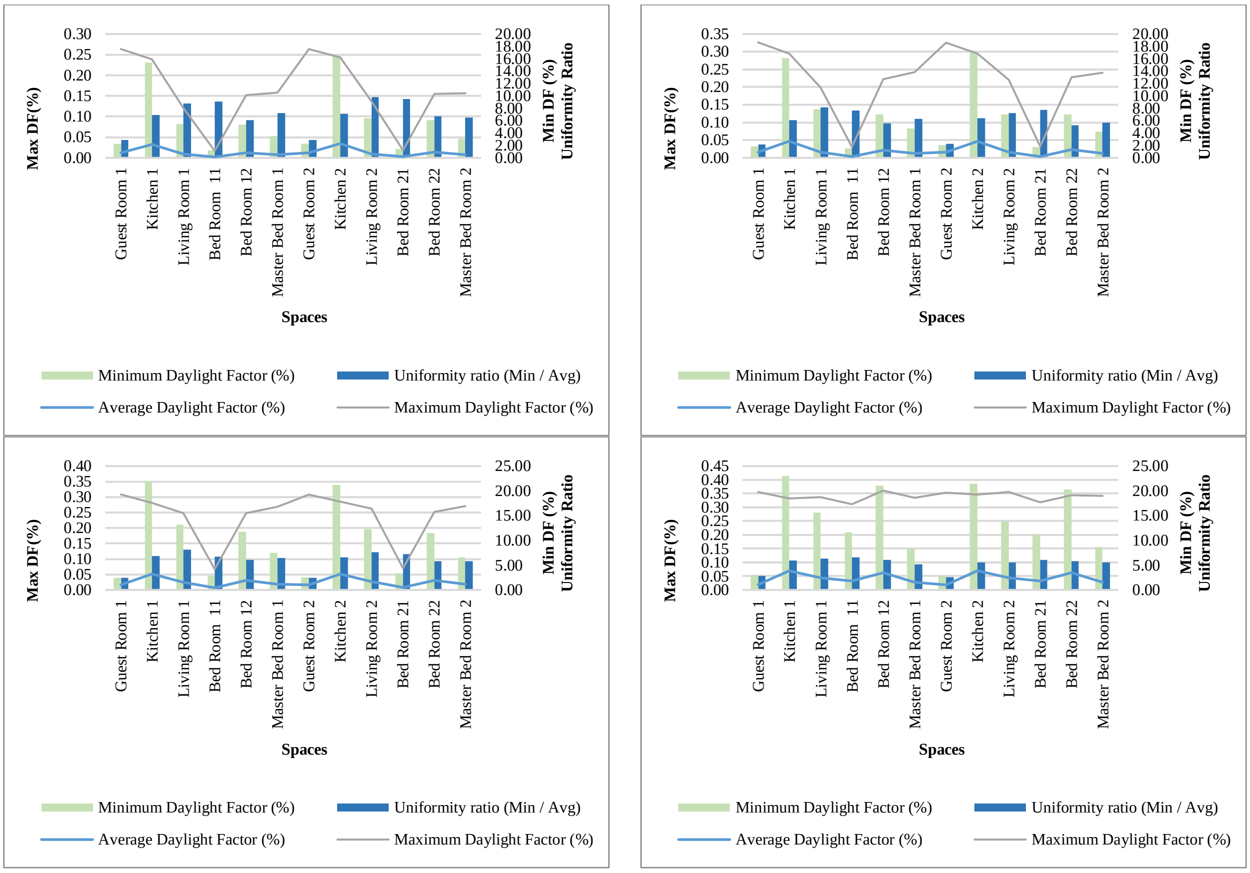


Figure 5.37: Daylighting in residential building , first, second, third and fourth floors (North-East Street Case).

For a North-East oriented main road, the required heating loads in winter from mid-November to mid-April if not surrounded by any adjacent buildings will be 24.83 kWh/m^2, 24.49 kWh/m^2, 27.24 kWh/m^2, 49.40 kWh/m^2 for the first, second, third and fourth floor respectively. When five-story buildings are placed to the south-east, south-west, and northwest at a distance of 6m, 8m, and 6m respectively as regulated by Palestinian Local Authorities, then the required heating loads will rise to become 31.28 kWh/m^2, 29.84 kWh/m^2, 30.83 kWh/m^2, 50.86 kWh/m^2 with an increasing percentage than a north-east base case scenario of about 26.02%, 21.98%, 13.17% and 2.96% for the first, second, third and fourth floors respectively. Figures below present the consumed heating loads in each space at the first, second, third and fourth floors in comparison with the increasing percentages than the base case. Therefore, it is considered the second highest consumer of heating energies than the base case after case No. 1 at almost all floors.

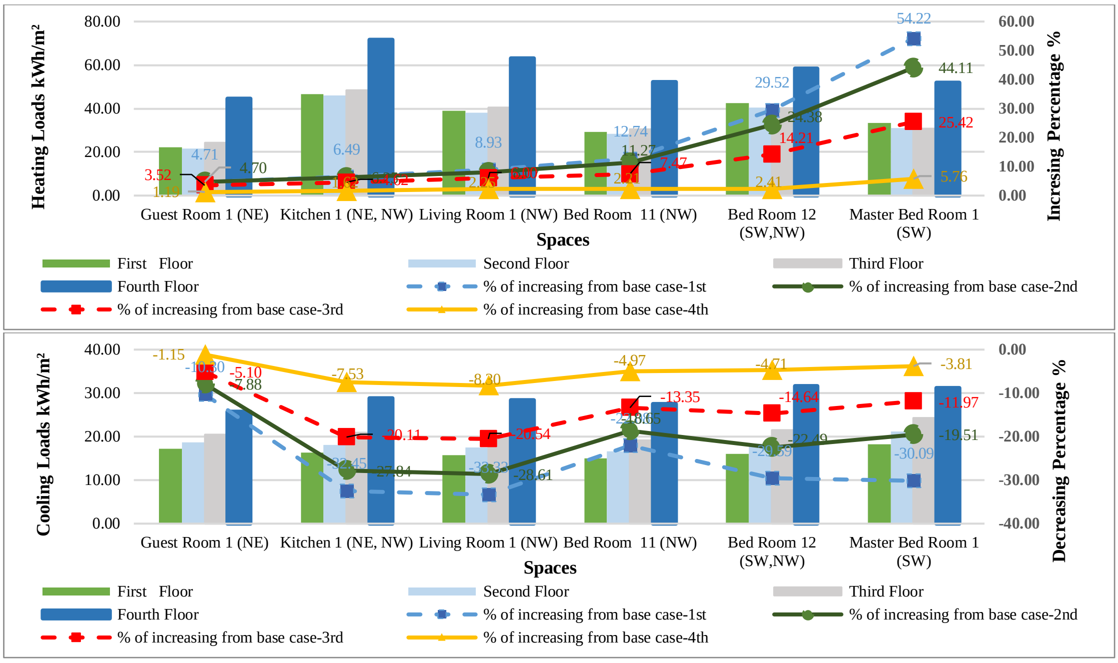


Figure 5.38: Heating and Cooling loads consumption in the North-East oriented street compared with North-East base case- Apartment No.1.

On the other hand, adjacent buildings have a significant influence on cooling loads consumption. The required cooling loads for the north-east base case when the building was not surrounded by any other buildings in all directions were 22.02 kWh/m^2, 23.06 kWh/m^2, 24.41 kWh/m^2 and 30.12 kWh/m^2 for the first, second, third and fourth floors respectively. This was reduced by 22.02%, 16.67%, 10.55% and 3.36% at the first, second, third and fourth floors respectively since the cooling loads were minimized and has recorded 17.17 kWh/m^2, 19.21 kWh/m^2, 21.84 kWh/m^2 and 29.10 kWh/m^2 respectively from first to fourth floor when the target building was surrounded by five story buildings from all sides.

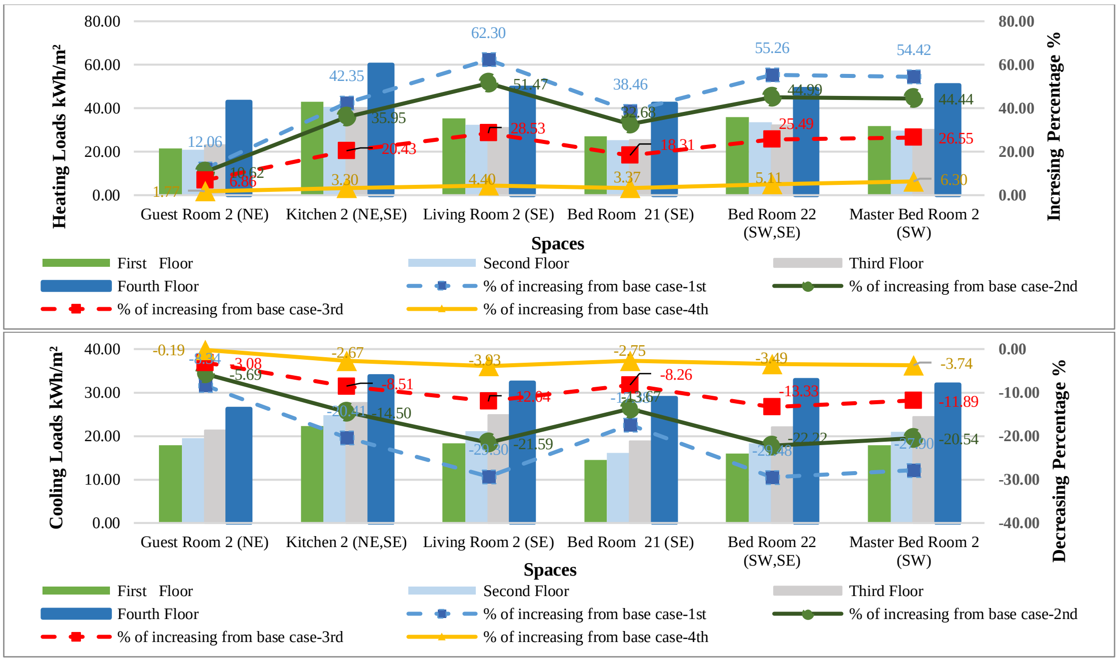


Figure 5.39: Heating and Cooling loads consumption in the North-East oriented street compared with North-East base case- Apartment No.2.

Figures 5.38 and 5.39 record the heating and cooling consumption per square meter per living space, with detailed information about the amount of increase or decrease in consumption than the base case scenario for Apartment No. 1 and 2.

5.4.2.3.Street oriented to the East (Case No.3):

For east-oriented main street case, the daylight results show that the quantity of daylighting in residential spaces particularly on lower floors are insufficient and poorly distributed. As shown in Figure 5.40, DF values don't achieve the minimum required standards. However, the fourth floor was the only floor getting natural daylight within the required standards.

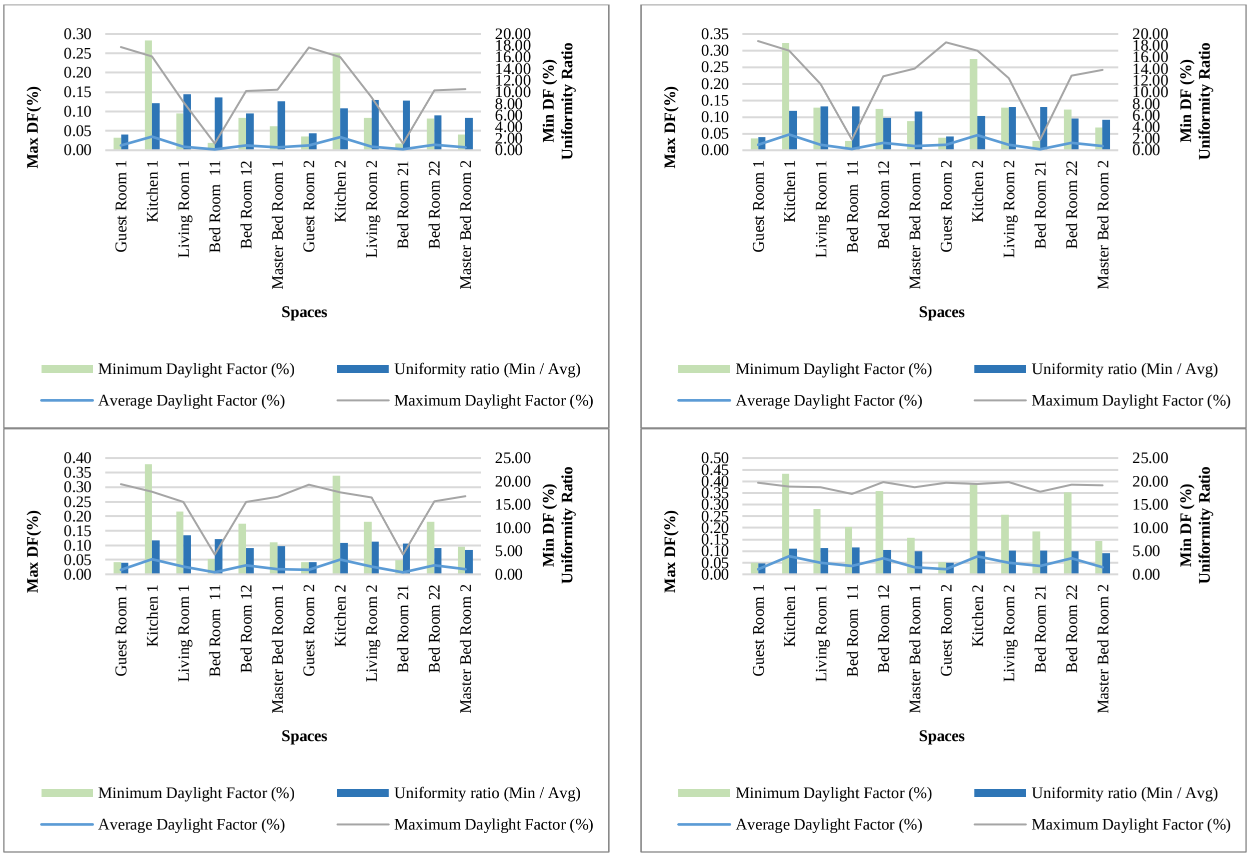


Figure 5.40: Daylighting in residential building , first, second, third and fourth floors (East Street Case).

Heating load demand, in this case, was higher than the base case by 25.21%, 19.91%, 10.80%, and 2.72% for the first, second, third, and fourth floors. The East base case records 24.14 kWh/m^2 on the first floor, 23.77 kWh/m^2 on the second floor, 26.57 kWh/m^2 on the third floor, and 48.98 kWh/m^2 on the fourth floor. While, if the building was surrounded by an adjacent building, the consumption will rise to 30.22 kWh/m^2, 28.51 kWh/m^2, 29.44 kWh/m^2, and 50.22 kWh/m^2, respectively as shown in Figure 5.41 and Figure 5.42. The consumption has increased in living room 1 _which is oriented to the north_ by 3.53% which is the lowest increasing percentage records in apartment No. 1 on the first floor. On the contrary, the southern living room in apartment No.2 records the highest increasing percentage in heating loads on the first floor. This is because the solar altitude angles are generally low in Palestine in winter, and the sun moves from southeast to southwest. Thus, when an adjacent building is placed on the south side of the building, it prevents the sun from reaching the simulated building, and thus highly increased heating loads consumption.

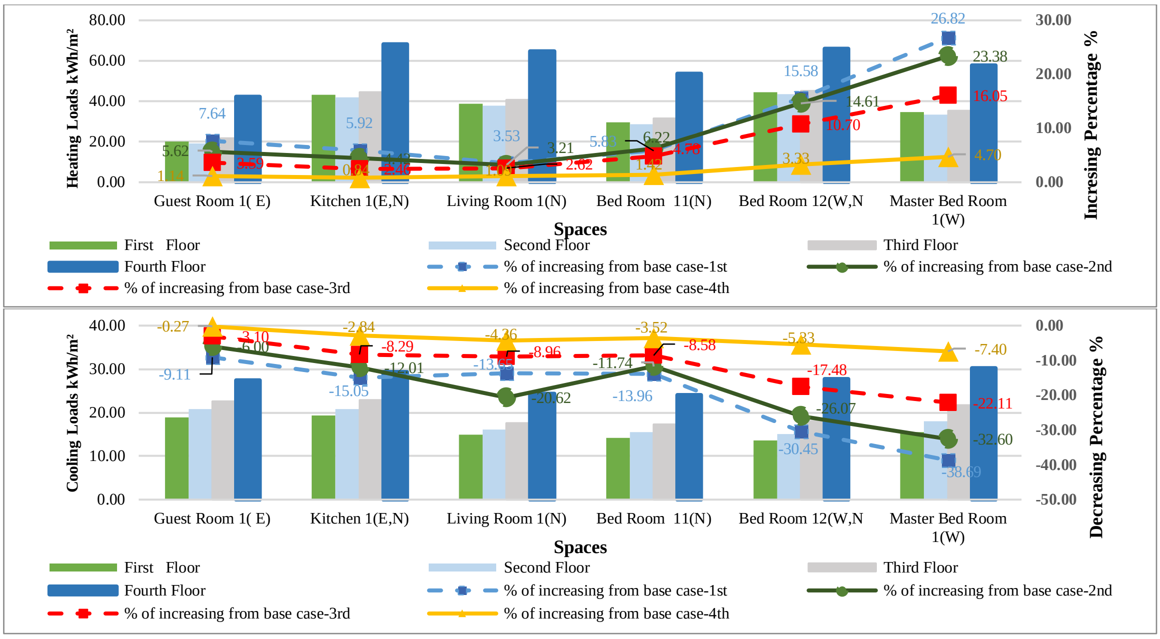


Figure 5.41: Heating and Cooling loads consumption in the East oriented street compared with East base case- Apartment No.1.

When placing five-story buildings on the east, south, west, and north sides at a distance of 20m, 6.00m, 8.00m, and 6.00m from the simulated building, respectively, the annual cooling loads needed reached 17.55 kWh/m^2, 19.41 kWh/m^2, 21.83 kWh/m^2 and 28.64 kWh/m^2 with a decreasing percentage of 19.56%, 15.93%, 10.02% and 3.25% than the base case scenario for the first, second, third and fourth floors respectively. The maximum decreasing percentage occurred when the adjacent building was oriented to the west.

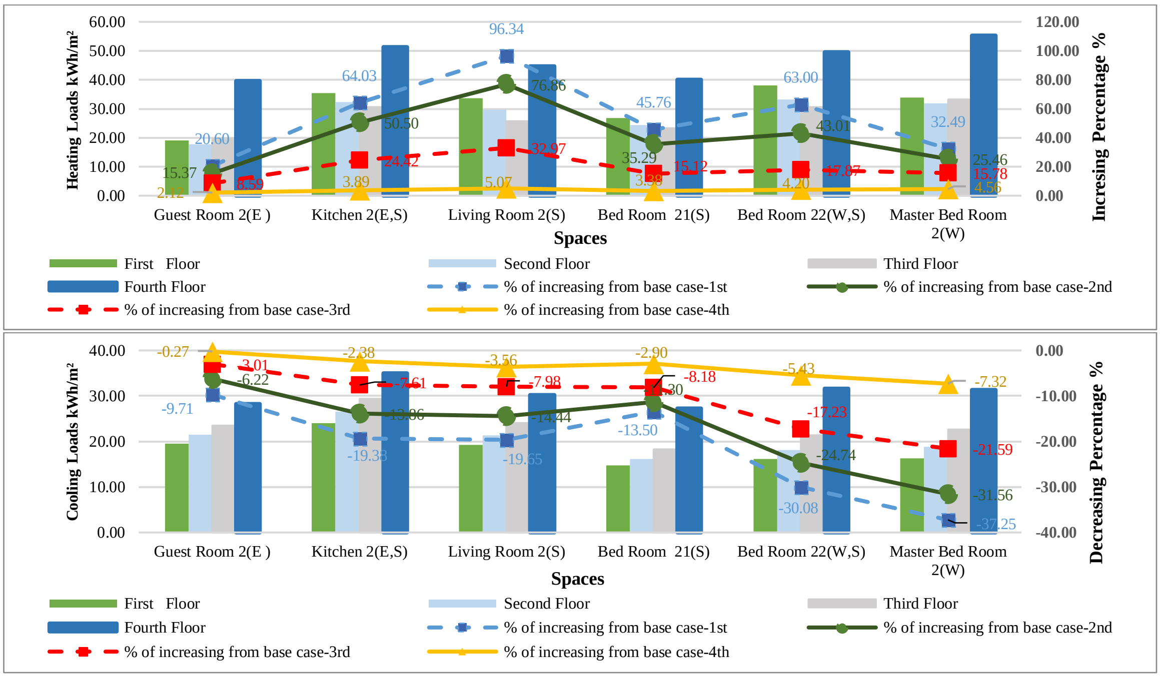


Figure 5.42: Heating and Cooling loads consumption in the East oriented street compared with East base case- Apartment No.2.

5.4.2.4.Street oriented to the South- East (Case No.4):

This case presents placing five-story buildings at 20m distance from the South-East, 6m distance from south-west, 8m distance from north-west and 6m distance from north-east. In this case, the average Daylight Factor values in apartment No.1 and 2 spaces are lower than the required standards in the first, second and third floors.

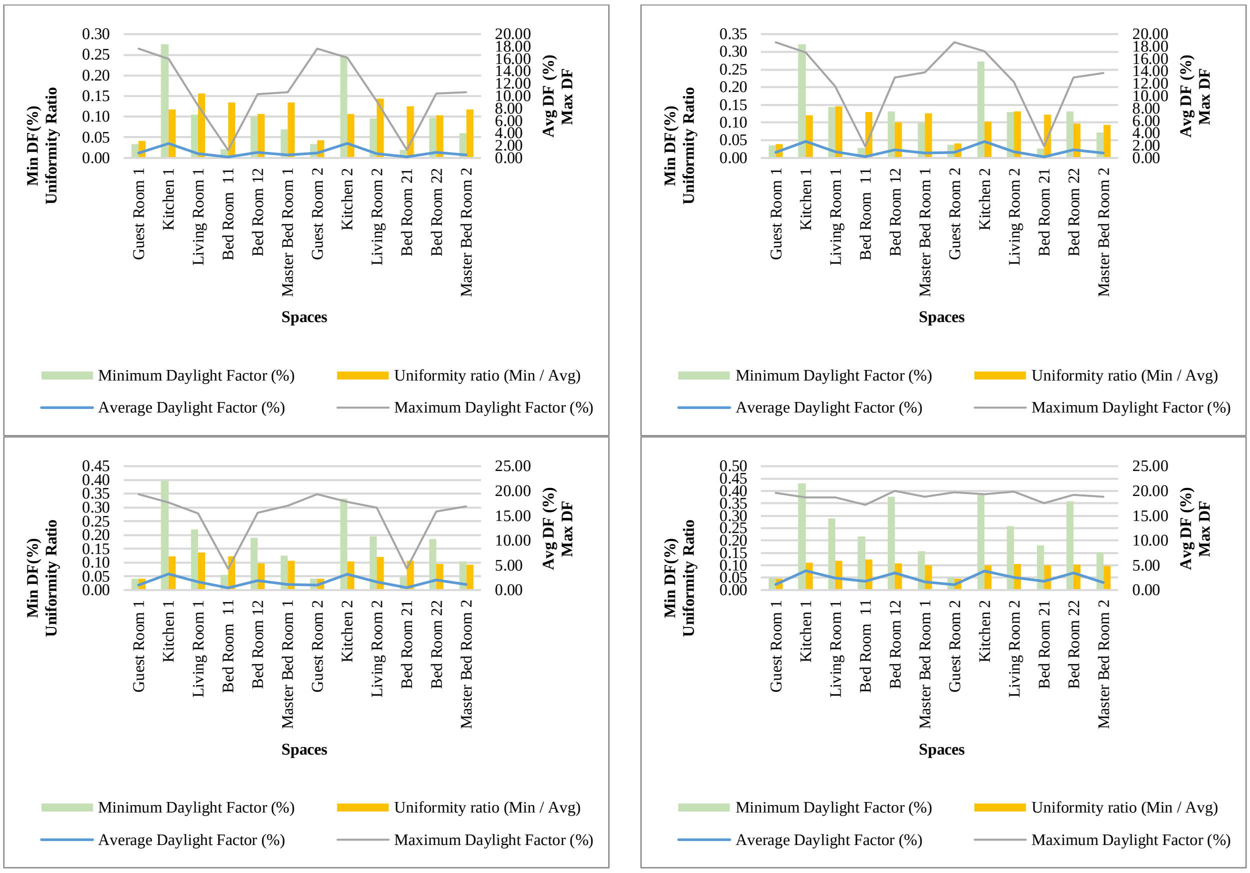
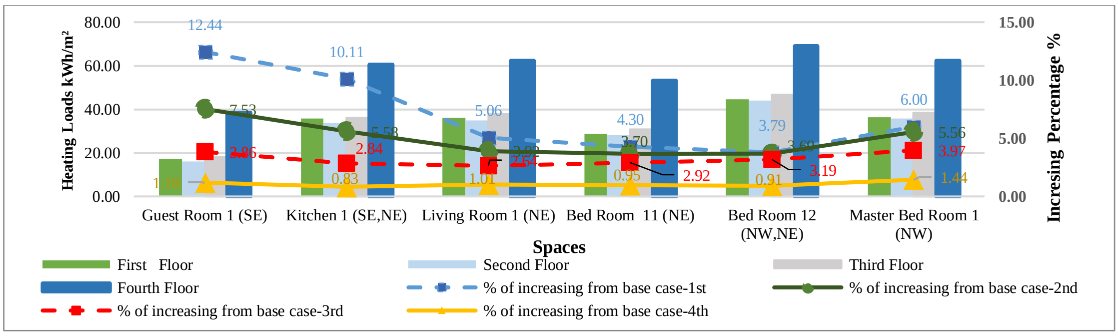


Figure 5.43: Daylighting in residential building , first, second, third and fourth floors (South-East Street Case).

The results show that the residential apartments on the first floor are the best in terms of cooling loads consumption but the worst on daylight availability and heating loads. The annual heating loads consumption will rise from 24.07 kWh/m^2, 23.72 kWh/m^2, 26.52 kWh/m^2, and 49.03 kWh/m^2 in the base case scenario to 28.78 kWh/m^2, 27.48 kWh/m^2, 29.16 kWh/m^2, and 50.38 kWh/m^2 for the first, second, third and fourth floor respectively in the case of having adjacent buildings in all directions. In apartment No. 1, southeastern spaces record the highest increasing percentage in the heating loads consumption and at the same time the lowest decreasing percentage in the cooling loads' consumption than the base case. since adjacent buildings were blocking the sun and prevents it from reaching the building.



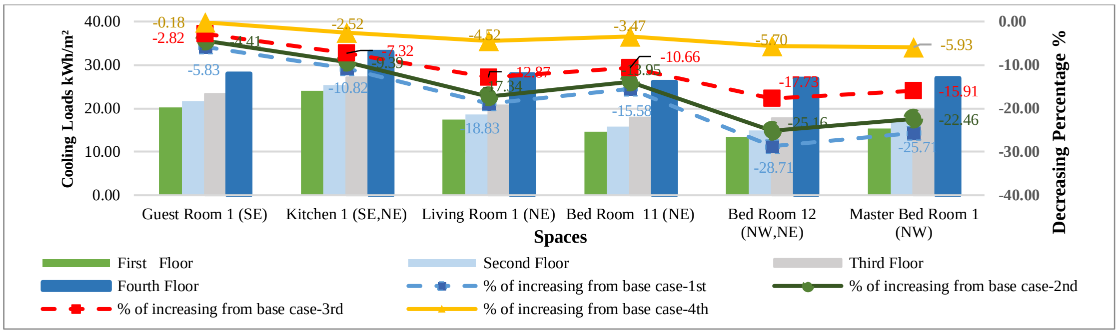


Figure 5.44: Heating and Cooling loads consumption in the South-East oriented street compared with South-East base case- Apartment No.1.

Similar results were found at apartment No.2, the heating loads consumption in the southwestern spaces are higher than other spaces especially in the first floor. As for cooling loads, the consumption was reduced by 20.35%, 15.70%, 10.79% and 3.37% than base case and has reached 18.21 kWh/m^2, 20.10 kWh/m^2, 22.57 kWh/m^2 and 29.39 kWh/m^2 in the first, second, third and fourth floors. The cooling loads decreasing percentage in the southwestern spaces in apartment No.2 is the highest due to the blockage of the summer sun by south-west adjacent building (see Figure 5.45).

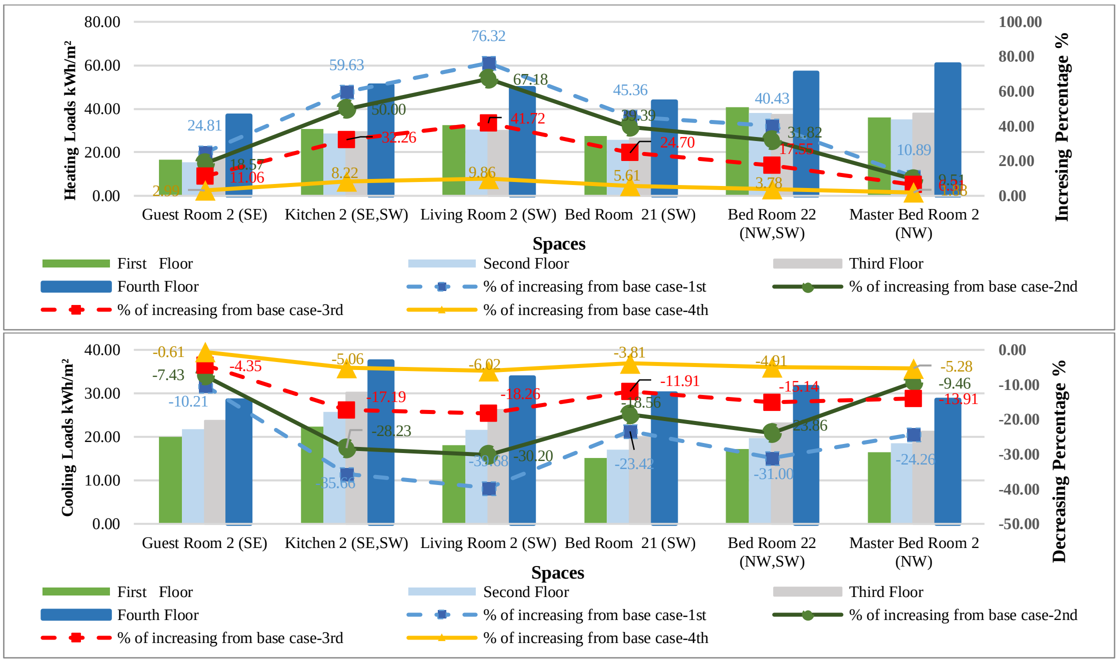


Figure 5.45: Heating and Cooling loads consumption in the South-East oriented street compared with South-East base case- Apartment No.2.

5.4.2.5.Street oriented to the South (Case No.5):

For a south oriented main street that has caused the distance between the building and the neighboring southern building to reach 20 m, the daylight availability as well as the heating and cooling loads were positively affected compared to other urban context cases (see figures below).

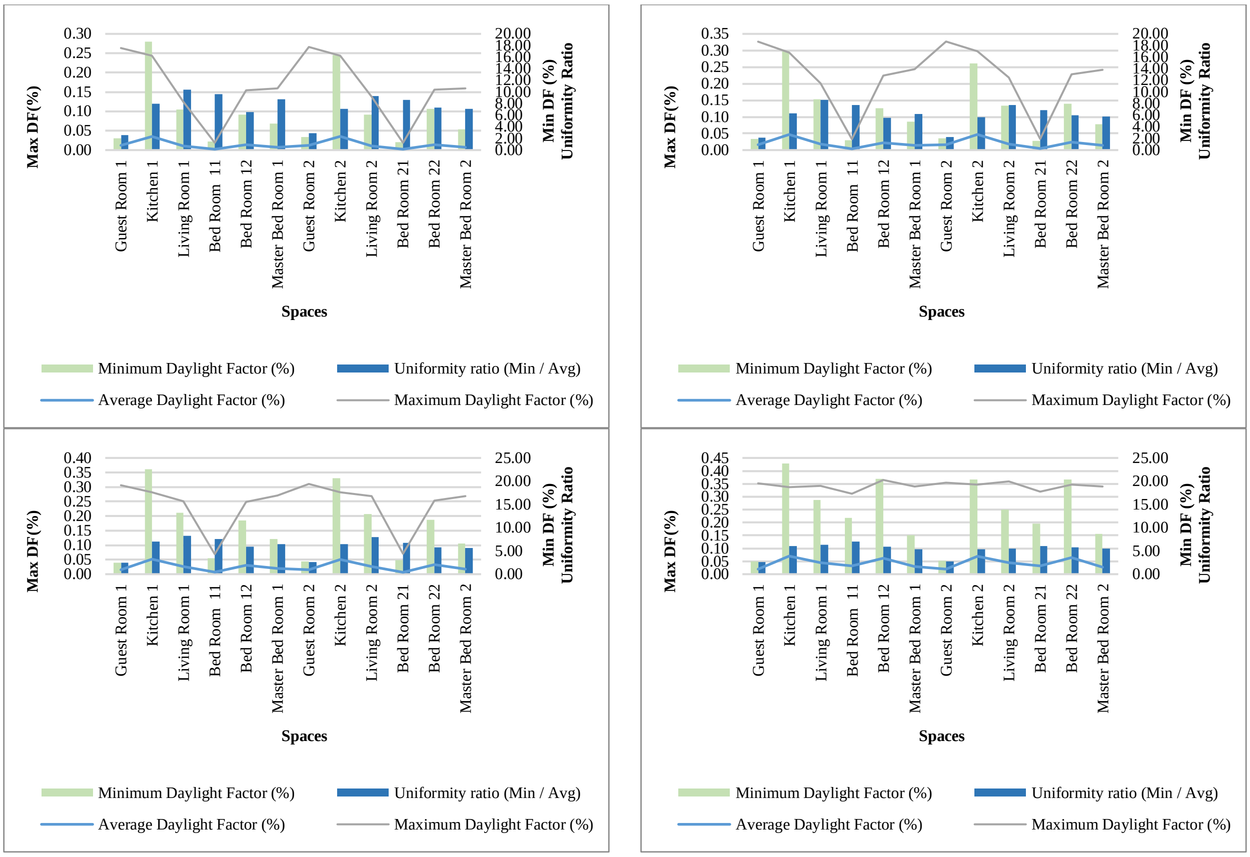
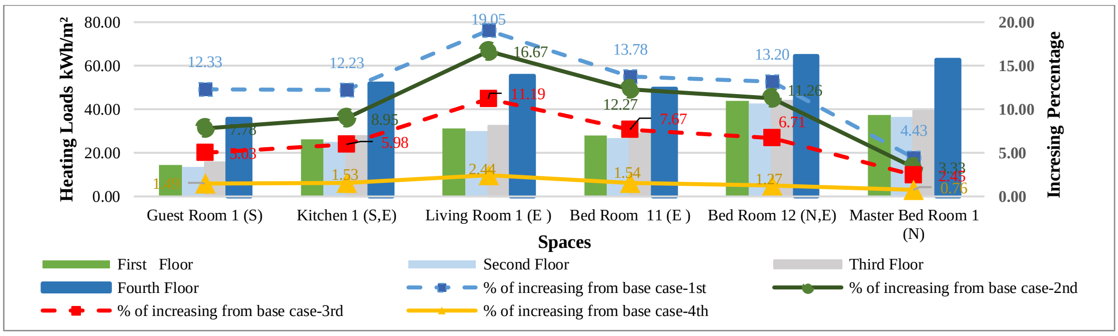


Figure 5.46: Daylighting in residential building , first, second, third and fourth floors (South Street Case).

This case records the best readings especially in thermal energy consumption. It records the lowest increasing percentage per floors in heating loads in comparison to other urban context cases. The south base case consumes 23.47 kWh/m^2, 23.12 kWh/m^2, 25.93 kWh/m^2 and 48.47 kWh/m^2 of heating loads per first, second, third and fourth floors. When a five story buildings placed to the south, west, north and east at a distance of 20m, 6m, 8m and 6m, the required heating loads became 26.95 kWh/m^2, 25.96 kWh/m^2, 28.15 kWh/m^2 and 49.64 kWh/m^2 with increasing percentage of 14.82%, 12.30%, 8.56% and 2.42% in the first, second, third and fourth floors respectively.



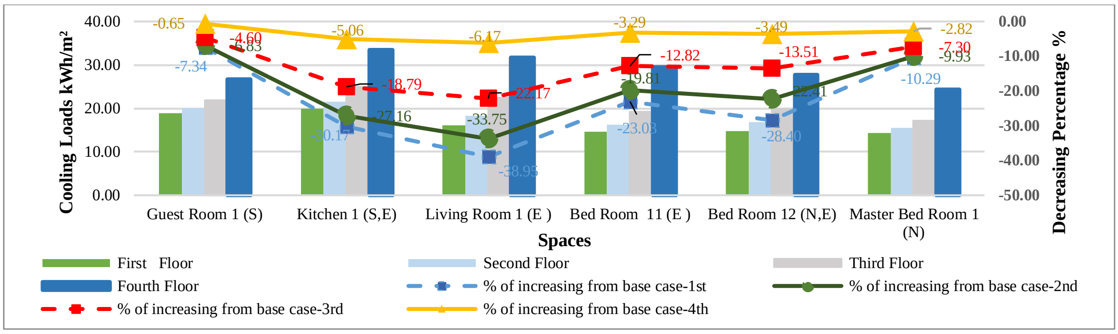


Figure 5.47: Heating and Cooling loads consumption in the South oriented street compared with South base case- Apartment No.1.

As for the cooling loads, the consumption has decreased from 22.21 kWh/m^2, 23.35 kWh/m^2, 24.61 kWh/m^2 and 29.69 kWh/m^2 to 16.88 kWh/m^2, 18.39 kWh/m^2, 20.97 kWh/m^2, and 28.35 kWh/m^2 when the base case building is surrounded by external obstruction buildings with 24.02%, 21.26%, 14.78% and 4.50% decreasing percentage in consumption at the first, second, third and fourth floors respectively. Figure 5.47 and Figure 5.48 present the heating and cooling loads consumption inside residential spaces in comparison to the increasing and decreasing percentages from the base case.

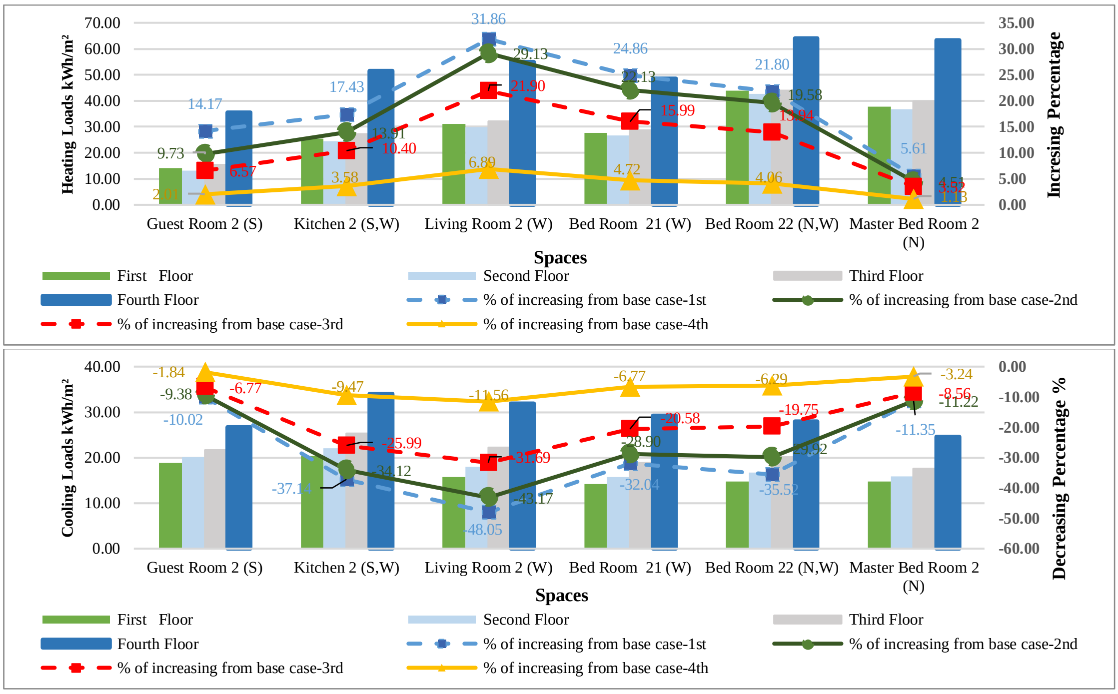


Figure 5.48: Heating and Cooling loads consumption in the South oriented street compared with South base case- Apartment No.2.

5.4.2.6.Street oriented to the South-West (Case No.6):

As shown in Figure 5.49, most of residential spaces in apartment No. 1 and 2 in the first and second floors don't meet the required standards. On the other hand, kitchen 1, kitchen 2, bedroom12 and bedroom 22 record the best results in terms of daylighting availability. The average DF values inside these spaces are more than 1% in the bedrooms and 2% in the kitchen on all floors with external obstructions on the opposite sides of these spaces.

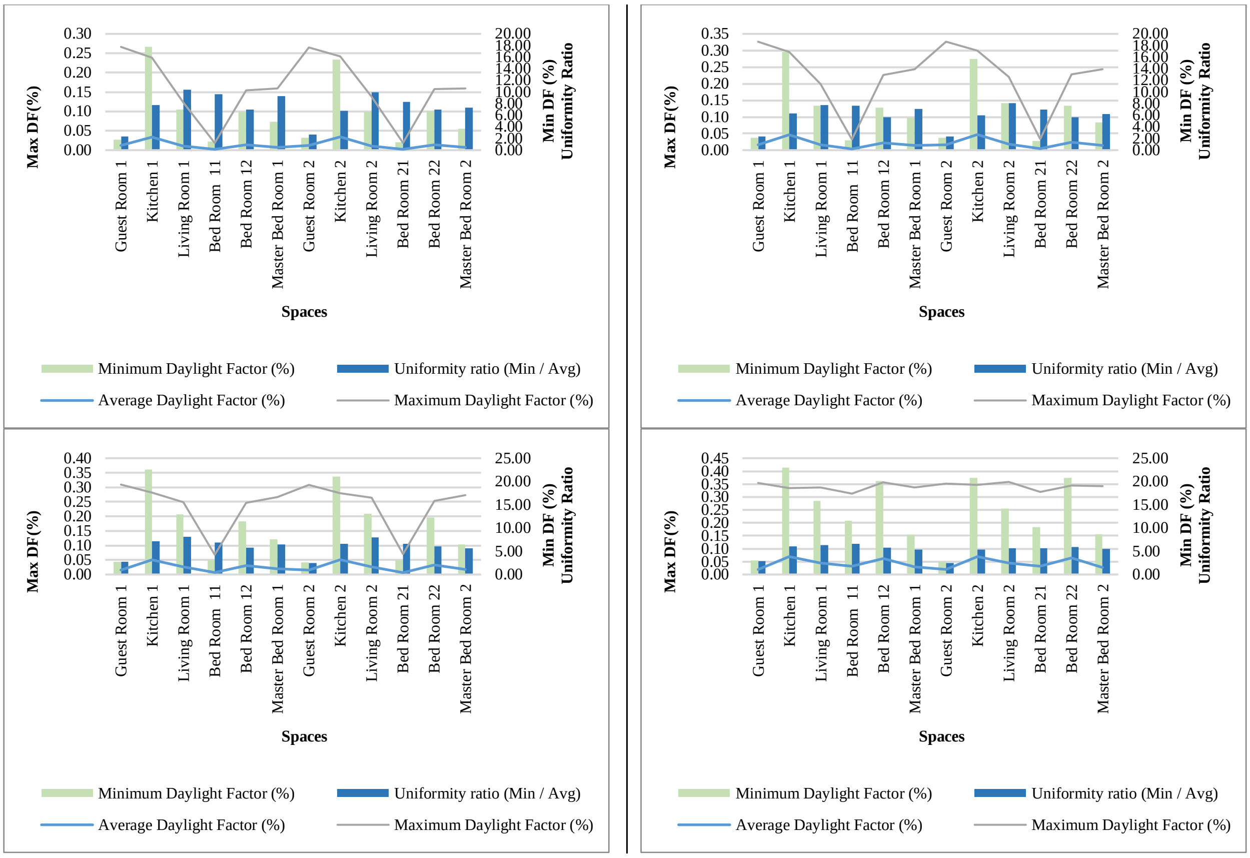


Figure 5.49: Daylighting in residential building , first, second, third and fourth floors (South-West Street Case).

As for heating and cooling loads consumption as shown in Figure 5.50, living room in apartment No.1 which is oriented to the south-east records the highest increasing percentage in the heating loads and the lowest decreasing percentage in the cooling loads in all floors. Figure 5.51 showed that the guest room in apartment No.2 records the highest increasing percentage in the heating loads, and the lowest increasing percentage in all floor's records in master bed room which is oriented to the north-east.

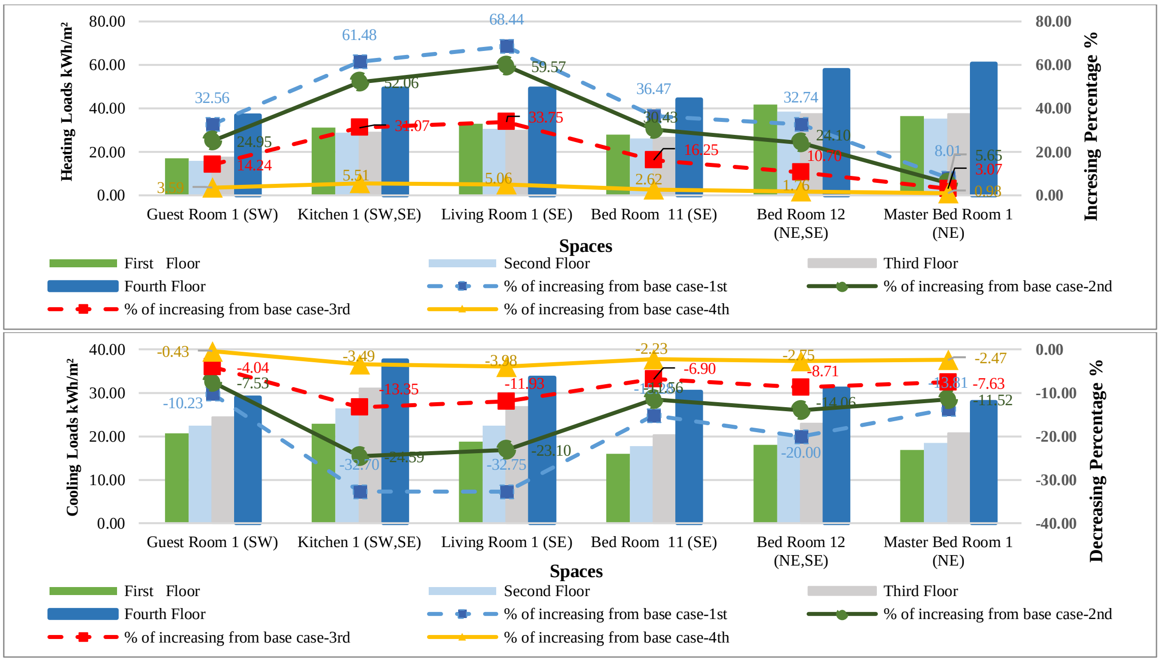


Figure 5.50: Heating and Cooling loads consumption in the South-West oriented street compared with South-West base case- Apartment No.1.

The simulation results showed that placing five story buildings on the south-west, north-west, north-east and south-east sides to a building will reduce its cooling loads by 18.33%, 14.77%, 9.53% and 2.98% while increase its heating loads by 22.06%, 17.44%, 10.20% and 2.46% when compared to the base case scenarios at the first, second, third and fourth floors respectively. The consumption of heating loads has increased from 24.00 kWh/m^2 to 29.30 kWh/m^2 in the first floor, from 23.63 kWh/m^2 to 27.75 kWh/m^2 in the second floor, from 26.43 kWh/m^2 to 29.12 kWh/m^2 in the third floor and from 48.90 kWh/m^2 to 50.10 kWh/m^2 in the fourth floor. However, the consumption of cooling loads has decreased from 23.05 kWh/m^2 to 18.82 kWh/m^2 in the first floor, from 24.24 kWh/m^2 to 20.66 kWh/m^2 in the second floor, from 25.47 kWh/m^2 to 23.05 kWh/m^2 in the third floor and from 30.54 kWh/m^2 to 29.63 kWh/m^2 in the fourth floor.

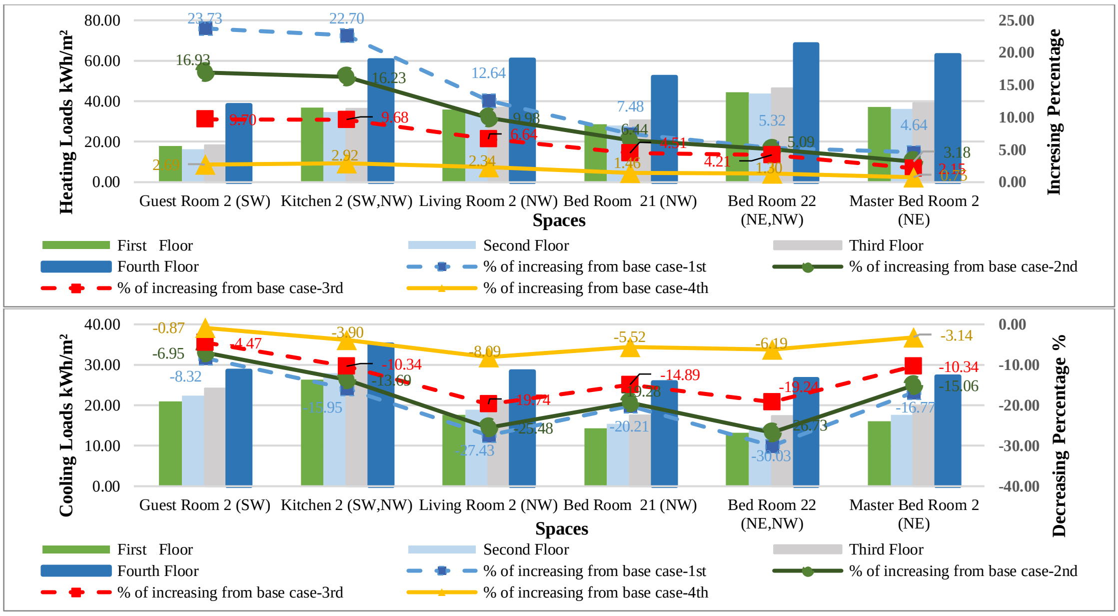
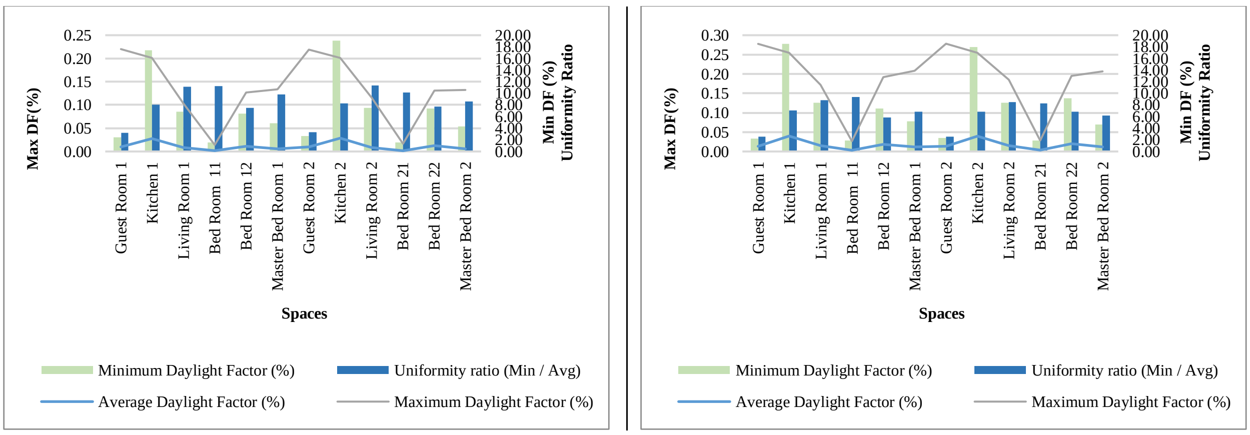


Figure 5.51: Heating and Cooling loads consumption in the South-West oriented street compared with South-West base case- Apartment No.2.

5.4.2.7.Street oriented to the West (Case No.7):

The level of daylight is also affected in comparison to the west base case when surrounding buildings are available especially on the first floor. In apartment No.1, the average DF values decreased from 3.9% to 2.4% in the guest room, 0.8% to 0.4% in the bedroom 11, 2.7% to 0.7% in the living room, 2.7% to 0.9% in the bedroom 12 and from 1.7% to 0.5% in the master bed room, as shown in Figure 5.52.



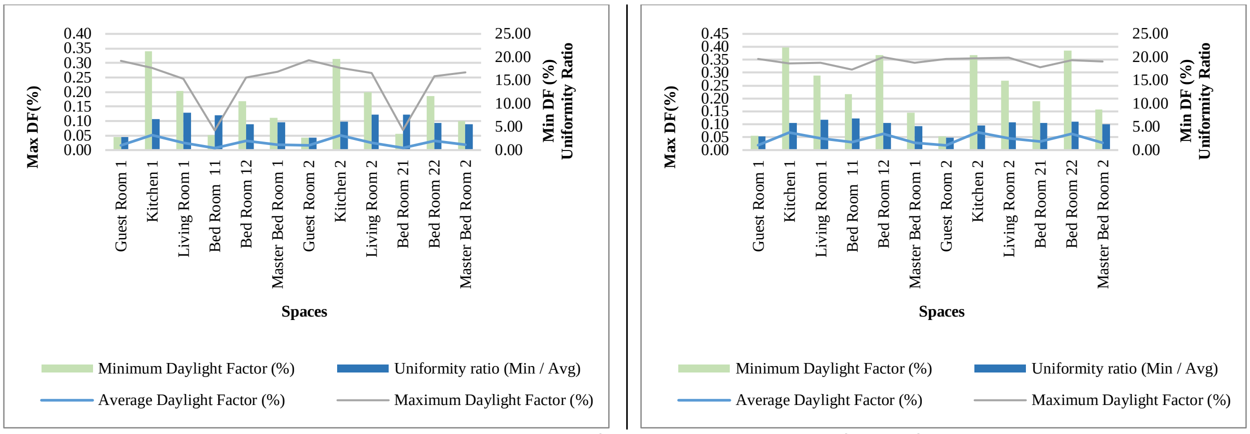


Figure 5.52: Daylighting in residential building , first, second, third and fourth floors (West Street Case).

The heating loads in south facing living room in apartment No.1 increase by 98.78%, 77.37%, 31.56% and 5.02% in the first, second, third and fourth floors as a result of the external neighboring buildings (see Figure 5.53).

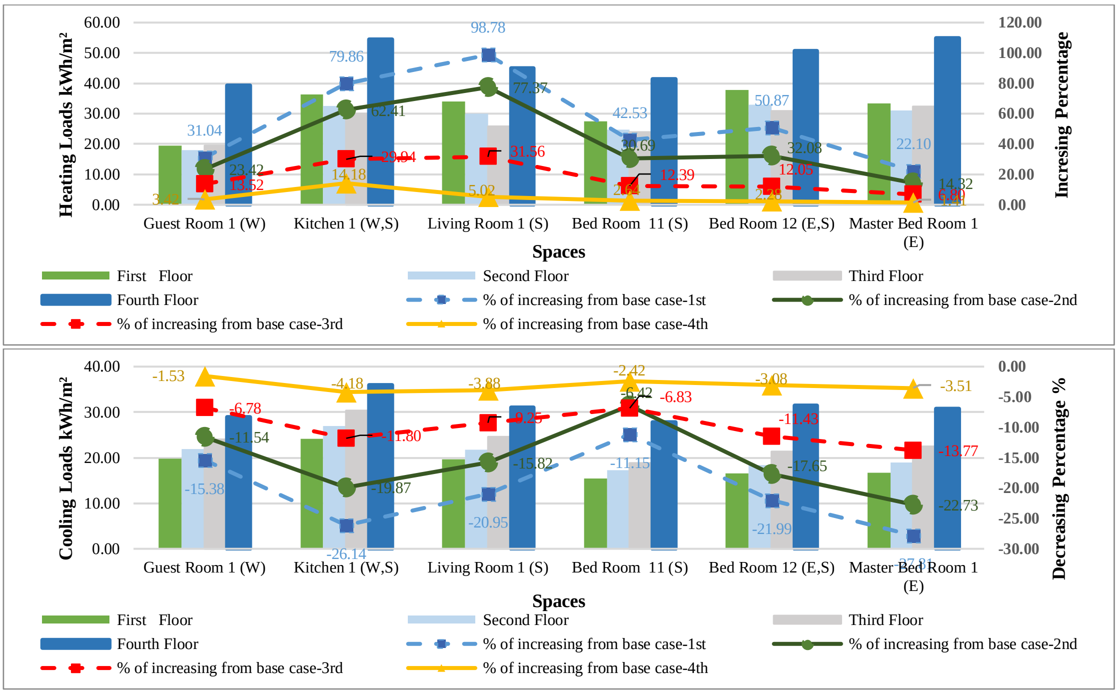
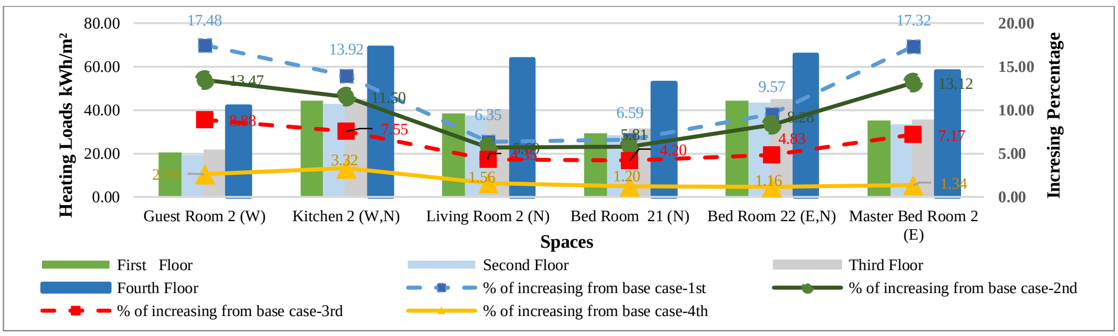


Figure 5.53: Heating and Cooling loads consumption in the West oriented street compared with West base case- Apartment No.1.

The kitchen which is oriented to the south-west in apartment No.1 and the master bedroom which is oriented to the east in apartment No.2 record the largest impact on cooling energies with a reduction by 26.14% and 28.72%, respectively.



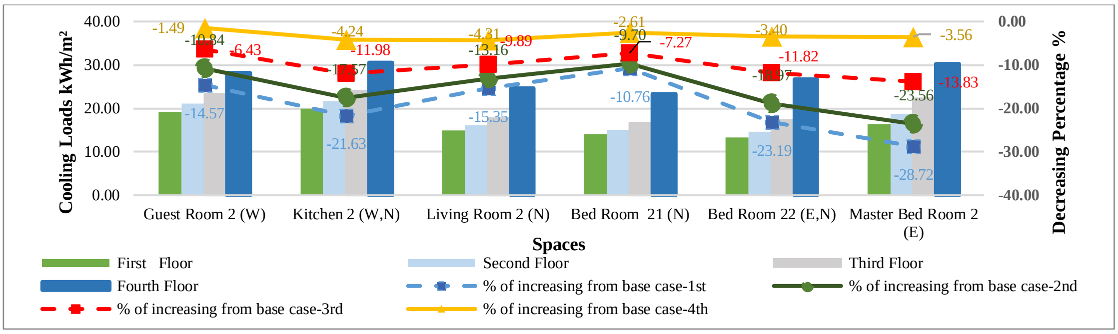


Figure 5.54: Heating and Cooling loads consumption in the West oriented street compared with West base case- Apartment No.2.

As for average floor annual heating and cooling loads consumption, this case record an increase in heating loads by 26.54%, 19.99%, 10.28% and 3.04%, and about 19.34%, 15.11% 9.50% and 2.86% decrease in cooling loads at the first, second, third and fourth floors than the west base case scenario. This case consumed about 30.49 kWh/m^2, 28.50 kWh/m^2, 29.24 kWh/m^2 and 50.28 kWh/m^2 of heating loads and 17.82 kWh/m^2, 19.75 kWh/m^2, 22.19 kWh/m^2, 28.96 kWh/m^2 of cooling loads in the first, second, third and fourth floors respectively.

5.4.2.8.Street oriented to the North-West (Case No.8):

The daylight simulation results showed that most of the residential spaces don’t meet the minimum requirements of daylight standards. All the previous cases and their results proved that it’s nor the width of the street, neither the front setbacks distances for land plots are enough in creating comfortable intensity of natural daylight in the indoor residential spaces that are overlooking the main street.

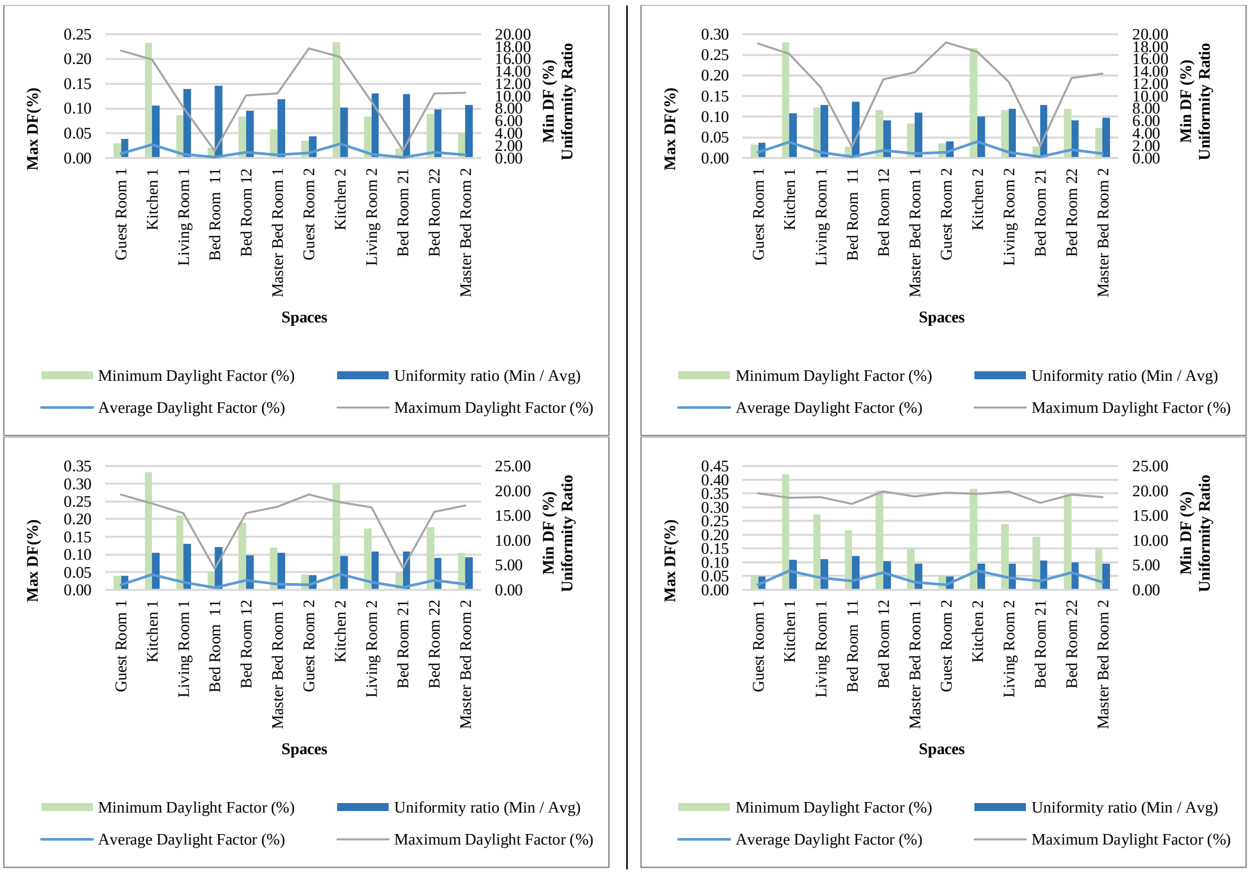


Figure 5.55: Daylighting in residential building , first, second, third and fourth floors (North-West Street Case).

This case has recorded the lowest consumption in terms of cooling loads after the south and north east oriented street cases with annual consumption of 17.51 kWh/m^2, 19.51 kWh/m^2, 22.12 kWh/m^2 and 29.37 kWh/m^2 in the first, second, third and fourth floor.

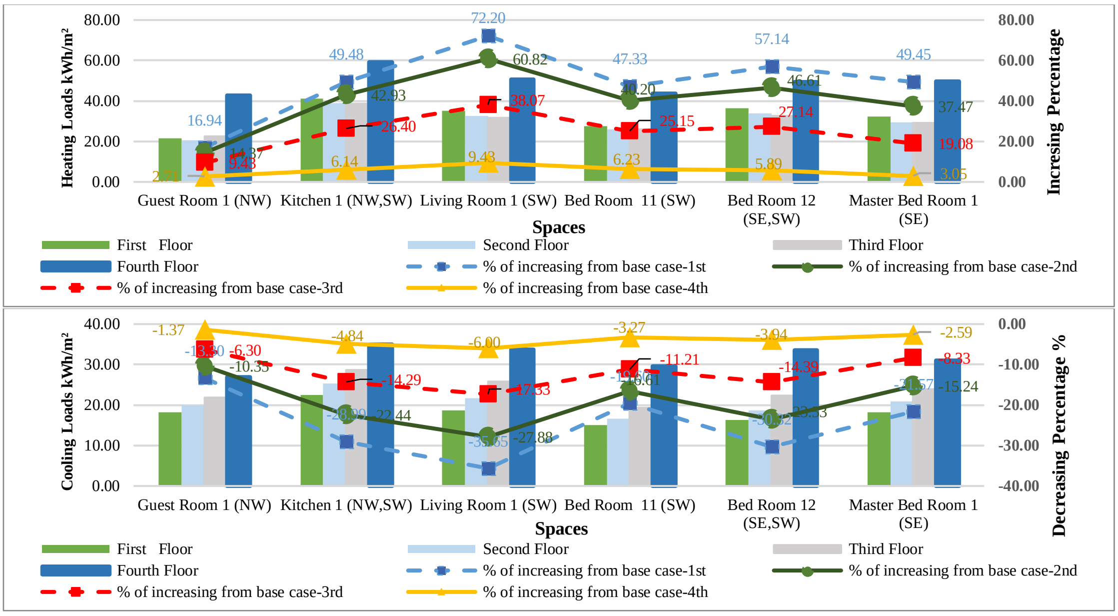


Figure 5.56: Heating and Cooling loads consumption in the North-West oriented street compared with North-West base case- Apartment No.1.

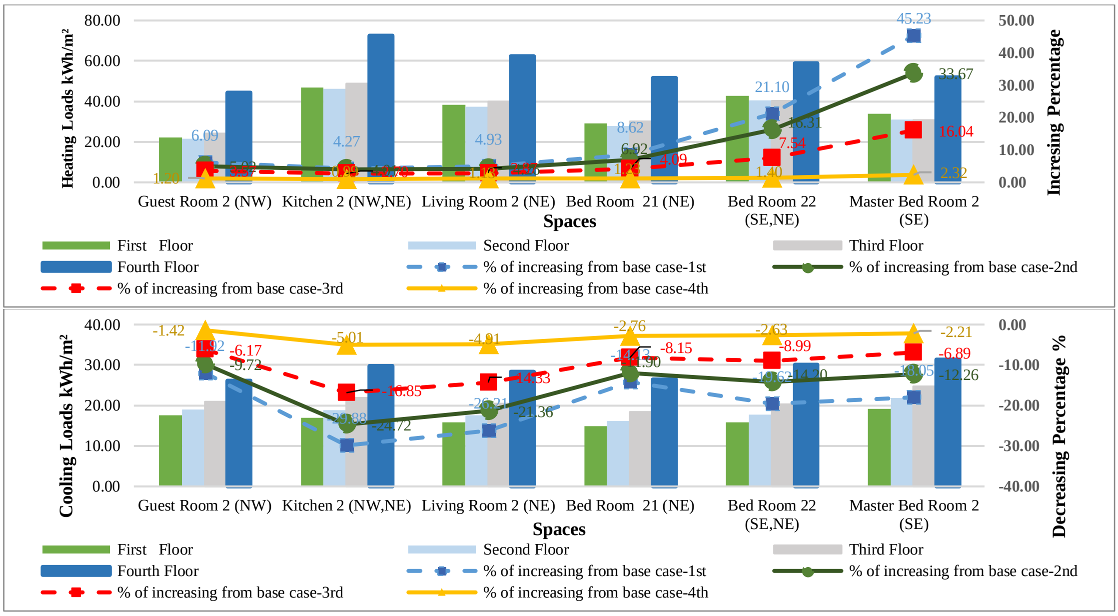


Figure 5.57: Heating and Cooling loads consumption in the North-West oriented street compared with North-West base case- Apartment No.2.

Based on the previous results, it was made clear that current regulated setbacks between buildings are insufficient to provide energy-efficient performance and adequate daylighting in multi-story residential buildings in the residential B-zone in Palestine. The simulation results showed that the south oriented street has the best performance. However, all other cases still need to be optimized to enhance their performance. The simulation results showed high consumption of heating and cooling energies and poor daylighting levels in residential spaces for almost many urban context scenarios. This has led to a significant question; how can we reduce the energy consumption and improve daylighting in multi-story residential buildings in the residential B-zone in Palestine.

5.5. Summary:

In this chapter, different urban context scenarios were introduced to a five-story residential building which represent the common building type in residential zones in Palestine. External obstructions (buildings) were placed at 20m, 6m, 8m and 6m from front, right side, rear and left side from the reference building respectively. A parametric study was conducted to evaluate the impact of external obstruction on the daylighting availability and energy performance inside residential spaces. The results indicate that; the lower floors are the most vulnerable to the existence of external obstruction. Therefore, spaces especially on the lower floors don't meet the minimum daylighting requirements and consume large amounts of heating loads in winter and are highly affected by the unstudied building regulations and specifically the setbacks distances related regulations.

In the high density cities like Palestinian cities, buildings are close to each other with minimum distance of setback and in most cases the distances between buildings are lower than regulated setback distance. As seen in the results, shading from surrounding buildings reduces the solar exposure of buildings which reduces the potential for natural lighting and increases the need for artificial lighting energy and heating loads. Further analysis also shows the impact of adjacent buildings is not necessarily negative. The simulation has shown that external obstruction in the surrounding environment blocks solar radiation in summer which reduces the amount of cooling loads required to reach thermal comfort during hot summers. On the other hand, the amount of cooling loads increased to move the heat resulting from the artificial lighting (Hui, 2001; Sabry et al., 2010). From the results, also it was clear that the impact of external obstruction is different in all orientations. Different room orientations have a significant impact on energy consumption. In winter, the solar altitude angles in Palestine are generally low, which allows the sun to reach the simulated building when it is moved from south-east to southwest, thus reducing the heating loads required. In summer, sun altitude angles are high, and the time when the sun is directed on the south facade is lower than in winter. Thus the cooling consumption decreased. These results emphasize on the importance of studying such effects during the early design stage since this will have a great impact on the quality of the indoor environment and on the energy performance of spaces.

Generally, in Palestine's urban context, the current building regulations in Palestine failed to provide sufficient daylighting and energy efficiency in residential spaces. The results of the simulation in this chapter showed that there is a certain problem affecting the indoor environment and energy consumption in multi-story residential buildings in Palestine. Therefore, building regulations must be in accordance with daylighting and energy performance and it should be studied during the early design stage. For this reason, the following chapter aims to enhance the residential buildings performance by enhancing the setback regulation at the first phase, and proposed alternative strategies at building level.

Chapter Six

6. Optimization of Building Thermal Energy Performance and Daylighting Inside Residential Spaces

6.1. Introduction:

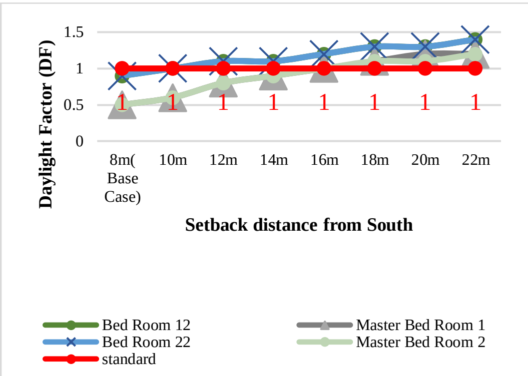
The quality as well as the quantity of natural daylight and solar radiation entering residential spaces depend on **both internal and external factors** (Li & Lam, 2001). One of the objectives of this thesis is to enhance the quality of the indoor environment in terms of daylight availability and energy consumption. There are different passive design strategies to achieve this aim. Internal factors include all variables at the building level such as windows position and size, building envelope materials, space layout, depth and shape as well as interior surface characteristics, etc. Externally, the access of natural daylight and solar radiation is highly affected by the surrounding environment, which mainly includes adjacent buildings (Li & Lam, 2001; Li et al., 2006). Designing low-energy residential buildings within urban context requires special care to provide coordination and integration between the building's urban context and its architectural features so as to improve the quality of the residential spaces and the living conditions.

This chapter presents a heuristic parametric optimization process and sensitivity analysis of daylighting and thermal energy performance at daytime in residential B-zone in Palestine. This phase aims not only to find the optimum solution to enhance the indoor environment in terms of setbacks regulations, but also to provide architects with the mechanism to optimize their designs in the early stage, and also to develop a group of recommendations and a set of design parameters that may impact daylighting and thermal performance in residential spaces.

The main objective of this chapter is to identify the most effective techniques impacting energy performance and daylighting availability. To do this, two levels were considered to optimize the current status of residential apartments in multi-story buildings in the residential B-zone in Palestine (Quan et al., 2014). The first level has focused on the urban level and the relation between the building and adjacent buildings at different urban context cases. In this level, setbacks distance is the main studied parameter and has been determined based on local building regulations in Palestine. The second level is the building level. This level investigates the effects of architectural elements such as floor layout, window to wall ratio, and shading elements on daylight and thermal performance. The findings were used to establish some guidelines at urban and at building levels to achieve energy efficiency and adequate daylighting in residential buildings.

6.2. Parametric Process and Sensitivity Analysis:

After reviewing the literature about the different parameters that can be studied to enhance the building performance, a set of linking parameters that affect both the daylighting and thermal energy performance of the residential spaces by using simulation were determined in the parametric process. Then, sensitivity analysis method was used to specify the most influence parameters on the indoor environment performance by varying the selected parameters one at a time and keeping other variables constant to identify the ranking of tested parameters in terms of their impact on the daylighting and thermal energy consumption and to exclude the unimportant input parameters (Reitmeier & Paetzold, 2012). The literature review shows that there are different parameters at urban and building levels that have a significant impact on enhancing daylighting availability and thermal energy performance. The selected parameters are divided into two categories; the first one is urban scale parameters including setback distances and building heights, and the second category is building scale parameters which include WWR, shading elements, wall insulation, space orientation, glazing type and light selves. Then, the simulation process was carried out for each parameter separately to give an indication concerning the level of individual parameter effect on the specific conditions for the north oriented street when the study area is flat. All these factors are used in the optimization in the previous studies, parameters like shading elements and light shelves are not widely used in the Palestinian community but if they have a significant impact in enhancing the performance of the indoor environment, the study recommended to use these strategies.



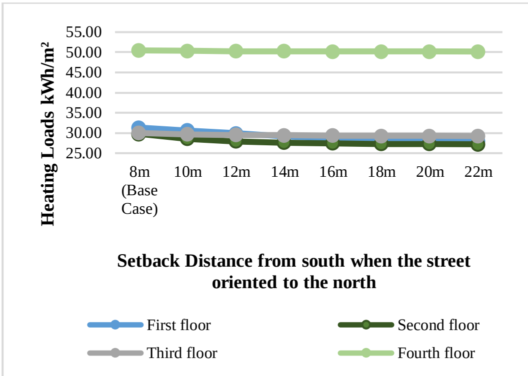
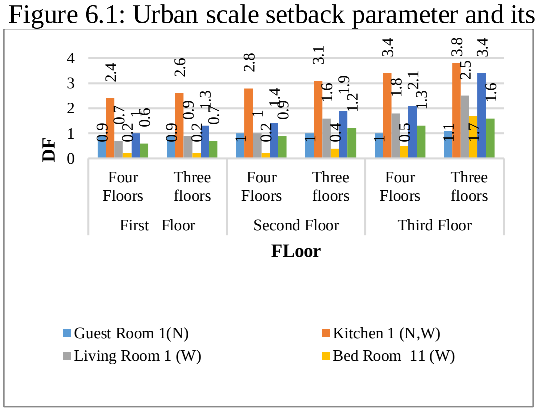


Figure 6.1: Urban scale setback parameter and its impact on the natural daylight and thermal energy.



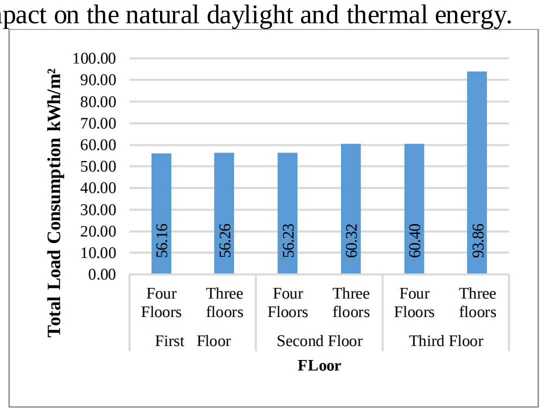


Figure 6.2: Urban scale building heights parameter and its impact on the natural daylight and thermal energy.

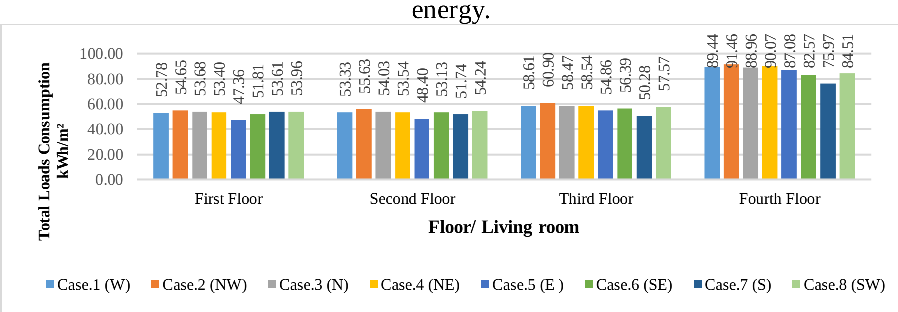


Figure 6.3: Space orientation (Building scale parameters) and its impact on the thermal energy.

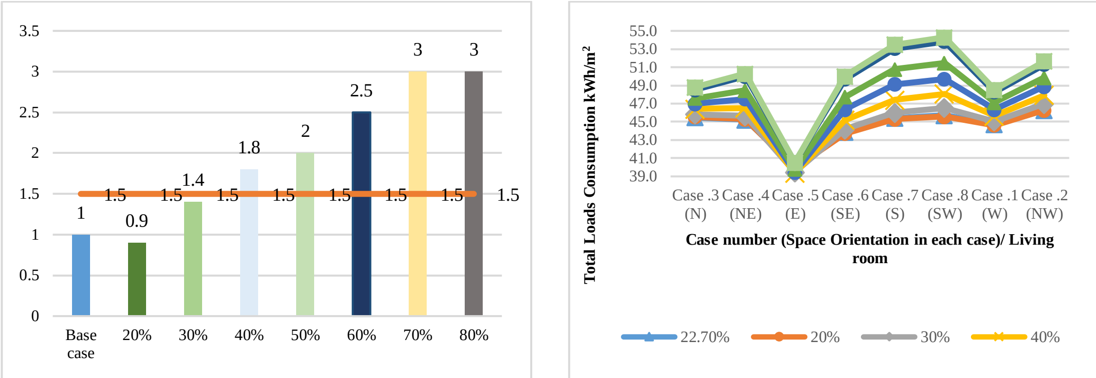


Figure 6.4: WWR (Building scale parameters) and its impact on the natural daylight and thermal energy.

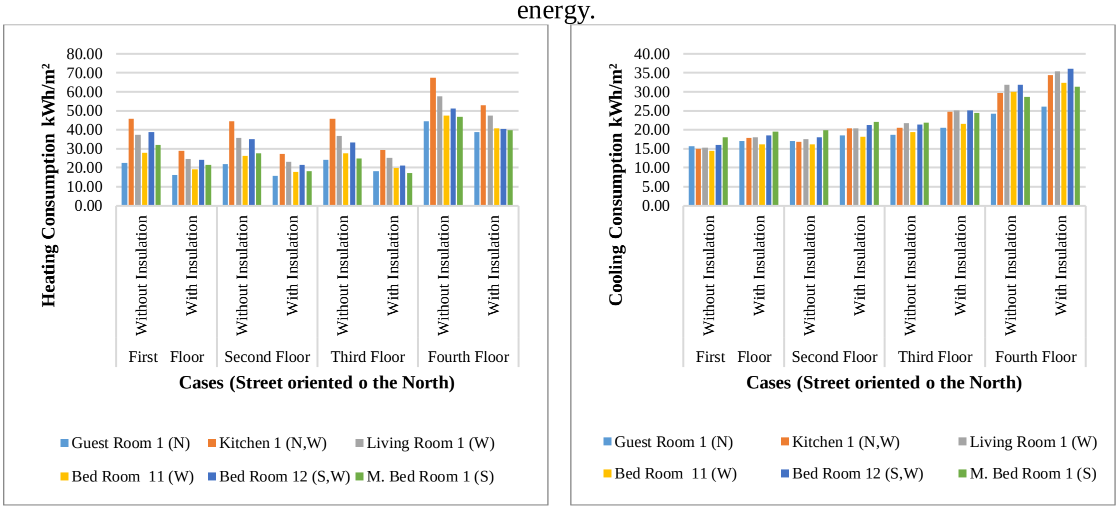
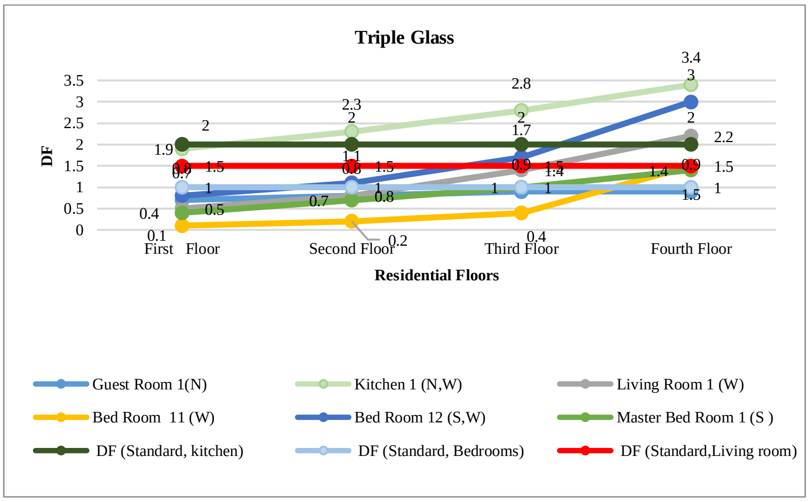


Figure 6.5: External wall insulation -(Expanded Polystyrene 3cm)-(Building scale parameters) and its impact on the thermal energy.



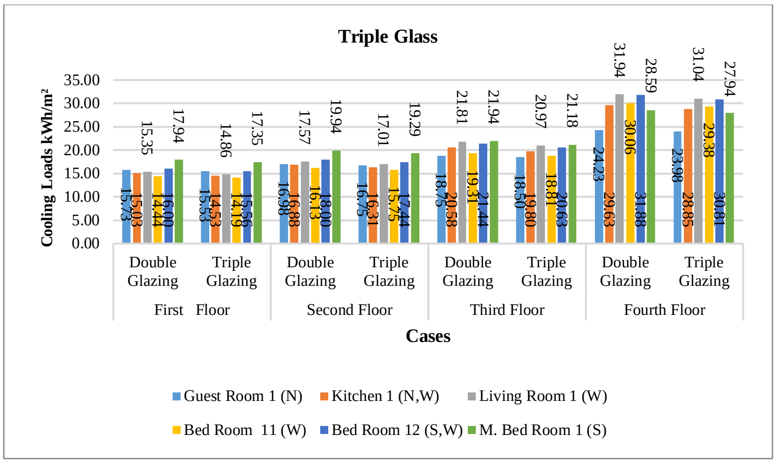


Figure 6.6: Glazing type (Building scale parameters) and its impact on the natural daylight and thermal energy.

Figure 6.7: Shading devices (Building scale parameters) and its impact on the natural daylight and thermal energy.

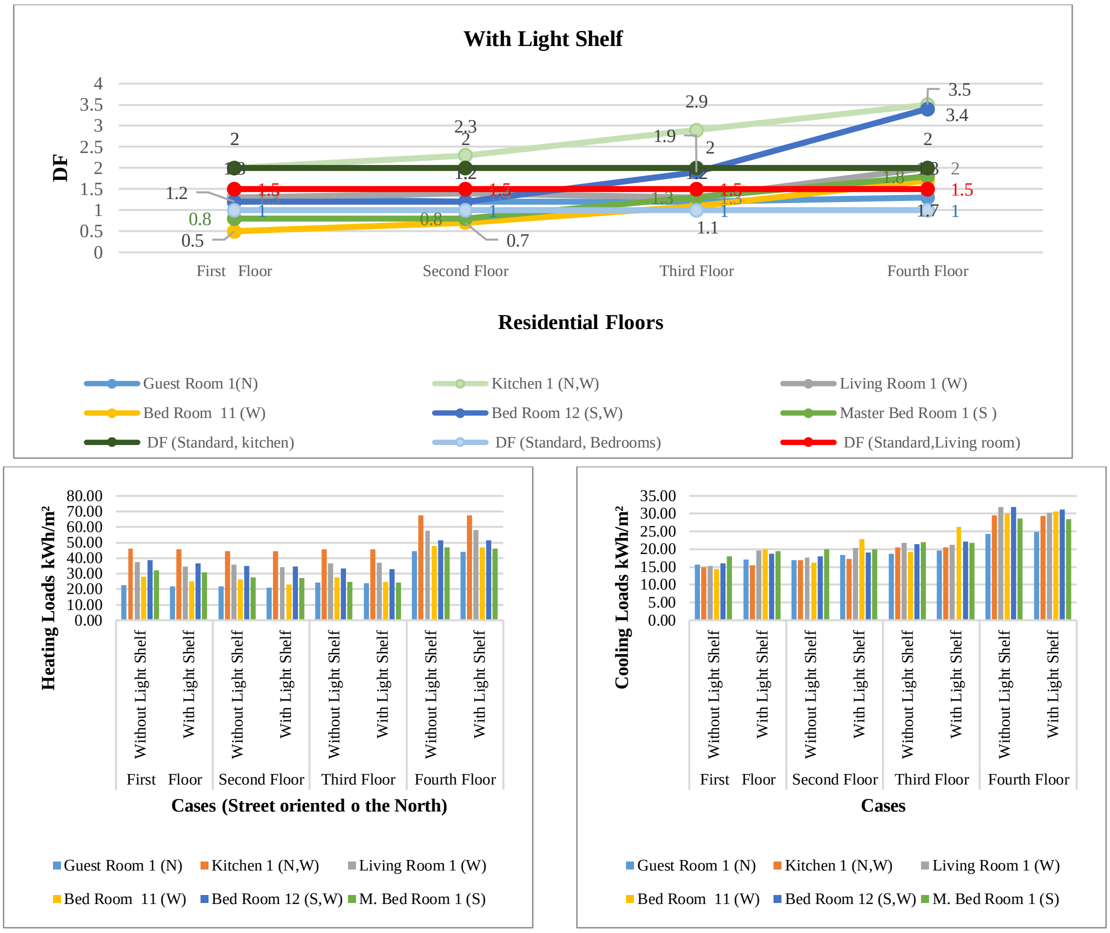


Figure 6.8: Light shelf (Building scale parameters) and its impact on the natural daylight and thermal energy.

When comparing the sensitivity analysis simulation results for urban and building scales parameter with the base cases (without shading elements, double glazing, air gap as an insulation material) in order to select the most relevant parameters to the thesis objective show that; at urban scale, increasing separation distance (setback distance) between buildings is the most influence urban parameter on the daylighting availability and energy consumption than decreasing building height that as show in the simulation results enhance the daylighting availability, but on the other hand, the total load consumption increased due to the cooling loads, also, the built up area significantly decreased. As for building scale parameters, indoor spaces orientations, WWR (window to wall ratio), shading devices and light selves are the most influential parameters due to their significant impact on daylighting availability and energy consumption. Unlike other factors such as wall insulation which has no impact on enhancing daylight inside buildings despite its good impact on thermal energy consumption, especially heating loads. Glazing type has a notable impact on the heating and cooling loads reduction, and it also decreases the intensity of natural daylight inside residential spaces.

So, the optimization was conducted by two phases, the first phase by increasing setback distances between buildings because it is the most efficient tested parameter at urban level. For building level parameters, WWR, shading elements and spaces orientation have a significant influence on the indoor environment between all tested parameters.

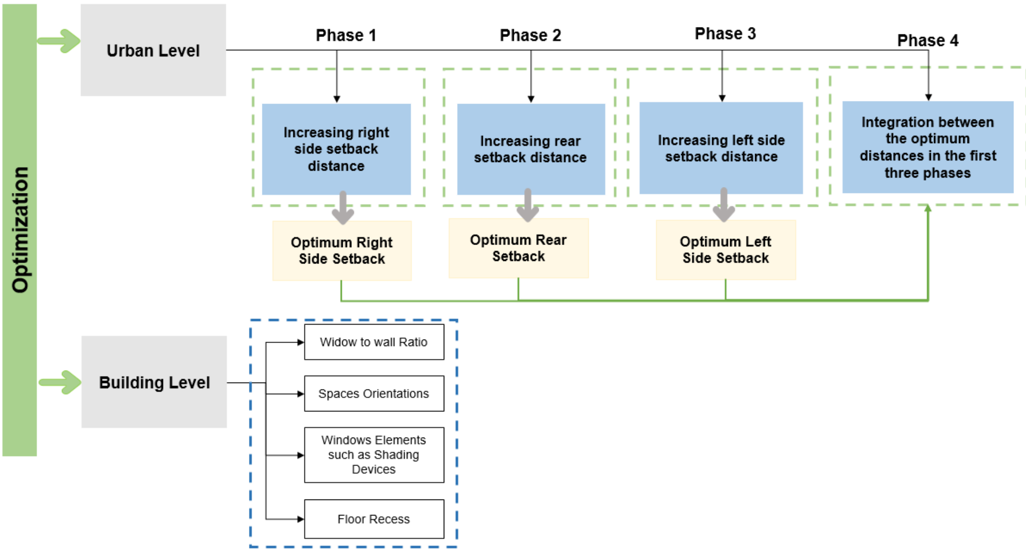


Figure 6.9: Optimization methodology.

6.3. Optimization at Urban Level:

High-density residential areas in Palestine have poor living conditions and an unhealthy indoor environment. It has confronted many challenges in obtaining housing needs. In Palestine, so as to meet the growing population needs and land scarcity problems, most residential buildings in different residential zones especially in main cities are multi-story residential buildings. Multi story buildings have become the common type of residential buildings recently and consist of more than one apartment on each floor. Moreover, residential buildings in Palestine are usually constructed very close to each other following minimum setback distances accepted by the construction law. Consequently, the apartments, especially the ones on the lower floors, receive a very limited amount of natural daylight and solar radiation, but consume greater energy to achieve a more comfortable level of lighting than top floors during the daytime (Arifin et al., 2017). Meanwhile, these spaces need additional energy for heating than upper floors since they don't receive enough solar radiation in winter (Arifin et al., 2017; Li & Lam, 2001).

The relationship between urban context and the indoor environment in residential buildings has become increasingly important, especially since it has a great effect on daylight performance and thermal energy consumption. According to (Arifin et al., 2017; Li et al., 2006) studies, the key parameters affecting indoor environmental quality especially daylighting and solar radiation are building floor area and its orientation, glazing area and type, shading and external obstruction. Quan et al. gave a concentration on four other factors affecting energy performance of buildings: the used HVAC system, occupancy behavior, urban context and the building design (Quan et al., 2014). Among all these factors, the external obstruction is the core and critical factor that affects the performance of the indoor environment. It is presented in the urban context surrounding any building. It mainly depends on the height of surrounding buildings and on the separation distances between them. The building separation distance which is also called setbacks distance has an essential influence on the solar rights and the thermal energy in buildings (Alzoubi & Dwairi, 2015; Arifin et al., 2017; Li et al., 2006). These two parameters are identified by building codes and regulations.

Consequently, this study aims to find the optimum building separation distance (setbacks distances) that provides optimum daylighting and minimum energy consumption in multi-story residential buildings in residential B-zone. A residential B zone of about 15 dunums was taken as a sample to be simulated using Design Builder software. In this section, four phases of urban level optimization were planned:

- Phase 1: Increasing the right-side setbacks distances, then evaluate the impact on natural daylighting intensity and thermal performance on the right side spaces.
- Phase 2: Increasing the rear setback distances, then evaluate the impact on natural daylighting intensity and thermal performance for the back spaces in apartments No.1 and 2.
- Phase 3: Increasing the left side setbacks distances, then evaluate the impact on natural daylighting intensity and thermal performance on the left side spaces.
- Phase 4: Integration between the first, second and third phases in order to determine the optimal solution for setbacks distances and compare the simulation results to achieve optimum setbacks distances results.

This optimization process helps to determine how the changes in rear and sides setbacks distances will influence the performance of the indoor environment in living spaces and bedrooms. In the first, second, and third optimization phases, only one setback distance will be set as the main variable, and the other setbacks will be constant throughout the optimization. Moreover, the front setback and the height of the simulated building and adjacent buildings were set as constant parameters[2]. Front setback distance is very important because the main residential spaces are located on the front side of the building, such as the living area, kitchen, guest, and dining rooms in which occupants spend most of their time. The setback distance starts at 5m, 4m, and 3m from the front, rear, and sides setbacks and then increases by 1m in each direction to reach 22m between building blocks (1m in each lot). When the setback distance increased, angle of obstruction also increased from 57° to 51°, 57°, 46°, 41°, 38°, 34° and 29° from rear, from 64° to 57° to 51°, 57°, 46°, 41°, 38°, 34° and 29° from sides while the front angle remains 31° (see Figure 6.10 and Figure 6.11, 23 combinations of obstruction distance from the simulated building was generated for each urban context scenario). Therefore 368 simulations were carried out at urban level phase. The results were compared with the urban context scenarios, which will be considered base cases in the optimization phase.

[2] In all cases, the front setback distance kept constant because it separates between the building and the main street. Thus the separation front distance between the simulated building and adjacent building is at least 20 m which is the largest than rear and sides setbacks.

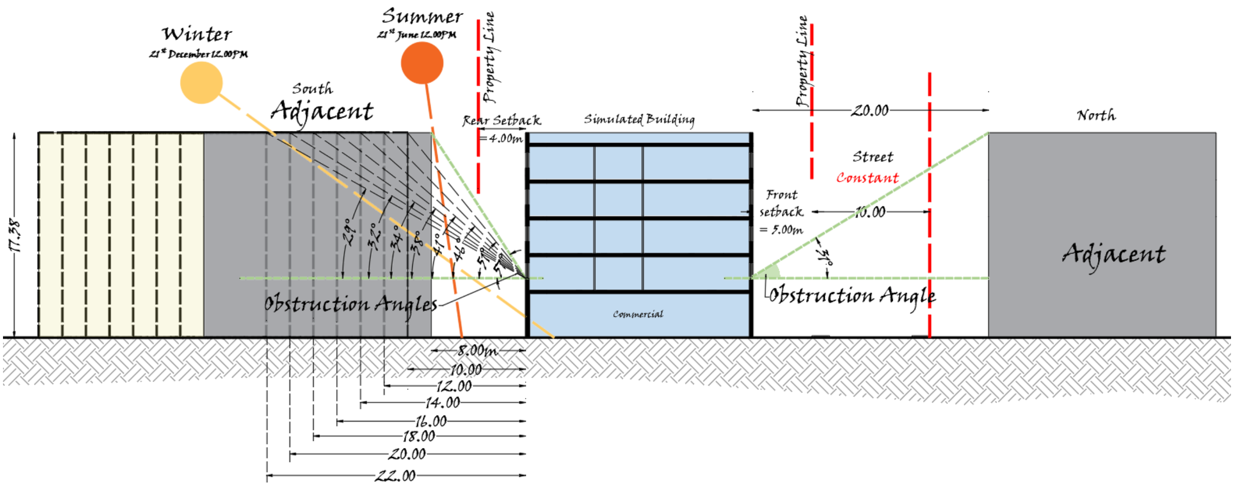


Figure 6.10: Angle of obstruction when the rear setback distance increased from 8m to 22m.

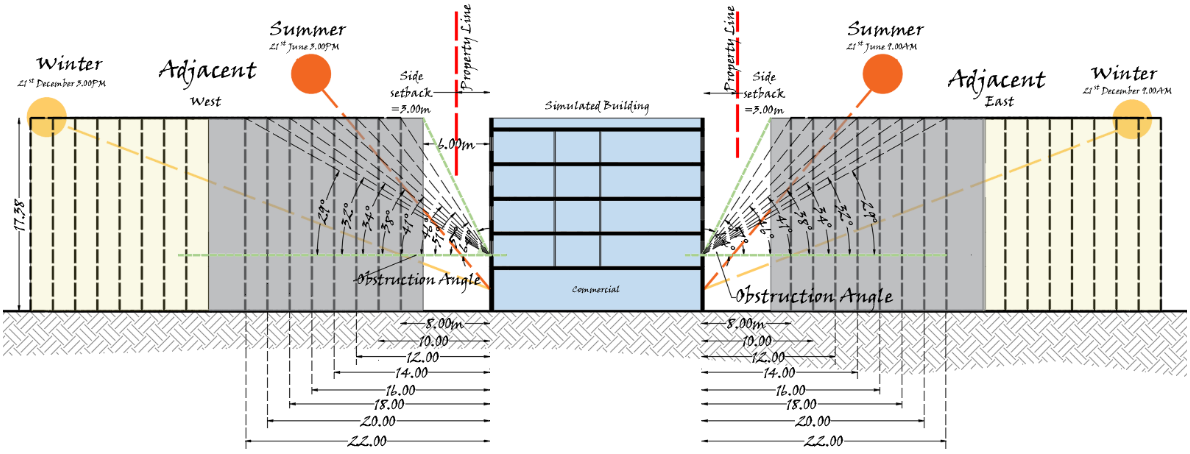


Figure 6.11: Angle of obstruction when the sides setbacks distances increased from 6m to 22m.

Different studies have investigated the impact of building separation distances on the indoor environment. Arifin et al.(Arifin et al., 2017) determine the optimum distance between two low-cost high-rise residential buildings consisting of 18 floors for five orientations (north, south, east, west and northwest), depending on Radiance computer simulation software. They study the performance in living areas on the lower, middle, and upper floors. The assessment phase depends on increasing building separation distance from 3m to 30m and then determining the impact on the indoor daylighting availability. The results show that 30m of separation distance is the optimum distance to achieve adequate daylighting level inside living areas. Alzoubi and Dwairi focus on setback regulations in the Greater Amman Municipality in Jordan and their impact on heating loads in winter. The study was firstly conducted on a 1-story east-west oriented building with a 200m^2 floor area when the building was not surrounded by any adjacent buildings in all directions. In the second stage, the adjacent building is placed on the south side at a 7m distance from the simulated building. The study concludes that at least 15m should be a separation distance when a 2-story building is placed on the south side of the simulated building to acquire its solar rights (Alzoubi & Dwairi, 2015).

A parametric study was conducted by Sun and others to investigate the influence of external obstruction on the natural daylight and on thermal energy consumption using Energy Plus software. A five-storey building with no obstruction was considered as the base case scenario. Different combinations of obstruction angles, obstruction height and road width were tested. The results showed that larger road width between building and adjacent buildings doesn't guarantee a lower energy consumption for lighting or air conditioning. A road width of 20m between a building and an adjacent building records the lowest consumption than 30m and 10m in north, east, south and west orientations. In addition, when the obstruction angle increases, energy consumed on lighting increases and air conditioning energy decreases for the same road width (Sun et al., 2017). Sabry et al. (Sabry et al., 2010) investigated the daylighting performance in the living room when the distance between building and external obstruction and the height of facing obstruction increase under constant sky view angle. A living room which faces external obstruction at different orientation at distance of 3m with 10^{o} sky view angle was simulated as a base case. Then, the distance of obstruction was increased at regular intervals (multiples of 3.00m) to reach 27m. The outcomes showed a significant difference in daylighting level when increasing the separation distance.

6.3.1. Strategy in The Optimum Setback Distances Selection:

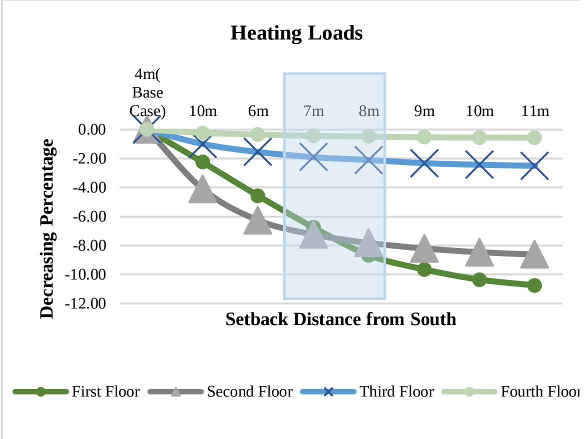
The selection of the optimum setback distances in all urban context cases depends mainly on two criteria; daylight factor must be at least the minimum requirement in the standards in the same time with decreasing the thermal energy consumption (total consumption for heating and cooling loads) in the spaces which affected by increasing setback distance. In details, the distance when the daylight factor in living area, kitchen and bedroom reach 1.5%, 2% and 1% respectively according to the standards was considered the optimum distance in the same time with decreasing the heating and cooling loads in thi optimum setback distance.

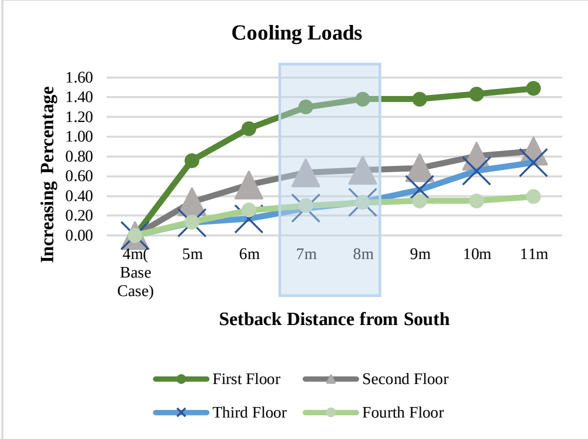
6.3.2. Results and Discussion:

6.3.2.1. Street oriented to the North (Case No.1):

When the southern setback distance increases, heating consumption decreases significantly with a reduction of up to 10.75% on the first floor, 8.62% on the second floor, 2.5% on the third floor, and less than 0.6% on the fourth floor. On the other hand, the amounts of cooling consumption in summer increases due to the penetration of massive amount of solar radiation to residential spaces when the distance is increased. Thus a decrease in total consumption occurs when the southern setback distance between buildings becomes about 14m and 16m. The total energy consumption reduction on the first and second floors begins to stabilize approximately after 16m. As for the third floor, when separation distance increases, the total consumption decreases slowly while still at a low level and becomes stable when the separation distance reaches higher than 20m. The decreasing percentage in the heating loads when the separation distance increased from 4m to 11m was lower in the upper floors, this is because the upper floors receive the maximum amount of solar radiation than the lower floors whether the separation distance 4m or 11m, so the amount of solar radiation increased slightly when the distance increased but the amount of solar radiation they reached the lower floors increased significantly.

Table 6.1:North Street oriented street case heating, cooling and total loads consumption results when south setback was increased.



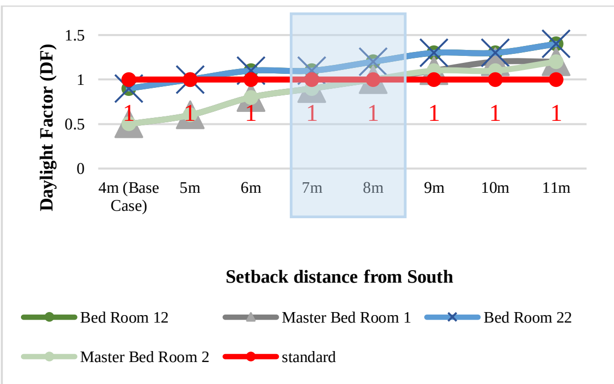


Total Load consumption (kWh/m^2)

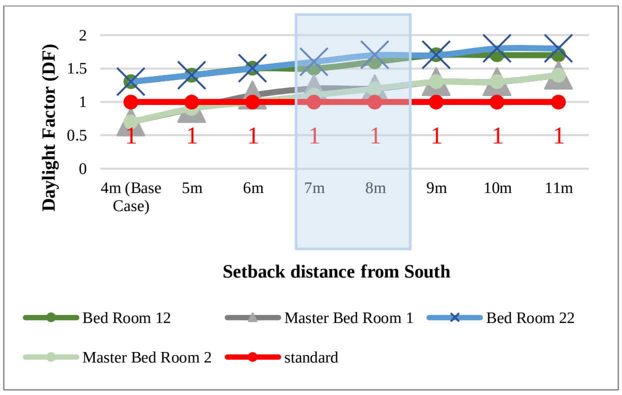
	4m	**5m**	**%**	**6m**	**%**	**7m**	**%**	**8m**	**%**	**9m**	**%**	**10m**	**%**	**11m**	**%**
1st Floor	47.05	46.47	-1.25	45.80	-2.66	45.14	-4.06	44.55	-5.31	44.25	-5.96	44.04	-6.42	43.92	-6.66
2nd Floor	47.22	46.06	-2.46	45.44	-3.76	45.17	-4.34	45.00	-4.69	44.90	-4.92	44.84	-5.04	44.80	-5.12
3rd Floor	50.15	49.88	-0.54	49.72	-0.86	49.64	-1.03	49.59	-1.12	49.55	-1.20	49.56	-1.19	49.55	-1.20
4th Floor	78.59	78.51	-0.10	78.49	-0.12	78.45	-0.17	78.44	-0.19	78.42	-0.22	78.41	-0.23	78.42	-0.22

Note: percentage of increasing or decreasing from base case current setback distances.

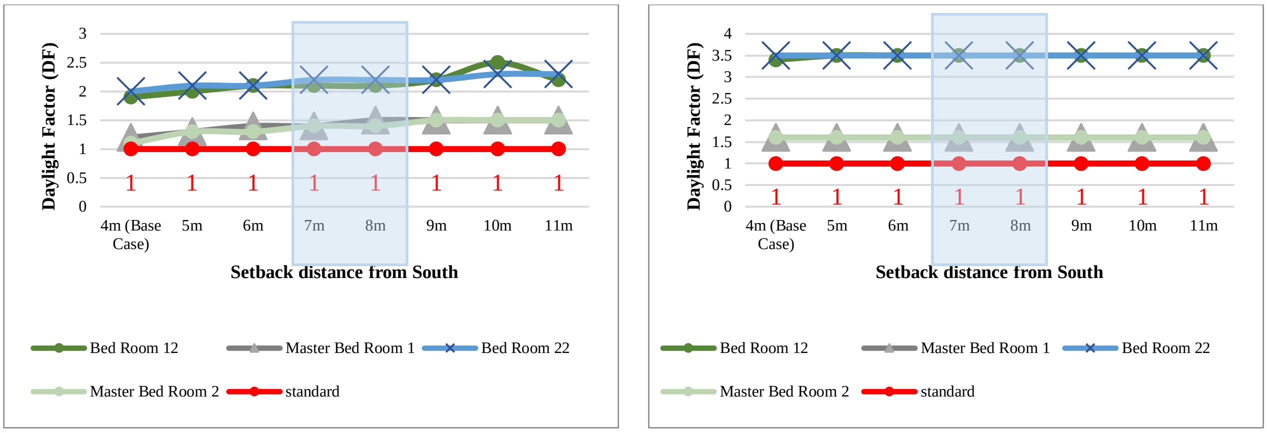
In terms of natural daylight, when the southern setback increased, there was an increase in the intensity of lighting in the southern spaces. This increase has covered bedroom 2 and the master bedroom in apartment No.1 and bedroom 2 and the master bedroom in apartment No.2. Daylight Factor (DF) values in all of these spaces became equal to or more than the standard required value (equal or more than 1% in bedrooms) when the distance became 16 meters and more in the first floor (see Figure 6.12). In the second floor, when distance is 12m the average Daylight Factor becomes 1% in all of the southern spaces. But in the third and fourth floors, current setback distance is sufficient to provide acceptable value for Daylight Factor and the DF values get stable when the separation distance increases from 8m to 22m.



First Floor



Second Floor

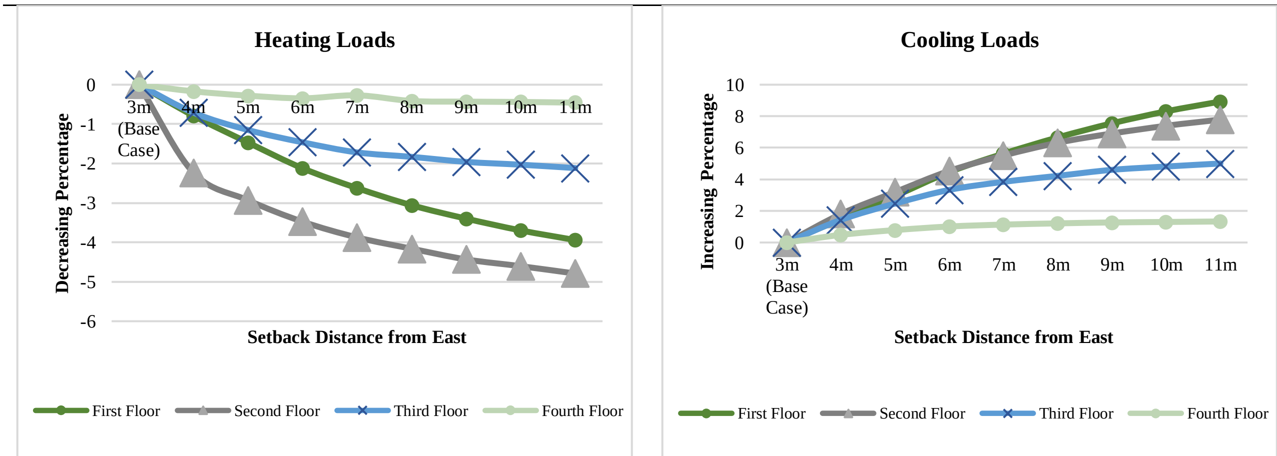


Third Floor Fourth Floor

Figure 6.12: North Street oriented street case Daylight Factor results when south setback was increased.

In the second optimization phase, when the east setback distance increases, heating consumption decreases, especially on the second floor. The reduced percentage was 2.23%, 2.93%, 3.47%, 3.87%, 4.16%, 4.43%, 4.60%, and 4.74% when the distance increased from 6m (the base case) to 22m (step 2m, 1m in each side). These percentages were lower on other floors. As for the annual cooling load consumption, the consumption increase at the second floor with a percentage of 1.81%, 3.20%, 4.54%, 5.52%, 6.32%, 6.91%, 7.40%, 7.79%, when the distance was 8m, 10m, 12m, 14m, 16m, 18m, 20m, 22m from the eastern side respectively. The obstruction angle decreases when the separation distance increases, the cooling consumption increases slowly and becomes stable when the distance reaches 14m in the third and fourth floors. The heating loads follow the similar trend. Total load consumption also increases when compared to the base case scenario as shown in Table 6.2.

Table 6.2:North Street oriented street case heating, cooling and total loads consumption results when East setback was increased.

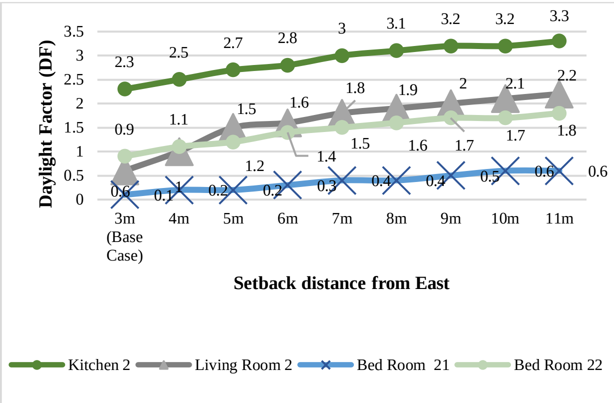


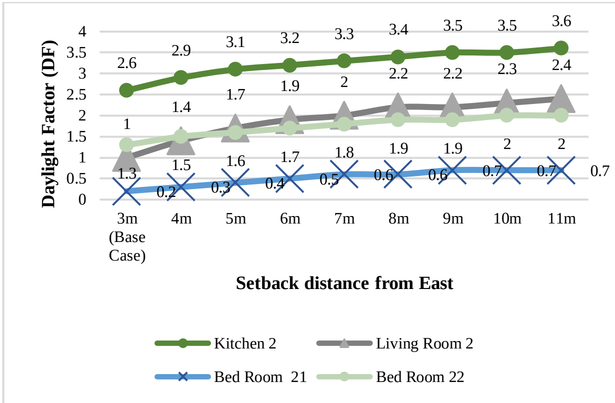
Total Load consumption (kWh/m²)

	3m	4m	%	5m	%	6m	%	7m	%	8m	%	9m	%	10m	%	11m	%
1st Floor	47.05	47.04	-0.03	47.06	0.01	47.09	0.08	47.12	0.14	47.14	0.19	47.18	0.26	47.20	0.32	47.22	0.36
2nd Floor	47.22	46.87	-0.74	46.90	-0.67	46.98	-0.51	47.03	-0.41	47.08	-0.29	47.10	-0.24	47.14	-0.17	47.15	-0.14
3rd Floor	50.15	50.23	0.15	50.31	0.31	50.39	0.47	50.41	0.52	50.46	0.60	50.49	0.68	50.52	0.72	50.53	0.75
4th Floor	78.59	78.64	0.07	78.67	0.10	78.70	0.14	78.77	0.23	78.72	0.17	78.73	0.18	78.73	0.18	78.73	0.18

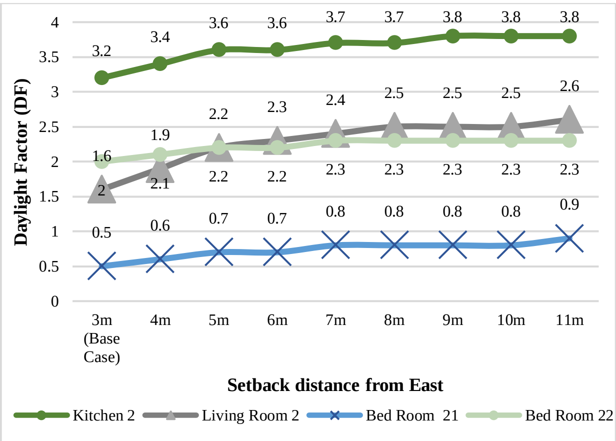
Note: percentage of increasing or decreasing from base case current setback distances.

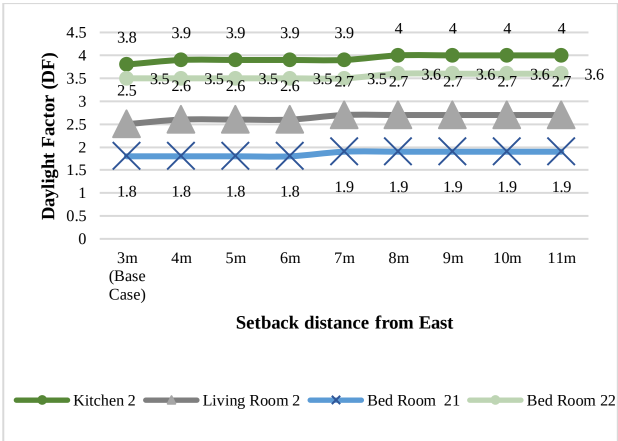
In terms of DF and its distribution inside spaces, the increase in the eastern setback led to the enhancement in daylighting distribution in apartment No.2 in the eastern rooms: kitchen2, living room2, bedroom21, and bedroom22, especially on the first and second floors when the distance becomes 10m. As for the third and fourth floors, the impact of increasing the setback distance on DF is very limited (see Figure 6.13). At the 10m distance, the average DF value of the living room2 on the first floor becomes equal to the standard required value (1.5%). For the same distance, bedroom 21 recorded 1.2%, which is higher than the standard required value. As for bedroom 22, the increase in the setback led to a minimal improvement in the natural daylight intensity, and it was less than the required standard value at the first, second, and third floors. However, it was acceptable on the fourth floor.





First Floor Second Floor



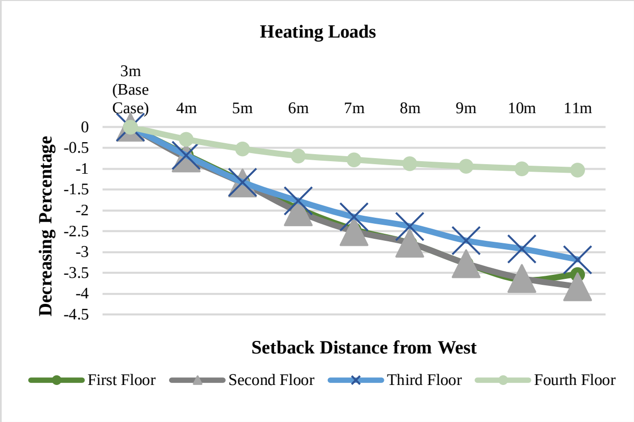


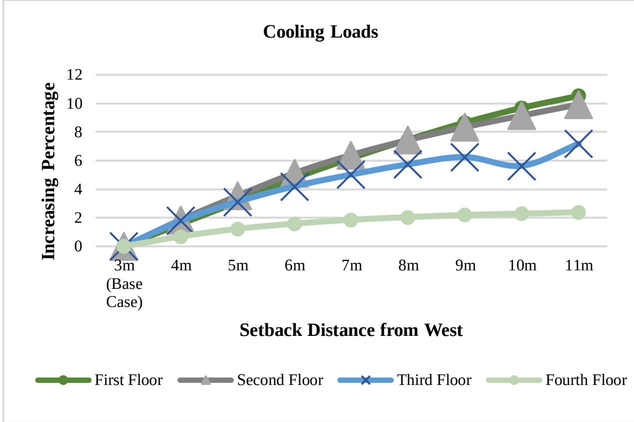
Third Floor Fourth Floor

Figure 6.13:North Street oriented street case Daylight Factor results when East setback was increased.

During the third optimization stage, when the side setback increases from the west, a slight increase in the total energy consumption occurred compared to the base case consumption due to the rise in the cooling loads more than the decrease in the required heating loads. For example, heating loads decreased by 1.96% and 3.53%. Simultaneously, cooling loads increase by 4.76% and 10.53% on the first floor when the distance between buildings is 12m and 22m respectively. In details, the increasing rate in the annual total load consumption ranged between 0.08% to 1.17% at the first floor, 0.22% to 1.25% at the second floor, 0.30% to 0.98% at the third floor, and between 0.06% to 0.19% at the fourth respectively when the distance increase from 6m to 22 m between the simulated building and the adjacent building from the west (see Table 6.3).

Table 6.3:North Street oriented street case heating, cooling and total loads consumption results when West setback was increased.



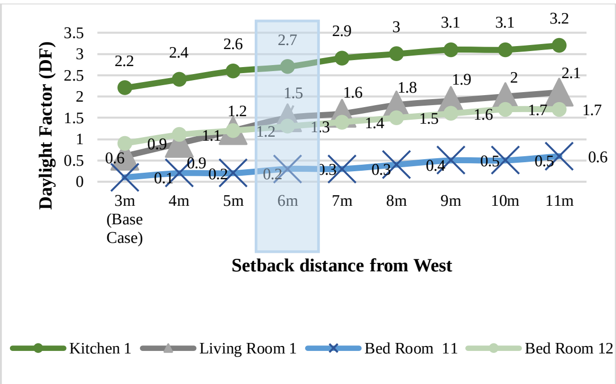


Total Load consumption (kWh/m²)

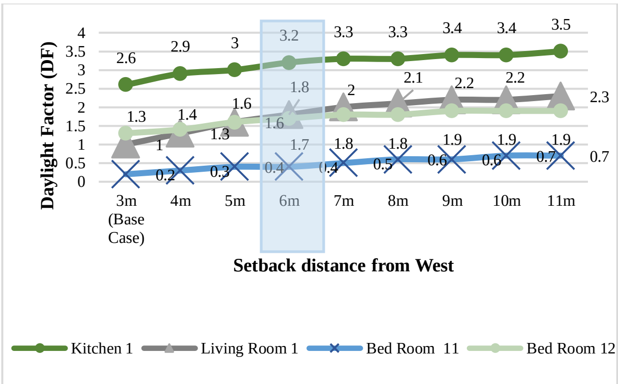
	3m	4m	%	5m	%	6m	%	7m	%	8m	%	9m	%	10m	%	11m	%
1st Floor	47.05	47.09	0.08	47.13	0.17	47.19	0.29	47.25	0.43	47.36	0.64	47.39	0.71	47.43	0.80	47.60	1.17
2nd Floor	47.22	47.32	0.22	47.44	0.46	47.51	0.61	47.59	0.78	47.69	0.99	47.70	1.02	47.74	1.09	47.81	1.25
3rd Floor	50.15	50.31	0.31	50.39	0.47	50.47	0.63	50.52	0.73	50.60	0.88	50.60	0.88	50.41	0.52	50.65	0.98
4th Floor	78.59	78.64	0.06	78.67	0.10	78.69	0.12	78.72	0.16	78.73	0.17	78.74	0.18	78.74	0.18	78.75	0.19

Note: percentage of increasing or decreasing from base case current setback distances.

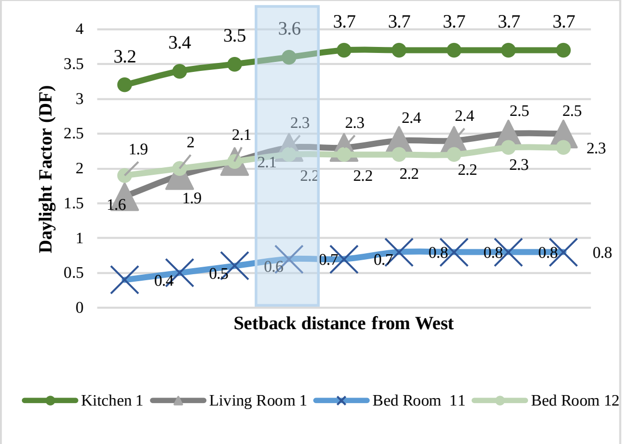
At this stage, the effect of the western setback in North oriented street was limited to the western spaces in Apartment No. 1, as the increase in the distance between the buildings led to improved lighting in kitchen1 and living room1, bedroom11 and bedroom 12, especially when the distance is 12 m, where most of the spaces on the first floor reached acceptable DF values, except for the bedroom 11, which still needs more optimization.

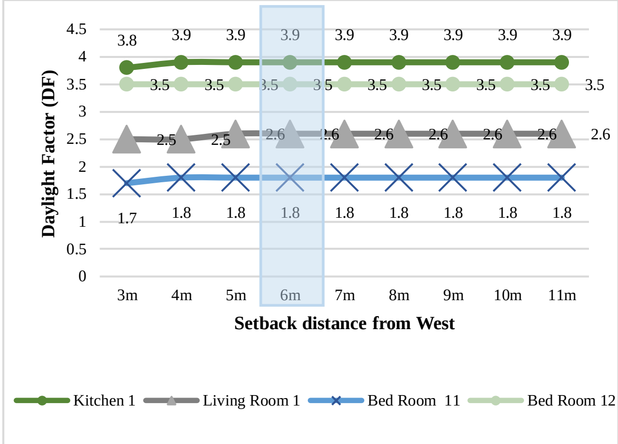


First Floor



Second Floor





Third Floor Fourth Floor

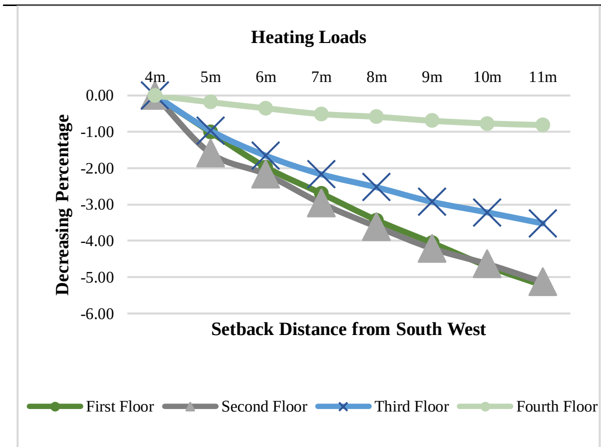
Figure 6.14: North Street oriented street case Daylight Factor results when West setback was increased.

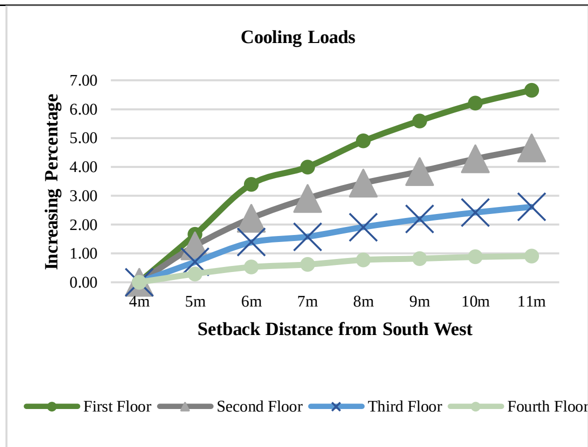
At the third and fourth floors, the average DF were not affected by the increased setback distance. Based on the optimization results, it was revealed that 16m, 10m and 12m separation distances between the simulated building and adjacent buildings from south, east and north sides respectively, give an acceptable daylighting level in indoor spaces and achieve minimized thermal load consumption as much as possible.

6.3.2.2. Street oriented to the North-East (Case No.2):

As shown in Table 6.4, when the rear setback distance increases from the southwestern side when the main street is oriented to the north-east, the total load consumption decreases very slightly, and the decreasing percentage in the first floor does not exceed 1.65% at the 20m distance. This percentage decreases on the other floors and it becomes worthless.

Table 6.4:North East Street oriented street case heating, cooling and total loads consumption results when South West setback was increased.



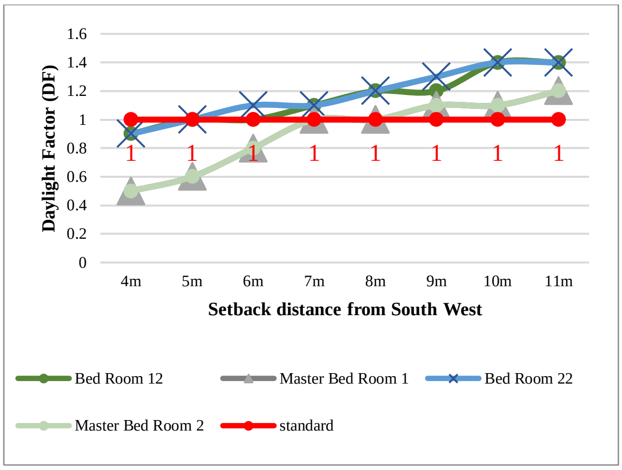


Total Load consumption (kWh/m^2)

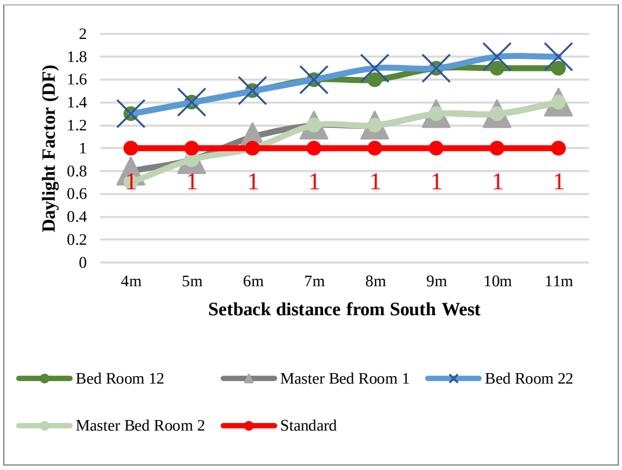
	4m	5m	%	6m	%	7m	%	8m	%	9m	%	10m	%	11m	%
1st Floor	48.88	48.85	-0.05	48.86	-0.04	48.74	-0.29	48.66	-0.44	48.59	-0.58	48.07	-1.65	48.41	-0.95
2nd Floor	49.05	48.82	-0.47	48.83	-0.45	48.73	-0.67	48.63	-0.85	48.53	-1.06	48.49	-1.15	48.41	-1.30
3rd Floor	52.67	52.52	-0.27	52.04	-1.20	52.35	-0.61	52.31	-0.69	52.24	-0.81	52.21	-0.88	52.15	-0.98
4th Floor	79.96	79.95	-0.01	79.94	-0.03	79.88	-0.10	79.89	-0.09	79.85	-0.14	79.83	-0.17	79.82	-0.19

Note: percentage of increasing or decreasing from base case current setback distances.

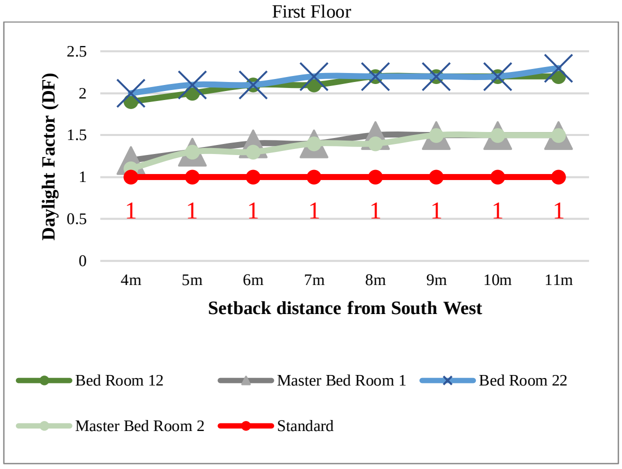
But when analyzing the effect of the setback distance on the total energy consumption and the lighting intensity inside the southwestern spaces, the results showed that increasing the distance between buildings from the southwestern orientations increase the daylighting intensity inside the building and the lighting intensity becomes acceptable in bedrooms since the average DF becomes equal to or more than 1 %, and in this case, adequate lighting was obtained when the distance between buildings was equal to or more than 14 meters. Starting at a distance of 14m, the adjacent building from south-west has no significant impact on the DF.



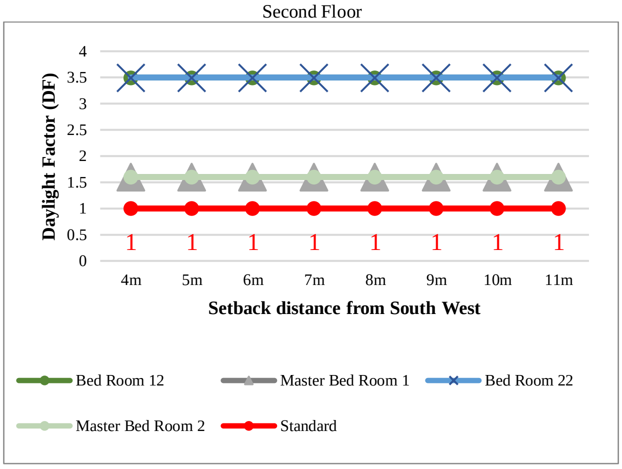
First Floor



Second Floor



Third Floor

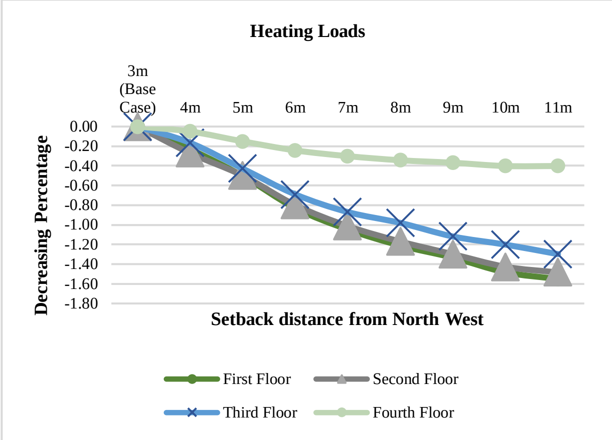


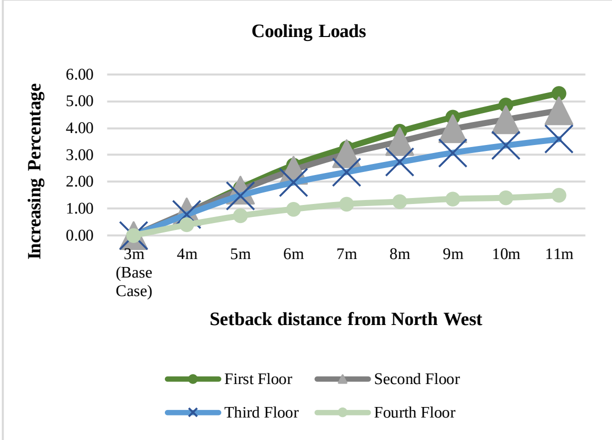
Fourth Floor

Figure 6.15: North-East Street oriented street case Daylight Factor results when South-West setback was increased.

The increase in the northeastern side's setback distance led to a significant and noticeable increase in the amount of cooling loads. On the other hand, the amount of heating loads decreased by 1.55%. Thus, an increase in the total energy consumption occurred in this case than the base case energy consumption. This is because the solar path and sun altitude angles allow a higher amount of solar radiation to access the northeastern façade in summer than in winter, leading to higher consumption of cooling loads.

Table 6.5:North East Street oriented street case heating, cooling and total loads consumption results when North West setback was increased.

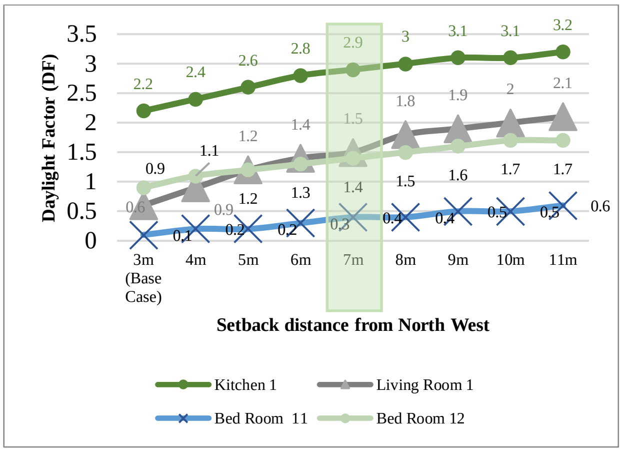




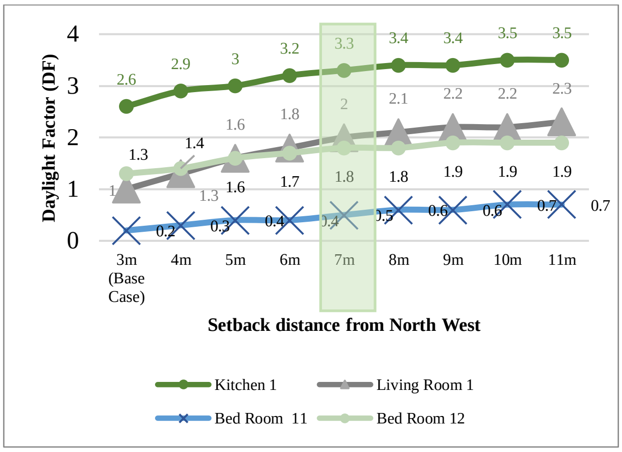
Total Load consumption (kWh/m²)																	
	3m	**4m**	**%**	**5m**	**%**	**6m**	**%**	**7m**	**%**	**8m**	**%**	**9m**	**%**	**10m**	**%**	**11m**	**%**
1st Floor	48.88	48.95	0.16	49.03	0.31	49.08	0.41	49.12	0.51	49.18	0.62	49.23	0.73	49.27	0.80	49.32	0.91
2nd Floor	49.05	49.14	0.17	49.23	0.36	49.28	0.47	49.33	0.57	49.37	0.66	49.43	0.76	49.46	0.82	49.50	0.92
3rd Floor	52.67	52.36	-0.58	52.86	0.36	52.89	0.41	52.92	0.47	52.96	0.56	52.99	0.62	53.03	0.69	53.05	0.73
4th Floor	79.96	80.05	0.11	80.10	0.17	80.13	0.20	80.15	0.23	80.16	0.24	80.17	0.26	80.17	0.26	80.19	0.29

Note: percentage of increasing or decreasing from base case current setback distances.

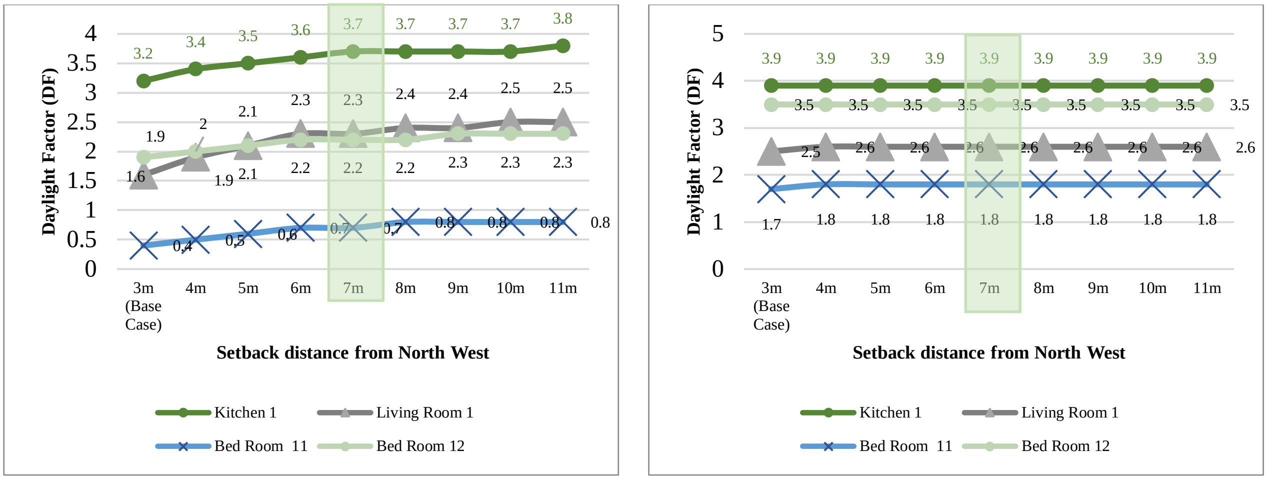
Meanwhile, when the distance between buildings increases from the northeast side, the intensity of natural daylighting that enters the spaces of apartment No. 1; kitchen1, living room1, bedroom11, and bedroom12 increases. The first floor is the most critical floor in terms of the availability of natural lighting. However, when the distance became 14 meters, the obstruction angle increased from 64° to 41°, most northeastern spaces have sufficient daylighting (see Figure 6.16).



First Floor



Second Floor

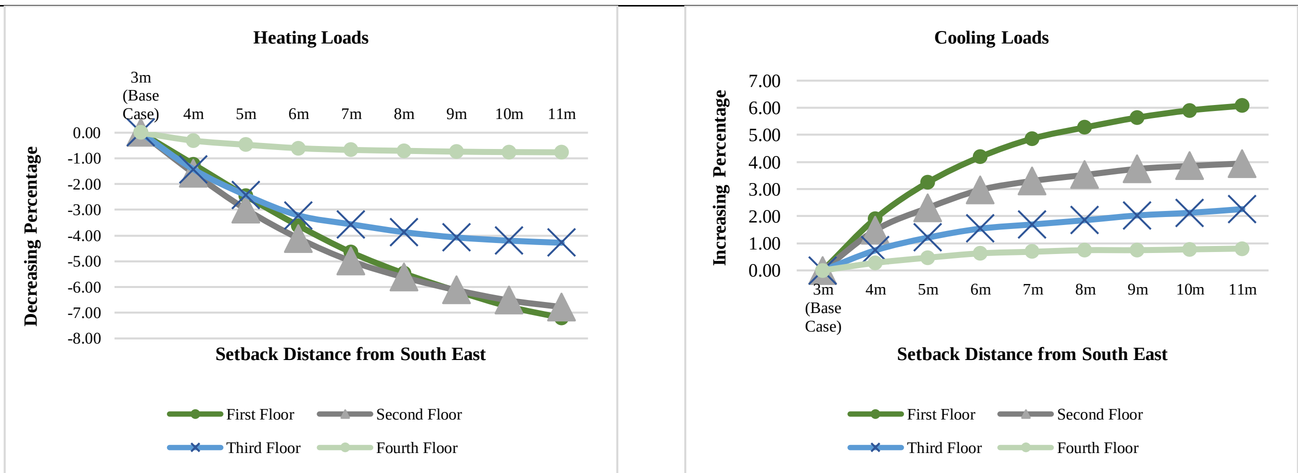


Third Floor Fourth Floor

Figure 6.16: North-East Street oriented street case Daylight Factor results when North-West setback was increased.

The heating loads consumption was decreased when the distance between the simulated building and the adjacent building from the southeast side increased from 6 m to 22 m (step 2m) with a percentage of 1.22%, 2.46%, 3.62%, 4.65%, 5.47%, 6.15%, 6.76%, and 7.20% respectively on the first floor, and about 1.57%, 2.98%, 4.11%, 5.62%, 6.12%, 6.52%, and 6.78% respectively on the second floor. On the other hand, cooling loads got increased, but at a lower rate, and ranged from 1.91%, 3.24%, 4.19%, 4.86%, 5.28%, 5.64%, 5.91%, and 6.07% when the setback distance increased from 6m to 22m on the first floor (see Table 6.6). Resulting in the decrease of the total energy consumption when compared to the base case scenario. Simultaneously, the energy consumed on the use of artificial lighting was decreased at a distance12m, as the amount of lighting in the southwestern spaces became sufficient and the average DF was equal to or more than the standard values (see Figure 6.17).

Table 6.6:North-East Street oriented street case heating, cooling and total loads consumption results when South-East setback was increased.



Total Load consumption (kWh/m²)

	3m	4m	%	5m	%	6m	%	7m	%	8m	%	9m	%	10m	%	11m	%
1st Floor	48.88	48.83	-0.10	48.68	-0.41	48.48	-0.81	48.28	-1.23	48.09	-1.60	47.94	-1.91	47.80	-2.20	47.69	-2.42
2nd Floor	49.05	48.87	-0.37	48.60	-0.91	48.39	-1.34	48.19	-1.74	48.05	-2.04	47.94	-2.26	47.85	-2.46	47.79	-2.58

3rd Floor	52.67	52.39	-0.53	52.18	-0.92	52.01	-1.24	51.94	-1.38	51.88	-1.50	51.86	-1.54	51.84	-1.58	51.84	-1.57
4th Floor	79.96	79.89	-0.10	79.86	-0.13	79.84	-0.15	79.82	-0.18	79.82	-0.18	79.81	-0.20	79.81	-0.20	79.81	-0.20

Note: percentage of increasing or decreasing from base case current setback distances.

When the separation distance is 12m, the obstruction angle is 46°. Angle 45° of obstruction at bed rooms is not enough to achieve acceptable level of daylighting.

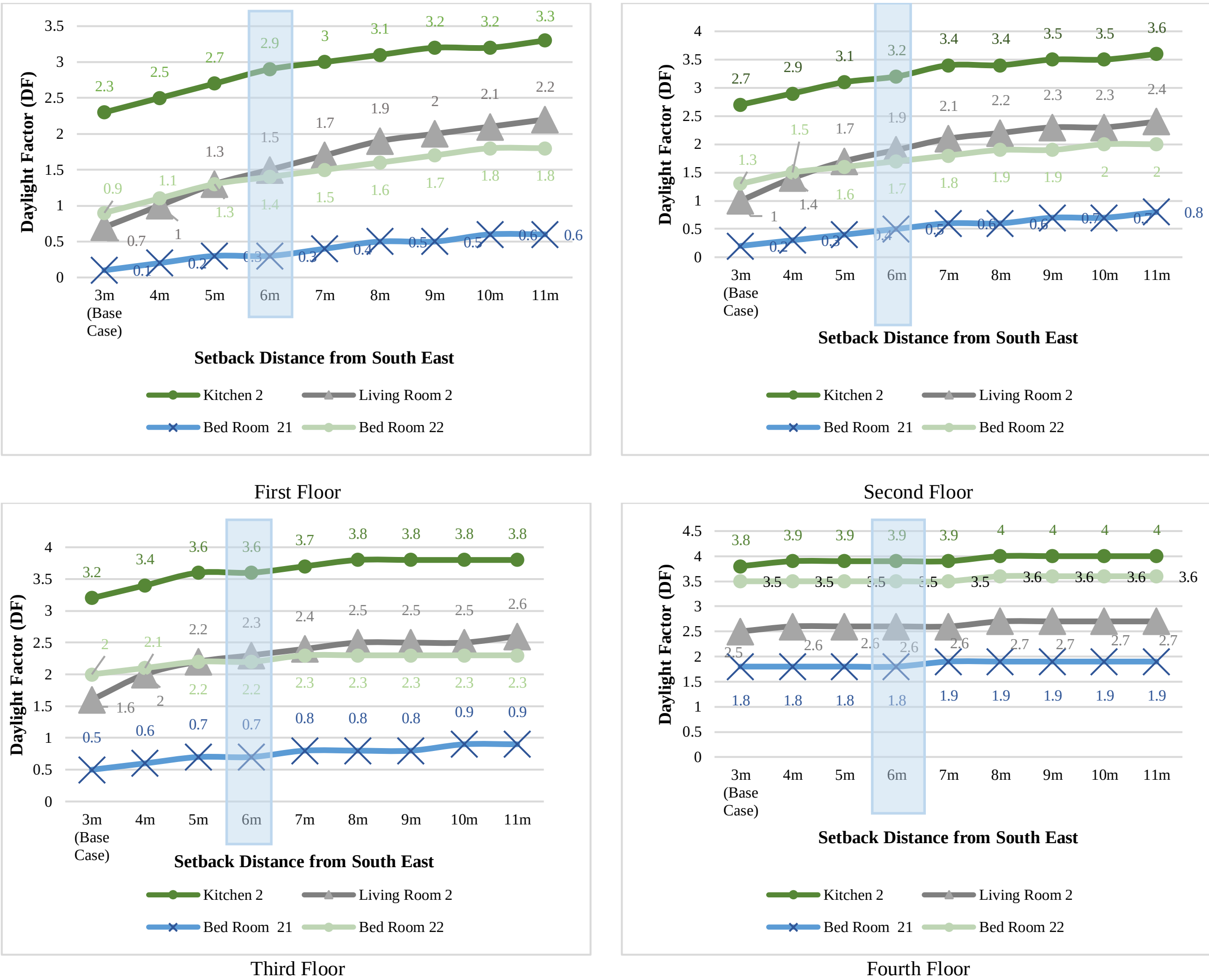


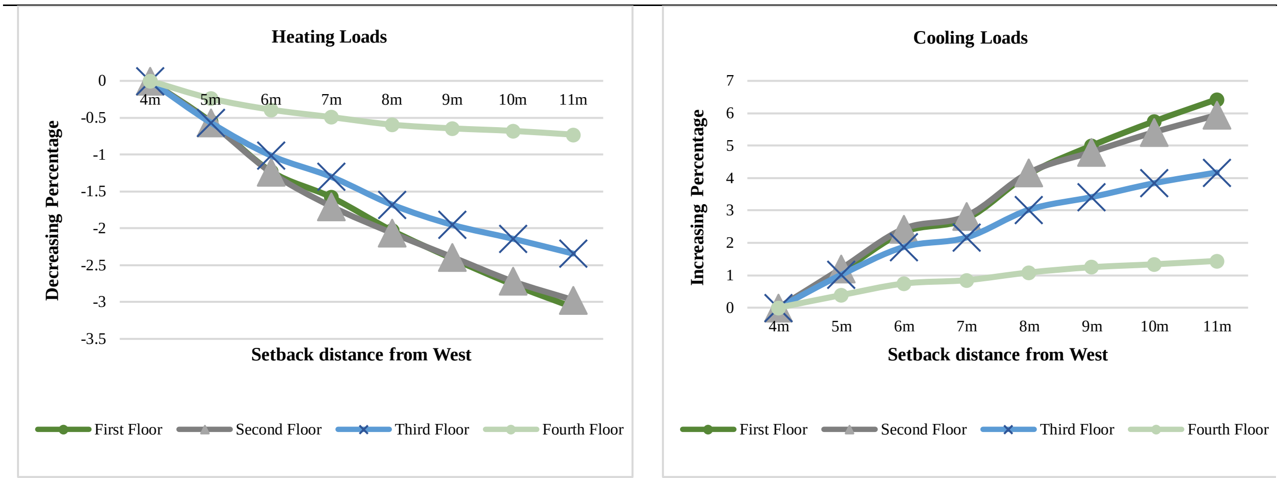
Figure 6.17: North- East Street oriented street case Daylight Factor results when South-East setback was increased.

6.3.2.3. Street oriented to the East (Case No.3):

In the first optimization phase, when the main street is oriented to the East, increasing the setback from the west side was studied. As shown in the results below, when the Western setback increases, the amount of cooling loads required during hot summer months also increases, on the other hand, the heating loads consumption in winter decreases, which leads to a very slight increases in the annual total consumption than the base case (see Table 6.7). Moreover, increasing the distance between buildings contributed to improved lighting inside the spaces, especially when the distance was 16 meters or more, thus reducing the artificial lighting energy required during daylight hours as shown in Figure 6.18. At 16m, the decreasing in the obstruction angle from

57 ° to 38 ° led to a 2.03% reduction in the heating consumption and 4.13% increasing in the cooling loads.

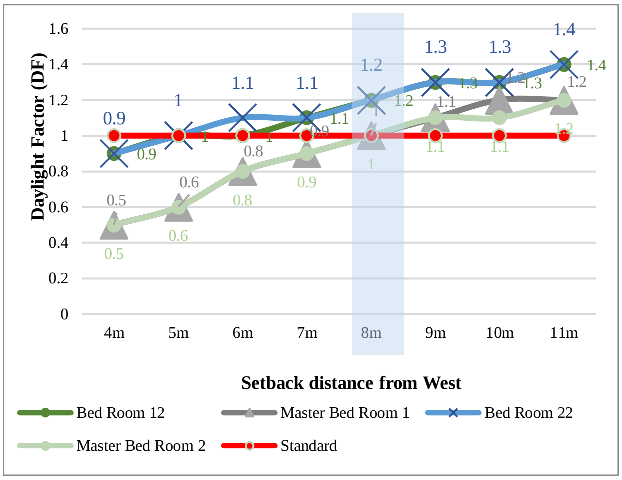
Table 6.7: East Street oriented street case heating, cooling and total loads consumption results West setback was increased.



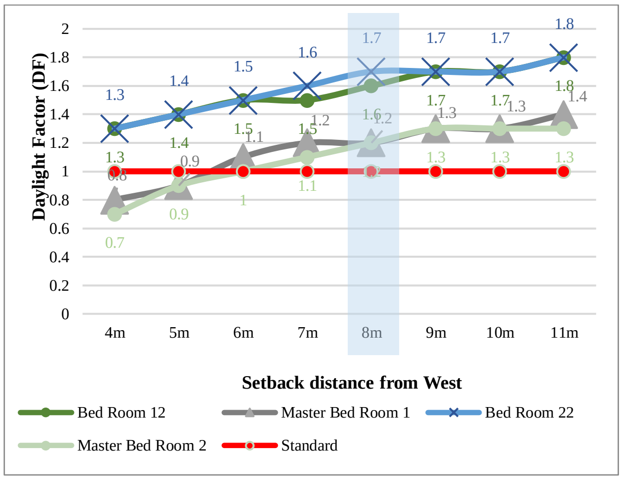
Total Load consumption (kWh/m²)

	4m	5m	%	6m	%	7m	%	8m	%	9m	%	10m	%	11m	%
1st Floor	47.76	47.79	0.06	47.80	0.08	47.77	0.01	47.88	0.23	47.91	0.31	47.94	0.37	47.96	0.42
2nd Floor	47.92	47.99	0.15	48.04	0.25	47.98	0.13	48.14	0.46	48.17	0.52	48.19	0.58	48.22	0.64
3rd Floor	51.27	51.33	0.11	51.38	0.22	51.36	0.17	51.44	0.32	51.44	0.33	51.48	0.41	51.49	0.43
4th Floor	78.86	78.85	-0.01	78.88	0.02	78.86	0.00	78.87	0.02	78.90	0.04	78.90	0.05	78.91	0.06

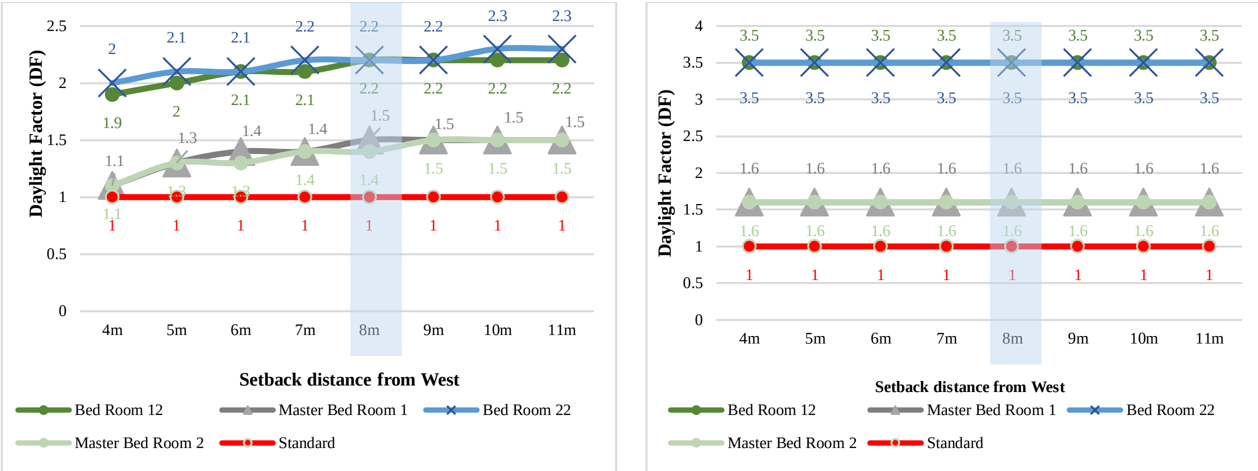
Note: percentage of increasing or decreasing from base case current setback distances.



First Floor



Second Floor

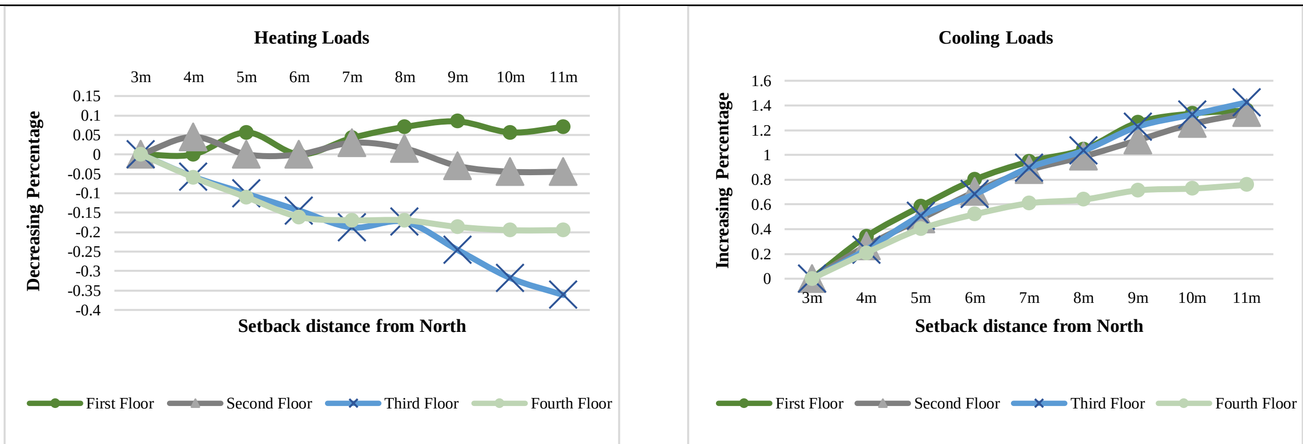


Third Floor Fourth Floor

Figure 6.18: East Street oriented street case Daylight Factor results when West setback was increased.

The northern façade receives solar radiation from the east and west orientations, especially in summer, so increasing the northern setback is ineffective because it causes an increase in the cooling and heating loads, especially on the first and second floors, which also leads to an increase in the total energy consumption, as found in Table 1. As for the third and fourth floors, increasing the northern setback reduces heating loads by a very small percentage, reaching 0.36% on the third floor and 0.19% on the fourth floor when the distance is 22 meters.

Table 6.8: East Street oriented street case heating, cooling and total loads consumption results North setback was increased.

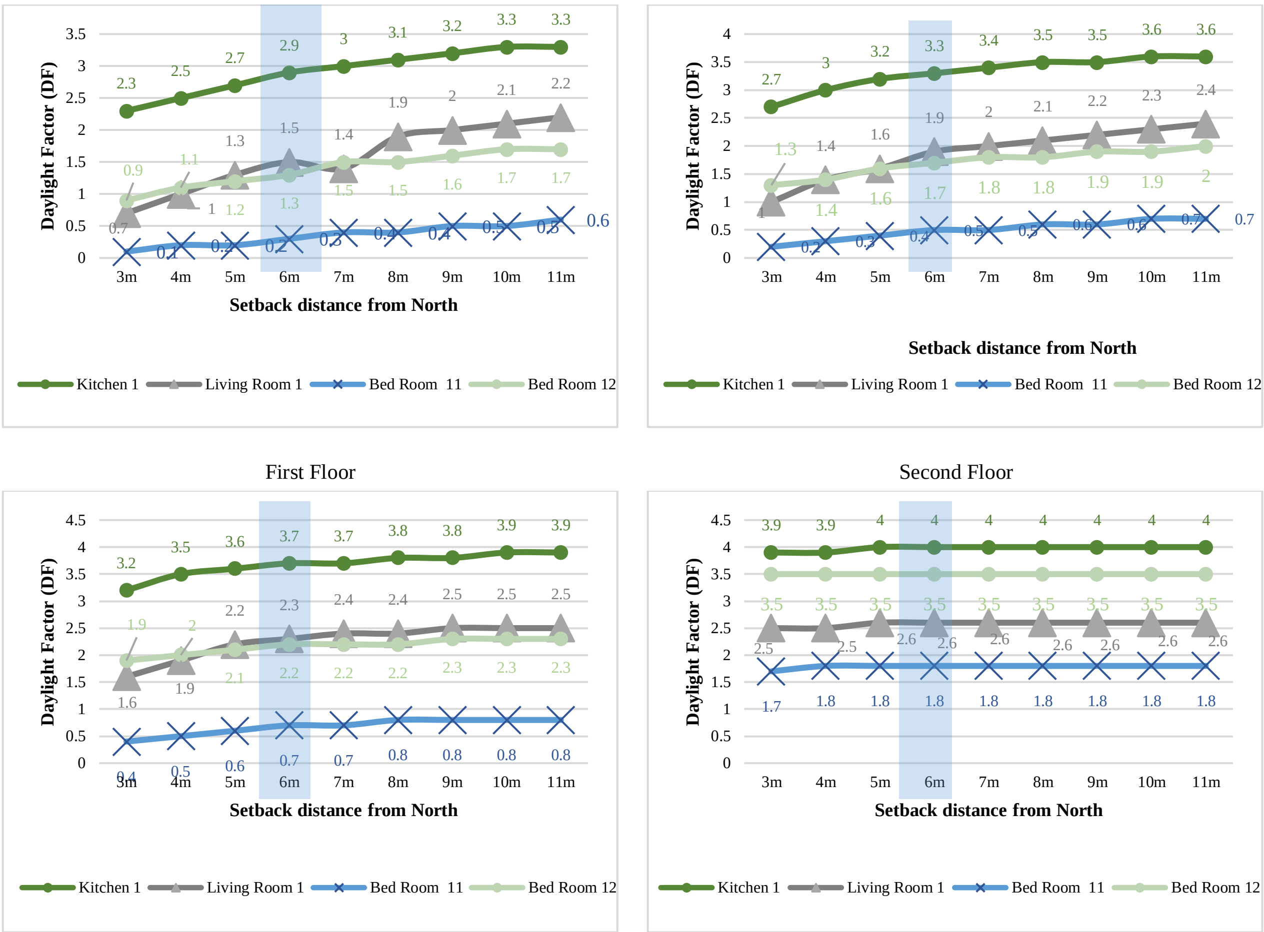


Total Load consumption (kWh/m²)

	3m	4m	%	5m	%	6m	%	7m	%	8m	%	9m	%	10m	%	11m	%
1st Floor	47.76	47.82	0.12	47.88	0.25	47.91	0.29	47.94	0.37	47.97	0.43	48.01	0.52	48.02	0.53	48.02	0.54
2nd Floor	47.92	47.98	0.13	48.01	0.20	48.05	0.28	48.10	0.37	48.11	0.41	48.13	0.44	48.15	0.48	48.17	0.52
3rd Floor	51.27	51.31	0.07	51.35	0.16	51.38	0.21	51.41	0.27	51.45	0.34	51.47	0.38	51.47	0.38	51.48	0.40
4th Floor	78.86	78.89	0.04	78.92	0.08	78.93	0.09	78.95	0.11	78.96	0.12	78.97	0.14	78.97	0.14	78.98	0.15

Note: percentage of increasing or decreasing from base case current setback distances.

On the other hand, at obstruction angle of 64º, the current setback distance is not sufficient to provide an acceptable amount of natural daylight inside spaces oriented to the northern façade, these spaces need a setback distance between buildings not less than 12 meters on the first floor (about 46° obstruction angle), so that the value of the Daylight Factor exceeds 1% in the bedrooms and 1.5% in living spaces.



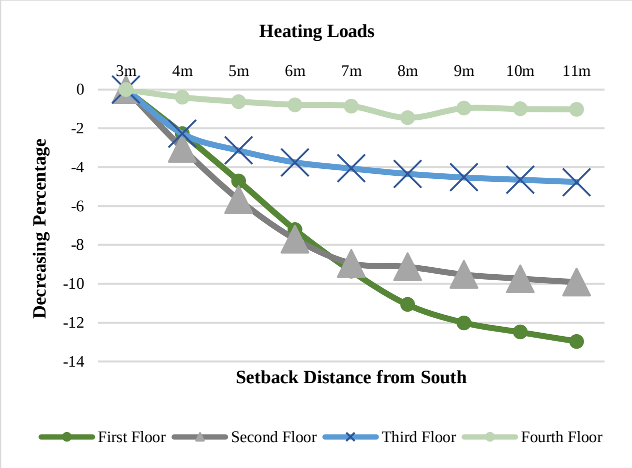
Third Floor

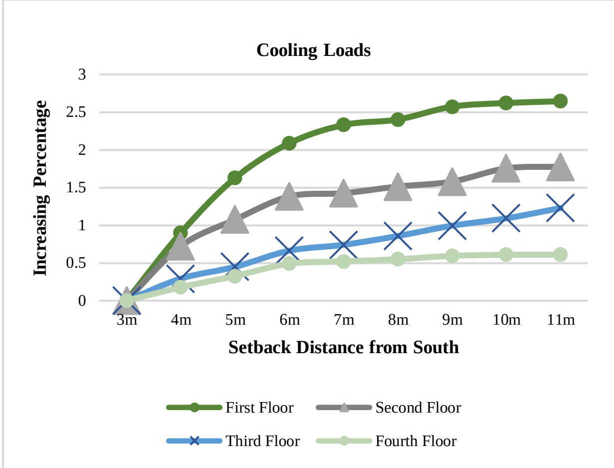
Fourth Floor

Figure 6.19: East Street oriented street case Daylight Factor results when North setback was increased.

The southern façade is the most efficient façade in terms of solar radiation falling on it during winter and summer, especially in winter days when the solar altitude angles are low. When the southern setback increased in this case, the cooling loads decrease by 2.27%, 4.71%, 7.21%, 9.34%, 11.07%, 12.00%, 12.50%, and 12.96% when the distance increase from 6 m to 22 m on the first floor, respectively. On the second floor, the cooling loads decreased by 3.02%, 5.66%, 7.69%, 8.95%, 9.12%, 9.53%, 9.74% and 9.92% respectively. On the other hand, the cooling loads slightly increase when compared to the decreased heating loads. The percentage of increase did not exceed 2.64%, 1.78%, 1.23%, and 0.61% in the first, second, third, and fourth floors, respectively when the southern setback distance was 22 m (11m setback distance). Thus, the total energy consumption per square meter is significantly reduced, especially on the first and second floors, as shown in Table 6.9.

Table 6.9: East Street oriented street case heating, cooling and total loads consumption results South setback was increased.



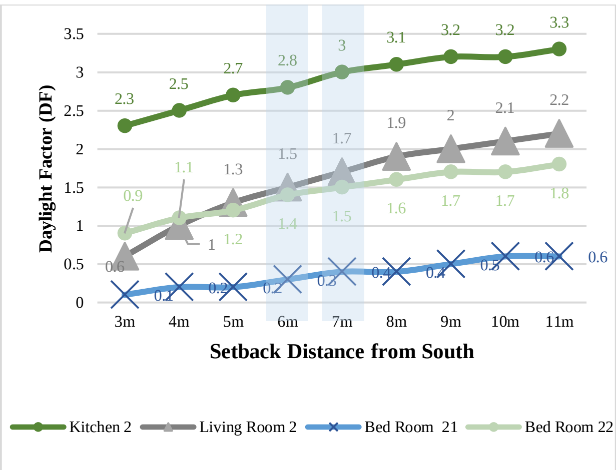


Total Load consumption (kWh/m²)

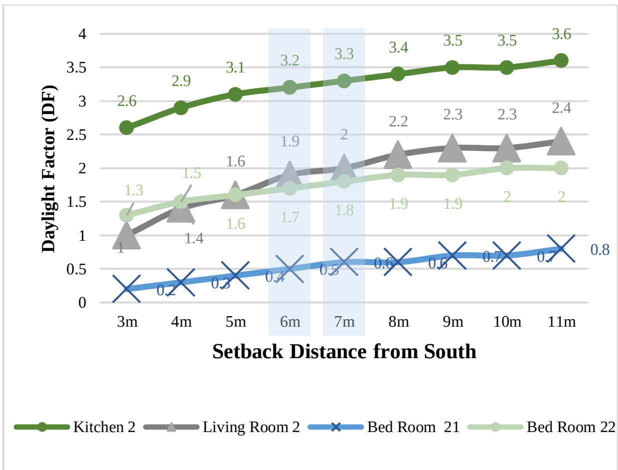
	3m	4m	%	5m	%	6m	%	7m	%	8m	%	9m	%	10m	%	11m	%
1st Floor	47.76	47.24	-1.11	46.63	-2.38	45.95	-3.80	45.35	-5.05	44.84	-6.12	44.59	-6.65	44.45	-6.94	44.31	-7.23
2nd Floor	47.92	47.20	-1.50	46.51	-2.93	45.99	-4.02	45.64	-4.74	45.61	-4.82	45.51	-5.03	45.48	-5.08	45.44	-5.18
3rd Floor	51.27	50.67	-1.18	50.45	-1.61	50.32	-1.87	50.24	-2.02	50.18	-2.13	50.16	-2.18	50.14	-2.20	50.14	-2.20
4th Floor	78.86	78.71	-0.19	78.64	-0.28	78.61	-0.32	78.58	-0.35	78.29	-0.72	78.55	-0.39	78.53	-0.42	78.53	-0.42

Note: percentage of increasing or decreasing from base case current setback distances.

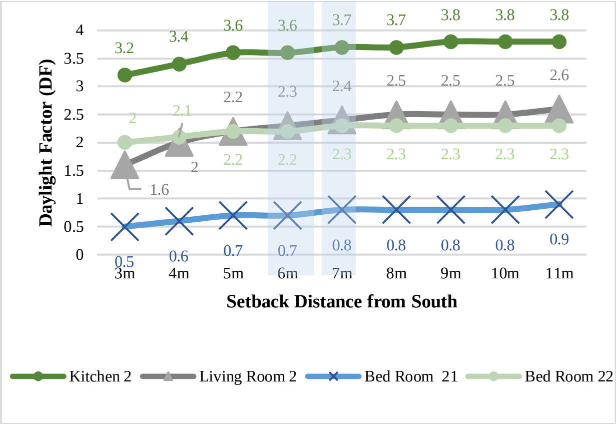
When increased the southern setback distance, the natural daylight intensity inside apartment No.2 southern spaces improved, and the average DF values in the kitchen, living room, and bedroom 22 equal or more than the required one when the setback distance more than 12m and the obstruction angle less than 45º, except bedroom 21 in the first, second and third floors as shown in the Figure 6.20.



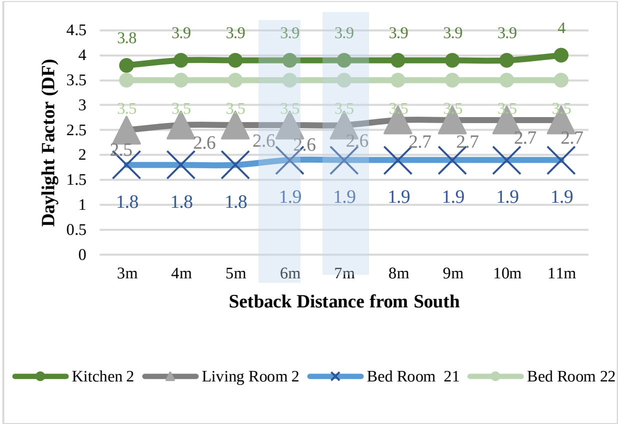
First Floor



Second Floor



Third Floor



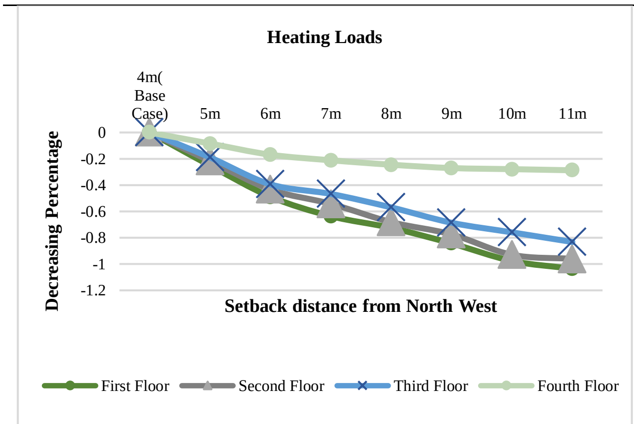
Fourth Floor

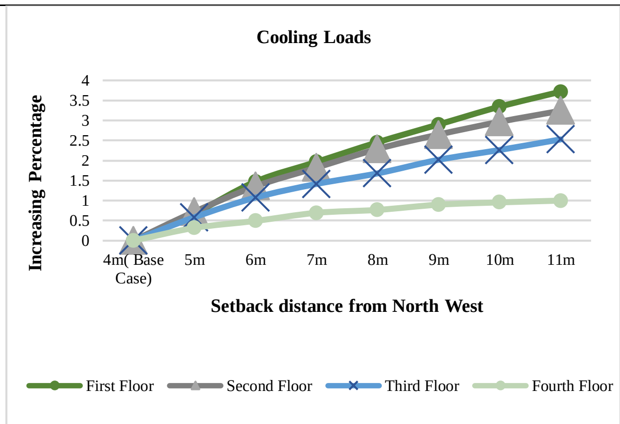
Figure 6.20: East Street oriented street case Daylight Factor results when South setback was increased.

6.3.2.4. Street oriented to the South-East (Case No.4):

The northwestern façade gets solar radiation during the afternoon when the sun moves from the south to the west and northwest orientations when the solar altitude angles are less than at noontime. Therefore, in summer, heat gain occurs due to solar radiation on the northwestern façade. And in this situation, the cooling loads are highly needed to reduce the northwest spaces' heat increase. In winter, the solar radiation rarely falls on the northwestern façade, and solar altitude angles are low. Hence, the decrease in heating loads is minimal when the setback distance increase from this direction. Thus, the total energy consumption increases when compared to the base case.

Table 6.10: South-East Street oriented street case heating, cooling and total loads consumption results North-West setback was increased.





Total Load consumption (kWh/m^2)

	4m	5m	%	6	%	7m	%	8m	%	9m	%	10m	%	11m	%
1st Floor	46.99	47.04	0.11	47.12	0.27	47.16	0.37	47.23	0.51	47.28	0.61	47.32	0.70	47.37	0.81
2nd Floor	47.58	47.67	0.18	47.74	0.32	47.80	0.46	47.85	0.57	47.90	0.67	47.92	0.72	47.97	0.81
3rd Floor	51.73	51.81	0.15	51.86	0.25	51.92	0.35	51.95	0.41	51.99	0.49	52.02	0.56	52.06	0.63
4th Floor	79.77	79.82	0.06	79.83	0.07	79.87	0.12	79.87	0.13	79.90	0.16	79.91	0.18	79.92	0.19

Note: percentage of increasing or decreasing from base case current setback distances.

As for the DF, the distance between the two buildings must be at least 14 m to provide a sufficient amount of natural daylighting in the northwestern spaces on the first floor. On the second floor, these spaces need a distance of at least 12 m for the DF value to be acceptable.

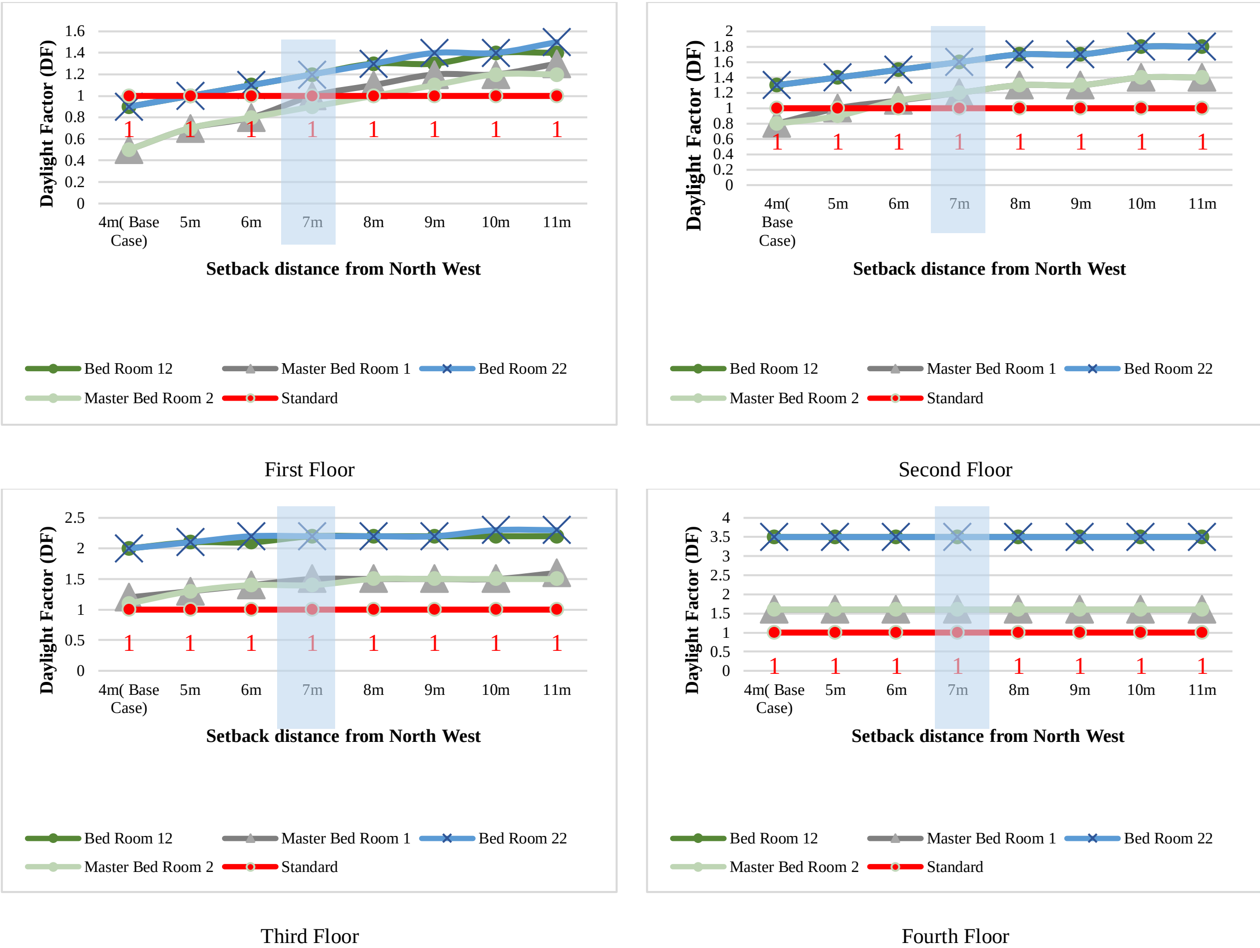
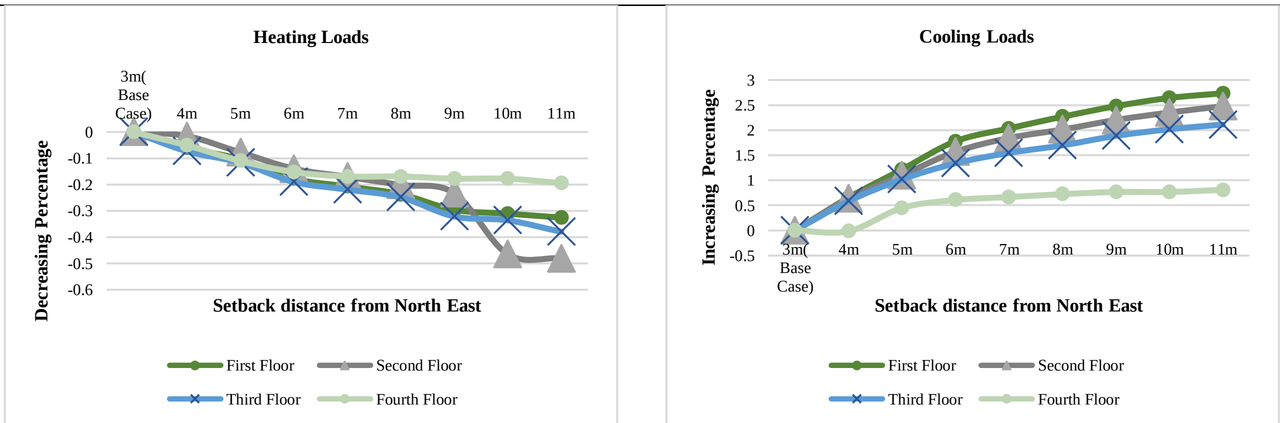


Figure 6.21: South- East Street oriented street case Daylight Factor results when North-West setback was increased.

When the setback distance increases from the northeastern side where the solar radiation falls on during the morning period, an unnoticeable decrease in heating loads in winter was found with a percentage that does not exceed 0.50% when the distance is 22 m between the simulated building and northeastern adjacent building. Simultaneously, the amount of cooling loads increases in the summer, which affects the total energy consumption. It became slightly higher than the base case. With a setback distance of 12m, and while increasing the obstruction angle to 46°, increasing in the total thermal load consumption occurred.

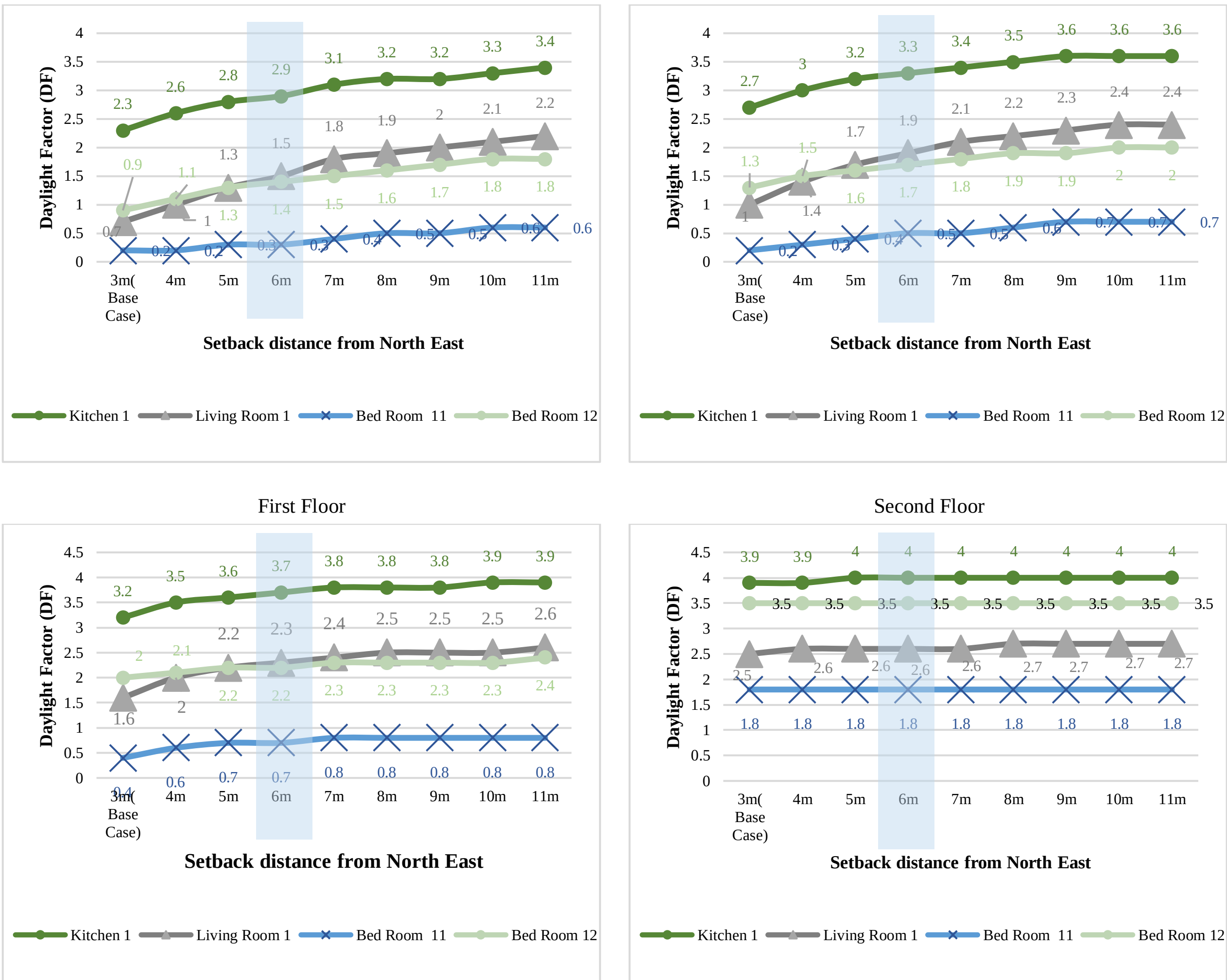
Table 6.11: South-East Street oriented street case heating, cooling and total loads consumption results North-East setback was increased.



	Total Load consumption (kWh/m^2)																
	3m	4m	%	5m	%	6m	%	7m	%	8m	%	9m	%	10m	%	11m	%
1st Floor	46.99	47.09	0.22	47.18	0.41	47.26	0.58	47.30	0.66	47.33	0.73	47.36	0.78	47.38	0.83	47.39	0.86
2nd Floor	47.58	47.71	0.26	47.78	0.42	47.86	0.58	47.91	0.68	47.93	0.73	47.96	0.80	47.93	0.72	47.95	0.77
3rd Floor	51.73	51.84	0.21	51.93	0.38	51.98	0.48	52.02	0.55	52.04	0.60	52.06	0.64	52.09	0.69	52.10	0.71
4th Floor	79.77	79.94	-0.04	79.85	0.10	79.87	0.13	79.88	0.14	79.90	0.16	79.90	0.17	79.90	0.17	79.91	0.18

Note: percentage of increasing or decreasing from base case current setback distances.

To reduce the amount of artificial lighting energy required during the day, the distance between the simulated building and the adjacent building from the northeastern side must be at least 12 m. In this case, the DF value in residential spaces is sufficient and is equal to or at a higher range than the required standards.



First Floor

Second Floor

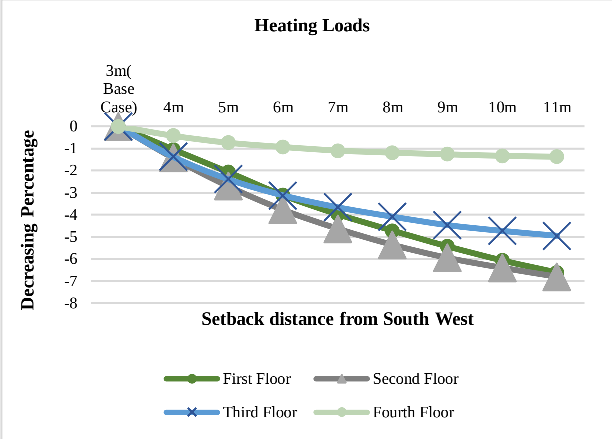
Third Floor

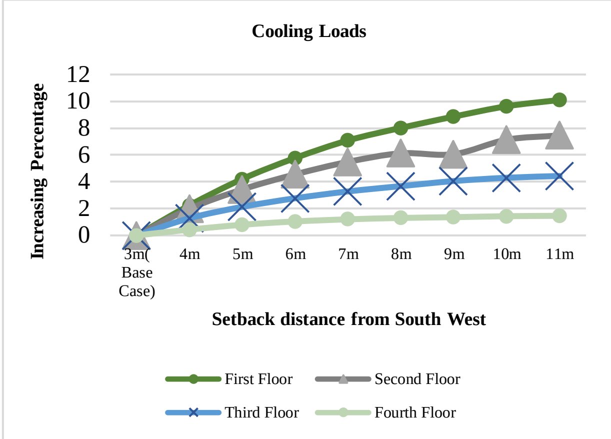
Fourth Floor

Figure 6.22: South- East Street oriented street case Daylight Factor results when North-East setback was increased.

As shown in Table 6.12, when the setback distance increase from the southwestern side, the amount of heating loads decrease significantly, especially when the distance between buildings is 22 m, as it was decreased with a percentage of 6.61%, 6.80%, 4.95%, and 1.38% on the first, second, third and fourth floors. With the decrease in heating loads, the total consumption sometimes decreased, and in other cases, it increased when compared to the base case scenario, as shown in the table below.

Table 6.12: South-East Street oriented street case heating, cooling and total loads consumption results South-West setback was increased.



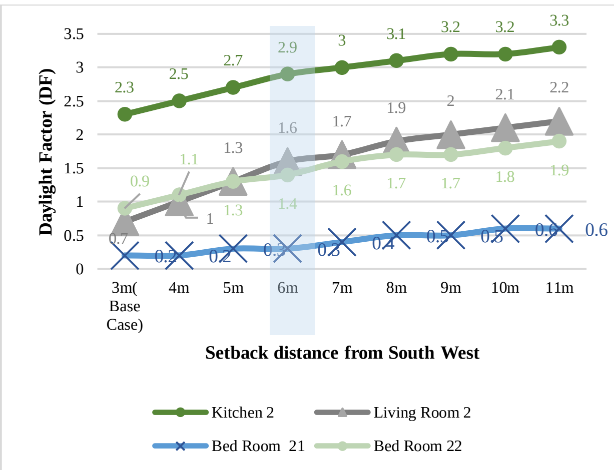


Total Load consumption (kWh/m^2)

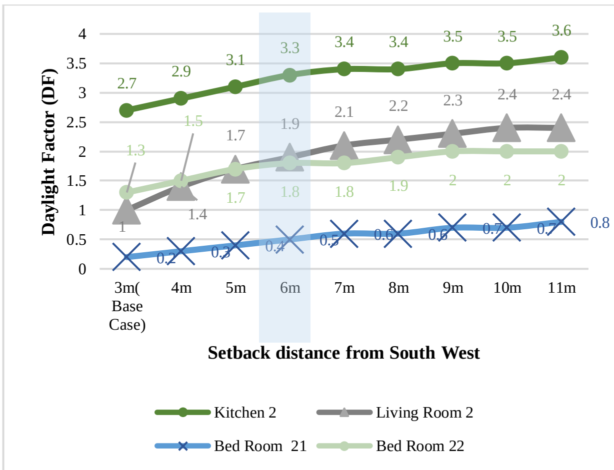
	3m	4m	%	5m	%	6m	%	7m	%	8m	%	9m	%	10m	%	11m	%
1st Floor	46.99	47.09	0.23	47.16	0.36	47.14	0.33	47.13	0.31	47.09	0.22	47.04	0.11	46.99	0.02	46.93	-0.14
2nd Floor	47.58	47.59	0.01	47.53	-0.12	47.46	-0.26	47.41	-0.36	47.34	-0.51	47.16	-0.88	47.26	-0.68	47.21	-0.78
3rd Floor	51.73	51.62	-0.22	51.52	-0.42	51.45	-0.55	51.41	-0.63	51.37	-0.70	51.35	-0.75	51.32	-0.79	51.29	-0.86
4th Floor	79.77	79.68	-0.11	79.63	-0.18	79.60	-0.21	79.57	-0.25	79.55	-0.27	79.53	-0.30	79.52	-0.31	79.50	-0.33

Note: percentage of increasing or decreasing from base case current setback distances.

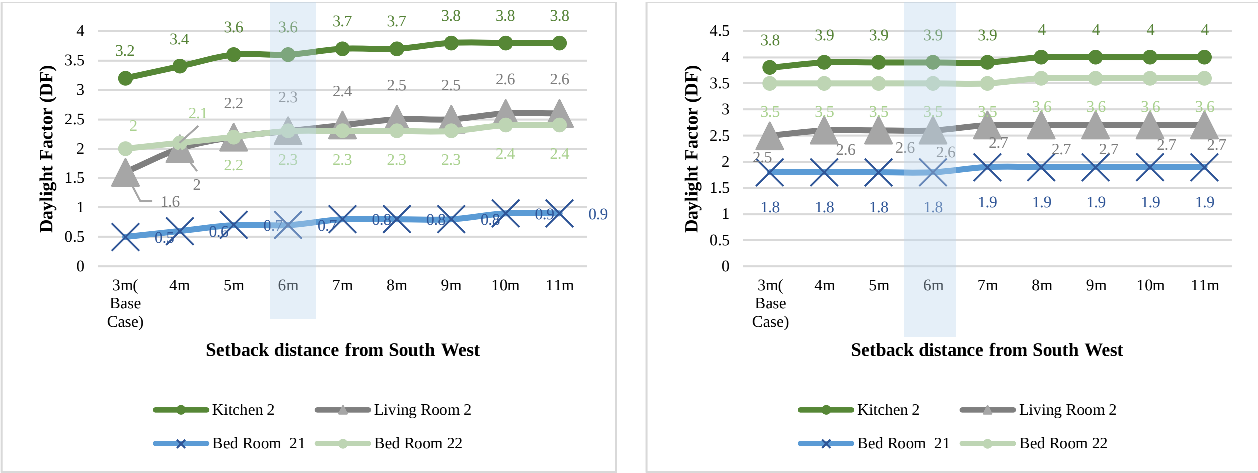
When studying the intensity of natural daylighting inside spaces in this case, according to the results, a distance of 12 m between the building and the adjacent building with 46° obstruction angle is sufficient to obtain suitable lighting intensity inside the southwest spaces in Apartment No. 2, where DF was within the required standards in the kitchen 2 and living room 2 and bedroom 22 (see Figure 6.23).



First Floor



Second Floor



Third Floor

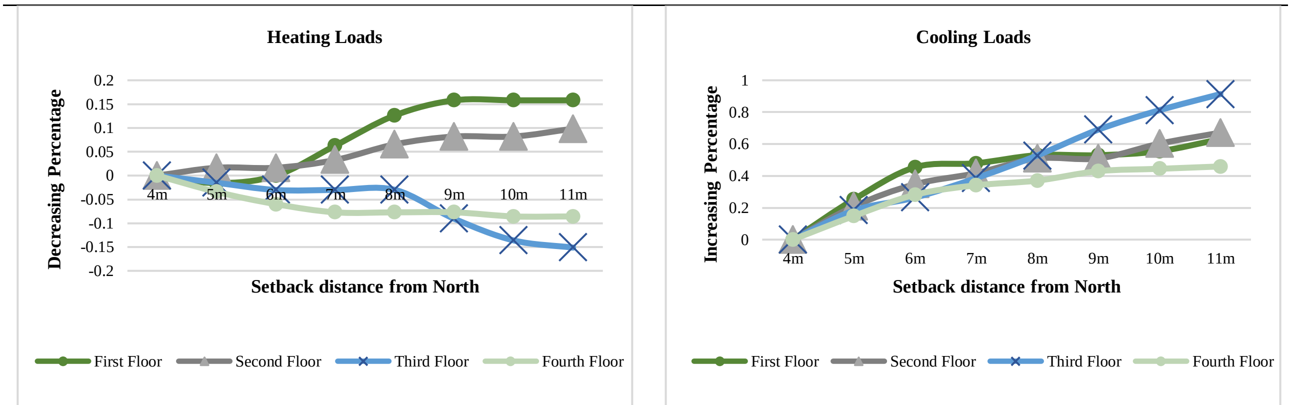
Fourth Floor

Figure 6.23: South- East Street oriented street case Daylight Factor results when South-West setback was increased.

6.3.2.5. Street oriented to the South (Case No.5):

When the setback distance between the building and the adjacent northern building increases, the heating loads in winter significantly increase on the first and second floors and slightly decrease on the third and fourth floors because the northern façade is exposed to the direct solar radiation in winter. And so, the consumption increases somewhat from the base case for the cooling loads, which contributes to increased overall consumption, as shown in Table 6.13. But when the northern distance increases, space's performance improves in terms of lighting when the distance is 14 m or more (see Figure 6.24).

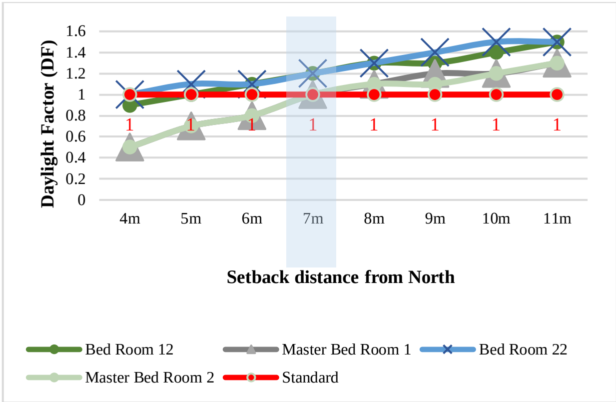
Table 6.13: South Street oriented street case heating, cooling and total loads consumption results North setback was increased.



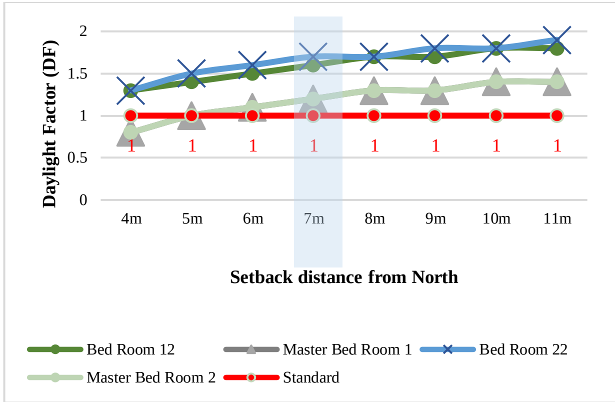
Total Load consumption (kWh/m^2)

	4m	5m	%	6m	%	7m	%	8m	%	9m	%	10m	%	11m	%
1st Floor	43.83	43.86	0.09	43.90	0.17	43.92	0.22	43.95	0.28	43.96	0.30	43.96	0.31	43.98	0.34
2nd Floor	44.35	44.39	0.10	44.42	0.15	44.44	0.19	44.46	0.25	44.47	0.26	44.48	0.30	44.50	0.34
3rd Floor	49.12	49.15	0.07	49.17	0.10	49.19	0.15	49.23	0.22	49.24	0.24	49.25	0.27	49.27	0.30
4th Floor	78.38	78.41	0.03	78.43	0.07	78.44	0.08	78.45	0.09	78.47	0.11	78.47	0.11	78.47	0.11

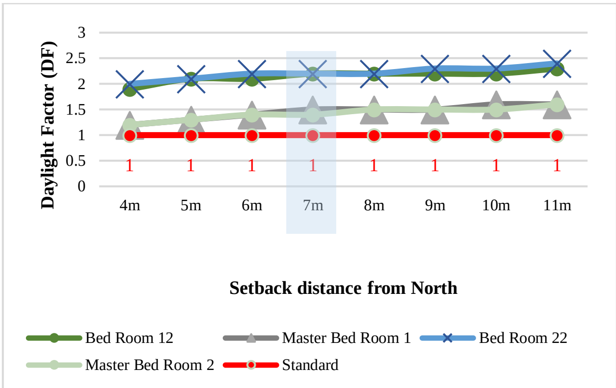
Note: percentage of increasing or decreasing from base case current setback distances.



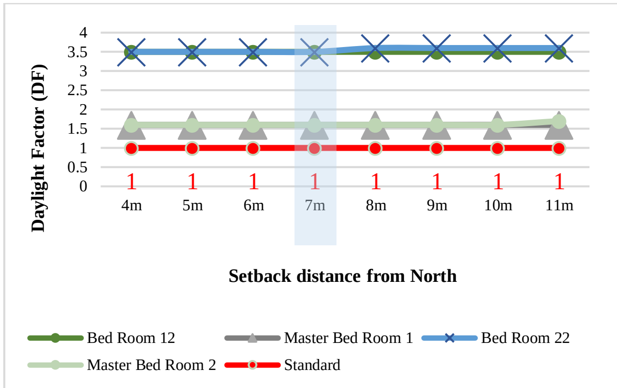
First Floor



Second Floor



Third Floor



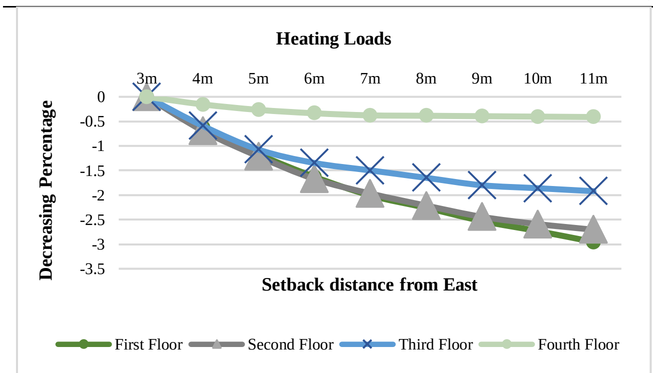
Fourth Floor

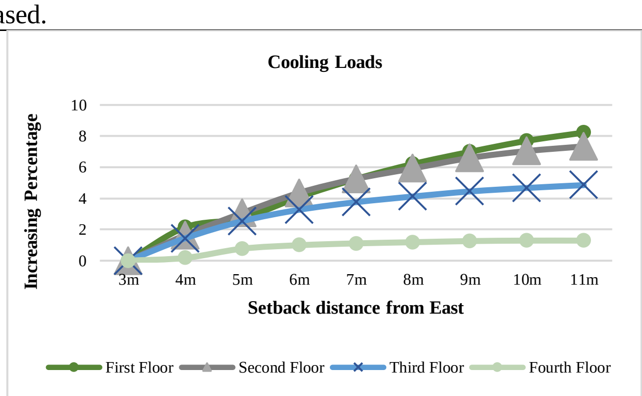
Figure 6.24: South Street oriented street case Daylight Factor results when North setback was increased.

In the north side, the average DF values are not affected by increasing the separation distance and have no significant impact starting from a distance of 14m.

The solar radiation that falls on the eastern façade in summer during the morning hours when the sun altitude is low when the solar radiation is low. In addition, the incidence period and its temperature, which are higher in summer than winter, has caused a reduction in heating loads in winter while increasing the consumption slightly in summer as a result of the increase of the eastern setback distance (see Table 6.14).

Table 6.14: South Street oriented street case heating, cooling and total loads consumption results East setback was increased.





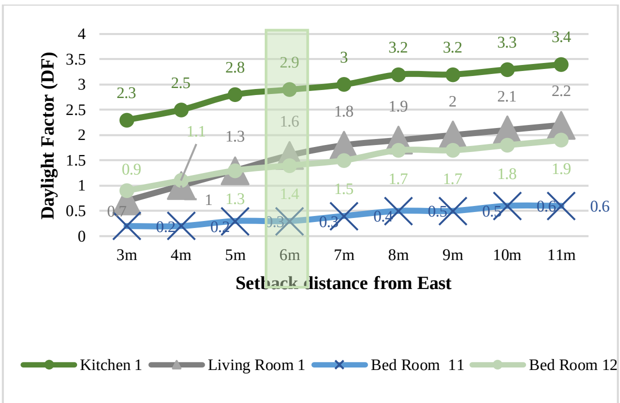
Total Load consumption (kWh/m^2)

	3m	4m	%	5m	%	6m	%	7m	%	8m	%	9m	%	10m	%	11m	%
1st Floor	43.83	44.02	0.44	43.97	0.33	44.08	0.57	44.17	0.79	44.27	1.00	44.32	1.14	44.39	1.28	44.42	1.35

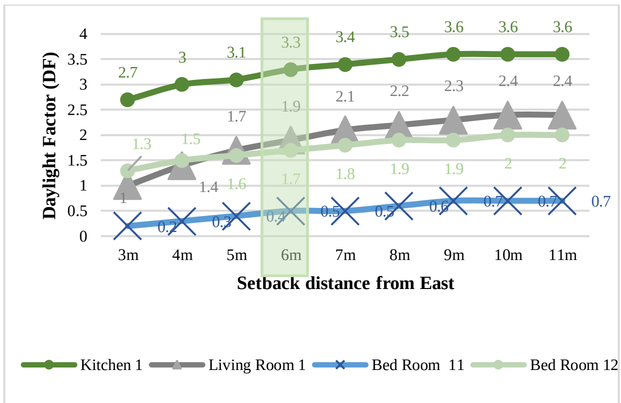
2nd Floor	44.35	44.47	0.28	44.60	0.56	44.72	0.83	44.81	1.03	44.87	1.16	44.93	1.31	44.97	1.40	44.99	1.46
3rd Floor	49.12	49.25	0.28	49.35	0.47	49.43	0.62	49.48	0.75	49.52	0.81	49.54	0.87	49.57	0.93	49.60	0.97
4th Floor	78.38	78.35	-0.03	78.47	0.11	78.50	0.15	78.51	0.17	78.53	0.19	78.55	0.21	78.55	0.22	78.55	0.21

Note: percentage of increasing or decreasing from base case current setback distances.

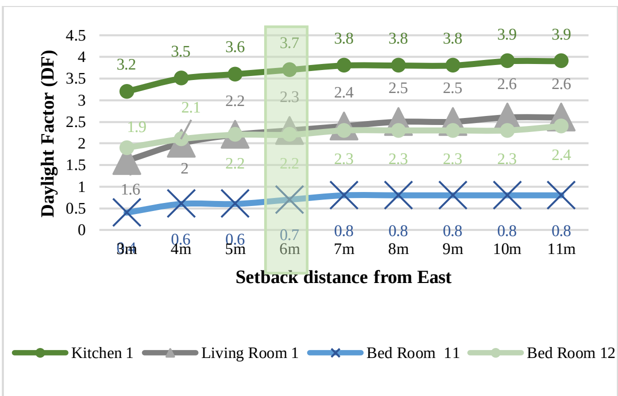
The current setback distance is insufficient to obtain an acceptable level of natural daylight in the eastern spaces in Apartment No. 2. Therefore, increasing this distance has a positive impact in providing an adequate amount of lighting so that the DF is more than 1% in the bedrooms, 2% in the kitchen, and 1 .5% in the living rooms, and it also reduces the use of artificial lighting during daylight hours. In this case, as shown in Figure 6.25, when the distance between the building and the adjacent building is 12 meters from the eastern side, and the obstruction angle is 46°, it is sufficient to achieve acceptable values of DF in kitchen 2, living room 2, and bedroom 12 in the first, second and third floors and in all eastern oriented spaces in the fourth floor.



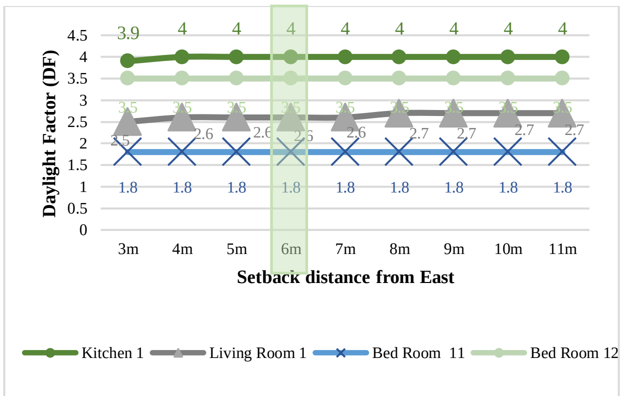
First Floor



Second Floor



Third Floor

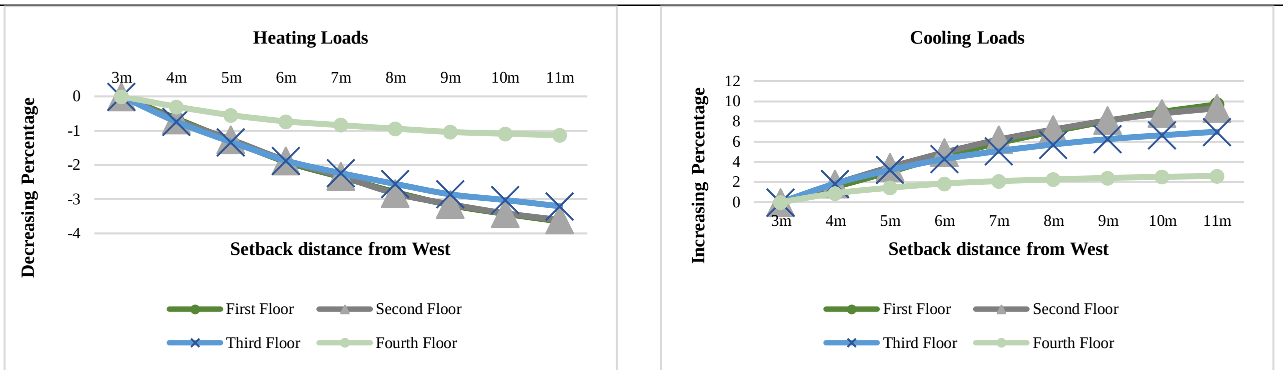


Fourth Floor

Figure 6.25: South Street oriented street case Daylight Factor results when East setback was increased.

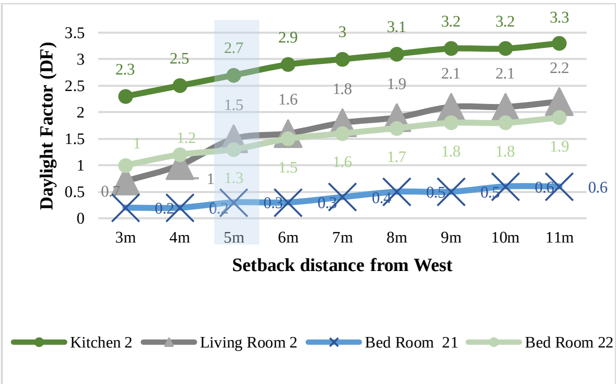
The heat gain on the western façade in summer during the afternoon hours is very high, as the temperature of the solar radiation during this period is also very high, which increases the consumption of cooling loads significantly. When the distance between buildings increase from the western side from 6m to 22m (by 2m step), the cooling loads rise in comparison to the base case up to 1.51%, 3.00%, 4.57%, 5.88%, 7.01%, 8.05%, 8.96% and 9.69% in the first floor, 1.83%, 3.47%, 4.93%, 6.21%, 7.20%, 8.10%, 8.80% and 9.31% in the second floor, 1.85%, 3.19%, 4.28%, 5.08%, 5.72%, 6.25%, 6.64%, 6.698% in the third floor and up to 0.89%, 1.43%, 1.85%, 2.09%, 2.26%, 2.41%, 2.51%, 2.60% in the fourth floor. Regarding natural lighting, when the distance was 12 m from the west, the DF values on the first floor were acceptable in most spaces as shown in Figure 6.26.

Table 6.15: South Street oriented street case heating, cooling and total loads consumption results West setback was increased.

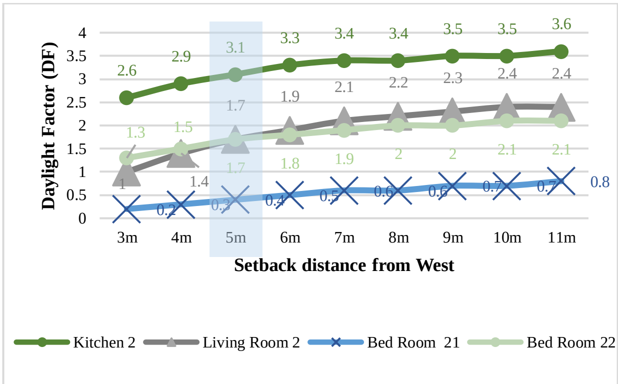


Total Load consumption (kWh/m²)

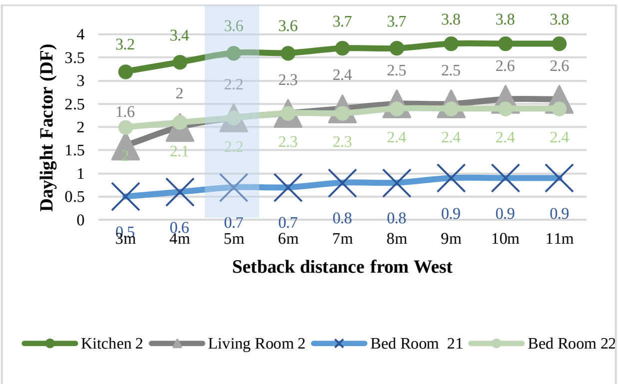
	3m	4m	%	5m	%	6m	%	7m	%	8m	%	9m	%	10m	%	11m	%
1st Floor	43.83	43.91	0.18	43.98	0.36	44.08	0.58	44.18	0.82	44.26	0.98	44.33	1.15	44.41	1.34	44.48	1.49
2nd Floor	44.35	44.51	0.36	44.66	0.70	44.77	0.95	44.89	1.21	44.94	1.32	45.02	1.52	45.08	1.65	45.13	1.75
3rd Floor	49.12	49.30	0.36	49.41	0.60	49.49	0.75	49.55	0.88	49.60	0.98	49.63	1.03	49.66	1.10	49.68	1.14
4th Floor	78.38	78.06	-0.41	78.09	-0.37	78.12	-0.33	78.13	-0.32	78.13	-0.32	78.13	-0.32	78.13	-0.32	78.13	-0.32



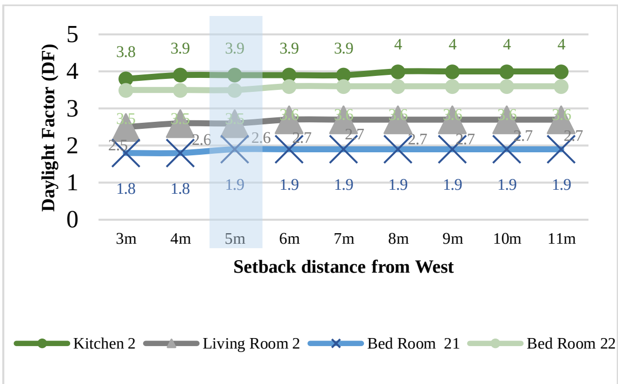
First Floor



Second Floor



Third Floor



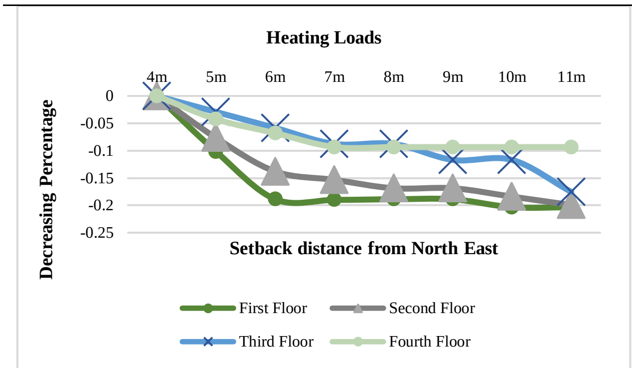
Fourth Floor

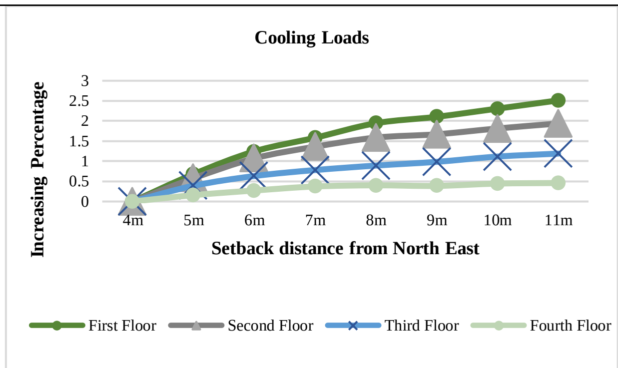
Figure 6.26: South Street oriented street case Daylight Factor results when West setback was increased.

6.3.2.6. *Street oriented to the South-West (Case No.6):*

Since the solar radiation falls on the northeastern façade in the early morning during summer and winter. Its temperature during this period is low in winter and higher than its temperature at the same hours in summer. Thus, increasing the distance between buildings from this direction reduces heating loads slightly but contributes to heat gain during the summer, which increases overall annual load consumption as shown in the Table 6.16.

Table 6.16: South-West Street oriented street case heating, cooling and total loads consumption results North-East setback was increased.



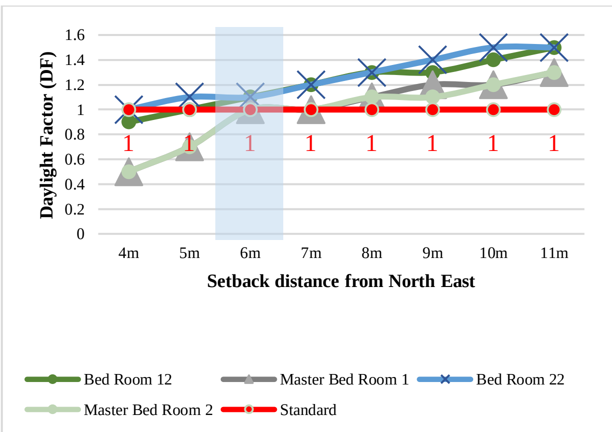


Total Load consumption (kWh/m²)

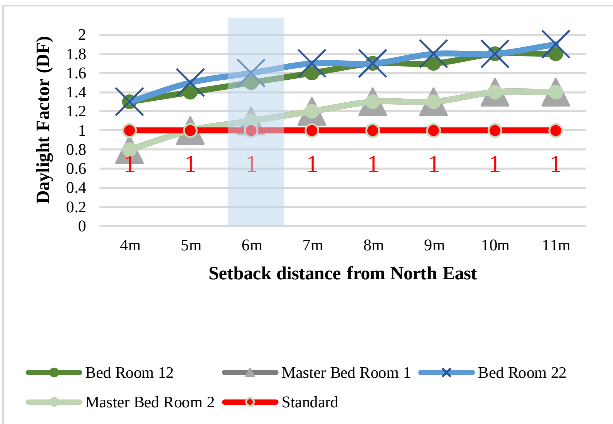
	4m	5m	%	6m	%	7m	%	8m	%	9m	%	10m	%	11m	%
1st Floor	48.12	48.22	0.20	48.30	0.37	48.36	0.50	48.43	0.65	48.46	0.71	48.50	0.78	48.54	0.86
2nd Floor	48.40	48.50	0.20	48.59	0.38	48.64	0.49	48.68	0.58	48.70	0.62	48.73	0.67	48.75	0.71
3rd Floor	52.01	52.09	0.16	52.14	0.25	52.17	0.29	52.19	0.34	52.21	0.37	52.24	0.43	52.24	0.43
4th Floor	79.73	79.76	0.03	79.78	0.06	79.79	0.08	79.80	0.09	79.80	0.09	79.82	0.11	79.82	0.11

Note: percentage of increasing or decreasing from base case current setback distances.

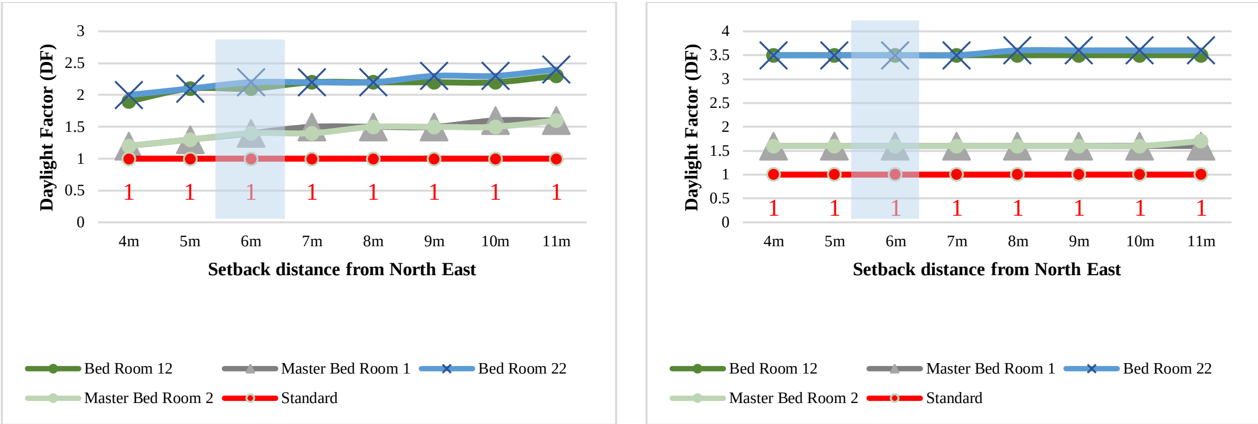
As shown in Table 6.16 and Figure 6.27 , the decreasing percentage in heating loads becomes constant when the distance between the buildings on the northeastern side is equal to or greater than 12 meters. Similar effects occurred for lighting, at the 12 m distance, the DF value becomes within the required standards in all the northeast bedrooms, which is the bedroom 12, master bedroom1, bedroom 22, master bedroom 2, where the DF value in these spaces is higher or equal to 1% in all floors.



First Floor



Second Floor

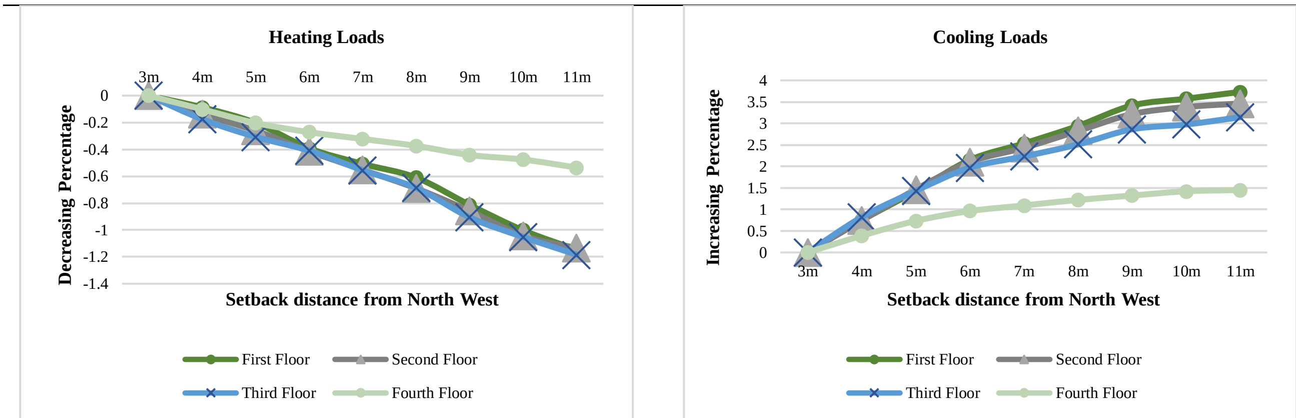


Third Floor Fourth Floor

Figure 6.27: South-West Street oriented street case Daylight Factor results when North-East setback was increased.

When the distance between the target building and the adjacent building from the northwest side increases, the consumption of cooling loads increases, which also increases the total energy consumption (see Table 6.17). But at the same time, the artificial lighting energy required decreases, as when the distance between the two buildings is 10 or more. An acceptable level of lighting is available in the kitchen 2, living room 2, and bedroom 22 on all floors as shown in Figure 6.28.

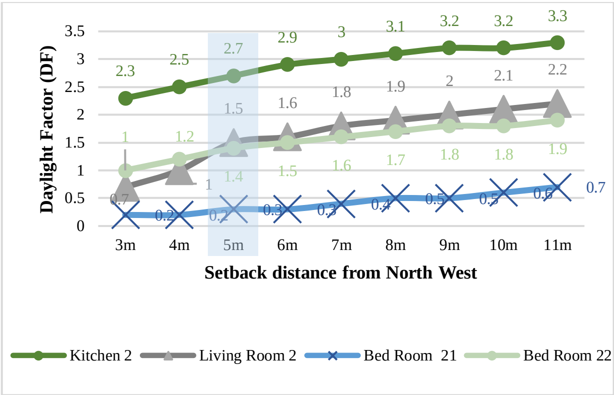
Table 6.17: South-West Street oriented street case heating, cooling and total loads consumption results North-West setback was increased.



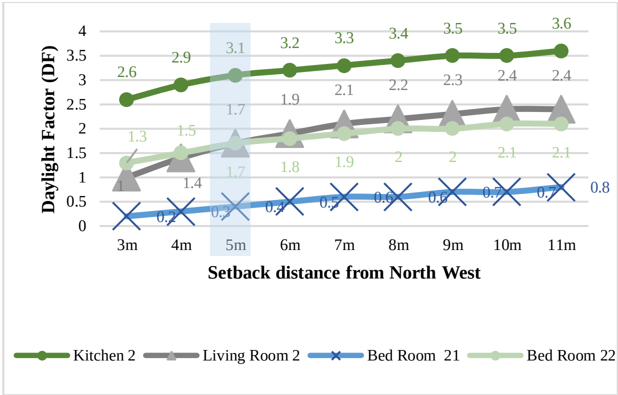
Total Load consumption (kWh/m^2)

	3m	4m	%	5m	%	6m	%	7m	%	8m	%	9m	%	10m	%	11m	%
1st Floor	48.12	48.24	0.24	48.33	0.43	48.41	0.60	48.45	0.68	48.50	0.78	48.53	0.84	48.50	0.79	48.49	0.76
2nd Floor	48.40	48.52	0.24	48.63	0.47	48.72	0.66	48.75	0.72	48.80	0.81	48.83	0.88	48.81	0.84	48.80	0.83
3rd Floor	52.01	52.15	0.26	52.25	0.46	52.35	0.64	52.36	0.67	52.39	0.72	52.41	0.75	52.39	0.72	52.39	0.72
4th Floor	79.73	79.79	0.08	79.85	0.14	79.88	0.19	79.89	0.20	79.90	0.22	79.90	0.21	79.91	0.23	79.89	0.20

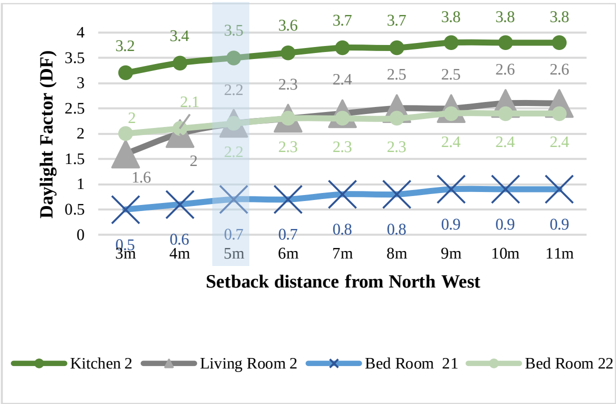
Note: percentage of increasing or decreasing from base case current setback distances.



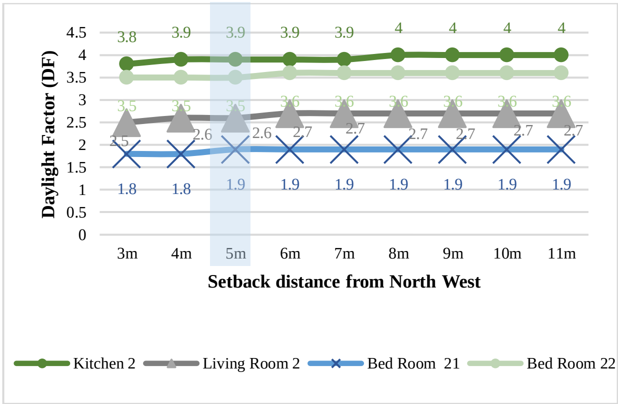
First Floor



Second Floor



Third Floor

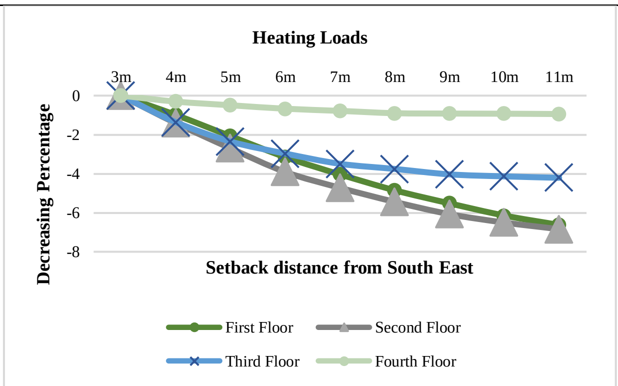


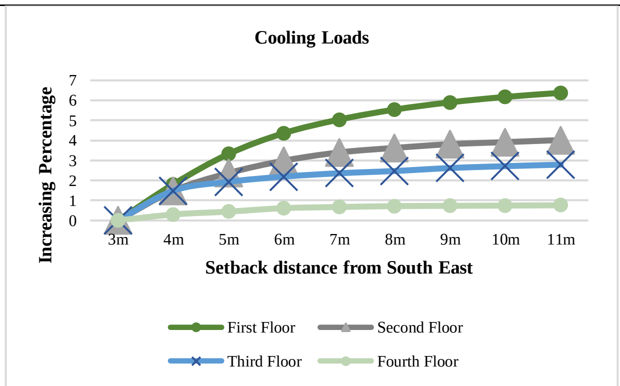
Fourth Floor

Figure 6.28: South-West Street oriented street case Daylight Factor results when North-West setback was increased.

The increase in the southeast side's setback distances showed better results when the street is oriented to the southwest. The total energy consumption decreased due to the decrease in heating loads in winter months. As the southeastern façade get exposed to direct solar radiation from the morning period until noon, causing heat gain from outside to the indoor environment during winter and thus reduce annual heating loads. In terms of daylight, the results below show that when the distance between the target building and the southeastern building is 14 meters or more (setback distance equal or more than 7m), and the obstruction angle is lower than 41º, the average DF is acceptable in kitchen 1, living room 1, and bedroom 12 on all floors. And this contributes to reducing the loads needed to use artificial lighting during daylight hours.

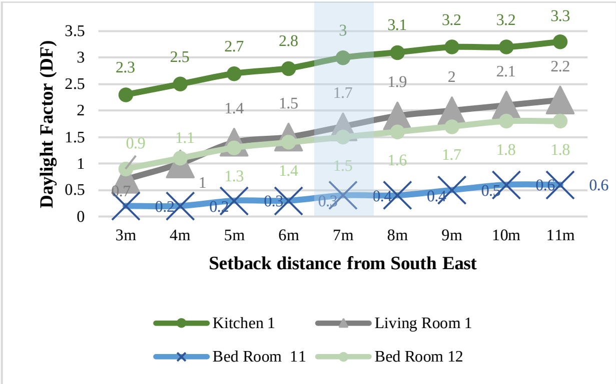
Table 6.18: South-West Street oriented street case heating, cooling and total loads consumption results South-East setback was increased.



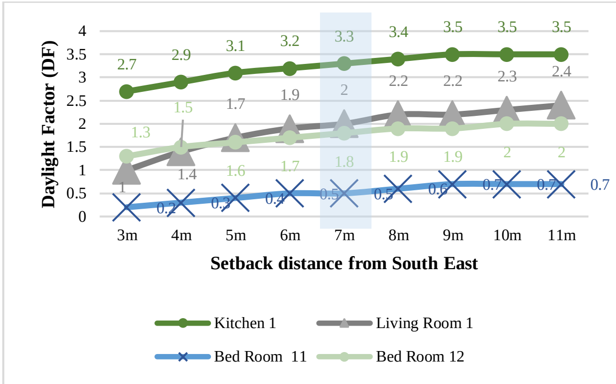


Total Load consumption (kWh/m^2)																	
	3m	4m	%	5m	%	6m	%	7m	%	8m	%	9m	%	10m	%	11m	%
1st Floor	48.12	48.17	0.11	48.14	0.04	48.02	-0.21	47.89	-0.49	47.74	-0.79	47.62	-1.05	47.48	-1.33	47.38	-1.54
2nd Floor	48.40	48.32	-0.18	48.14	-0.54	47.94	-0.97	47.79	-1.26	47.64	-1.57	47.51	-1.86	47.41	-2.06	47.33	-2.21
3rd Floor	52.01	51.96	-0.11	51.77	-0.47	51.65	-0.70	51.54	-0.92	51.49	-1.01	51.44	-1.11	51.43	-1.12	51.43	-1.13
4th Floor	79.73	79.67	-0.08	79.62	-0.14	79.58	-0.19	79.54	-0.24	79.49	-0.30	79.49	-0.30	79.49	-0.30	79.48	-0.31

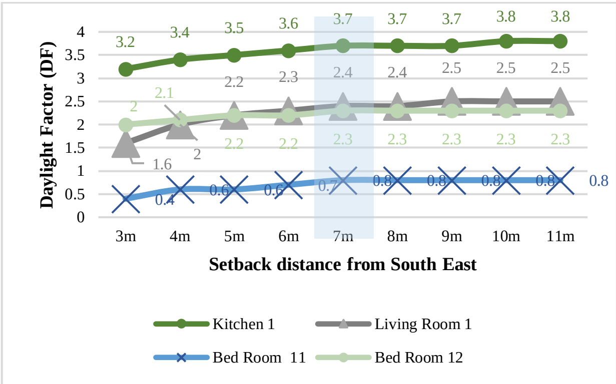
Note: percentage of increasing or decreasing from base case current setback distances.



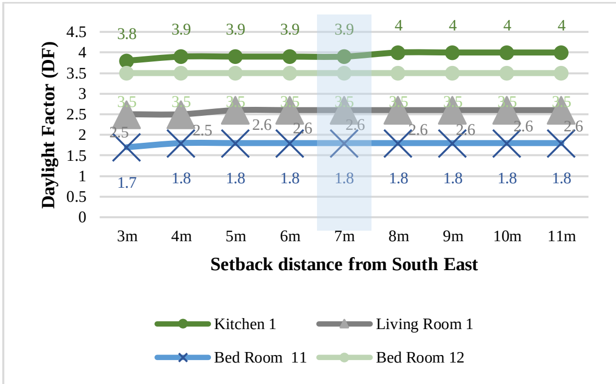
First Floor



Second Floor



Third Floor



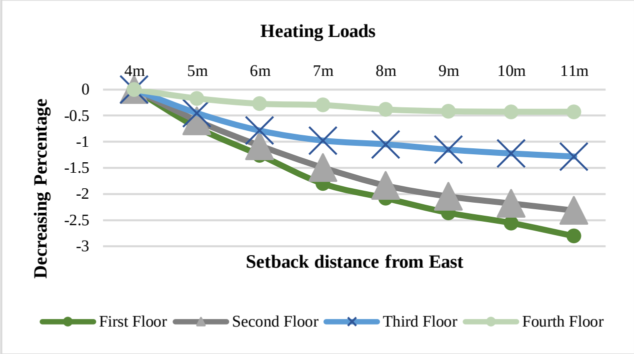
Fourth Floor

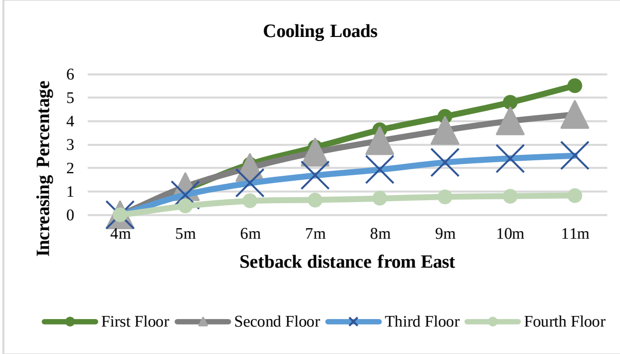
Figure 6.29: South-West Street oriented street case Daylight Factor results when South-East setback was increased.

6.3.2.7. Street oriented to the West (Case No.7):

When increasing the eastern rear setback, the total energy consumption increases slightly and unnoticeably as the heating loads decrease slightly during winter since the morning sun temperature is somewhat low. Simultaneously, it is higher in summer, so it increases the cooling loads' consumption. Although the effect of increasing the eastern setback is useless on the total annual thermal loads (see Table 6.19), it contributes to an improvement in the amount of natural lighting in bedroom 12, master bedroom 1, bedroom 22, and master bedroom 2, especially when the distance is 12 m or more between the building and the adjacent eastern building as shown in Figure 6.30.

Table 6.19: West Street oriented street case heating, cooling and total loads consumption results East setback was increased.

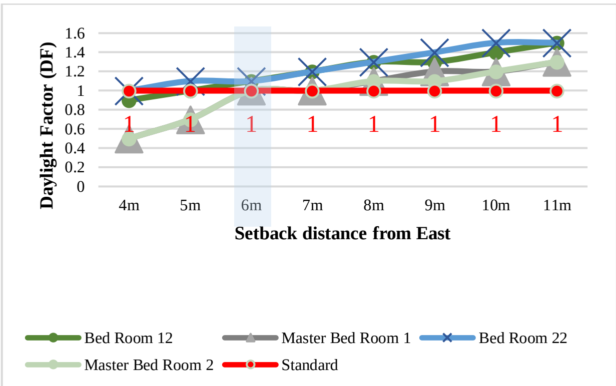


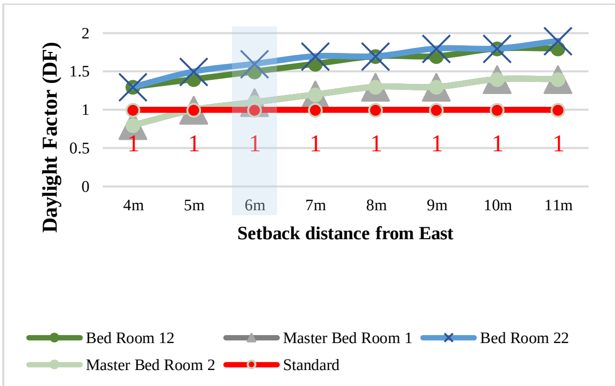


Total Load consumption (kWh/m²)

	4m	5m	%	6m	%	7m	%	8m	%	9m	%	10m	%	11m	%
1st Floor	48.31	48.29	-0.05	48.32	0.01	48.28	-0.07	48.33	0.03	48.34	0.06	48.39	0.16	48.44	0.26
2nd Floor	48.25	48.31	0.14	48.34	0.19	48.35	0.21	48.35	0.21	48.38	0.27	48.42	0.35	48.43	0.39
3rd Floor	51.43	51.49	0.12	51.51	0.14	51.52	0.17	54.56	0.24	51.60	0.31	51.61	0.35	51.62	0.36
4th Floor	79.23	79.26	0.03	79.27	0.05	79.27	0.05	79.24	0.02	79.24	0.02	79.25	0.03	79.26	0.04

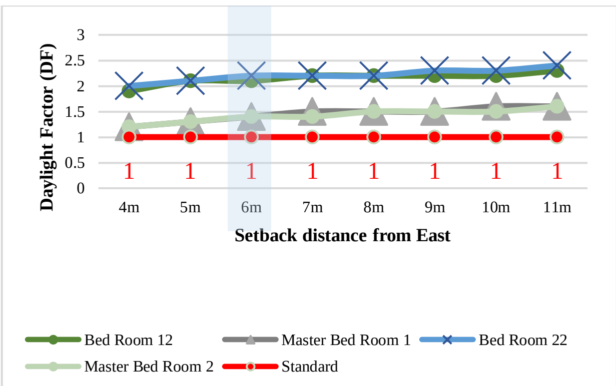
Note: percentage of increasing or decreasing from base case current setback distances.

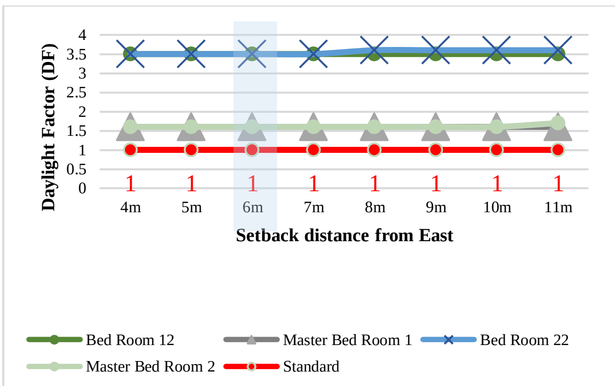




First Floor

Second Floor





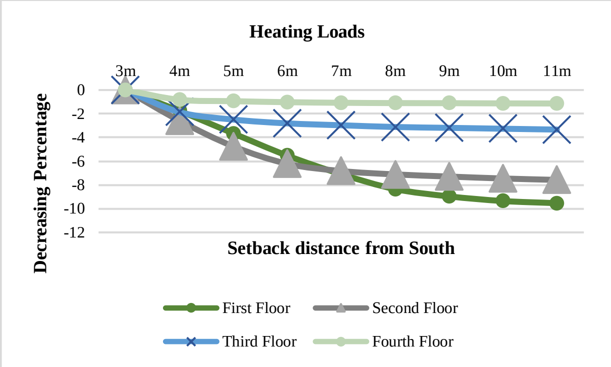
Third Floor

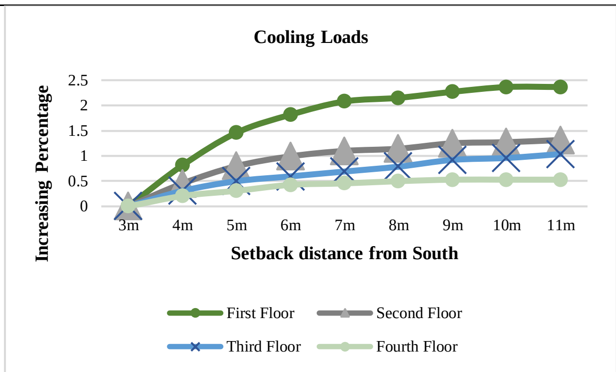
Fourth Floor

Figure 6.30: West Street oriented street case Daylight Factor results when East setback was increased.

As shown in the results, the southern setback increase has given the best effects in reducing the total thermal load consumption when the distance between buildings increased from the south. It contributes to reducing the heating loads consumption more than its contribution to increasing the cooling loads' consumption during the summer because the amount of solar energy that passes from a southern window on a sunny day in winter is greater than that which passes from the same window on a sunny day in the summer. This is due to the total hours of solar radiation in winter (10 hours), and throughout this period, it shines on the southern façade. But in summer, the sunrise hours which is about 14 hours a day, during which it moves from the northeast to the northwest, so the share of the southern facade is less than winter. Also, the sun's altitude angles in winter are lower than in summer, and therefore the amount of solar radiation falling into the building is greater than in summer) Majjad, 1995).

Table 6.20: West Street oriented street case heating, cooling and total loads consumption results South setback was increased.



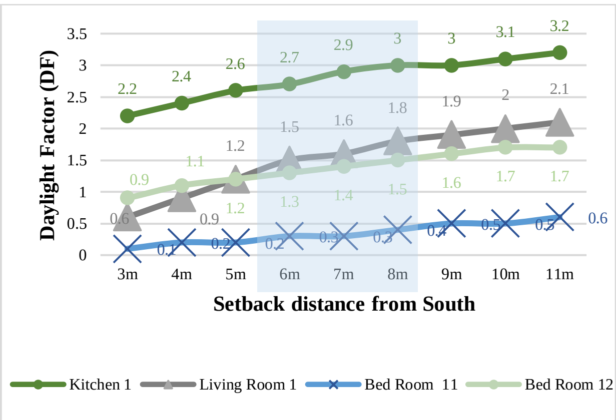


Total Load consumption (kWh/m²)

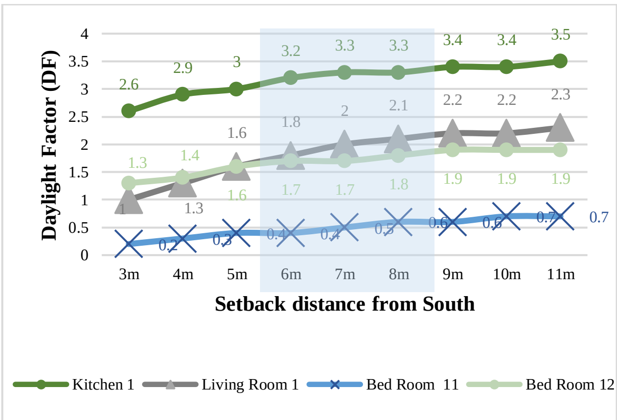
	3m	4m	%	5m	%	6m	%	7m	%	8m	%	9m	%	10m	%	11m	%
1st Floor	48.31	47.92	-0.81	47.46	-1.77	46.95	-2.82	46.52	-3.71	46.15	-4.48	45.99	-4.82	45.88	-5.03	45.83	-5.15
2nd Floor	48.25	47.60	-1.34	47.05	-2.48	46.67	-3.27	46.52	-3.58	46.44	-3.73	46.42	-3.79	46.37	-3.88	46.35	-3.94
3rd Floor	51.43	50.96	-0.93	50.82	-1.20	50.75	-1.34	50.72	-1.39	50.70	-1.43	50.71	-1.42	50.69	-1.44	50.69	-1.45
4th Floor	79.23	78.88	-0.45	78.85	-0.48	78.84	-0.49	78.82	-0.52	78.82	-0.52	78.83	-0.51	78.82	-0.52	78.81	-0.53

Note: percentage of increasing or decreasing from base case current setback distances.

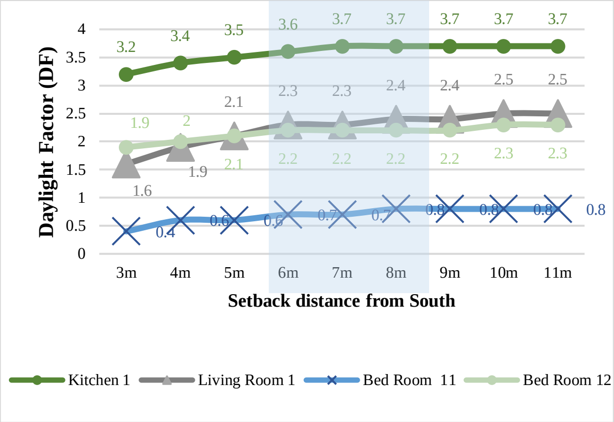
To provide an adequate level of natural daylight within the southern spaces, a distance of 12 m between buildings is sufficient to obtain acceptable DF values equal to or more than standards. But in terms of energy consumption, the annual load consumption decreasing percentage at 16 m is twice lower than the decreasing percentage at 12 m, so the most efficient distance between the simulated building and the adjacent southern building is 16 m.



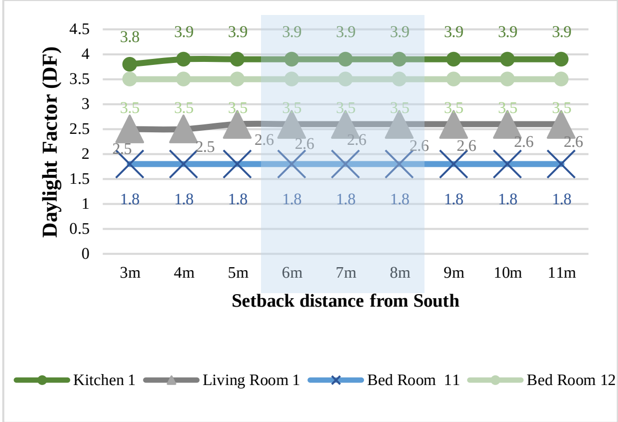
First Floor



Second Floor



Third Floor

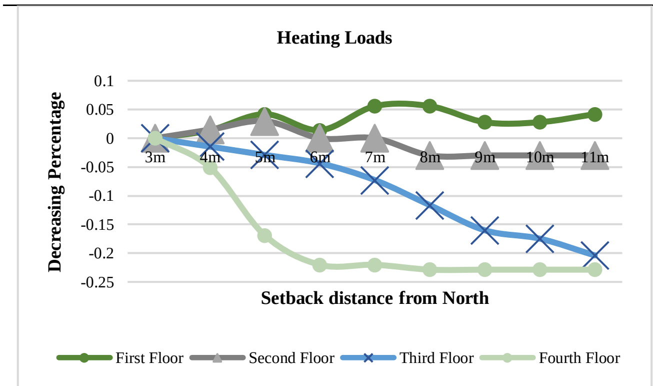


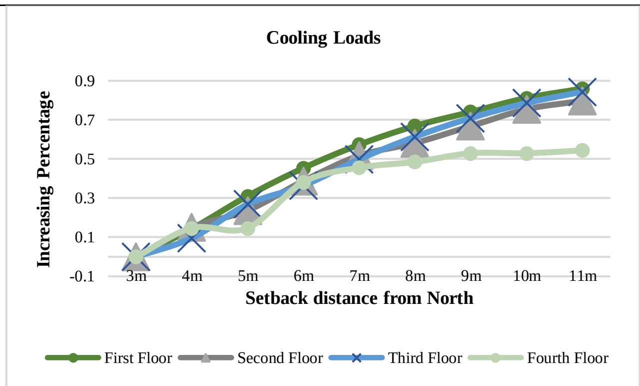
Fourth Floor

Figure 6.31: West Street oriented street case Daylight Factor results when South setback was increased.

Increased northern setback had similar effect in almost all urban context cases. As mentioned previously, the north façade does not receive direct solar radiation in summer and winter, which slightly decreases the cooling loads' consumption as well as increases the amount of heating loads on the first and second floors while decreasing the amount of heating loads in the third and fourth. This has caused an overall increase in the total consumption in comparison to the base case when increasing the northern setback distance. As shown in the results in Table 6.21 and Figure 6.32, at a distance of 12 m to the north of the simulated building, it is possible to obtain an adequate lighting level in the northern spaces. At the same time, there is a slight increase in the annual thermal load consumption.

Table 6.21: West Street oriented street case heating, cooling and total loads consumption results North setback was increased.

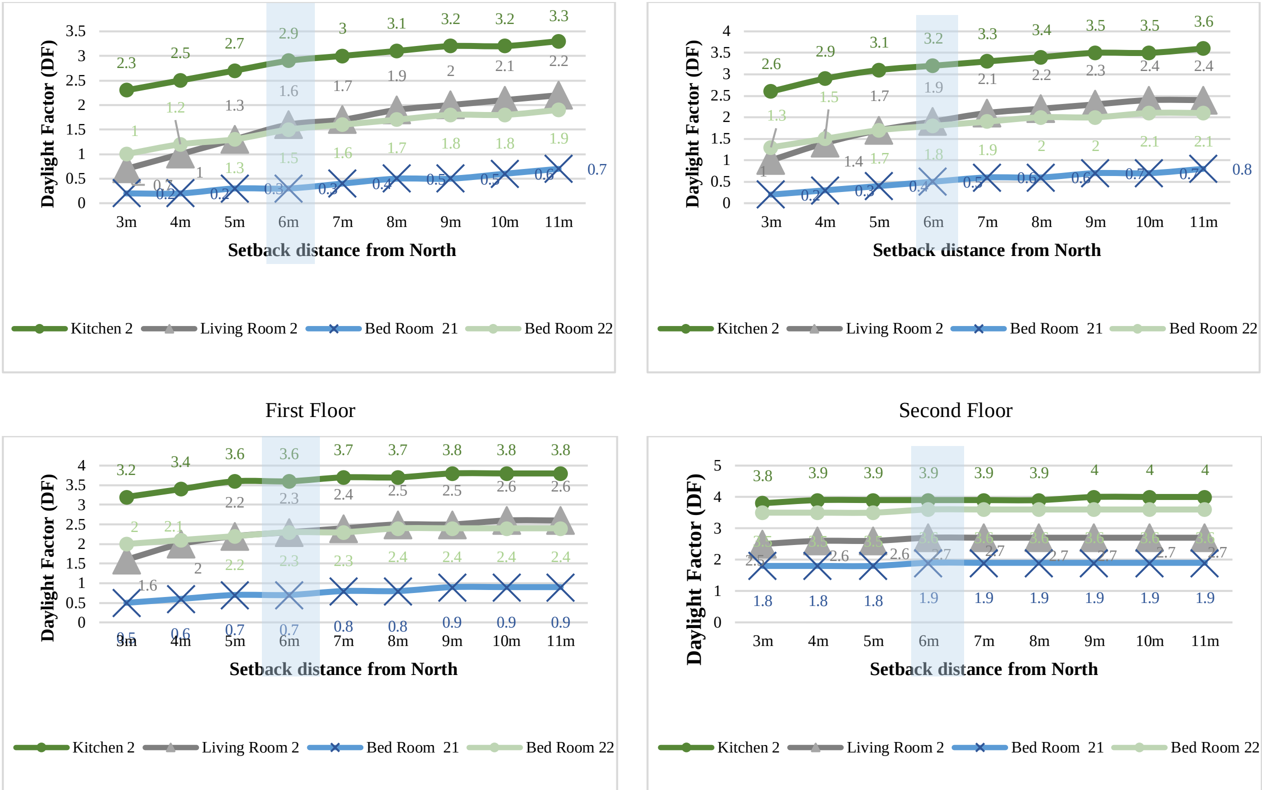




Total Load consumption (kWh/m^2)

	3m	4m	%	5m	%	6m	%	7m	%	8m	%	9m	%	10m	%	11m	%
1st Floor	48.31	48.34	0.06	48.38	0.14	48.40	0.18	48.43	0.25	48.45	0.28	48.45	0.29	48.47	0.32	48.48	0.34
2nd Floor	48.25	48.28	0.07	48.30	0.11	48.32	0.16	48.35	0.21	48.36	0.22	48.37	0.26	48.39	0.29	48.39	0.31
3rd Floor	51.43	51.4	0.03	51.49	0.10	51.50	0.13	51.52	0.17	51.54	0.20	51.55	0.22	51.56	0.24	51.56	0.25
4th Floor	79.23	79.25	0.02	79.19	-0.05	79.23	0.00	79.25	0.03	79.26	0.03	79.27	0.05	79.27	0.05	79.27	0.05

Note: percentage of increasing or decreasing from base case current setback distances.



First Floor | Second Floor

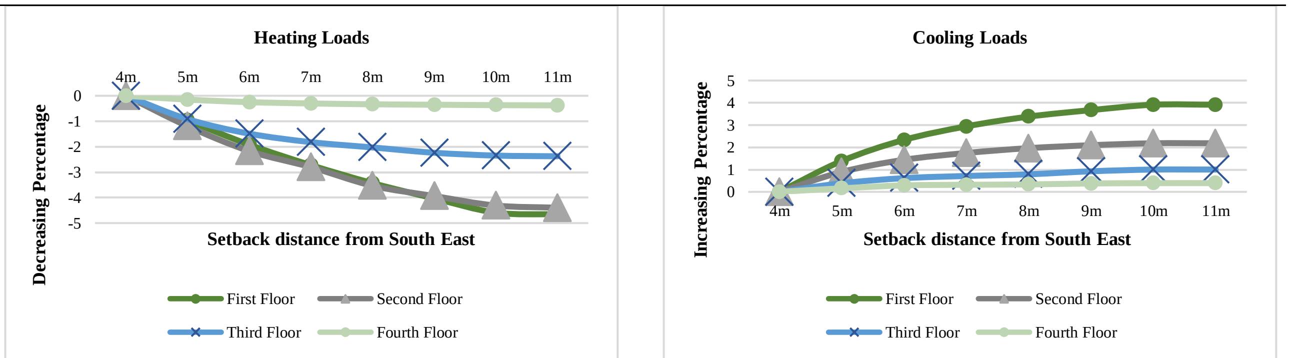
Third Floor | Fourth Floor

Figure 6.32: West Street oriented street case Daylight Factor results when North setback was increased.

6.3.2.8. Street oriented to the North-West (Case No.8):

When the solar radiation falls on the southeast façade in the winter, and while the distance between buildings increases from 8 m to 22 m, the heating loads decrease by up to 0.97%, 1.92%, 2.72% 3.43%, 4.03%, 4.59%, 4.66% respectively in the first floor, and around 1.19%, 2.17%, 2.80%, 3.53%, 3.94%, 4.31%, 4.40% respectively in the second floor. In the summer, the solar altitude angles are higher than in winter. Thus, the percentage of the increased cooling loads is lower than the decreased heating loads, which leads to a decrease in the overall load consumption, especially when the distance is 16 m. On the other hand, this distance is sufficient to achieve an acceptable level of lighting in bedroom 12, master bedroom 1, bedroom 22, and master bedroom 2 in all floors.

Table 6.22: North-West Street oriented street case heating, cooling and total loads consumption results South-East setback was increased.



Total Load consumption (kWh/m^2)															
	4m	**5m**	**%**	**6m**	**%**	**7m**	**%**	**8m**	**%**	**9m**	**%**	**10m**	**%**	**11m**	**%**
1st Floor	48.77	48.71	-0.12	48.58	-0.39	48.43	-0.69	48.29	-0.99	48.15	-1.27	48.02	-1.54	47.99	-1.58
2nd Floor	49.14	48.96	-0.36	48.78	-0.74	48.65	-1.00	48.48	-1.35	48.38	-1.54	48.29	-1.73	48.26	-1.78
3rd Floor	52.75	52.55	-0.37	52.43	-0.61	52.35	-0.76	52.30	-0.85	52.27	-0.91	52.25	-0.94	52.24	-0.96
4th Floor	80.22	80.19	-0.04	80.18	-0.05	80.16	-0.07	80.15	-0.09	80.14	-0.08	80.15	-0.09	80.14	-0.10

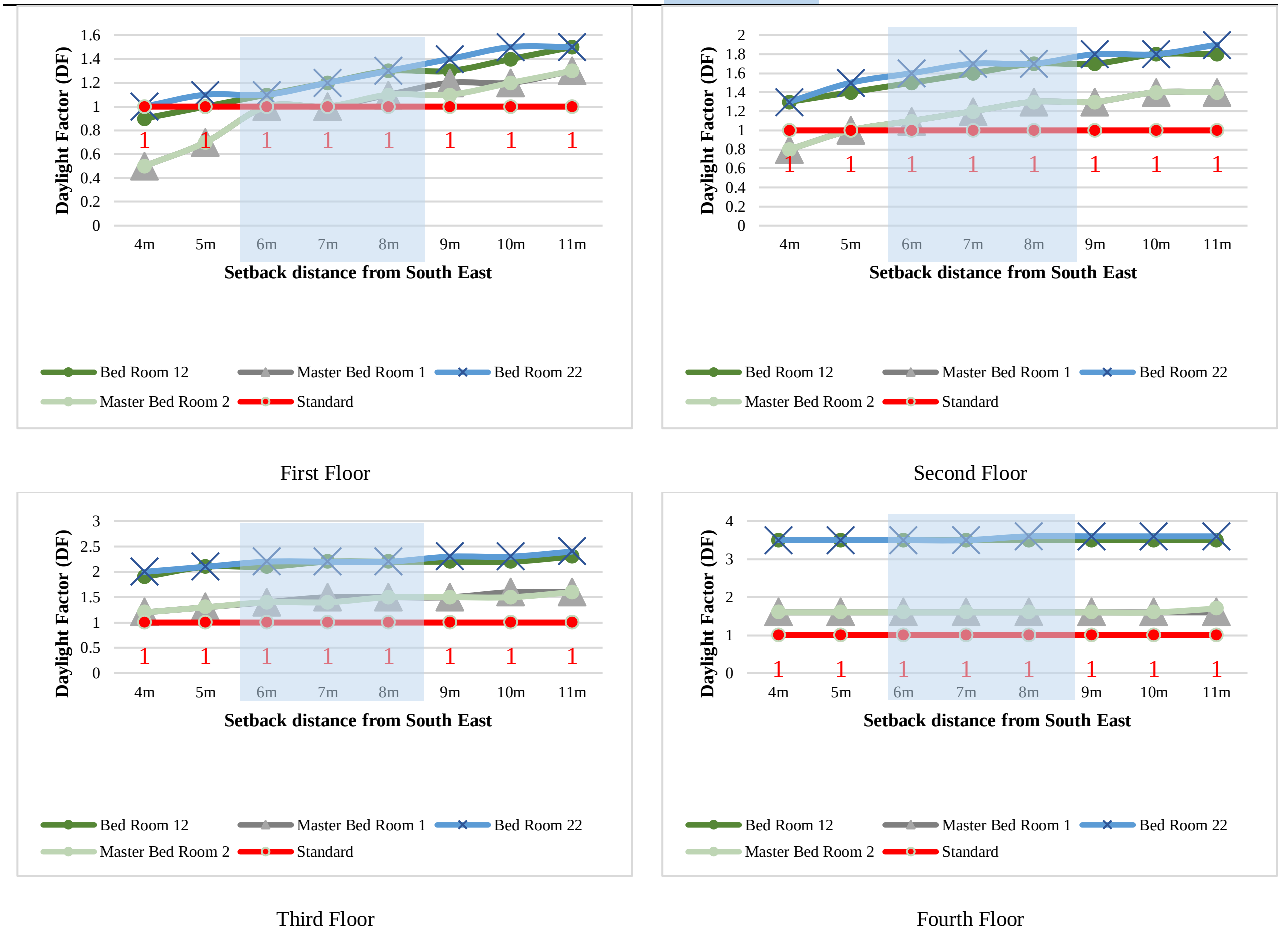
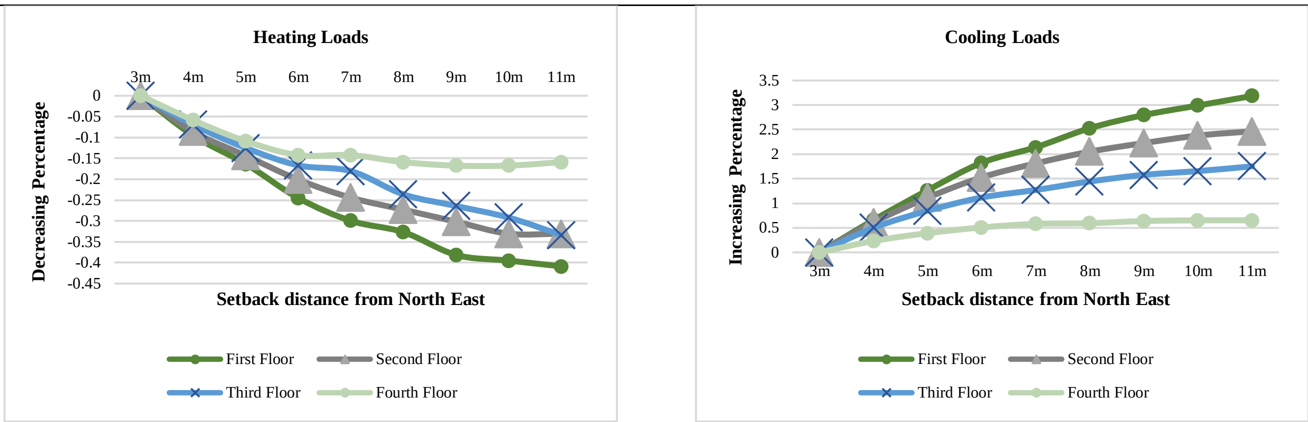


Figure 6.33: North-West Street oriented street case Daylight Factor results when South-East setback was increased.

The amount of solar radiation falling on the northeast façade in winter is very small, so increasing the distance between the building and the northeastern building is considered useless and has negative effects on heating loads. Simultaneously, the morning sun in the summer contributes to raising the heat gain of the northeastern spaces, which increases the cooling load consumption. A distance of 12 m between the simulated building and the adjacent building is considered sufficient in terms of providing proper lighting during the day and it's the best setback distance with an unnoticeable impact on the annual thermal load consumption that got highly increase after 12m setback distance (see Table 6.23 and Figure 6.34).

Table 6.23: North-West Street oriented street case heating, cooling and total loads consumption results North-East setback was increased.



Total Load consumption (kWh/m^2)

	3m	4m	%	5m	%	6m	%	7m	%	8m	%	9m	%	10m	%	11m	%
1st Floor	48.77	48.85	0.17	48.94	0.35	49.01	0.50	49.05	0.58	49.11	0.70	49.14	0.76	49.17	0.82	49.20	0.88
2nd Floor	49.14	49.23	0.19	49.31	0.36	49.38	0.49	49.42	0.57	49.46	0.65	49.48	0.70	49.51	0.75	49.52	0.78
3rd Floor	52.75	52.84	0.17	52.90	0.28	52.95	0.37	52.98	0.43	52.99	0.47	53.02	0.51	53.03	0.52	53.04	0.54
4th Floor	80.22	80.26	0.05	80.28	0.07	80.30	0.10	80.32	0.12	80.31	0.12	80.32	0.13	80.33	0.13	80.33	0.14

Note: percentage of increasing or decreasing from base case current setback distances.

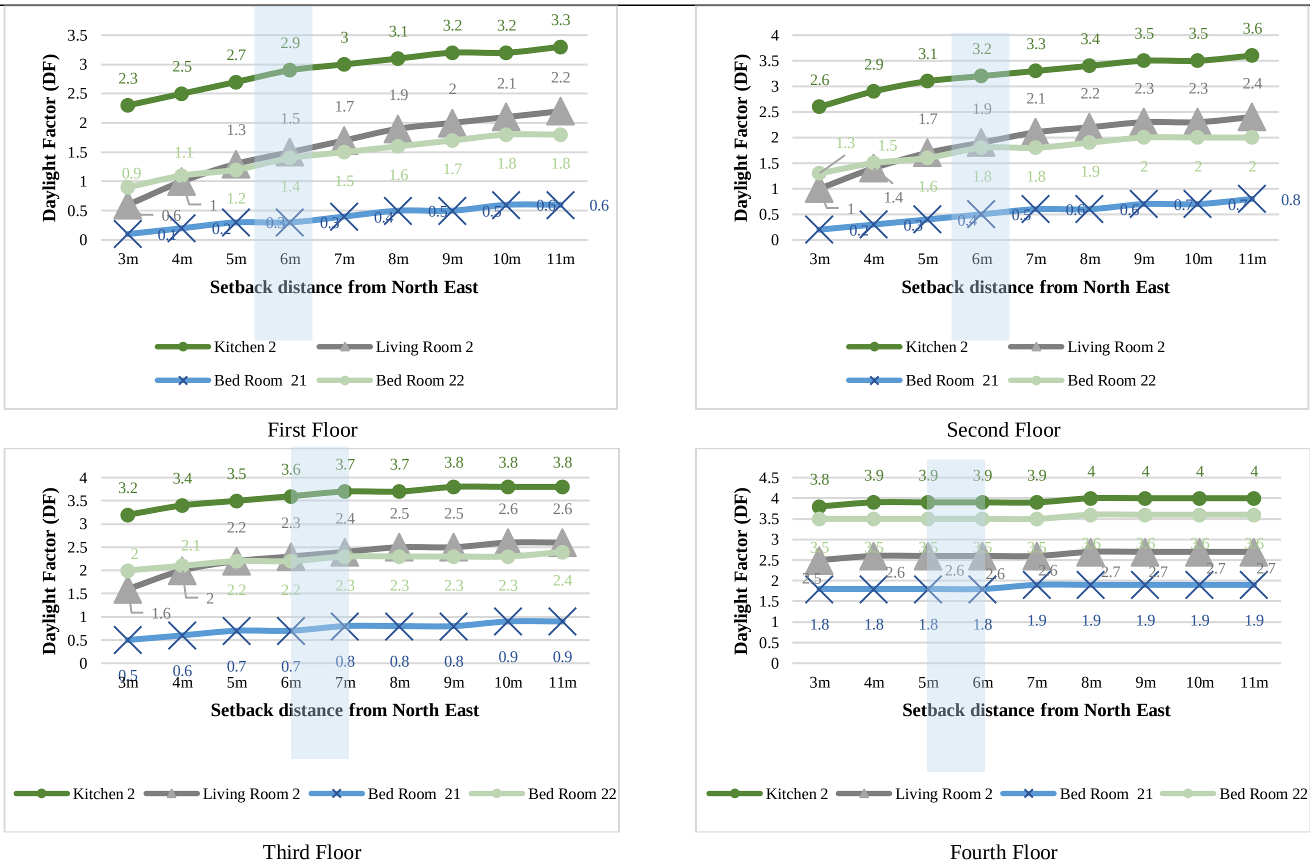
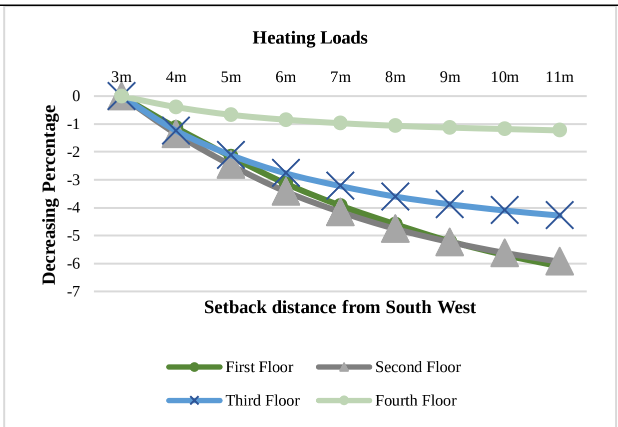
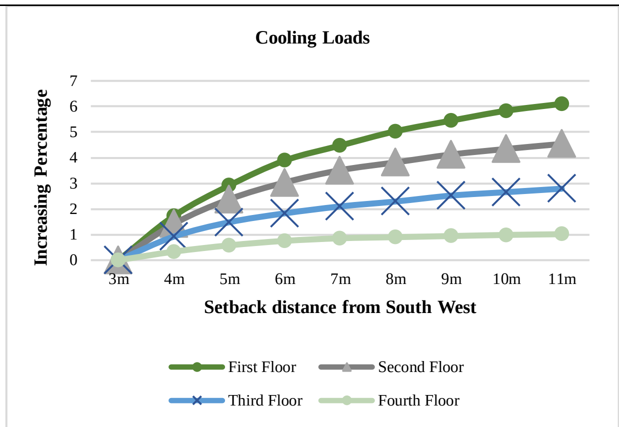


Figure 6.34: North-West Street oriented street case Daylight Factor results when North-East setback was increased.

Increasing the setback distance from the southwest side reduces the overall consumption of heating and cooling loads and reduces the dependence on artificial lighting during the day, especially when the distance between the simulated building and the adjacent southwestern building is 16 m or more. The heating loads have decreased approximately 4.59%, 4.76%, 3.60%, and 1.06% from the North-West oriented street base case on the first, second, third, and fourth floors, respectively, this has decreased the overall consumption, as shown in Table 6.24. Also, this distance is sufficient to provide an acceptable lighting level for all the southwestern spaces on the fourth floor. As for the first, second, and third floors, the lighting was adequate except for bedroom 11 in apartment No.1. Starting from 14m, the adjacent building from south-west has no significant impact on the DF in the third and fourth floors.

Table 6.24: North-West Street oriented street case heating, cooling and total loads consumption results South-West setback was increased.

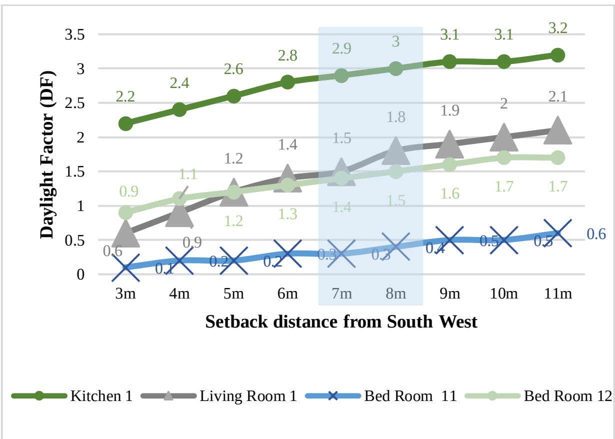




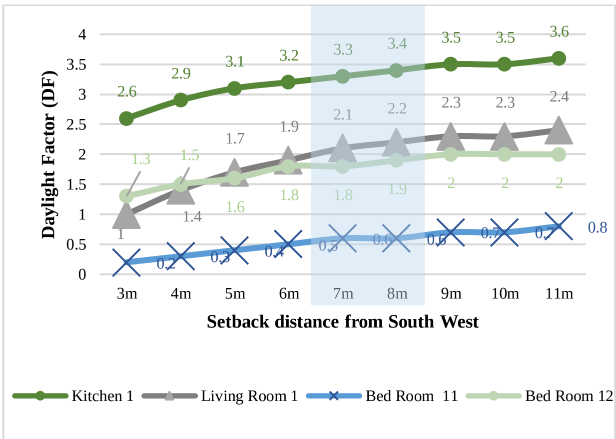
Total Load consumption (kWh/m²)

	3m	4m	%	5m	%	6m	%	7m	%	8m	%	9m	%	10m	%	11m	%
1st Floor	48.77	48.72	-0.10	48.60	-0.34	48.47	-0.61	48.33	-0.91	48.22	-1.13	48.10	-1.38	48.01	-1.55	47.93	-1.72
2nd Floor	49.14	49.02	-0.25	48.87	-0.55	48.72	-0.86	48.60	-1.11	48.48	-1.35	48.39	-1.52	48.32	-1.66	48.27	-1.78
3rd Floor	52.75	52.58	-0.33	52.43	-0.61	52.31	-0.84	52.23	-0.99	52.15	-1.13	52.12	-1.19	52.08	-1.27	52.06	-1.32
4th Floor	80.22	80.12	-0.13	80.05	-0.21	80.01	-0.26	79.98	-0.30	79.94	-0.34	79.92	-0.37	79.90	-0.39	79.89	-0.41

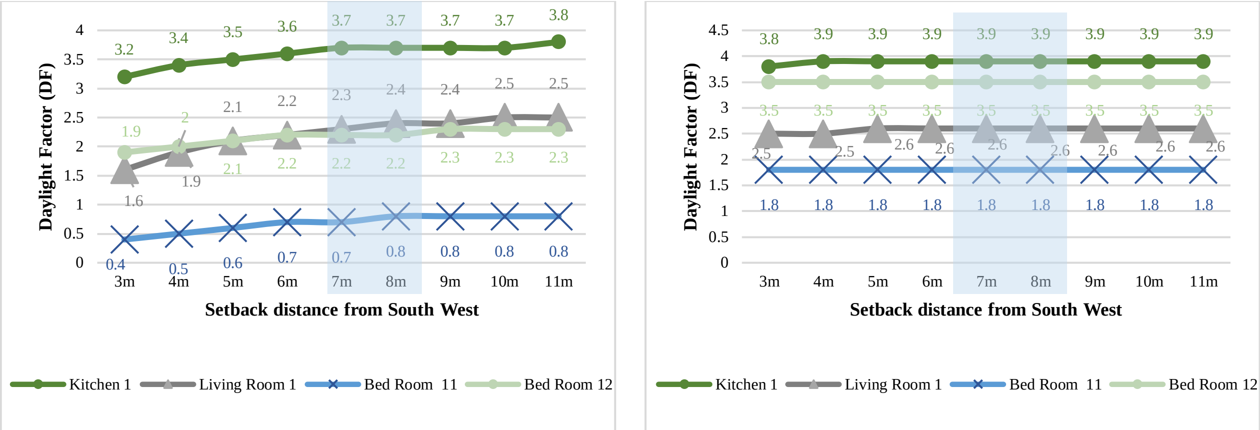
Note: percentage of increasing or decreasing from base case current setback distances.



First Floor



Second Floor



Third Floor Fourth Floor

Figure 6.35: North-West Street oriented street case Daylight Factor results when South-West setback was increased.

At the urban level, not having appropriate setback distances and regulated building height in the surrounding environment reduces the amount of natural daylighting and solar radiation that penetrates into the residential spaces, which also affects thermal energy consumption. As shown in the results below (Table 6.25), optimum setback distances vary from 5-8m as an offset from the land property lines.

From the previous results, it can be seen that at urban level, most residential spaces meet minimum daylight requirements at least at the optimum setbacks distances. On the other hand, when the separation distances between buildings increased, cooling loads also increased, and heating loads decreased noticeably. This is because when the distance increases, the simulated building acquires its solar and natural daylight rights which is useful in winter. But in summer, the building needs more cooling energy to reach thermal comfort. At the same time, artificial lighting energy consumption decreased as a result of the available adequate level of natural daylight inside residential spaces during the daytime.

The optimum setback distance is considered somewhat large due to the land scarcity in Palestine and its high prices. Also, multi-story residential buildings are usually built for investments, so it becomes insufficient and a bad solution to leave all this space between buildings without being used in the construction from the investor's point of view. These all demonstrate the necessity to find alternatives to overcome these problems. Enhance building design and provide alternatives at building level that contribute in improving the indoor environment of residential buildings should be taken into consideration in the early design stage.

Table 6.25: Optimum setback distances in urban context cases.

<table>
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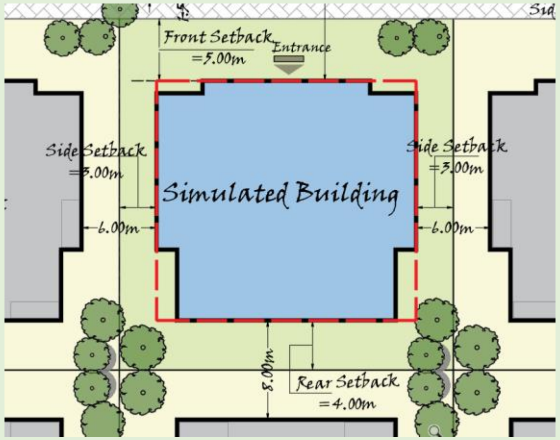
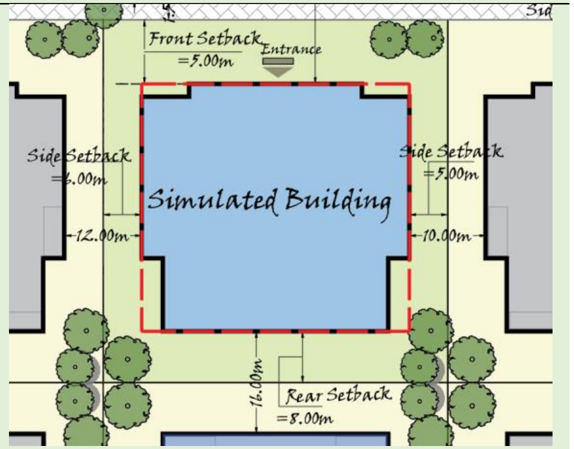
</td><td>5</td><td>4</td><td>3</td><td>3</td><td>
</td><td>5</td><td>8</td><td>6</td><td>5</td><td>
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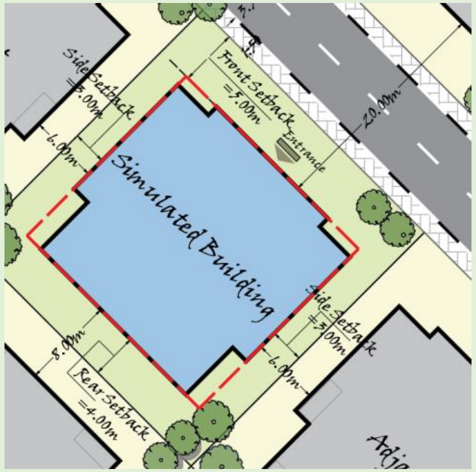
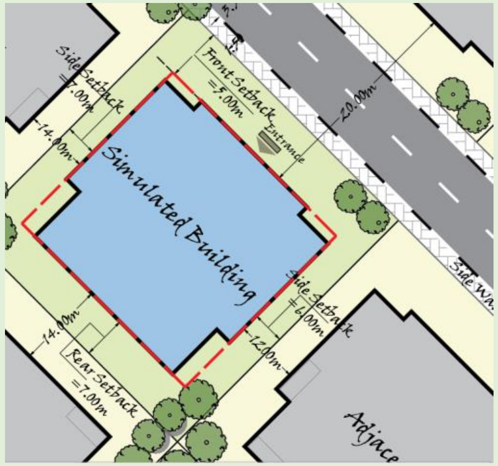
</td><td>5</td><td>4</td><td>3</td><td>3</td><td>
</td><td>5</td><td>7</td><td>7</td><td>6</td><td>
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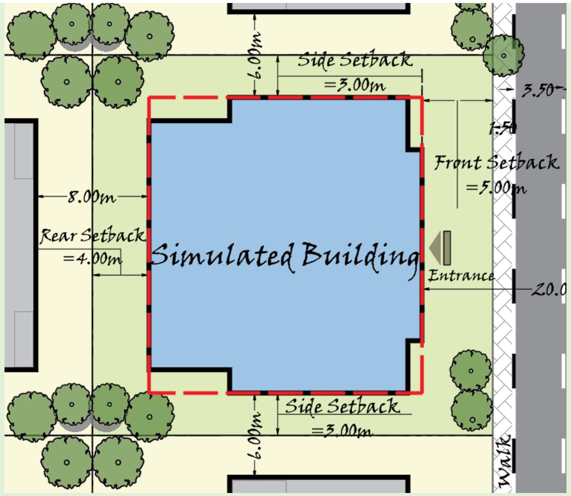
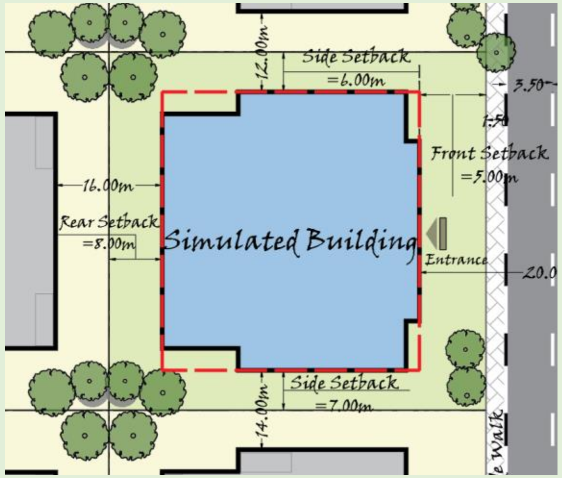
<tr><td rowspan="2">East oriented Street</td><td>E</td><td>W</td><td>N</td><td>S</td><td rowspan="2">
</td><td>E</td><td>W</td><td>N</td><td>S</td><td rowspan="2">
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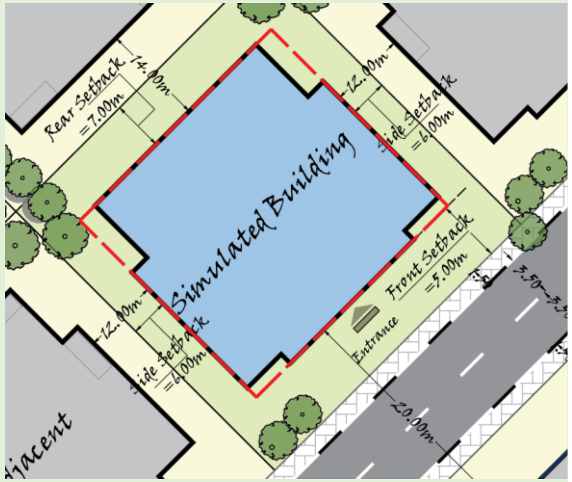
</td><td>SE</td><td>NW</td><td>NE</td><td>SW</td><td rowspan="2">
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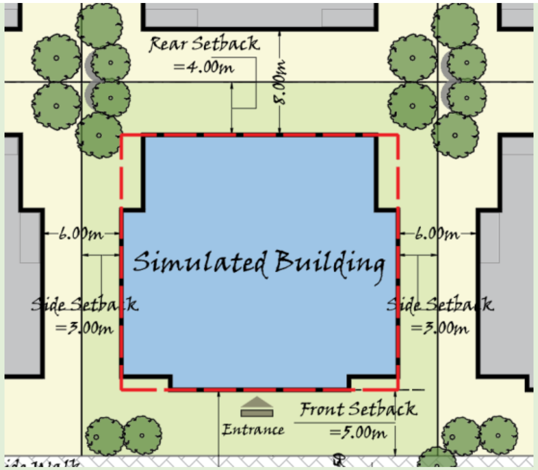
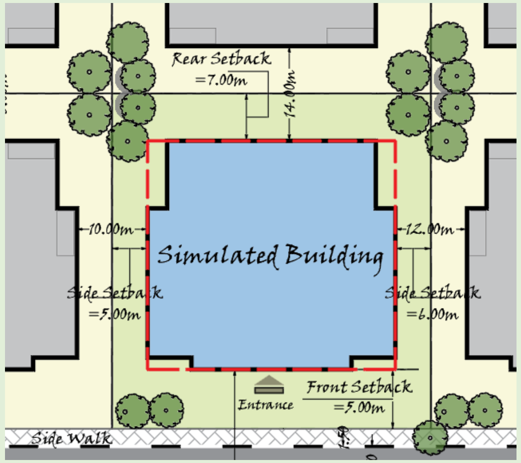
South oriented Street	5	4	3	3		5	7	6	5	
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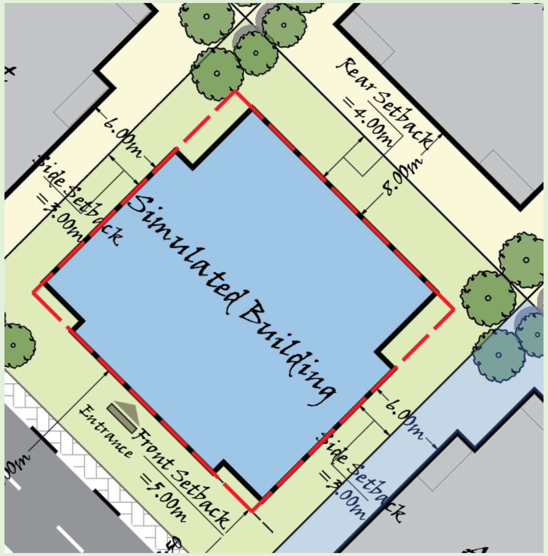
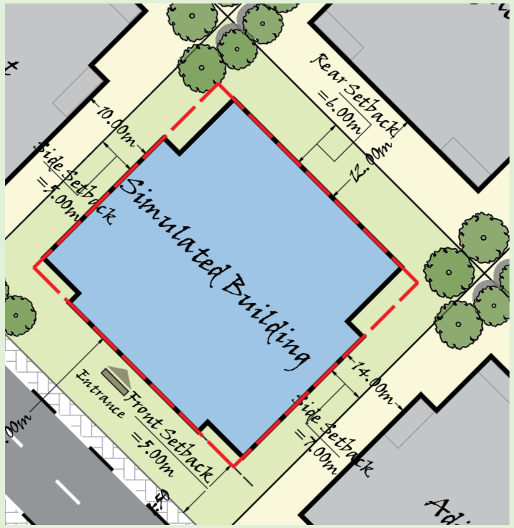
South-West oriented Street	5	4	3	3		5	6	7	5	

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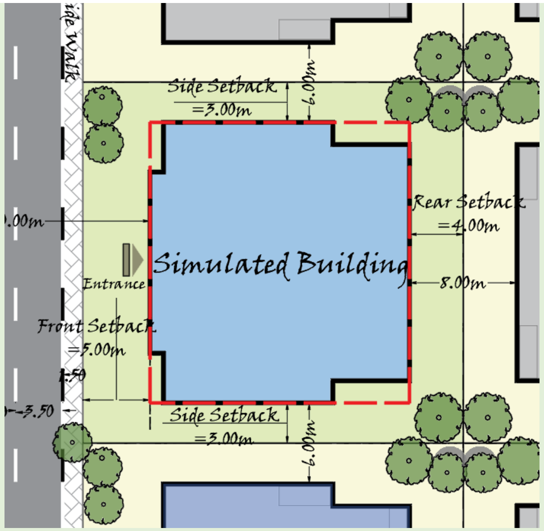
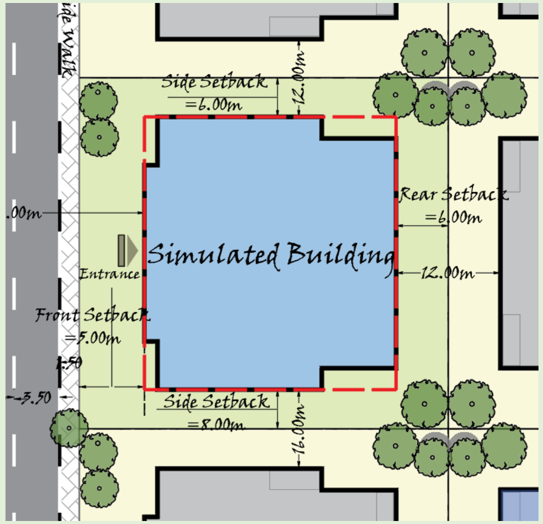
West oriented Street 	5	4	3	3		5	6	8	6	
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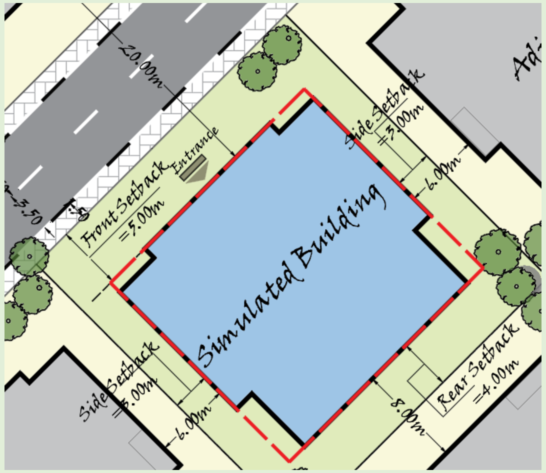
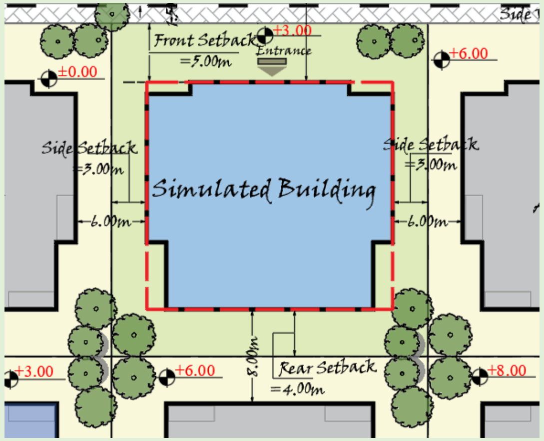
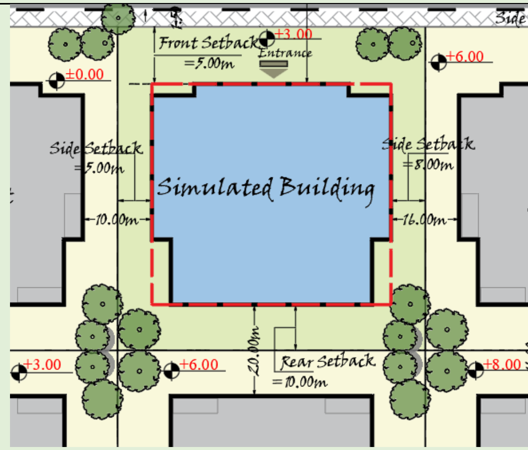
North-West oriented Street 	5	4	3	3		5	8	8	6	

Urban Cases	Existing Setback Distance				"Slopped site"	Optimum Setbacks				
	Front	Back	Side			Front	Back	Side		
	N	S	W	E		N	S	W	E	
North oriented Street 	5	4	3	3		5	10	5	8	
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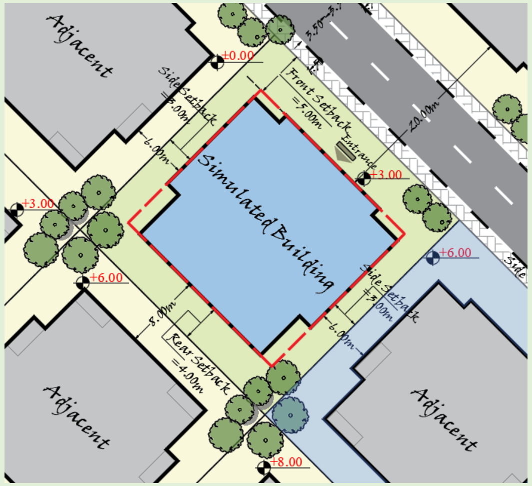
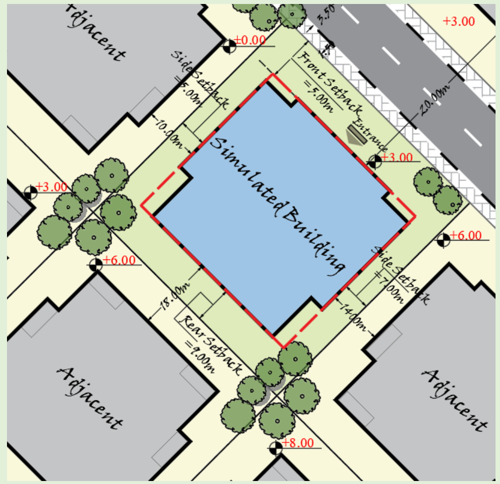
North-East oriented Street 	5	4	3	3		5	9	5	7	

East oriented Street

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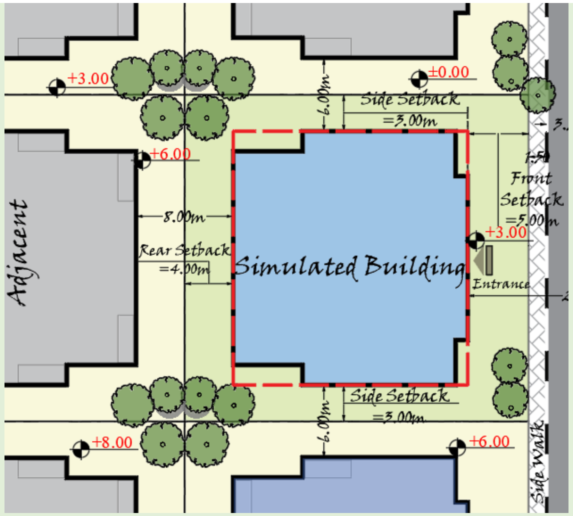
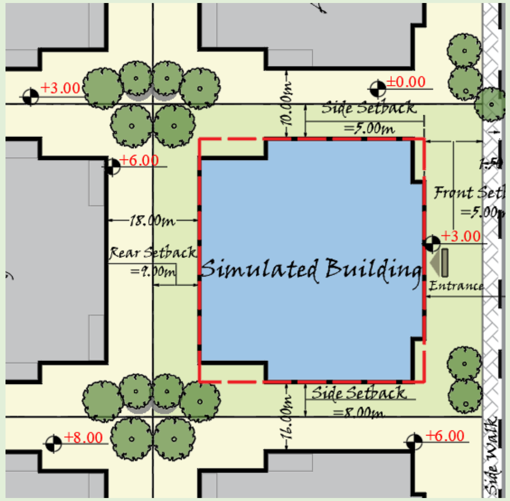


E	W	N	S
5	9	5	8



South-East oriented Street

SE	NW	NE	SW
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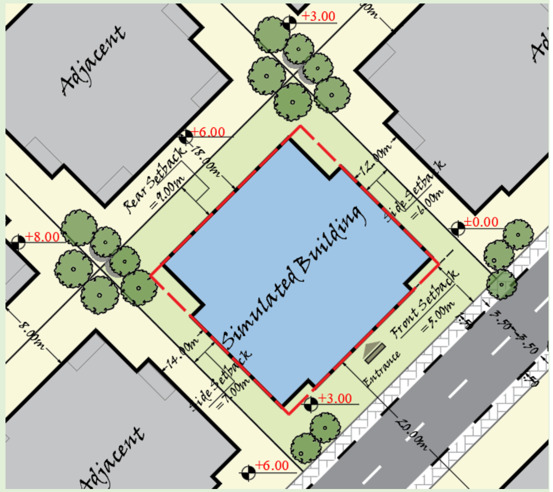
SE	NW	NE	SW
5	9	6	7



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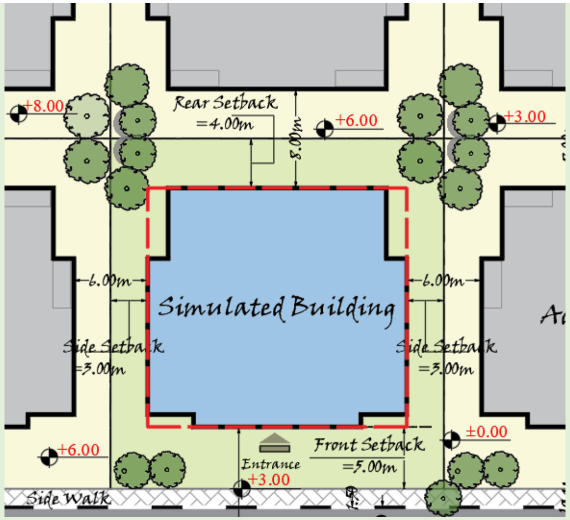
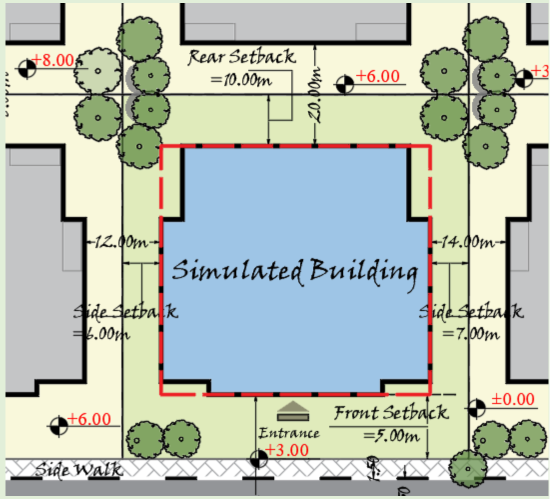
<tr><td>South oriented Street</td><td>5</td><td>4</td><td>3</td><td>3</td><td>
</td><td>5</td><td>10</td><td>7</td><td>6</td><td>
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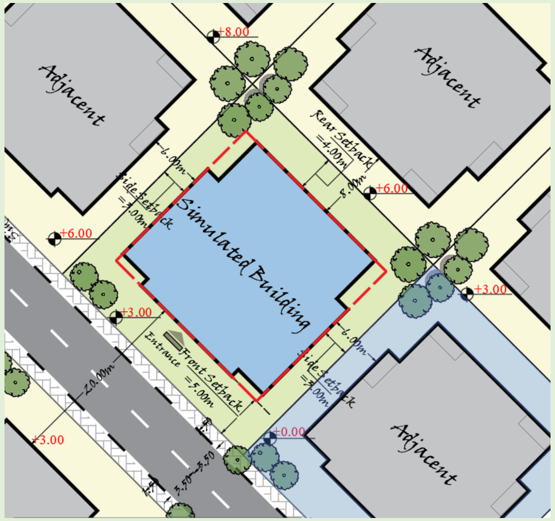
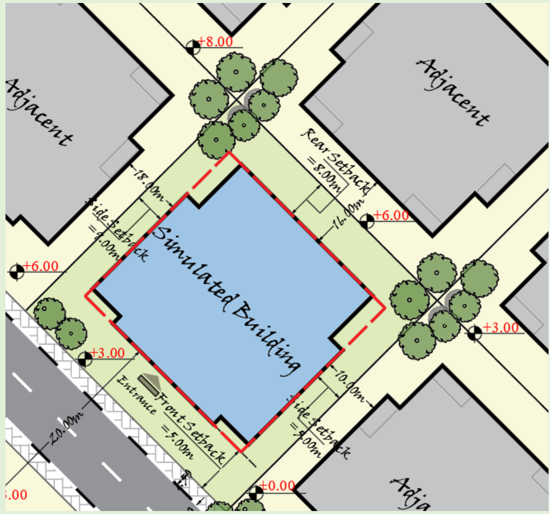
<tr><td>South-West oriented Street</td><td>5</td><td>4</td><td>3</td><td>3</td><td>
</td><td>5</td><td>8</td><td>5</td><td>9</td><td>
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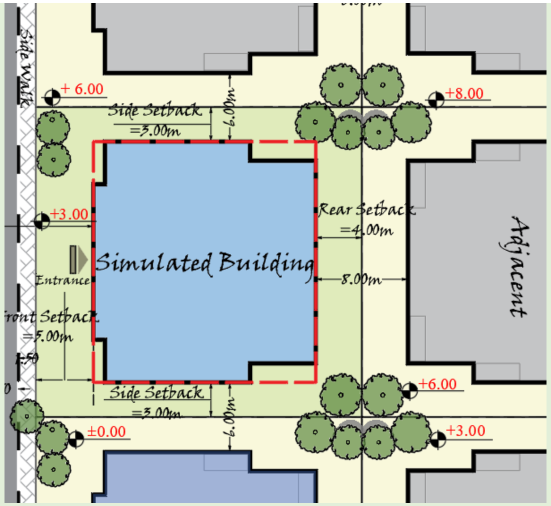
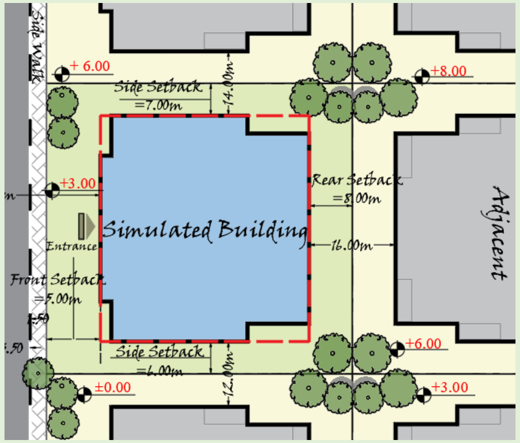
West oriented Street	5	4	3	3		5	8	6	7	
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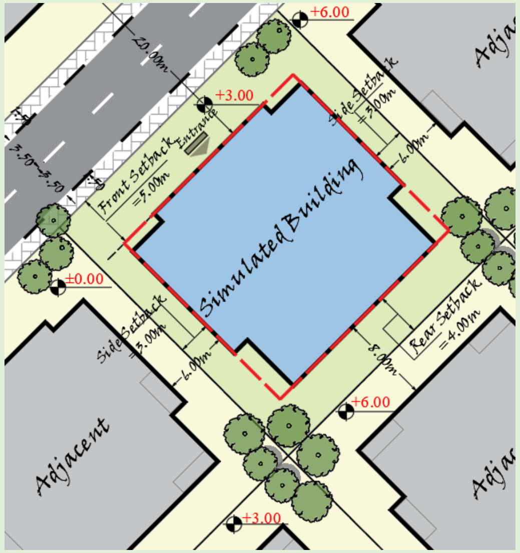
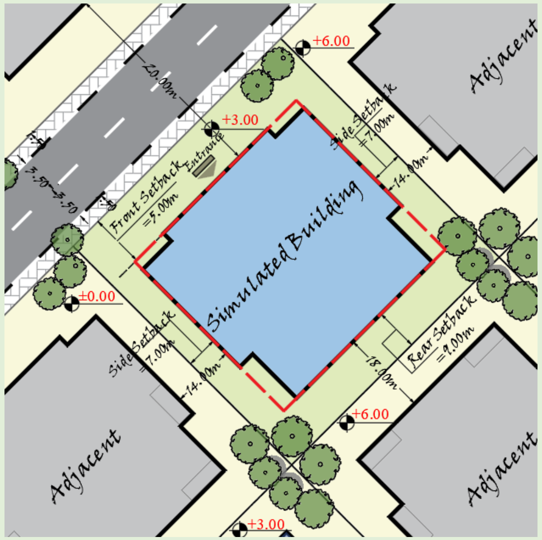
North-West oriented Street	5	4	3	3		5	9	7	7	

6.4. Optimization at Building Level:

As thoroughly studied at the urban level optimization phase when the optimum setback distance was considerable and tested, it was concluded that the optimum distance between buildings should be up to 16m. Leaving such distance in Palestine between buildings is ineffective, especially when the land lots areas are small. Therefore, it is essential to find other solutions that improve the indoor environment performance and reduce thermal energy consumption at the building design level. This is because each space in the building at different floors and different orientations should have its own specific design considerations to improve its performance within the context of the existing surrounding environment.

The building level's optimization process was divided into two phases to reveal the possible solutions to improve the natural daylighting and thermal energy consumption for different urban context cases. The first one begins with a literature review about building-level parameters that will enhance the indoor environment and energy savings in residential buildings. The second phase aims to examine the impact of selected parameters such as windows to wall ratio, and shading devices compatible with existing regulated setbacks' distances and to identify the most influential parameters impacting daylight availability and thermal performance in multi-story residential buildings in a Mediterranean climate in Palestine.

According to the literature review, two groups of parameters were simulated as an alternative at building level to analyze their impact on the daylighting availability and thermal energy performance; window to wall ratio and shading elements. These parameters were applied for 16 urban context scenarios in first, second, third and fourth floors. At this level, one parameter was varied while the others were fixed to identify the most sensitive parameter. For example, when WWR varied from 20% to 80%, shading elements were not considered, to determine the optimum WWR in each space without any influence of other factors. Then, when the optimum window sizes were selected, the second parameter was varied, and WWR became constant to determine the impact of different shading device types on the optimum cases.

The second phase in the optimization process at the building level focused on determining the optimum WWR in each floor for different urban context cases. Then, more parameters were added to achieve better performance in the configurations by using shading elements. In another word, adding shading devices was to study their impact on enhancing daylighting levels and energy savings inside residential spaces at optimum WWR results.

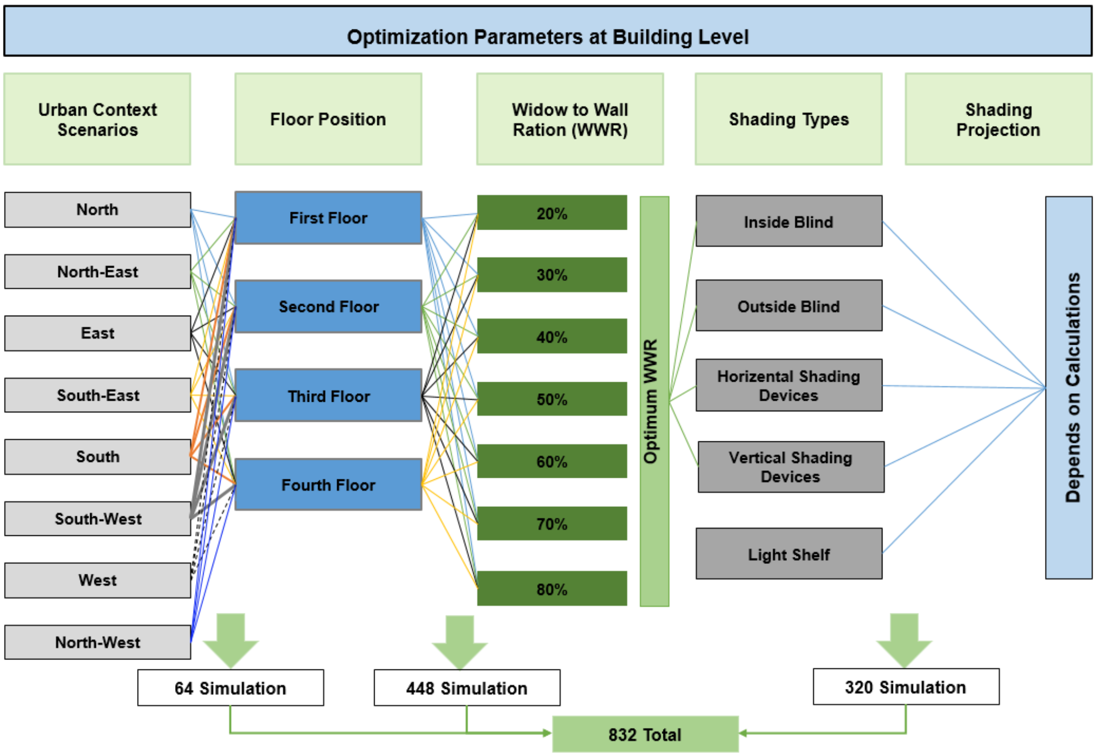


Figure 6.36: Building level parameters.

The most studied parameter this study has focused at during building level optimization is windows design and their characteristics because the heat and natural light transferred in summer and winter mainly through glazing surfaces. Windows are the most important element in the building envelope in terms of its impact on energy consumption and daylighting availability. Thus, passive design strategies like window size and shading device installation have a huge potential for energy savings and to provide adequate daylighting inside spaces (Carletti, Sciurpi, & Pierangioli, 2014).

6.4.1. Window to Wall Ratio (WWR):

Windows are considered the most important element in the building envelope because of their impact on the building thermal behavior which affects the amount of the required energy within. Also, window characteristics play a significant role in affecting the daylight availability inside buildings. It is an essential part to provide natural ventilation, as well as achieving outdoor visibility, therefore it should be chosen carefully (Elghamry & Hassan, 2020; Muhaisen & Dabboor, 2013).

Building glazing is a passive design strategy to collect solar radiation and natural daylight (Didwania & Mathur, 2011). Solar radiation accessibility is considered one of the most essential ways used to reduce heating energy consumption inside buildings in winter. On the other hand, natural daylight has a substantial impact because of its importance in reducing energy consumption used in artificial lighting, also it provides a thermal and visual comfort environment for occupants inside spaces (Yassin et al., 2017). As it is known that windows are the most important resource for daylight and solar energy inside buildings, and proper windows design saves artificial lighting energy, also improve thermal comfort which may reduce the heating energy consumption in winter, since major heat gain mainly occurs through windows (Alshaibani, 1996; P. Littlefair, 2001; Yassin et al., 2017).

Consequently, the effect of windows on natural daylighting and annual energy consumption is determined in this section. It is one of the passive design strategies in the optimization process. It was investigated by assessing opening orientation in addition to the window area in order to find the optimum windows area for residential spaces in residential B-zone at different urban context scenarios and at different floors. Window area is commonly defined by WWR which is the ratio between the window area and the overall external wall area (Li et al., 2006). In Palestine, the existing building regulations don't take into consideration window area.

A lot of studies have measured the impact of windows design on the total energy consumption. Elghamry and Hassan presented the influence of windows characteristics such as WWR, window width to the height ratio, window position in the wall and orientation on the building cooling, heating and lighting loads. Moreover, the impact on the indoor thermal comfort, energy cost and CO_2 is also studied in $20m^2$ office room in semi- arid climatic condition using Design Builder software. This study shows that, increasing WWR decrease heating and lighting required energy and increase cooling energy and indoor temperature. And so, studying and emphasizing on window related parameters help reducing lighting energy, cooling loads, CO_2 emissions, annual energy consumption and energy cost by 39%, 30%, 22%, 24%, 12% respectively (Elghamry & Hassan, 2020).

In Alghoul, Rijabo and Mashena study, the effect of window parameters such as window to wall ratio (WWR) and orientation on annual energy consumption was investigated for a clear double glazed window in an office room in Libya using Energy Plus software. The results show that, when WWR increases cooling loads also increase and heating loads decrease to zero in the southern wall because of heating gain in winter (Alghoul et al., 2017).

In the local context, parametric study was carried out in the Gaza strip climatic condition using IES virtual environment and ECOTECT software to examine the effect of windows design parameters such as WWR, window orientation and glass thermal properties on heating and cooling energy consumption. The results indicate that the optimal window area for all different facades is 10% from total wall area. At the same time, it is very important to use glazing materials with low U-value to reduce total energy consumption inside residential spaces (Muhaisen & Dabboor, 2013).

The WWR at the base cases in the assessment stage is different from one space to another according to the space use and to the outdoor façade area. According to the proposed design for residential building prototype as mentioned in chapter 4, window areas varied between 15% to 23% as a percentage from wall area, and the window position in the wall is at the middle and 1.04 m higher than floor level.

In the optimization stage at the building level, Design Builder software is used to examine the daylight performance, heating, cooling and total energy consumption for different WWR values which range between 20% to 80% (step 10%) in each residential space. The increase in the window area was presented firstly by vertical expansion by raising the windows lintel because this increases the amount of daylight and sunlight and improves their distribution deeper within the space, see Figure 6.37 (P. J. Littlefair, 2011) , and then by horizontal expansion.

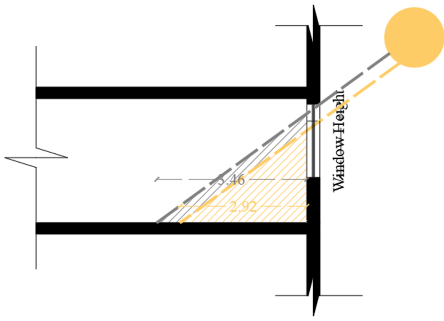


Figure 6.37: The impact of window height on daylight availability inside space (Source: Researcher).

As shown in the results (See Appendix 2C), when WWR increases, cooling loads also increase, but heating and artificial lighting energy decreases. Living room heating and cooling results in apartment No. 1 are presented in Figure 6.38-Figure 6.45. Also, the overall impact of WWR on the total heating and cooling loads consumption is shown in Figure 6.46-Figure 6.49. The values of energy consumption are presented in kWh/m2. The heating consumption as shown in the Figure 6.38 and Figure 6.39 for the first and second floors came out to be approximately same and ranged from 17 kWh/m2 to 33 and from 14.8 kWh/m^2 to 32.3 kWh/m^2 for first and second floor respectively due to the same effect from surroundings. While the consumption for the higher floors third and fourth was different in all WWR values and the consumption increased suddenly due to the roof effect of heat loss and gain which lead to higher consumption of heating energy.

The figures below illustrate that, Eastern orientation (case No. 5, street oriented to the south) has recorded the lowest values of heating energy consumption per square meter at all WWR values, followed by southern side (case No. 7, street oriented to the west) in the first and second floors. While the maximum heating energy consumption occurred at northern and northern west sides when the street was oriented to the east and oriented to the north east respectively among all WWR values because of no direct solar radiation in these orientations, and thus consumed a high amount of heating energy in winter, which affects the total energy consumption in all floors. As for lowest heating energy in the third and fourth floors, the living room at South façade (Case No. 7, street oriented to the west) consumed the lowest amount of heating energy at all WWR values.

The increase in WWR plays a significant role in reducing heating energy when WWR varying between 20% to 80% from 26.5 kWh/m^2 -17.00 kWh/m^2, 27.90 kWh/m^2 -19.6 kWh/m^2 and 28.80 kWh/m^2- 21.2 kWh/m^2 for East, South East and South external wall facing respectively for the living room 1 in the first floor. When WWR increase from 20% to 80% for East, South East, South and South west in the second floor, the annual heating energy was reduced from 25.50 kWh/m^2 to14.90 kWh/m^2, 26.00 kWh/m^2 to15.80 kWh/m^2, 25.40 kWh/m^2 to 14.80 kWh/m^2 and from 27.50 kWh/m^2 to 18.60 kWh/m^2 respectively. In the north, north-east, south-east, south-west, west and north-west oriented streets, positioning a 60% WWR in the living room on the first floor appears to be effective. Also 50% WWR is effective when the street is oriented to the east and south.

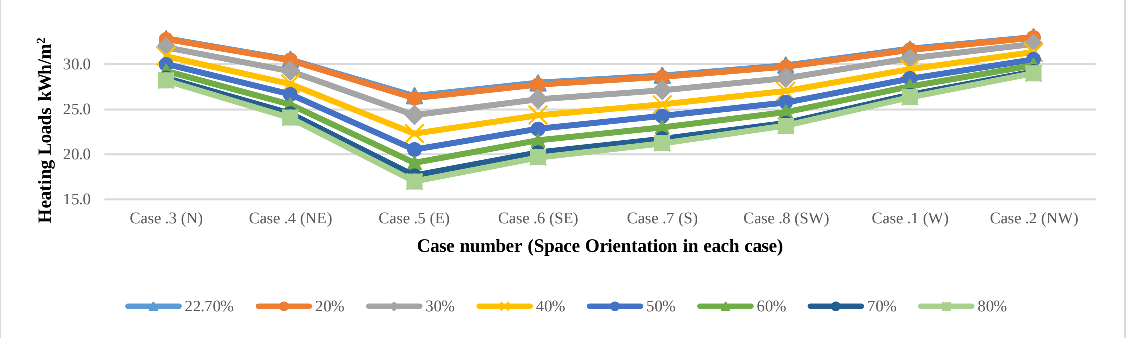


Figure 6.38: First floor heating loads consumption in living room - apartment No.1 for different urban context scenario in kWh/m2.

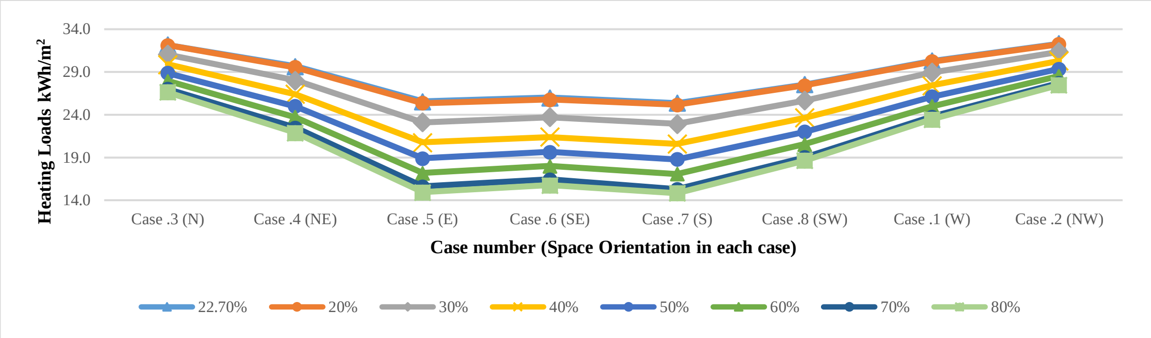


Figure 6.39: Second floor heating loads consumption in living room - apartment No.1 for different urban context scenario in kWh/m^2.

In the third and fourth floors, the annual heating energy consumption is reduced significantly when WWR increases from 20% to 80% for North East, East, South East, South, South West and west orientations. In the third floor, the consumption is decreased from 23.10 kWh/m^2 to 23.50 kWh/m^2, 27.50 kWh/m^2 to 15.50 kWh/m^2, 25.20 kWh/m^2 to 12.40 kWh/m^2, 21.80 kWh/m^2 to 8.40 kWh/m^2, 26.90 kWh/m^2 to 15.60 kWh/m^2, 31.20 kWh/m^2 to 21.30 kWh/m^2 respectively. For the fourth floor heating energy loads, the consumption was from 52.70 kWh/m^2 to 42.90 kWh/m^2, 46.90 kWh/m^2 to 32.00 kWh/m^2, 41.50 kWh/m^2 to 23.20 kWh/m^2, 38.10 kWh/m^2 to 19.20 kWh/m^2, 43.00 kWh/m^2 to 27.50 kWh/m^2 and from 48.70 kWh/m^2 to 37.10 kWh/m^2 respectively.

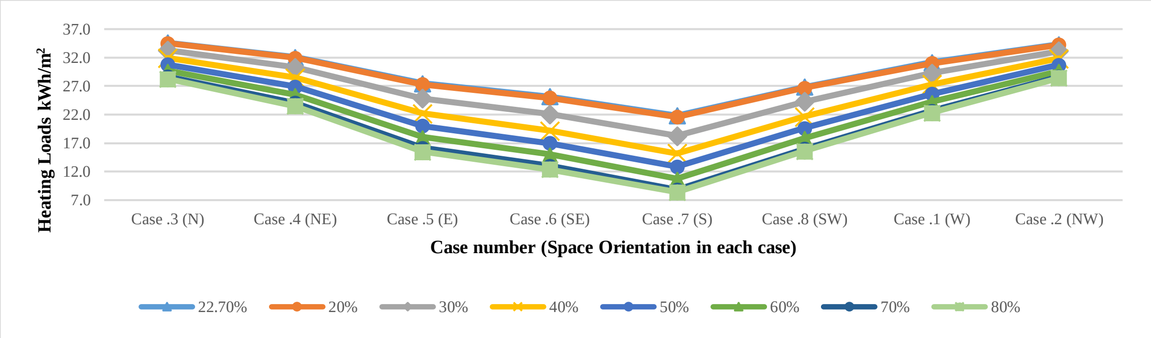


Figure 6.40: Third floor heating consumption in living room - apartment No.1 for different urban context scenario in kWh/m^2.

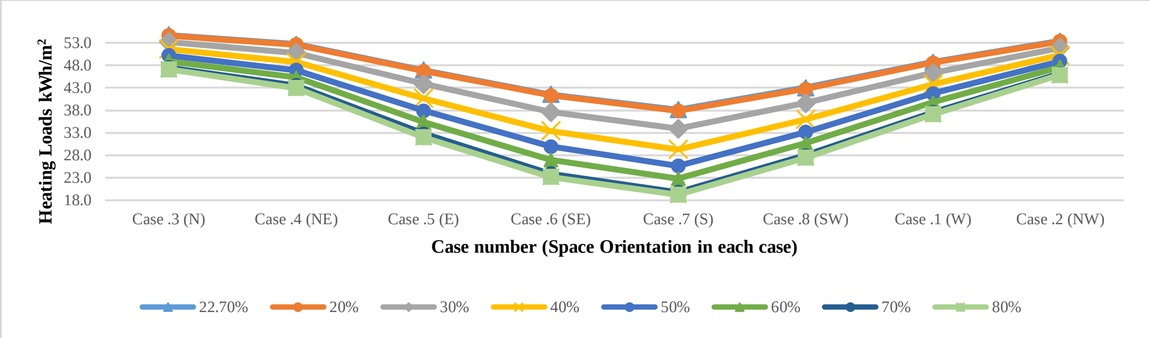


Figure 6.41: Fourth floor heating loads consumption in living room - apartment No.1 for different urban context scenario in kWh/m^2.

The impact on cooling loads is shown in the figures 5.9- 5.12. As shown, increasing the WWR causes an increase in the cooling energy in all urban context scenarios because of an increase in heat gain in summer months. Living room with southern windows consume the highest cooling energy for all WWR values in the first floor which increase from 16.60 kWh/m^2 to 32.20 kWh/m^2 when WWR changes from 20% to 80%. But in the second, third and fourth floors, living room at southern east and southern west facades was the highest cooling energy consumer, while the northern one consumed the lowest cooling energy for all floors among all WWR values. For example, when WWR is 80% at fourth floor, the cooling energy consumption was 32.10 kWh/m^2, 41.90 kWh/m^2, 54.00 kWh/m^2, 59.60 kWh/m^2, 53.30 kWh/m^2, 62.70 kWh/m^2, 57.50 kWh/m^2, 44.10 kWh/m^2 for North, North East, East, South East, South, South West, West and North West living room façade orientations respectively. In the first floor, West and North West orientation consumed roughly the same amount of cooling energy but in the second floor North East and East are the same as West and North West.

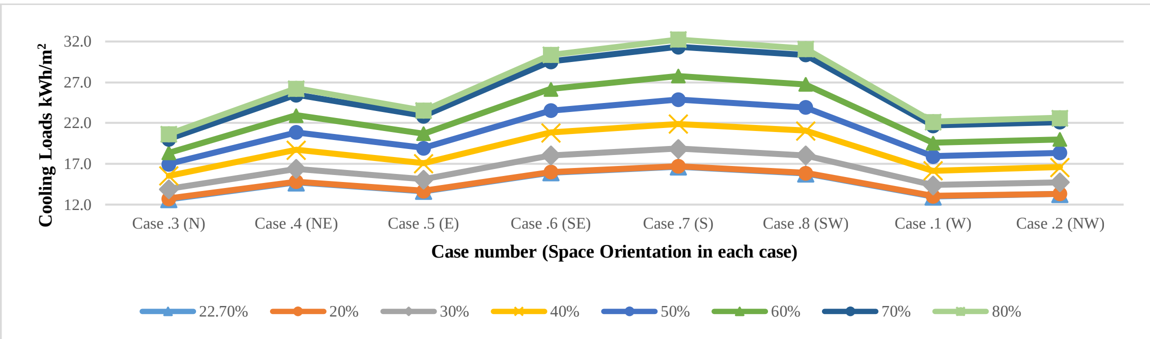


Figure 6.42: First floor cooling loads consumption in living room - apartment No.1 for different urban context scenario in kWh/m^2.

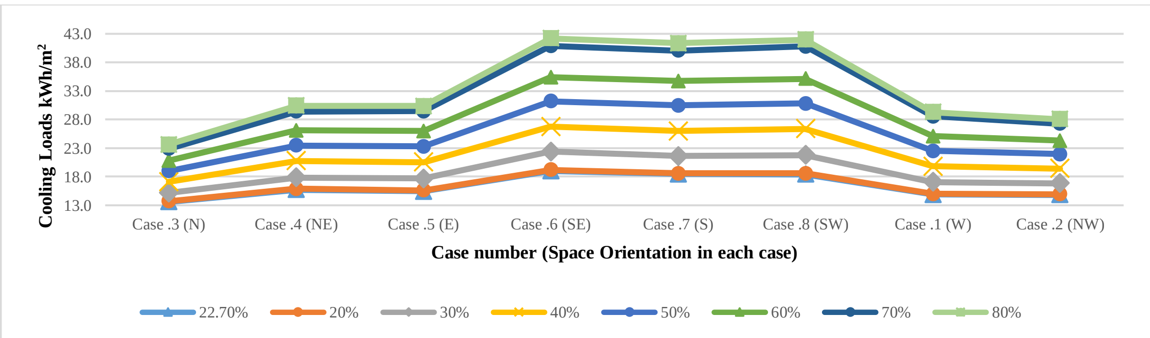


Figure 6.43: Second floor cooling loads consumption in living room - apartment No.1 for different urban context scenario in kWh/m^2.

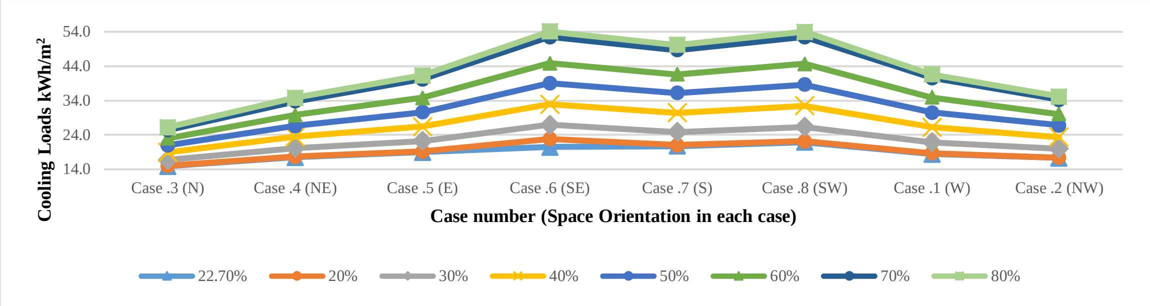


Figure 6.44: Third floor cooling loads consumption in living room - apartment No.1 for different urban context scenario in kWh/m².

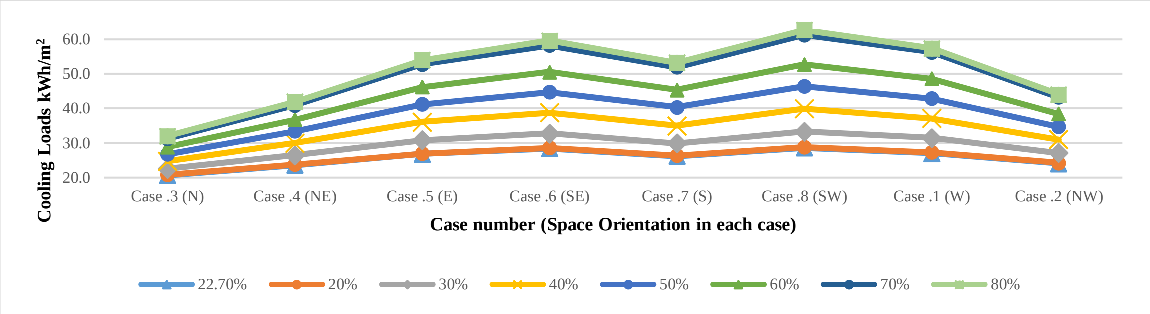


Figure 6.45: Fourth floor cooling loads consumption in living room - apartment No.1 for different urban context scenario in kWh/m².

As for total energy consumption, figures below show the annual total energy consumption for heating and cooling loads together. As seen, the highest total energy consumption occurred at South and South West orientations in the first floor, South East and South West in the second and third floors, South West and West in the fourth floor when WWR increased from 20% to 80%. While, East orientation in the first floor consumed the lowest energy which got increased slightly from 40.10 kWh/m² to 40.50 kWh/m² when WWR changed from 20% to 80%. The same thing has happened in the second floor but the increasing was higher than the increase at first floor. It got increased from 41.00 kWh/m² to 45.30 kWh/m² for East orientation. In this floor a 40% WWR is sufficient in term of daylighting and energy consumption for north, east, south, south west, west and north-west oriented streets and 30% for east and south east oriented streets.

As for the third and fourth floors, the situation is completely different, South orientation was the lowest consumer for overall annual energy consumption when increasing WWR values. Also, due to the movement of the sun towards the south, when studying energy consumption with natural lighting, the southern façade needs a smaller percentage of window to wall area compared to other cases.

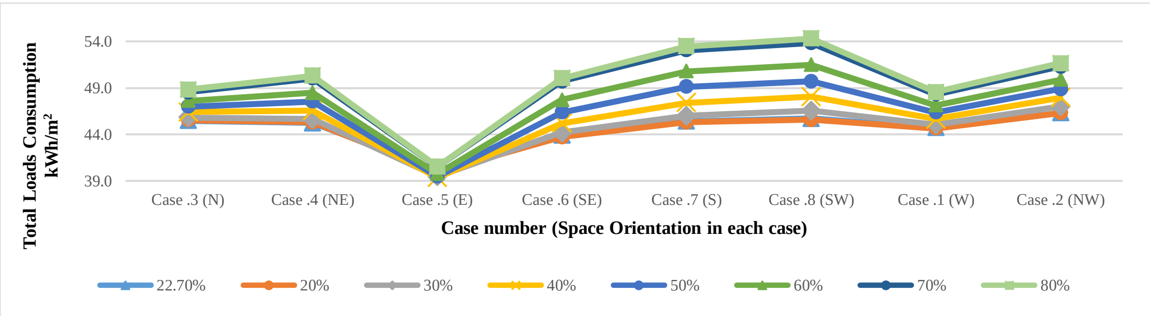


Figure 6.46: First floor total loads consumption in living room - apartment No.1 for different urban context scenario in kWh/m².

As shown in the total energy consumption results, when the living room faces north, east, and west on the first floor, north and East on the second floor, north and north-east on the third floor and north, north-east and south, the total consumption is less affected by the increasing WWR.

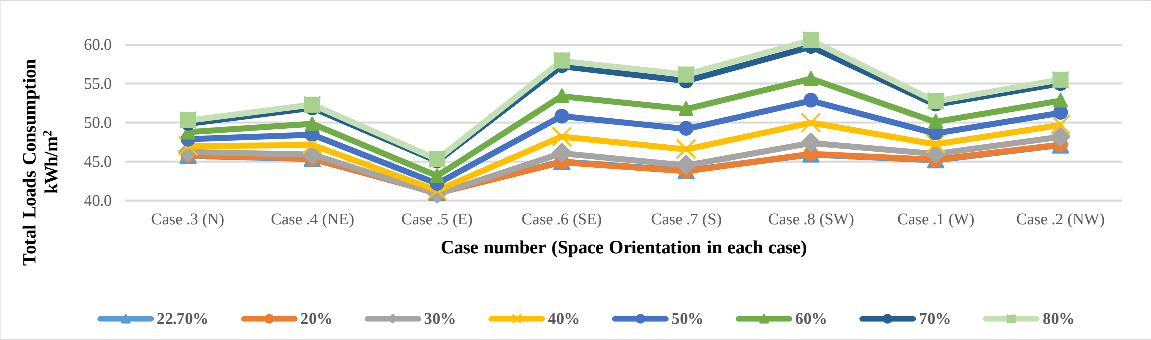


Figure 6.47: Second floor total loads consumption in living room - apartment No.1 for different urban context scenario in kWh/m^2.

As shown in the total energy consumption and daylighting results, living room window size should be at least 50% in the first floor to achieve acceptable daylighting levels. In the third floor, 20% WWR is effective to provide adequate level of daylighting more than 1.5% in north and north-east oriented streets, and 30% WWR is proper for other cases. And in the fourth floor, 20% WWR is effective for daylighting and energy reduction for all urban cases except east oriented street which is 30% WWR is effective.

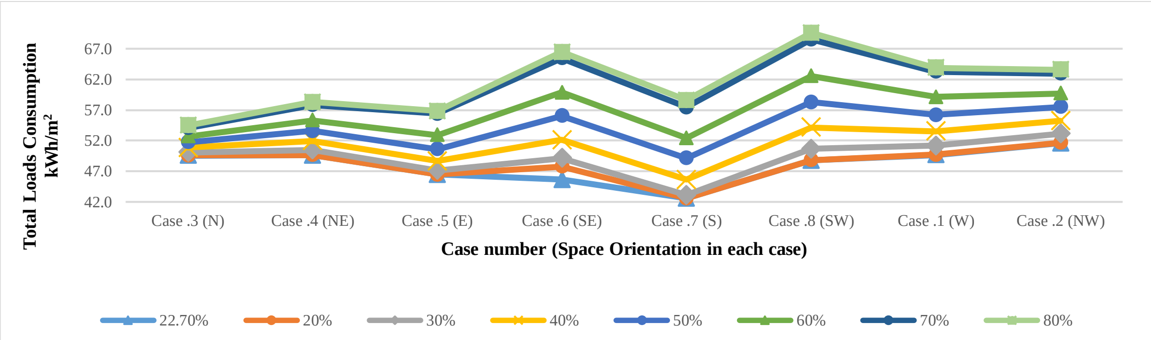


Figure 6.48: Third floor total loads consumption in living room - apartment No.1 for different urban context scenario in kWh/m^2.

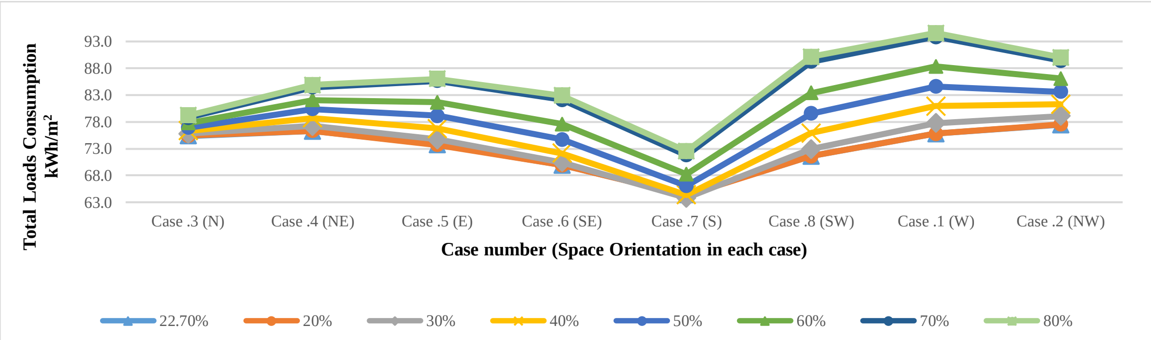


Figure 6.49: Fourth floor total loads consumption in living room - apartment No.1 for different urban context scenario in kWh/m^2.

According to the results, windows with similar properties such as area to the wall ratio and materials has different influence on the total energy consumption and daylighting for the same space at different urban context scenarios and for different street orientations. Thus, varying WWR at different orientations and floors for the same space was essential which is opposing to the common design of the current residential buildings windows in Palestine.

Low winter sun angle need to find its way to indoor spaces through windows. Under such situation when low sun angles were found and large obstruction in residential zones to the south and other orientations are present, large glazed area in winter may reduce the amount of heating loads as shown in Figure 6.38 to Figure 6.41, and enhance the amount of natural daylighting which enters to the residential spaces. On the other hand, large glazing area in comparison to the overall wall area receives a large amount of solar radiation and heat gain during summer and this increased cooling energy consumption as shown in figures Figure 6.42-Figure 6.45. In the optimization stage when choosing the optimal WWR for each space, it is important to achieve the minimum requirement for DF inside residential spaces whilst mitigating overheating in summer months. Based on the simulation results, the optimal WWR for each residential space at different floors and urban context cases was chosen to achieve suitable average daylight factor not less than 1% for bedrooms, 1.5% for living area and 2% for kitchen (P. Littlefair, 2001; P. J. Littlefair, 2011) which has reduced the amount of energy used for artificial lighting. At the same time, trying to keep cooling and heating energy minimized as much as possible.

As shown in the previous results, increasing windows size significantly impacts energy consumption and natural daylight availability. Changing WWR from 20% to 80% reduces heating loads, improves daylighting inside spaces, and increases cooling load consumption. To achieve the best performance of these windows, firstly, it is essential to choose the size of the optimum windows in each space required to reduce heating loads in winter and improve daylighting distribution in residential spaces (see Table 6.26). And the second requirement concerns the choice of proper shading devices to prevent excessive solar gain in summer, reducing the cooling load consumption, which has increased due to the increase in windows size. On the other hand, it is necessary to consider winter solar gain and daylighting availability when shading devices are chosen.

Table 6.26: Optimum WWR for each space in all urban context scenarios.

	Space	Current WWR	Case No.1 Street oriented to the North				Case No.2 Street oriented to the North East			
			First Floor	Second Floor	Third Floor	Fourth Floor	First Floor	Second Floor	Third Floor	Fourth Floor
Apartment 1	Guest Room	19.3%	40%	40%	30%	30%	40%	40%	40%	30%
	Kitchen	18.90% 17.5%	20%	20%	20%	20%	20%	20%	20%	20%
	Living Room	22.70%	60%	40%	20%	20%	60%	30%	20%	20%
	Bedroom 1	17%	100%	100%	70%	20%	100%	100%	70%	20%
	Bedroom 2	17% 17%	30%	20%	20%	20%	30%	20%	20%	20%
	Master Room	15.90%	30%	20%	20%	20%	40%	20%	20%	20%
Apartment 2	Guest Room	19.3%	40%	40%	30%	30%	40%	40%	40%	30%
	Kitchen	18.90% 17.5%	20%	20%	20%	20%	20%	20%	20%	20%
	Living Room	22.70%	60%	40%	20%	20%	50%	30%	20%	20%
	Bedroom 1	17%	100%	100%	60%	20%	100%	100%	60%	20%
	Bedroom 2	17% 17%	30%	20%	20%	20%	20%	20%	20%	20%
	Master Room	15.90%	40%	20%	20%	20%	30%	20%	20%	20%
	Space	C ur re nt W	Case No.3 Street oriented to the East				Case No.4 Street oriented to the South-East			

Apartment	Space	Current WWR	First Floor	Second Floor	Third Floor	Fourth Floor	First Floor	Second Floor	Third Floor	Fourth Floor
Apartment 1	Guest Room	19.3%	50%	40%	40%	40%	40%	40%	30%	30%
	Kitchen	18.90% 17.5%	20%	20%	20%	20%	20%	20%	20%	20%
	Living Room	22.70%	50%	40%	30%	30%	60%	30%	30%	20%
	Bedroom 1	17%	100%	100%	60%	20%	100%	100%	70%	20%
	Bedroom 2	17% 17%	30%	30%	20%	20%	20%	20%	20%	20%
	Master Room	15.90%	40%	30%	20%	20%	30%	20%	20%	20%
Apartment 2	Guest Room	19.3%	40%	40%	40%	40%	40%	40%	40%	30%
	Kitchen	18.90% 17.5%	20%	20%	20%	20%	20%	20%	20%	20%
	Living Room	22.70%	60%	30%	30%	30%	60%	30%	20%	20%
	Bedroom 1	17%	100%	100%	60%	20%	100%	100%	60%	20%
	Bedroom 2	17% 17%	30%	30%	20%	20%	20%	20%	20%	20%
	Master Room	15.90%	30%	30%	20%	20%	30%	20%	20%	20%

Apartment	Space	Current WWR	Case No.5 Street oriented to the South First Floor	Second Floor	Third Floor	Fourth Floor	Case No.6 Street oriented to the South West First Floor	Second Floor	Third Floor	Fourth Floor
Apartment 1	Guest Room	19.3%	40%	40%	30%	30%	40%	40%	40%	30%
	Kitchen	18.90% 17.5%	20%	20%	20%	20%	20%	20%	20%	20%
	Living Room	22.70%	50%	40%	30%	20%	60%	40%	30%	20%
	Bedroom 1	17%	100%	100%	70%	20%	100%	100%	70%	20%
	Bedroom 2	17% 17%	30%	20%	20%	20%	30%	20%	20%	20%
	Master Room	15.90%	40%	30%	20%	20%	40%	30%	20%	20%
Apartment 2	Guest Room	19.3%	40%	40%	30%	30%	40%	40%	40%	30%
	Kitchen	18.90% 17.5%	20%	20%	20%	20%	20%	20%	20%	20%
	Living Room	22.70%	60%	40%	30%	20%	60%	40%	30%	20%
	Bedroom 1	17%	80%	80%	70%	20%	80%	80%	70%	20%
	Bedroom 2	17% 17%	30%	20%	20%	20%	30%	20%	20%	20%
	Master Room	15.90%	40%	30%	20%	20%	40%	30%	20%	20%

Apartment	Space	Current WWR	Case No.7 Street oriented to the West First Floor	Second Floor	Third Floor	Fourth Floor	Case No.8 Street oriented to the North West First Floor	Second Floor	Third Floor	Fourth Floor
Apartment 1	Guest Room	19.3%	40%	40%	40%	30%	50%	40%	40%	30%
	Kitchen	18.90% 17.5%	20%	20%	20%	20%	20%	20%	20%	20%
	Living Room	22.70%	60%	40%	30%	20%	60%	40%	30%	20%
	Bedroom 1	17%	100%	100%	70%	20%	100%	90%	70%	20%
	Bedroom 2	17% 17%	40%	30%	20%	20%	30%	20%	20%	20%
	Master Room	15.90%	40%	30%	20%	20%	30%	20%	20%	20%
Apartment 2	Guest Room	19.3%	40%	40%	40%	30%	50%	40%	40%	30%
	Kitchen	18.90% 17.5%	20%	20%	20%	20%	20%	20%	20%	20%
	Living Room	22.70%	60%	40%	30%	20%	60%	40%	30%	20%
	Bedroom 1	17%	80%	100%	90%	20%	90%	90%	60%	20%
	Bedroom 2	17% 17%	40%	30%	20%	20%	30%	20%	20%	20%
	Master Room	15.90%	40%	30%	20%	20%	30%	20%	20%	20%

As shown in the results above, lower floors especially first floor is more obstructed than others by surrounding buildings, and need larger windows area to provide the same required amount of lighting available at the higher floors. Bedroom 11 in apartment No.1 and bedroom 21 in apartment No.2 don't meet minimum daylighting requirements and standards despite the increasing of window to wall ratio in these spaces. This is because the balconies above windows will restrict natural daylight and reduce the average DF values inside space. The results of this study then formed the second stage, which investigate the effects of shading devices as a design parameter to enhance the indoor thermal performance and also maintain proper lighting levels.

6.4.2. Shading Devices:

The results of the simulations in the previous section proved that after increasing WWR in each space in the first, second, third and fourth floors for different urban context scenarios, heating and lighting energy consumption decrease while cooling loads consumption significantly increase due to the increasing of solar heat gain though windows which was the highest contributors to increase cooling loads inside buildings (Ghabra, 2018).

Shading elements can significantly reduce cooling loads consumption in relation to solar heat gain through glazing (M. Kim et al., 2015). The importance came from their ability to prevent direct sunlight and solar radiation from entering building spaces in summer and allow diffuse daylighting to be admitted (Ghabra, 2018; Li et al., 2006). In this regard, the main objective of this section is to investigate the ability of shading devices to improve thermal performance in summer months in multi- story apartment buildings in residential Zone-B at existing setback regulation with the optimum WWR which were reached in the previous section for each case. Also to give and introduce simple design considerations that should be taken to determine the efficiency of using different types of shading devices in reducing cooling loads for residential spaces.

Shading devices characteristics vary according to their shape, mobility and their location on the façade (Ghabra, 2018). There are two main groups of shading devices; external and internal shading devices. External shading devices include fixed types such as louvers, horizontal overhang, vertical side fins and egg crates that include vertical and horizontal shading elements, also includes moveable types. While internal shading devices include venation blinds, vertical blind slats and roller shades.

External shading devices control the amount of solar radiation which penetrates through windows into building indoor spaces, and this can significantly reduce cooling loads consumption and prevent glare because they interrupt and reduce incident solar radiation before it passes through windows, reducing, therefore, solar heat gain, which reduces the inside temperature (Carletti et al., 2014). On the other hand, they can block natural daylighting, increase the dependency on artificial lighting during daytime hours. External shading elements can also prevent solar radiation on winter days thus increase heating loads consumption (Ghabra, 2018).

As for internal shading devices, Palestinian residential buildings are mostly equipped with internal shading devices such as drapes that are ineffective in providing thermal and visual comfort, they can trap heat radiated from interior surfaces and heat absorbed from the external environment, and thus increases the cooling consumption during overheating periods (Ghabra, 2018). On this side, Kim et al. compared the impact of three types of external shading devices, including; horizontal overhang, horizontal light self, and experimental tilted overhang, with the impact of internal venation blinds on the heating and cooling loads savings in residential buildings. The results show that the internal shading devices are less effective than external types in reducing cooling loads consumption. As for external types, the experimental tilt overhang provides the best performance in energy consumption (G. Kim et al., 2012).

Regarding external fixed shading devices Kim et al. found that, for office buildings in Incheon about 35.1% reduction in total loads consumption may be achieved when using external shading devices (M. Kim et al., 2015). Samaan et al study the impact of different design parameters on the cooling energy and daylighting using building performance simulation (BPS) tools. The study found that, using external shading devices such as horizontal overhangs and louvers provide 26% to 31% reduction in cooling consumption compared to the base case consumption of educational spaces in Egyptian universities.

Designing effective and suitable shading devices can reduce energy consumption and environmental effects. However, accurate information about building location, solar incident radiation, altitude and sun angles, natural daylight availability to know when it is important to block the sun and when to admit it are needed to design appropriate shading devices for each space and to prevent undesirable effects such as blocking natural daylight or solar radiation in winter day (M. Kim et al., 2015). The methodology of shading devices impact analysis in this study depends on six sequential phases in the designing of shading devices and then compare their effect on building performance within different urban context cases.

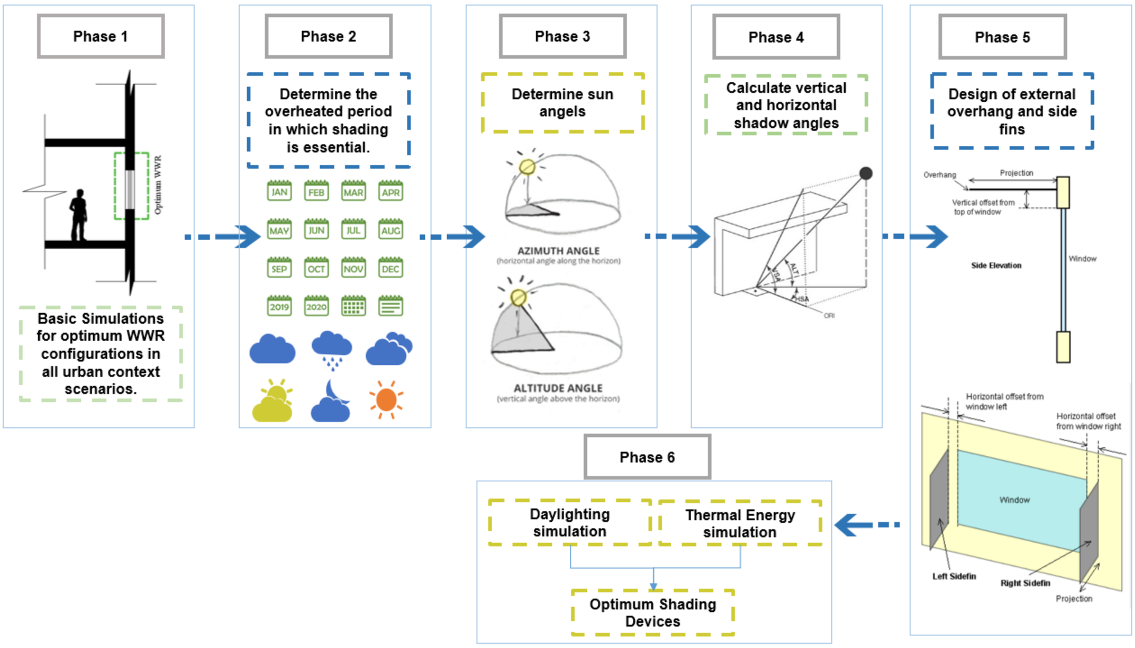


Figure 6.50: Summary of the phases performed in designing shading devices.

To design effective external shading devices, it is very important to know when you need to block sun and when to admit it by studying sun angles (see Figure 6.51). Design method was based on equations to calculate the depth for horizontal overhang and vertical side fins shading devices for each space which was depending on windows characteristics (width and height), vertical and horizontal shadow angles for different windows locations (See Eq. 5-1, Eq. 5-2).

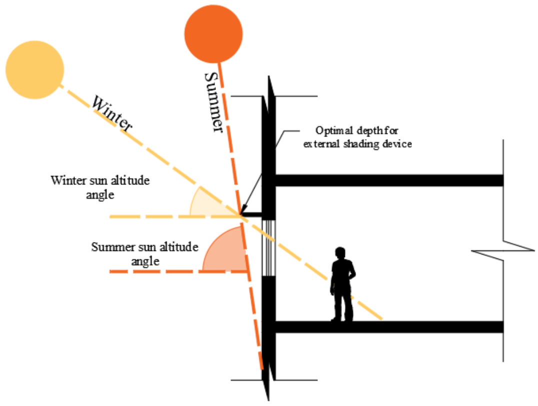


Figure 6.51: External Shading Strategy for block or admit solar radiations in different seasons.

The depth of horizontal and vertical shading devices is given by (Ghabra, 2018; M. Kim et al., 2015; MOLG, 2004):

$$\textit{Depth of Horizental Shading Devices} = W_H / \tan \lambda \qquad \textbf{Eq. 6.1}$$

$$\textit{Depth of Vertical Shading Devices} = W_W / \tan \delta \qquad \textbf{Eq. 6.2}$$

Where δ: horizontal shadow angle (HSD), λ: vertical shadow angle (VSD), W_H: window height, W_W: window width. Horizontal shadow angle is defined as the angle between solar azimuth angle and the normal of the window pane. On the other hand, vertical shadow angle is defined as the projection of solar coordinates on the plane perpendicular to the facade and indicates the angle at which solar radiation incident on the concerned surface during the day (Aste, Adhikari, & Del Pero, 2012). To determine vertical and horizontal shadow angles (see eq. 5.3, eq. 5.4), it is necessary to understand the sun position in the sky in cooling season and window orientation. Sun's position is expressed mainly by two angles; solar altitude angle and solar azimuth angle. Solar altitude angle is the vertical angle up from horizon and solar azimuth angle is the horizontal rotation angle from due north.

$$\delta = \alpha - \varepsilon \qquad \textbf{Eq. 6.3}$$

$$\tan \lambda = \tan \Upsilon \, . \sec \delta \qquad \textbf{Eq. 6.4}$$

Where δ: horizontal shadow angle (HSD), α: wall azimuth angle, ε: solar azimuth angle, λ: vertical shadow angle (VSD), Υ: solar altitude angle (M. Kim et al., 2015; Matusiak, 2006; MOLG, 2004).

As seen in the previous equations, solar altitude and azimuth angles must be calculated. These angles differ according to the month and according to the time of day. Before the shading is designed, the overheated period in which the highest solar radiation was falling on the building's facades must be estimated in order to know which month and time of day the shading devises are needed, and the building was designed to be shaded during this period (M. Kim et al., 2015). To determine this period, two steps were followed. First, monthly solar radiation analysis was carried out for each case, each façade and at different floors and for all orientations using Design Builder software to determine in which month the solar radiation is the highest and the shading devices are desired. The second step is to study hourly solar incident radiation on the 21st day of the highest month according to the falling solar radiation for all directions to estimate the overheated hour during the day.

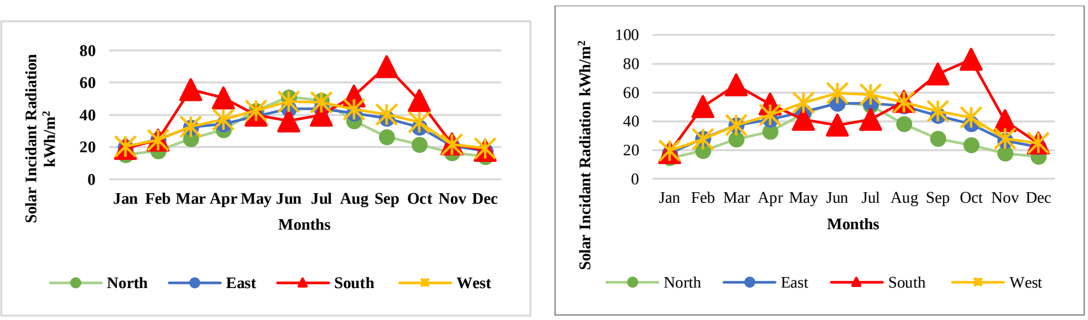
6.4.2.1. Overheated period:

The overheated period must be estimated to determine for which window, shading is needed to prevent excessive solar radiation from reaching the building. Monthly and hourly incident solar radiation of external facing walls for all urban context cases were calculated. The solar incident radiation of each façade depends on the sun path diagram in specific location (Wang, Gong, Zhou, & Qin, 2018). As show in Figure 6.52, in summer, the sun rises from the north east and sets to the north west for 14 hours of which only 6 hours, the solar radiation is on the southern façade. In winter the sun moves from south east to the south west for ten hours and throughout that time it shines on the southern façade.

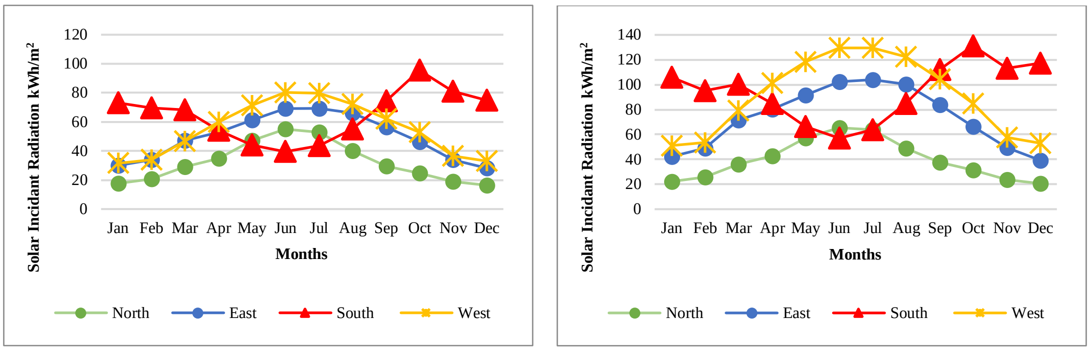
Figure 6.52: Sun path diagram in Palestine in 21st, June and 21st, January respectively at 12.00 PM Source (SunCalc).

1. ***Monthly Solar Incident Radiation:***

Figure 6.53 - Figure 6.60 present the average monthly incident solar radiation (kWh/m^2) falling on each orientation for different floors in all urban context scenarios. Figure 6.53 illustrates that when the main street oriented to the North, the Northern and Eastern facades received the highest amount of solar radiation an all floors during June and July respectively. Meanwhile, the southern façade received the highest amount of radiation during winter months when the solar radiation is very important to reduce heating loads consumption. But during the summer season, south orientation needs shading to reduce heat gain through windows in the September for the first floor and in the October for the second, third and fourth floors. On the other hand, west façade received the maximum amount of solar radiation in the hot months during summer compared to with other orientations especially in June for the first, second and third floors and in July for the fourth floor.



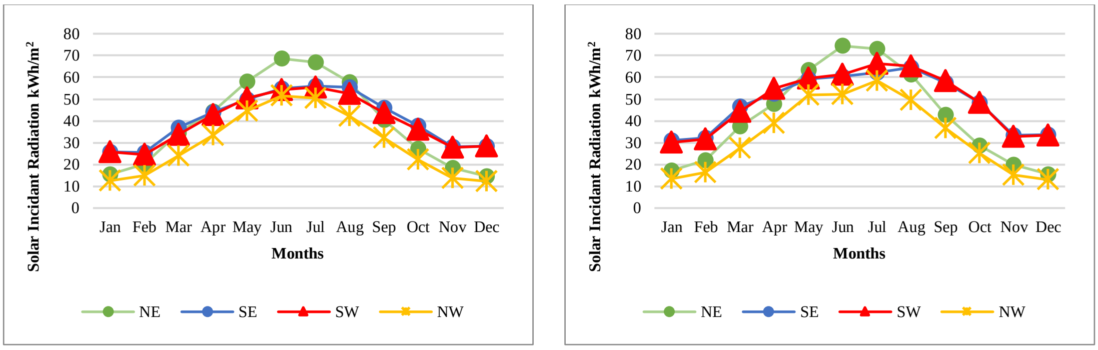
First Floor Second Floor



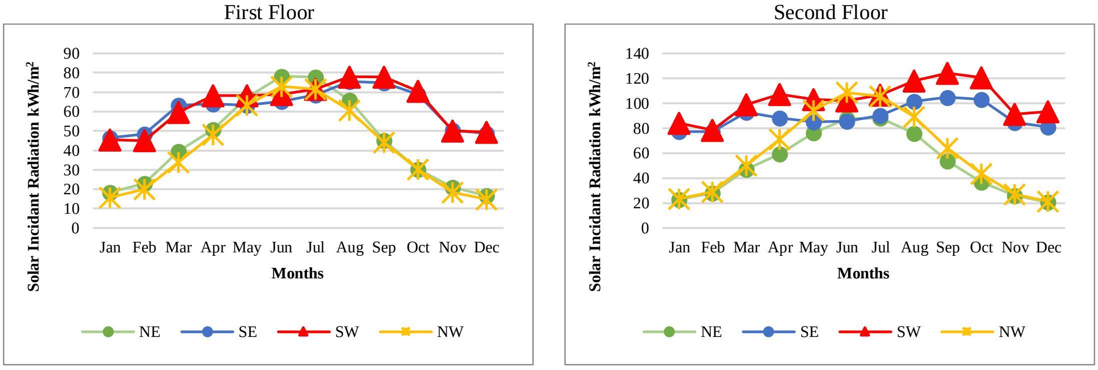
Third Floor Fourth Floor

Figure 6.53: The average total monthly incident solar radiation falling on the North oriented street in the First, Second, Third and Fourth floors, Source (Design Builder software).

As for North-east oriented street, the performance of solar incident radiation was similar at all orientations (see Figure 6.54), the solar radiation falling on all facades recorded their highest values during the summer months. For Northeastern façade, the maximum solar incident radiation in the first, second and third floors is in June, and in July for the fourth floor. In June, the Northwestern façade records the highest falling of solar radiation for the first, third, and fourth floors and in July for the second floor. When comparing the results of the southeastern and southwestern facades, we note that the solar radiation performance is almost same in both cases, as also found on the first floor that in July the two orientations has recorded the highest amount of solar radiation. As for the second floor, August and July recorded the highest values for the southeast and southwest façade respectively. At the same time, August and September recorded the highest values for the third and fourth floors, respectively for both orientations.



First Floor Second Floor



Third Floor Fourth Floor

Figure 6.54: The average total monthly incident solar radiation falling on the North-East oriented street in the First, Second, Third and Fourth floors, Source (Design Builder software).

Figure 6.55 illustrates that North, East and West facades in the East oriented street case receive the highest solar radiation during hot summer months from May to October in all floors. On the other hand, South facades received the smallest values of solar incident radiation especially in the third and fourth floors, where the highest solar radiation is recorded in summer and in September for first and second floors and in October for third and fourth floors. The figure also shows that June receives the highest solar incidence during summer on the North façade for all floors. As for East and West facades which received the highest value in July for first, second, third and fourth floors.

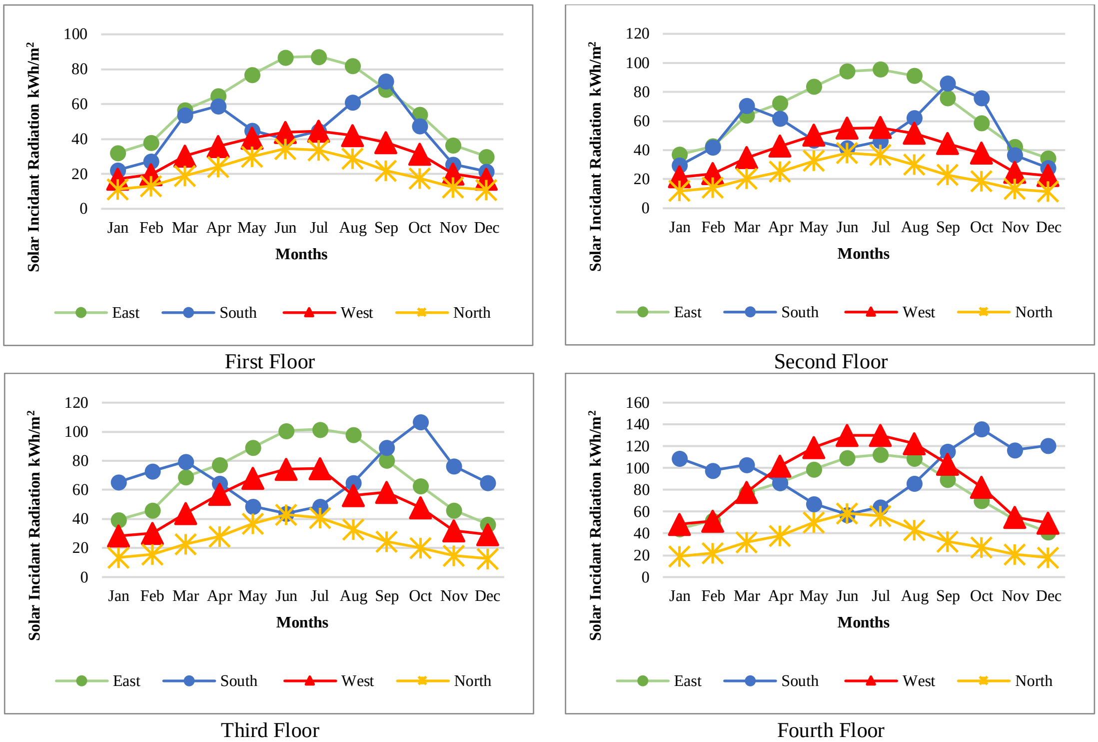
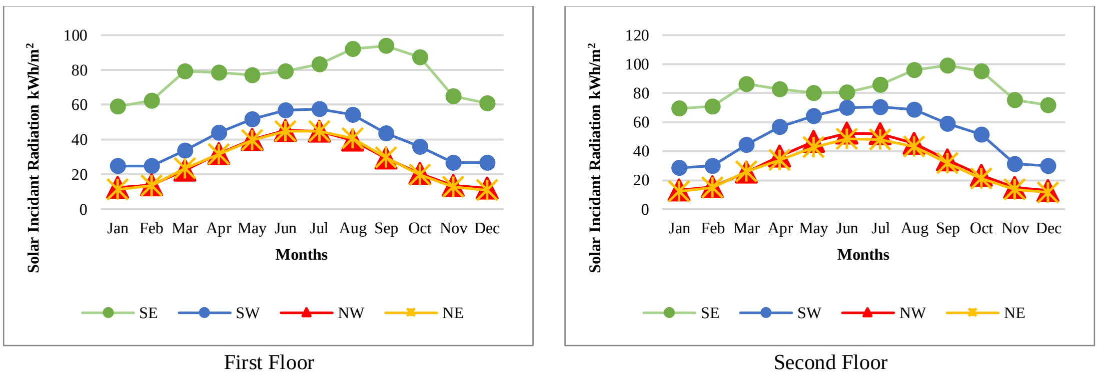
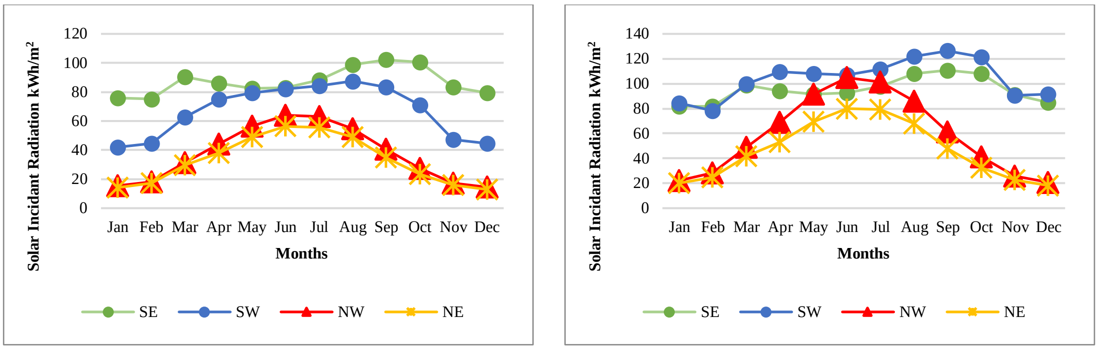


Figure 6.55: The average total monthly incident solar radiation falling on the East oriented street in the First, Second, Third and Fourth floors, Source (Design Builder software).

As seen in Figure 6.56, South- East façade become overheated during September which is also as a result of receiving the maximum amount of solar radiation during September more than other orientations in the first, second and third floors. But in the fourth floor, South- West was the highest, and the importance of shading devices for this façade was in July for first and second floors and in August and September for third and fourth floors respectively. In June days, North-West façade in all floors received a large amount of radiation compared to other summer months.

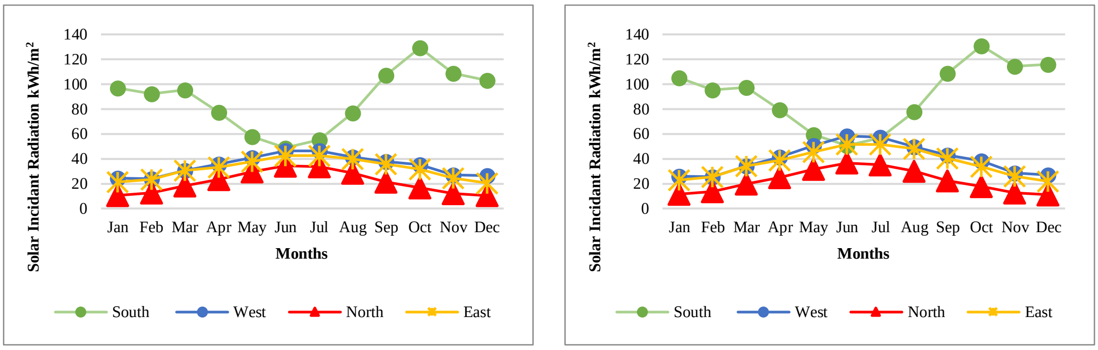




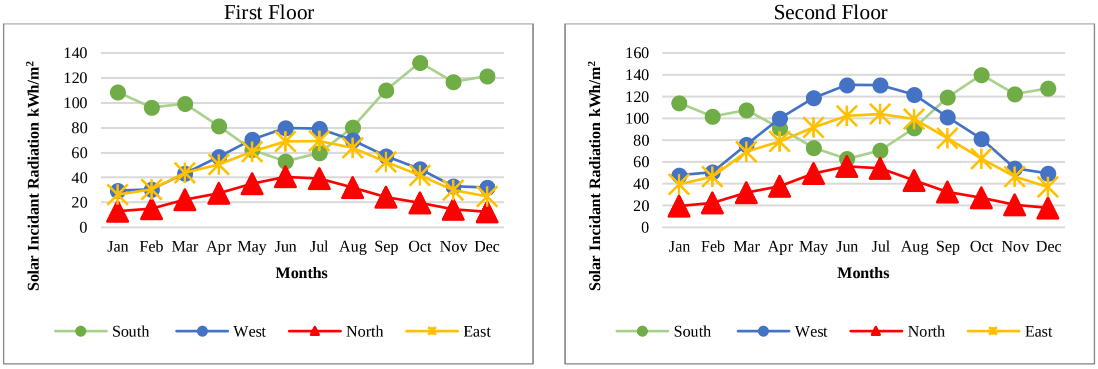
Third Floor Fourth Floor

Figure 6.56: The average total monthly incident solar radiation falling on the South-East oriented street in the First, Second, Third and Fourth floors, Source (Design Builder software).

For the case of South oriented street, south façade become overheated during October in the first, second and third floors. West façade received the highest amount of solar radiation in July for the first floor and on June for the second, third and fourth floors. In June, North façade in all floors received a large amount of radiation compared to other summer months. As for eastern façade, it received the strong solar radiation in June at first and second floors, and on July for third and fourth floors.



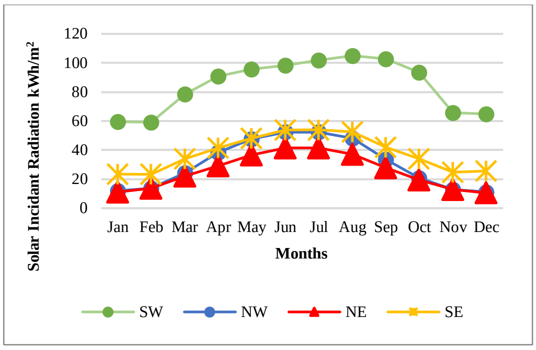
First Floor Second Floor



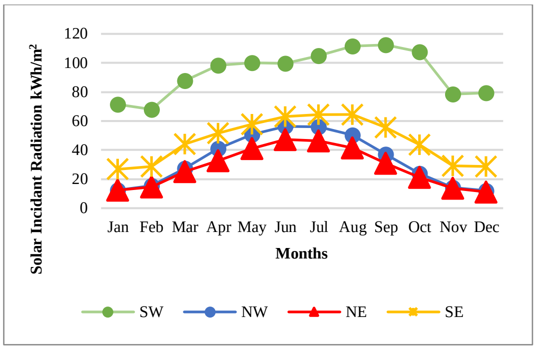
Third Floor Fourth Floor

Figure 6.57: The average total monthly incident solar radiation falling on the South oriented street in the First, Second, Third and Fourth floors, Source (Design Builder software).

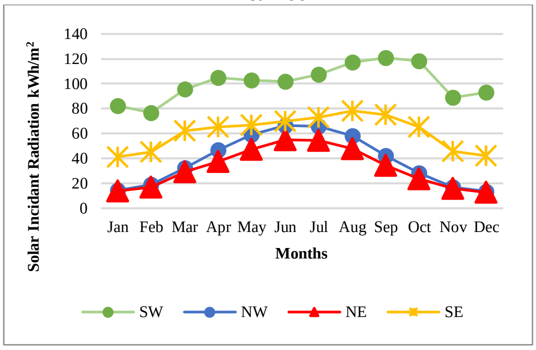
In August, south-west façade in the case of south west oriented street records the highest values of incident solar radiations on the first floor. But on the second, third and fourth floors, the highest radiation occurred in September. As for south-east side, the performance is varying in each floor, in July, August, September. It received the highest solar radiation on the first, second, third and fourth floors respectively.



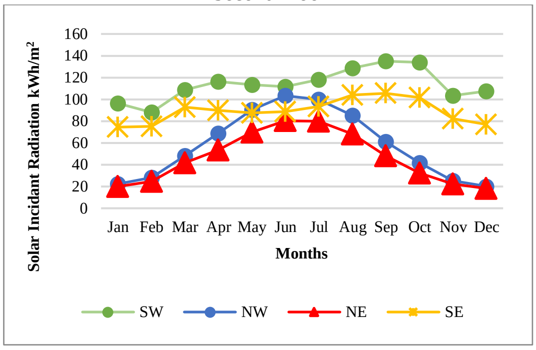
First Floor



Second Floor

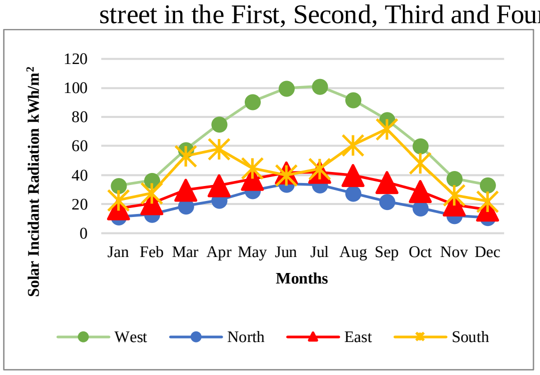


Third Floor

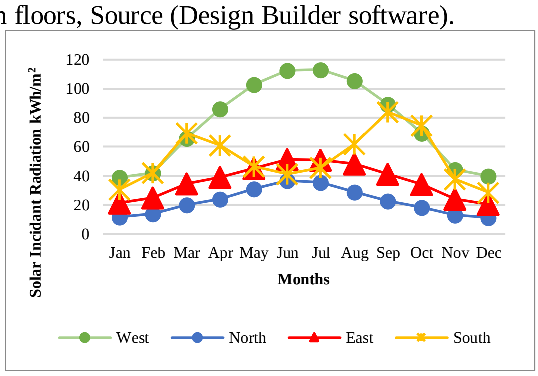


Fourth Floor

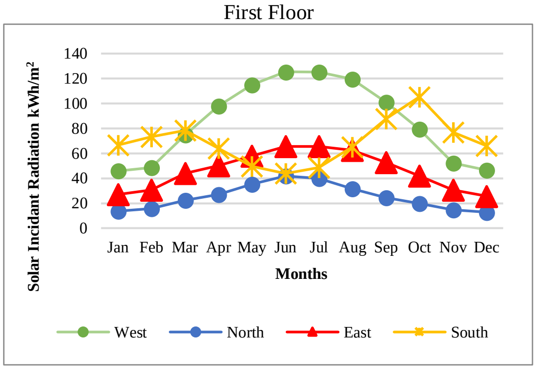
Figure 6.58: The average total monthly incident solar radiation falling on the South-West oriented street in the First, Second, Third and Fourth floors, Source (Design Builder software).



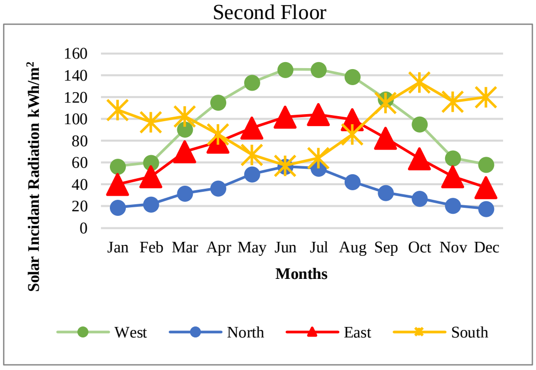
First Floor



Second Floor



Third Floor



Fourth Floor

Figure 6.59: The average total monthly incident solar radiation falling on the West oriented street in the First, Second, Third and Fourth floors, Source (Design Builder software).

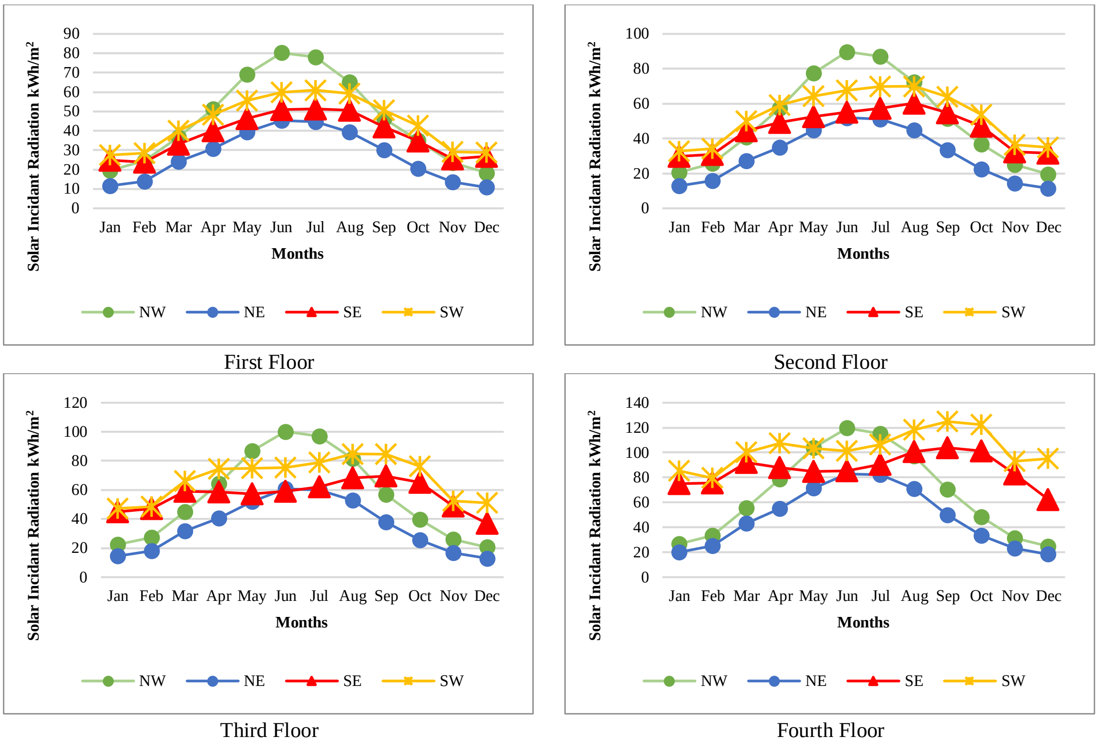


Figure 6.60: The average total monthly incident solar radiation falling on the North-West oriented street in the First, Second, Third and Fourth floors, Source (Design Builder software).

2. ***Hourly Solar Incident Radiation:***

As mentioned previously, when we designed horizontal and vertical shading devices, it very important to know when the shading is needed during the day for different orientations. For example, eastern facades mainly received solar radiation in the morning, while the western spaces received direct solar radiation mostly during afternoon when the sun altitude angle is low and solar radiation is strong. The simulations were conducted for all urban context cases at 21st day in the overheated months to determine in which time during the day the solar radiation is maximum (see appendix 2D).

6.4.2.2.Results and Discussion:

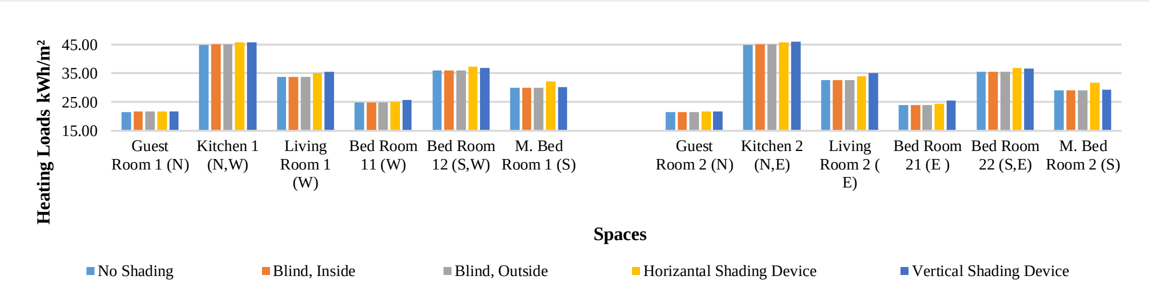
Based on the determined overheated period, external shading devices for each residential zone for different urban context scenarios during this period were designed using Equations 5.1, 5.2, to study the impact of using different shading devices for residential spaces on daylighting and thermal energy consumption. The depth of horizontal and vertical shading devices was calculated using the vertical and horizontal shadow angles, which is based on the time of the day in the overheated month for each case as shown in the appendix 2D. The depth of external shading devices ranged from 0.03m to 2.26m, 0.08m to 4.50m, 0.10m to 8.60m, 0.08m to 3.15m, 0.03m to 9.00m, 0.08m to 2.95m, 0.03m to 27.70m, 0.08m to 3.30m in North, North-East, East, South-East, South, South-West, West, North-West oriented street cases respectively. However, calculations were disregarded if the depth of external shading devices exceed 1.00 m because of their negative impact on natural daylight availability, heating loads consumption and external appearance. As shown in the Appendix 2D, higher depths were obtained when the façade was oriented to the North-East East, South-East, South-West, West and North-West for horizontal overhang and to the North, North-East, South-East and North-West for vertical fins.

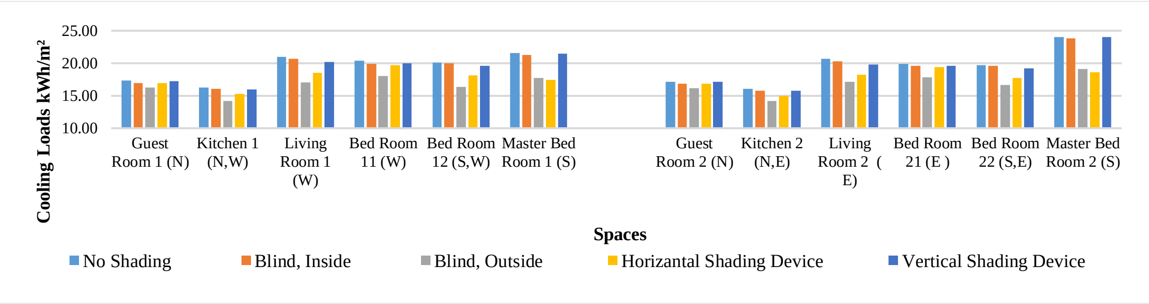
In addition to the horizontal overhang and vertical side fins, external and internal blinds with high reflectivity slats were also tested specifically in hot months to reduce cooling loads, and at the same time to allow solar radiation to enter during cold months.

In order to understand the contribution of shading devices to the energy consumption and daylighting availability in multi-story residential buildings in residential Zone-B, a series of 320 simulations were run and the performance was evaluated by determining the increase and decrease in annual heating loads, annual cooling loads, annual overall load consumption and daylight levels inside residential spaces. The results were analyzed in relation to the reduction in cooling loads, the increase in heating loads, the impact on the total consumption and daylighting availability for the four variations of shading device depth by comparison with the non-shaded base cases (without shading devices). As for the base cases models, the windows design considerations outlined in the WWR section were utilized in the creation of the eight base cases representing the North, Northeast, East, Southeast, South, West and Northwest orientations which were used in this section to determine the influence of using shading devices on the indoor environment.

1. *Street oriented to the North (Case No.1):*

Figure 6.61 shows that in the North oriented street case, the percentage of decreasing the cooling loads consumption when horizontal shading devices were used ranged between 1.88% and 22.5%, 2.93% and 18.93%, 3.63% and 21.28% and from 2.97% to 21.28% for first, second, third and fourth floors respectively. In details horizontal shading devices for the Northern spaces such as guest room1 and guest room 2 were modeled with a fixed depth of 0.30m (see appendix 1), but the vertical side fins were ignored for the previously mentioned spaces. The results showed that the decreasing percentage in the overall load consumption was insignificant for all floors, so they were neglected.





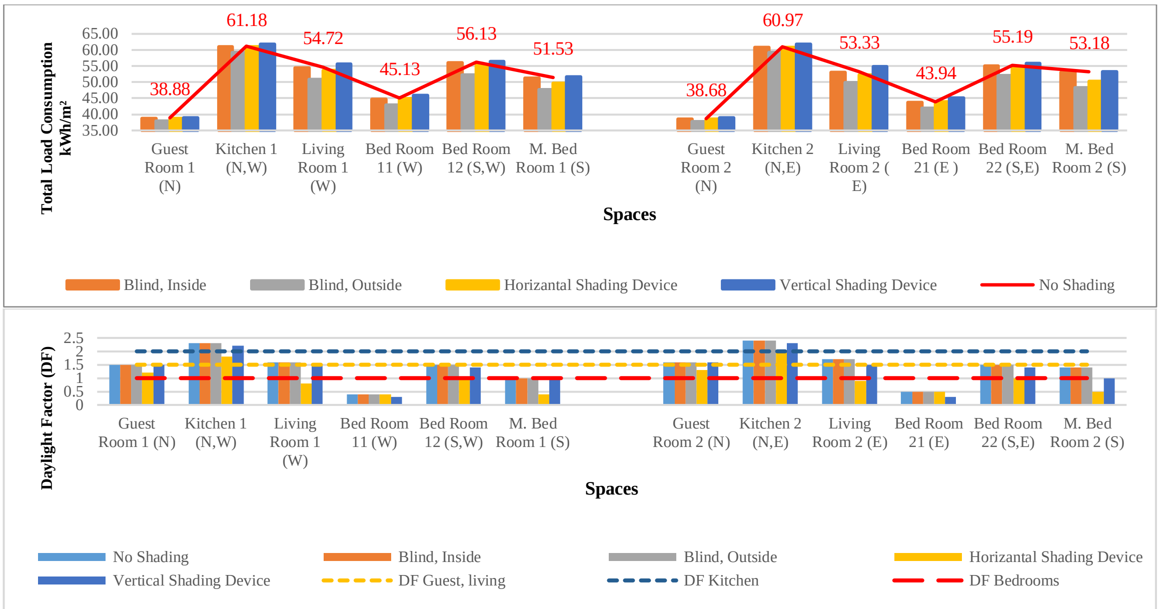
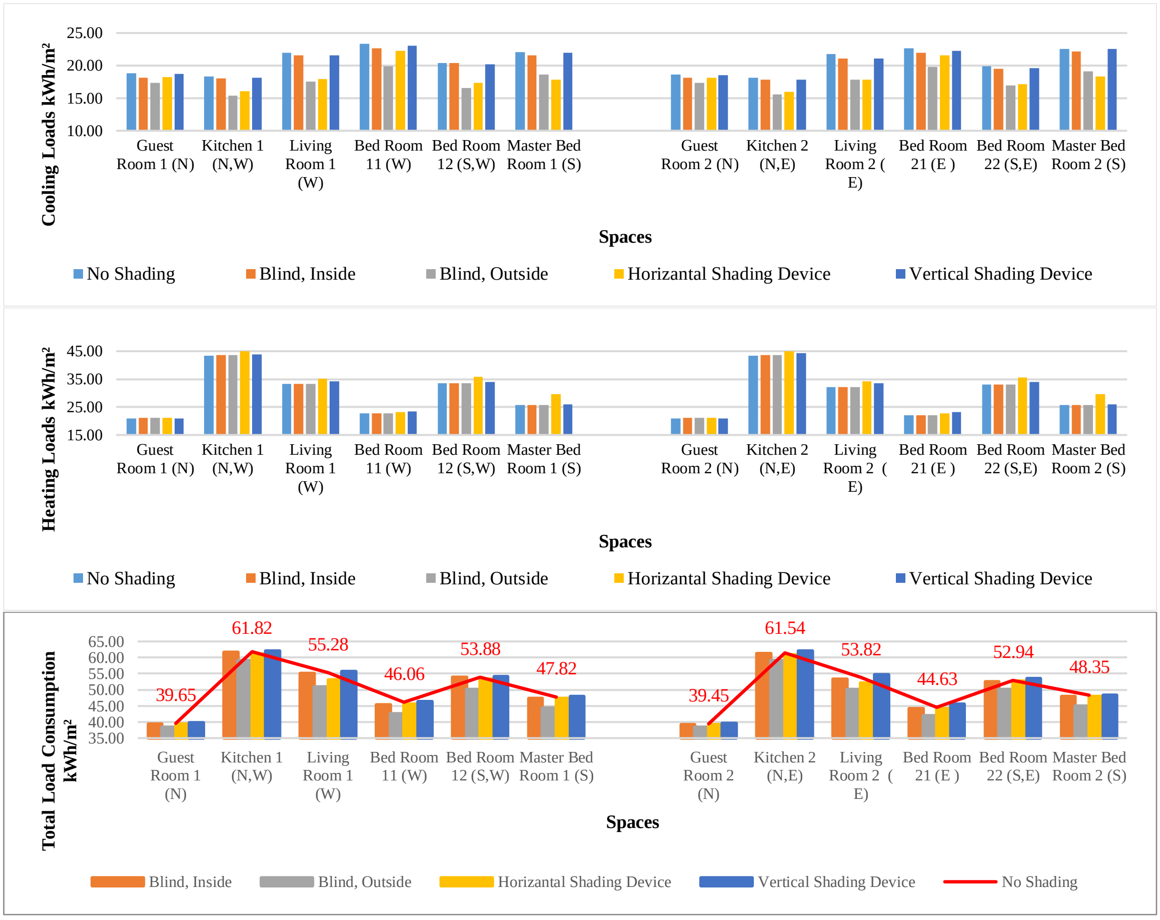


Figure 6.61: The effect of adding different types of internal and external shading devices, First floor, North oriented street.

In this case for all floors, outside blinds with high reflectivity slats which were scheduled to use in the hot months have a significant impact on total loads consumption in all spaces more than horizontal and vertical shading elements. At the same time, the influence of outside blinds on daylighting reduction insignificant.



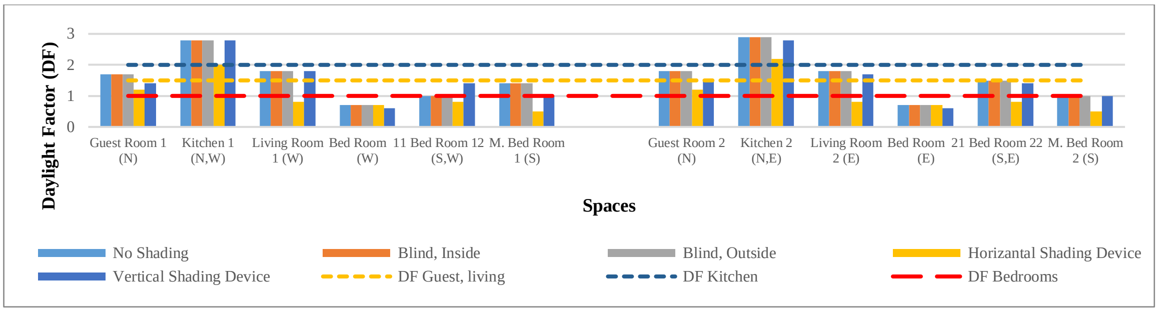
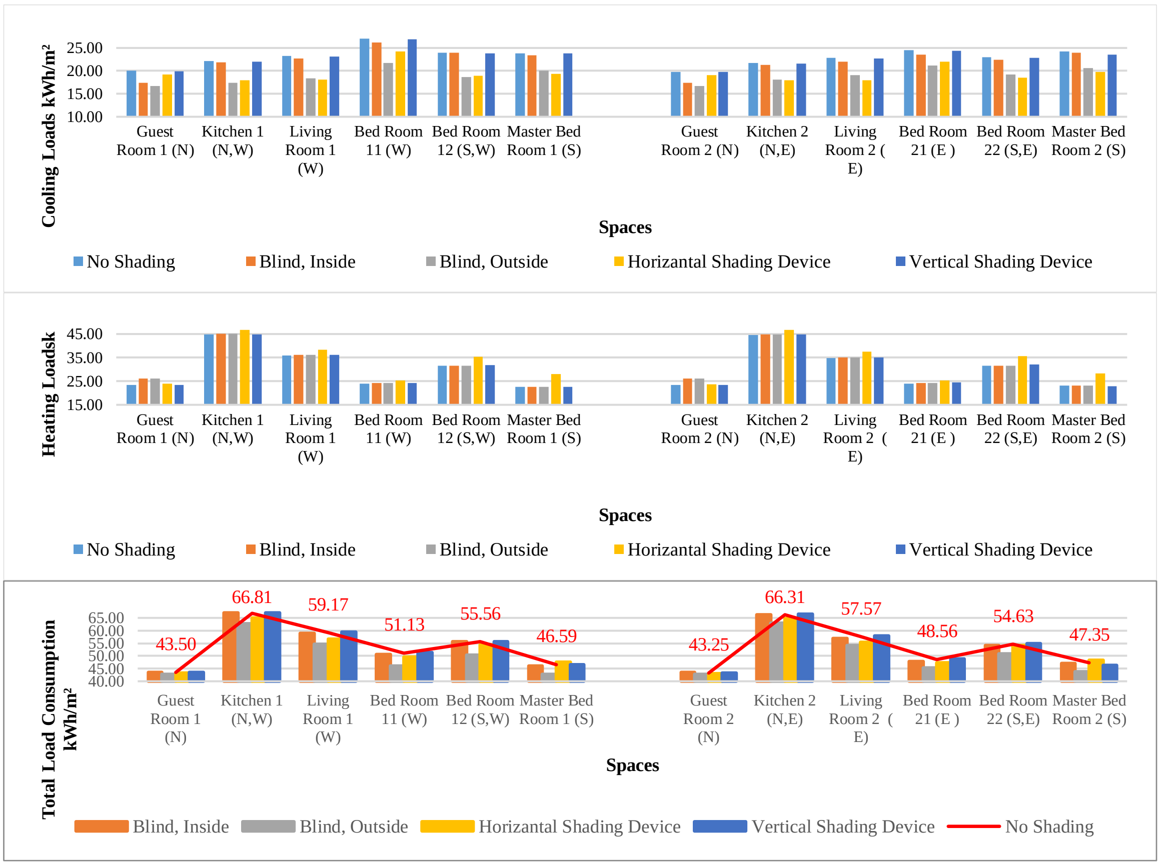


Figure 6.62: The effect of adding different types of internal and external shading devices, Second floor, North oriented street.

In the third and fourth floors, the impact of horizontal and outside blinds were almost the same especially on northern windows, in guest rooms and kitchens, and on eastern side in living room 2 and bedroom 21. Nevertheless, their impact on the natural daylight availability was completely different; horizontal overhang prevents natural daylight from entering building spaces and provide lighting level less than the required standards especially in the first and second floors. In the third and fourth floors, average daylight factor in all spaces were less than what was achieved at the base case model, but at the same time, the results were equal to or even higher than the required standards in most spaces.

As for vertical shading devices, the decreasing percentage in cooling loads consumption was insufficient, and ranged from 0.24% to 4.36%, 0.26% to 2.88%, 0.13% to 3.15% and from 0.10% to 0.65% for first, second, third and fourth floors respectively. But at the same time, it has a significant impact on natural daylighting more than horizontal shading devices, because it doesn't prevent natural daylight from reaching to the interior spaces.



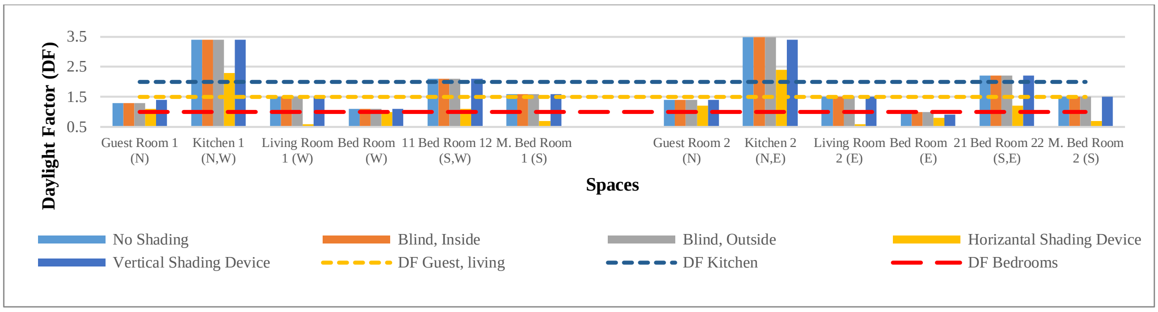


Figure 6.63: The effect of adding different types of internal and external shading devices, Third floor, North oriented street.

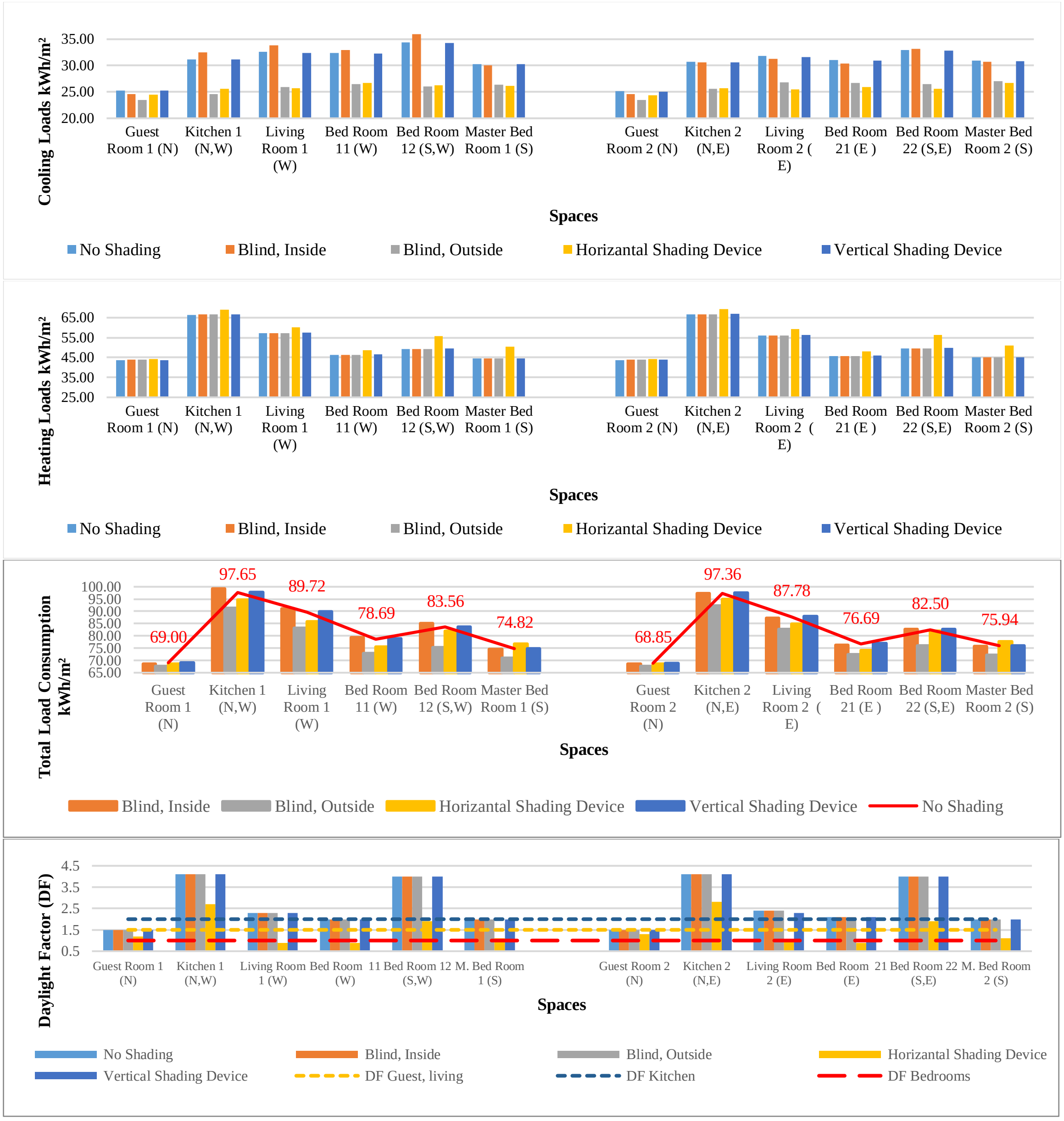


Figure 6.64: The effect of adding different types of internal and external shading devices, Fourth floor, North oriented street.

2. *Street oriented to the North-East (Case No.2):*

Inside blinds, outside blinds, horizontal overhang and vertical side fins were modeled and analyzed for the North-East oriented street case to determine the optimum type of shading devices for each space. The results as shown in Figures 6.81, 6.82, 6.83 and 6.84 demonstrated the effectiveness of outside blinds with high reflectivity slates on this cases with 15% to 20%, 16% to 22%, 18% to 23% and 24% to 29% reduction in the annual cooling loads consumption for first, second, third and fourth floors respectively.

Figure 6.65: The effect of adding different types of internal and external shading devices, First floor, North-East oriented street.

At the same time, there has shown no effect on heating loads in winter when inside and outside blinds were used. The impact of inside blinds on decreasing cooling energy consumption ranged from 0% to 3%, 1% to 3.5%, 1% to 6% and from 0.50% to 5% for first, second, third and fourth floors respectively. And for some spaces especially on the fourth when inside blinds were used, the cooling loads consumption was increased because of heat gain through the blinds themselves that has affected the indoor environment.

Figure 6.66: The effect of adding different types of internal and external shading devices, Second floor, North-East oriented street.

As for horizontal overhang, the percentage of cooling loads reduction ranged between 4.00% to 23.00% in the first floor, 5.00% to 25.00% in the second floor, 6.00% to 26.00% in the third and fourth floors. On the other hand, horizontal shading devices prevent solar radiation in winter months, thus the heating loads consumption was increased by 1% to 8% at the first floor, 1% to 11% for the second floor, 1.5% to 17% for the third floor and 1.8% to 15% for the fourth floor than the base case model for North-East oriented street case. In addition, it has also reduced the amount of natural daylight in the indoor spaces.

Figure 6.67: The effect of adding different types of internal and external shading devices, Third floor, North-East oriented street.

In this case, the increasing percentage of heating loads are much lower when vertical side fins were used as shading elements. Heating energy got increased by about 1.5% to 7%, 2.5% to 7.5%, 2.5% to 8.00% and by 1.00% to 4.00% for the first, second, third and fourth floors respectively. At the same time, the impact of vertical shading elements on daylighting as shown in the figures 5.63,5.64, 5.65, 5.66 is very slight.

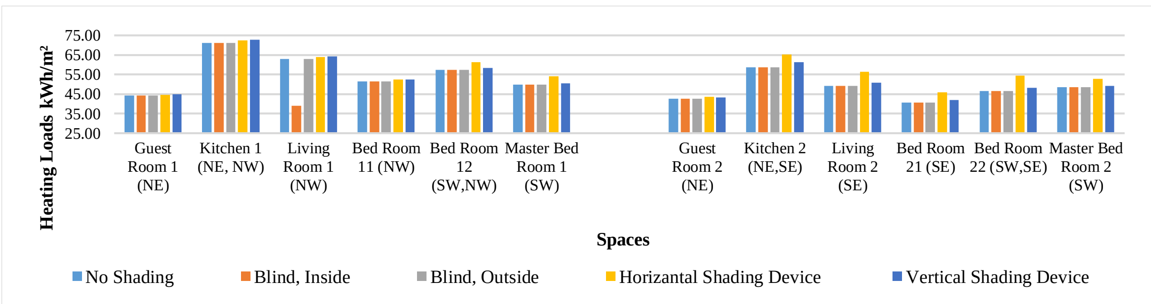
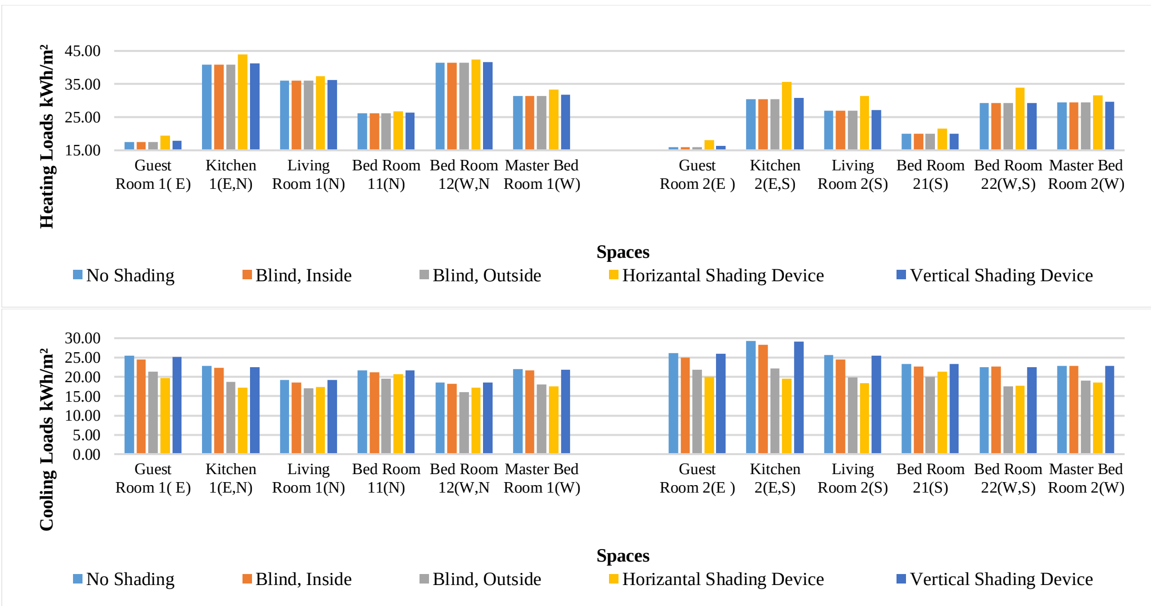


Figure 6.68: The effect of adding different types of internal and external shading devices, Fourth floor, North-East oriented street.

3. Street oriented to the East (Case No.3):

As for the East oriented street, the results were analyzed in relation to the percentage of reduction in cooling loads and on total energy consumption using the four different types of shading devices and were compared with the East oriented street base case scenario when no shading devices were used. The figures 5.68,5.69, 5.70, 5.71 and appendix 2D illustrate that a reduction of at least 10%, 11%, 10% and 9% in annual cooling loads could be achieved by using outside blinds in the first, second, third and fourth floors respectively, and at the same time there is no impact on heating loads consumption. This percentages of decreasing in cooling loads can reach up to 26%, 24%, 25% and 24% for the first, second, third and fourth floors respectively. As for vertical side fine, in the southern and northern facades, it was neglected as mentioned before due to its large depth that has reached up to 14 meters in some cases. As for the southern façade, the value of the horizontal shadow angle was zero, therefore, it does not need vertical shading elements. At the same time, when vertical shading device was used in this case, it has a negative impact on total loads consumption in most of spaces at the different floors, it was higher when compared to the base case scenario when no shading was considered. Because of this, vertical side fine in East oriented cases were neglected.

Figure 6.69: The effect of adding different types of internal and external shading devices, First floor, East oriented street.



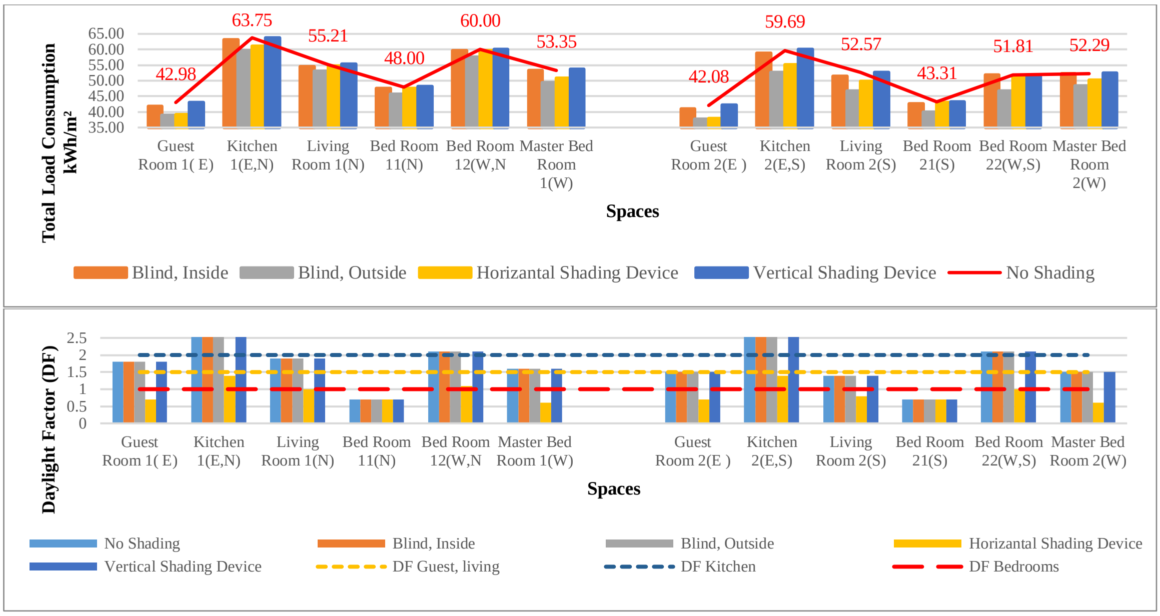
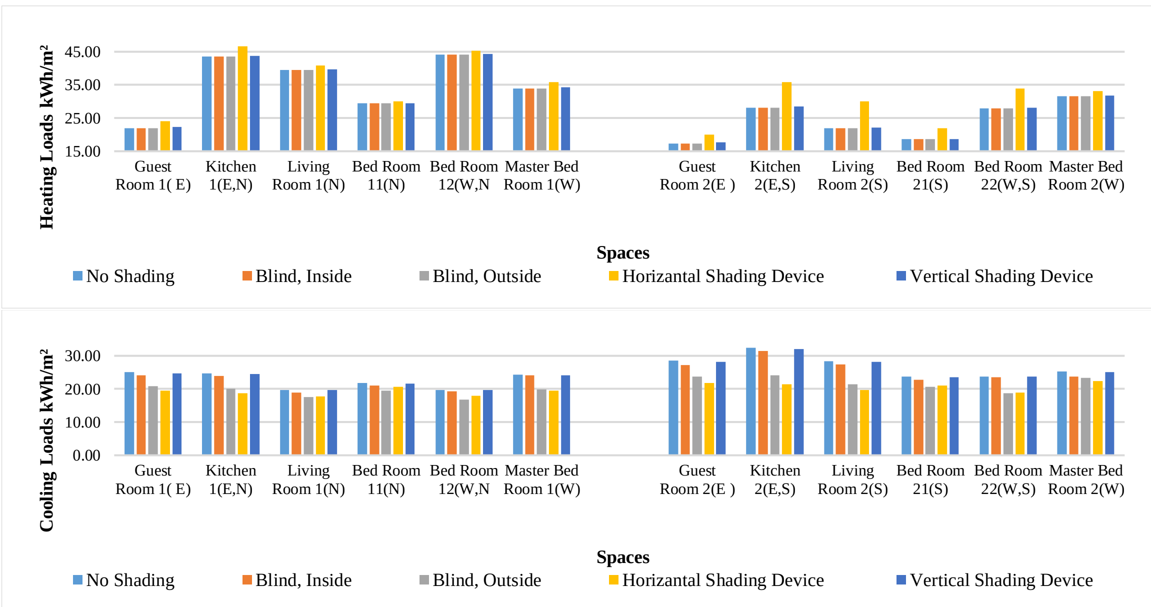


Figure 6.70: The effect of adding different types of internal and external shading devices, Second floor, East oriented street.

When comparing outside blinds results with inside blinds and horizontal overhang, the results show that outside blind is the most effective type in all floors because of its positive impact in reducing the total loads consumption and on daylight level inside spaces. When horizontal shading devices were used, the reduction in cooling loads reached up to 30% in the first floor, 33% in the second floor, 34% and 25% in the third and fourth floors respectively. As seen, horizontal overhang can be used in bedroom 12 and bedroom 22 in the second floor, in bedroom 11, bedroom 12, bedroom 22 and master bedroom 2 in the third floor and in kitchen 1, kitchen 2, living room 1, living room 2, bedroom 11, bedroom 12, master bedroom 1, bedroom 21, and master bedroom 2 in the fourth floor, where its impact on natural daylight inside these spaces is acceptable, in addition to its contribution to reduce overall energy consumption. The reduction in cooling loads when horizontal shading device was used is more effective than outside blinds, but it also increases the amount of heating loads consumption in winter months.



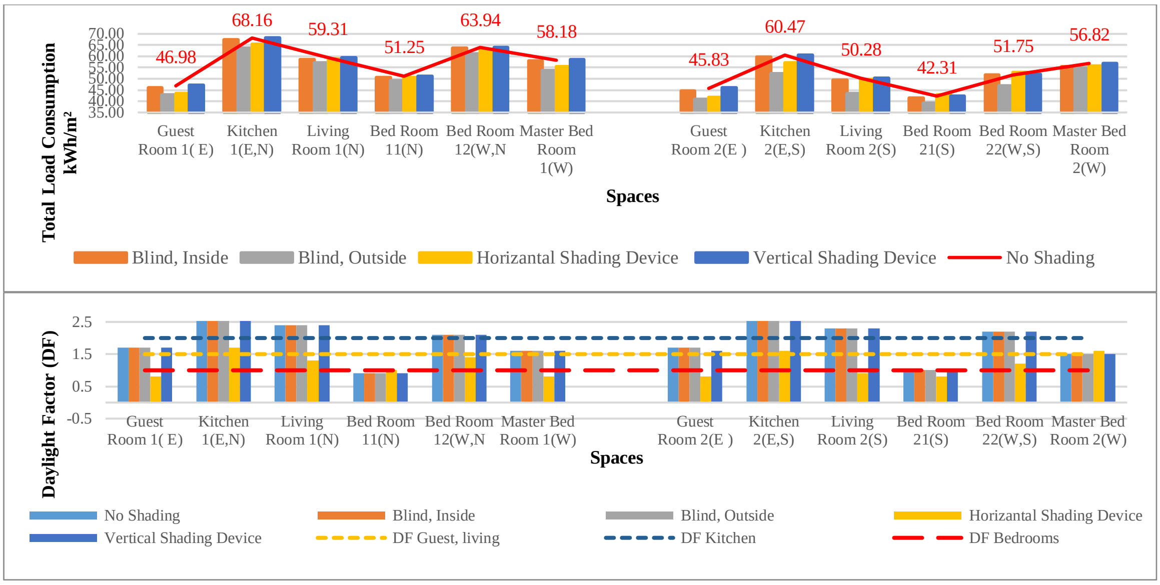


Figure 6.71: The effect of adding different types of internal and external shading devices, Third floor, East oriented street.

Figure 6.72: The effect of adding different types of internal and external shading devices, Fourth floor, East oriented street.

4. *Street oriented to the South-East (Case No.4):*

When the main street is facing to the south-east, horizontal overhang and vertical side fins shadings would provide 9.97%, 12.32%, 18.29% 7.77% and 3.68%, 4.18%, 4.08% and 2.13% increasing in heating loads consumption compared to the optimum WWR case without shading devices on the first, second, third and fourth floors respectively.

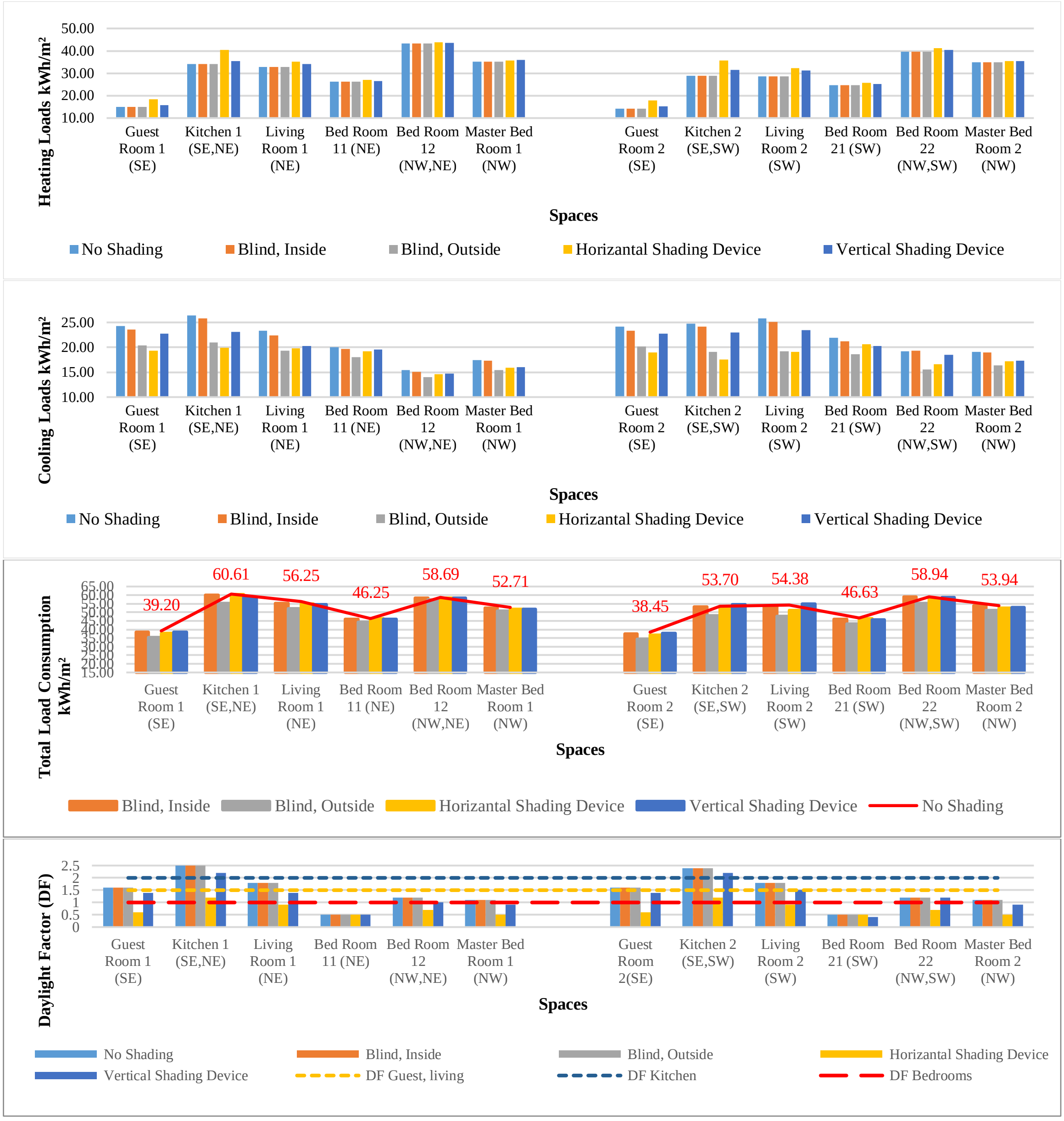


Figure 6.73: The effect of adding different types of internal and external shading devices, First floor, South-East oriented street.

On the first floor, window shading of inside blinds, outside blinds, horizontal overhang, and vertical side fins would provide a 2.38%, 16.71%, 17.10%, and 7.26% reduction of cooling loads and 0.92%, 6.33%, 1.99% and 1.21% reduction of total load consumption than optimum WWR without the use of shading devices. All results show that average daylight factor values are the worst when horizontal shading devices are used.

On the second floor, horizontal overhang shading devices significantly impact cooling consumption that was reduced by 5.17% in the north-east spaces to 33.00% in the south-east and southwest spaces. On the other hand, it has the most significant influence on daylight factor values reduction but still better than first-floor spaces. To enhance the daylighting level when horizontal overhang was used, reflected light selves could be used. According to the total load consumption, outside blinds is the best in all spaces. But when comparing horizontal overhang and vertical side fins, installing overhang above guest room1, bedroom 12, master bedroom1, guestroom 2, kitchen 2, living room2, bedroom22 and master bedroom 2 external windows is better than vertical side fins which can be used in the kitchen 1, living room 1, bedroom11, bedroom 12, bedroom 21 and master bedroom 2 external windows (see Figure 6.74).

Figure 6.74: The effect of adding different types of internal and external shading devices, Second floor, South-East oriented street.

On the third floor, installing horizontal shading devices on guest room1, kitchen 1, guest room 2, kitchen 2, living room 2, and bedroom 22 significantly increase and decrease heating and cooling loads consumption, respectively. It could provide 23.5%, 17.90%, 23.20%, 12.90%, 3.46% and 24.90% increasing in the heating consumption respectively. On the other hand, a reduction of about 20.40%, 24.53%, 29.02%, 26.34%, 13.68%, and 21.40% occurred in cooling load consumption. And the average daylight factor values become better at the first and second floors, since they become close to the standards.

Figure 6.75: The effect of adding different types of internal and external shading devices, Third floor, South-East oriented street.

The increasing rate in the annual heating consumption on the fourth floor was 7.77% and 2.13% when horizontal overhang and vertical side fins were installed, respectively. As for cooling loads consumption, inside blinds increase the annual consumption by 0.85% due to the heat gain. On the other hand, a reduction of 14.91%, 13.84%, and 5.98% for apartments No. 1 and 2 when outside blinds, horizontal overhang, and side fins were used, respectively. As shown in Figure 6.76, the daylighting level inside most residential spaces in the fourth-floor apartments is equal to or more than the required standards, except guest rooms 1 and 2 when horizontal overhang was applied.

Figure 6.76: The effect of adding different types of internal and external shading devices, Fourth floor, South-East oriented street.

The use of horizontal shading devices at living room 1, bedroom 11, bedroom12, master bedroom1, kitchen 2, living room 2, bedroom 21 and master bedroom 2 gave the best results after the inside blinds in terms of annual total thermal loads consumption.

5. Street oriented to the South (Case No.5):

When the main street is oriented to the south, inside blinds, outside blinds, horizontal overhang and vertical side fins were installed and analyzed for each residential space to determine the optimum type of shading devices. The results in the

Figures below demonstrates the effectiveness of using outside blinds with high reflectivity slates on the reduction of the annual cooling loads consumption by 15.12%, 16.46%, 16.97% and 14.99% for first, second, third and fourth floors respectively. At the same time, the effect on heating consumption in winter when inside and outside blinds were used was insignificant because these blinds need to be used only in hot months to reduce cooling loads consumption. The impact of inside blinds on reducing cooling energy consumption for first, second, third and fourth floors was unnoticeably. The using of horizontal overhang on southern and western spaces increases the heating loads consumption significantly due to the blockage of the sun in winter and prevents is from reaching to the inside spaces.

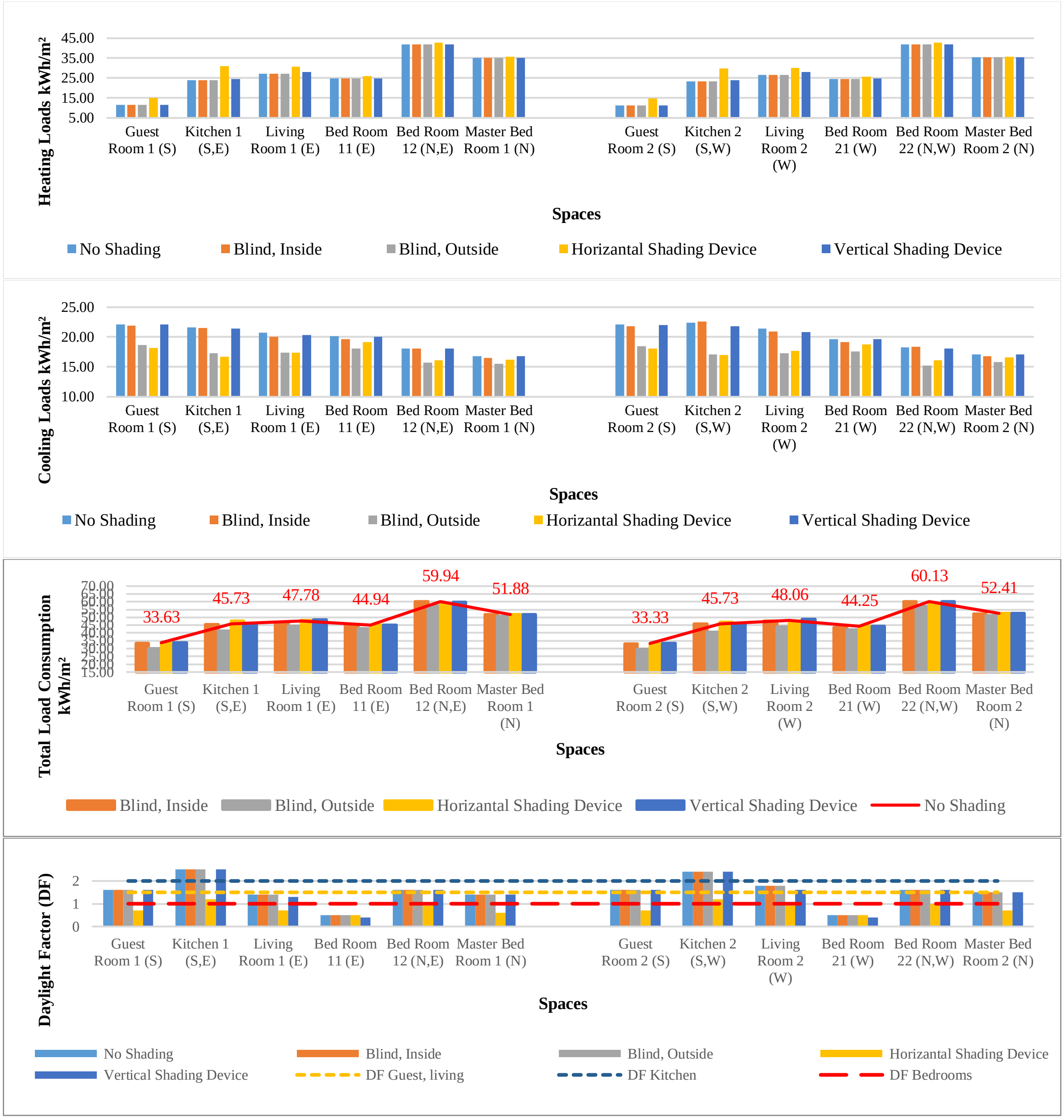


Figure 6.77: The effect of adding different types of internal and external shading devices, First floor, South oriented street.

Horizontal overhangs have a substantial impact on reducing the cooling loads at all floors. It provides a reduction of 14.14%, 16.32%, 17.63%, and 15.21% on the first, second, third, and fourth floors, respectively. On the contrary, vertical side fins records only a reduction of 0.69%, 0.5%, 0.28%, and a 0.35% on the cooling consumption for the first, second, third, and fourth floors.

The second floor follows a similar trend. The use of outside blinds has the best influence on overall thermal load consumption and daylighting availability than other types of shading elements. Eastern and western spaces are most affected by increased heating loads due to horizontal shading devices. This is because eastern and western facades receive direct sunlight, mostly during morning and afternoon, respectively. At these times, sun altitude angles are small, and was easily blocked. After the outside blinds, horizontal devices are the optimum for kitchen 1, bedroom 11, bedroom 12, and kitchen 2 according to the annual total load consumption and daylighting availability. The reduction in the total loads was 1.06% and 7.42% when inside and outside blinds were used, and about 0.25% and 0.27% increase than the base case when horizontal and vertical devices were used on the second floor.

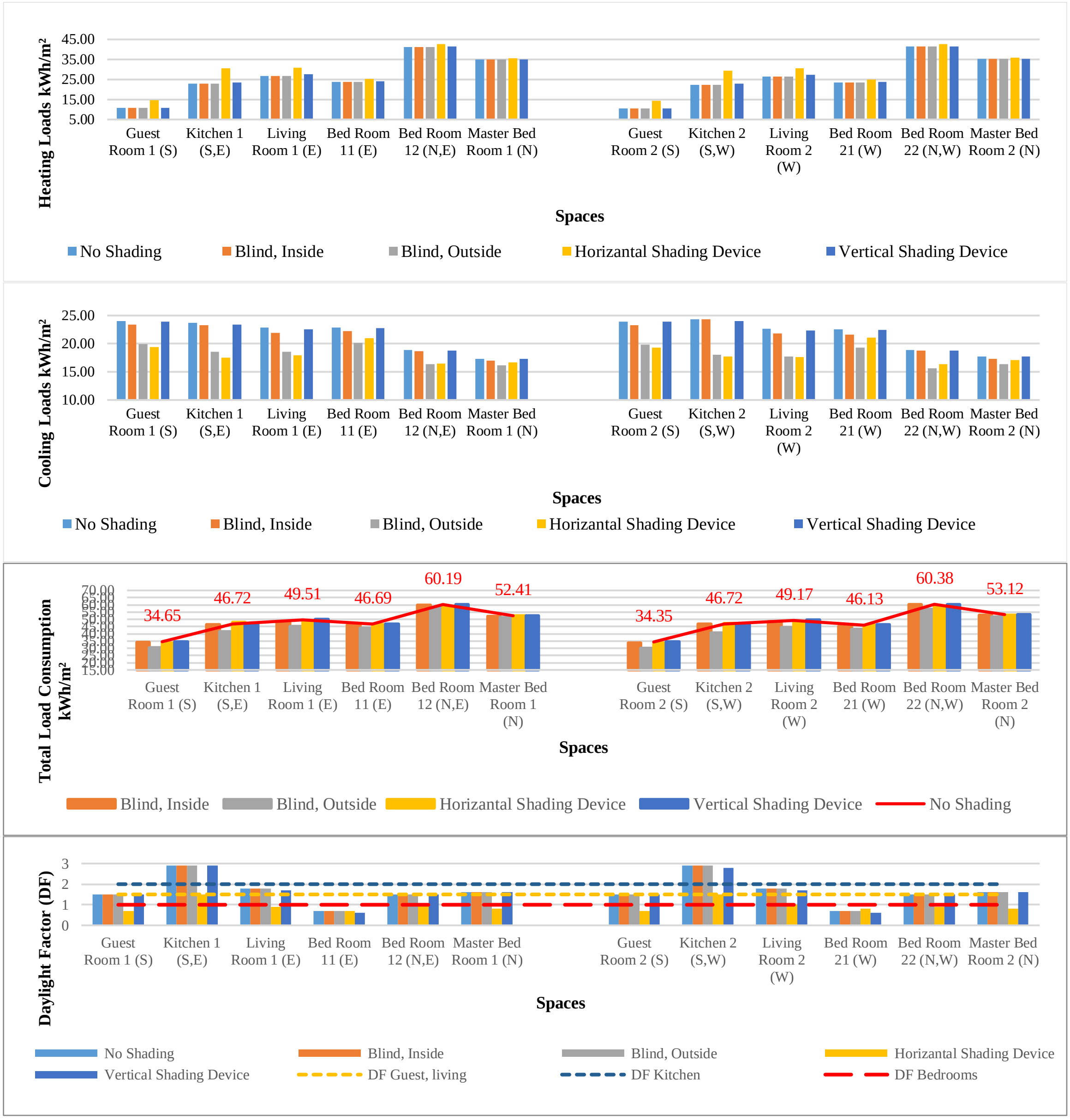


Figure 6.78: The effect of adding different types of internal and external shading devices, Second floor, South oriented street

On the third floor, the use of inside, outside blinds, and vertical side fins have an unnoticeable impact on the average daylight factor reduction, and all of the spaces in apartments No.1 and 2 successfully achieved comfort lighting zone. On the contrary, horizontal overhang reduces the amount of natural daylight entering residential spaces especially in living spaces such as guest rooms, kitchens, and living rooms. As shown in the figures below, the heating consumption increased significantly when a horizontal overhang was installed on the external windows with about 9.30% increasing percentage in the total third-floor heating consumption. On the other hand, vertical fins have increased the consumption by 0.44% only. According to the cooling load consumption, shading devices reduce the consumption by 2.43%, 16.97% 17.63%, and 0.28% when inside blinds, outside blinds, horizontal overhang, and vertical side fins were applied on the external windows. As for total load consumption, horizontal elements consume about 1.19% lower than base case without shading elements. Which is the lowest percentage after the outside blinds.

Figure 6.79: The effect of adding different types of internal and external shading devices, Third floor, South oriented street.

In this case, when the main street is placed on the southern side, the performance eastern, southern, and western spaces of the fourth floor is better when vertical side fins were used on the exterior windows in terms of daylighting levels inside rooms. But it causes higher consumption in some areas than horizontal overhang. Shading elements provide a reduction by 0.1%, 14.99%, 15.21% and 0.35% in cooling loads consumption when the inside blinds, outside blinds, horizontal and vertical devices were used. According to the overall consumption a reduction up to 6.02% and 1.78% occurred when the outside blinds and horizontal elements are placed on the external facades, and about 0.12% and 0.13% increasing in the total consumption by inside blinds and vertical elements. The daylighting performance is better than lower floors when different types were applied.

Figure 6.80: The effect of adding different types of internal and external shading devices, Fourth floor, South oriented street

6. *Street oriented to the South-West (Case No.6):*

This case recorded the highest decreasing rate in the annual total load consumption when the outside blinds were used in all floors compared to the other urban context cases. When outside blinds were installed on the external windows, a reduction of overall consumption by 8.71%, 9.70%, 9.80%, and 6.58% was on the first, second, third, and fourth floors. As for vertical side fins, this case also provides the largest energy decreasing rate that has reached up to 2.08%, 2.10% and 2.03% in the first, second and third floor.

At the first floor level, horizontal shading device is the second best type for south-eastern and south-western spaces and vertical fins for north-eastern and north-western spaces after outside blinds. As for heating loads, horizontal and vertical shading devices increased the consumption by 8.36% and 3.75% respectively. On the other hand, outside blinds, horizontal and vertical side fins provide 20.08%, 17.69% and 8.90% reduction of cooling load consumption.

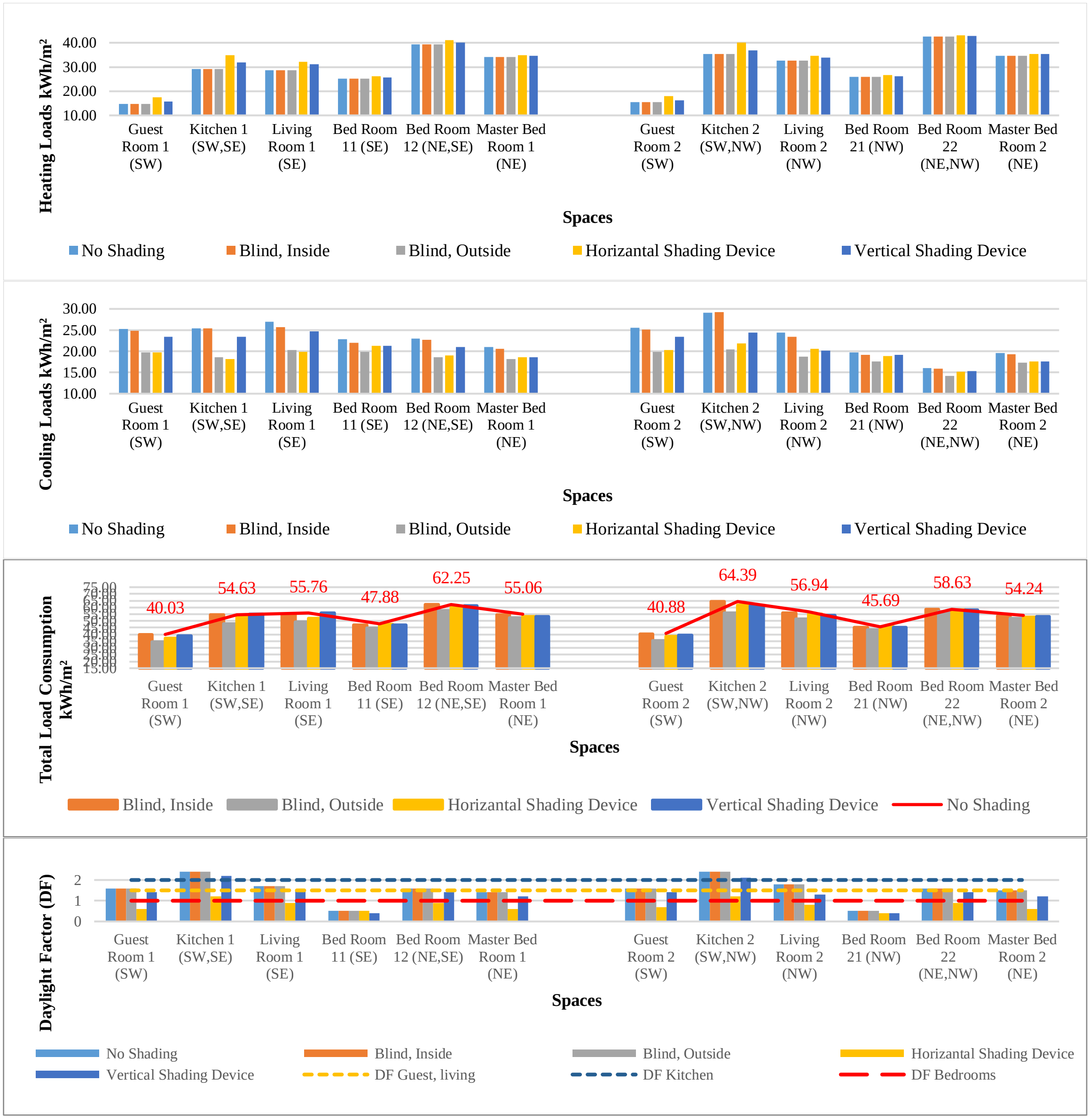


Figure 6.81: The effect of adding different types of internal and external shading devices, First floor, South-West oriented street.

Vertical side fins performance in providing acceptable level of natural daylight is better than horizontal overhang. At the same time, most spaces with horizontal type consume lower overall load per square meter than vertical type. The inside blinds decrease the cooling consumption by 20.80%, 21.18%, 21.06% and 16.84% on the first, second, third and fourth floors respectively. At the same time, the impact on heating consumption was unnoticeable. When horizontal and vertical devices were used in the second floor, heating consumption increased by 10.70% and 2.78%.

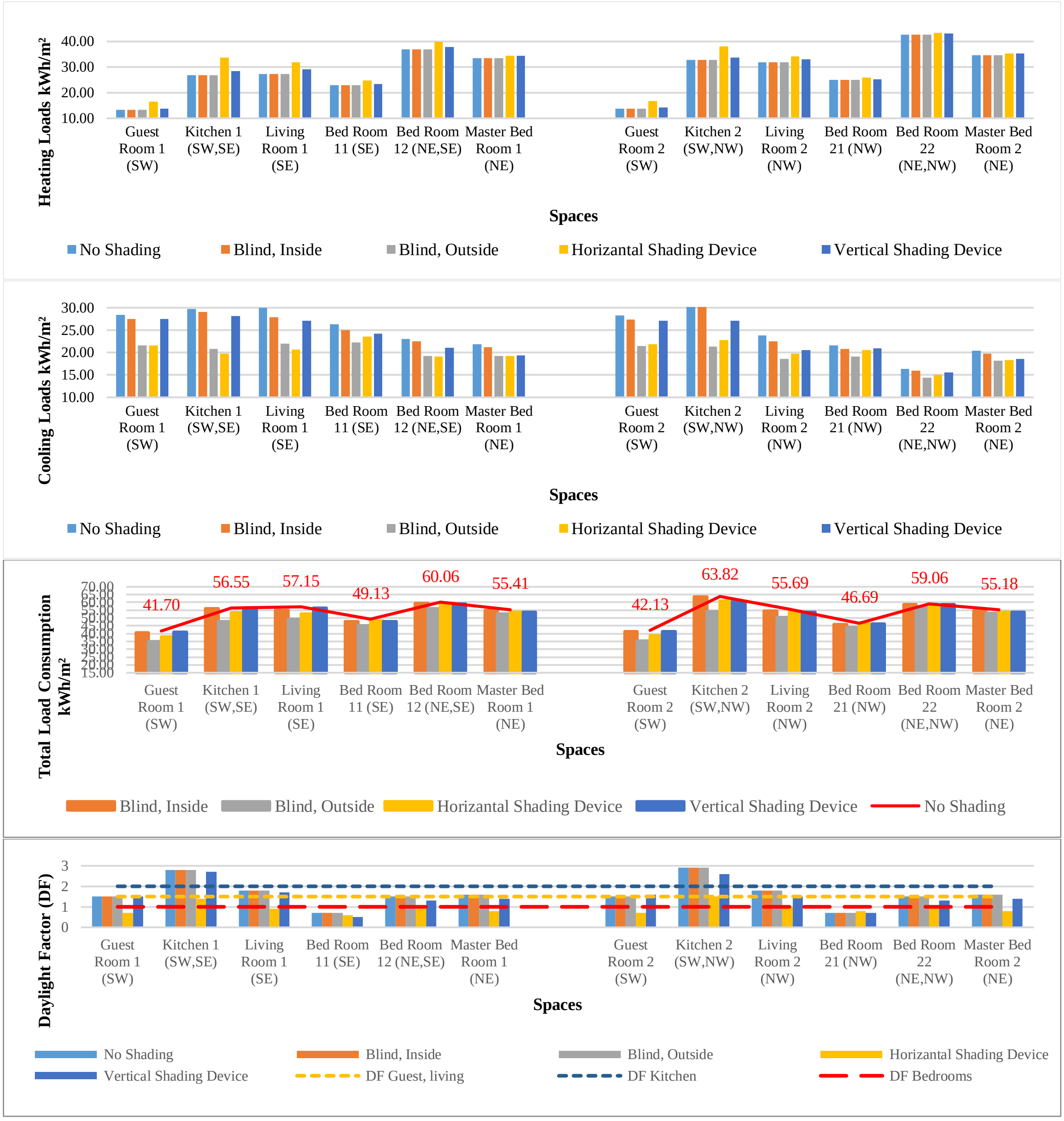


Figure 6.82: The effect of adding different types of internal and external shading devices, Second floor, South-West oriented street.

Figure 6.83 illustrates that a reduction of at least 2.97%, 21.06%, 20.24% and 6.57% in annual cooling loads could be achieved by using inside blinds, outside blinds, horizontal overhang and vertical side fins shading devices on the third floor façades; furthermore, this could be equal to 1.44%, 9.80%, 2.20% and 2.03% reduction on the total energy consumption. On the other hand, the results also indicate that daylight factor values are now higher than what it has recorded on the lower floors and become close to or equal to the requirements especially when overhang was used.

Figure 6.83: The effect of adding different types of internal and external shading devices, Third floor, South-West oriented street.

The impact of inside blinds on the fourth floor reacted differently. When it was installed on the external windows, there was no noticeable effect on the heating loads consumption, and sometimes, it increased the loads required to cool the spaces in summer which in the turn increase the total loads consumption in some spaces such as; kitchen 1, master bedroom1, bedroom 22 and kitchen 2 which were oriented to the south-east, south-west, north-east and north-west sides. As shown in the figures below, the outside blinds achieved a maximum of 6.58% reduction, while the vertical fins reached 1.12%, and the horizontal type increased total loads consumption on all floor by 0.82%.

Figure 6.84: The effect of adding different types of internal and external shading devices, Fourth floor, South-West oriented street.

7. *Street oriented to the West (Case No.7):*

The performance of a shading device can be mainly verified by the actual saving amount of the cooling load consumption. For this purpose, a series of energy simulations was conducted to estimate savings in cooling and total loads consumption without forgetting its impact on heating loads. Among the various shading devices dealt with in this study, the outside blinds shading device shows the most efficient performance in the cooling and heating seasons in all floors in different urban context cases. While the total load consumption without shading elements on the first floor is 50.13 kWh/m^2, the total load reduction with an outside blind, which is designed for the summer season, is 8.03% and the total load consumption with the horizontal overhang, which is designed for summer and winter seasons as a fixed type, is 47.72 kWh/m^2, which is less by about 3.36% for the first floor.

Figure 6.85: The effect of adding different types of internal and external shading devices, First floor, West oriented street.

While the impact of shading elements on the cooling loads is significant important, the increasing of heating loads and decreasing on the natural daylighting level must be taken into consideration as well when the impact of shading devices was analyzed. Shading devices are designed to block the sun in overheated period, which on the other hand can cause many problems such as prevent sunlight and solar radiation from reaching the building when needed. As shown in Figure 6.86, horizontal overhang increases the heating loads consumption to reach thermal comfort in winter by about 6.88%, 10.10%, 11.63% and 6.86% in comparison with no shading scenario of fourth floor on the first, second, third and fourth floors. On the second floor, the total loads consumption per square meter when vertical side fins are placed on the windows is significantly higher than horizontal devices consumption in this case. The horizontal devices decrease the total consumption by 3.31% while the vertical ones increase the consumption by 0.23%. At the same time, there is a 9.28% reduction of total consumption when outside blinds are used.

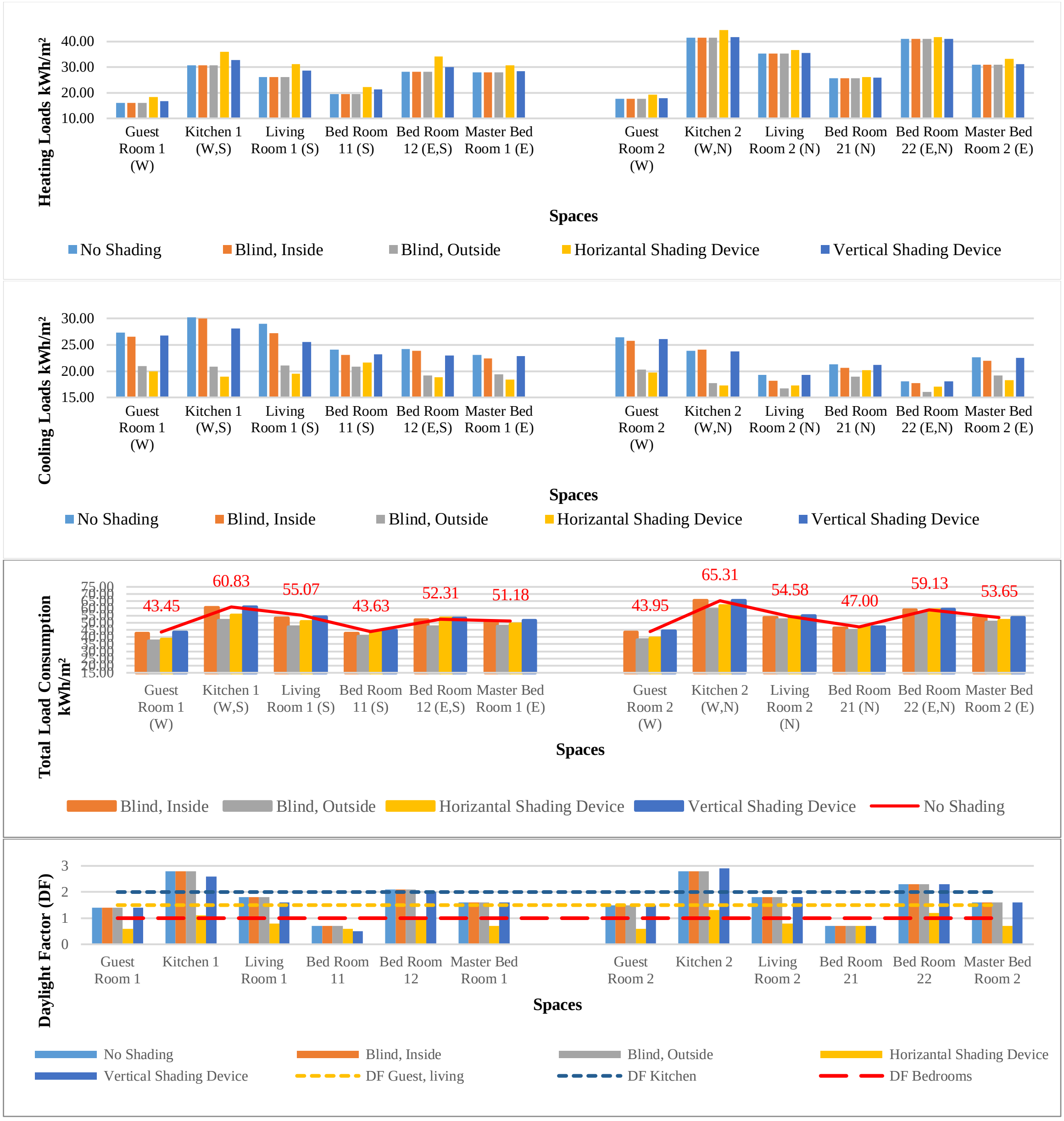


Figure 6.86: The effect of adding different types of internal and external shading devices, Second floor, West oriented street.

On the third floor, the total load consumption per square meter when the street is oriented to the west is extremely lower when assessing the horizontal overhang than the vertical type but close to outside blinds consumption in many spaces. When the impact on the total consumption and daylighting were analyzed, the results conclude that vertical fins are the optimum for western and eastern spaces like guest room1, guest room2, master bedroom 1 and masterbedroom2. In these spaces, the total consumption as a result of the vertical type is higher than the horizontal one, but at the same time, the daylighting level in these spaces are in the acceptable zone when vertical type is installed. As for the living rooms, which was oriented to the south and north in the apartment No.1 and apartment No.2 respectively, the total consumption is 50.49 kWh/m^2 and 51.25 kWh/m^2 in the living room 1 and about 57.64 kWh/m^2 and 58.40 kWh/m^2 in the living room 2 for horizontal and vertical shading elements respectively.

On the other hand, the daylighting level is lower than required when horizontal type is used and on the acceptable lighting zone for vertical type.

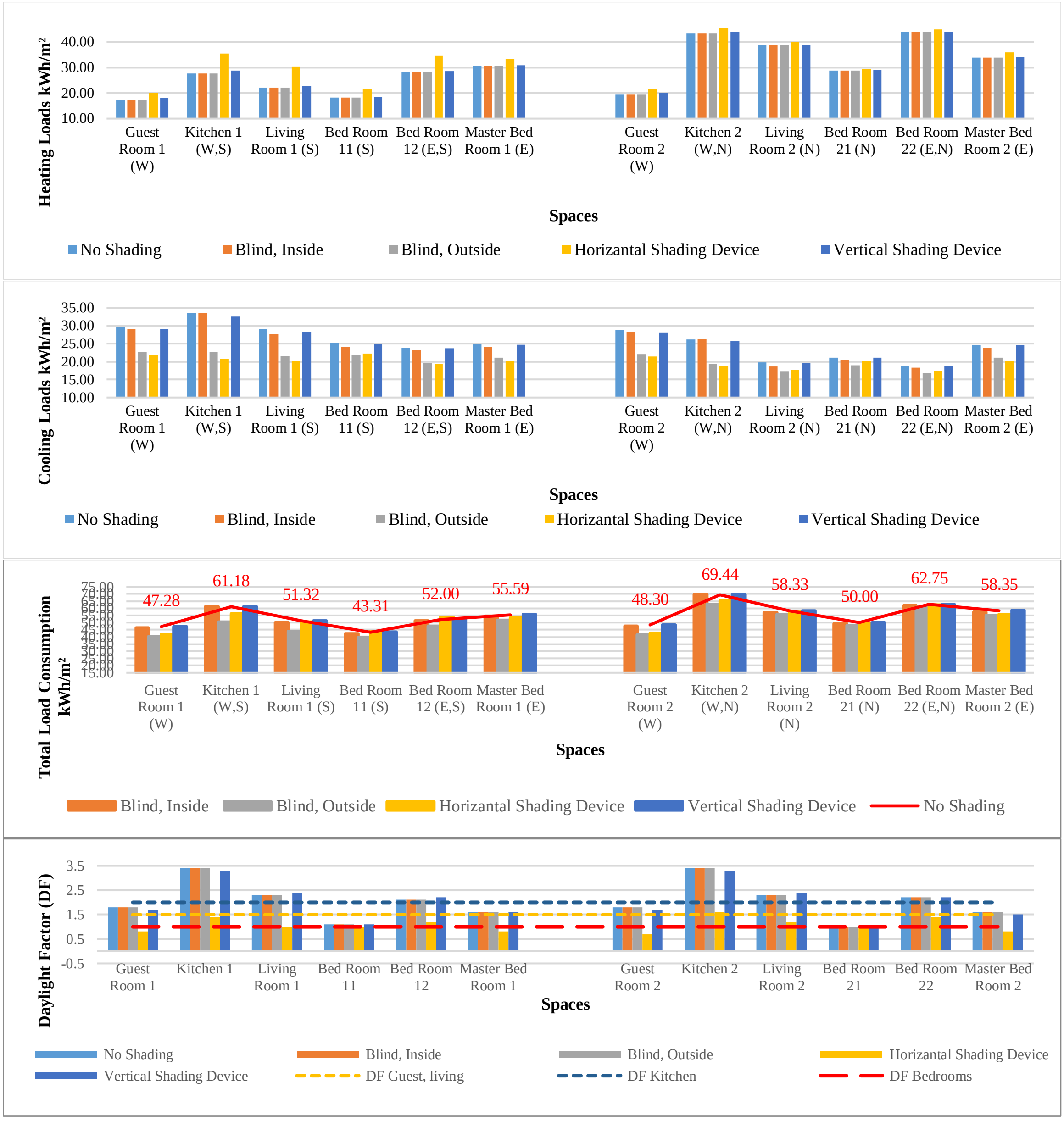


Figure 6.87: The effect of adding different types of internal and external shading devices, Third floor, West oriented street.

On the fourth floor, almost all spaces have acceptable level of daylighting when all shading devices types were used. For western spaces such as guest room 1 and guest room 2, the daylighting performance for vertical side type is better than horizontal overhang. On the other hand, the total consumption for vertical is higher than horizontal type and slightly higher than no shading case scenario. In this case, the using of shading devices can be neglected. As for southern spaces in the apartment No.1 like living room, bedroom 11 and bedroom 12, the total consumption for vertical type is lower than horizontal and at the same time it provides acceptable levels for daylighting in these spaces.

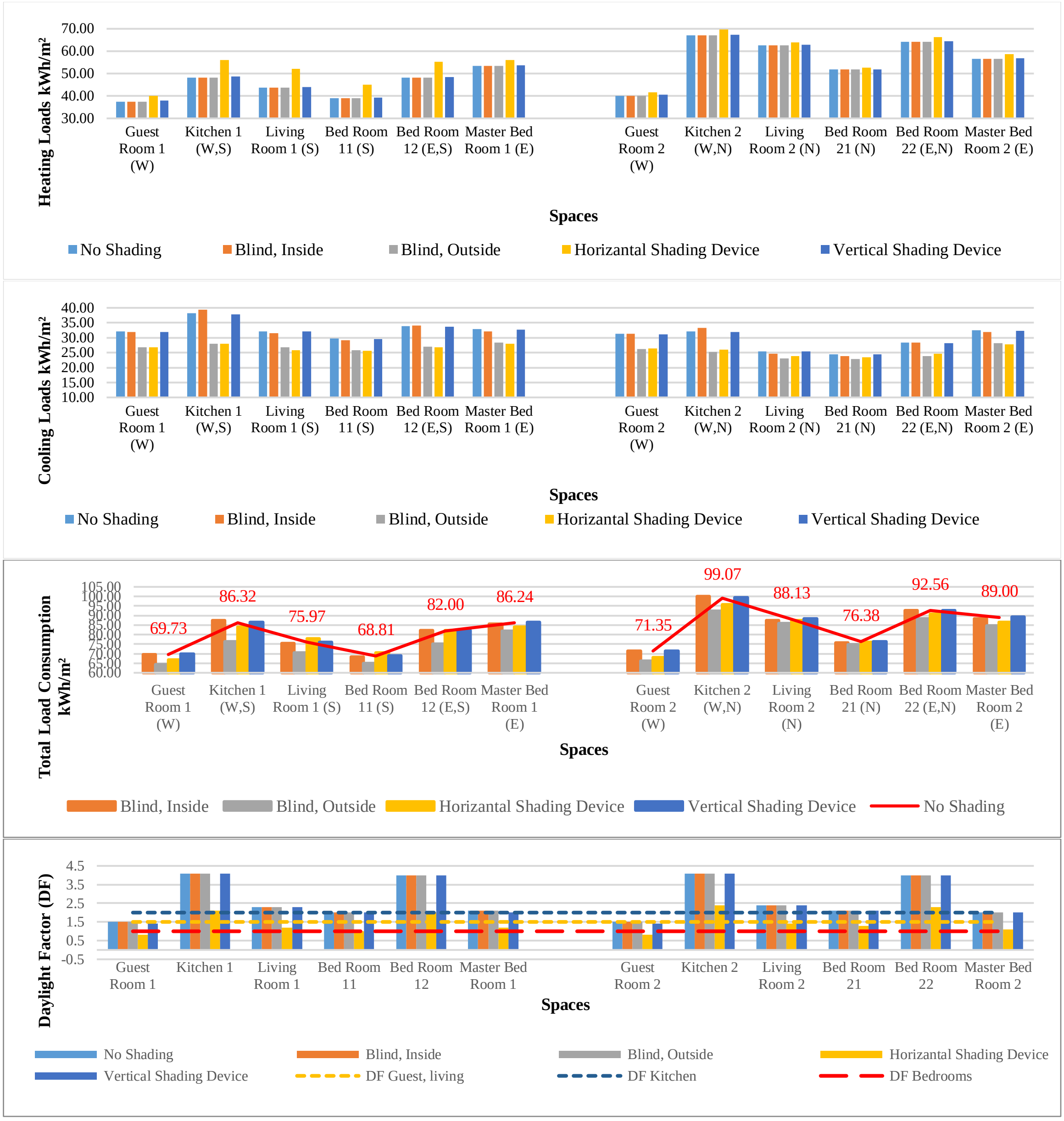


Figure 6.88: The effect of adding different types of internal and external shading devices, Fourth floor, West oriented street.

In this case, the impact of horizontal shading devices is the best on the first, second and third floors comparing with other urban context case in term of total consumption reduction per floor. It provides 3.36%, 3.31% and 2.55% reduction to the overall loads consumption on the first, second and third floors.

8. Street oriented to the North-West (Case No.8):

Outside blinds and horizontal shading devices in this case can provide significant reduction in the total load consumption on all floors. They can provide 7.42% and 2.87% reduction of total consumption per square meter on the first floor, 8.13% and 2.54% on the second floor, 8.71% and 1.88% on the third floor and about 6.51% and 1.40% on the fourth floor. As for heating loads consumption, the performance of this case is different than other urban context cases especially on the first floor, the highest increasing percentage recorded when the vertical side fins were installed on the external windows. Horizontal shading devices increased the consumption of heating loads by 4.15%, 6.29%, 9.08% and 6.51%, and vertical shading devices provide 5.02%, 5.04%, 5.09% and 2.42% increasing of heating loads for first, second, third and fourth floors respectively.

Figure 6.89: The effect of adding different types of internal and external shading devices, First floor, North-West oriented street.

As for cooling loads consumption, horizontal overhang can provide significant reduction by 14.27%, 16.18%, 17.41% and 14.22% of cooling than the similar case without shading devices. The vertical type provides 9.77%, 9.37%, 9.52% and 6.41% cooling load reduction. As for second floor, when horizontal overhang was installed, spaces consume less total energy than when vertical type shading device was installed. However, vertical shading devices provide acceptable level of natural daylighting than horizontal and a reduction of total consumption than similar case without shading devices in all residential spaces except bedroom 11, bedroom 12 and master bedroom 1, where the shading elements can be neglected due to their negative impact on total load consumption.

Figure 6.90: The effect of adding different types of internal and external shading devices, Second floor, North-West oriented street.

In general, shading devices reduce the daylighting levels especially for the lower floors. But on the third and fourth floors, almost all spaces achieve acceptable levels of daylighting when different types of shading devices are installed on the external windows. On the third floor, the performance of north-eastern and north-western spaces such as guest rooms, living room 2 and bedroom 21 in the case of vertical shading devices is better than horizontal type in terms of daylighting. At the same time, it also provides a significant reduction in total load consumption than the case of no shading.

Figure 6.91: The effect of adding different types of internal and external shading devices, Third floor, North-West oriented street.

On the fourth floor, the impact of different types of shading devices such as horizontal and vertical elements can be neglected when were installed on the guest rooms external windows which were oriented to the north western side. This is due to its negative impact on daylighting, however, at the same time, there are slightly reduction on the total loads consumption. In this situation, the decision is left to the designer based on the case which he was designed. The acceptable level of daylighting and total load reduction in the case of vertical shading devices occurred in living room 1 and living room2. Consequently, placing horizontal overhang in other spaces is better than vertical type for decreasing total load consumption and providing adequate level of daylighting.

Figure 6.92: The effect of adding different types of internal and external shading devices, Fourth floor, North-West oriented street.

As shown in all previous results, Blinds and shading devices are reasonable solutions to reduce the amount of overall load consumption and maintain a sufficient amount of natural daylight inside residential spaces. In other words, shading devices should help to create pleasant spaces with optimal situations in terms of lighting and heat gain. The results conclude that the outside blinds with high reflectivity slats which were scheduled to use in the hot months have a significant impact on the total load consumption in different urban context cases than other studied shading devices types. The aim of this section is not only to point out the optimal shading devices types, but also to provide simple guidelines for designer about the impact of each type on the indoor environment performance, so the designers will be able to choose the most appropriate type based on their designs.

6.5. *Summary:*

For cities with limited land areas such as Palestine, designing for higher density residential zones seems to be the only option in the future. Because of this, through better design at urban and building levels, high density cities could be providing resident's needs. This parametric study leads to simple design guidelines at urban and building levels which enhance the quality of the indoor environment.

It was found out at this chapter that optimizing the residential building design at building level and improving building elements in the early design stage have the greatest potential to reduce energy consumption in the building and to improve the quality of the indoor environment. According to the previous results, Windows characteristics particularly WWR and shading devices greatly influence energy load reduction and provide acceptable daylighting levels compared to other parameters. At building level, recommendations for enhancement have been drawn to overcome the problems of external obstruction and insure solar and natural daylight access. As for urban level, it is possible to observe the effect of changing setback distances on energy consumption behavior and daylighting in the different urban context configurations. The results indicated that, the orientations of residential buildings must be considered in the optimizing setbacks regulations, due to the changing in the solar radiation intensity and daylighting availability at various orientations. Also the results show that, the optimum setbacks distances are higher than current ones in all urban context cases and its great comparison with the land plots area available in Palestine. At a setback distance of 12m at least, the obstruction angle increased to 45º, which is adequate to achieve sufficient amount of daylighting inside the bedrooms.

Chapter Seven

7. Results Discussion, Conclusion and Recommendations:

7.1. Results Discussion:

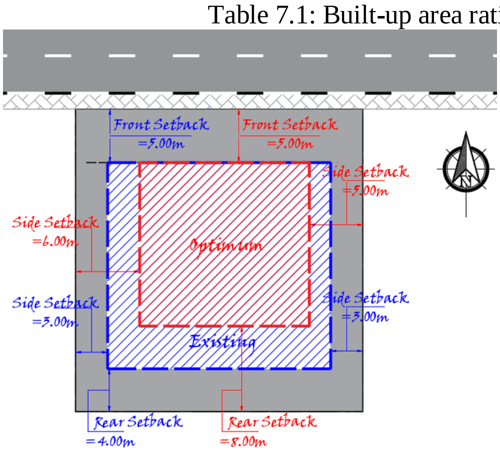
This section aims to analyze and discuss the optimization results of the parametric simulation at urban and building levels integrally so as to find the optimal solutions for urban context cases that could balance between the two levels alternatives by taking into account other factors than daylighting and thermal performance.

From the previous analysis in the optimization process, the optimal solutions and alternatives thorough urban and building levels that could balance daylight availability and thermal energy performance in multi-story residential buildings in Palestine with the highest possible energy savings were mostly achieved for each urban context case was depended on two criteria; firstly on Daylight Factor which must be equal or more than standards requirements in each residential spaces and secondly on energy saving percentages in heating and cooling loads from the base urban context cases. In other words, these proposed solutions took into consideration the environmental aspect only by reducing energy consumption, whether for lighting or for improving thermal performance, in contrast, neglected any other effects on the other aspects such as social and economic aspects. For example, increased setback distances at urban level have contributed to improve the performance of the indoor environment in terms of daylighting and energy consumption, also provide open and green spaces in Palestinian cities, which are almost without such these areas. Most of the these spaces are not exceeding the separation spaces between buildings which have caused social problems (M Itma, 2014). But on the other hand the impact on the built-up area ratio that has a significant impact on the economic aspect was neglected.

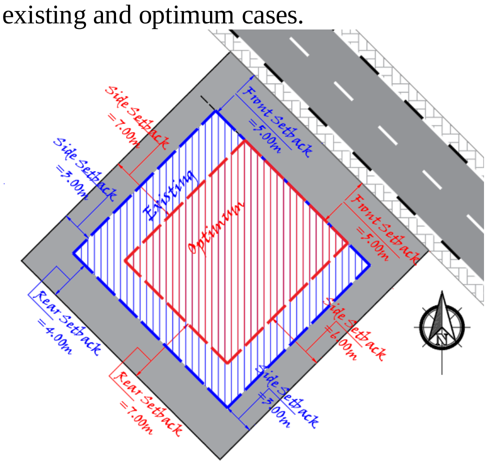
As mentioned previously, the increase in the population growth led to an increase in the housing units' demand in parallel with limited permitted land for setting up housing projects, this is an inevitable consequence of the Palestinian cities master plans boundary, which have contributed to limited land and developable residential zones. At the same time, the presence of areas classified as "C areas" under Israeli civilian and military control at the border of Palestinian cities has contributed to preventing any possibility of expanding cities master plans limitation and developing residential areas. All these factors have contributed to the existence of the current common pattern of Palestinian cities, which is based on the construction of buildings, especially residential buildings, within the setback's distances line imposed by the Palestinian Building Regulations, and in most cases, the owner's resort to non-compliance with the distances required to obtain a higher built-up area ratio and thus improve investment, especially in housing projects and multi-story.

As shown in the Table 6.25, the optimum distance for setbacks in different urban context cases was higher than the existing distance imposed by building regulations which in some cases equals twice the current distance. This contributes to a reduction in the built-up area ratio (given by the ratio of the building surface to the total site area) by about half in all cases, especially for the cases when the main street was oriented to the East, West, and North West. This reduction led to smaller residential areas or a smaller number of dwellings and a lower residential area per capita, affecting investment in residential projects and thus affecting the economic aspect. The built-up area ratio for existing and optimal cases for urban context cases was shown in Table 7.1.

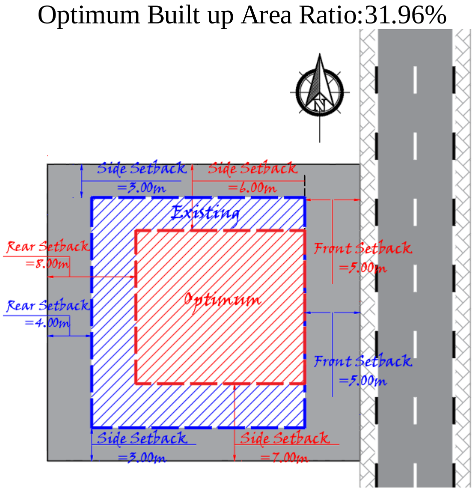
Table 7.1: Built-up area ratio for existing and optimum cases.



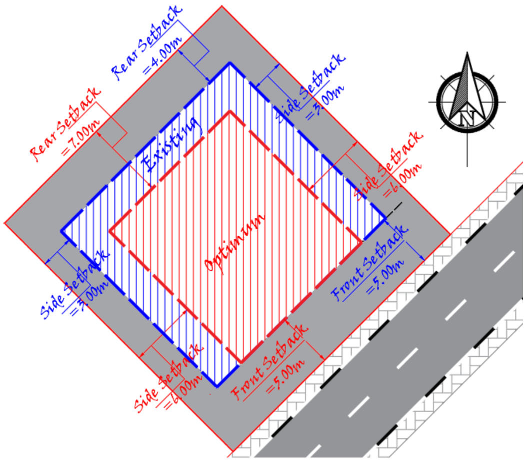
Existing Built up Area Ratio:53.00%
Optimum Built up Area Ratio:31.96%



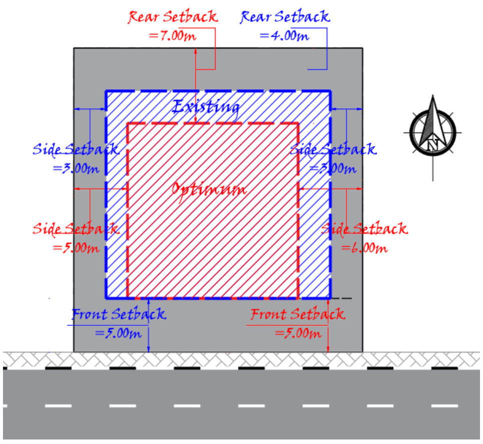
Existing Built up Area Ratio: 53.00%
Optimum Built up Area Ratio:29.76%



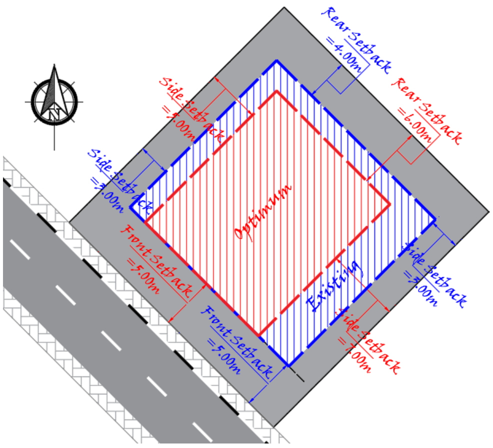
Existing Built up Area Ratio: 53.00%
Optimum Built up Area Ratio:27.94%



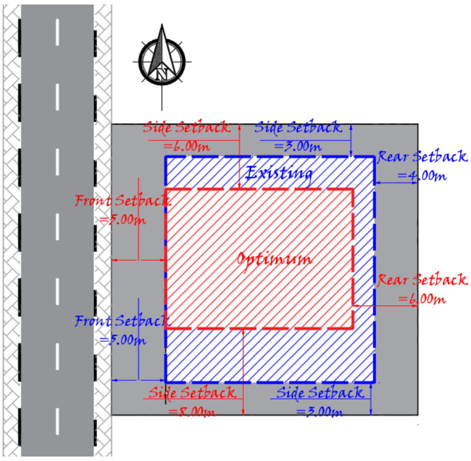
Existing Built up Area Ratio: 53.00%
Optimum Built up Area Ratio:31.90%



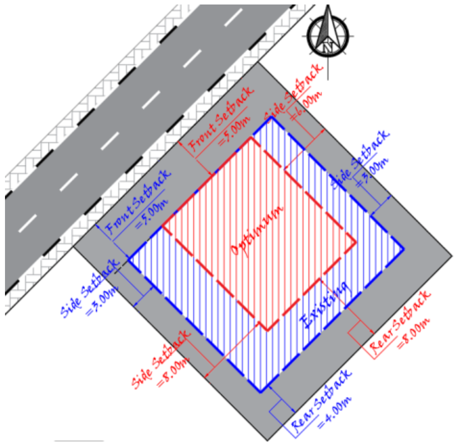
Existing Built up Area Ratio: 53.00%
Optimum Built up Area Ratio:34.05%



Existing Built up Area Ratio: 53.00%
Optimum Built up Area Ratio:33.86%

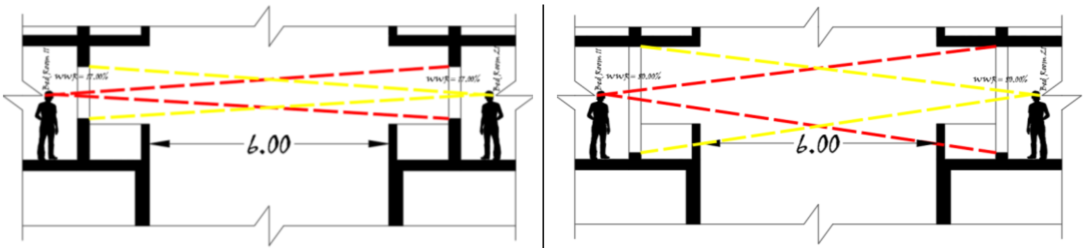


Existing Built up Area Ratio: 53.00%
Optimum Built up Area Ratio:29.32%



Existing Built up Area Ratio: 53.00%
Optimum Built up Area Ratio:25.93%

On the other hand, when the optimization was conducted on the building level, different parameters were tested. The result show that, WWR was the most effective parameter on enhancing daylighting intensity and reducing thermal energy especially heating loads in winter under existing setback regulations. In the same time, the optimal WWR for residential spaces have a significant impact on the residents' privacy inside their apartments, so the social aspect was affected negatively (see figure below).



Before, WWR=17.00%　　　After, WWR=80.00%

Figure 7.1: The impact of increasing WWR on the social aspect "privacy".

according to the previous discussion, a combination optimization had been conducted between the building and urban parameters exploring integral parameters approach's effectiveness in balancing daylight and thermal performance through the proposed solutions. In the same time, taking into account social aspect by enhancing the privacy between buildings when WWR decreased and setback distance increased integrally and economic aspect by increasing the built-up area ratio when the optimum setbacks was decreased. The results showed that the combination optimization by increasing setback distance in the same time with increasing WWR allowed wide variety of solution configurations to be used depending on the situation and the potential in each project. For example, the north oriented street, the configuration of 5m, 6m and 8m setback distances for the right side (east), left side (west) and rear setback (south) was the optimal distances for this case for the optimization at urban level that balance daylighting and thermal performance in residential spaces in residential B-Zone at existing WWR. And the optimum WWR was conducted at current and existing setback distances.

The base case in the combination optimization was conducted when the setback at existing distance and WWR at optimum size. Then, the setback distance was increased and measured the optimum WWR at each distance. For example, when the setback distance from the eastern side in the case of the street was oriented to the north is 3m (existing distance), the optimum WWR in the living room in the apartment 2 was 60%, 40%, 20% and 20% for the first, second, third and fourth floors. When the setback distance increased to 4m from the eastern side, the WWR decreased to 40%, 30% in the first and second floors, and still 20% in the third and fourth floor to allow view to outside environment.

The optimum setback distance from the southern side was 8m, thus, in the combination phase, the setback distance was increased from 4m (existing case) to 7m. the result show that, the WWR in the master bedroom in the first floor decreased from 40% to 30% when the setback distance increased from 4m to 5m, and to 20% when the distance was 6m or 7m (see Figure 7.2 and Figure 7.3).

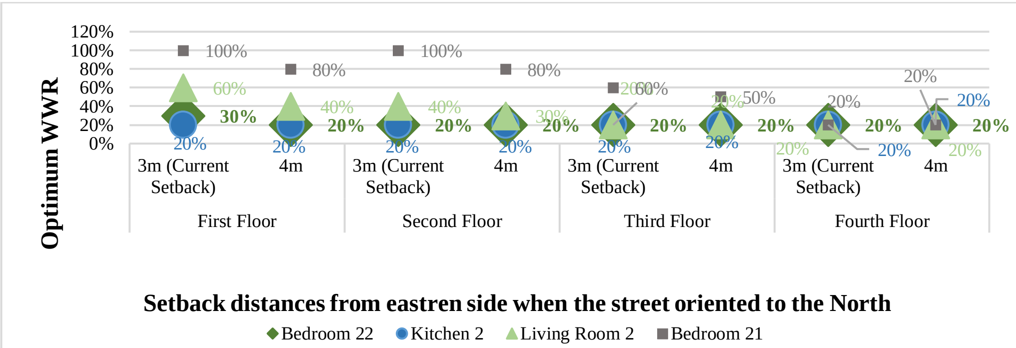


Figure 7.2: Optimum WWR when the eastern setback distance increased when the steer was oriented to the North.

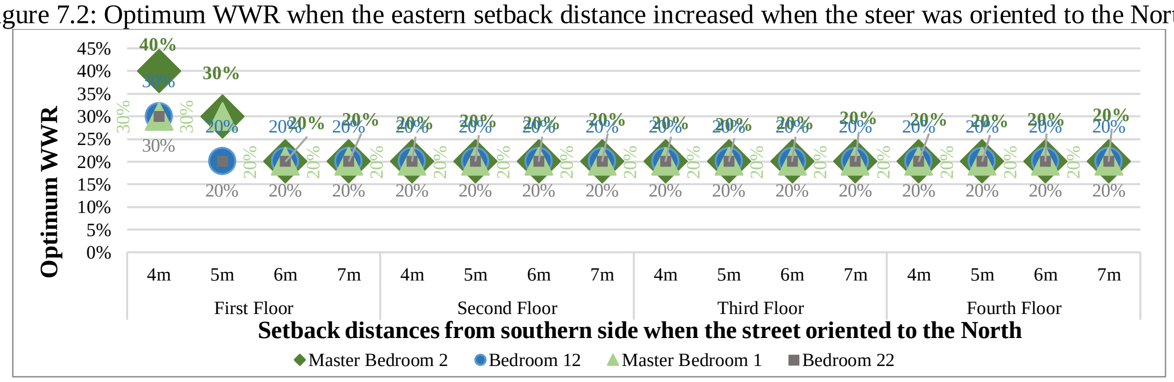


Figure 7.3: Optimum WWR when the southern setback distance increased when the steer was oriented to the North.

As for western side, when the setback distance increased from 3m (current distance) to 4m and 5m (6m is the optimum distance), the WWR for the bedroom 1 in the apartment 1 was decreased from 100% to 90% in the first floor, 100% to 80% and 70% in the second floor, from 70% to 70% and 60% in the third floor and from 40% to 20% in the fourth floor as shown the figure below.

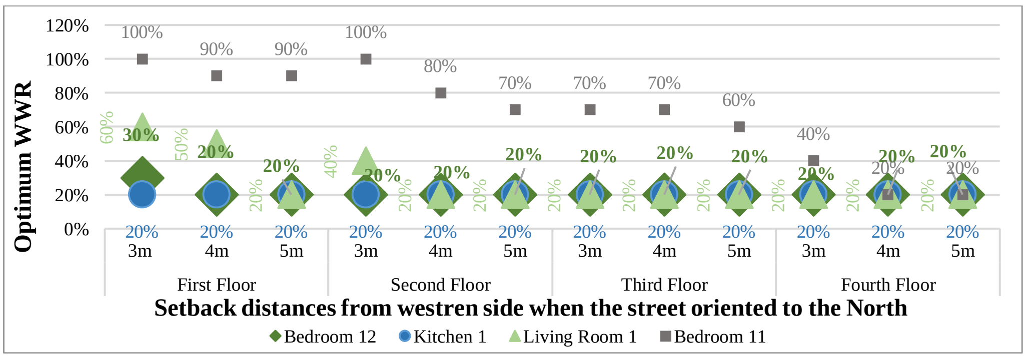


Figure 7.4:Optimum WWR when the western setback distance increased when the steer was oriented to the North.

7.2. Conclusion and Recommendations:

From this study, examining the interaction between the quality of the indoor environment and setback regulations in Palestine become increasingly important. In addition to evaluate the current status of residential apartments in multi-story residential buildings in terms of regulated setback distances, this thesis also aims to improve the performance of the indoor environment in residential apartment buildings by optimizing the design at urban and building levels and improve building elements at the early design stage, which is plays a significant potential in providing adequate daylighting level and reducing energy consumption than other stages.

As response to the thesis questions and objectives, this study firstly evaluates the impact of current setbacks regulations under permitted building height on the natural daylighting and thermal energy consumption inside residential spaces in residential B-Zone through 32 base and urban context cases. Then, propose various alternatives at urban and building levels and check whether these alternatives can enhance the indoor environment performance and minimize energy consumption.

From the first stage of simulation, the study found that regulated setbacks distances are not sufficient to provide acceptable levels of daylighting and energy efficiency especially heating loads. This is also because at building level most of residential buildings in Palestine are designed with no regard to the local climatic conditions. Instead, occupants depend on active systems to overcome the impact of an uncomfortable indoor environment. These systems contribute to high energy consumption and carbon dioxide emissions. Thus, these regulations should be studied to reduce their negative impact on the building performance. As for building design, it should be adapted to local climate and site conditions to reduce energy needs for heating, cooling and artificial lighting.

In the second simulation stage, an optimization process is conducted for all urban context cases to enhance the quality of the indoor environment and minimize energy consumption by finding optimum solutions at different levels. Also, to provide general guidelines for architects to optimize their design in specific design conditions. Optimization at urban level found that, the optimum setback distance to achieve adequate natural daylighting and reduce total energy consumption should be at least 5m (10m separating distance) in many cases and it reaches to 8m on each side from the plot boundaries in some cases. As for the current status in Palestine and the problem of land availability, these optimum distances can be insufficient due to the reduction in the built-up area ratio which reaches to 25% reduction in some cases. For this reason, the study suggested that these distances can be used in new neighborhoods around the city center and when the plot size is suitable for that. But in the other cases, the designer can use building-level alternatives and solutions. As for optimization at building level, various parameters from the prior literature review were studied including window to wall ratio and internal and external shading devices.

The most essential parameter which is studied at building level is WWR as the results found due to its significant impact on natural daylight availability, minimizing heating loads consumption in winter, and increasing cooling loads consumption. For this reason, shading devices should be used to minimize the amount of solar radiation reaching residential spaces in hot months. The using of shading elements especially outside blinds for cooling loads reduction in summer have a significant impact on the building performance in terms of provide acceptable level of natural daylight, reduction cooling energy consumption by 5%-22%, 9%-24%, 10%-26%, 9%-30%, 6%-28%, 4%-35%, 6%-33% and 10%-32% for north, north-east, east, south-east, south, south-west, west and north-west urban context cases respectively. This research also suggested that other types of shading devices can be used depending on design conditions for each project. For example, horizontal overhang shading devices can be used when the reducing cooling loads are more significant than reducing heating loads or improving natural lighting etc.

When analyzing the previous results at the urban and building levels in terms of the ability to implement them in the Palestinian cities, it becomes clear that there is a missing point for the application of the optimal results, which is the ability of these proposed alternatives to improve the current reality of Palestinian cities from the three aspects of sustainability, the environmental, social and economic aspects. These solutions, especially changing the setback distance and increasing WWR, reducing energy consumption needed for lighting, cooling, and heating, but they neglected the social and cultural characteristics of the Palestinian society as well economic aspect. For example, increasing setback distances on the one hand affects the urban density in the Palestinian cities as it reduces the built-up area ratio. This will affect the investment, the price of apartments as well as land prices because the desired benefit from the land has decreased from the investor's point of view, which causes problems in the economic aspect for the housing sector. On the other hand, the scarcity in the availability of the land within the master plans of Palestinian cities boundaries negatively affects the possibility of providing the community's increasing needs of housing units. On the contrary, the presence of large setback distances around the building contributes to providing green and open spaces in Palestinian cities, and when it is possible, it is important to apply the optimum setback distances. As for social aspect, the low setback distance affects the privacy of the residents inside their apartments, as well as the parameters at the building level, as the increase in the WWR at a minimum separation distance between buildings affects the privacy negatively.

As shown in the results, it is possible by depending on urban and building levels parameters to improve the environmental, economic, and social aspects of multi-story residential buildings in residential B-Zone by combining parameters at the two levels especially setback distance and WWR that have significantly helped in enhancing the environmental performance by improving the daylighting and thermal performance of residential buildings as well as economic and social aspects. The increase in the setback distances than existing ones at the same time with decreasing WWR than optimum results can respect the three aspects and enhance the indoor environment performance.

The thesis recommended simple guidelines for legislators and architects at initial design stages of multi-story residential buildings in residential B-zone aiming to enhance the daylighting performance and energy efficiency in relation to the external urban context:

7.2.1. Recommendations for Planners and Legislator:

- Based on the previous study, it concluded that there are many factors and variables that affect the efficiency of the indoor environment in the residential buildings and that are linked to the building regulations, so the regulations and codes need to take all these factors into account and to re-examine all regulations that have direct and indirect impact on the indoor environment.
- When the setback regulations were enacted, the principle of a uniform setback distances within the same residential zone must not be relied upon. Different factors must be taken into account such as, land orientation, the location of the main street, the location and the price of the land and the need for green and open spaces within the residential zone. Each case must be studied separately to determine the required setbacks distances.
- Building codes must impose the obligation of optimal setback distance when it is possible, and in cases where it is difficult to comply, building level or combination solutions must be applied by the Directorate of Local Government with Architects.
- In the existing urban conditions, the availability of natural daylight is scarce due to the external obstruction. To enhance the daylighting performance under existing setback regulation, changing the reflectance of the external surface of the neighboring building could have a positive impact. This is because, in the dense urban context, most indoor natural daylight is reflected light from the surrounding environment whereas buildings or other urban elements. Thus, it is very important to use reflective materials on the outer surfaces of the surrounding buildings. Here's shows the role of the legislator. Article 8 of the Palestinian Building Regulation provides for the use of natural stone in external facades without addressing any other characteristics. So it is very important to make an extensive study of building materials that can be used in facades which increase the reflection of solar radiation and natural daylighting and thus improve the quality of the indoor environment.

7.2.2. Recommendations for Architects:

- Good building design is the best solution to get the occupant needs from natural daylighting and has a significant impact on energy consumption. So, it is very important for architects to study all parameters that are related to the residential project at an early design stage to choose the most suitable solutions that can enhance the indoor environment performance. Architects should study project location, project area, orientation, investor requirements and site characteristics to determine when the urban or building parameters can be used.
- When the WWR solutions were used, the architect can propose the use of glazing types which prevent the view from the surrounding buildings.
- Balconies become a pull element in the residential apartment buildings, which behave like shading devices, because of this, staggered balconies may improve daylighting availability and solar radiation amount in cold months. This may be required from architects to design mismatched floors in the interior spaces.
- The residential spaces with a higher daylighting requirement such as living spaces can be located near the south façade for more solar radiation especially in winter, and the spaces with a lower lighting requirement which mainly used in night can be

located in the north, north-east and north west façades as shown in the orientation results.

7.3. Future Work

- Much researches must have been oriented towards developing simple methods and guidelines for architects during the early design stage to improve the indoor performance in heavily obstructed urban contexts.
- Further studies are needed to include additional parameters at building and urban levels (window configurations, wall insulation, etc.), study other residential zones and other prototypes (more than two apartments in the floor, other types of insulation materials, occupancy densities, other climatic zones) to enhance the residential spaces performance.
- This study will focus on apartments with two residential units per floor and in future studies, more types and other prototypes for residential apartment buildings can be elaborated and studied.
- Investigating the use of dynamic shading systems for more enhancement especially in the cold months.

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APPENDICES

A. Appendix 1:

Appendix 1A- Conducted Interviews:

8.1.1. Interview 1:

Interviewee Name:	Eng. Yousef Rabei
Interviewee Title:	Teacher of Architecture engineering at the department of architecture, Palestine Polytechnic University.
Interviewer:	Eng. Kholoud Manassra
Date:	23, October 2019

Q1	How the building regulations in Palestine developed evolved to the form they are today, especially the setback regulations?
Q2	Who is responsible for adopting building regulations and approving changes to existing regulations and codes?
Q3	Which building regulations are currently in force in Palestine?

8.1.2. Interview 2:

Interviewee Name:	Eng. Arwa Abu-Alhija
Interviewee Title:	Head of Local Government Directorate- Bethlehem
Interviewer:	Eng. Kholoud Manassra
Date:	12, November 2019

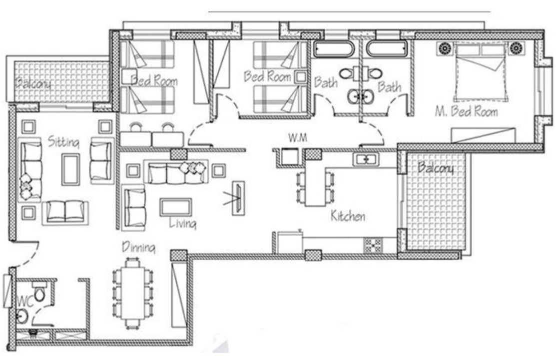
Q1	What is the current status of building regulations in different residential zones?
Q2	What are the regulations and the codes that have detailed the setback distances?
Q3	What's the reason for the infractions and trespasses on the setback regulation?

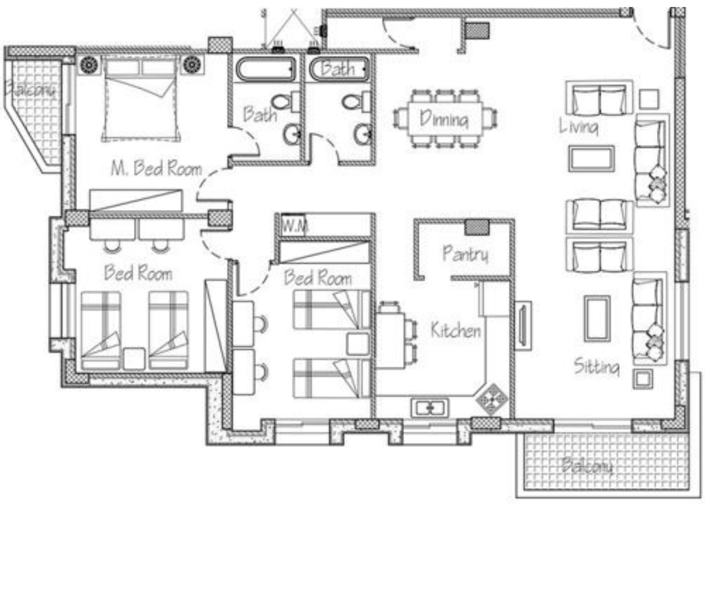
Appendix 1B- Local Cases for Multi-Story Residential Buildings in Palestinian Cities:

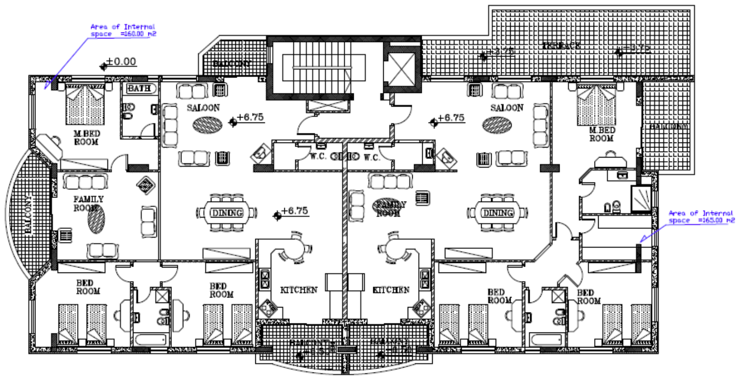
Different cases for multi-story residential building were studied in order to understand the common design for residential apartment buildings in the local housing projects market.

Table A.1: Local cases for residential apartment buildings in Palestinian cities.

Bethlehem

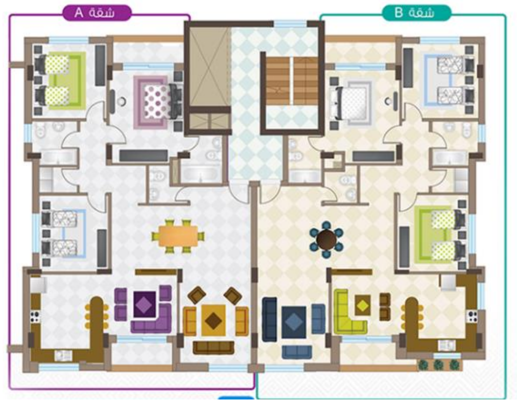






Nablus

Ramallah



شقة A
شقة B

غرفة خدمات
1.3x2.8
مطبخ
5.9x4.0
حمام
3.4x1.7
غرفة ملابس
3.4x3.6
غرفة نوم رئيسية
3.3x3.7
حمام
1.1x2.4
مصعد
حمام
1.7x2.8
غرفة معيشة
5.3x5.0
صالة طعام
3.8x2.1
غرفة نوم
3.7x3.7
صالون
3.8x5.5
حمام
1.8x2.0
فرندة
1.35x3.0
غرفة نوم
3.5x3.7
غرفة نوم رئيسية
4.7x3.9
تيراس
تيراس
مدخل خاص

Rawabi 3D Animation and Graphics

Appendix 1C- POE Survey:

POE is very important tool to evaluate the performance of apartments in multi-story residential buildings in terms of natural lighting and energy consumption in addition to the problem Identification. In this study, POE questionnaire used to collect information to analyze the degree of satisfaction of the residents of residential buildings in residential B-Zone about the quality of the indoor environment in terms of natural lighting and energy consumption and their relationship to the neighboring urban context.

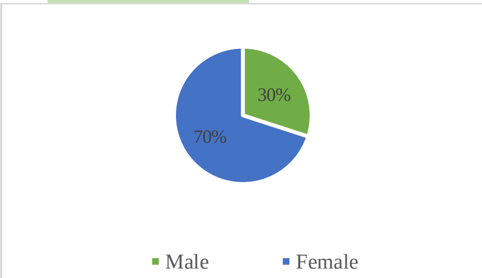
Table A.2: POE survey structure.

Section No.	Information	Aspects	Questions
Section 1	**General Information**		Gender: ☐ Male ☐ Female Age: How long have you been living in this apartment? How long do you spend in the apartment during the day? Do you rent or own your dwelling? How many people live in your household?
Section 2	**The Building Overall (Building Scale)**		Building Orientation (main street orientation). ☐ N ☐ NE ☐ E ☐ SE ☐ S ☐ SW ☐ W ☐ NW How many floors are the building? .... On which floor the apartment is located? What is the use of the ground floor? ☐ Residence ☐ Parking ☐ Stores ☐ Shops How many apartments are there on the floor? How many facades of the building have external openings? describes your unit spaces.
Section 3	**Urban Context Characteristics (Urban Scale)**		• Is the building surrounded by neighboring buildings? • How many sides are the buildings surrounded by neighboring buildings? ☐ One Side ☐ Two Sides ☐ Three Sides ☐ Fourth Sides
Section 4	**Occupant's Satisfaction**	Natural Light	• How satisfied are you with the accessibility of natural daylight from street to front spaces? **Unsatisfied** **Satisfied** -3 | -2 | -1 | 0 | +1 | +2 | +3 • How satisfied are you with the accessibility of natural daylight from side and rear separation distance to the side and rear spaces? Unsatisfied Satisfied -3 | -2 | -1 | 0 | +1 | +2 | +3 • Do you think that the neighboring buildings block the natural daylight from reaching the apartment? ☐ Yes ☐ No
		Solar Radiation	• How satisfied are you with the accessibility of solar radiation in Summer? Unsatisfied Satisfied -3 | -2 | -1 | 0 | +1 | +2 | +3 • How satisfied are you with the accessibility of solar radiation in Winter? Unsatisfied Satisfied -3 | -2 | -1 | 0 | +1 | +2 | +3

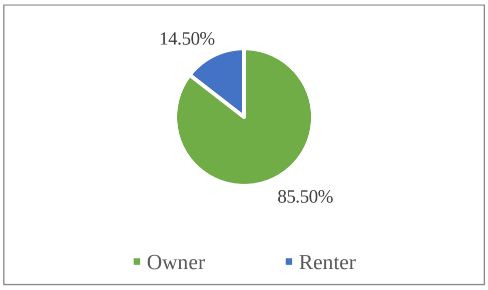
			• Do you think that the neighboring buildings block the solar radiation from reaching the apartment? ☐ Yes ☐ No
		Separation Distance	• How satisfied are you with the separation distances between building and surrounding buildings in terms of natural daylight and solar radiation accessibility? Unsatisfied Satisfied -3 -2 -1 0 +1 +2 +3
		Privacy	• Do you use blinds on windows? ☐ Yes ☐ No • What is the main reason for using blinds? ☐ For Privacy ☐ Blocking solar radiation • In which spaces do you use blinds? ☐ Spaces located on the street ☐ Spaces located on the side and rear. ☐ All residential spaces. • Do you open the blinds during daylight hours? • In which season do you open the blinds during daylight hours? • How satisfied are you with the separation distances between building and surrounding buildings in terms of privacy in the spaces located to the neighboring buildings from rear and side? Unsatisfied Satisfied -3 -2 -1 0 +1 +2 +3 • How satisfied are you with the separation distances between building and surrounding buildings in terms of privacy in the spaces located to the neighboring buildings from street to front spaces? Unsatisfied Satisfied -3 -2 -1 0 +1 +2 +3
Note: -3 -2 -1 0 +1 +2 +3 +3: Very satisfied, +2: Satisfied, +1: Fairly Satisfied, 0: Neutral, -1: Fairly Unsatisfied, -2: Unsatisfied, -3: Very unsatisfied			

8.1.3. *C-1: Results and Discussion:*

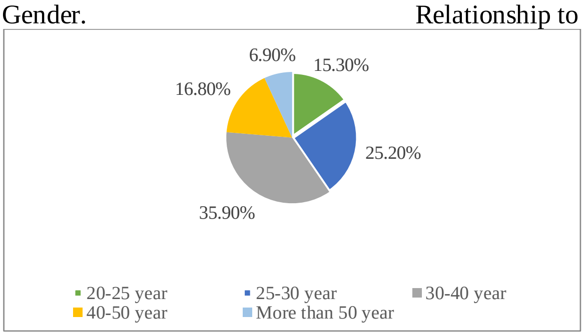
1. *General Information and Sample Description:*



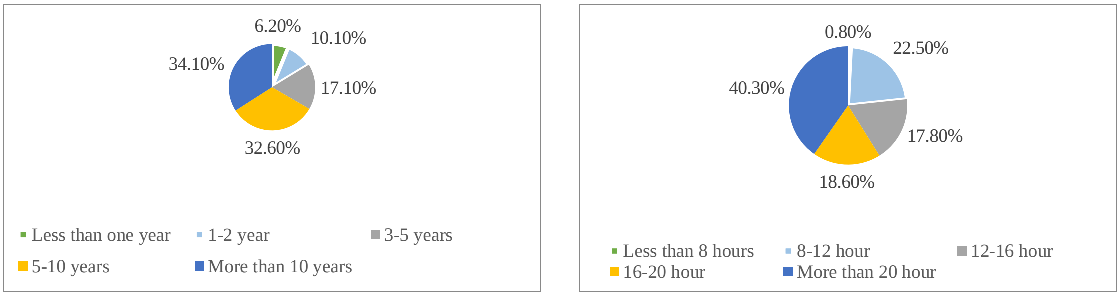
Sample Gender.



Relationship to the apartment.



Sample age .



Number of years which the sample have been living in the apartment.

Number of hours which the sample spend in the apartment during the day.

Figure A.1: General information for the study sample.

2. *The buildings Overall (Building Scale):*

As shown in the results, high-rise buildings are the common pattern in Palestinian cities, as most of the buildings contravene the building regulations in terms of the number of floors and setbacks between buildings. The study also included buildings with fewer floors than the permissible in order to study their performance and compare them with taller buildings performance in the same context, see Figure 4.5.

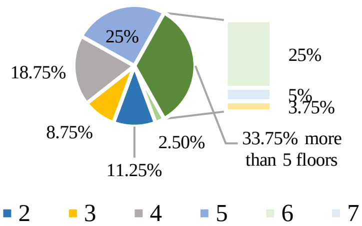


Figure A.2: Number of floors in the study buildings.

More than one apartment per selected buildings was used for the purpose of the evaluation. However, among the limitations of this survey is that many apartments were uninhabited and there are many who refused to provide any information. As shown in the figure below, about 41.50%, 43.10% and 15.40% of the study apartments are in the bottom, middle and top floor respectively. Top floors in most of the cases are uninhabited. In addition to the location of the apartment on the building floors, the number of apartments on each floor also affects the performance of the residential spaces in the apartment and the availability of natural lighting and solar radiation. When the number of apartments per floor increase, the external facades that contain openings decrease, and thus the amount of natural lighting and solar radiation that reaches the spaces decrease, which is also affected by the surrounding buildings. As shown in the figure below ,65.38% of the evaluated buildings contain two apartments per floor, and therefore each apartment contains at least three external facades that allow natural light and sunlight to enter the building.

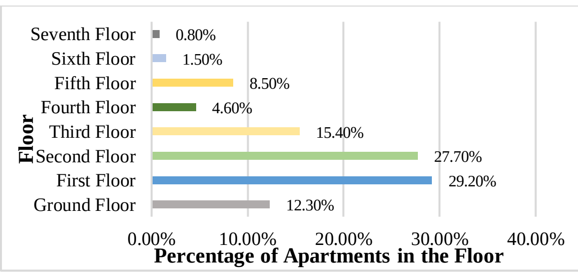


Figure A.3: Percentage of study apartments in each floor.

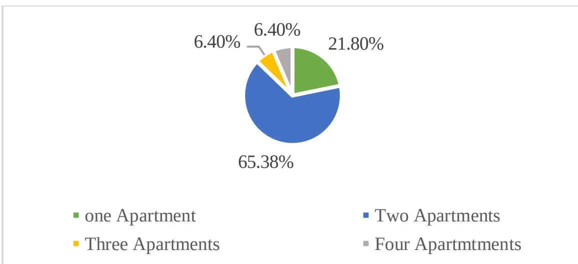


Figure A.4: Percentage of apartments number on each floor in the studied cases.

According to the Buildings and Organizing Code for Local Authorities No. 5 that was established in 2011 AD (BOC), ground floor in residential B-Zone can be used for local commercial functions such as kindergarten, health clinics, Pharmacy, supermarkets, etc. For this reason, the survey asked residents about the use of the ground floor in their buildings. The results found that, 23.08% of the studied multi-story residential buildings contains apartments in their ground floor and 76.92% of the studied sample contains other uses such as parking, stores and shops, etc… see Figure 4.8. The survey intent was not only to ass and evaluate the performance of indoor spaces but also to determine the common residential spaces in each apartment which can help in the prototype creation in this study. The results showed that, all apartments in the study consist of: guest room, living room, kitchen, master bedroom and at least two other bedrooms. In most cases, the apartment includes two or three bathrooms and at least one or two balconies.

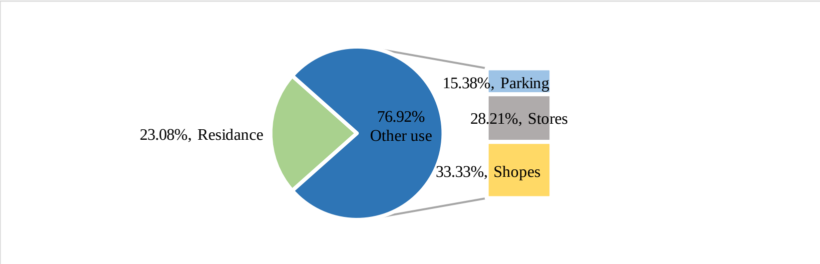


Figure A.5: Ground floor function.

3. *Urban Context Characteristics (Urban Scale):*

The main objective of this thesis is to study the impact of the urban context and neighboring buildings on the building performance, especially in terms of the availability of natural lighting and solar radiation. This section of the survey aims to determine and understand the characteristics of the urban context and the surrounding buildings in order to analyze their impact on the indoor environment. To achieve this goal, the sample selected buildings which are surrounded by neighboring buildings only, whether from all sides or at least one side. The aim of this is to study the critical and the worst cases scenarios in which the building is surrounded by buildings on all sides, and also to make a comparison between the satisfaction of the users of these buildings and between the buildings surrounded by neighboring buildings from three sides or less. Within the 78 selected samples, there is one building only that is not surrounded by any neighboring buildings while about 42.31% of the studied samples are surrounded by neighboring buildings from all sides.

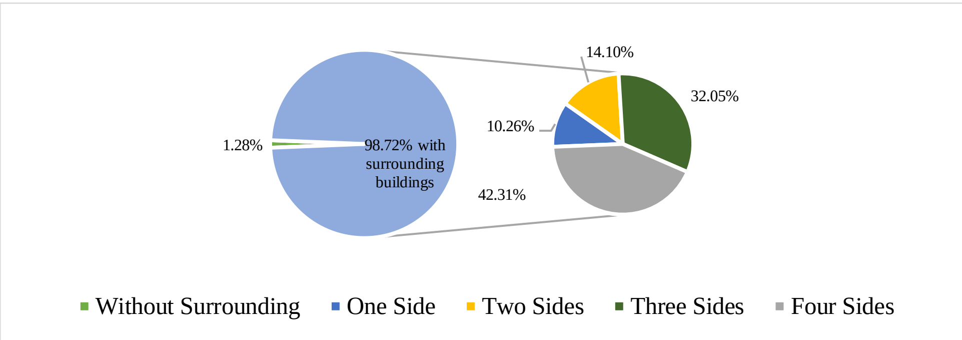


Figure A.6: Surrounding buildings.

4. *Occupant's Satisfaction:*

The study done by the researcher on the satisfaction of occupants towards indoor environment performance and their perception towards the impact of the surrounding buildings on the daylighting and solar radiation reaching to indoor residential spaces. The survey has been simplified by focusing on three parameters and the impact on the urban context of these parameters from occupant's point of view. A 7-point Likert Scale format was used in the questionnaire to evaluate the occupant's satisfaction where -3 represents very unsatisfied and very bad, -2 represents unsatisfied, -1 represents fairly unsatisfied, 0 represents neutral, +1 represent fairly satisfied, +2 represents satisfied and +3 represents very satisfied and very good.

A. *Natural Daylight:*

The participants' answers indicated satisfied and dissatisfied in front spaces which are located facing the main street. Most of occupants who feel dissatisfied in terms of natural lighting inside residential spaces are those who live in apartment buildings that contain at least two or more apartments per floor, so the daylighting is somewhat less than buildings that contain only one apartment per floor. As well as, the daylighting performance was found to be dissatisfactory to the occupants in the buildings which is surrounded by neighboring buildings from all sides as well as occupants who live in apartments located on the ground and first floors and surrounded by adjacent buildings that are higher than the building itself. As these factors contributed to the apartment occupants feeling dissatisfied in terms of natural lighting and its availability inside their apartments.

On the other hand, 50.38% of the respondents were satisfied with the daylighting level in the front spaces facing the main road. Through the analysis, it was clear that in general, the feeling of satisfaction was evident in the apartments on the upper floors, apartments in the buildings which are not surrounded by neighboring buildings from all sides, or when the surrounding buildings were not high and shorter than the target building. In addition, the answers show that males who spend about 8-12 hours per day inside the apartment believed that the lighting was sufficient. The same thing occurs to males over the age of fifty years who spend their entire day in the apartment and insisted that they do not open the blinds during daytime hours. There are some cases in which the building is surrounded from the four sides by neighboring buildings, but it is at a distance that is farther than setback distance or buildings which located on two main streets, in these cases, the effect of surrounding buildings was somewhat slightly on the daylighting performance.

As for sides and rear spaces, 47.01% and 37.32% from the study sample felt satisfied and dissatisfied in these spaces respectively. The satisfied occupants are in the apartments in the upper floors, apartments that have three stories or less and apartments surrounded by buildings from less than three sides. The dissatisfied occupants lived in apartments where the distance between buildings from sides and rear sides are lower than front distance. The dissatisfied percentage is concentrated in the apartments on the lower floors which are surrounded by adjacent buildings from all sides.

The most important part of the daylighting evaluation is how the occupants react and think about urban context and surrounding buildings in blocking natural daylighting from reaching the apartment spaces. 73.1% from the respondents think that the surrounding buildings block the sun from reaching their residential spaces in the multi-story residential building while taking into consideration the existing separation distances between buildings. On the other hand, 22.30% from the occupants disagree with the idea that neighboring buildings block natural daylight. 2.33%, 23.33%, 16.67% and 36.67% _from the 22.30% who disagreed with the idea that neighboring buildings affect or block natural daylight_ are occupants living in apartments surrounded by buildings from one, two, three and four sides respectively. When the building is not surrounded by adjacent buildings from all sides, this can allow natural daylight to reach to the residential spaces more than when the buildings is surrounded from all sides. About 81.82% of respondents who lived in the upper floors and mostly in the last floor were satisfied with the natural daylight even if their apartment was surrounded by adjacent buildings from all sides and 18.18% who lived in the bottom floors and felt satisfied even when their apartments were surrounded by adjacent buildings from all side were males aged more than 50 years old and don't open the blinds during daytime. These results about adjacent buildings indicated that the separation distances between buildings from the occupant's point of view was marked as "not sufficient" performance.

Table A.3: Percentage of occupants which satisfied and dissatisfied in terms of natural daylight inside residential spaces.

Natural daylighting in front spaces.

Unsatisfied				Satisfied		
-3	-2	-1	0	+1	+2	+3
9.16%	8.40%	18.32%	13.74%	16.03%	25.19%	9.16%
35.88%			13.70%	50.38%		

Natural daylighting in sides and rear spaces.

Unsatisfied				Satisfied		
-3	-2	-1	0	+1	+2	+3
10.46%	11.19%	15.67%	15.67%	17.16%	21.65%	8.20%
37.32%			15.67%	47.01%		

B. Solar Radiation:

This section included questions about the users 'satisfaction with the amount of solar radiation that reaches the apartment spaces in summer and winter. The reason for this is when the amount of solar radiation in the winter increase, the energy consumption needed for heating decrease, while on the contrary it increases the amount of energy needed to reach thermal comfort in summer. 76.90% and 72.90% from the occupants think that the surrounding buildings prevent solar radiation from penetrating to the residential spaces in winter and summer respectively. In the winter, 42.31% of the survey sample were satisfied from the amount of solar radiation in their apartments, 9.09% from them lived in buildings that have less than three floors, 38.18% lived in the upper floors, 52.78% from them lived in two apartments per floor buildings, their buildings surrounded by adjacent from three sides and less. On the other hand, in summer, 37.69% from the occupants feel dissatisfied from the amount of solar radiation in which mostly 61.22% from them lived in the upper floors. As for satisfied occupants, 52.11% and 26.76% from them lived in the bottom and in middle floors. The results show that, apartments occupants feel more satisfied according to the solar radiation amount in summer than in winter.

Table A.4: Percentage of occupants which satisfied and dissatisfied in terms of solar radiation amount in summer and winter.

Solar radiation in the winter.

Unsatisfied				Satisfied		
-3	-2	-1	0	+1	+2	+3
16.92%	13.85%	16.15%	10.77%	19.23%	13.85%	9.23%
46.92%			10.77%	42.31%		

Solar radiation in the summer.

Unsatisfied				Satisfied		
-3	-2	-1	0	+1	+2	+3
8.46%	13.08%	16.15%	7.69%	23.85%	14.62%	16.15%
37.69%			7.69%	54.62%		

C. Separation Distances:

The most important part in the POE survey is the question about how the occupants feel about the separating distances between buildings in terms of its effects on daylighting availability, solar radiation and privacy. This question was directed to the residents to know their impression and satisfaction or dissatisfaction with the separating distances between buildings and whether they think it is sufficient or such as daylighting availability throughout the year, solar radiation especially in winter, as well as what is the effect of these distances on the occupants' privacy inside their spaces.

The POE survey results conclude that, occupants who feel satisfied toward the separating distances between buildings lived in buildings that are surrounded by adjacent buildings from one, two or three sides. In addition, in some cases, the separation distances between buildings are more than regulated distances in the local regulation, and this makes the residents feel satisfied with the indoor environment performance which was equal to about 25.38% from all respondents. As for dissatisfied people, 64.62% from the POE sample think that the separating distances are not enough to get adequate daylighting level, privacy and sufficient amount of solar radiation in winter.

Table A.5: Occupants satisfaction toward separation distances between buildings.

Separation distances between buildings

Unsatisfied				Satisfied		
-3	-2	-1	0	+1	+2	+3
22.31%	20.77%	21.54%	10.00%	19.23%	4.62%	1.53%
64.62%			10.00%	25.38%		

D. Privacy:

The main objective of studying the privacy in the multi-story residential buildings is to understand the residents' behavior regarding the use of shading devices inside residential buildings in Palestine, such as internal blinds, and to know the main reason for using these elements which plays a significant role in controlling the amount of natural daylight and solar radiation that enters the indoor spaces. According to the survey, 91.5% from the respondents use internal blinds, 77.30% from them use the blinds in all spaces, 18.50% use it on the rear and side spaces only and about 4.20% use blinds on the front spaces only which is located facing the street. From 77.3% that use blinds, 95.80% used it for privacy reasons and 4.20% to block solar radiation. 95.80% from the occupants open these blinds during daytime, so as to take advantage of the daylight and solar radiation because the main goal from using the blinds is to achieve night privacy. In order to allow natural daylight and solar radiation to enter residential spaces, 91.20% from the occupants' open blinds during daytime throughout the year, 7.00% in the summer months only and 1.80% in the winter months only. These percentages explain the importance of obtaining natural daylight and solar radiation for occupants and that their use of shading elements is only for privacy reasons because the separating distances between buildings does not provide sufficient privacy and at the same time prevents daylight and solar radiation from reaching the building.

As for visual privacy in the residential spaces, 56.59% and 62.01% of the occupants feel dissatisfied in the front and side spaces respectively. Achieving privacy in the side and rear spaces in residential B-Zone is more difficult than in the front spaces, because the separating distance between the buildings from the sides and rear is less than the front distance facing the street and adding its width to the total front distance.

Table A.6: Percentage of occupants which satisfied and dissatisfied in terms of privacy inside residential spaces.

Privacy in the front spaces.

Unsatisfied				Satisfied		
-3	-2	-1	0	+1	+2	+3
14.73%	17.83%	24.03%	13.95%	21.70%	6.20%	1.55%
56.59%			13.95%	29.46%		

Privacy in the sides and rear spaces.

Unsatisfied				Satisfied		
-3	-2	-1	0	+1	+2	+3
15.50%	17.83%	28.68%	11.63%	21.71%	3.88%	0.77%
62.01%			11.63%	26.36%		

Appendix 1D- Residential Building Prototype in Palestine:

8.1.4. D-1 Residential Building Prototype Development Survey structure:

This survey aims to collect information about the most common designs of residential buildings (apartments) in Palestine from engineering offices.

Dear respected engineers:

I am a postgraduate researcher in architecture - sustainable architecture at Palestine Polytechnic University. I am conducting a study on the impact of the setback regulation on the indoor environment performance in residential building in Palestine and I would like to collect information about the most common prototype of apartment building design in Palestine in order to meet educational needs and to support master's thesis. The results of this questionnaire will have a significant impact on guiding the study. Please complete this 5-minute survey and I hope that you will provide the information with accuracy and objectivity, by reading the survey questions carefully. I would like to assure that the information will be private and for academic purposes and that personal privacy will be taken into account. ***Thank you for your participation.***

- **Section one- General Information:**

1- Region (city) to which the engineering office is affiliated?

2- Classification of the engineering office?

☐ Consulting Offices
☐ First-class Engineering Offices
☐ Second-Class Engineering Offices
☐ Third-Class Engineering Offices

- **Section Two- identifying the residential building prototype:**

1- What is the common number of apartments per floor for the majority of residential buildings (apartments) that is usually designed and constructed in your area?

☐ One apartment per floor
☐ Two apartments per floor
☐ Three apartments per floor
☐ Four apartments per floor
☐ More than four apartments per floor

2- What is the average approximate area of the majority of apartments?

☐ Less than 120 square meters
☐ 120 m2 - 130 m^2
☐ 130 m2 – 140 m^2
☐ 140 m2– 150 m^2
☐ More than 150 square meters

3- How many facades are open to the outside environment?

☐ One facade
☐ Two facades
☐ Three facades
☐ Four facades

- **Section Three- The characteristics of the residential building’s envelopee:**

1- What are the common construction materials used in the building's exterior envelopee (external walls), with an explanation of the material thickness and arrangement if possible?

2- What are the common construction materials used in the internal walls (internal partitions) with an explanation of the thicknesses of the materials and their arrangement if possible?

3- What is the type of glass used in windows?

☐ Single Glass
☐ Double Glass
☐ Triple Glass

- **Section Four- The characteristics of the internal residential spaces**

1- What are the dimensions of kitchen, and windows properties (width, height and sill height)?

2- What are the dimensions of guest room, and windows properties (width, height and sill height)?

3- What are the dimensions of living room, and windows properties (width, height and sill height)?

4- What are the dimensions of bedrooms, and windows properties (width, height and sill height)?

What are the dimensions of bathroom, and windows properties (width, height and sill height)?

5- What are the dimensions of living room, and windows properties (width, height and sill height)?

6- Are there external balconies or not, and if there are, please mention the name of the space on which these balconies are located?

8.1.5. D-2 Online Survey Analysis:

1. Section One:

The first section in the questionnaire has aimed to collect information about the engineering offices characteristics such as the location and the engineering office classifications. On average, the sample consists of 41.7% of offices from Ramallah, 16.5% from Hebron, 4.2% from Bethlehem, 4.2% from Jerusalem, and 33.4% from Nablus, Salfite, Tulkarem, and Jenin. About 57.1% of engineering offices were consulting offices, 17.9% first-class engineering offices, 21.4% second class engineering offices, and 3.6% third engineering offices (see Figure 4.13).

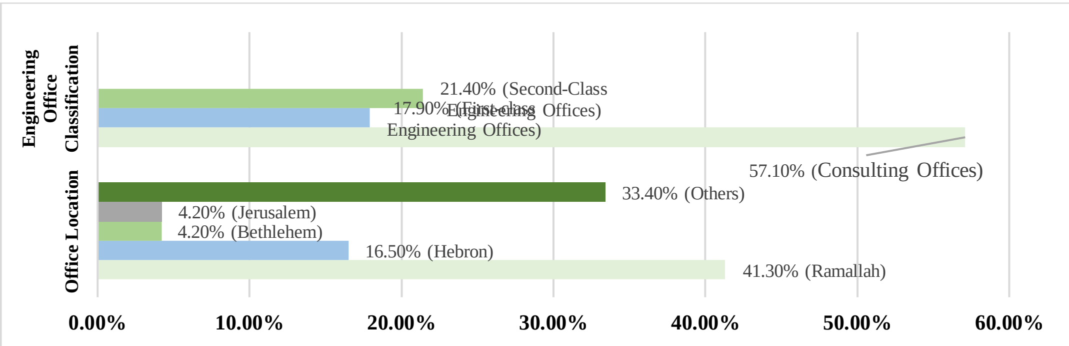


Figure A.7: General information about engineering offices.

2. Section Two:

The main objective of this section was to identify the residential building prototype according to the common design standards followed by engineering offices. In the first phase, the general layout of the residential building prototype was created. 60.7% from the engineering offices designed residential buildings that consist of two apartments per floor, 21.4%, 7.1% designed three apartments per floor, more than four apartments as well as single apartment, and 3.6% designed four apartments per floor. This study will focus on apartments with two residential units per floor and in future studies, more types can be elaborated and studied. The average apartment area was investigated by considering several options. Almost 42.3% of respondents have designed residential apartments with an average area of 140-150 m2, 30.8% designed apartments with an average area of more than 150 m2 in most cases and 19.20% have designed apartments with an average area between 140-130 m2 apartments. Among the cases of more than one apartment on each floor, 61.50% of these apartments designed to be exposed to the outdoor environment from three sides, 19.2 % from two sides and 15.4% partly or totally from four sides.

3. ***Section Three:***

The data collected in this section helped in determining the characteristics of the residential building's envelope. This section mainly consists of three questions. The first one was about the building envelope materials that is usually used in the external walls and their thicknesses. Most responses mentioned that residential buildings envelopes usually consist of 5 -7 cm stone, 13-20 cm concrete, 3 cm insulation material (in some cases) such as air gap (37.5% from the responses use air gap as an insulation material in the external walls) and 10 cm cement block. The second question is about the internal partitions' materials. All responses agreed that 10 cm cement block is the most common covered by 2-3 cm cement plaster on each side. The last question was about the common glazing type that is usually used in apartment buildings. 64% of the responses use double glass in their projects, 32 % and 4% using single and double respectively.

4. ***Section Four:***

The last part of this survey is specialized in the characteristics of the internal residential spaces, their dimensions, and windows properties. In this part, there were differences and varieties between the offices' answers. With regard to the characteristics of windows in all the spaces, most of the answers explain that the height of the windows sill from the ground is about 1.04 meters (about four stone courses). Also, the height of the window itself is about five stone courses (1.30 m) and width of 1.40-1.60 meters. The questionnaire asked questions about the orientation of the residential spaces, there were no answers that could be generalized. As for the dimensions of the internal spaces, there were somewhat similar responses, for example, the kitchen dimensions ranged between 3.50-4.00 m, bedrooms were about 4.00 * 4.00, guest room 4.00 * 6.00, and the living room 4.00 *4.00. Likewise, when asked about the numbers of balconies, most of the responses mentioned that there are usually two balconies in the apartment, one connected to the kitchen or living room and the other to the master bedroom.

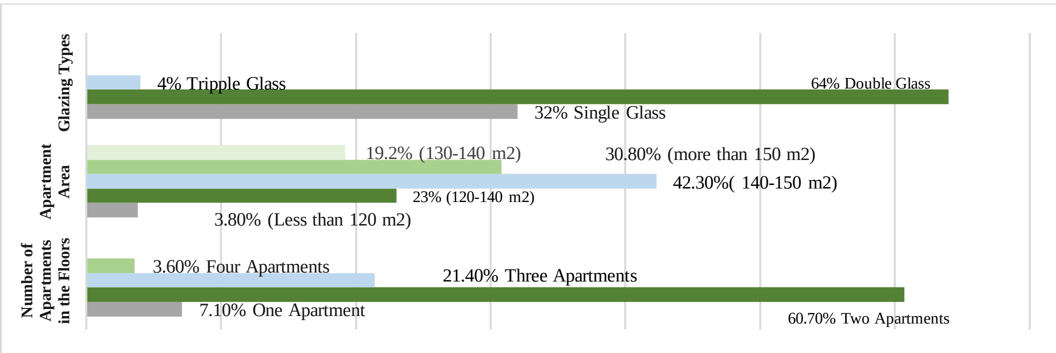


Figure A.8: : Questionnaire answers.

B. Appendix 2:

Appendix 2A: Infiltration Rate Error:

All simulation results in this thesis were based on a value of 3 ac/h for the infiltration rate. When comparing these results with the value determined by ASHRE standard, which is 0.1to 2ac/h in residential buildings (Speert & Legge, 2012), so, there will be an error in the simulation results ranging as in the following table:

Cases	**Infiltration Rate**					
	Heating Loads (for building)			**Cooling Loads(for building)**		
	Infiltration 3 ac/h	**Infiltration 1.5 ac/h**	**Error %**	**Infiltration 3 ac/h**	**Infiltration 1.5 ac/h**	**Error %**
Street Oriented to the North	54.2MWh	20.32MWh	-62.5%	29.30MWh	33.41MWh	+14.0%
Street Oriented to the North-East	54.47MWh	20.59MWh	-62.2%	31.30MWh	35.81MWh	+14.4%
Street Oriented to the East	52.76MWh	19.58MWh	-62.9%	31.76MWh	36.45MWh	+14.8%
Street Oriented to the South-East	51.21MWh	18.83MWh	-63.2%	32.68MWh	37.60MWh	+15.0%
Street Oriented to the South	47.76MWh	17.58MWh	-63.2%	31.12MWh	36.15MWh	+16.2%
Street Oriented to the South-West	50.19MWh	18.91MWh	-62.3%	33.67MWh	39.19MWh	+16.4%
Street Oriented to the West	51.49MWh	19.49MWh	-62.1%	32.49MWh	37.71MWh	+16.1%
Street Oriented to the North-West	52.92MWh	20.31MWh	-61.6%	32.03MWh	37.06MWh	+15.7%

Appendix 2C-Window to Wall Ratio Results:

1- Street oriented to the North:

Table B.1: Heating loads for north oriented street / first floor.

Heating Loads/ First Floor																
WWR	Base case	20%	%	30%	%	40%	%	50%	%	60%	%	70%	%	80%	%	Orientation
Guest Room 1	897	895	-0.22	876	-2.34	857	-4.46	838	-6.58	822	-8.36	806	-10.14	793	-11.59	N
Kitchen 1	645	640	-0.78	614	-4.81	584	-9.46	562	-12.87	537	-16.74	518	-19.69	504	-21.86	N,W
Living Room 1	539	537	-0.37	521	-3.34	501	-7.05	483	-10.39	468	-13.17	452	-16.14	448	-16.88	W
Bed Room 11	449	446	-0.67	431	-4.01	415	-7.57	398	-11.36	387	-13.81	373	-16.93	362	-19.38	W
Bed Room 12	620	610	-1.61	569	-8.23	530	-14.52	496	-20.00	470	-24.19	442	-28.71	420	-32.26	S,W
Master Bed Room 1	544	530	-2.57	501	-7.90	469	-13.79	442	-18.75	419	-22.98	397	-27.02	375	-31.07	S
Guest Room 2	895	893	-0.22	874	-2.35	855	-4.47	836	-6.59	820	-8.38	804	-10.17	789	-11.84	N
Kitchen 2	646	640	-0.93	610	-5.57	583	-9.75	561	-13.16	536	-17.03	516	-20.12	500	-22.60	N,E
Living Room 2	524	524	0.00	507	-3.24	486	-7.25	467	-10.88	452	-13.74	434	-17.18	421	-19.66	E
Bed Room 21	441	438	-0.68	422	-4.31	406	-7.94	388	-12.02	377	-14.51	363	-17.69	351	-20.41	E
Bed Room 22	613	603	-1.63	562	-8.32	522	-14.85	483	-21.21	459	-25.12	429	-30.02	406	-33.77	S,E
Master Bed Room 2	545	530	-2.75	500	-8.26	467	-14.31	439	-19.45	415	-23.85	392	-28.07	369	-32.29	S

Table B.2: Heating loads for north oriented street / second floor.

Heating Loads/ Second Floor																
WWR	Base case	20%	%	30%	%	40%	%	50%	%	60%	%	70%	%	80%	%	Orientation
Guest Room 1	872	869	-0.34	845	-3.10	820	-5.96	797	-8.60	776	-11.01	756	-13.30	740	-15.14	N
Kitchen 1	625	618	-1.12	586	-6.24	549	-12.16	524	-16.16	494	-20.96	471	-24.64	454	-27.36	N,W
Living Room 1	515	514	-0.19	492	-4.47	466	-9.51	444	-13.79	425	-17.48	404	-21.55	399	-22.52	W
Bed Room 11	422	418	-0.95	396	-6.16	373	-11.61	351	-16.82	336	-20.38	318	-24.64	305	-27.73	W
Bed Room 12	562	548	-2.49	491	-12.63	439	-21.89	395	-29.72	364	-35.23	331	-41.10	307	-45.37	S,W
Master Bed Room 1	468	444	-5.13	394	-15.81	342	-26.92	305	-34.83	273	-41.67	244	-47.86	216	-53.85	S
Guest Room 2	869	866	-0.35	842	-3.11	817	-5.98	794	-8.63	774	-10.93	753	-13.35	735	-15.42	N
Kitchen 2	624	617	-1.12	579	-7.21	545	-12.66	520	-16.67	489	-21.63	465	-25.48	446	-28.53	N,E
Living Room 2	499	498	-0.20	475	-4.81	449	-10.02	427	-14.43	407	-18.44	385	-22.85	368	-26.25	E
Bed Room 21	415	411	-0.96	388	-6.51	365	-12.05	341	-17.83	327	-21.20	309	-25.54	294	-29.16	E
Bed Room 22	554	541	-2.35	483	-12.82	429	-22.56	379	-31.59	350	-36.82	316	-42.96	290	-47.65	S,E
Master Bed Room 2	469	445	-5.12	394	-15.99	341	-27.29	303	-35.39	271	-42.22	241	-48.61	212	-54.80	S

Table B.3: Heating loads for north oriented street / third floor.

Heating Loads/ Third Floor																
WWR	Base case	20%	%	30%	%	40%	%	50%	%	60%	%	70%	%	80%	%	Orientation
Guest Room 1	968	964	-0.41	934	-3.51	903	-6.71	875	-9.61	849	-12.29	823	-14.98	802	-17.15	N
Kitchen 1	642	632	-1.56	593	-7.63	548	-14.64	518	-19.31	480	-25.23	453	-29.44	433	-32.55	N,W
Living Room 1	530	527	-0.57	498	-6.04	464	-12.45	436	-17.74	412	-22.26	385	-27.36	379	-28.49	W
Bed Room 11	442	435	-1.58	404	-8.60	372	-15.84	344	-22.17	323	-26.92	299	-32.35	282	-36.20	W
Bed Room 12	533	514	-3.56	440	-17.45	375	-29.64	325	-39.02	288	-45.97	252	-52.72	227	-57.41	S,W
Master Bed Room 1	421	388	-7.84	322	-23.52	257	-38.95	213	-49.41	179	-57.48	149	-64.61	122	-71.02	S
Guest Room 2	965	961	-0.41	931	-3.52	901	-6.63	873	-9.53	848	-12.12	823	-14.72	800	-17.10	N
Kitchen 2	639	630	-1.41	583	-8.76	542	-15.18	512	-19.87	474	-25.82	446	-30.20	422	-33.96	N,E
Living Room 2	510	508	-0.39	479	-6.08	446	-12.55	417	-18.24	392	-23.14	364	-28.63	342	-32.94	E
Bed Room 21	436	430	-1.38	399	-8.49	369	-15.37	338	-22.48	319	-26.83	295	-32.34	276	-36.70	E
Bed Room 22	532	513	-3.57	439	-17.48	373	-29.89	315	-40.79	282	-46.99	243	-54.32	215	-59.59	S,E
Master Bed Room 2	427	394	-7.73	328	-23.19	263	-38.41	219	-48.71	185	-56.67	154		128	-70.02	S

Table B.4: Heating loads for north oriented street / fourth floor.

Heating Loads/ Fourth Floor																
WWR	Base case	20%	%	30%	%	40%	%	50%	%	60%	%	70%	%	80%	%	Orientation
Guest Room 1	1779	1774	-0.28	1734	-2.53	1698	-4.55	1662	-6.58	1627	-8.54	1593	-10.46	1565	-12.03	N
Kitchen 1	948	935	-1.37	887	-6.43	830	-12.45	792	-16.46	743	-21.62	707	-25.42	680	-28.27	N,W
Living Room 1	828	825	-0.36	787	-4.95	744	-10.14	709	-14.37	676	-18.36	638	-22.95	631	-23.79	W
Bed Room 11	762	749	-1.71	700	-8.14	654	-14.17	616	-19.16	579	-24.02	540	-29.13	512	-32.81	W
Bed Room 12	822	790	-3.89	687	-16.42	595	-27.62	533	-35.16	470	-42.82	416	-49.39	381	-53.65	S,W
Master Bed Room 1	798	758	-5.01	670	-16.04	576	-27.82	509	-36.22	451	-43.48	397	-50.25	348	-56.39	S
Guest Room 2	1779	1774	-0.28	1737	-2.36	1700	-4.44	1665	-6.41	1632	-8.26	1599	-10.12	1568	-11.86	N
Kitchen 2	950	938	-1.26	880	-7.37	827	-12.95	789	-16.95	739	-22.21	702	-26.11	670	-29.47	N,E
Living Room 2	810	808	-0.25	771	-4.81	727	-10.25	689	-14.94	656	-19.01	618	-23.70	588	-27.41	E
Bed Room 21	749	736	-1.74	689	-8.01	642	-14.29	601	-19.76	566	-24.43	526	-29.77	495	-33.91	E
Bed Room 22	825	794	-3.76	691	-16.24	596	-27.76	522	-36.73	464	-43.76	404	-51.03	364	-55.88	S,E
Master Bed Room 2	805	766	-4.84	679	-15.65	585	-27.33	517	-35.78	460	-42.86	406	-49.57	358	-55.53	S

Table B.5: Cooling loads for north oriented street / first floor.

Cooling Loads/ First Floor																
WWR	Base case	20%	%	30%	%	40%	%	50%	%	60%	%	70%	%	80%	%	Orientation
Guest Room 1	629	632	0.48	664	5.56	701	11.45	736	17.01	770	22.42	806	28.14	838	33.23	N
Kitchen 1	211	217	2.84	251	18.96	299	41.71	336	59.24	386	82.94	430	103.79	472	123.70	N,W

Living Room 1	221	222	0.45	245	10.86	275	24.43	305	38.01	333	50.68	369	66.97	377	70.59	W
Bed Room 11	231	236	2.16	258	11.69	281	21.65	304	31.60	325	40.69	351	51.95	372	61.04	W
Bed Room 12	256	269	5.08	321	25.39	379	48.05	435	69.92	494	92.97	570	122.66	637	148.83	S,W
Master Bed Room 1	305	323	5.90	369	20.98	430	40.98	485	59.02	540	77.05	603	97.70	673	120.66	S
Guest Room 2	624	628	0.64	660	5.77	695	11.38	728	16.67	762	22.12	797	27.72	831	33.17	N
Kitchen 2	208	214	2.88	250	20.19	299	43.75	323	55.29	368	76.92	408	96.15	448	115.38	N,E
Living Room 2	219	220	0.46	242	10.50	271	23.74	299	36.53	326	48.86	360	64.38	391	78.54	E
Bed Room 21	227	232	2.20	253	11.45	275	21.15	298	31.28	318	40.09	343	51.10	366	61.23	E
Bed Room 22	252	264	4.76	312	23.81	365	44.84	420	66.67	470	86.51	538	113.49	601	138.49	S,E
Master Bed Room 2	311	329	5.79	375	20.58	435	39.87	490	57.56	545	75.24	608	95.50	678	118.01	S

Table B.6: Cooling loads for north oriented street / second floor.

Cooling Loads/ Second Floor																
WWR	Base case	20%	%	30%	%	40%	%	50%	%	60%	%	70%	%	80%	%	Orientation
Guest Room 1	679	684	0.74	726	6.92	776	14.29	823	21.21	870	28.13	919	35.35	962	41.68	N
Kitchen 1	237	247	4.22	293	23.63	362	52.74	415	75.11	489	106.33	555	134.18	616	159.92	N,W
Living Room 1	253	255	0.79	290	14.62	337	33.20	383	51.38	427	68.77	486	92.09	498	96.84	W
Bed Room 11	258	264	2.33	294	13.95	328	27.13	364	41.09	393	52.33	432	67.44	464	79.84	W
Bed Room 12	288	306	6.25	379	31.60	464	61.11	549	90.63	637	121.18	750	160.42	850	195.14	S,W
Master Bed Room 1	339	364	7.37	429	26.55	519	53.10	301	-11.21	684	101.77	778	129.50	882	160.18	S
Guest Room 2	675	680	0.74	722	6.96	769	13.93	813	20.44	860	27.41	906	34.22	952	41.04	N
Kitchen 2	235	244	3.83	294	25.11	350	48.94	397	68.94	463	97.02	521	121.70	580	146.81	N,E
Living Room 2	252	254	0.79	286	13.49	330	30.95	373	48.02	414	64.29	469	86.11	517	105.16	E
Bed Room 21	252	259	2.78	287	13.89	319	26.59	354	40.48	381	51.19	418	65.87	451	78.97	E
Bed Room 22	283	300	6.01	366	29.33	442	56.18	522	84.45	596	110.60	697	146.29	787	178.09	S,E
Master Bed Room 2	346	370	6.94	435	25.72	524	51.45	605	74.86	686	98.27	780	125.43	884	155.49	S

Table B.7: Cooling loads for north oriented street / third floor.

Cooling Loads/ Third Floor																
WWR	Base case	20%	%	30%	%	40%	%	50%	%	60%	%	70%	%	80%	%	Orientation
Guest Room 1	750	756	0.80	806	7.47	866	15.47	921	22.80	978	30.40	1037	38.27	1088	45.07	N
Kitchen 1	289	304	5.19	370	28.03	469	62.28	546	88.93	658	127.68	758	162.28	851	194.46	N,W
Living Room 1	314	318	1.27	372	18.47	446	42.04	519	65.29	593	88.85	690	119.75	707	125.16	W
Bed Room 11	309	318	2.91	365	18.12	418	35.28	476	54.05	522	68.93	586	89.64	637	106.15	W
Bed Room 12	343	367	7.00	467	36.15	585	70.55	703	104.96	825	140.52	981	186.01	1119	226.24	S,W
Master Bed Room 1	373	401	7.51	477	27.88	584	56.57	681	82.57	780	109.12	891	138.87	1016	172.39	S
Guest Room 2	745	751	0.81	800	7.38	855	14.77	908	21.88	962	29.13	1019	36.78	1075	44.30	N
Kitchen 2	287	300	4.53	371	29.27	450	56.79	516	79.79	615	114.29	698	143.21	785	173.52	N,E

Living Room 2	311	314	0.96	363	16.72	428	37.62	494	58.84	560	80.06	646	107.72	722	132.15	E
Bed Room 21	300	308	2.67	350	16.67	397	32.33	448	49.33	488	62.67	544	81.33	593	97.67	E
Bed Room 22	334	355	6.29	443	32.63	544	62.87	652	95.21	751	124.85	885	164.97	1003	200.30	S,E
Master Bed Room 2	380	408	7.37	483	27.11	589	55.00	686	80.53	782	105.79	893	135.00	1016	167.37	S

Table B.8: Cooling loads for north oriented street / fourth floor.

Cooling Loads/ Fourth Floor																
WWR	Base case	20%	%	30%	%	40%	%	50%	%	60%	%	70%	%	80%	%	Orientation
Guest Room 1	969	976	0.72	1028	6.09	1089	12.38	1145	18.16	1203	24.15	1264	30.44	1315	35.71	N
Kitchen 1	416	435	4.57	516	24.04	642	54.33	738	77.40	878	111.06	1003	141.11	1125	170.43	N,W
Living Room 1	460	464	0.87	535	16.30	632	37.39	729	58.48	826	79.57	958	108.26	977	112.39	W
Bed Room 11	481	502	4.37	592	23.08	694	44.28	793	64.86	896	86.28	1030	114.14	1140	137.01	W
Bed Room 12	510	545	6.86	689	35.10	857	68.04	1007	97.45	1191	133.53	1417	177.84	1616	216.86	S,W
Master Bed Room 1	486	514	5.76	585	20.37	680	39.92	768	58.02	860	76.95	964	98.35	1080	122.22	S
Guest Room 2	964	971	0.73	1023	6.12	1080	12.03	1135	17.74	1192	23.65	1251	29.77	1308	35.68	N
Kitchen 2	412	428	3.88	515	25.00	613	48.79	693	68.20	808	96.12	907	120.15	1009	144.90	N,E
Living Room 2	450	453	0.67	515	14.44	601	33.56	686	52.44	766	70.22	874	94.22	969	115.33	E
Bed Room 21	466	484	3.86	563	20.82	651	39.70	737	58.15	821	76.18	930	99.57	1024	119.74	E
Bed Room 22	493	524	6.29	650	31.85	797	61.66	940	90.67	1085	120.08	1272	158.01	1434	190.87	S,E
Master Bed Room 2	497	524	5.43	594	19.52	688	38.43	777	56.34	867	74.45	970	95.17	1084	118.11	S

2- Street oriented to the North-East:

Table B.9: Heating loads for north-east oriented street / first floor.

Heating Loads/ First Floor																
WWR	Base case	20%	%	30%	%	40%	%	50%	%	60%	%	70%	%	80%	%	Orientation
Guest Room 1	889	887	-0.22	868	-2.36	850	-4.39	831	-6.52	815	-8.32	800	-10.01	786	-11.59	
Kitchen 1	656	652	-0.61	629	-4.12	602	-8.23	583	-11.13	560	-14.63	543	-17.23	530	-19.21	
Living Room 1	561	560	-0.18	548	-2.32	533	-4.99	519	-7.49	508	-9.45	496	-11.59	493	-12.12	
Bed Room 11	469	466	-0.64	455	-2.99	444	-5.33	434	-7.46	425	-9.38	416	-11.30	408	-13.01	
Bed Room 12	680	673	-1.03	644	-5.29	619	-8.97	596	-12.35	576	-15.29	555	-18.38	540	-20.59	
Master Bed Room 1	566	554	-2.12	528	-6.71	498	-12.01	474	-16.25	453	-19.96	432	-23.67	412	-27.21	
Guest Room 2	864	861	-0.35	839	-2.89	817	-5.44	795	-7.99	776	-10.19	757	-12.38	740	-14.35	
Kitchen 2	605	598	-1.16	563	-6.94	531	-12.23	508	-16.03	479	-20.83	457	-24.46	439	-27.44	
Living Room 2	508	506	-0.39	487	-4.13	464	-8.66	444	-12.60	427	-15.94	408	-19.69	393	-22.64	
Bed Room 21	432	429	-0.69	412	-4.63	394	-8.80	375	-13.19	363	-15.97	348	-19.44	335	-22.45	
Bed Room 22	576	564	-2.08	518	-10.07	474	-17.71	434	-24.65	408	-29.17	378	-34.38	356	-38.19	
Master Bed Room 2	542	528	-2.58	498	-8.12	464	-14.39	437	-19.37	414	-23.62	391	-27.86	370	-31.73	

Table B.10: Heating loads for north-east oriented street /second floor.

Heating Loads/ second Floor																
WWR	Base case	20%	%	30%	%	40%	%	50%	%	60%	%	70%	%	80%	%	Orientation
Guest Room 1	868	865	-0.35	842	-3.00	819	-5.65	797	-8.18	778	-10.37	759	-12.56	743	-14.40	
Kitchen 1	646	640	-0.93	613	-5.11	582	-9.91	560	-13.31	535	-17.18	516	-20.12	501	-22.45	
Living Room 1	549	548	-0.18	533	-2.91	515	-6.19	499	-9.11	485	-11.66	471	-14.21	467	-14.94	
Bed Room 11	454	451	-0.66	436	-3.96	422	-7.05	408	-10.13	398	-12.33	386	-14.98	377	-16.96	
Bed Room 12	648	638	-1.54	599	-7.56	565	-12.81	534	-17.59	509	-21.45	483	-25.46	463	-28.55	
Master Bed Room 1	526	507	-3.61	469	-10.84	427	-18.82	396	-24.71	369	-29.85	343	-34.79	318	-39.54	
Guest Room 2	833	829	-0.48	800	-3.96	771	-7.44	745	-10.56	721	-13.45	697	-16.33	676	-18.85	
Kitchen 2	571	562	-1.58	517	-9.46	477	-16.46	448	-21.54	412	-27.85	386	-32.40	364	-36.25	
Living Room 2	465	464	-0.22	435	-6.45	403	-13.33	377	-18.92	353	-24.09	328	-29.46	310	-33.33	
Bed Room 21	406	402	-0.99	377	-7.14	352	-13.30	327	-19.46	312	-23.15	292	-28.08	277	-31.77	
Bed Room 22	535	518	-3.18	460	-14.02	406	-24.11	360	-32.71	331	-38.13	298	-44.30	274	-48.79	
Master Bed Room 2	507	488	-3.75	446	-12.03	402	-20.71	368	-27.42	341	-32.74	313	-38.26	288	-43.20	

Table B.11: Heating loads for north-east oriented street / third floor.

Heating Loads/ Third Floor																
WWR	Base case	20%	%	30%	%	40%	%	50%	%	60%	%	70%	%	80%	%	Orientation
Guest Room 1	970	967	-0.31	940	-3.09	913	-5.88	887	-8.56	864	-10.93	841	-13.30	822	-15.26	
Kitchen 1	680	673	-1.03	642	-5.59	607	-10.74	583	-14.26	553	-18.68	531	-21.91	514	-24.41	
Living Room 1	583	582	-0.17	563	-3.43	541	-7.20	522	-10.46	504	-13.55	487	-16.47	483	-17.15	
Bed Room 11	489	484	-1.02	464	-5.11	445	-9.00	428	-12.47	413	-15.54	397	-18.81	385	-21.27	
Bed Room 12	643	629	-2.18	574	-10.73	524	-18.51	485	-24.57	450	-30.02	416	-35.30	390	-39.35	
Master Bed Room 1	523	497	-4.97	444	-15.11	389	-25.62	350	-33.08	315	-39.77	284	-45.70	256	-51.05	
Guest Room 2	919	914	-0.54	877	-4.57	840	-8.60	807	-12.19	775	-15.67	745	-18.93	717	-21.98	
Kitchen 2	560	547	-2.32	487	-13.04	434	-22.50	398	-28.93	351	-37.32	321	-42.68	294	-47.50	
Living Room 2	446	444	-0.45	404	-9.42	359	-19.51	325	-27.13	295	-33.86	263	-41.03	240	-46.19	
Bed Room 21	407	399	-1.97	361	-11.30	325	-20.15	290	-28.75	269	-33.91	243	-40.29	223	-45.21	
Bed Room 22	512	490	-4.30	414	-19.14	349	-31.84	297	-41.99	262	-48.83	225	-56.05	199	-61.13	
Master Bed Room 2	510	483	-5.29	429	-15.88	373	-26.86	332	-34.90	298	-41.57	266	-47.8431	237	-53.53	

Table B.12: Heating loads for north-east oriented street /fourth floor.

Heating Loads/ Fourth Floor

WWR	Base case	20%	%	30%	%	40%	%	50%	%	60%	%	70%	%	80%	%	Orientation
Guest Room 1	1787	1784	-0.17	1750	-2.07	1716	-3.97	1683	-5.82	1653	-7.50	1623	-9.18	1596	-10.69	
Kitchen 1	1006	998	-0.80	962	-4.37	920	-8.55	890	-11.53	853	-15.21	825	-17.99	804	-20.08	
Living Room 1	908	906	-0.22	882	-2.86	855	-5.84	831	-8.48	810	-10.79	785	-13.55	780	-14.10	
Bed Room 11	834	825	-1.08	796	-4.56	766	-8.15	743	-10.91	718	-13.91	692	-17.03	673	-19.30	
Bed Room 12	934	918	-1.71	839	-10.17	765	-18.09	719	-23.02	659	-29.44	609	-34.80	574	-38.54	
Master Bed Room 1	881	848	-3.75	779	-11.58	702	-20.32	646	-26.67	595	-32.46	548	-37.80	503	-42.91	
Guest Room 2	1723	1717	-0.35	1670	-3.08	1623	-5.80	1578	-8.42	1536	-10.85	1494	-13.29	1456	-15.50	
Kitchen 2	845	827	-2.13	747	-11.60	675	-20.12	624	-26.15	560	-33.73	514	-39.17	473	-44.02	
Living Room 2	712	709	-0.42	655	-8.01	591	-16.99	537	-24.58	491	-31.04	441	-38.06	402	-43.54	
Bed Room 21	675	657	-2.67	591	-12.44	527	-21.93	474	-29.78	430	-36.30	382	-43.41	347	-48.59	
Bed Room 22	781	748	-4.23	639	-18.18	544	-30.35	472	-39.56	416	-46.73	361	-53.78	323	-58.64	
Master Bed Room 2	860	826	-3.95	754	-12.33	678	-21.16	620	-27.91	570	-33.72	522	-39.30	478	-44.42	

Table B.13: Cooling loads for north-east oriented street / first floor.

Cooling Loads/ First Floor																
WWR	Base case	20%	%	30%	%	40%	%	50%	%	60%	%	70%	%	80%	%	Orientation
Guest Room 1	688	693	0.73	741	7.70	797	15.84	852	23.84	906	31.69	964	40.12	1019	48.11	
Kitchen 1	229	236	3.06	277	20.96	330	44.10	372	62.45	428	86.90	478	108.73	522	127.95	
Living Room 1	226	227	0.44	251	11.06	282	24.78	312	38.05	340	50.44	376	66.37	385	70.35	
Bed Room 11	340	245	-27.94	269	-20.88	296	-12.94	325	-4.41	347	2.06	378	11.18	404	18.82	
Bed Room 12	257	269	4.67	321	24.90	379	47.47	435	69.26	491	91.05	561	118.29	624	142.80	
Master Bed Room 1	309	330	6.80	382	23.62	451	45.95	512	65.70	572	85.11	640	107.12	718	132.36	
Guest Room 2	714	720	0.84	774	8.40	835	16.95	895	25.35	956	33.89	1021	43.00	1085	51.96	
Kitchen 2	312	326	4.49	406	30.13	497	59.29	576	84.62	685	119.55	782	150.64	877	181.09	
Living Room 2	263	265	0.76	299	13.69	345	31.18	391	48.67	435	65.40	492	87.07	542	106.08	
Bed Room 21	233	239	2.58	261	12.02	286	22.75	310	33.05	332	42.49	359	54.08	382	63.95	
Bed Room 22	256	269	5.08	321	25.39	379	48.05	437	70.70	491	91.80	561	119.14	623	143.36	
Master Bed Room 2	305	325	6.56	373	22.30	436	42.95	492	61.31	574	88.20	611	100.33	682	123.61	

Table B.14: Cooling loads for north-east oriented street / second floor.

Cooling Loads/ second Floor																
WWR	Base case	20%	%	30%	%	40%	%	50%	%	60%	%	70%	%	80%	%	Orientation
Guest Room 1	748	754	0.80	819	9.49	892	19.25	965	29.01	1038	38.77	1117	49.33	1190	59.09	
Kitchen 1	254	263	3.54	317	24.80	388	52.76	445	75.20	522	105.51	590	132.28	649	155.51	
Living Room 1	252	254	0.79	286	13.49	330	30.95	373	48.02	413	63.89	464	84.13	477	89.29	
Bed Room 11	266	272	2.26	305	14.66	343	28.95	382	43.61	413	55.26	457	71.80	494	85.71	

Bed Room 12	293	310	5.80	383	30.72	468	59.73	552	88.40	634	116.38	738	151.88	833	184.30	
Master Bed Room 1	359	389	8.36	466	29.81	570	58.77	664	84.96	758	111.14	865	140.95	987	174.93	
Guest Room 2	779	787	1.03	859	10.27	940	20.67	1021	31.07	1103	41.59	1191	52.89	1277	63.93	
Kitchen 2	348	365	4.89	469	34.77	588	68.97	693	99.14	836	140.23	965	177.30	1092	213.79	
Living Room 2	305	308	0.98	358	17.38	426	39.67	495	62.30	562	84.26	649	112.79	726	138.03	
Bed Room 21	259	266	2.70	296	14.29	330	27.41	365	40.93	394	52.12	432	66.80	465	79.54	
Bed Room 22	294	312	6.12	385	30.95	470	59.86	560	90.48	639	117.35	744	153.06	835	184.01	
Master Bed Room 2	356	386	8.43	459	28.93	557	56.46	645	81.18	734	106.18	836	134.83	951	167.13	

Table B.15: Cooling loads for north-east oriented street / third floor.

Cooling Loads/ Third Floor																
WWR	Base case	20%	%	30%	%	40%	%	50%	%	60%	%	70%	%	80%	%	Orientation
Guest Room 1	819	827	0.98	900	9.89	985	20.27	1068	30.40	1152	40.66	1243	51.77	1325	61.78	
Kitchen 1	294	306	4.08	373	26.87	463	57.48	535	81.97	634	115.65	722	145.58	798	171.43	
Living Room 1	294	296	0.68	340	15.65	398	35.37	456	55.10	511	73.81	583	98.30	598	103.40	
Bed Room 11	305	314	2.95	358	17.38	407	33.44	458	50.16	501	64.26	559	83.28	608	99.34	
Bed Room 12	344	365	6.10	461	34.01	571	65.99	680	97.67	790	129.65	930	170.35	1056	206.98	
Master Bed Room 1	412	450	9.22	549	33.25	683	65.78	804	95.15	928	125.24	1069	159.47	1229	198.30	
Guest Room 2	850	859	1.06	939	10.47	1031	21.29	1122	32.00	1215	42.94	1314	54.59	1411	66.00	
Kitchen 2	387	406	4.91	526	35.92	665	71.83	786	103.10	955	146.77	1106	185.79	1255	224.29	
Living Room 2	358	362	1.12	426	18.99	516	44.13	609	70.11	698	94.97	815	127.65	919	156.70	
Bed Room 21	300	308	2.67	350	16.67	396	32.00	446	48.67	487	62.33	541	80.33	589	96.33	
Bed Room 22	351	374	6.55	475	35.33	595	69.52	724	106.27	835	137.89	982	179.77	1107	215.38	
Master Bed Room 2	415	452	8.92	548	32.05	679	63.61	798	92.29	918	121.20	1056	154.46	1211	191.81	

Table B.16: Cooling loads for north-east oriented street /fourth floor.

Cooling Loads/ Fourth Floor																
WWR	Base case	20%	%	30%	%	40%	%	50%	%	60%	%	70%	%	80%	%	Orientation
Guest Room 1	1028	1036	0.78	1108	7.78	1189	15.66	1269	23.44	1349	31.23	1434	39.49	1511	46.98	
Kitchen 1	405	420	3.70	496	22.47	597	47.41	676	66.91	787	94.32	885	118.52	971	139.75	
Living Room 1	409	412	0.73	462	12.96	527	28.85	591	44.50	653	59.66	735	79.71	750	83.37	
Bed Room 11	440	455	3.41	518	17.73	588	33.64	653	48.41	721	63.86	806	83.18	877	99.32	
Bed Room 12	506	541	6.92	679	34.19	839	65.81	978	93.28	1165	130.24	1385	173.72	1580	212.25	
Master Bed Room 1	530	569	7.36	667	25.85	800	50.94	917	73.02	1041	96.42	1182	123.02	1344	153.58	
Guest Room 2	1052	1061	0.86	1138	8.17	1225	16.44	1310	24.52	1396	32.70	1486	41.25	1574	49.62	
Kitchen 2	474	494	4.22	609	28.48	740	56.12	854	80.17	1013	113.71	1154	143.46	1295	173.21	
Living Room 2	465	469	0.86	535	15.05	628	35.05	724	55.70	815	75.27	938	101.72	1045	124.73	
Bed Room 21	460	479	4.13	555	20.65	641	39.35	724	57.39	811	76.30	919	99.78	1007	118.91	

Bed Room 22	526	564	7.22	716	36.12	897	70.53	1074	104.18	1250	137.64	1476	180.61	1671	217.68	
Master Bed Room 2	541	580	7.21	679	25.51	812	50.09	931	72.09	1054	94.82	1196	121.07	1357	150.83	

3- Street oriented to East:

Table B.17: Heating loads for east oriented street / first floor.

Heating Loads/ First Floor																
WWR	Base case	20%	%	30%	%	40%	%	50%	%	60%	%	70%	%	80%	%	Orientation
Guest Room 1	803	799	-0.50	764	-4.86	730	-9.09	698	-13.08	670	-16.56	643	-19.93	620	-22.79	
Kitchen 1	608	602	-0.99	568	-6.58	535	-12.01	510	-16.12	481	-20.89	460	-24.34	444	-26.97	
Living Room 1	558	557	-0.18	542	-2.87	525	-5.91	510	-8.60	497	-10.93	484	-13.26	479	-14.16	
Bed Room 11	472	470	-0.42	459	-2.75	448	-5.08	438	-7.20	430	-8.90	421	-10.81	414	-12.29	
Bed Room 12	712	706	-0.84	676	-5.06	662	-7.02	643	-9.69	625	-12.22	607	-14.75	594	-16.57	
Master Bed Room 1	591	581	-1.69	560	-5.25	536	-9.31	516	-12.69	499	-15.57	481	-18.61	464	-21.49	
Guest Room 2	761	756	-0.66	716	-5.91	677	-11.04	643	-15.51	611	-19.71	582	-23.52	555	-27.07	
Kitchen 2	497	487	-2.01	432	-13.08	384	-22.74	350	-29.58	310	-37.63	283	-43.06	262	-47.28	
Living Room 2	483	481	-0.41	456	-5.59	429	-11.18	407	-15.73	386	-20.08	363	-24.84	345	-28.57	
Bed Room 21	430	427	-0.70	408	-5.12	390	-9.30	372	-13.49	359	-16.51	344	-20.00	331	-23.02	
Bed Room 22	608	596	-1.97	552	-9.21	511	-15.95	477	-21.55	449	-26.15	421	-30.76	399	-34.38	
Master Bed Room 2	575	564	-1.91	538	-6.43	510	-11.30	487	-15.30	467	-18.78	448	-22.09	429	-25.39	

Table B.18: Heating loads for east oriented street / second floor.

Heating Loads/ second Floor																
WWR	Base case	20%	%	30%	%	40%	%	50%	%	60%	%	70%	%	80%	%	Orientation
Guest Room 1	770	766	-0.52	724	-5.97	684	-11.17	647	-15.97	614	-20.26	584	-24.16	556	-27.79	
Kitchen 1	591	584	-1.18	544	-7.95	506	-14.38	478	-19.12	446	-24.53	421	-28.76	404	-31.64	
Living Room 1	547	546	-0.18	528	-3.47	508	-7.13	491	-10.24	475	-13.16	459	-16.09	453	-17.18	
Bed Room 11	461	458	-0.65	445	-3.47	432	-6.29	420	-8.89	410	-11.06	400	-13.23	391	-15.18	
Bed Room 12	698	690	-1.15	662	-5.16	635	-9.03	612	-12.32	591	-15.33	570	-18.34	554	-20.63	
Master Bed Room 1	570	557	-2.28	529	-7.19	498	-12.63	473	-17.02	451	-20.88	429	-24.74	409	-28.25	
Guest Room 2	713	708	-0.70	658	-7.71	610	-14.45	567	-20.48	528	-25.95	491	-31.14	459	-35.62	
Kitchen 2	453	440	-2.87	373	-17.66	316	-30.24	279	-38.41	235	-48.12	207	-54.30	185	-59.16	
Living Room 2	428	425	-0.70	388	-9.35	350	-18.22	319	-25.47	290	-32.24	261	-39.02	239	-44.16	
Bed Room 21	391	385	-1.53	356	-8.95	328	-16.11	302	-22.76	284	-27.37	263	-32.74	247	-36.83	
Bed Room 22	532	514	-3.38	450	-15.41	395	-25.75	352	-33.83	318	-40.23	285	-46.43	262	-50.75	
Master Bed Room 2	542	526	-2.95	491	-9.41	454	-16.24	424	-21.77	399	-26.38	375	-30.81	352	-35.06	

Table B.19: Heating loads for east oriented street / third floor.

Heating Loads/ Third Floor																
WWR	Base case	20%	%	30%	%	40%	%	50%	%	60%	%	70%	%	80%	%	Orientation
Guest Room 1	866	861	-0.58	813	-6.12	767	-11.43	724	-16.40	684	-21.02	648	-25.17	615	-28.98	
Kitchen 1	624	617	-1.12	572	-8.33	530	-15.06	498	-20.19	462	-25.96	434	-30.45	415	-33.49	
Living Room 1	588	587	-0.17	566	-3.74	543	-7.65	523	-11.05	505	-14.12	487	-17.18	480	-18.37	
Bed Room 11	504	500	-0.79	484	-3.97	468	-7.14	454	-9.92	441	-12.50	427	-15.28	417	-17.26	
Bed Room 12	724	714	-1.38	677	-6.49	642	-11.33	614	-15.19	585	-19.20	559	-22.79	539	-25.55	
Master Bed Room 1	600	582	-3.00	545	-9.17	504	-16.00	473	-21.17	445	-25.83	418	-30.33	392	-34.67	
Guest Room 2	784	776	-1.02	714	-8.93	654	-16.58	601	-23.34	552	-29.59	507	-35.33	467	-40.43	
Kitchen 2	428	409	-4.44	328	-23.36	262	-38.79	221	-48.36	174	-59.35	146	-65.89	126	-70.56	
Living Room 2	371	367	-1.08	311	-16.17	261	-29.65	223	-39.89	188	-49.33	155	-58.22	133	-64.15	
Bed Room 21	373	365	-2.14	320	-14.21	280	-24.93	243	-34.85	221	-40.75	194	-47.99	175	-53.08	
Bed Room 22	488	465	-4.71	386	-20.90	320	-34.43	271	-44.47	237	-51.43	203	-58.40	179	-63.32	
Master Bed Room 2	565	545	-3.54	500	-11.50	453	-19.82	417	-26.19	386	-31.68	355	-37.17	328	-41.95	

Table B.20: Heating loads for east oriented street / fourth floor.

Heating Loads/ Fourth Floor																
WWR	Base case	20%	%	30%	%	40%	%	50%	%	60%	%	70%	%	80%	%	Orientation
Guest Room 1	1685	1680	-0.30	1624	-3.62	1568	-6.94	1515	-10.09	1465	-13.06	1417	-15.91	1374	-18.46	
Kitchen 1	958	950	-0.84	899	-6.16	849	-11.38	812	-15.24	765	-20.15	731	-23.70	707	-26.20	
Living Room 1	930	928	-0.22	904	-2.80	877	-5.70	853	-8.28	831	-10.65	807	-13.23	801	-13.87	
Bed Room 11	858	852	-0.70	828	-3.50	804	-6.29	785	-8.51	764	-10.96	743	-13.40	728	-15.15	
Bed Room 12	1056	1037	-1.80	983	-6.91	933	-11.65	897	-15.06	852	-19.32	813	-23.01	785	-25.66	
Master Bed Room 1	980	957	-2.35	910	-7.14	858	-12.45	818	-16.53	779	-20.51	742	-24.29	704	-28.16	
Guest Room 2	1588	1578	-0.63	1503	-5.35	1426	-10.20	1355	-14.67	1290	-18.77	1226	-22.80	1168	-26.45	
Kitchen 2	721	700	-2.91	596	-17.34	506	-29.82	445	-38.28	376	-47.85	329	-54.37	293	-59.36	
Living Room 2	643	638	-0.78	572	-11.04	496	-22.86	435	-32.35	387	-39.81	337	-47.59	301	-53.19	
Bed Room 21	642	623	-2.96	548	-14.64	481	-25.08	428	-33.33	384	-40.19	339	-47.20	309	-51.87	
Bed Room 22	794	762	-4.03	656	-17.38	562	-29.22	492	-38.04	437	-44.96	382	-51.89	344	-56.68	
Master Bed Room 2	940	916	-2.55	863	-8.19	804	-14.47	758	-19.36	715	-23.94	673	-28.40	633	-32.66	

Table B.21: Cooling loads for east oriented street / first floor.

Cooling Loads/ First Floor																
WWR	Base case	20%	%	30%	%	40%	%	50%	%	60%	%	70%	%	80%	%	Orientation
Guest Room 1	758	764	0.79	836	10.29	918	21.11	1000	31.93	1085	43.14	1176	55.15	1266	67.02	
Kitchen 1	271	279	2.95	339	25.09	414	52.77	479	76.75	565	108.49	639	135.79	701	158.67	

Living Room 1	215	217	0.93	237	10.23	264	22.79	289	34.42	312	45.12	341	58.60	351	63.26	
Bed Room 11	228	232	1.75	253	10.96	275	20.61	296	29.82	314	37.72	337	47.81	357	56.58	
Bed Room 12	217	225	3.69	257	18.43	292	34.56	323	48.85	355	63.59	393	81.11	427	96.77	
Master Bed Room 1	263	277	5.32	310	17.87	351	33.46	387	47.15	423	60.84	464	76.43	510	93.92	
Guest Room 2	781	788	0.90	864	10.63	952	21.90	1040	33.16	1132	44.94	1230	57.49	1330	70.29	
Kitchen 2	337	349	3.56	441	30.86	546	62.02	642	90.50	773	129.38	891	164.39	1003	197.63	
Living Room 2	278	280	0.72	316	13.67	365	31.29	416	49.64	463	66.55	523	88.13	577	107.55	
Bed Room 21	237	242	2.11	265	11.81	291	22.78	316	33.33	338	42.62	367	54.85	392	65.40	
Bed Room 22	258	271	5.04	324	25.58	384	48.84	449	74.03	504	95.35	580	124.81	647	150.78	
Master Bed Room 2	278	293	5.40	328	17.99	374	34.53	415	49.28	455	63.67	501	80.22	553	98.92	

Table B.22: Cooling loads for east oriented street / second floor.

Cooling Loads/ second Floor																
WWR	Base case	20%	%	30%	%	40%	%	50%	%	60%	%	70%	%	80%	%	Orientation
Guest Room 1	831	840	1.08	934	12.39	1045	25.75	1156	39.11	1270	52.83	1392	67.51	1511	81.83	
Kitchen 1	293	303	3.41	377	28.67	470	60.41	551	88.05	658	124.57	751	156.31	828	182.59	
Living Room 1	231	233	0.87	258	11.69	291	25.97	323	39.83	354	53.25	389	68.40	402	74.03	
Bed Room 11	248	254	2.42	279	12.50	307	23.79	334	34.68	358	44.35	388	56.45	413	66.53	
Bed Room 12	241	251	4.15	295	22.41	344	42.74	389	61.41	435	80.50	490	103.32	539	123.65	
Master Bed Room 1	306	327	6.86	379	23.86	446	45.75	506	65.36	567	85.29	635	107.52	712	132.68	
Guest Room 2	859	868	1.05	971	13.04	1090	26.89	1211	40.98	1337	55.65	1470	71.13	1604	86.73	
Kitchen 2	373	390	4.56	510	36.73	651	74.53	780	109.12	956	156.30	1112	198.12	1262	238.34	
Living Room 2	308	311	0.97	361	17.21	433	40.58	506	64.29	576	87.01	665	115.91	743	141.23	
Bed Room 21	259	265	2.32	296	14.29	330	27.41	366	41.31	396	52.90	436	68.34	473	82.63	
Bed Room 22	289	306	5.88	381	31.83	470	62.63	567	96.19	647	123.88	759	162.63	857	196.54	
Master Bed Room 2	321	343	6.85	399	24.30	471	46.73	536	66.98	602	87.54	677	110.90	761	137.07	

Table B.23: Cooling loads for east oriented street / third floor.

Cooling Loads/ Third Floor																
WWR	Base case	20%	%	30%	%	40%	%	50%	%	60%	%	70%	%	80%	%	Orientation
Guest Room 1	905	914	0.99	1019	12.60	1142	26.19	1265	39.78	1392	53.81	1527	68.73	1658	83.20	
Kitchen 1	321	332	3.43	412	28.35	514	60.12	603	87.85	720	124.30	823	156.39	907	182.55	
Living Room 1	254	256	0.79	285	12.20	322	26.77	357	40.55	391	53.94	432	70.08	446	75.59	
Bed Room 11	277	283	2.17	313	13.00	346	24.91	377	36.10	406	46.57	441	59.21	471	70.04	
Bed Room 12	288	302	4.86	364	26.39	434	50.69	498	72.92	566	96.53	645	123.96	716	148.61	
Master Bed Room 1	370	402	8.65	482	30.27	586	58.38	679	83.51	776	109.73	885	139.19	1011	173.24	
Guest Room 2	936	947	1.18	1061	13.35	1195	27.67	1331	42.20	1471	57.16	1621	73.18	1770	89.10	
Kitchen 2	413	433	4.84	575	39.23	744	80.15	895	116.71	1102	166.83	1286	211.38	1464	254.48	

Living Room 2	346	349	0.87	412	19.08	504	45.66	599	73.12	689	99.13	805	132.66	908	162.43	
Bed Room 21	292	300	2.74	338	15.75	382	30.82	430	47.26	470	60.96	525	79.79	573	96.23	
Bed Room 22	341	363	6.45	464	36.07	585	71.55	716	109.97	824	141.64	974	185.63	1107	224.63	
Master Bed Room 2	385	419	8.83	501	30.13	609	58.18	708	83.90	808	109.87	924	140.00	1055	174.03	

Table B.24: Cooling loads for east oriented street /fourth floor.

Cooling Loads/ Fourth Floor																
WWR	Base case	20%	%	30%	%	40%	%	50%	%	60%	%	70%	%	80%	%	Orientation
Guest Room 1	1100	1110	0.91	1207	9.73	1318	19.82	1430	30.00	1541	40.09	1659	50.82	1774	61.27	
Kitchen 1	411	422	2.68	501	21.90	599	45.74	684	66.42	796	93.67	892	117.03	972	136.50	
Living Room 1	351	354	0.85	384	9.40	421	19.94	455	29.63	491	39.89	532	51.57	545	55.27	
Bed Room 11	384	393	2.34	428	11.46	465	21.09	498	29.69	534	39.06	576	50.00	609	58.59	
Bed Room 12	444	469	5.63	570	28.38	683	53.83	772	73.87	904	103.60	1048	136.04	1173	164.19	
Master Bed Room 1	513	550	7.21	645	25.73	767	49.51	877	70.96	994	93.76	1127	119.69	1281	149.71	
Guest Room 2	1127	1138	0.98	1244	10.38	1362	20.85	1482	31.50	1604	42.32	1732	53.68	1861	65.13	
Kitchen 2	492	511	3.86	640	30.08	790	60.57	927	88.41	1113	126.22	1279	159.96	1437	192.07	
Living Room 2	434	437	0.69	494	13.82	579	33.41	668	53.92	752	73.27	862	98.62	959	120.97	
Bed Room 21	435	450	3.45	516	18.62	591	35.86	668	53.56	745	71.26	842	93.56	924	112.41	
Bed Room 22	505	540	6.93	686	35.84	857	69.70	1026	103.17	1196	136.83	1426	182.38	1630	222.77	
Master Bed Room 2	532	571	7.33	667	25.38	794	49.25	908	70.68	1027	93.05	1164	118.80	1322	148.50	

4- Street oriented to the South-East:

Table B.25: Heating loads for south-east oriented street / first floor.

Heating Loads/ First Floor																
WWR	Base case	20%	%	30%	%	40%	%	50%	%	60%	%	70%	%	80%	%	Orientation
Guest Room 1	687	683	-0.58	631	-8.15	584	-14.99	542	-21.11	504	-26.64	470	-31.59	440	-35.95	
Kitchen 1	501	494	-1.40	442	-11.78	393	-21.56	358	-28.54	319	-36.33	293	-41.52	276	-44.91	
Living Room 1	519	518	-0.19	497	-4.24	473	-8.86	453	-12.72	434	-16.38	417	-19.65	409	-21.19	
Bed Room 11	461	458	-0.65	446	-3.25	434	-5.86	422	-8.46	413	-10.41	402	-12.80	394	-14.53	
Bed Room 12	712	707	-0.70	686	-3.65	665	-6.60	647	-9.13	630	-11.52	612	-14.04	599	-15.87	
Master Bed Room 1	618	612	-0.97	598	-3.24	581	-5.99	568	-8.09	555	-10.19	544	-11.97	532	-13.92	
Guest Room 2	659	654	-0.76	602	-8.65	553	-16.08	510	-22.61	471	-28.53	436	-33.84	405	-38.54	
Kitchen 2	431	421	-2.32	360	-16.47	311	-27.84	277	-35.73	240	-44.32	216	-49.88	199	-53.83	
Living Room 2	469	467	-0.43	439	-6.40	408	-13.01	382	-18.55	358	-23.67	335	-28.57	317	-32.41	
Bed Room 21	439	436	-0.68	420	-4.33	404	-7.97	390	-11.16	378	-13.90	364	-17.08	354	-19.36	
Bed Room 22	653	643	-1.53	609	-6.74	578	-11.49	552	-15.47	529	-18.99	505	-22.66	486	-25.57	
Master Bed Room 2	611	605	-0.98	589	-3.60	571	-6.55	556	-9.00	543	-11.13	529	-13.42	517	-15.38	

Table B.26: Heating loads for south-east oriented street / second floor.

Heating Loads/ second Floor

WWR	Base case	20%	%	30%	%	40%	%	50%	%	60%	%	70%	%	80%	%	Orientation
Guest Room 1	643	637	-0.93	577	-10.26	520	-19.13	470	-26.91	426	-33.75	385	-40.12	350	-45.57	
Kitchen 1	473	465	-1.69	405	-14.38	349	-26.22	310	-34.46	268	-43.34	240	-49.26	221	-53.28	
Living Room 1	504	502	-0.40	476	-5.56	449	-10.91	425	-15.67	403	-20.04	382	-24.21	372	-26.19	
Bed Room 11	449	446	-0.67	432	-3.79	417	-7.13	404	-10.02	392	-12.69	380	-15.37	370	-17.59	
Bed Room 12	703	696	-1.00	671	-4.55	647	-7.97	626	-10.95	420	-40.26	587	-16.50	572	-18.63	
Master Bed Room 1	608	600	-1.32	582	-4.28	562	-7.57	545	-10.36	530	-12.83	516	-15.13	501	-17.60	
Guest Room 2	613	607	-0.98	544	-11.26	485	-20.88	434	-29.20	387	-36.87	345	-43.72	308	-49.76	
Kitchen 2	402	390	-2.99	321	-20.15	266	-33.83	228	-43.28	189	-52.99	162	-59.70	144	-64.18	
Living Room 2	438	435	-0.68	398	-9.13	360	-17.81	329	-24.89	300	-31.51	273	-37.67	253	-42.24	
Bed Room 21	414	410	-0.97	387	-6.52	365	-11.84	345	-16.67	329	-20.53	312	-24.64	299	-27.78	
Bed Room 22	609	595	-2.30	548	-10.02	506	-16.91	472	-22.50	442	-27.42	411	-32.51	389	-36.12	
Master Bed Room 2	599	590	-1.50	569	-5.01	546	-8.85	527	-12.02	610	1.84	493	-17.70	477	-20.37	

Table B.27: Heating loads for south-east oriented street /third floor.

Heating Loads/ Third Floor																
WWR	Base case	20%	%	30%	%	40%	%	50%	%	60%	%	70%	%	80%	%	Orientation
Guest Room 1	727	720	-0.96	650	-10.59	584	-19.67	525	-27.79	473	-34.94	424	-41.68	383	-47.32	
Kitchen 1	507	498	-1.78	432	-14.79	371	-26.82	328	-35.31	280	-44.77	248	-51.08	227	-55.23	
Living Room 1	545	543	-0.37	515	-5.50	484	-11.19	458	-15.96	433	-20.55	409	-24.95	399	-26.79	
Bed Room 11	494	490	-0.81	473	-4.25	456	-7.69	441	-10.73	427	-13.56	412	-16.60	401	-18.83	
Bed Room 12	745	737	-1.07	707	-5.10	678	-8.99	653	-12.35	630	-15.44	607	-18.52	589	-20.94	
Master Bed Room 1	655	645	-1.53	623	-4.89	598	-8.70	578	-11.76	559	-14.66	541	-17.40	523	-20.15	
Guest Room 2	683	675	-1.17	599	-12.30	529	-22.55	468	-31.48	412	-39.68	362	-47.00	319	-53.29	
Kitchen 2	410	396	-3.41	318	-22.44	255	-37.80	214	-47.80	171	-58.29	143	-65.12	125	-69.51	
Living Room 2	428	425	-0.70	377	-11.92	330	-22.90	294	-31.31	261	-39.02	229	-46.50	206	-51.87	
Bed Room 21	419	412	-1.67	379	-9.55	343	-18.14	313	-25.30	291	-30.55	267	-36.28	250	-40.33	
Bed Room 22	596	577	-3.19	514	-13.76	457	-23.32	414	-30.54	378	-36.58	342	-42.62	318	-46.64	
Master Bed Room 2	640	629	-1.72	602	-5.94	573	-10.47	549	-14.22	528	-17.50	506	-20.9375	486	-24.06	

Table B.28: Heating loads for south-east oriented street / fourth floor.

Heating Loads/ Fourth Floor																
WWR	Base case	20%	%	30%	%	40%	%	50%	%	60%	%	70%	%	80%	%	Orientation
Guest Room 1	1543	1535	-0.52	1448	-6.16	1363	-11.67	1281	-16.98	1206	-21.84	1135	-26.44	1071	-30.59	
Kitchen 1	849	838	-1.30	764	-10.01	693	-18.37	638	-24.85	574	-32.39	528	-37.81	497	-41.46	
Living Room 1	896	894	-0.22	863	-3.68	828	-7.59	798	-10.94	770	-14.06	740	-17.41	730	-18.53	
Bed Room 11	852	846	-0.70	822	-3.52	798	-6.34	778	-8.69	756	-11.27	734	-13.85	718	-15.73	
Bed Room 12	1103	1091	-1.09	1050	-4.81	1011	-8.34	981	-11.06	946	-14.23	914	-17.14	889	-19.40	

Master Bed Room 1	1056	1042	-1.33	1015	-3.88	983	-6.91	957	-9.38	933	-11.65	909	-13.92	884	-16.29	
Guest Room 2	1479	1469	-0.68	1371	-7.30	1273	-13.93	1184	-19.95	1100	-25.63	1022	-30.90	952	-35.63	
Kitchen 2	711	692	-2.67	589	-17.16	501	-29.54	440	-38.12	373	-47.54	328	-53.87	296	-58.37	
Living Room 2	713	709	-0.56	649	-8.98	584	-18.09	532	-25.39	486	-31.84	439	-38.43	405	-43.20	
Bed Room 21	696	680	-2.30	620	-10.92	564	-18.97	520	-25.29	480	-31.03	440	-36.78	412	-40.80	
Bed Room 22	905	881	-2.65	797	-11.93	721	-20.33	662	-26.85	610	-32.60	557	-38.45	520	-42.54	
Master Bed Room 2	1030	1016	-1.36	983	-4.56	946	-8.16	916	-11.07	888	-13.79	860	-16.50	833	-19.13	

Table B.29: Cooling loads for south-east oriented street / first floor.

Cooling Loads/ First Floor																
WWR	Base case	20%	%	30%	%	40%	%	50%	%	60%	%	70%	%	80%	%	Orientation
Guest Room 1	807	814	0.87	897	11.15	994	23.17	1093	35.44	1195	48.08	1306	61.83	1414	75.22	
Kitchen 1	338	351	3.85	434	28.40	551	63.02	650	92.31	782	131.36	900	166.27	1007	197.93	
Living Room 1	250	252	0.80	279	11.60	318	27.20	355	42.00	390	56.00	433	73.20	446	78.40	
Bed Room 11	233	237	1.72	258	10.73	280	20.17	301	29.18	321	37.77	345	48.07	364	56.22	
Bed Room 12	216	224	3.70	257	18.98	289	33.80	319	47.69	351	62.50	390	80.56	423	95.83	
Master Bed Room 1	260	272	4.62	302	16.15	339	30.38	371	42.69	403	55.00	440	69.23	480	84.62	
Guest Room 2	800	808	1.00	893	11.63	989	23.63	1089	36.13	1191	48.88	1303	62.88	1416	77.00	
Kitchen 2	314	329	4.78	413	31.53	511	62.74	601	91.40	724	130.57	833	165.29	932	196.82	
Living Room 2	260	262	0.77	297	14.23	343	31.92	389	49.62	434	66.92	492	89.23	542	108.46	
Bed Room 21	242	247	2.07	273	12.81	302	24.79	333	37.60	358	47.93	392	61.98	422	74.38	
Bed Room 22	276	291	5.43	355	28.62	426	54.35	499	80.80	566	105.07	657	138.04	738	167.39	
Master Bed Room 2	281	296	5.34	332	18.15	378	34.52	419	49.11	458	62.99	504	79.36	553	96.80	

Table B.30: Cooling loads for south-east oriented street / second floor.

Cooling Loads/ second Floor																
WWR	Base case	20%	%	30%	%	40%	%	50%	%	60%	%	70%	%	80%	%	Orientation
Guest Room 1	867	877	1.15	980	13.03	1103	27.22	1229	41.75	1359	56.75	1499	72.90	1634	88.47	
Kitchen 1	357	372	4.20	470	31.65	510	42.86	728	103.92	886	148.18	1028	187.96	1154	223.25	
Living Room 1	267	270	1.12	304	13.86	353	32.21	399	49.44	444	66.29	500	87.27	517	93.63	
Bed Room 11	253	258	1.98	284	12.25	313	23.72	340	34.39	365	44.27	396	56.52	421	66.40	
Bed Room 12	238	249	4.62	290	21.85	335	40.76	376	57.98	607	155.04	472	98.32	518	117.65	
Master Bed Room 1	290	307	5.86	349	20.34	402	38.62	448	54.48	495	70.69	548	88.97	607	109.31	
Guest Room 2	872	882	1.15	992	13.76	1120	28.44	1252	43.58	1388	59.17	1535	76.03	1683	93.00	
Kitchen 2	361	379	4.99	500	38.50	639	77.01	763	111.36	936	159.28	1088	201.39	1228	240.17	
Living Room 2	312	315	0.96	370	18.59	446	42.95	522	67.31	596	91.03	692	121.79	778	149.36	
Bed Room 21	272	278	2.21	316	16.18	358	31.62	406	49.26	441	62.13	492	80.88	538	97.79	
Bed Room 22	316	337	6.65	427	35.13	531	68.04	640	102.53	737	133.23	871	175.63	990	213.29	

Master Bed Room 2	316	335	6.01	385	21.84	449	42.09	506	60.13	562	77.85	628	98.73	700	121.52	

Table B.31: Cooling loads for south-east oriented street / third floor.

Cooling Loads/ Third Floor																
WWR	Base case	20%	%	30%	%	40%	%	50%	%	60%	%	70%	%	80%	%	Orientation
Guest Room 1	930	941	1.18	1051	13.01	1183	27.20	1317	41.61	1455	56.45	1604	72.47	1745	87.63	
Kitchen 1	380	396	4.21	501	31.84	648	70.53	772	103.16	941	147.63	1091	187.11	1223	221.84	
Living Room 1	298	301	1.01	343	15.10	399	33.89	453	52.01	507	70.13	574	92.62	592	98.66	
Bed Room 11	285	292	2.46	325	14.04	360	26.32	394	38.25	425	49.12	464	62.81	494	73.33	
Bed Room 12	283	298	5.30	355	25.44	418	47.70	476	68.20	539	90.46	611	115.90	673	137.81	
Master Bed Room 1	333	355	6.61	410	23.12	480	44.14	541	62.46	604	81.38	676	103.00	754	126.43	
Guest Room 2	946	958	1.27	1081	14.27	1223	29.28	1370	44.82	1521	60.78	1684	78.01	1847	95.24	
Kitchen 2	424	448	5.66	604	42.45	783	84.67	940	121.70	1162	174.06	1357	220.05	1543	263.92	
Living Room 2	376	381	1.33	457	21.54	563	49.73	672	78.72	778	106.91	918	144.15	1042	177.13	
Bed Room 21	318	328	3.14	381	19.81	441	38.68	509	60.06	561	76.42	634	99.37	700	120.13	
Bed Room 22	370	396	7.03	513	38.65	649	75.41	792	114.05	919	148.38	1095	195.95	1253	238.65	
Master Bed Room 2	359	383	6.69	446	24.23	527	46.80	599	66.85	670	86.63	752	109.47	843	134.82	

Table B.32: Cooling loads for south-east oriented street / fourth floor.

Cooling Loads/ Fourth Floor																
WWR	Base case	20%	%	30%	%	40%	%	50%	%	60%	%	70%	%	80%	%	Orientation
Guest Room 1	1118	1127	0.81	1228	9.84	1344	20.21	1460	30.59	1576	40.97	1703	52.33	1825	63.24	
Kitchen 1	464	480	3.45	578	24.57	713	53.66	825	77.80	978	110.78	1114	140.09	1233	165.73	
Living Room 1	401	404	0.75	450	12.22	510	27.18	569	41.90	625	55.86	696	73.57	713	77.81	
Bed Room 11	417	430	3.12	477	14.39	529	26.86	574	37.65	625	49.88	682	63.55	726	74.10	
Bed Room 12	430	454	5.58	539	25.35	633	47.21	711	65.35	810	88.37	920	113.95	1012	135.35	
Master Bed Room 1	460	485	5.43	546	18.70	624	35.65	691	50.22	761	65.43	841	82.83	929	101.96	
Guest Room 2	1136	1147	0.97	1258	10.74	1383	21.74	1509	32.83	1637	44.10	1776	56.34	1914	68.49	
Kitchen 2	525	550	4.76	706	34.48	887	68.95	1045	99.05	1270	141.90	1469	179.81	1662	216.57	
Living Room 2	484	488	0.83	568	17.36	679	40.29	797	64.67	908	87.60	1059	118.80	1194	146.69	
Bed Room 21	480	501	4.38	594	23.75	700	45.83	805	67.71	909	89.38	1046	117.92	1166	142.92	
Bed Room 22	504	538	6.75	679	34.72	843	67.26	1009	100.20	1175	133.13	1401	177.98	1602	217.86	
Master Bed Room 2	484	510	5.37	576	19.01	659	36.16	733	51.45	807	66.74	892	84.30	987	103.93	

5- *Street oriented to the South:*

Table B.33: Heating loads for south oriented street / first floor.

Heating Loads/ First Floor

WWR	Base case	20%	%	30%	%	40%	%	50%	%	60%	%	70%	%	80%	%	Orientation
Guest Room 1	574	561	-2.26	499	-13.07	440	-23.34	390	-32.06	347	-39.55	309	-46.17	277	-51.74	
Kitchen 1	367	355	-3.27	294	-19.89	239	-34.88	203	-44.69	169	-53.95	148	-59.67	133	-63.76	
Living Room 1	450	446	-0.89	414	-8.00	379	-15.78	349	-22.44	324	-28.00	300	-33.33	289	-35.78	
Bed Room 11	446	440	-1.35	425	-4.71	409	-8.30	394	-11.66	382	-14.35	369	-17.26	359	-19.51	
Bed Room 12	703	694	-1.28	670	-4.69	647	-7.97	627	-10.81	608	-13.51	589	-16.22	575	-18.21	
Master Bed Room 1	636	620	-2.52	607	-4.56	592	-6.92	579	-8.96	568	-10.69	557	-12.42	545	-14.31	
Guest Room 2	564	550	-2.48	486	-13.83	428	-24.11	377	-33.16	334	-40.78	297	-47.34	264	-53.19	
Kitchen 2	357	345	-3.36	281	-21.29	234	-34.45	202	-43.42	171	-52.10	150	-57.98	136	-61.90	
Living Room 2	447	442	-1.12	411	-8.05	377	-15.66	349	-21.92	325	-27.29	302	-32.44	284	-36.47	
Bed Room 21	442	435	-1.58	420	-4.98	404	-8.60	390	-11.76	377	-14.71	364	-17.65	354	-19.91	
Bed Room 22	704	695	-1.28	671	-4.69	648	-7.95	627	-10.94	610	-13.35	591	-16.05	576	-18.18	
Master Bed Room 2	640	624	-2.50	611	-4.53	596	-6.88	583	-8.91	571	-10.78	560	-12.50	549	-14.22	

Table B.34: Heating loads for south oriented street / second floor.

Heating Loads/ second Floor																
WWR	Base case	20%	%	30%	%	40%	%	50%	%	60%	%	70%	%	80%	%	Orientation
Guest Room 1	540	531	-1.67	460	-14.81	393	-27.22	336	-37.78	289	-46.48	247	-54.26	213	-60.56	
Kitchen 1	353	341	-3.40	273	-22.66	213	-39.66	175	-50.42	141	-60.06	118	-66.57	104	-70.54	
Living Room 1	434	431	-0.69	393	-9.45	353	-18.66	321	-26.04	292	-32.72	265	-38.94	254	-41.47	
Bed Room 11	430	425	-1.16	406	-5.58	387	-10.00	370	-13.95	353	-17.91	340	-20.93	329	-23.49	
Bed Room 12	682	672	-1.47	642	-5.87	612	-10.26	588	-13.78	565	-17.16	542	-20.53	525	-23.02	
Master Bed Room 1	620	611	-1.45	594	-4.19	575	-7.26	560	-9.68	546	-11.94	532	-14.19	519	-16.29	
Guest Room 2	530	520	-1.89	448	-15.47	381	-28.11	325	-38.68	278	-47.55	236	-55.47	202	-61.89	
Kitchen 2	344	332	-3.49	262	-23.84	210	-38.95	175	-49.13	142	-58.72	120	-65.12	106	-69.19	
Living Room 2	430	426	-0.93	389	-9.53	350	-18.60	319	-25.81	292	-32.09	266	-38.14	247	-42.56	
Bed Room 21	425	421	-0.94	401	-5.65	382	-10.12	365	-14.12	350	-17.65	335	-21.18	322	-24.24	
Bed Room 22	684	675	-1.32	645	-5.70	615	-10.09	590	-13.74	569	-16.81	546	-20.18	528	-22.81	
Master Bed Room 2	626	617	-1.44	600	-4.15	581	-7.19	565	-9.74	551	-11.98	537	-14.22	524	-16.29	

Table B.35: Heating loads for south oriented street /third floor.

Heating Loads/ Third Floor																
WWR	Base case	20%	%	30%	%	40%	%	50%	%	60%	%	70%	%	80%	%	Orientation
Guest Room 1	627	618	-1.44	538	-14.19	461	-26.48	396	-36.84	341	-45.61	294	-53.11	255	-59.33	
Kitchen 1	390	377	-3.33	303	-22.31	236	-39.49	194	-50.26	155	-60.26	129	-66.92	113	-71.03	
Living Room 1	467	464	-0.64	422	-9.64	377	-19.27	340	-27.19	307	-34.26	275	-41.11	263	-43.68	
Bed Room 11	463	458	-1.08	434	-6.26	410	-11.45	388	-16.20	369	-20.30	350	-24.41	336	-27.43	

Bed Room 12	700	688	-1.71	648	-7.43	609	-13.00	578	-17.43	548	-21.71	518	-26.00	496	-29.14	
Master Bed Room 1	668	659	-1.35	639	-4.34	615	-7.93	597	-10.63	579	-13.32	562	-15.87	545	-18.41	
Guest Room 2	616	607	-1.46	524	-14.94	448	-27.27	383	-37.82	329	-46.59	282	-54.22	242	-60.71	
Kitchen 2	382	369	-3.40	290	-24.08	232	-39.27	194	-49.21	156	-59.16	132	-65.45	115	-69.90	
Living Room 2	462	458	-0.87	415	-10.17	371	-19.70	336	-27.27	304	-34.20	275	-40.48	252	-45.45	
Bed Room 21	457	452	-1.09	426	-6.78	401	-12.25	379	-17.07	360	-21.23	340	-25.60	325	-28.88	
Bed Room 22	703	690	-1.85	650	-7.54	611	-13.09	579	-17.64	550	-21.76	521	-25.89	499	-29.02	
Master Bed Room 2	676	666	-1.48	646	-4.44	622	-7.99	603	-10.80	585	-13.46	568	-15.97	551	-18.49	

Table B.36: Heating loads for south oriented street / fourth floor.

Heating Loads/ Fourth Floor																
WWR	Base case	20%	%	30%	%	40%	%	50%	%	60%	%	70%	%	80%	%	Orientation
Guest Room 1	1430	1419	-0.77	1312	-8.25	1204	-15.80	1107	-22.59	1021	-28.60	940	-34.27	871	-39.09	
Kitchen 1	729	713	-2.19	621	-14.81	528	-27.57	463	-36.49	394	-45.95	346	-52.54	314	-56.93	
Living Room 1	798	794	-0.50	746	-6.52	691	-13.41	644	-19.30	602	-24.56	558	-30.08	544	-31.83	
Bed Room 11	792	781	-1.39	742	-6.31	703	-11.24	672	-15.15	640	-19.19	607	-23.36	584	-26.26	
Bed Room 12	1034	1016	-1.74	958	-7.35	903	-12.67	859	-16.92	815	-21.18	770	-25.53	737	-28.72	
Master Bed Room 1	1067	1059	-0.75	1030	-3.47	1001	-6.19	978	-8.34	955	-10.50	932	-12.65	910	-14.71	
Guest Room 2	1418	1407	-0.78	1296	-8.60	1188	-16.22	1091	-23.06	1003	-29.27	922	-34.98	850	-40.06	
Kitchen 2	724	707	-2.35	606	-16.30	523	-27.76	463	-36.05	400	-44.75	357	-50.69	328	-54.70	
Living Room 2	791	787	-0.51	737	-6.83	686	-13.27	643	-18.71	601	-24.02	558	-29.46	527	-33.38	
Bed Room 21	777	766	-1.42	726	-6.56	688	-11.45	659	-15.19	627	-19.31	595	-23.42	572	-26.38	
Bed Room 22	1025	1007	-1.76	949	-7.41	895	-12.68	852	-16.88	810	-20.98	767	-25.17	736	-28.20	
Master Bed Room 2	1075	1063	-1.12	1038	-3.44	1008	-6.23	984	-8.47	961	-10.60	938	-12.74	915	-14.88	

Table B.37: Cooling loads for south oriented street / first floor.

Cooling Loads/ First Floor																
WWR	Base case	20%	%	30%	%	40%	%	50%	%	60%	%	70%	%	80%	%	Orientation
Guest Room 1	757	755	-0.26	823	8.72	905	19.55	991	30.91	1079	42.54	1175	55.22	1269	67.64	
Kitchen 1	280	289	3.21	355	26.79	450	60.71	532	90.00	641	128.93	739	163.93	826	195.00	
Living Room 1	232	233	0.43	257	10.78	290	25.00	322	38.79	352	51.72	389	67.67	400	72.41	
Bed Room 11	234	237	1.28	258	10.26	280	19.66	302	29.06	321	37.18	346	47.86	365	55.98	
Bed Room 12	237	246	3.80	287	21.10	331	39.66	369	55.70	413	74.26	463	95.36	507	113.92	
Master Bed Room 1	244	247	1.23	268	9.84	293	20.08	314	28.69	335	37.30	358	46.72	383	56.97	
Guest Room 2	754	752	-0.27	821	8.89	903	19.76	989	31.17	1079	43.10	1176	55.97	1275	69.10	
Kitchen 2	286	298	4.20	379	32.52	474	65.73	561	96.15	680	137.76	787	175.17	891	211.54	
Living Room 2	227	228	0.44	253	11.45	285	25.55	318	40.09	349	53.74	388	70.93	423	86.34	
Bed Room 21	227	229	0.88	251	10.57	274	20.70	296	30.40	315	38.77	340	49.78	361	59.03	

Bed Room 22	236	245	3.81	289	22.46	337	42.80	382	61.86	425	80.08	480	103.39	528	123.73	
Master Bed Room 2	250	253	1.20	274	9.60	300	20.00	322	28.80	343	37.20	366	46.40	391	56.40	

Table B.38: Cooling loads for south oriented street / second floor.

Cooling Loads/ second Floor																
WWR	Base case	20%	%	30%	%	40%	%	50%	%	60%	%	70%	%	80%	%	Orientation
Guest Room 1	805	811	0.75	896	11.30	1000	24.22	1108	37.64	1219	51.43	1340	66.46	1456	80.87	
Kitchen 1	303	316	4.29	397	31.02	516	70.30	618	103.96	754	148.84	875	188.78	984	224.75	
Living Room 1	263	265	0.76	301	14.45	349	32.70	396	50.57	442	68.06	501	90.49	516	96.20	
Bed Room 11	259	263	1.54	292	12.74	324	25.10	356	37.45	383	47.88	418	61.39	445	71.81	
Bed Room 12	270	284	5.19	341	26.30	405	50.00	462	71.11	525	94.44	601	122.59	666	146.67	
Master Bed Room 1	263	272	3.42	298	13.31	330	25.48	358	36.12	385	46.39	416	58.17	448	70.34	
Guest Room 2	802	807	0.62	895	11.60	1000	24.69	1108	38.15	1222	52.37	1344	67.58	1467	82.92	
Kitchen 2	309	323	4.53	424	37.22	544	76.05	652	111.00	801	159.22	935	202.59	1068	245.63	
Living Room 2	258	260	0.78	297	15.12	346	34.11	395	53.10	443	71.71	505	95.74	560	117.05	
Bed Room 21	251	256	1.99	286	13.94	318	26.69	352	40.24	381	51.79	417	66.14	448	78.49	
Bed Room 22	267	282	5.62	346	29.59	416	55.81	484	81.27	551	106.37	636	138.20	709	165.54	
Master Bed Room 2	269	278	3.35	305	13.38	338	25.65	366	36.06	394	46.47	425	57.99	458	70.26	

Table B.39: Cooling loads for south oriented street / third floor.

Cooling Loads/ Third Floor																
WWR	Base case	20%	%	30%	%	40%	%	50%	%	60%	%	70%	%	80%	%	Orientation
Guest Room 1	871	879	0.92	973	11.71	1087	24.80	1204	38.23	1325	52.12	1456	67.16	1578	81.17	
Kitchen 1	350	368	5.14	466	33.14	610	74.29	731	108.86	897	156.29	1045	198.57	1175	235.71	
Living Room 1	323	326	0.93	379	17.34	450	39.32	520	60.99	592	83.28	684	111.76	703	117.65	
Bed Room 11	306	314	2.61	355	16.01	402	31.37	451	47.39	491	60.46	544	77.78	585	91.18	
Bed Room 12	320	339	5.94	416	30.00	503	57.19	583	82.19	669	109.06	775	142.19	863	169.69	
Master Bed Room 1	292	303	3.77	334	14.38	372	27.40	404	38.36	436	49.32	472	61.64	510	74.66	
Guest Room 2	868	877	1.04	974	12.21	1089	25.46	1207	39.06	1333	53.57	1466	68.89	1599	84.22	
Kitchen 2	356	376	5.62	501	40.73	647	81.74	775	117.70	970	172.47	1125	216.01	1287	261.52	
Living Room 2	319	322	0.94	381	19.44	458	43.57	534	67.40	613	92.16	716	124.45	806	152.66	
Bed Room 21	301	310	2.99	356	18.27	408	35.55	464	54.15	509	69.10	569	89.04	620	105.98	
Bed Room 22	321	343	6.85	432	34.58	532	65.73	629	95.95	725	125.86	851	165.11	959	198.75	
Master Bed Room 2	299	310	3.68	342	14.38	381	27.42	414	38.46	447	49.50	484	61.87	523	74.92	

Table B.40: Cooling loads for south oriented street / fourth floor.

Cooling Loads/ Fourth Floor																
WWR	Base case	20%	%	30%	%	40%	%	50%	%	60%	%	70%	%	80%	%	Orientation
Guest Room 1	1070	1079	0.84	1165	8.88	1268	18.50	1370	28.04	1468	37.20	1586	48.22	1694	58.32	
Kitchen 1	469	489	4.26	593	26.44	749	59.70	873	86.14	1048	123.45	1203	156.50	1341	185.93	
Living Room 1	456	459	0.66	524	14.91	614	34.65	701	53.73	786	72.37	898	96.93	918	101.32	
Bed Room 11	471	488	3.61	565	19.96	650	38.00	732	55.41	813	72.61	915	94.27	994	111.04	
Bed Room 12	443	466	5.19	557	25.73	658	48.53	749	69.07	850	91.87	973	119.64	1079	143.57	
Master Bed Room 1	414	427	3.14	461	11.35	502	21.26	536	29.47	572	38.16	611	47.58	653	57.73	
Guest Room 2	1067	1077	0.94	1166	9.28	1268	18.84	1371	28.49	1473	38.05	1590	49.02	1707	59.98	
Kitchen 2	478	501	4.81	638	33.47	796	66.53	932	94.98	1133	137.03	1312	174.48	1490	211.72	
Living Room 2	459	463	0.87	537	16.99	637	38.78	738	60.78	841	83.22	979	113.29	1103	140.31	
Bed Room 21	468	488	4.27	576	23.08	674	44.02	770	64.53	867	85.26	993	112.18	1099	134.83	
Bed Room 22	447	474	6.04	580	29.75	698	56.15	813	81.88	932	108.50	1090	143.85	1231	175.39	
Master Bed Room 2	418	432	3.35	466	11.48	507	21.29	543	29.90	578	38.28	618	47.85	660	57.89	

6- *Street oriented to the South-West:*

Table B.41: Heating loads for south-west oriented street / first floor.

Heating Loads/ First Floor																
WWR	Base case	20%	%	30%	%	40%	%	50%	%	60%	%	70%	%	80%	%	Orientation
Guest Room 1	684	670	-2.05	622	-9.06	575	-15.94	534	-21.93	497	-27.34	463	-32.31	435	-36.40	
Kitchen 1	436	425	-2.52	373	-14.45	321	-26.38	288	-33.94	254	-41.74	231	-47.02	215	-50.69	
Living Room 1	475	471	-0.84	444	-6.53	414	-12.84	388	-18.32	366	-22.95	343	-27.79	334	-29.68	
Bed Room 11	449	442	-1.56	427	-4.90	412	-8.24	398	-11.36	386	-14.03	373	-16.93	364	-18.93	
Bed Room 12	669	657	-1.79	626	-6.43	597	-10.76	574	-14.20	551	-17.64	528	-21.08	511	-23.62	
Master Bed Room 1	620	604	-2.58	589	-5.00	571	-7.90	557	-10.16	545	-12.10	532	-14.19	520	-16.13	
Guest Room 2	709	696	-1.83	648	-8.60	602	-15.09	562	-20.73	525	-25.95	492	-30.61	463	-34.70	
Kitchen 2	519	511	-1.54	458	-11.75	415	-20.04	383	-26.20	347	-33.14	323	-37.76	307	-40.85	
Living Room 2	517	513	-0.77	493	-4.64	470	-9.09	450	-12.96	432	-16.44	415	-19.73	401	-22.44	
Bed Room 21	460	453	-1.52	442	-3.91	430	-6.52	418	-9.13	408	-11.30	398	-13.48	390	-15.22	
Bed Room 22	713	704	-1.26	683	-4.21	662	-7.15	643	-9.82	627	-12.06	610	-14.45	597	-16.27	
Master Bed Room 2	631	615	-2.54	601	-4.75	585	-7.29	571	-9.51	559	-11.41	548	-13.15	536	-15.06	

Table B.42: Heating loads for south-west oriented street / second floor.

Heating Loads/ second Floor																
WWR	Base case	20%	%	30%	%	40%	%	50%	%	60%	%	70%	%	80%	%	Orientation
Guest Room 1	631	623	-1.27	564	-10.62	506	-19.81	457	-27.58	414	-34.39	375	-40.57	343	-45.64	
Kitchen 1	406	394	-2.96	333	-17.98	276	-32.02	240	-40.89	203	-50.00	178	-56.16	161	-60.34	
Living Room 1	442	438	-0.90	403	-8.82	364	-17.65	334	-24.43	306	-30.77	279	-36.88	268	-39.37	

Bed Room 11	420	415	-1.19	393	-6.43	371	-11.67	351	-16.43	335	-20.24	318	-24.29	306	-27.14	
Bed Room 12	618	603	-2.43	559	-9.55	518	-16.18	486	-21.36	454	-26.54	423	-31.55	402	-34.95	
Master Bed Room 1	598	587	-1.84	567	-5.18	544	-9.03	527	-11.87	510	-14.72	494	-17.39	479	-19.90	
Guest Room 2	656	648	-1.22	590	-10.06	534	-18.60	487	-25.76	444	-32.32	406	-38.11	373	-43.14	
Kitchen 2	487	478	-1.85	417	-14.37	369	-24.23	332	-31.83	294	-39.63	268	-44.97	250	-48.67	
Living Room 2	496	493	-0.60	467	-5.85	440	-11.29	416	-16.13	395	-20.36	374	-24.60	358	-27.82	
Bed Room 21	446	441	-1.12	427	-4.26	412	-7.62	398	-10.76	387	-13.23	374	-16.14	364	-18.39	
Bed Room 22	702	694	-1.14	669	-4.70	644	-8.26	622	-11.40	604	-13.96	584	-16.81	569	-18.95	
Master Bed Room 2	616	606	-1.62	588	-4.55	568	-7.79	552	-10.39	537	-12.82	523	-15.10	509	-17.37	

Table B.43: Heating loads for south-west oriented street / third floor.

Heating Loads/ Third Floor																
WWR	Base case	20%	%	30%	%	40%	%	50%	%	60%	%	70%	%	80%	%	Orientation
Guest Room 1	690	682	-1.16	611	-11.45	541	-21.59	483	-30.00	431	-37.54	385	-44.20	350	-49.28	
Kitchen 1	405	391	-3.46	321	-20.74	257	-36.54	218	-46.17	177	-56.30	151	-62.72	134	-66.91	
Living Room 1	428	424	-0.93	376	-12.15	326	-23.83	289	-32.48	255	-40.42	221	-48.36	211	-50.70	
Bed Room 11	422	415	-1.66	379	-10.19	345	-18.25	314	-25.59	292	-30.81	267	-36.73	251	-40.52	
Bed Room 12	600	581	-3.17	519	-13.50	461	-23.17	417	-30.50	377	-37.17	339	-43.50	313	-47.83	
Master Bed Room 1	637	626	-1.73	601	-5.65	573	-10.05	550	-13.66	530	-16.80	510	-19.94	491	-22.92	
Guest Room 2	724	717	-0.97	648	-10.50	583	-19.48	526	-27.35	475	-34.39	430	-40.61	393	-45.72	
Kitchen 2	510	500	-1.96	433	-15.10	378	-25.88	338	-33.73	295	-42.16	266	-47.84	247	-51.57	
Living Room 2	530	528	-0.38	498	-6.04	466	-12.08	439	-17.17	414	-21.89	389	-26.60	370	-30.19	
Bed Room 21	487	483	-0.82	466	-4.31	448	-8.01	432	-11.29	417	-14.37	403	-17.25	390	-19.92	
Bed Room 22	742	733	-1.21	702	-5.39	673	-9.30	647	-12.80	625	-15.77	602	-18.87	584	-21.29	
Master Bed Room 2	665	655	-1.50	634	-4.66	609	-8.42	589	-11.43	572	-13.98	554	-16.69	537	-19.25	

Table B.44: Heating loads for south-west oriented street / fourth floor.

Heating Loads/ Fourth Floor																
WWR	Base case	20%	%	30%	%	40%	%	50%	%	60%	%	70%	%	80%	%	Orientation
Guest Room 1	1472	1462	-0.68	1365	-7.27	1268	-13.86	1181	-19.77	1103	-25.07	1029	-30.10	969	-34.17	
Kitchen 1	689	670	-2.76	577	-16.26	479	-30.48	417	-39.48	353	-48.77	310	-55.01	280	-59.36	
Living Room 1	706	702	-0.57	640	-9.35	568	-19.55	509	-27.90	459	-34.99	406	-42.49	395	-44.05	
Bed Room 11	706	690	-2.27	628	-11.05	567	-19.69	518	-26.63	474	-32.86	427	-39.52	397	-43.77	
Bed Room 12	924	900	-2.60	816	-11.69	739	-20.02	677	-26.73	620	-32.90	561	-39.29	519	-43.83	
Master Bed Room 1	1029	1015	-1.36	986	-4.18	950	-7.68	922	-10.40	896	-12.93	869	-15.55	844	-17.98	
Guest Room 2	1526	1517	-0.59	1428	-6.42	1341	-12.12	1260	-17.43	1187	-22.21	1118	-26.74	1056	-30.80	

Kitchen 2	846	834	-1.42	756	-10.64	688	-18.68	636	-24.82	576	-31.91	533	-37.00	504	-40.43	
Living Room 2	874	872	-0.23	838	-4.12	802	-8.24	771	-11.78	740	-15.33	710	-18.76	686	-21.51	
Bed Room 21	835	829	-0.72	804	-3.71	779	-6.71	758	-9.22	737	-11.74	714	-14.49	697	-16.53	
Bed Room 22	1092	1079	-1.19	1038	-4.95	998	-8.61	966	-11.54	934	-14.47	901	-17.49	877	-19.69	
Master Bed Room 2	1069	1057	-1.12	1031	-3.55	1000	-6.45	976	-8.70	952	-10.94	929	-13.10	906	-15.25	

Table B.45: Cooling loads for south-west oriented street / first floor.

Cooling Loads/ First Floor																
WWR	Base case	20%	%	30%	%	40%	%	50%	%	60%	%	70%	%	80%	%	Orientation
Guest Room 1	825	825	0.00	918	11.27	1028	24.61	1140	38.18	1254	52.00	1378	67.03	1498	81.58	
Kitchen 1	321	333	3.74	418	30.22	530	65.11	626	95.02	757	135.83	872	171.65	971	202.49	
Living Room 1	271	272	0.37	307	13.28	354	30.63	400	47.60	445	64.21	502	85.24	516	90.41	
Bed Room 11	255	257	0.78	284	11.37	312	22.35	342	34.12	367	43.92	400	56.86	428	67.84	
Bed Room 12	288	301	4.51	361	25.35	428	48.61	492	70.83	559	94.10	643	123.26	717	148.96	
Master Bed Room 1	287	294	2.44	328	14.29	372	29.62	409	42.51	447	55.75	487	69.69	532	85.37	
Guest Room 2	837	836	-0.12	935	11.71	1048	25.21	1164	39.07	1284	53.41	1412	68.70	1541	84.11	
Kitchen 2	369	385	4.34	499	35.23	631	71.00	753	104.07	921	149.59	1073	190.79	1217	229.81	
Living Room 2	254	253	-0.39	287	12.99	328	29.13	369	45.28	408	60.63	456	79.53	500	96.85	
Bed Room 21	229	231	0.87	252	10.04	275	20.09	296	29.26	316	37.99	340	48.47	362	58.08	
Bed Room 22	212	219	3.30	251	18.40	285	34.43	318	50.00	348	64.15	387	82.55	421	98.58	
Master Bed Room 2	273	279	2.20	307	12.45	343	25.64	374	37.00	404	47.99	438	60.44	475	73.99	

Table B.46: Cooling loads for south-west oriented street / second floor.

Cooling Loads/ second Floor																
WWR	Base case	20%	%	30%	%	40%	%	50%	%	60%	%	70%	%	80%	%	Orientation
Guest Room 1	897	906	1.00	1029	14.72	1177	31.22	1327	47.94	1480	64.99	1647	83.61	1807	101.45	
Kitchen 1	371	389	4.85	505	36.12	663	78.71	797	114.82	978	163.61	1139	207.01	1276	243.94	
Living Room 1	323	326	0.93	381	17.96	455	40.87	530	64.09	602	86.38	695	115.17	717	121.98	
Bed Room 11	283	289	2.12	325	14.84	365	28.98	410	44.88	448	58.30	493	74.20	533	88.34	
Bed Room 12	324	342	5.56	423	30.56	516	59.26	608	87.65	702	116.67	821	153.40	926	185.80	
Master Bed Room 1	315	331	5.08	376	19.37	435	38.10	486	54.29	537	70.48	593	88.25	656	108.25	
Guest Room 2	897	906	1.00	1032	15.05	1179	31.44	1329	48.16	1485	65.55	1652	84.17	1821	103.01	
Kitchen 2	390	410	5.13	548	40.51	711	82.31	862	121.03	1069	174.10	1257	222.31	1434	267.69	
Living Room 2	272	275	1.10	315	15.81	368	35.29	422	55.15	473	73.90	537	97.43	594	118.38	
Bed Room 21	247	252	2.02	279	12.96	308	24.70	336	36.03	362	46.56	394	59.51	421	70.45	
Bed Room 22	233	244	4.72	286	22.75	332	42.49	376	61.37	417	78.97	470	101.72	517	121.89	
Master Bed Room 2	299	313	4.68	352	17.73	401	34.11	444	48.49	487	62.88	535	78.93	589	96.99	

Table B.47: Cooling loads for south-west oriented street / third floor.

Cooling Loads/ Third Floor																
WWR	Base case	20%	%	30%	%	40%	%	50%	%	60%	%	70%	%	80%	%	Orientation
Guest Room 1	974	986	1.23	1123	15.30	1289	32.34	1456	49.49	1629	67.25	1816	86.45	1992	104.52	
Kitchen 1	435	457	5.06	602	38.39	803	84.60	970	122.99	1198	175.40	1402	222.30	1580	263.22	
Living Room 1	348	388	11.49	459	31.90	560	60.92	664	90.80	763	119.25	892	156.32	919	164.08	
Bed Room 11	324	332	2.47	379	16.98	433	33.64	493	52.16	540	66.67	605	86.73	659	103.40	
Bed Room 12	367	389	5.99	488	32.97	602	64.03	716	95.10	831	126.43	977	166.21	1106	201.36	
Master Bed Room 1	351	372	5.98	426	21.37	496	41.31	557	58.69	619	76.35	688	96.01	764	117.66	
Guest Room 2	962	974	1.25	1111	15.49	1271	32.12	1433	48.96	1603	66.63	1785	85.55	1967	104.47	
Kitchen 2	416	437	5.05	586	40.87	760	82.69	922	121.63	1146	175.48	1348	224.04	1540	270.19	
Living Room 2	305	308	0.98	358	17.38	422	38.36	486	59.34	550	80.33	629	106.23	699	129.18	
Bed Room 21	280	287	2.50	322	15.00	360	28.57	396	41.43	430	53.57	472	68.57	508	81.43	
Bed Room 22	277	292	5.42	351	26.71	416	50.18	479	72.92	538	94.22	612	120.94	676	144.04	
Master Bed Room 2	338	357	5.62	406	20.12	468	38.46	523	54.73	577	70.71	639	89.05	707	109.17	

Table B.48: Cooling loads for south-west oriented street / fourth floor.

Cooling Loads/ Fourth Floor																
WWR	Base case	20%	%	30%	%	40%	%	50%	%	60%	%	70%	%	80%	%	Orientation
Guest Room 1	1157	1168	0.95	1291	11.58	1435	24.03	1580	36.56	1728	49.35	1883	62.75	2036	75.97	
Kitchen 1	526	550	4.56	686	30.42	885	68.25	1047	99.05	1269	141.25	1469	179.28	1644	212.55	
Living Room 1	483	487	0.83	558	15.53	659	36.44	761	57.56	860	78.05	990	104.97	1014	109.94	
Bed Room 11	483	501	3.73	582	20.50	674	39.54	763	57.97	855	77.02	972	101.24	1066	120.70	
Bed Room 12	496	525	5.85	643	29.64	777	56.65	896	80.65	1038	109.27	1209	143.75	1358	173.79	
Master Bed Room 1	474	497	4.85	553	16.67	626	32.07	688	45.15	752	58.65	823	73.63	901	90.08	
Guest Room 2	1141	1152	0.96	1273	11.57	1409	23.49	1547	35.58	1690	48.12	1844	61.61	1998	75.11	
Kitchen 2	493	513	4.06	648	31.44	806	63.49	952	93.10	1157	134.69	1343	172.41	1517	207.71	
Living Room 2	409	413	0.98	466	13.94	535	30.81	602	47.19	669	63.57	755	84.60	832	103.42	
Bed Room 21	411	424	3.16	476	15.82	532	29.44	582	41.61	636	54.74	700	70.32	752	82.97	
Bed Room 22	424	447	5.42	534	25.94	630	48.58	717	69.10	809	90.80	922	117.45	1020	140.57	
Master Bed Room 2	462	484	4.76	537	16.23	605	30.95	664	43.72	724	56.71	790	71.00	863	86.80	

7- Street oriented to the West:

Table B.49: Heating loads for west oriented street / first floor.

Heating Loads/ First Floor																
WWR	Base case	20%	%	30%	%	40%	%	50%	%	60%	%	70%	%	80%	%	Orientation
Guest Room 1	781	767	-1.79	730	-6.53	694	-11.14	661	-15.36	631	-19.21	603	-22.79	580	-25.74	
Kitchen 1	509	497	-2.36	453	-11.00	405	-20.43	374	-26.52	340	-33.20	315	-38.11	298	-41.45	

Living Room 1	489	486	-0.61	461	-5.73	434	-11.25	412	-15.75	391	-20.04	369	-24.54	361	-26.18	
Bed Room 11	439	432	-1.59	413	-5.92	394	-10.25	376	-14.35	362	-17.54	345	-21.41	333	-24.15	
Bed Room 12	605	590	-2.48	545	-9.92	502	-17.02	467	-22.81	436	-27.93	404	-33.22	381	-37.02	
Master Bed Room 1	569	548	-3.69	522	-8.26	492	-13.53	468	-17.75	447	-21.44	426	-25.13	406	-28.65	
Guest Room 2	820	807	-1.59	774	-5.61	742	-9.51	713	-13.05	687	-16.22	664	-19.02	642	-21.71	
Kitchen 2	622	615	-1.13	579	-6.91	549	-11.74	526	-15.43	498	-19.94	477	-23.31	462	-25.72	
Living Room 2	553	551	-0.36	536	-3.07	519	-6.15	504	-8.86	491	-11.21	478	-13.56	467	-15.55	
Bed Room 21	469	463	-1.28	452	-3.62	441	-5.97	431	-8.10	423	-9.81	414	-11.73	407	-13.22	
Bed Room 22	710	700	-1.41	678	-4.51	656	-7.61	636	-10.42	620	-12.68	602	-15.21	588	-17.18	
Master Bed Room 2	596	577	-3.19	555	-6.88	529	-11.24	509	-14.60	491	-17.62	473	-20.64	454	-23.83	

Table B.50: Heating loads for west oriented street / first floor.

Heating Loads/ second Floor																
WWR	Base case	20%	%	30%	%	40%	%	50%	%	60%	%	70%	%	80%	%	Orientation
Guest Room 1	722	714	-1.11	667	-7.62	619	-14.27	577	-20.08	539	-25.35	504	-30.19	478	-33.80	
Kitchen 1	458	445	-2.84	389	-15.07	333	-27.29	297	-35.15	259	-43.45	232	-49.34	213	-53.49	
Living Room 1	431	428	-0.70	390	-9.51	350	-18.79	319	-25.99	290	-32.71	260	-39.68	252	-41.53	
Bed Room 11	396	390	-1.52	360	-9.09	331	-16.41	303	-23.48	284	-28.28	262	-33.84	247	-37.63	
Bed Room 12	527	508	-3.61	444	-15.75	386	-26.76	342	-35.10	306	-41.94	270	-48.77	245	-53.51	
Master Bed Room 1	527	509	-3.42	473	-10.25	433	-17.84	402	-23.72	375	-28.84	350	-33.59	326	-38.14	
Guest Room 2	775	768	-0.90	728	-6.06	690	-10.97	655	-15.48	623	-19.61	594	-23.35	568	-26.71	
Kitchen 2	601	594	-1.16	551	-8.32	517	-13.98	489	-18.64	457	-23.96	434	-27.79	417	-30.62	
Living Room 2	539	537	-0.37	519	-3.71	498	-7.61	481	-10.76	465	-13.73	449	-16.70	437	-18.92	
Bed Room 21	455	451	-0.88	438	-3.74	425	-6.59	413	-9.23	403	-11.43	392	-13.85	383	-15.82	
Bed Room 22	693	684	-1.30	657	-5.19	629	-9.24	605	-12.70	586	-15.44	565	-18.47	549	-20.78	
Master Bed Room 2	569	553	-2.81	524	-7.91	491	-13.71	465	-18.28	442	-22.32	420	-26.19	397	-30.23	

Table B.51: Heating loads for west oriented street /third floor.

Heating Loads/ Third Floor																
WWR	Base case	20%	%	30%	%	40%	%	50%	%	60%	%	70%	%	80%	%	Orientation
Guest Room 1	781	772	-1.15	711	-8.96	650	-16.77	597	-23.56	549	-29.71	505	-35.34	472	-39.56	
Kitchen 1	421	402	-4.51	332	-21.14	267	-36.58	227	-46.08	182	-56.77	154	-63.42	135	-67.93	
Living Room 1	371	367	-1.08	311	-16.17	258	-30.46	219	-40.97	183	-50.67	150	-59.57	143	-61.46	
Bed Room 11	381	372	-2.36	327	-14.17	286	-24.93	248	-34.91	224	-41.21	196	-48.56	178	-53.28	
Bed Room 12	493	470	-4.67	390	-20.89	322	-34.69	271	-45.03	234	-52.54	197	-60.04	173	-64.91	
Master Bed Room 1	550	531	-3.45	486	-11.64	438	-20.36	400	-27.27	367	-33.27	335	-39.09	306	-44.36	
Guest Room 2	858	852	-0.70	803	-6.41	755	-12.00	713	-16.90	674	-21.45	637	-25.76	606	-29.37	
Kitchen 2	627	619	-1.28	570	-9.09	529	-15.63	498	-20.57	461	-26.48	434	-30.78	415	-33.81	

Living Room 2	576	574	-0.35	552	-4.17	529	-8.16	508	-11.81	490	-14.93	471	-18.23	456	-20.83	
Bed Room 21	496	491	-1.01	476	-4.03	460	-7.26	445	-10.28	433	-12.70	419	-15.52	408	-17.74	
Bed Room 22	716	709	-0.98	673	-6.01	638	-10.89	608	-15.08	584	-18.44	557	-22.21	538	-24.86	
Master Bed Room 2	598	580	-3.01	543	-9.20	501	-16.22	600	0.33	439	-26.59	411	-31.2709	383	-35.95	

Table B.52: Heating loads for west oriented street / fourth floor.

Heating Loads/ Fourth Floor																
WWR	Base case	20%	%	30%	%	40%	%	50%	%	60%	%	70%	%	80%	%	Orientation
Guest Room 1	1573	1564	-0.57	1488	-5.40	1406	-10.62	1333	-15.26	1266	-19.52	1201	-23.65	1151	-26.83	
Kitchen 1	765	684	-10.59	598	-21.83	496	-35.16	437	-42.88	374	-51.11	330	-56.86	299	-60.92	
Living Room 1	648	644	-0.62	577	-10.96	498	-23.15	436	-32.72	388	-40.12	336	-48.15	327	-49.54	
Bed Room 11	662	643	-2.87	569	-14.05	500	-24.47	444	-32.93	399	-39.73	351	-46.98	320	-51.66	
Bed Room 12	809	778	-3.83	670	-17.18	573	-29.17	501	-38.07	438	-45.86	377	-53.40	337	-58.34	
Master Bed Room 1	933	910	-2.47	857	-8.15	798	-14.47	751	-19.51	708	-24.12	665	-28.72	623	-33.23	
Guest Room 2	1666	1660	-0.36	1601	-3.90	1542	-7.44	1486	-10.80	1434	-13.93	1384	-16.93	1339	-19.63	
Kitchen 2	965	947	-1.87	890	-7.77	841	-12.85	804	-16.68	757	-21.55	722	-25.18	698	-27.67	
Living Room 2	912	910	-0.22	885	-2.96	857	-6.03	833	-8.66	810	-11.18	786	-13.82	767	-15.90	
Bed Room 21	842	835	-0.83	812	-3.56	789	-6.29	769	-8.67	749	-11.05	728	-13.54	712	-15.44	
Bed Room 22	1048	1030	-1.72	977	-6.77	926	-11.64	886	-15.46	847	-19.18	807	-23.00	778	-25.76	
Master Bed Room 2	986	964	-2.23	918	-6.90	864	-12.37	822	-16.63	783	-20.59	745	-24.44	705	-28.50	

Table B.53: Cooling loads for west oriented street / first floor.

Cooling Loads/ First Floor																
WWR	Base case	20%	%	30%	%	40%	%	50%	%	60%	%	70%	%	80%	%	Orientation
Guest Room 1	792	792	0.00	876	10.61	975	23.11	1075	35.73	1177	48.61	1286	62.37	1392	75.76	
Kitchen 1	339	352	3.83	441	30.09	569	67.85	675	99.12	820	141.89	950	180.24	1068	215.04	
Living Room 1	283	284	0.35	321	13.43	372	31.45	423	49.47	472	66.78	533	88.34	548	93.64	
Bed Room 11	247	249	0.81	273	10.53	298	20.65	323	30.77	346	40.08	374	51.42	398	61.13	
Bed Room 12	266	276	3.76	327	22.93	385	44.74	42	-84.21	500	87.97	574	115.79	638	139.85	
Master Bed Room 1	283	292	3.18	326	15.19	370	30.74	408	44.17	447	57.95	489	72.79	538	90.11	
Guest Room 2	768	766	-0.26	847	10.29	939	22.27	1032	34.38	1129	47.01	1232	60.42	1335	73.83	
Kitchen 2	279	287	2.87	358	28.32	436	56.27	509	82.44	605	116.85	690	147.31	763	173.48	
Living Room 2	215	215	0.00	236	9.77	262	21.86	288	33.95	313	45.58	341	58.60	365	69.77	
Bed Room 21	224	226	0.89	246	9.82	267	19.20	289	29.02	306	36.61	329	46.88	349	55.80	
Bed Room 22	212	219	3.30	294	38.68	282	33.02	316	49.06	343	61.79	380	79.25	413	94.81	
Master Bed Room 2	278	286	2.88	317	14.03	357	28.42	393	41.37	428	53.96	467	67.99	511	83.81	

Table B.54: Cooling loads for west oriented street / second floor.

Cooling Loads/ second Floor																
WWR	Base case	20%	%	30%	%	40%	%	50%	%	60%	%	70%	%	80%	%	Orientation
Guest Room 1	874	882	0.92	998	14.19	1138	30.21	1277	46.11	1422	62.70	1576	80.32	1725	97.37	
Kitchen 1	379	397	4.75	517	36.41	689	81.79	833	119.79	1032	172.30	1213	220.05	1377	263.32	
Living Room 1	314	316	0.64	367	16.88	442	40.76	518	64.97	590	87.90	681	116.88	703	123.89	
Bed Room 11	277	272	-1.81	303	9.39	338	22.02	373	34.66	404	45.85	444	60.29	476	71.84	
Bed Room 12	294	309	5.10	380	29.25	462	57.14	546	85.71	630	114.29	736	150.34	829	181.97	
Master Bed Room 1	323	342	5.88	395	22.29	463	43.34	524	62.23	586	81.42	655	102.79	734	127.24	
Guest Room 2	847	854	0.83	964	13.81	1092	28.93	1222	44.27	1358	60.33	1502	77.33	1648	94.57	
Kitchen 2	305	316	3.61	405	32.79	506	65.90	600	96.72	726	138.03	838	174.75	934	206.23	
Living Room 2	231	233	0.87	259	12.12	293	26.84	326	41.13	358	54.98	395	71.00	427	84.85	
Bed Room 21	242	246	1.65	271	11.98	298	23.14	325	34.30	349	44.21	378	56.20	404	66.94	
Bed Room 22	235	243	3.40	284	20.85	329	40.00	377	60.43	414	76.17	465	97.87	511	117.45	
Master Bed Room 2	318	336	5.66	386	21.38	450	41.51	507	59.43	564	77.36	628	97.48	700	120.13	

Table B.55: Cooling loads for west oriented street / third floor.

Cooling Loads/ Third Floor																
WWR	Base case	20%	%	30%	%	40%	%	50%	%	60%	%	70%	%	80%	%	Orientation
Guest Room 1	963	974	1.14	1110	15.26	1271	31.98	1433	48.81	1602	66.36	1783	85.15	1956	103.12	
Kitchen 1	426	448	5.16	592	38.97	798	87.32	971	127.93	1212	184.51	1432	236.15	1631	282.86	
Living Room 1	353	357	1.13	422	19.55	518	46.74	616	74.50	708	100.57	827	134.28	853	141.64	
Bed Room 11	300	307	2.33	345	15.00	389	29.67	435	45.00	475	58.33	528	76.00	571	90.33	
Bed Room 12	341	361	5.87	452	32.55	560	64.22	669	96.19	780	128.74	917	168.91	1038	204.40	
Master Bed Room 1	382	411	7.59	486	27.23	584	52.88	520	36.13	762	99.48	864	126.18	978	156.02	
Guest Room 2	931	941	1.07	1069	14.82	1217	30.72	1368	46.94	1525	63.80	1692	81.74	1861	99.89	
Kitchen 2	338	350	3.55	450	33.14	564	66.86	670	98.22	815	141.12	944	179.29	1055	212.13	
Living Room 2	255	257	0.78	287	12.55	325	27.45	363	42.35	399	56.47	441	72.94	478	87.45	
Bed Room 21	268	274	2.24	303	13.06	335	25.00	366	36.57	393	46.64	427	59.33	458	70.90	
Bed Room 22	276	288	4.35	343	24.28	403	46.01	469	69.93	519	88.04	589	113.41	651	135.87	
Master Bed Room 2	380	408	7.37	479	26.05	572	50.53	672	76.84	740	94.74	837	120.26	945	148.68	

Table B.56: Cooling loads for west oriented street / fourth floor.

Cooling Loads/ Fourth Floor																
WWR	Base case	20%	%	30%	%	40%	%	50%	%	60%	%	70%	%	80%	%	Orientation
Guest Room 1	1157	1168	0.95	1292	11.67	1435	24.03	1577	36.30	1723	48.92	1882	62.66	2035	75.89	
Kitchen 1	504	525	4.17	656	30.16	842	67.06	1002	98.81	1222	142.46	1425	182.74	1608	219.05	

Living Room 1	446	449	0.67	508	13.90	596	33.63	687	54.04	772	73.09	884	98.21	906	103.14	
Bed Room 11	444	459	3.38	523	17.79	596	34.23	669	50.68	747	68.24	842	89.64	918	106.76	
Bed Room 12	503	535	6.36	664	32.01	815	62.03	949	88.67	1118	122.27	1313	161.03	1484	195.03	
Master Bed Room 1	522	556	6.51	640	22.61	751	43.87	847	62.26	947	81.42	1059	102.87	1186	127.20	
Guest Room 2	1127	1137	0.89	1255	11.36	1388	23.16	1521	34.96	1658	47.12	1805	60.16	1955	73.47	
Kitchen 2	429	442	3.03	540	25.87	650	51.52	751	75.06	892	107.93	1017	137.06	1126	162.47	
Living Room 2	355	357	0.56	389	9.58	426	20.00	463	30.42	500	40.85	543	52.96	580	63.38	
Bed Room 21	373	381	2.14	415	11.26	451	20.91	484	29.76	518	38.87	559	49.87	593	58.98	
Bed Room 22	426	449	5.40	536	25.82	634	48.83	727	70.66	817	91.78	931	118.54	1027	141.08	
Master Bed Room 2	515	548	6.41	629	22.14	735	42.72	828	60.78	922	79.03	1029	99.81	1150	123.30	

8- Street oriented to the North-West:

Table B.57: Heating loads for north-west oriented street / first floor.

Heating Loads/ First Floor																
WWR	Base case	20%	%	30%	%	40%	%	50%	%	60%	%	70%	%	80%	%	Orientation
Guest Room 1	856	843	-1.52	818	-4.44	792	-7.48	768	-10.28	747	-12.73	726	-15.19	709	-17.17	
Kitchen 1	577	568	-1.56	534	-7.45	494	-14.38	467	-19.06	436	-24.44	411	-28.77	392	-32.06	
Living Room 1	508	505	-0.59	484	-4.72	459	-9.65	438	-13.78	420	-17.32	399	-21.46	394	-22.44	
Bed Room 11	442	436	-1.36	418	-5.43	400	-9.50	380	-14.03	368	-16.74	352	-20.36	340	-23.08	
Bed Room 12	583	568	-2.57	521	-10.63	477	-18.18	438	-24.87	410	-29.67	380	-34.82	358	-38.59	
Master Bed Room 1	547	524	-4.20	494	-9.69	460	-15.90	434	-20.66	411	-24.86	390	-28.70	369	-32.54	
Guest Room 2	889	876	-1.46	856	-3.71	836	-5.96	816	-8.21	799	-10.12	782	-12.04	766	-13.84	
Kitchen 2	660	655	-0.76	628	-4.85	604	-8.48	585	-11.36	562	-14.85	545	-17.42	531	-19.55	
Living Room 2	553	551	-0.36	539	-2.53	523	-5.42	510	-7.78	499	-9.76	486	-12.12	477	-13.74	
Bed Room 21	466	459	-1.50	448	-3.86	438	-6.01	427	-8.37	419	-10.09	410	-12.02	403	-13.52	
Bed Room 22	683	673	-1.46	647	-5.27	621	-9.08	599	-12.30	582	-14.79	564	-17.42	403	-41.00	
Master Bed Room 2	578	556	-3.81	531	-8.13	502	-13.15	479	-17.13	458	-20.76	438	-24.22	418	-27.68	

Table B.58: Heating loads for north-west oriented street /second floor.

Heating Loads/ second Floor																
WWR	Base case	20%	%	30%	%	40%	%	50%	%	60%	%	70%	%	80%	%	Orientation
Guest Room 1	820	813	-0.85	782	-4.63	749	-8.66	720	-12.20	693	-15.49	668	-18.54	648	-20.98	
Kitchen 1	546	535	-2.01	493	-9.71	443	-18.86	411	-24.73	372	-31.87	344	-37.00	323	-40.84	
Living Room 1	468	466	-0.43	436	-6.84	402	-14.10	374	-20.09	349	-25.43	323	-30.98	317	-32.26	
Bed Room 11	415	408	-1.69	384	-7.47	359	-13.49	334	-19.52	318	-23.37	298	-28.19	284	-31.57	
Bed Room 12	541	525	-2.96	466	-13.86	413	-23.66	369	-31.79	337	-37.71	304	-43.81	280	-48.24	
Master Bed Room 1	499	477	-4.41	435	-12.83	391	-21.64	357	-28.46	329	-34.07	302	-39.48	277	-44.49	

Guest Room 2	858	853	-0.58	828	-3.50	803	-6.41	780	-9.09	760	-11.42	740	-13.75	722	-15.85	
Kitchen 2	649	643	-0.92	612	-5.70	584	-10.02	563	-13.25	537	-17.26	517	-20.34	502	-22.65	
Living Room 2	538	536	-0.37	521	-3.16	503	-6.51	487	-9.48	474	-11.90	459	-14.68	448	-16.73	
Bed Room 21	448	444	-0.89	430	-4.02	416	-7.14	402	-10.27	393	-12.28	382	-14.73	372	-16.96	
Bed Room 22	649	639	-1.54	603	-7.09	568	-12.48	534	-17.72	513	-20.96	487	-24.96	467	-28.04	
Master Bed Room 2	528	508	-3.79	470	-10.98	429	-18.75	397	-24.81	369	-30.11	344	-34.85	319	-39.58	

Table B.59: Heating loads for north-west oriented street / third floor.

Heating Loads/ Third Floor																
WWR	Base case	20%	%	30%	%	40%	%	50%	%	60%	%	70%	%	80%	%	Orientation
Guest Room 1	905	899	-0.66	860	-4.97	818	-9.61	782	-13.59	747	-17.46	714	-21.10	689	-23.87	
Kitchen 1	541	527	-2.59	473	-12.57	412	-23.84	373	-31.05	329	-39.19	297	-45.10	275	-49.17	
Living Room 1	457	454	-0.66	413	-9.63	368	-19.47	334	-26.91	304	-33.48	272	-40.48	265	-42.01	
Bed Room 11	418	410	-1.91	372	-11.00	336	-19.62	304	-27.27	282	-32.54	255	-39.00	237	-43.30	
Bed Room 12	520	499	-4.04	423	-18.65	359	-30.96	310	-40.38	272	-47.69	236	-54.62	211	-59.42	
Master Bed Room 1	493	466	-5.48	409	-17.04	351	-28.80	310	-37.12	274	-44.42	240	-51.32	210	-57.40	
Guest Room 2	957	953	-0.42	924	-3.45	895	-6.48	868	-9.30	843	-11.91	819	-14.42	797	-16.72	
Kitchen 2	684	676	-1.17	643	-5.99	611	-10.67	587	-14.18	558	-18.42	535	-21.78	518	-24.27	
Living Room 2	573	572	-0.17	553	-3.49	532	-7.16	514	-10.30	498	-13.09	480	-16.23	466	-18.67	
Bed Room 21	483	479	-0.83	460	-4.76	442	-8.49	425	-12.01	412	-14.70	397	-17.81	385	-20.29	
Bed Room 22	642	628	-2.18	575	-10.44	525	-18.22	479	-25.39	450	-29.91	415	-35.36	389	-39.41	
Master Bed Room 2	521	493	-5.37	439	-15.74	382	-26.68	340	-34.74	305	-41.46	272	-47.79	241	-53.74	

Table B.60: Heating loads for north-west oriented street / fourth floor.

Heating Loads/ Fourth Floor																
WWR	Base case	20%	%	30%	%	40%	%	50%	%	60%	%	70%	%	80%	%	Orientation
Guest Room 1	1708	1701	-0.41	1652	-3.28	1599	-6.38	1552	-9.13	1507	-11.77	1461	-14.46	1427	-16.45	
Kitchen 1	830	812	-2.17	746	-10.12	665	-19.88	615	-25.90	554	-33.25	511	-38.43	479	-42.29	
Living Room 1	731	727	-0.55	673	-7.93	612	-16.28	564	-22.85	521	-28.73	475	-35.02	467	-36.11	
Bed Room 11	699	681	-2.58	617	-11.73	557	-20.31	510	-27.04	468	-33.05	425	-39.20	397	-43.20	
Bed Room 12	791	758	-4.17	648	-18.08	552	-30.21	488	-38.31	423	-46.52	366	-53.73	329	-58.41	
Master Bed Room 1	846	812	-4.02	738	-12.77	655	-22.58	593	-29.91	540	-36.17	483	-42.91	432	-48.94	
Guest Room 2	1775	1771	-0.23	1735	-2.25	1699	-4.28	1665	-6.20	1633	-8.00	1601	-9.80	1572	-11.44	
Kitchen 2	1018	1009	-0.88	968	-4.91	930	-8.64	902	-11.39	865	-15.03	837	-17.78	814	-20.04	
Living Room 2	898	897	-0.11	874	-2.67	848	-5.57	825	-8.13	805	-10.36	782	-12.92	763	-15.03	
Bed Room 21	824	816	-0.97	788	-4.37	761	-7.65	737	-10.56	715	-13.23	691	-16.14	672	-18.45	
Bed Room 22	941	917	-2.55	838	-10.95	764	-18.81	704	-25.19	652	-30.71	597	-36.56	559	-40.60	
Master Bed Room 2	883	850	-3.74	779	-11.78	698	-20.95	639	-27.63	582	-34.09	529	-40.09	477	-45.98	

Table B.61: Cooling loads for north-west oriented street / first floor.

Cooling Loads/ First Floor																
WWR	Base case	20%	%	30%	%	40%	%	50%	%	60%	%	70%	%	80%	%	Orientation
Guest Room 1	730	728	-0.27	788	7.95	859	17.67	927	26.99	996	36.44	1070	46.58	1138	55.89	
Kitchen 1	316	330	4.43	408	29.11	527	66.77	621	96.52	751	137.66	868	174.68	979	209.81	
Living Room 1	269	270	0.37	307	14.13	358	33.09	407	51.30	455	69.14	516	91.82	529	96.65	
Bed Room 11	242	244	0.83	268	10.74	293	21.07	318	31.40	340	40.50	368	52.07	390	61.16	
Bed Room 12	262	274	4.58	327	24.81	386	47.33	442	68.70	501	91.22	574	119.08	636	142.75	
Master Bed Room 1	309	322	4.21	369	19.42	429	38.83	482	55.99	536	73.46	599	93.85	668	116.18	
Guest Room 2	702	699	-0.43	755	7.55	817	16.38	878	25.07	940	33.90	1006	43.30	1072	52.71	
Kitchen 2	237	244	2.95	293	23.63	343	44.73	388	63.71	447	88.61	500	110.97	547	130.80	
Living Room 2	228	229	0.44	251	10.09	281	23.25	311	36.40	338	48.25	373	63.60	403	76.75	
Bed Room 21	237	239	0.84	263	10.97	288	21.52	315	32.91	336	41.77	366	54.43	392	65.40	
Bed Room 22	254	263	3.54	309	21.65	361	42.13	415	63.39	460	81.10	523	105.91	580	128.35	
Master Bed Room 2	327	341	4.28	391	19.57	456	39.45	514	57.19	572	74.92	639	95.41	714	118.35	

Table B.62: Cooling loads for north-west oriented street / second floor.

Cooling Loads/ second Floor																
WWR	Base case	20%	%	30%	%	40%	%	50%	%	60%	%	70%	%	80%	%	Orientation
Guest Room 1	797	803	0.75	885	11.04	984	23.46	1078	35.26	1175	47.43	1273	59.72	1372	72.15	
Kitchen 1	356	375	5.34	478	34.27	637	78.93	764	114.61	941	164.33	1100	208.99	1249	250.84	
Living Room 1	313	316	0.96	370	18.21	448	43.13	524	67.41	597	90.73	693	121.41	713	127.80	
Bed Room 11	266	272	2.26	303	13.91	339	27.44	376	41.35	407	53.01	447	68.05	478	79.70	
Bed Room 12	299	317	6.02	393	31.44	481	60.87	568	89.97	656	119.40	764	155.52	857	186.62	
Master Bed Room 1	356	381	7.02	451	26.69	543	52.53	625	75.56	710	99.44	807	126.69	914	156.74	
Guest Room 2	762	767	0.66	842	10.50	925	21.39	1009	32.41	1094	43.57	1185	55.51	1275	67.32	
Kitchen 2	265	274	3.40	339	27.92	408	53.96	468	76.60	549	107.17	620	133.96	685	158.49	
Living Room 2	254	255	0.39	287	12.99	328	29.13	370	45.67	409	61.02	458	80.31	502	97.64	
Bed Room 21	259	265	2.32	295	13.90	329	27.03	367	41.70	394	52.12	434	67.57	470	81.47	
Bed Room 22	284	298	4.93	361	27.11	432	52.11	509	79.23	572	101.41	661	132.75	739	160.21	
Master Bed Room 2	372	398	6.99	470	26.34	565	51.88	651	75.00	737	98.12	836	124.73	948	154.84	

Table B.63: Cooling loads for north-west oriented street / third floor.

Cooling Loads/ Third Floor																
WWR	Base case	20%	%	30%	%	40%	%	50%	%	60%	%	70%	%	80%	%	Orientation
Guest Room 1	877	886	1.03	981	11.86	1096	24.97	1206	37.51	1319	50.40	1438	63.97	1547	76.40	
Kitchen 1	402	425	5.72	547	36.07	738	83.58	890	121.39	1104	174.63	1299	223.13	1482	268.66	

Living Room 1	372	376	1.08	448	20.43	553	48.66	657	76.61	759	104.03	893	140.05	918	146.77	
Bed Room 11	309	318	2.91	362	17.15	413	33.66	467	51.13	512	65.70	572	85.11	617	99.68	
Bed Room 12	357	382	7.00	487	36.41	611	71.15	735	105.88	860	140.90	1013	183.75	1144	220.45	
Master Bed Room 1	407	441	8.35	528	29.73	647	58.97	755	85.50	865	112.53	991	143.49	1132	178.13	
Guest Room 2	837	844	0.84	930	11.11	1027	22.70	1124	34.29	1223	46.12	1328	58.66	1432	71.09	
Kitchen 2	306	319	4.25	400	30.72	485	58.50	558	82.35	660	115.69	748	144.44	830	171.24	
Living Room 2	293	295	0.68	336	14.68	389	32.76	443	51.19	494	68.60	559	90.78	615	109.90	
Bed Room 21	293	300	2.39	338	15.36	380	29.69	425	45.05	461	57.34	511	74.40	556	89.76	
Bed Room 22	324	342	5.56	419	29.32	507	56.48	603	86.11	682	110.49	791	144.14	889	174.38	
Master Bed Room 2	419	452	7.88	538	28.40	657	56.80	764	82.34	872	108.11	996	137.71	1136	171.12	

Table B.64: Cooling loads for north-west oriented street /fourth floor.

Cooling Loads/ Fourth Floor																
WWR	Base case	20%	%	30%	%	40%	%	50%	%	60%	%	70%	%	80%	%	Orientation
Guest Room 1	1079	1088	0.83	1178	9.18	1284	19.00	1384	28.27	1485	37.63	1592	47.54	1690	56.63	
Kitchen 1	491	514	4.68	632	28.72	816	66.19	964	96.33	1173	138.90	1364	177.80	1543	214.26	
Living Room 1	486	490	0.82	567	16.67	679	39.71	789	62.35	897	84.57	1042	114.40	1066	119.34	
Bed Room 11	474	494	4.22	579	22.15	674	42.19	767	61.81	865	82.49	984	107.59	1078	127.43	
Bed Room 12	536	574	7.09	728	35.82	912	70.15	1076	100.75	1277	138.25	1512	182.09	1718	220.52	
Master Bed Room 1	527	561	6.45	649	23.15	765	45.16	869	64.90	977	85.39	1101	108.92	1238	134.91	
Guest Room 2	1045	1053	0.77	1136	8.71	1229	17.61	1320	26.32	1413	35.22	1510	44.50	1607	53.78	
Kitchen 2	417	431	3.36	520	24.70	612	46.76	691	65.71	803	92.57	899	115.59	987	136.69	
Living Room 2	407	410	0.74	455	11.79	514	26.29	572	40.54	628	54.30	699	71.74	760	86.73	
Bed Room 21	423	436	3.07	491	16.08	552	30.50	610	44.21	667	57.68	738	74.47	800	89.13	
Bed Room 22	481	510	6.03	624	29.73	753	56.55	880	82.95	1003	108.52	1167	142.62	1309	172.14	
Master Bed Room 2	532	565	6.20	650	22.18	762	43.23	863	62.22	966	81.58	1086	104.14	1220	129.32	

Appendix 2D-Shading Devices Design:

8.1.6. Hourly Solar Incident Radiation:

	N Street		NE Street		E Street		SE Street		S Street		SW Street		W Street		NW Street	
First Floor																
	Design Month	**Design Hour**	**Design Month**	**Design Hour**	**Design Month**	**Design Hour**	**Design Month**	**Design Month**	**Design Hour**	**Design Hour**	**Design Month**	**Design Hour**	**Design Month**	**Design Hour**	**Design Month**	**Design Hour**
Guest Room 1	Jun	12	Jun	8	July	8	Sep	9	Oct	12	Aug	15	July	16	Jun	16
Kitchen 1	Jun	12	Jun	8	July	8	Sep	9	Oct	12	Aug	15	July	16	Jun	16
Living Room 1	Jun	13	Jun	14	Jun	17	July	9	Jun	10	July	10	Sep	14	July	14
Bed Room 11	Jun	13	Jun	14	Jun	17	July	9	Jun	10	July	10	Sep	14	July	14
Bed Room 12	Sep	12	July	14	July	14	Jun	15	Jun	17	Jun	9	July	10	July	10
Master Bed Room 1	Sep	12	July	14	July	14	Jun	15	Jun	17	Jun	9	July	10	July	10
Guest Room 2	Jun	12	Jun	8	July	8	Sep	9	Oct	12	Aug	15	July	16	Jun	16
Kitchen 2	Jun	12	Jun	8	July	8	Sep	9	Oct	12	Aug	15	July	16	Jun	16
Living Room 2	July	11	July	10	Sep	12	July	14	July	14	July	16	Jun	16	Jun	9
Bed Room 21	July	11	July	10	Sep	12	July	14	July	14	July	16	Jun	16	Jun	9
Bed Room 22	Sep	12	July	14	July	14	Jun	15	Jun	17	Jun	9	July	10	July	10
Master Bed Room 2	Sep	12	July	14	July	14	Jun	15	Jun	17	Jun	9	July	10	July	10
Second Floor																
Guest Room 1	Jun	12	Jun	8	July	8	Sep	9	Oct	12	Sep	14	July	16	Jun	17
Kitchen 1	Jun	12	Jun	8	July	8	Sep	9	Oct	12	Sep	14	July	16	Jun	17
Living Room 1	Jun	14	July	15	Jun	17	Jun	8	Jun	10	Sep	11	Oct	14	Aug	14
Bed Room 11	Jun	14	July	15	Jun	17	Jun	8	Jun	10	Sep	11	Oct	14	Aug	14
Bed Room 12	Oct	12	July	15	July	15	Jun	15	Jun	17	Jun	9	Jun	9	Aug	10
Master Bed Room 1	Oct	12	July	15	July	15	Jun	15	Jun	17	Jun	9	Jun	9	Aug	10
Guest Room 2	Jun	12	Jun	8	July	8	Sep	9	Oct	12	Sep	14	July	16	Jun	17
Kitchen 2	Jun	12	Jun	8	July	8	Sep	9	Oct	12	Sep	14	July	16	Jun	17
Living Room 2	July	10	Aug	10	Sep	12	July	14	Jun	14	Jun	15	Jun	17	Jun	9
Bed Room 21	July	10	Aug	10	Sep	12	July	14	Jun	14	Jun	15	Jun	17	Jun	9
Bed Room 22	Oct	12	July	15	July	15	Jun	15	Jun	17	Jun	9	Jun	9	Aug	10
Master Bed Room 2	Oct	12	July	15	July	15	Jun	15	Jun	17	Jun	9	Jun	9	Aug	10
Third Floor																
Guest Room 1	Jun	12	Jun	8	July	8	Sep	9	Oct	12	Sep	14	Jun	17	Jun	17
Kitchen 1	Jun	12	Jun	8	July	8	Sep	9	Oct	12	Sep	14	Jun	17	Jun	17

Living Room 1	Jun	15	Jun	16	Jun	17	Jun	8	July	9	Aug	9	Oct	12	Aug	15
Bed Room 11	Jun	15	Jun	16	Jun	17	Jun	8	July	9	Aug	9	Oct	12	Aug	15
Bed Room 12	Oct	12	Aug	15	July	15	Jun	16	Jun	17	Jun	8	Jun	9	Sep	9
Master Bed Room 1	Oct	12	Aug	15	July	15	Jun	16	Jun	17	Jun	8	Jun	9	Sep	9
Guest Room 2	Jun	12	Jun	8	July	8	Sep	9	Oct	12	Sep	14	Jun	17	Jun	17
Kitchen 2	Jun	12	Jun	8	July	8	Sep	9	Oct	12	Sep	14	Jun	17	Jun	17
Living Room 2	July	9	Aug	9	Oct	12	Aug	15	Jun	15	Jun	16	Jun	17	Jun	8
Bed Room 21	July	9	Aug	9	Oct	12	Aug	15	Jun	15	Jun	16	Jun	17	Jun	8
Bed Room 22	Oct	12	Aug	15	July	15	Jun	16	Jun	17	Jun	8	Jun	9	Sep	9
Master Bed Room 2	Oct	12	Aug	15	July	15	Jun	16	Jun	17	Jun	8	Jun	9	Sep	9
Fourth Floor																
Guest Room 1	Jun	12	July	8	July	8	Sep	9	Oct	12	Sep	14	Jun	16	Jun	17
Kitchen 1	Jun	12	July	8	July	8	Sep	9	Oct	12	Sep	14	Jun	16	Jun	17
Living Room 1	July	16	Jun	17	Jun	17	Jun	8	July	8	Sep	9	Oct	12	Sep	14
Bed Room 11	July	16	Jun	17	Jun	17	Jun	8	July	8	Sep	9	Oct	12	Sep	14
Bed Room 12	Oct	12	Sep	14	Jun	16	Jun	17	Jun	17	Jun	8	July	9	Sep	9
Master Bed Room 1	Oct	12	Sep	14	Jun	16	Jun	17	Jun	17	Jun	8	July	9	Sep	9
Guest Room 2	Jun	12	July	8	July	8	Sep	9	Oct	12	Sep	14	Jun	16	Jun	17
Kitchen 2	Jun	12	Sep	9	July	8	Sep	9	Oct	12	Sep	14	Jun	16	Jun	17
Living Room 2	July	8	Sep	9	Oct	12	Sep	14	Jun	16	Jun	17	Jun	18	Jun	8
Bed Room 21	July	8	Sep	9	Oct	12	Sep	14	Jun	16	Jun	17	Jun	18	Jun	8
Bed Room 22	Oct	12	Sep	14	Jun	16	Jun	17	Jun	17	Jun	8	July	9	Sep	9
Master Bed Room 2	Oct	12	Sep	14	Jun	16	Jun	17	Jun	17	Jun	8	July	9	Sep	9