Effect of Built Environment on Passive Building Design in-terms of Natural Ventilation in Hot Climate–Mağusa Case

Aref Arfaei

iSubmitted to the
Institute of Graduate Studies and Research
in partial fulfillment of the requirements for the degree of

Doctor of Philosophy
in
Architecture

Eastern Mediterranean University
August 2020
Gazimağusa, North Cyprus

Approval of the Institute of Graduate Studies and Research

Prof. Dr. Ali Hakan Ulusoy
Director

I certify that this thesis satisfies all the requirements as a thesis for the degree of Doctor of Philosophy in Architecture.

Prof. Dr. Resmiye Alpar Atun
Chair, Department of Architecture

We certify that we have read this thesis and that in our opinion it is fully adequate in scope and quality as a thesis for the degree of Doctor of Philosophy in Architecture.

Asst. Prof. Dr. Polat Hançer
Supervisor

Examining Committee

1. Prof. Dr. Gülay Zorer Gedik
2. Prof. Dr. Filiz Şenkal Sezer
3. Prof. Dr. Sadiye Müjdem Vural
4. Assoc. Prof. Dr. Halil Zafer Alibaba
5. Asst. Prof. Dr. Polat Hançer

ABSTRACT

Passive building architecture is regulated differently by the legislation of various countries as definition in energy standards. The ultimate goal is how to reduce the total amount of energy usage in buildings. There are several factors that need to be considered, such as: building envelope, orientation, location, renewable energy usage and so on. There is no denying that all factors play an important role in this field. Natural ventilation and its effect on enhancing thermal comfort indoors should be studied and included in energy codes. Estimating building thermal efficiency does not consider the close environment effect on indoor thermal conditions. In the route to the house, the air flow will be disrupted by both natural and manmade elements and these obstacles will alter fundamental aspects of wind.

This thesis by focusing on manmade close environment and aims to develop a system for architects, designers, energy consultants and urban planners to enhance the indoor thermal comfort by taking natural ventilation into account. Reducing the information gap would be the first step towards incorporating natural ventilation in building as a powerful building energy consumption reducer tool. Based on supportive advance computer tools, the dynamic mathematical calculation approach provides the ability to run digital simulation and analyze various models to realize the changes under different conditions. For this thesis, the use of Computing Fluid Dynamic (CFD) simulation software is chosen which is the most suitable way to analyze simulated conditions. Comparison of simulation results and outcome categorization demonstrated the response to the value of natural ventilation and the effect of closed build environments on thermal comfort. Methodological approach for architects created and guide for developing appropriate methods that will be adaptable around the globe while the environment selected for this study is hot, but the process will show the steps as a guidance to adapt other climate conditions and properly locate them in the process and find a relevant response to any area. Methodological approach followed to construct a model in which designers can forecast their buildings' performance according to various scenarios.

Keywords: Passive Building Design, Energy Consumption, Natural Ventilation, Built Environment, Indoor Thermal Comfort, Air Movement and its Behavior.

ÖZ

Pasif bina tasarımı, birçok ülkenin enerji standartlarında kapsam olarak farklı şekilde tanımlanmaktadır. Pasif bina tasarımına ulaşmak için, binalarda toplam enerji tüketiminin azaltılması hedeflenir. Bu hedefe ulaşılabilmesi için birçok faktörün dikkate alınması gerekir: bina kabuğu, yönlendirme, konum, yenilenebilir enerjinin kullanımı vb. gibi faktörlerin önemli bir rol oynadığı inkar edilemez, ve bu konuda yapılan çalışmalar araştırmacılar tarafından sürdürülmektedir. Doğal havalandırma ve iç mekan ısıl konforuna olan katkısı bina ile ilgili enerji standartlarında irdelenmeli ve değerlendirilmelidir. Bina ısıl performansının hesaplanmasında, genelde bina yapılı yakın çevresinin performansa etkisi ihmal edilmektedir. Hava hareketleri, yapılı ve doğal çevre etkisiyle özellikleri farklılaşmakta ve bina ısıl performansına etkisi değişmektedir.

Bu tezde, mimarlar, tasarımcılar, enerji danışmanları ve kentsel tasarımcılar için binalarda iç mekan ısıl konfor ortamının iyileştirilmesi açısından, doğal havalandırmanın etkin kullanımını sağlayacak metodolojik bir yaklaşım geliştirilmiştir. Doğal havalandırma ile binalarda enerji tüketiminin azaltılmasını amaçlayan çalışmaların ortaya konması tezin ilk adımı oluşturmuştur. Bilgisayar yazılımları ile, dinamik matematiksel hesaplama yöntemi kullanılarak, farklı koşulların dijital simülasyonu ve çeşitli modelleri inceleme fırsatı yaratır. Bu çalışmada, özellikle hava hareketi ve akışkanların davranışlarını incelemek için CFD (Computing Fluid Dynamic) simülasyon yazılımı kullanılmıştır. Simülasyon çıktılarının karşılaştırılması ve sınıflandırılması ile elde sonuçların değerlendirilmesiyle, yapılı çevrenin bina ısıl performansına etkisi ortaya konmuştur.

Oluşturulan metodolojik yaklaşımla, tasarımcıların, farklı senaryolara göre binalarının performanslarını tahmin edebileceği bir model geliştirilmiştir.

Anahtar Kelimeler: Pasif Bina Tasarımı, Enerji Tüketimi, Doğal Havalandırma, Yapılı Çevre, İç Mekan Termal Konfor, Hava Hareketi ve Davranışı.

This study is dedicated to my beloved family who have always been my source of inspiration and motivation.

I hope this accomplishment would be humble appreciation for my wife's effort during all these years.

It's their absolute love which motivates me to remain strong.

ACKNOWLEDGMENT

I wish to express my appreciation to Assist. Prof. Dr. Polat Hançer who made working under his supervision an amazing experience by giving constructive advice and guidance from the early stages of this thesis until completion. Above all and most importantly, he has provided me with constant support; his opinions, observations, and concerns during the process shaped and improved my growth as a student. I would also like to acknowledge the efforts of my graduate committee members; Prof. Dr. Sadiye Müjdem Vural for her crucial contribution to this study who has supported me in every step and led me in the right direction to facilitate my path, as well as Assoc. Prof. Dr. Halil Zafer Alibaba whose experience in my study field was helpful for this thesis process. In addition to the external jury members who shared their knowledge and show me the bigger picture in my field of study: Prof. Dr. Gülay Zorer Gedik and Prof. Dr. Filiz Şenkal Sezer. I am grateful in every possible way.

Many thanks go to my friends who have helped and encouraged me during my study period and this thesis. Mr. Armin Torabi, for supporting me throughout my whole life, also many thanks go to Mr. Pooya Lotfabadi, Mr. Farzad Fard and all my beloved friends.

I am eternally grateful to my parents for consistently helping me overcome every obstacle personally and professionally, this achievement would not be possible without their aid, in addition to my lovely sisters for their emotional support. Last but not least, my wife and her pure love, commitment and understanding in every difficulty during this journey.

TABLE OF CONTENTS

LIST OF TABELS

LIST OF FIGURES

Chapter 1

INTRODUCTION

Benefit of renewable energy considering the climate condition has been part of design in history all around the planet when the city development and building design were considering the nature as the main principles for their life style, but modern life style and technological development forced urban designers to be responsive to the problem in hand at that time and they did not consider valuable lessons from the past and adapt new system by taking the effect of nature on people life and our construction on nature into consideration. In 1980s researchers with the support of their governments started to study and involve the improvement of energy usage system and reduce the amount of burned fuels as the main source of energy for building construction and develop guide lines and standards based on the results (Ward, 2004).

There are several topics which normally included in different countries' energy standards which should be meet in construction now days. As an example, in Europe Energy Performance of Building Directive (EPBD 2002/91/EC) was the strong step towards reducing the energy usage in building construction covered by United Nations Economic Commission for Europe (UNECE). In 2018 the research outcome published by UNEC organization which shows the percentage of usage based on various headlines in the energy standards over Europe. Following list illustrate the general application of each title in building construction in order to minimize the amount of energy usage:

- Thermal bridge (53%)
- Usage of renewable energy (53%)
- Boiler and AC system (88%)
- Artificial lighting system (65%)
- Daylight requirements (65%)
- Solar absorbance of external surface (29%)
- **Ventilation for summer comfort (18%)**
- Periodic transmittance (29%)
- External solar protection (29%)
- Natural and mechanical ventilation for air quality (82%)
- Air tightness (41%)
- Solar gain [G-value] (65%)
- Specified thermal comfort level for summer and winter (35%)
- Thermal insulation including U value (94%) (United Nations Economic Commission for Europe, 2018).

As it is clear in above information the usage of natural ventilation factors in case of improving the level of thermal comfort has the minimum percentage into consideration. As the general usage for natural ventilation in regulations normally mixed with HVAC system and based on the function and space organization that need to be ventilated spaces is directly related to the human health where there are many researches based on it and counted as apart of building codes. The fact that natural ventilation and its usefulness for thermal comfort improvement in building is not in the right place within the standards motivate author to focused on this topic and try to illustrate the possibilities and importance on natural ventilation in building.

As a brief information, illustrating what is the problem will make the author interested in finding the solution and the aim of the study will be cleared to show what the goal to reach is and the methodology of the thesis will be explained and limitation will be specified. Case study and steps of this study to reach the conclusion will be named.

1.1 Statement of Thesis Problem

Understanding the necessity of energy calculation and how it is possible to implement standards around the world to have passive building thus, more energy is going to be saved and used consider as one of the most important criteria in global warming. Generally, passive building means have benefited as much as possible from any kinds of energy that has been used to overcome the needs. Buildings and thermal comfort consider as the most important portion of energy usage; insomuch providing a comfortable environment for people who lives or work indoor is costing lots of energy consumption. “Architecture and building offer the greatest potential for a sustainable shaping of the environment” (Hegger, Matthias, Stark, & Zeumer, 2008). Energy consumption calculation in buildings includes different codes according to climate, constructing methods and way of measuring and building energy loss controlling; but this fact that the appropriate background in installing standards in different areas is inconspicuous.

There are various studies on natural ventilation for building design scale and testing the distinct ventilation models to check the benefits and increase the benefit to maximum in building design. The necessity of natural ventilation for indoor and outdoor thermal comfort relation is rising towards the higher level of energy factors pyramid. Experiencing the ventilation act in different situation is having lots of benefit, but there is a gap in between. In most calculation or model testing, the wind is measured from the main weather data without considering the effect of natural and built environment located in the path to the construction site. In some examinations, it is possible to find trace of close environment on mathematical calculation on built environment close to the building and the wind acts according to barriers in the way in different scales.

Analyzing and understanding the natural ventilation and design accordingly is a wide field of study and there need to be specialist to extract needed and effective data for ongoing design process. Lack of simple method and information which will be adaptable and to be followed by everyone in different climate condition create the main problem. Based to the existing gap in this topic for supporting the passive building design; The goal is concluding the effective way of presentation and clarification about the wind and natural ventilation for indoor environment. illustrate the effective factors on the thesis problem and design the common ground as systematic approach is the main goal and full fill the missing knowledge in energy standards which will be concluded for achieving the highest possible benefit of air movement as a clean energy on increasing the level of thermal comfort percentage.

As a summary nowadays energy performance of buildings is estimating during design stage by mathematical calculation, however most of them do not consider passive building solution and building context with solar energy benefit, passive insulation techniques, and natural ventilation properties are neglected. For optimization of building thermal performance architects need to evaluate all the factors accordingly however this process is mostly appropriate for engineers' point of view. It is possible to specify the problem as lack of consideration on close environment in energy calculation based on natural ventilation point of view (Figure 1). Conclusion will be illustrated after answering the following thesis question:

1-What are the effects of closed environment on natural ventilation?

2-What will be different factors' impact on building natural ventilation system?

3-What are the missing factors in order to increase the level of natural ventilation effect on maximizing indoor thermal comfort in passive building design?

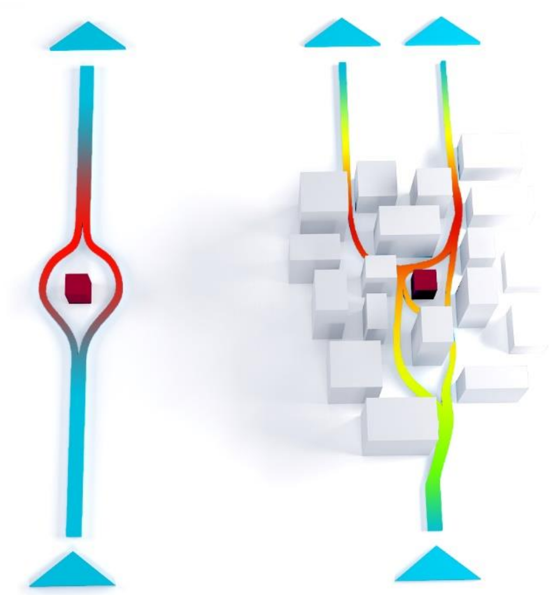


Figure 1: Statement of thesis problem (Designed by author).

1.2 Thesis Aim

The aim is to provide the method which is applicable for any climate condition and the guidance how to use the systematic approach in order to find the result adaptable to the construction. This study aimed to illustrate the effect of natural ventilation on user's indoor thermal comfort based on neighborhood pattern and surrounding natural and built environment (Figure 2). On the other hand, it is needed to understand and study natural ventilation in micro climate scale in order to be able to have maximum benefit. There are two main categories which are existing context and design with context while under each heading there will be two sub-categories. For existing context either natural ventilation effect on thermal comfort for existing building is going to be calculated or there will be new building construction while in design with context large construction site in order to have complex design is going to be considered or further development for the City planning and air circulation calculation factors have to be brought to attention in other to find the rightful place of natural ventilation during the development process.

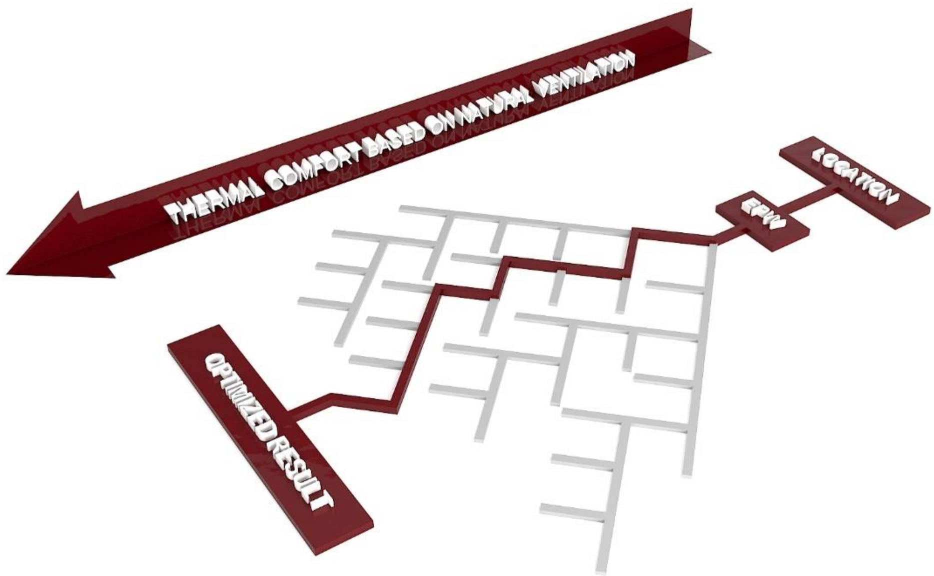


Figure 2: Thesis aim (Designed by author).

City blocks and built environment together with natural effect from the greeneries and landscapes are considered as a puzzle peace for natural ventilation calculation, in order to show the connection and relation between existing human built environment and passive building designed development in order to illustrate the effect of close environment situation which is directly under the influence of city scale ventilation pattern and checks how natural ventilation factors affected.

As a summary the aim of this study is evaluating the built environment effect in order to achieve more successful calculation for passive building design. It is obvious that the human built environment had effect on air movement. This issue needs to be evaluated from different perspective to find the most suitable guidance according climate condition.

1.3 Thesis Focus

This thesis is focusing to provide the systematic approach as method for architects, designers, and urban planners to be able to follow system approach in order to find the simple way to integrate closed environment in their energy calculation to increase the benefit of natural ventilation on users thermal comfort and estimate the amount of energy saving if the surrounding design properly for passive building construction for any location in any scale.

As the overview which is presented in Figure 3, the steps in thesis process adaptable to any type of climate in mind is explained. This process defines the strategy in order to find the necessary data related to any specific location which they want to apply the natural ventilation effect without any mechanical device support. This thesis is focusing on hot climate as the general decision as far as natural ventilation play important role specially for summer passive cooling in hot climate but it is possible to follow the same steps with various factors in mind as a new focus and reach the result which is aimed for any type of study. According to climate conscious building design which directs towards different energy saving strategies such as passive heating, passive cooling, day light usage and natural ventilation there will be option elimination stage and change the direction on the way to the thesis aim, ventilation in passive cooling and wind driven ventilation method are going to be the main focused for this thesis. As the general undeniable step, it is must to process all weather data factors which are applicable according to any location and the information will be integrate in energy calculation from natural ventilation point of view. They are four main categories as the general outcome accordingly.

- Thermal comfort calculation for existing building in existing climate should follow the close environment effect on natural ventilation strategy as far as the indoor condition will be affected by surrounding. In order to find more realistic result and design; better strategy is to consider natural ventilation and related factors in to account.
- Design the new building in the existing context which is going to be useful for new building design and improve the level of energy efficiency based on dictated built environment surrounded the building site. In this category, size and the site shape are clear and the construction boundary is defined according to the municipality rules and regulations. It is important to mention the street width and orientation in relation with wind direction is going to be fixed in this category as well.
- Designing stage context is going to be related to the large field for construction which the design contains different function or the project is going to be complex design. In this category architects are freer to define the street width and orientation plus the land size and shape next to the pattern can be modified according to the needs. Thus, it is important to consider all factors to have maximum benefit from natural ventilation in this type of construction.
- The last category is pre-design stage context which is related to the city expansion and development. In this section there are many other factors which

plays important rules in any decision. The city planning department is responsible for the further steps in city design but it is important to consider the role of natural ventilation in building design as a base to give a chance for improvement of energy efficiency level.

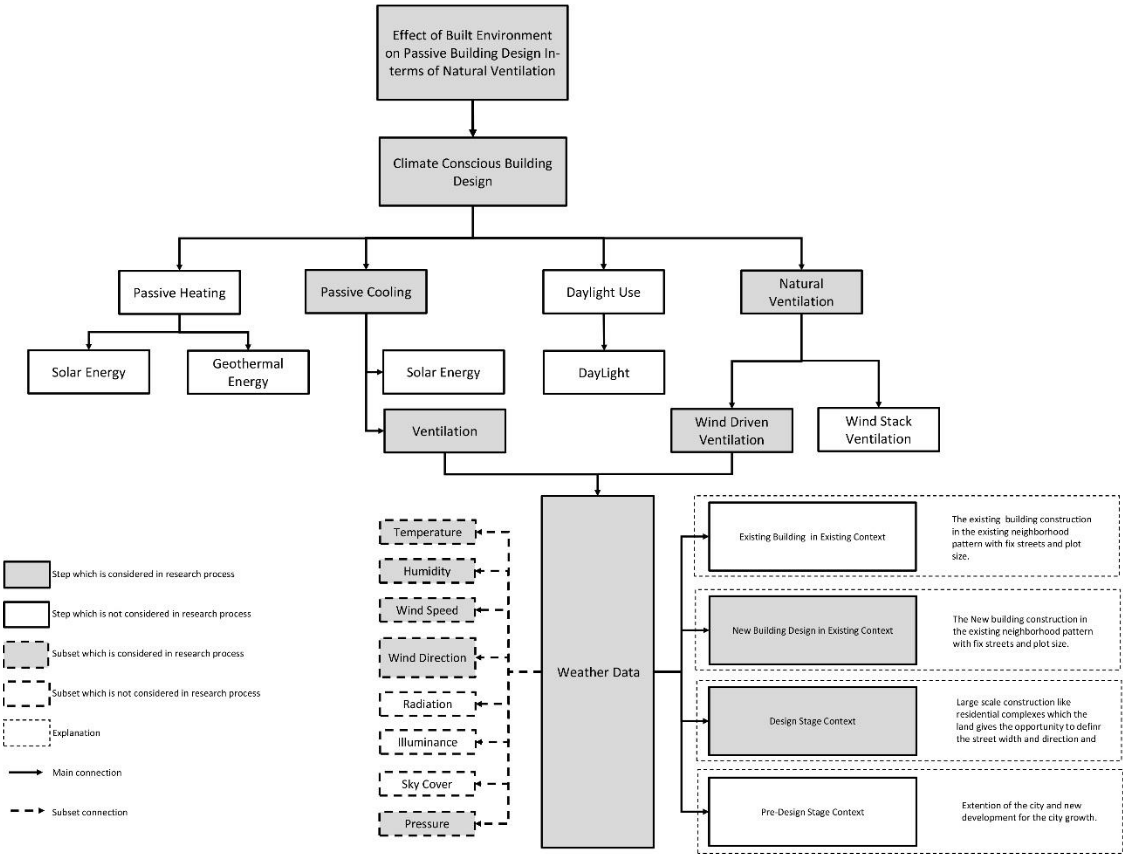


Figure 3: Thesis focus (Designed by author).

1.4 Thesis Limitation

Undeniable the topic is very wide based on the different city patterns and building types and there should be a reachable work which fits to the time frame, in that case in order to get the better understanding about the level of indoor thermal comfort and illustrating the importance of the thesis topic; the main calculation has been done for the residential buildings, considered as the space with user's presents as maximum time duration. Obviously it is mandatory to check the natural ventilation different effects (positive and negative) on human which also will be the part of pre study stage of the thesis, but the main limitation will be the built environment which have more close relation with the new construction of residential passive building with various effective factors on the best performing designed passive building with maximum benefit of the natural ventilation on user thermal comfort and check the different results affected by selected closed environments.

The other limitation has been put on building height. Based on the construction and building style two, four and ten story buildings are selected. Two story building which may represent mostly villa construction and some individual residential units. Four story buildings are brought to attention because it represents the middle-class suburb area construction and at the ten story which is the average of construction for higher buildings. Also, the building location in site is limited by the construction at the middle of the land with proper set back from the land boundary. Calculations will be limited by three different orientation towards prevailing wind as zero, forty-five and ninety degree plus the general pattern is considered for the individual building design. Three main angles are selected based on higher effecting estimation on calculation process and in-between degrees are not going to be more dominant, thus in this thesis the other orientations are going to be eliminated. The graphical summary of the thesis limitation is presented in Figure 4.

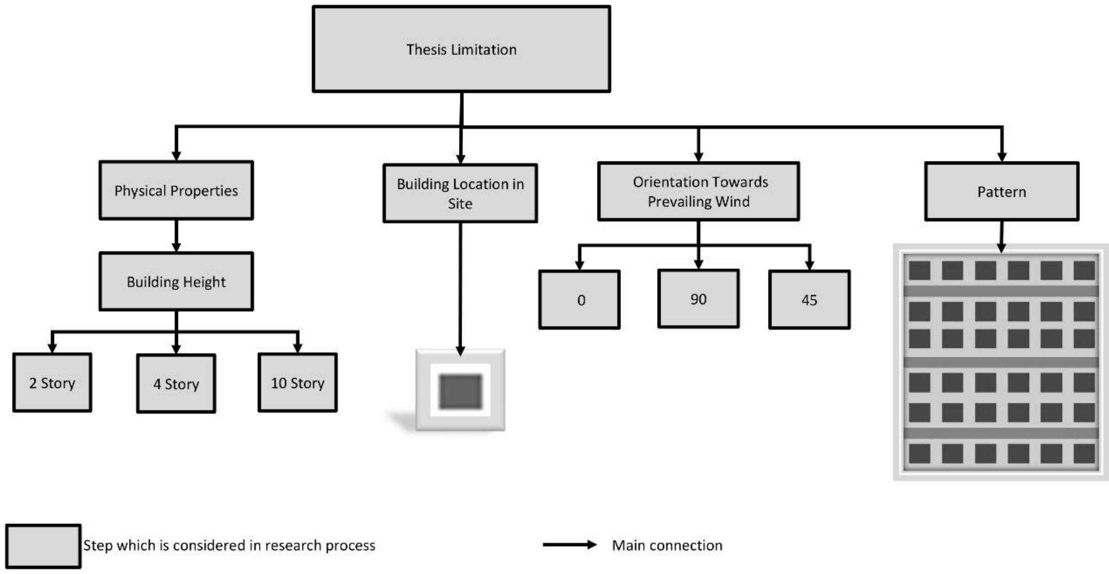


Figure 4: Built environment properties (Designed by author).

It is important to explain the clothing factor on users' thermal comfort during winter (three-piece clothing is considered) and summer (two-piece clothing) periods. It is obvious that there is change based on clothing level variations. So, author had to limit the clothing level. The other limitation for mathematical calculation is related to the rules in different countries which are explained in Chapter 4 which is covering the regulation in the selected case for this thesis. Nearby built environment is the vocabulary which defines the surrounding buildings for specific site which is going to be used in this thesis in order to make the statements more understandable.

1.4 Hypothesis

Architects are the head and responsible for design team which is affecting building thermal performance. Different design strategies need to take different actions for maximizing performances. Systematical approach should develop in order to be guidance for this purpose. Engineers evaluate and improve building performances after design stage and it cannot reach appropriate goal. Nearby built environment effects the building performance in a significant performance based on natural ventilation for users' thermal comfort and now a day building performance are calculating without consideration of the nearby built environment effect on air movement. The hypothesis is if the building performance will be evaluated according to nearby built environment effect on natural ventilation thus the calculation result is going to be more realistic results and the building performance will be more valuable and real-life users are going to be more satisfied.

1.5 Methodology

First step for thesis methodology is finding, and explaining the similar studies as back ground study and highlight direct related studies for the literature review. The data has been collected through books, articles and internet searching. In order to illustrate the important and helpful knowledge as a foundation for further steps. The intention is to survey the existing state on the climate application all over the world and find the best way to fill the gap in-between. The framework of this thesis methodology is to gather the result of compare and understand the processes of air movement behavior base on nearby built environment for improving the building indoor thermal comfort in order to find the most suitable path towards the thesis aim.

At the beginning of the field work, essential information about finding the right location for natural ventilation in standards and how much architects and energy experts should rely on this type of renewable energy is placed. And it is going to be followed by mathematical calculation system for finding the comparable result for highlights which shows the thermal comfort improvement as numeric evidence of thesis conclusion. Therefore, some sections during the process will follow the qualitative methods for the ground rules and defining the frame work. Also, quantitative method and numeric results are going to be the base for calculation in this thesis.

In Chapter 2 (literature review) the information gathered in the systematic way which goes from general and main topics to more detailed data which are related to this thesis topic and show the relation and continuation of this thesis with other similar fields of studies. Within this process, second Chapter is going to start with climates condition and show the location of the case study climate in related subheading followed by explanation and definition of thermal comfort which is the center point of the thesis goal. Also, explanation of different terminologies in the field, role of natural ventilation in city, wind and architecture, ventilation systems in building, how to analyze air movement, and wind constituent factors are going to be illustrated. At the end the energy regulation and their achievements around the world is going to be discussed followed by example of the natural ventilation codes and formulas in regulation to show the gap in energy calculation based on natural ventilation and the path regulators should follow to improve energy standards by considering natural ventilation on indoor thermal comfort improvement.

In Chapter 3 the systematic method design is going to be explained and all factors are going to be located in the related slots in order to make the process complete. In this chapter the path will follow the topics which should be considered for every location and show from which section the specific rules from the country or location should be integrated to the system. As the over view chapter three is the main goal of this study and is the guidance to conclusion.

In Chapter 4; selected case is going to be explained and the formula which clarified in chapter three is going to be tested according to the selected case construction rules and regulation in order to show the importance of the natural ventilation and how much it is possible to increase the level of thermal comfort by correcting the method of natural ventilation usage in energy calculation. The developed model will be tested with existing built environment condition which is located in Cyprus Island. As far as the island is divided into two parts thus, the focusing part in this thesis is the northern part (Turkish part) of Island which is known as the Turkish Republic of Northern Cyprus. This area has been selected carefully based on certain criteria such as being without any process regulations through the energy consumption calculation and modification buildings in order to avoid waste of energy in residential buildings. On the other hand, having a database for regulation energy efficiency regulations in the future. Magusa city located on the East part of the island has been selected for more detail analysis as far as height rises are constructions during the last two decades, before that most of residential settlements were low rises or villas so it gives the opportunity in order to check all focused neighborhood patterns and building heights. For this thesis Rhino Grasshopper has been selected as dynamic CFD computer simulation software for testing the formula.

Chapter 2

LITERATURE REVIEW

Architecture, urban planning, and building construction is one of the most energy consuming topics in energy use and energy efficiency principles in order to engage with user indoor daily activities to protecting them from the outdoor climate condition to increase the level of comfort for users (Muller, 2002). Technology advance influenced human lifestyle both emphatically and adversely. New innovation consistently changes people life without a doubt and takes it to another level (Goodland, Daly, & Serafy, 1992). Experts by using current technology are attempt to discover more successful approach in order to reduce the amount of energy consumption continuously (Hordeski, 2003). So, with the combination of the study and technology, clearly living atmosphere and design process is changing uninterrupted.

All changes guiding interested people to create the way of design system in order to reduce the level of energy usage and also increase the level of comfort for indoor spaces (Kalz & Pfafferott, 2014). Using renewable energy is solution currently which is happening everywhere (Sayigh, 2013). One of the clean energies is wind which is accessible all around the planet and it has direct effect on filling temperature (Da Rosa, 2009). Natural ventilation is not a new topic in building design (Alvarez, 1998). Ventilation took undeniable role in building from the early time in history when people realize natural ventilation has effect on indoor thermal comfort and also human health

(LI & Chen, 2003). It is possible to tracking the evolution of design by considering the air movement in building construction understand considered elements in historical cities. In traditional construction natural ventilation was under the accurate care by building architects (Elmualim, 2006). Buildings itself was designing by natural ventilation, and the group of buildings with consideration of accessibility were creating the neighborhoods and at the end shaping the cities. Thus, buildings were fully had benefits from ventilation (Cohen, 2017). Designing according to having maximum benefit from natural ventilation is highly effective on user thermal comfort feeling in hot climates which help to harness wind and bring down the indoor temperature to the acceptable level (Taleb, 2015).

After modernism, the life style and the process changed. According to the number of people who were coming to the cities, cities grown by following any rules (Smith, 1992). The main objective for city planners is designing spaces as the large-scale area factors and considering natural ventilation in building scale has been forgotten in their strategies (Morris, Simmonds, & Plummer, 2001). The city blocks are appearing and then buildings are designed to be constructed in the given described land boundary (Chen, Ooka, Huang, & Tsuchiya, 2009). So, achieving successful design from natural ventilation point of view which should consider many factors from larger scale is going to be very limited.

In order to redefining the relation between the city and building description firs it is needed to study what happened before and what is happening now days. For illustrating the system which is happening, researchers have done many studies which are going to be collected, group and sorted to play the role of background for this study. In each scale of city according to the natural ventilation perspective there are some factors which are the basic reason of forming the building and the level of building satisfaction for natural ventilation benefit (Levermore, 2013).

Each climate has different factors and user expectation is affected accordingly in order to be thermally comfort inside the building, thus cods are changing according to the climate (Hiyama & Glicksman, 2015). It is clear that for each climate style there should be changes for increasing the benefit of natural ventilation.

2.1 Climate Condition and Building Design

The climatic condition plays important role on the way of using natural ventilation in architecture. Based on the climate, decision about the method which is going to be more suitable for that condition will be made. Climate categories can generally be divided into five sections: temperate climate, tropical / mega thermal climate, dry (desert and semi-arid) climate, continental / microthermal climate, and polar climate. The selected case of the thesis is locating under temperate/mesothermal heading which means Mediterranean climate. In Figure 5 selected climate base on the case location has been illustrates (Kottek, Grieser, Beck, Roudolf, & Rubel, 2006).

- **Temperate Climate**

Temperate climates are commonly characterized as conditions with moderate precipitation spread over the year orbit of the year with the inconsistent dry season, mellow to warm summers and cool to cold winters (Perillo, Wolanski, Cahoon, & Hopkinson, 2019). Oceanic climate, high land climate, humid subtropical climate, and Mediterranean climate are grouped and located under this type.

- **Tropical Climate**

When added to the word 's rational feeling the phrase tropical has relatively clear meaning. Area with a tropical climate is united at every event part of the year with a regular temperature of over 18 degrees Celsius and substantial precipitation. Such territories are non-arid and relatively consistent with the conditions in the central atmosphere around the world (Reis, 2017). Tropical rain forest climate, tropical monsoon climate, and tropical wet and dry climate are grouped and located under this type.

- **Dry Climate**

The definition of dry climates is that precipitation is in possible aspiration to evaporate. Desert regions, clustered along the western shores of main lands in tropical or near-tropical areas, are marked by cooler temperatures than seen elsewhere at tantamount scopes and frequent nebulae and low bruises, provided that these spots are among the driest on earth in terms of actual precipitation. In this atmosphere, summers are sweltering to exceptionally blistering and it only from time to time rains. Winter days may be cool or dry, and winter evenings may be frosty. The air is warm, a few clouds is in there; sunshine is exceptional and glare can be a problem. There is a considerable difference in temperature among both day and night (ISC-Audubon, 2013). Hot desert climate, cold desert climate, hot semi-arid climate, and cold semi-arid climate are grouped and located under this type.

- **Continental Climate**

Continental climate is a significant atmosphere kind of the Köppen characterization that shows enormous occasional temperature appears differently in relation to blistering summers and cold winters. It is found somewhere in the range of 30° and 60° N in focal and eastern North America and Asia in the significant zone of contention among polar and tropical air masses. the mainland subarctic atmosphere is a basically Northern Hemispheric wonder since landmasses are missing at the critical scopes in the Southern Hemisphere (Rafferty, 2016). Hot summer continental climate, warm summer continental climate, and subarctic borealis climate are grouped and located under this type.

- **Polar Climate**

The polar climate with temperatures once in a while surpassing 0° C even in summer and with little precipitation as 100–200 mm for each year. Polar climate is generally snow- and ice-covered districts in the Arctic Ocean and its islands, Greenland, and Antarctica. Its mildest structure happens in the Atlantic area of the cold, and its most extreme structure on the level of Eastern Antarctica (Rhea, 2001). Tundra climate and ice cap climate are grouped and located under this type.

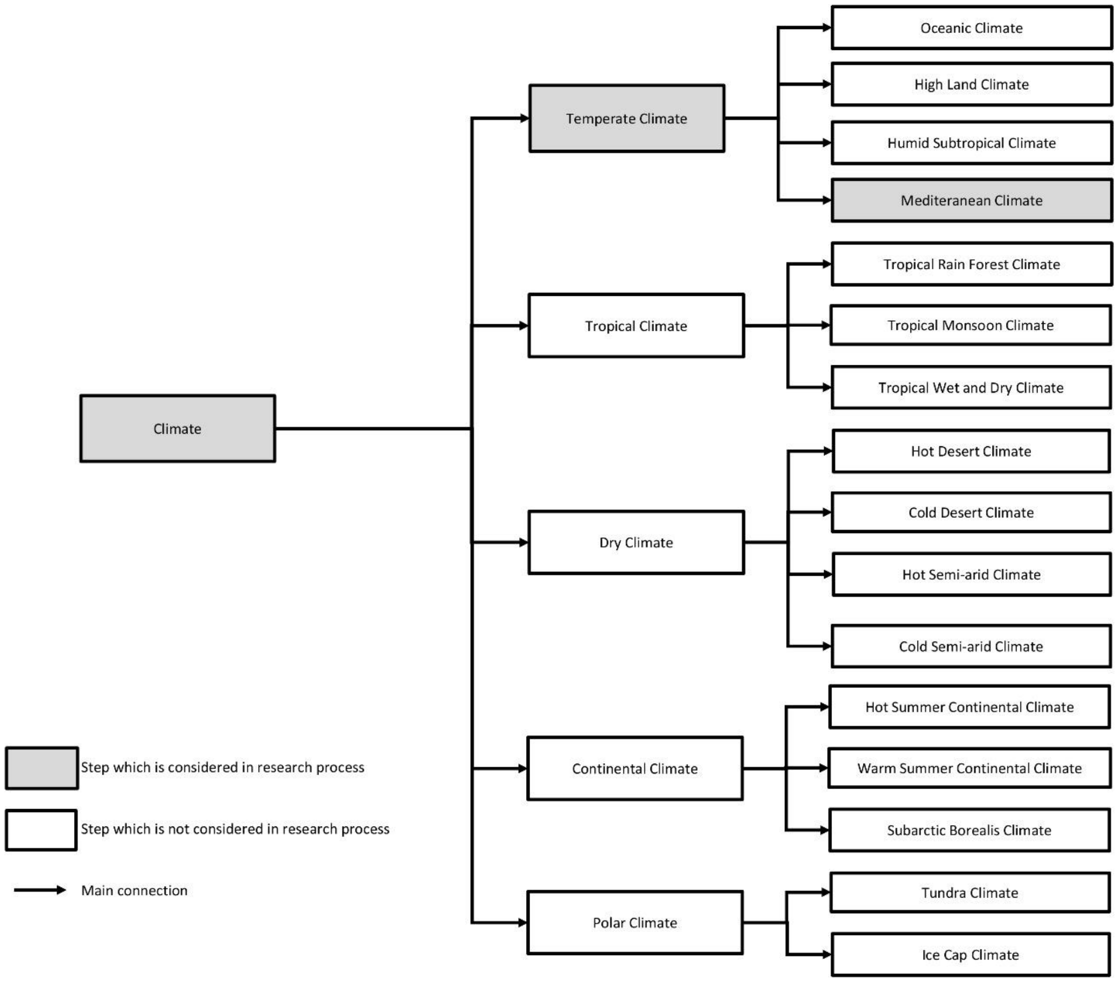


Figure 5: Climate categories (Kottek, Grieser, Beck, Roudolf, & Rubel, 2006).

2.2 Climate Analysis According to Thermal Comfort

At the point when individuals are disappointed with their warm condition, in addition to the fact that it is a potential wellbeing danger, it likewise impacts on their capacity to work viably, their fulfillment at work, shopping, eating in a restaurant or even the daily life in at home is going to be affected. BS EN ISO 7730 characterizes thermal comfort as that state of mind which communicates fulfillment with the thermal condition. The condition when somebody is not feeling either excessively hot or excessively cold (ISO, 2005). Human thermal comfort cannot be straight forward and communicable in degrees is not necessary. Nor would acceptable temperature ranges be able to characterize it pleasingly. It is an individual experience subject to an enormous number of rules and can be special within a similar space in relation to one person to another (ISO, 1995). The Health and Safety Executive (HSE) states that a condition can be said to achieve 'responsive comfort' when 80 percent of its occupants are thermally agreeable at any point. This implies that thermal comfort can be assessed by studying tenants to see if they are deceived by their thermal conditions (HSE, 2020). Figure 6 shows the thermal comfort subheadings and factors which together will define the feel of thermally comfort for users. All factors will be same for both indoor and outdoor situation. The green options are used in this study and for the human health it is considered as healthy for all users.

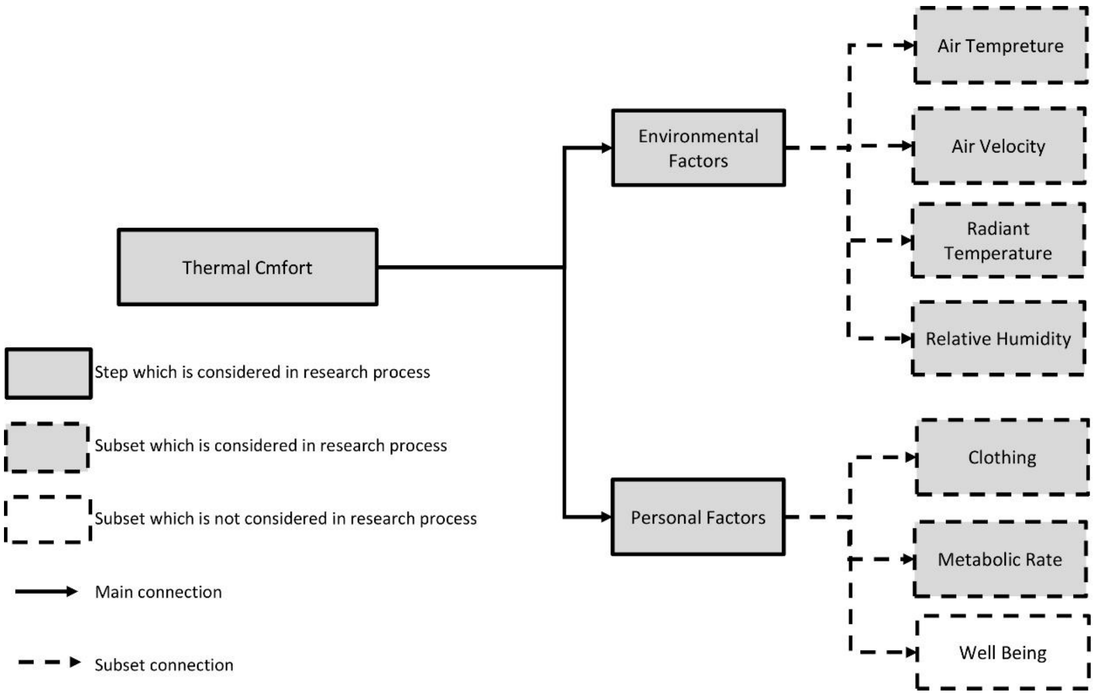


Figure 6: Thermal comfort factors (Erlandso, Cena, De Dear, & Havenith, 2014).

2.2.1 Environmental Factors

Many factors effect users which change their thermal feeling based on environment such as: air temperature, air velocity, radiant temperature, and relative humidity. In following section definition of each factor and how they will affect the thermal comfort feeling is going to be explained (Hegger, Fuchs, Stark, & Zeumer, 2012) (Hensen & Lamberts, 2012).

- **Air Temperature**

The air temperature is a proportion of the hot or cold air and is the most frequently measured parameter of the atmosphere. Perhaps more precisely, temperature reflects the active energy of the gases that make up the air, or the energy of motion. The temperature of the atmosphere increases as the gas particles move much quicker (Staff, 2010). The air temperature is the factor that shows that air movement will be beneficial in a positive or negative way to the user thermal condition. If the air temperature is very hot it is not beneficial to cool down the body during the summer and the cold weather in the winter period increases the sense of cool temperature in the human body (Shinichi & Kenichi, 1994).

- **Air Velocity**

Air velocity is a significant factor in thermal comfort for instance: air movement in warm or humid conditions will increase heat loss by convection with no temperature change. Physical action also expands the development of air, so that air speed could be remedied to represent the degree of physical activity of an individual (HSE, 2020). The airspeed is an individual factor to be in contact with and quicker the air is moving, the more prominent the trading of warmth between the human body and the air will take place.

- **Radiant Temperature**

The mean radiant temperature is a critical factor, particularly in structures in which envelopes were presented to a sun-based radiation, that traditional indoor temperature and stickiness control cannot ensure indoor solace. The temperature around a user's environmental factors is commonly communicated as mean radiant temperature and any solid mono-directional radiation, for example, radiation from the sun (Atmacha, Kaynaki, & Yigit, 2007).

- **Relative Humidity**

The relative humidity is the proportion between the real measure of water vapor noticeable all around and the greatest measure of water that the air can hold. Relative humidity somewhere in the range of 40% and 70% does not majorly affects thermal comfort. Relative humidity is measured by percentages and it will be more difficult for users’ body to lose heat through sweating when the humidity percentage is higher (Djamila, Chu, & Kumaresan, 2014). In most countries the higher boundary for having benefit from humidity in thermal comfort is set 0.012 (This translates approximately to a relative humidity of 75% at a dry bulb temperature of 21°C and 53% at 27°C) in energy mathematical calculations which means above mentioned number it is not going to be accurate for users to have change of feeling according to humidity (ASHRAE, 2017).

2.2.2 Personal Factors

Personal factors are variables which are changing based on individuals. It is not possible to generalize this factor as far as user is going to define how they prefer to act according to the thermal condition in order to improve personal thermal feeling.

- **Clothing**

clothes protect an individual from trading heat with the encompassing air and surfaces just as influencing the loss of heat through the evaporation of sweat. Clothing can be straightforwardly constrained by an individual while ecological elements might be outside their ability to control.

- **Metabolic Rate or Level of Activity**

Individuals have distinctive metabolic rates that can change because of movement level and ecological conditions. The ASHRAE 55 Standard characterizes metabolic rate as the degree of change of substance vitality into heat and mechanical work by metabolic exercises inside a life form, generally communicated as far as the union territory of the all-out body surface (ASHRAE, 2017). The Compendium of Physical Activities is utilized by doctors to record physical exercises. It has an alternate meaning as the proportion of the metabolic pace of the action being referred to a resting metabolic rate. Food and drink propensities may have an effect on metabolic rates, which is a roundabout way that impacts thermal comfort. These impacts may change contingent upon food and drink consumption also Body shape is another factor that influences thermal comfort. Warmth dispersal relies upon the body's surface region. A tall and thin individual has a bigger surface-to-volume proportion, can scatter heat all the more effectively, and can endure higher temperatures in excess of an individual with adjusted body shape (Lou, Wang, Ke, & Cao, 2018).

- **Well Being**

Wellbeing defines as the basic cold or influenza which influences our capacity to keep up an internal heat level of 37°C at the body core. Other contributing variables can incorporate; access to food and drink, acclimatization, and condition of wellbeing. thermal esthesia goes past this, suggesting the epicurean characteristics of the warm condition are resolved as much by the general warm condition of the subject as by the earth itself.

2.2.3 Predicting Thermal Comfort

Effective temperature, equivalent temperature, Wet Bulb Globe Temperature (WBGT), resultant temperature. BS EN ISO 7730 and BS EN ISO 10551 clarify Predicted Mean Vote (PMV) and Percentage People Dissatisfied (PPD) for thermal comfort. PMV and PPD were formulated on the basis of research that conducted to find out whether people feel relaxed in different situations and created equations that would predict comfort. Taking into account the equations; air temperature, mean radiant temperature, air movement, humidity, clothing and level of operation. “PMV is an index that predicts the mean vote of a group of people voting on how comfortable they are in an environment. PPD is a function of PMV” (ISO, 2005) (ISO, 2019).

The necessity of multiple assessment exists with non-uniform conditions, and, Computational Fluid Dynamics (CFD) analysis may be necessary in complex environments in order to have realistic measured thermal comfort. NB BREEAM proposes that: 'In BS EN ISO 7730:2005: Ergonomics of the thermal environment. Expository assurance and understanding of thermal comfort are characterized by utilizing the estimation of PMV and PPD indices and nearby thermal comfort models. It is likewise characterized as that state of brain which communicates fulfillment with the thermal comfort. The reason for this issue is to support fitting and powerful thought of thermal comfort subjects, and particular of suitable inhabitant controls to guarantee both the most extreme adaptability of the space and warm solace for most of the building tenants (BREEM UK, 2018). It additionally proposes that: thermal comfort examination apparatuses can be partitioned into various techniques for expanding multifaceted nature. The most perplexing of these and the one that gives the most prominent trust in results is the full unique model. This kind of model empowers yearly warming or cooling loads, overheating dangers, and control techniques to be evaluated (ISO, 2004).

2.3 City and Ventilation

There are evidences which illustrate the relation between city development and building construction with natural resources in historical settlements, thus it is obvious identical patterns all around the world in historical cities have been influence from climate conditions (Bandarin & Oers, 2014), it is needed to study the city planning due to history and use of renewable energy. Also, evaluation the level of natural ventilation consideration in city scale should be clear as well as hoe the residential units have been designed according to affective factor in the city based on air movement. In order to find out the effect of the city pattern on building scale natural ventilation situation basic knowledge should be gathered from the city planning regulations and standards (Mostafaeipour, Sedaghat, Dehghan-Niri, & Kalantar, 2011). Undeniable factors dictate from systematic city patterns which shape the working and living zones as a larger scale will have impact on citizens health and comfort (Carrer, et al., 2015).

- **Sustainable Urban Neighborhood**

The sustainable urban neighborhood is an urban structure model which is a piece of urban change hypothesis, moving endlessly from the normal rural advancement towards progressively mainland city styles. It rose in the UK during the 1990s, explicitly from spearheading work by The Urban and Economic Development Group an urban recovery consultancy focuses in Manchester. These focuses set out the attributes of urban, instead of rural, design. Ecological weights and social and statistic changes have stirred the significance of city living in the 21st century (Rudlin & Falk, 1999).

- **Urban Heat Island**

The new vocabulary added to the urban criteria is Urban Heat Island (UHI) which shows the unpleasant city area reasons and effect of human activity on it which needed to be considered (Lowe, 2016). Urban heat island happens if the urban area at the center of city became hotter than rural area because of people activities. The alteration is greater at night and it is more feel during summer and winter time (Solecki, et al., 2005). Unused heat produced by energy usage is not a main contributor. Increasing people number will cost the average temperature as a center of grows. Generally, heat island as a term apply when refer to any area which is comparatively hotter than the close environment (Yang & Xinyi, 2012).

Month to month precipitation is more prominent downwind of urban areas, in part because of the UHI. Increments in the warmth inside urban focuses expand the length of developing seasons and diminishes the event of weak tornadoes. The UHI diminishes air quality by expanding the generation of contaminations (Chakraborty & Lee, 2019). Relief of the urban heat island impact can be cultivated using green rooftops and the utilization of lighter-shaded surfaces in urban regions, which reflect more daylight and assimilate less heat (Oke, 1982). Researchers Concerns about conceivable commitment from urban heat islands to an abnormal weather change. Plane atmosphere changes based on heat island effect brought and reasoned in various researchers' study (Santamouris, 2014).

Density of the city center is the main element which will be the guidance for the wind in the city based on UHI. Considering natural ventilation for the main active area has direct impact on possibility to have higher thermal comfort level. Affective elements such as: neighborhood blocks dimension, buildings physic, also city vehicle and pedestrian circulation proportion are dictating the wind behavior (Sailor, 2011). Urban open spaces street and pedestrian level are accentuated regard to the air quality. The air pollution is the central point in highway and large street design while for avenue and circulation when pedestrian are actively use them air quality is provided by greeneries and equation between vehicle path and pedestrian, thus it is essential to improve the penetrance of the urban surface and covering and expanding the air volume (Buyantuyev & Wu, 2009).

2.3.1 Traditional City Planning

Duration between beginning of modernism and oil crisis, after oil crisis, due to history cities were shaping according to the small pieces of buildings generally. Designing pleasant condition and comfortable atmosphere affected by considering climate condition for social gathering places, proximity, passages, proximity, and so on as a response to people needs in history. One of the main factors for the city shape was considering the wind situation which together with climate region and sun direction shows the city orientation. Bushehr is one of the cities in south-west of Iran which directly design according to the prevailing wind direction. This region is hot humid and is attached to the Persian Gulf. Compared to other cities alongside the Persian Gulf, one of the characteristics of Bushehr location is its peninsular composition. This particular condition has led to winds catching in different directions. Because of this location, there are a few wind catchers alongside the Persian Gulf as opposed to other linear Iranian towns. One of the implications of Bushehr 's role is its creation and its directness.

Climatic condition mainly affects type of lanes. The Watt per Hour (W/H) of roads produces greatest shadow in more long periods of day. Least walled in area proportion (w/h) is 1/2. In certain boulevards we can see 1/6 proportion. Along these lines, the greater part of avenues had a ton of shadow zone during the day. A lot of open space intersections offer the wind circulation and most intense wind and structure relation. Central avenues have situated to the ocean for getting the breeze of ocean. Roads in Bushehr have a unique profile. The road width has diminished from down to up. This extraordinary profile expands air current. Structures attempt to get greatest breeze of avenues. Along these lines, there is a projection in first floor of structures. There is a little impasse road in old Bushehr as a result of making most extreme breeze catcher surfaces for structures. Current air diminishes mugginess and makes warm comfort. Moreover, assimilates mugginess of roads dividers. So, inward space humidity directs out in roads through air current have transmitted wind in the streets (Motalaei & Ranjbar, 2015).

2.3.2 Modern City Planning

After discovering fossil fuels people started to move to the cities with the hope of finding better jobs and having better life. The population needed place to live thus the cities developed with no manner of caring about the way of city factors which change the face of everything in the city. The solution came up by putting minimum coding in order to have systematic growth for the city. The grid plan became the solution to achieve the best result with the speed of city development in most cities. The idea was based on having the understandable division and creates the easy access to the other parts of the city and city blocks designed in square shapes. This arrangement had lots of benefit but important factors which were carefully applied for years and passed to people generation to generation had been forgotten and as a matter of fact on the top of the list cities developed according to the modern style of living instead of considering the human comfort for the outdoor spaces (Collins, Sitte, & Crase, 2006).

The great example of the grid system applied for the city is New York. NY City with huge amount of population and the grid system is working acceptable and the only reason is the central park of this city. This amount of greenery and water element at the center of the city is acting like lungs for the city. The city was exact example of non-enjoyable and unhealthy city for living before constructing the central park. But after all changes happened to the city still it is clear to follow the grid systematic design for urban planning coming from the time before oil crisis which many cities didn't have that much chance to adapt the spaces for human comfort (Grammenos & Lovegrove, 2015).

The gridle system and geranial orientation towards the prevailing wind is defining the success of the urban pattern and improvement of thermal comfort according to natural ventilation for both indoor and outdoor areas. After oil crisis and realizing about the fossil fuels are not endless, the idea of having the renewable energy for all dimension of human living became highlighted which continues to the current time. Urban planning is not separated from this happening and thinkers started to achieve the more suitable living situation for city public spaces with less usage of energy and having the comfortable outdoor areas again. In this manner there was a clear flash back to the old way of city design in order to understand and develop the new system according to the new life style and human needs but based on the respecting and having benefit from the history. It is obvious that there is a need of use from natural elements in order to reach the success and acceptable result. One of the most effective factors for the city planners is ventilation. Ventilation will reduce the level of heat and also carbon dioxide in the city and direct them to the outside of the city. It is possible to mention about the Masdar city in Abu Dhabi which is going to be the first zero carbon city from all points of view in the world. With analyzing the urban planning of this city, it is possible to understand how true design can change the impossible to possible with minimum amount of energy use (Sabnis, 2011).

For the basic information, Masdar placed in the dissert climate in Arabian Peninsula. The whole city designed by the idea of cutting fossil fuels from the human daily life. The whole complex has been designed carefully with keeping all possible chances from the nature and considering them in a correct way. Currently the education part of the city has been constructed which covers the classes, dormitories, labs, gym, café and restaurants, guest houses, seminar facilities and administration section. After personal visiting of the constructed parts, the firs elements which take the attraction is the way of combination of wind, water and shade. All pedestrian connections supported by the gutters which ends to the wind towers and covered by building shading elements or trees. After entering to the city, the change of temperature is witnessed. The building directions and street continuity is in the way of having the maximum benefit of airflow in the public spaces. In such climate the ventilation is the most important factor in order to make the space livable (Management Association, Information Reso, 2018). As a summary human as a part of the nature needs natural factors to feel comfortable in all scale of living. The outdoor gathering spaces considered as pulse of each city which should be carefully design in order to have usable and pleasant atmosphere for citizens. Looking at the urban public spaces from ventilation point of view it is obvious that these spaces need ventilation to have healthy area. Natural ventilation factors need to be design according to the climate and people needs first, but is impossible to illuminate this important factor from the people social gathering part of life. The successful design should consider many effective factors for human behavior in order to create acceptable and joyful area for the city, means urban planners need to deal with natural ventilation more carefully.

2.4 Passive Building Design

Energy productivity over the whole life cycle of a structure is the most significant objective of feasible design. Draftsmen utilize various detached and dynamic strategies to decrease the energy needs of structures and increment their capacity to catch or produce their own energy. Sustainable architecture is the design that tries to limit the negative ecological effect of construction by proficiency and balance in the utilization of materials, vitality, and improved space and the biological system. Also, utilizes an aware way to deal with vitality and natural protection in the building (Williamson, Radford, & Bennetts, 2003). By gathering the information related to sustainable building field and get familiar with terminologies the path which should be followed will be clearer during the process.

- **Carbon Emissions Definition**

There are numerous supporters of a structure's carbon impression, some self-evident, and some that aren't exactly so self-evident. The structure's vitality use is something that most everybody knows about, and endeavors to lessen that with sunlight based, wind, or geothermal components are genuinely normal. Water gracefully is another contributing variable, as siphoning it to the structure requires petroleum derivatives (Great Britain: Parliament: House of Commons: Environmental Audit Committee, 2010). Some lesser-realized components are the ozone harming substance discharges brought about by the transportation of materials to the place of work, just as the encapsulated carbon of those materials used to develop the structure. Building produce contamination both straightforwardly and in a roundabout way, speaking to 39% of carbon dioxide emanations as indicated by the US Green Building Council (Guillaume FABRE, 2010) (Huang, Cui, Li, Huang, & Lin, 2017).

- **Economy Definition**

In order to be able to discuss economy it is must to say sustainable buildings utilize less energy and materials are more advantageous and progressively agreeable spaces for inhabitants. Alongside lower natural effect, maintainable structures are moderately eased to run and in the long time, progressively important properties. To move away from the direct monetary model of taking, make, and squander and towards asset effectiveness needs of a feasible assembled condition is clear and undeniable. Also, part of building construction is one of the most asset expending segments as general for economy. it represents around half of all extricated materials, half of the complete energy utilization, 33% of water utilization, and 33% of waste in building which is the main focus to be reduces. That is the reason the built environment is a key objective in the arrangement for the circular economy which is a regenerative monetary framework in which asset and energy consumption is minimized. empowers the life cycle considering entire structure development, and supports clients right from the planning stage through to activity and control of a building. Buildings can likewise be utilized by appraisal and confirmation plans to ensure that their models mirror the most significant needs for the circular economy, and to empower the likeness of information and results across various structure execution rating frameworks (Migliore, Talamo, & Paganin, 2019).

- **Energy Consumption Definition**

Factsheet portrays chosen quantitative outcomes on the energy use coming from the Building Observatory. The energy utilization in structures has been diminishing since 2008, specifically, because of the endeavors saw in the residential segment. This pattern is because of energy effectiveness upgrades driven by different kinds of strategy measures, higher energy costs, and the downturn (Lyndon, Olgyay, Reynolds, & Yeang, 2015). Non-residential buildings are on normal 40% more energy concentrated than residential structures 250 kwh/ m² contrasted with 180 kwh/ m². Concerning residential structures, energy utilization per m² in administrations is heterogeneous. most nations use somewhere in the range of 200 and 300 kwh per m². Gas energy utilization speaks to the most elevated portion of energy use in building at the EU level 36% and it speaks to the biggest usage. Space warming is the most significant end-use in the residential segment 68%. Water warming positions second with a very steady offer of 13%. Electrical machines are having more noteworthy significance and speak to today 12% at the EU level. Cooking speaks to 5% of the aggregate, lighting 2% (Yap, 2017).

- **Ecological Building Definition**

The ecological (natural) building includes a scope of structural frameworks and materials that spot significant accentuation on sustainability. Methods for accomplishing maintainability through the natural building is around strength and the utilization of insignificantly handled, renewable resources, produce harm-free living conditions and keep up indoor air quality for user's health and wellbeing. The ecological buildings in general, depend on human work, more than technological advances. it relies on nature, geography, and climate; on the character of the specific structure site, and on the necessities and characters of the developers and clients (Kennedy & Smith, 2015).

- **Low-Energy House Definition**

A low-energy house is described by a vitality effective structure and specialized highlights which empower it to furnish high expectations for everyday comforts and solace with low vitality utilization (Thomas & Duffy, 2013). Low-energy buildings might be seen as instances of maintainable design. All through the world, organizations and non-benefit associations give rules and issue affirmations to ensure the vitality execution of building, their procedures, and materials. Low-vitality houses are commonly known as houses with a lower energy request than normal buildings directed by the national construction law. The expression low-energy house is utilized in certain nations for a particular sort of buildings, they are labeled as Ultra house, passive house, and Zero-energy house (Thullner, 2010); (Venkatarama Reddy & Jagadish, 2003).

- **Green Building Definition**

Green building alludes to both a structure and the utilization of procedures that are ecologically capable and asset effective all through a structure's life-cycle: from intending to plan, development, activity, support, remodel, and destruction. The Green building practice extends and supplements the traditional structure configuration worries of economy, utility, solidness, and solace (Kubba, 2012).

- **Passive Building Design Definition**

Passive design format, texture, and form to diminish or reduce mechanical cooling, heating, ventilation, and lighting request. Instances of inactive structure incorporate upgrading spatial arranging and direction to control sunlight-based gains and expand daylighting, controlling the building and texture to encourage natural ventilation systems and utilizing heat mass to help lessen inside temperatures. The passive design maximizes the use of natural heating, cooling and ventilation sources to establish agreeable conditions inside buildings. It equips natural conditions, such as sun-powered radiation, cool night air, and pneumatic force to push the inner condition. Passive measures don't include mechanical or electrical frameworks (BREEAM, 2018). The passive design maximizes the utilization of natural sources of heating, cooling, and ventilation to make agreeable conditions inside structures. It outfits natural conditions, for example, sun-powered radiation, cool night air, and pneumatic force contrasts to drive the inside condition. Passive measures don't include mechanical or electrical frameworks. However, while passive plans ought to make building to expend less energy, they don't generally create structures that may be considered sustainable as sustainability is reliant on a scope of measures, just one of which is energy use (Baker, 1987). Figure 7 illustrate the passive building design and subheadings which are affective for all passive cooling, passive heating, and passive ventilation systems.

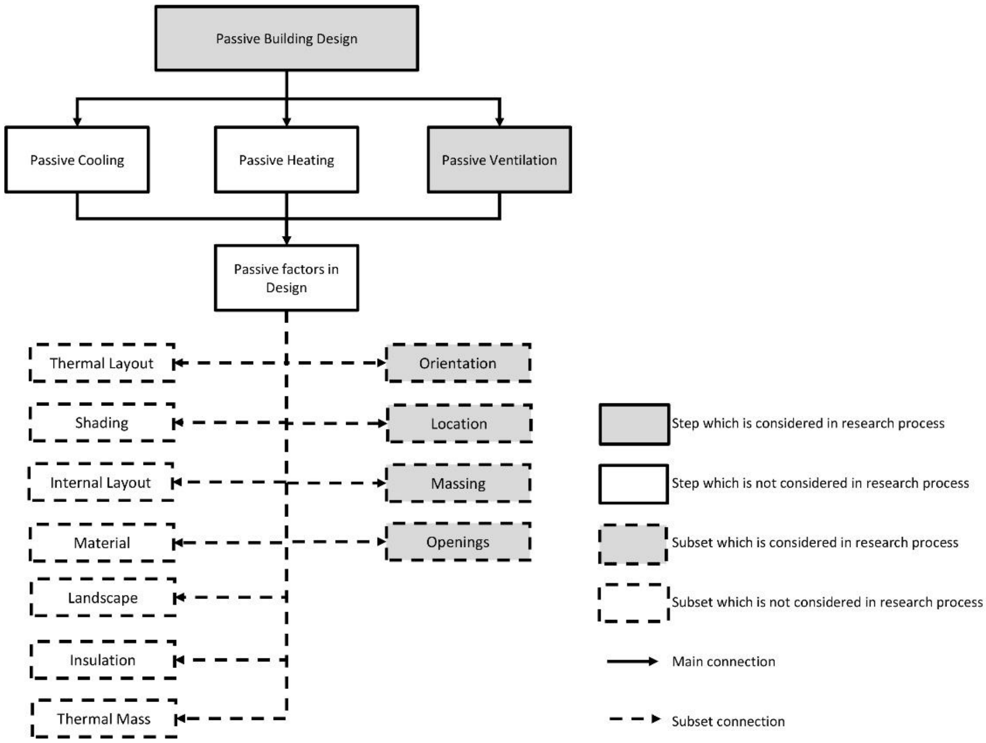


Figure 7: Passive building design details (BREEAM, 2018); (Baker, 1987).

As an example, narrow buildings orientated opposite to the prevailing wind with openings on the two sides, will permit daylight to infiltrate into the center of the structure and will empower cross ventilation. This ought to diminish the requirement for counterfeit lighting and may imply that cooling frameworks and mechanical ventilation may remove from the system. In taller structures, stack ventilation can be utilized to draw natural air through a building, and in more profound structures chambers or patios can be acquainted with permit light into the focal point of the floor plan. In any case, troubles emerge when structures have cell spaces that block the entry of sun-oriented radiation and air, or where site limitations make complex massing or imply that windows can't be opened on account of commotion or air quality issues. This can prompt the presentation of progressively complex passive measures, for example, trombe walls, solar chimneys, solar stacks, acoustic louvers, thermal labyrinths, and so on (Gonzalo & Habermann, 2012). Extra complexities can be presented by internal heat loads, for example, individuals and by inhabitance designs.

In an office with a moderate measure of introduced hardware, it might be conceivable to utilize warm mass to store heat loads during the day and afterward to vent these and cool the warm mass when the structure is vacant around evening time. This may not be conceivable with a structure, for example, an emergency clinic that is persistently occupied (Sullivan, 2003). As well as reducing energy consumption, adopting passive design strategies can help building ratings across standards such as Passive Haus, BREEAM, the Code for Sustainable Homes and LEED.

2.5 Natural Ventilation in Buildings

Wind is the energy of moving air which is considered as type of renewable energy which is produced by nature. Wind power and having benefits from wind turbine used in order to produces electricity in many locations all around the world which is going to be used by general electricity network. Also, natural ventilation will affect the building in two dimensions: the firs effect is on indoor air quality related to human health and the second effect is on user indoor thermal comfort. Mostly in current standards natural ventilation codes are focused on indoor air quality and increase thermal comfort is not covered properly in energy calculations. In Figure 8 the path from natural ventilation and how it is going to affect users is explained also the options which should be considered for building in order to improve the thermal comfort by taking natural ventilation into consideration (Li & Nelsen, 2011).

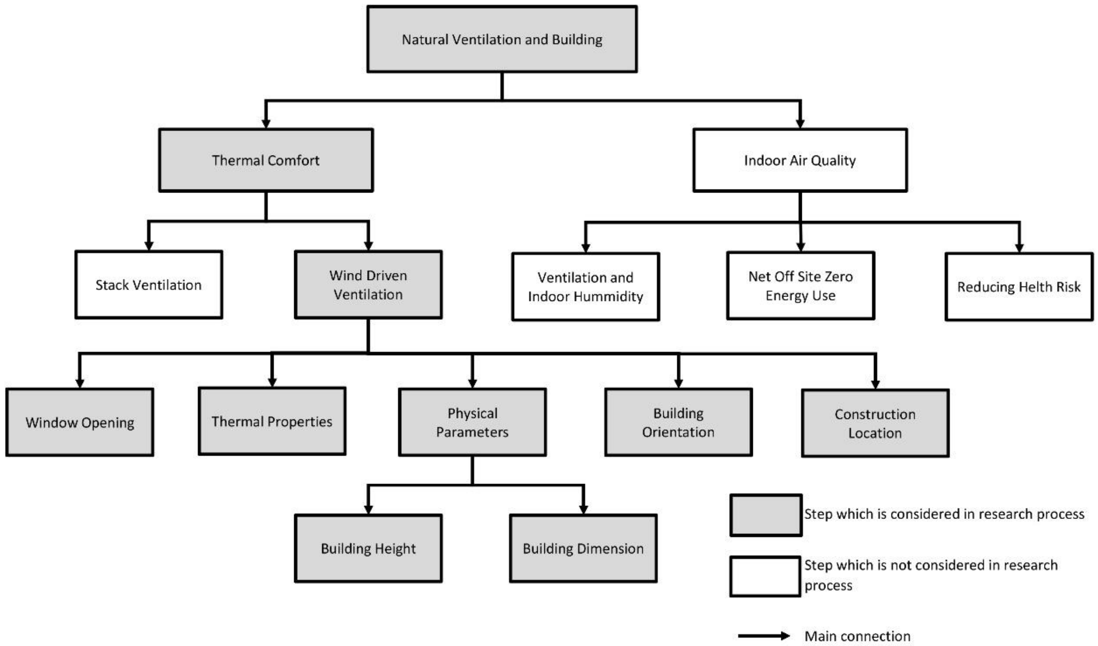


Figure 8: Natural ventilation and the thesis focus (Designed by author); *(Li & Nelsen, 2011)*.

2.5.1 Types of Natural Ventilation in Building

On thermal comfort there are two methods to benefit from the natural ventilation. First approach is called wind-driven ventilation, which usually blows briskly over a building; the breeze reaches the wind ward divider, which creates an immediate positive pressure (Figure 9). The breeze moves around the building and leaves the leeward divider with negative pressure, which called a sucking impact. In the event that there are any openings on the windward and leeward dividers of the building, natural air will surge in the windward opening and leave the leeward divider opening to adjust and relieve the pressure on the windward and leeward faces (Parker & Teekaram, 2005).

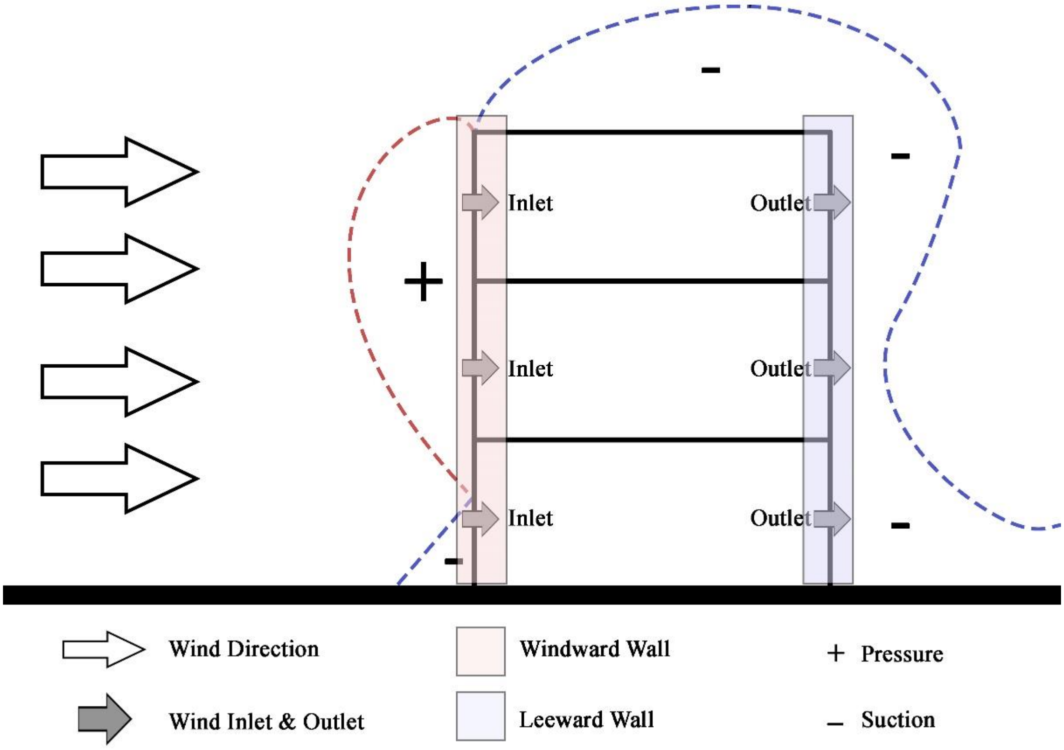


Figure 9: Wind driven ventilation (Designed by author).

The second approach is based on ventilation that can be caused by temperature or humidity that is generally used as the ventilation powered by the stacks. There must be a difference in temperature for the stack ventilation to function properly. When the warm air increases, which becomes less dense, the cold air is drawn from gaps in the system. The method is not breeze-dependent. Stack effect will occur on overheated summer days with no wind, with reasonably stable weather. Furthermore, on the grounds that it does not rely on the pressure and the direction of the wind, there is a more notable control of finding the air intake (Khan, Su, & Riffat, 2008). Figure 10 illustrate the how wind stuck ventilation happens inside the building.

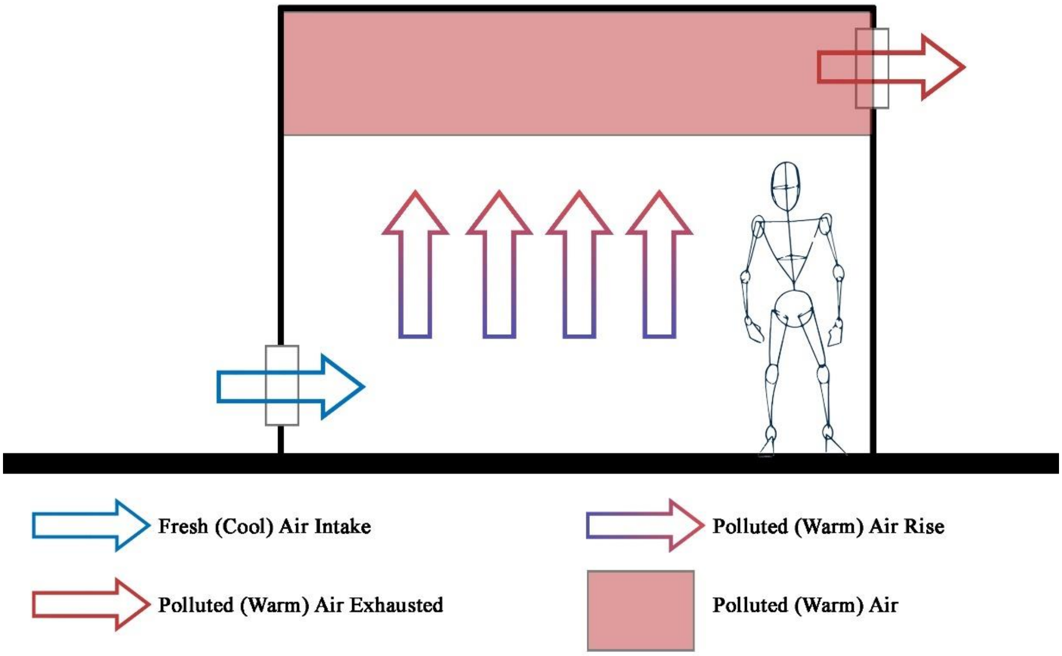


Figure 10: Wind stack ventilation (Designed by author).

As wind driven method is going to be the focus for this study the following information shows categories and information about types of wind driven ventilation as general. Ventilation can usually be divided into three categories: natural ventilation, mechanical ventilation and combination of other two types. In so far as mechanical ventilation is not part of the focus of the study, it will be omitted. Types which natural ventilation has effect on the are going to be mentioned as the following information. Mixed ventilation system means the mixture of mechanical and natural ventilation which demonstrated in Figure 11. Fan assisted stack, top down ventilation and buried pipe system are located under this category.

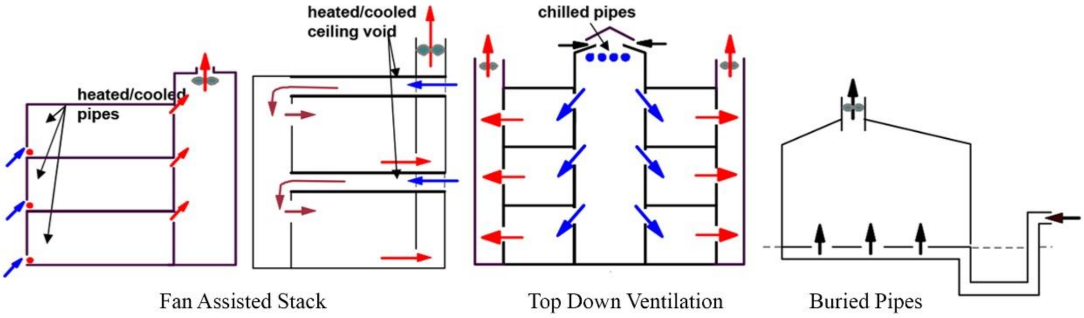


Figure 11: Mixed ventilation types (https://slideplayer.com/slide/8350421/25th).

Natural wind flow typologies are listed as: cross flow wind, wind tower, flue stack, and atrium stack. Within natural ventilation systems the cross-flow ventilation is the focus of this study in order to simplify the process of comparison. Natural ventilation types are explained in Figure 12.

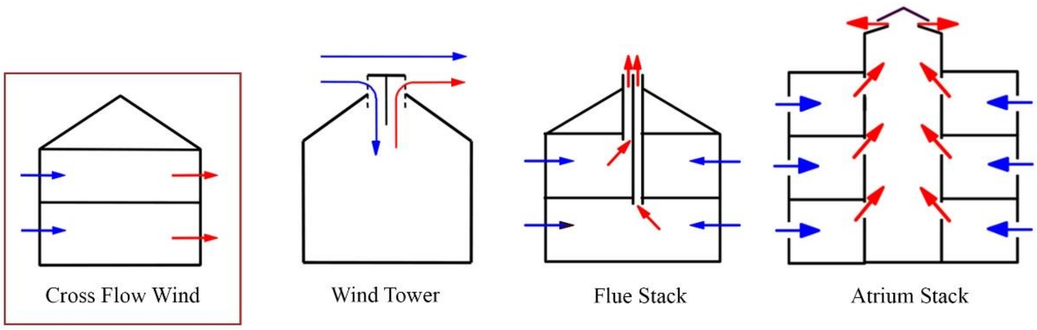


Figure 12: Natural ventilation typologies
(https://slideplayer.com/slide/8350421/25th).

2.5.2 Wind Analysis for Natural Ventilation in Buildings

Alluring air developments ought to be used for cooling in hot periods, and as a help from vapor during times of high total warm seasons. Alternately, air developments ought to be blocked and abstained from during the virus season. The measuring sticks the bioclimatic analysis of the region, which defines overheated and cold periods during the year and Identifies the needs for solace used to evaluate wind developments. Generally, wind is going to be affected by the nearby built environment which is going to change the wind properties (Figure 13). Nature itself is going to change the wind properties by obstacles like topography changes and surroundings like sea or jungle. Also, manmade structures are going to have the same effect as buildings and infrastructure.

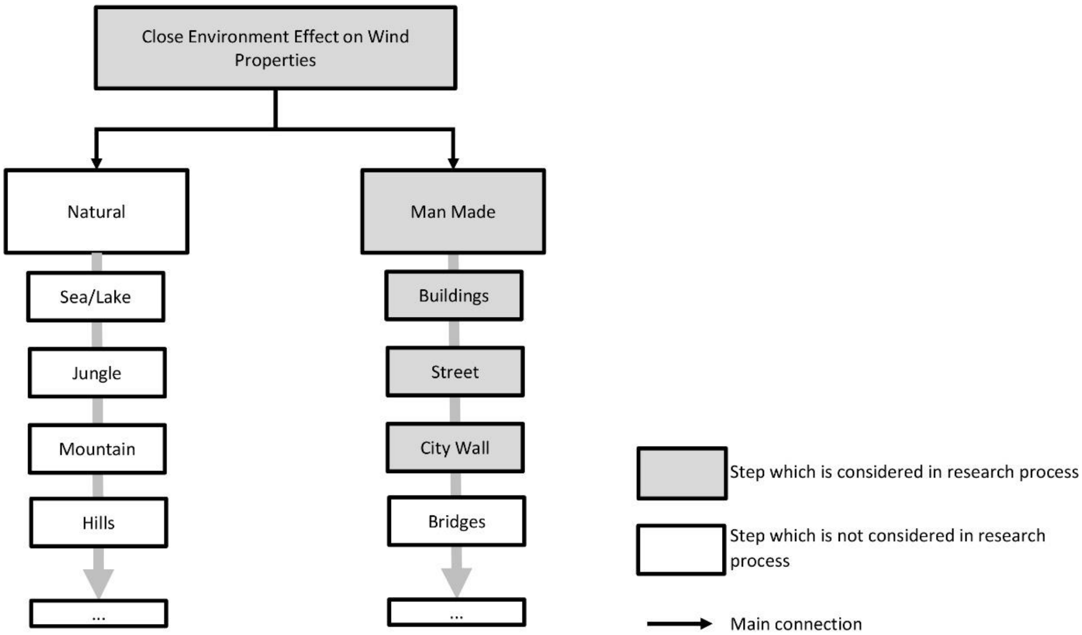


Figure 13: Nearby built environment effect on wind properties categories (Designed by author).

Wind effective factors and elements which change wind properties have been studied for many years and how it will change the thermal condition in building. It is possible to categories into six subheadings which they make the wind characteristic at the end: wind temperature, wind direction, relative humidity, wind speed, and wind circulation. Pressure is the element which based on the surfaces and the differences is going to influence wind speed thus, will have changes in air movement properties. In following section definition of each six parts is described.

- **Pressure**

Atmospheric pressure or air pressure is the force exerted by the air above the atmosphere when gravity drags it back to Earth which measured by biometer. Biometer acts as a mercury fragment in a glass jar, as the air pressure rises or falls (National Geographic, 2019).

- **Wind Temperature**

Air temperature is a sensation of the weather being hot or cold. It is the climate parameter that is usually measured the most. More specifically, temperature describes the air-dynamic strength of the gasses supplying the air. When gas particles travel further and velocity increases, the temperature of the air does increase. In general, influences of the air temperature are: evaporation rate, relative humidity, wind speed and direction (Environmental Monitor, 2019).

- **Wind Direction**

In general, wind direction is defined in cardinal ways or in degrees of azimuth by the north. Wind direction is measured in clockwise degrees as total in units between 0 and 360 degree (Akbar Gill, 2019).

- **Relative Humidity**

The relative humidity at a given temperature is the balance vapor weight of the atmosphere and amount of fractional weight which relies on intrigue setting temperature and weight. A comparable amount of water vapor in the cold environment contributes to higher relative humidity than the warm one. Percentage system defines the relative humidity; a higher number means an increase in the air-water (Babin, 2019).

- **Wind Speed**

Central barometric volume of air moving from high to low pressure is called wind speed, or rate of wind passage and usually it is due to temperature change. Based on earth rotation; wind is parallel to the isobars. Wind speed is currently measured by using an anemometer, but barriers will affect wind speed. Those involve the pressure gradient, barotropic waves, and jet streams, as well as the surrounding conditions (Oliver, 2004).

- **Wind Circulation**

The huge evolution of air in scale is air circulation. The mid-latitude or coastal convective cells happen as a natural occurrence, and such long-ago climatic. The Earth's climate is a consequence of the Sun's brightening and thermodynamic laws. The study done by the sun motor allows much of the air to move, and in this process, it redistributes and absorbs the surface of the Earth near to the tropics. The massive "cells" wind course moves poleward in warm and humid times, but remains generally consistent as they may (Manabe, 1969). Figure 14 is representative of the natural ventilation process from the general air movement data till the effect on indoor thermal comfort. The main topic which is the focus of the system is the elements which change the indoor air velocity as a key factor to the system.

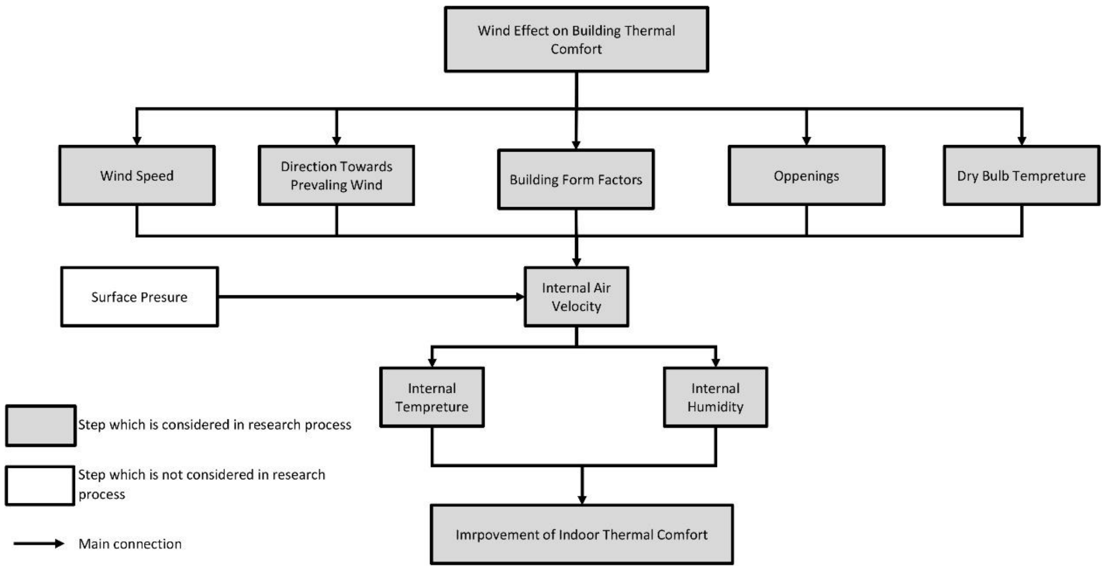


Figure 14: Wind and building indoor thermal comfort relation (Designed by author).

There are three general methods for measuring and estimating of natural ventilation effect in building and thermal comfort. The real building measuring and data recording is the field work with the help of devices, examining the real building and based on recorded data charts to show the level change on thermal comfort from air movement and effective factors will be concluded. The second system is experimental lab simulations which is working based on model creation and put in in the wind tunnel in order to find the natural ventilation behavior and accordingly calculation of thermal comfort in building (Dekay & Brown, 2014). And the last method is going to be computing fluid dynamic system done by advance software and computer simulation which the modeling is going to be done digitally and all setting for the building, climate variables, wind breaks, wind mask, and wind tunnel is going to be define with in the process in the computer program (Peters & Peters, 2018); (Tu, Yeoh, & Liu, 2012).

2.5.3 Wind Breaks

Enormous air masses can't be modified in their movement which is directed by contrasts of gaseous tension. Nonetheless, speeds close to the living, or ground, level can be controlled partly. The frictional drag of vegetation and the opposition and check made by trees can cause redirections in the wind current which might be used gainfully. Other than their stylish and shade-giving properties, the estimation of tree windbreaks lies in their capacity to lessen wind speeds. This mechanical impact brings detectable changes both in the temperature and stickiness of the air, in evaporative impacts and in the arrangement of snowdrifts, along these lines fundamentally influencing the development of plants. Hence, most information and perceptions on shelterbelts begin from farming investigations and analyses (Burke, 1998).

A windbreak, as demonstrated by Bates' description, four comprises the air moving upwards, and bearing in mind that before long turning back and clearing the ground again, an area of relative calm is generated near the ground. The most protected section of this zone is actually close to the leeward side of the windbreak; it turns out to be gradually exposed as the positive way from the windbreak increments until a point is reached where the air flows have achieved maximum pace again. On the windward side, there is a slighter territory, mostly when the windbreak is very thick. The windward side has little protection on the off chance it is open, and the air can pass through the trees. These receptivity on the leeward side will result in a smaller shielded area located more distant from the windbreak (Bates, Lane, & Ferguson, 2005). The definite type of windbreak used affects the resulting configuration of the wind stream and the protection territory. Powerful boundaries of wind, or dividers, create swirls over the top that reduce their viability. When all is said and done, three belts with more remarkable thickness and thickness will have a greater impact on wind assurance (Heisler & Dewalle, 1988); (Wight, 1988).

Building enthusiasm for wind insurance lies in open air solace conditions, yet in addition in its consequences for house warming. The general practical relationship for the warming burden, the breeze speed, the temperature distinction for the house, and the area of the shelterbelt can be communicated in a three-variable condition. The warming burden - fan unprotected house with a 20-mph wind s around 2.4 occasions as incredible as that for, 5 mph wind under a similar temperature condition. The warming burden for a secured awaken at 20 mph wind speeds was around twice as extraordinary with respect to a comparable animate presented to 5 mph wind impacts. This shows a safe house belt's viability increments at higher breeze speeds.

- **Windbreaks for Multiple Housing Layouts:**

The main thought in the arrangement of the windbreaks is with reference to the item or zone of assurance. The standards are applied here to an area unit in the New York

New Jersey zone. The lodging design is made out of four private states of around 1200 individuals each, gathered around a focal territory which contains business, authoritative, social, sports, and recreational offices. The winter winds which originate from the northwest are obstructed by thick evergreen belts planted toward the northwest of the neighborhoods. Wind shadow is demonstrated with various qualities comparing to level of security. Northwest roads are counterbalanced, or protected to shield them from getting to be wind channels. In summer winds are welcome. The boulevards are inclined toward the south and southwest (the bearings of the common summer winds), and are driven through the settlement, as much as other arranging and traffic issues permit. Since winter security and summer ventilation of the individual houses close to the outskirts is considered of essential significance, the focal segment of the design is left open for the common territory.

- **Wind Direction and Housing Layouts:**

Buildings situated opposite to the breeze course get on their uncovered side the full clear of the speeds. Situated at 45 ° the breeze speed is diminished to half; a few estimations utilize 66% as the revision factor. Building columns separated a good way off equivalent to multiple times their particular statures secure acceptable ventilation impact for every unit. The breeze has a propensity, be that as it may, to jump frog long parallel unit game plans. Structures arranged in line game plans cause a breeze shadow over the resulting units, which are strengthened by the inclination of the breeze to channel through free spaces and go by the later units. A game plan of stunned units exploits the bobbing example of the breeze since the houses direct the stream to ensuing structures. Note that the heading of stream is opposite to the third line of houses. The main kind of design is alluring for keeping away from winter wind impacts; the subsequent example verifies equivalent summer wind appropriation. As winter winds and summer winds as a rule originate from various headings, the two conditions might be fulfilled.

❖ **Impact of Landscaping on Areas Adjacent to Structures:**

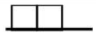
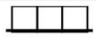
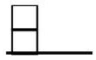
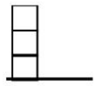
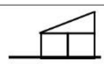
The prompt environment close to low structures have clear impacts both on wind current examples and on wind speeds. This liberates the structure to a limited degree from inflexible direction necessities. The scene structure components, including plant materials, trees and bushes, dividers and wall, can make high-and low-weight regions around a house with reference to its gaps. Care ought to be taken that courses of action don't dispense with the attractive cooling breezes during overheated periods, and planting ought to be intended to coordinate and quicken valuable air developments into the structure (Bates C. G., 1911).

2.5.4 Wind Mask Analysis

Downfield disturbed airflow which may cause by any obstacle like trees, hills, or buildings named wind shadow. Wind behavior changes within the wind shadow area and the circulation are going to be different (Karmer, Gerhardt, & Scherter, 1979). The area of the wind shadow is dictated by the dimension and density of the barrier. The distance for the wind shadow from the blocked object has direct relation with the proportion of the natural or manmade barrier also it is important to mention that the shape of the obstacle also effect on the shape and area of the wind shadow (Donald & Labs, 1983).

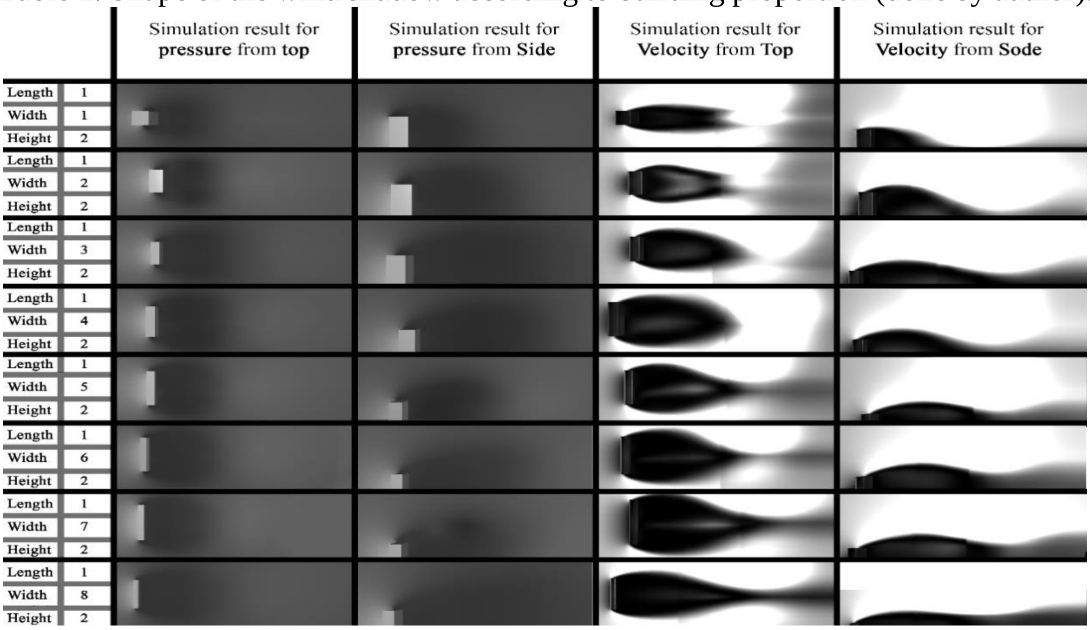
The relation between building proportion and the distance of affected area by wind shadow and also the shape of the roof is calculated for dome examples in Table 1. The definition of the length of the wind shadow depends on the dimensions of the building in terms of the width, height, duration and shape of the roof. The building's dimensions have influenced the wind mask, as it is calibrated to the wind speed and direction (Pourvahidi & Hancer, 2019). Wind mask is affecting the wind speed, wind direction, pressure changes, temperature, and humidity.

Table 1: Relation between building proportion and wind shadow (Donald & Kenet, 1983).

Width (W)	Height (H)	Sloppy Roof	Length of the Wind Shadow According to the Multiple of Height					
			2A	4A	8A	16A	24A	Wind Direction (→)
A	A	0°	$2\frac{1}{4}$	$3\frac{3}{4}$	$5\frac{1}{4}$	8	$8\frac{3}{4}$	
2A	A	0°	2	$2\frac{3}{4}$	$3\frac{3}{4}$	6	7	
3A	A	0°	$2\frac{1}{4}$	$3\frac{1}{4}$	$4\frac{1}{2}$	$5\frac{3}{4}$	$5\frac{1}{2}$	
A	2A	0°	$5\frac{1}{4}$	$8\frac{1}{4}$	$11\frac{3}{4}$	$16\frac{1}{4}$	18	
A	3A	0°	$6\frac{3}{4}$	$11\frac{1}{2}$	$16\frac{1}{2}$	$18\frac{3}{4}$	$20\frac{3}{4}$	
2A	2A	45°	$2\frac{3}{4}$	$5\frac{1}{4}$	$9\frac{1}{4}$	$13\frac{1}{4}$	15	
2A	1.6A	30°	3	4	$6\frac{3}{4}$	10	13	
2A	1.5A	15°	3	$5\frac{1}{4}$	$8\frac{1}{4}$	$11\frac{1}{2}$	$14\frac{3}{4}$	
2A	1.5A	15°	$2\frac{1}{4}$	$4\frac{1}{2}$	$6\frac{1}{2}$	11	$13\frac{3}{4}$	

As the next step it is needed to understand the wind mask shape according to the building proportion. In order to get familiar with shape and dimension of wind mas also the equation between building form and the relation with wind mass proportion the preliminary test has been done with "Autodesk Flow Design" software. For this experiment, the building was built on the basis of units that display the dimension relationship and is not determined by international standards of measurement and the rectangle is chosen as a building form to simplify the result in so far as this is not the subject of the study. Simulations are limited by two units while the length in X direction kept 1 unit and the width in Y direction changes from 1 unit to 8 units. In order to show the level of changes which need to be analyzed mainly as a further study will be followed in Table 2. Changes according to wind pressure and velocity activity behind the building are presented in different columns. According to the simulation result there is a mathematical equation between wind break and created wind shadow at the back which need more studies focused on this topic in order to find the suitable distance between buildings according to the size and height of it to be added in energy standards and be helpful for city planners and urban designers.

Table 2: Shape of the wind shadow according to building proportion (done by author).



All fluid dynamic software works with boundary which is going to block or guide the fluid inside. This boundary is either finical or imaginary limits. In wind simulation this boundary is called wind tunnel (Wong & Heyanto, 2004). For natural ventilation simulation this limit should be set properly, otherwise it will have effect on wind behavior during the simulation thus, the result will not be reliable. According to the wind tunnel limitation and proportion it looks the wind is hitting the boundary and change the direction, speed and temperature. It is needed to be mention the height of the wind tunnel will have the same effect on the wind behavior on the third dimension and it is three-dimensional box which needed to be design according to the model size.

In Figure 15 Two distinct wind tunnel settings with the same shape and size object are located and it is highlighted by color that the wind speed increases on the side of the model because the software considers the solid wall surrounding the simulation platform. The red colour shows the wind is getting faster and directed by this limitation. Also, the dept of wind turbulence at the back of the object plus the area and focus of them are affected as far as the air circulation will not happen freely.

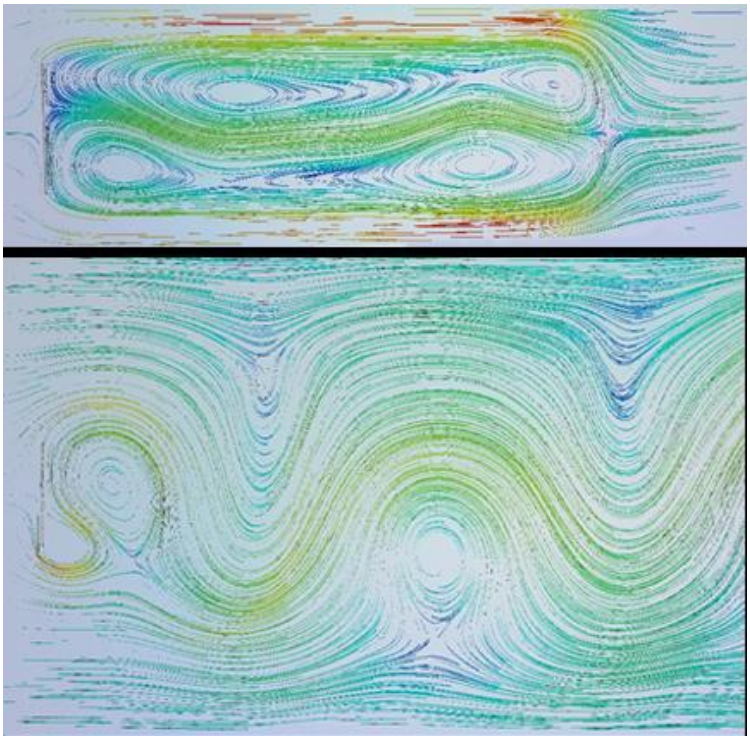


Figure 15: Wind tunnel effect on wind behavior (Done by author).

In comparison with only change of wind tunnel dimension is making the huge change in wind behavior. It makes it obvious that in order to have reliable outcome there are many challenges which needed to be tested before the final result. Thus, in both experimental and computing calculation system architects should define the wind tunnel proportion according to the size of the model in order to find the trust worthy result.

2.6 Critical Evaluation of Energy Efficiency Regulation and Natural Ventilation

Energy efficiency regulations are sets of techniques and guidelines that endorse the energy execution in building construction, in some countries offered price of building that are rated low in energy efficiency are less than the design which followed high level energy saving based on the ranking system. In some cases, and in some countries, constructors should follow minimum energy performance standards in order to be able to sell the unit (Wiel & McMahon, 2003). Prescriptive, performance-based codes and outcome-based code are considered as basic formats for current energy codes come in two basic formats. A Prescriptive way is a quick, authoritative, and traditionalist way to deal with code consistence. Materials and equipment must meet a specific degree of severity, which is measured in tables. These tables list the base and greatest necessities for the R-and U-estimations of materials, the reasonable watts per square foot of lighting frameworks, and the base energy efficiencies expected of mechanical frameworks. This way directs explicit prerequisites that must be met, yet does not represent conceivably vitality sparing highlights like opening direction.

Execution based codes are intended to accomplish specific outcomes, as opposed to meeting recommended necessities for singular structure segments. Execution ways ordinarily depend on the foreseen outcomes from the utilization of the prescriptive way. This way is helpful while measuring modern structure features, for example, passive solar and photovoltaic innovation. Execution based methodologies utilize a setup pattern estimation from which certain frameworks must perform. This way requires more insight into building plans, materials, and frameworks; in any case, it is a more adaptable methodology than the prescriptive way. Such a methodology is especially alluring for bigger construction, as it gives chances to exchange offs across energy affecting frameworks to think of the most financially savvy implies for accomplishing consistency. Execution based codes are innovation nonpartisan, in this manner empowering speedier joining of energy sparing advancements and practices into the commercial center. Outcome-based codes set up objective energy utilize a level and accommodate estimation and detailing of energy use to guarantee that the finished structure performs at the setup level. Such a code can have critical adaptability to reflect varieties across building types and can even cover existing or notable structures. Above all, it can address all energy used in building and give a measurement to decide the real nature of the structure development (VanGeem, 2016).

Different countries are considering their own regulations which is followed by developers in order to apply energy efficiency codes for construction section and within time based on global level, technology development and emperies in their codes they are developing and updating their standards (Arfaei, 2014). In most energy code the mix ventilation system is suggested and the window opening is defined for the natural ventilation aspect which is not close to enough. As an example, in Australia purpose of ventilation in openable window considered 5% of the floor space. Solution for achieving thermal comfort base on natural ventilation and nearby built environment is not considered in order to follow specific formula for calculation.

- **Natural Ventilation Codes**

In order to illustrate the current situation of natural ventilation in building energy standards the USA approach is selected to be the base as one of the leaders in developing and updating regulations constantly but as far as different states are following their own version of energy standards we have to find the most update one which covers more area in central America. Some of these standards are: American National Standard Institute (ANSI), Energy Standard for Buildings Except Low-Rise Residential Buildings, IES standard 90.1, and American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE). Between these codes ASHRAE is selected to be analyzed to find the location of natural ventilation in the energy code system. There are many codes for this guide book and ASHRAE 55 is selected as the focus of this study. In many regulations the definition of thermal comfort conditions is clarified. Table 3 illustrate the countries around Europe and the boundaries for indoor condition in order to be acceptable thermally (Seppänen, Brelih, Goeders, & Lițiu, 2012).

Table 3: Thermal comfort boundaries in different countries in Europe (Seppänen, Brelih, Goeders, & Lițiu, 2012).

Country	**reference**	**Temperature limits summer [°C]**	**Temperature limits Winter [°C]**	**Maximum air velocity in residences and offices -summer**	**Maximum air velocity in residences and offices -winter**	**Limit value for humidity of indoor air (min winter/ max summer) [%rh]**
Bulgaria	Regulation 15/28.07.2005CEN/CR 1752:1988	24.5 ± 2.5	22.0 ± 3.0	0.25 m/s	0.21 m/s	-
Czech Republic	Regulation 410/2005 Decree 361/2007	28	20	0.1 - 0.2 m/s	0.1 - 0.2 m/s	30 -70% RH
Finland	Building Regulations Part D2, Indoor climate and ventilation, 2010	25	21	0.3 m/s	0.2 m/s	No humidification above 45% RH
France	Code de la construction et de l'habitation	-	18	-	-	-
Germany	EN 15251, cat. II	26	20	-	-	max 12 g/kg
Greece	(TOTEE)2425/86	26	20	0.25 m/s	0.15 m/s	winter max: 40% RH

						summer max: 45% RH
Hungary	EN 15251, cat. II	26	20	-	-	30 - 70%
Italy	DM 18/12/1975; UNI 10339	-	20	-	-	45-55%
Lithuania	HN 42:2004; HN 69:2003	24.5±1.5	22±2	0.3 m/s	0.2 m/s	max. 75% RH
Netherlands	The Dutch Building Code 2012	-	-	0.15 m/s	0.2 m/s	-
Norway	Building Regulations Act, Technical regulations (TEK2010); Arbeidstilsy-net 444	26	19	0.15 m/s	0.2 m/s	only recommendations to prevent dampness and mold growth
Portugal	Decree law 79/2006	25	20	0.2 m/s in occupied areas		-
Romania	I5 normative	27	21	20°C: 0.10 - 0.16 m/s 21°C: 0.10 - 0.17 m/s 22°C: 0.11 - 0.18 m/s 24°C: 0.13 - 0.21 m/s 26°C: 0.15 - 0.25 m/s		11 for 20 - 27°C RH = 30 - 70% upper max 12 g/kg
Slovakia	Z.z. 259:2008	28	18	0.25 m/s	0.2 m/s 3	30 - 70% RH
Slovenia	ULRS 42/2002	26	19	0.25 m/s	0.21 m/s 3	30 - 70% RH
United Kingdom	UK Building Regulations Part F (2010)	28	19	0.15 m/s	0.15 m/s	-

In ASHRAE 55 the dedicated section to natural ventilation is “5.4 Determining Acceptable Thermal Conditions in Occupant-Controlled Naturally Conditioned Spaces.” Within this chapter the definition of the acceptable thermal environment and boundaries are explained and criteria are defined to show which categories will fit in the chapter.

- “There is no mechanical cooling system (e.g., refrigerated air conditioning, radiant cooling, or desiccant cooling) installed. No heating system is in operation.
- Representative occupants have metabolic rates ranging from 1.0 to 1.3 met.

- Representative occupants are free to adapt their clothing to the indoor and/or outdoor thermal conditions within a range at least as wide as 0.5 to 1.0 clo.
- The prevailing mean outdoor temperature is greater than 10°C (50°F) and less than 33.5°C (92.3°F)" (ASHRAE, 2017).

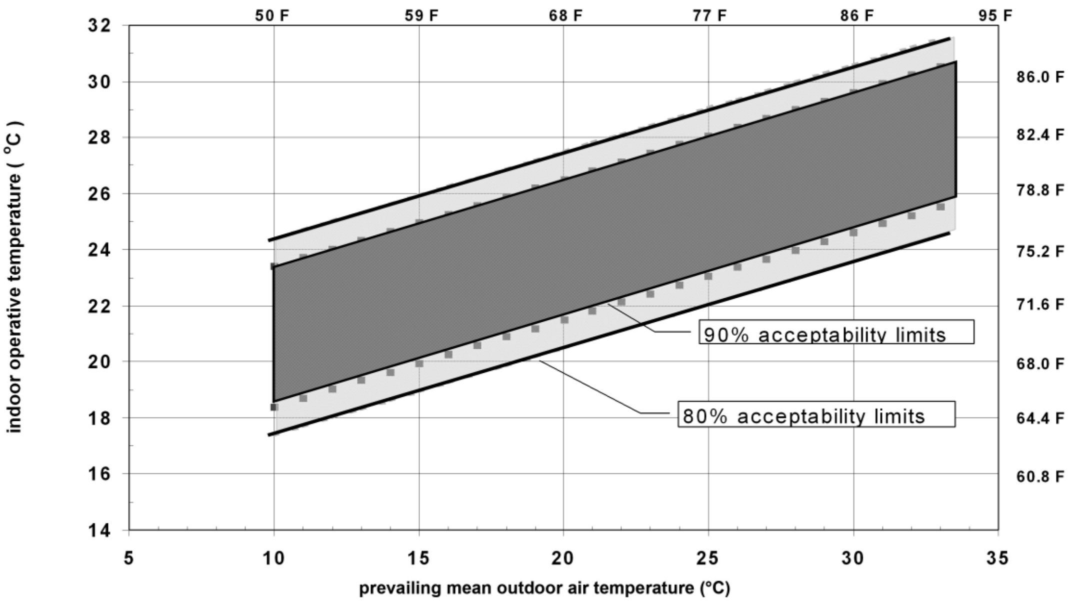


Figure 16: Acceptable operative temperature ranges for naturally conditioned spaces (ASHRAE, 2017).

Figure 16 shows the relation between indoor operative temperature in vertical side and prevailing mean outdoor air temperature range in horizontal direction. The overarching mean open-air temperature will be resolved as:

- It shall be based on no fewer than seven and no more than 30 sequential days prior to the day in question.
- It shall be a simple arithmetic mean of all of the mean daily outdoor air temperatures of all the sequential days in Section
- It shall be a simple arithmetic mean of all of the mean daily outdoor air temperatures of all the sequential days except weighting methods are

permitted, provided that the weighting curve continually decreases toward the more distant days such that the weight applied to a day is between 0.6 and 0.9 of that applied to the subsequent day. For this option, the upper limit on the number of days in the sequence does not apply. Mean daily outdoor air temperature $[t_{mda}(out)]$ for each of the sequential days shall be the simple arithmetic mean of all the outdoor dry-bulb temperature observations for the 24-hour day. The quantity of measurements shall be no less than two, and, in that case, shall be the minimum and maximum for the day. When using three or more measurements, the time periods shall be evenly spaced.

- Observations shall be from the nearest approved meteorological station, public or private, or Typical Meteorological Year (TMY) weather file except when weather data to calculate the prevailing mean outdoor air temperature are not available, it is permitted to use as the prevailing mean the published meteorological monthly means for each calendar month. It is permitted to interpolate between monthly means.
- It shall be permitted to use the following equations, which correspond to the acceptable operative temperature to ranges in Figure 16:
    - Upper 80% acceptability limit (°C) = 0.31 + 21.3
    - Upper 80% acceptability limit (°F) = 0.31 + 60.5
    - Lower 80% acceptability limit (°C) = 0.31 + 14.3
    - Lower 80% acceptability limit (°F) = 0.31 + 47.9
- The following effects are already accounted for in Figure 16 therefore it is not required that they be separately evaluated: local thermal discomfort, clothing insulation Icl, metabolic rate, humidity, and air speed.

- If [$t_0 > 25℃\ (77°F)$], then it shall be permitted to increase the upper acceptability temperature limits in Figure 16 by the corresponding [Δt_0]" (ASHRAE, 2017).

2.7 Chapter 2 Overview

As the summary the information exist related to the thesis topic has been explained and existing knowledge towards thesis focuses is illustrated. These data are used as the foundation for the general dynamic calculation method which is going to be discussed in chapter 3 as method for integrating natural ventilation in energy calculation formulas. As it is clear in Figure 17 the process will start by analyzing climate condition which means the weather data from the region that the architect is planning to have new design project. It is important in this stage to clarify the wind condition (wind temperature, wind speed, and wind direction) also find different periods in the year which the natural ventilation will be helpful for indoor thermal comfort and the times which there should be other strategies design to reach passive building.

Then the strategies for new project should be planed and during the process each strategy is going to be examined. For designing strategies, we have to consider passive building design factors and follow two main categories which are existing context or projects which should be designed with their context. In existing context category, we will deal with existing building and energy improvement process and calculation next to new building construction while in design with its context we have to consider nearby built environment calculation in the process for design stage and pre-design stage. Analyzing nearby built environment which clarify the patter is going to show the wind breach in the test and accordingly the wind mask creation. Within the pattern analysis the street direction, street dimension, plot orientation, plot proportion, and plot shape should be clarified. Design function and occupation will define the project category and then the information should go through the local construction regulation to create general platform which will end up with the design. After designing the project, it is time to do the mathematical calculation for thermal comfort and in order to be able to do that there should be input properties for natural ventilation and thermal comfort. Within this step the boundaries and definition for the calculation.

In chapter 3 step by step systematic approach for the method design is shown to be able to use and adaptive condition according to the location and find the relation between natural ventilation and indoor thermal comfort based on the geographical place. This method will show the difference between considering the nearby built environment and effect of it on natural ventilation during calculation process and free run calculation system which consider the building out of context for calculation. The method is going to examine in chapter 4 for detailed information and possibilities which will be achievable based on this systematic approach in order to have more realistic result and achieve real passive building design. Information below is acting as a foundation for the method design and clarification of steps and order of them.

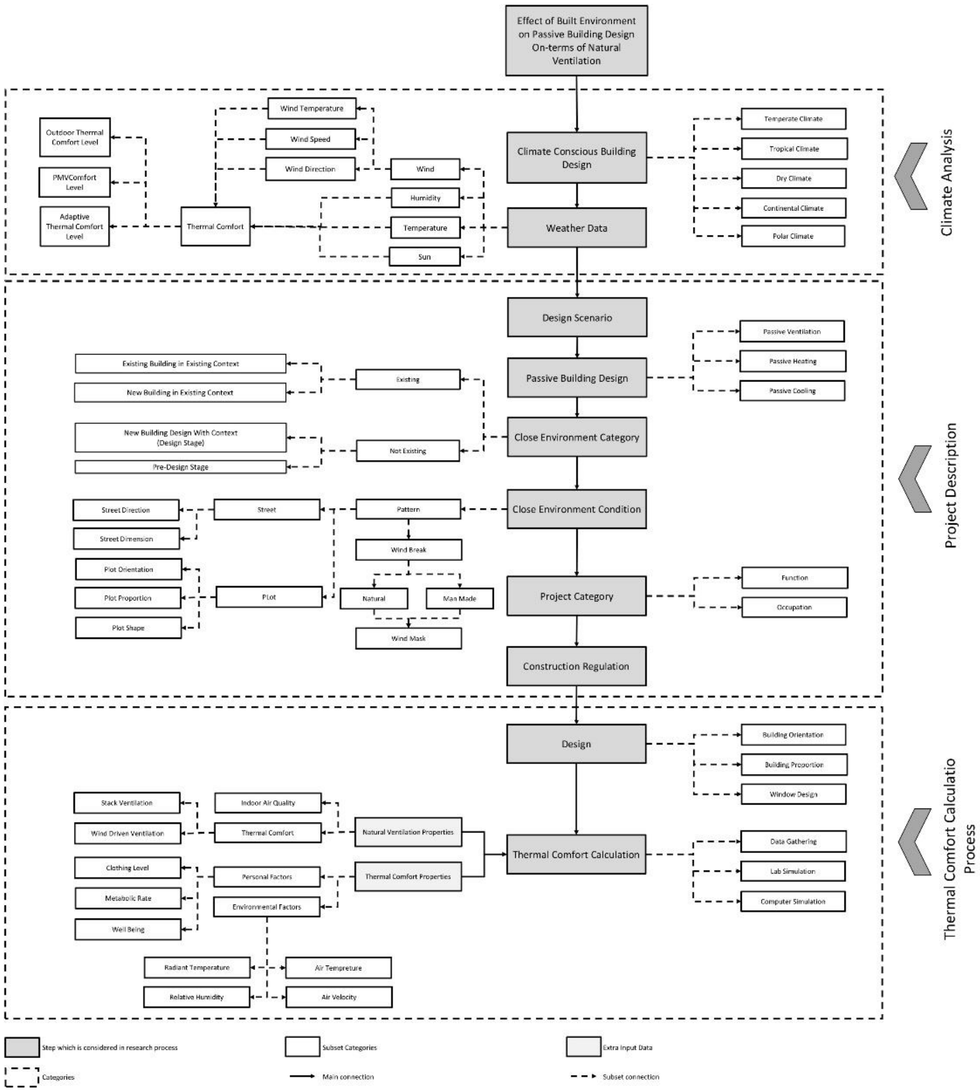


Figure 17: Literature review overview (Designed by author).

Chapter 3

APPROACH TO DETERMINE THE EFFECT OF BUILT ENVIRONMENT ON PASSIVE BUILDING DESIGN IN TERMS OF NATURAL VENTILATION

Literature review illustrated the existing knowledge and shows the air movement properties and which factors are making changes and how it is affecting thermal comfort. The 32nd introduction of the European Directive on the advancement of the utilization of energy from renewable sources expresses that Passive energy frameworks use building configuration to outfit the energy, implying that ideas concerning energy efficiency and renewable energy source are incorporated into the architecture. It is undeniable that they are vivacious components as well as they are in general architectonic spaces (DIRECTIVE 2009/28/EC, 2009).

Generally speaking, the energy performance calculation methods in the building can be separated into two fundamental classes: steady-state state and dynamic techniques (ISO, 2008). Clearly, the dynamic techniques can demonstrate in an increasingly reasonable manner the genuine wonders engaged with the physical conduct of the building and HVAC plans, also they give more reliable result information. In any case, there are reasons why steady-state methods are still applying in some countries. Truth be told, the steady-state strategies require less information, they are easier to be utilized, less time is expected to figure out how to use them appropriately (Passerini, Albatici, & Frattari, 2013). This study is following dynamic calculation method as far as the aim is providing more realistic response for indoor thermal comfort. Based on the logical stages to be followed, architects can benefit from any type of dynamic mathematical calculation system and any method can be used for their designs. In this chapter stages as the method which highlight the process in order to calculate level of thermal comfort in different scales are going to be explained as step by step enlightenment. Figure 18 is provided graphically in order to illustrate the process and in further sections each stage will be explained in detail and show for each category how scenarios to reach optimized result is going to be defined.

The process contains 7 main stages generally and the order are crucial to be followed in order to have realistic outcome. Stage 1 is going to focus on climate analysis as the first and base information for all categories as the fundamental data, followed by step 2 as defining design scenario. The scenario should be prepared based on design type and context. Step 3, nearby built environment should be analyzed to define wind mask as one of the most important variables for thermal comfort estimation and calculation which is the aim of this thesis to consider close built environment in thermal comfort calculation. Step 4 is after understanding the close environment condition, building for simulation should be designed within this step. In stage 5 all related information will be gathered from previous stages in order to prepare the input for mathematical calculation for providing numerical outcome in step 6. In the last step (Stage 7) based on the calculation results the level of thermal comfort will be exported to be evaluated and see if the answer is sufficient for specific scenario to be applied in design or not. After evaluating all defined scenarios outcomes, all results should be compared in order to have the optimized condition for the design project.

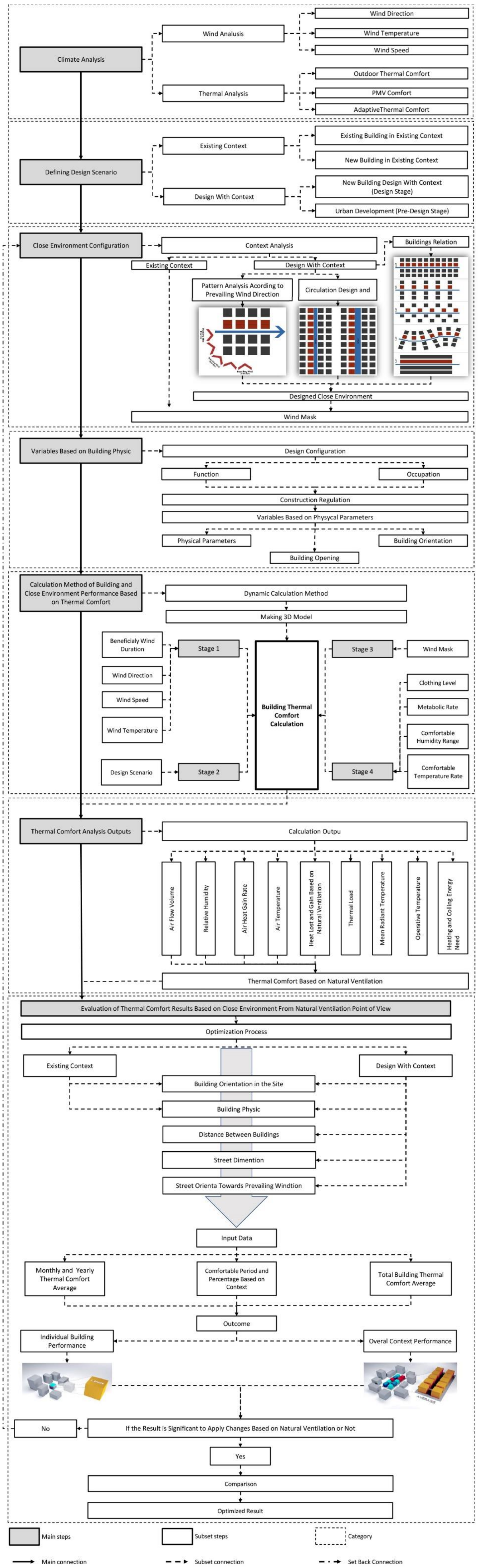


Figure 18: Thesis model (Designed by author).

During the rest of chapter three, author will explain the method in more detail and follow the process for illustrating the steps which should be followed in systematic way for better understanding and creating platform for designing the local outcome based on type of design and criteria.

3.1 Stage 1: Climate Analysis

As the common step for having successful model climate related variables have to be considered during the process and they have to narrow down to controllable and maintainable group of data. Based on this reason there is no fix result which will be applicable as far as the weather data is changing from location to another one. Energy strategies support providing thermal comfort with minimum energy consumption with taking natural ventilation into consideration. Topics such as the level of comfort during the year for specific location same as outdoor comfort and wind parameters are the basic information can be exported from the weather data collection in order to have perspective about the situation related to the project location. Figure 19 explain the relation between climate data and how it is possible to do analysis at the beginning.

Calculation and estimation for thermal comfort is going to be affected by many factors coming from the weather data such as: wind which means wind speed, wind direction, and wind temperature, plus the level of humidity and sun related factors next to general hourly temperature can be analyzed directly. Also, general thermal comfort calculations are possible. Estimating the result for general comfort extracted from weather data will be: outdoor thermal comfort level, PMV comfort level, and adaptive thermal comfort level. Any path according to calculation technique and outcome might be selected for further steps.

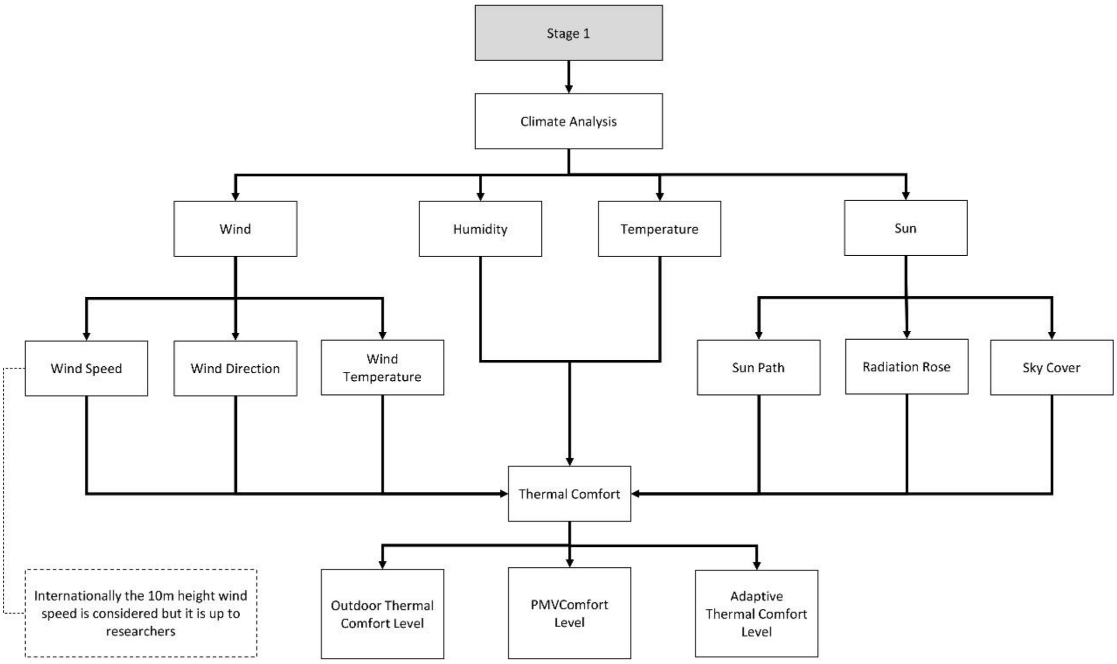


Figure 19: Stage 1; Climate analysis (Designed by author).

3.1.1 Climate Analysis According to Thermal Comfort

Understanding the thermal comfort conditions according to the construction location will gives the preliminary idea for which time during the year should be consider for thermal comfort strategies. With update weather data collection, it is simple to achieve simplistic charts which will be easy to understand hourly result for the year for any location. For thermal comfort condition presentation, the wind factors, humidity, temperature, sun, and sky conditions are going to play as fundamental information in understanding the situation and export hourly graphs for any time needed or even the complete year. It is possible to have charts which shows yearly outdoor thermal comfort level, PMV comfort level, and adaptive thermal comfort level. Figure 20 shows the hourly platform with colour codes easy to read and estimate temperature level during the year. On the Y direction of the chart, hours of the day as 24 hours are located and on the X direction, we can find the months of the year. On the right side we will find the color legend and information about each color temperature is located.

Based on this graph, which month of the year should be considered as hot season and which ones as cold seasons will be defined.

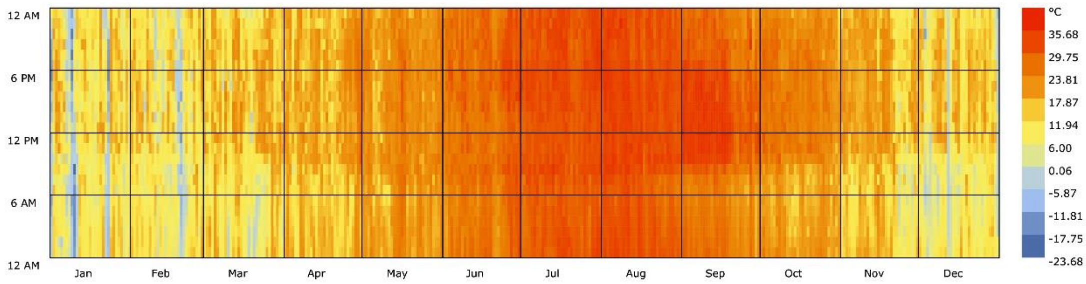


Figure 20: Hourly temperature chart (Exported from grasshopper for Magusa).

As the further step based on Figure 21 it is possible to convert the data into the yes or no chart which represent the same hourly division but instead of the temperature it will provide the information to show if that time in the year is thermally comfortable for users or not. This simplified temperature information is guidance to be aware of critical times during the year which needs more attention and the design should response as a solution to select the duration of the year for reducing the level of energy consumption. In Figure below the red color represents the comfortable time and the blue color is showing the discomfort during the hour in the year. The discomfort it might represent the weather is too cold or too hot for the users which makes them uncomfortable only based on temperature. It is important to mention the temperature proved in these graphs are going to be according to weather data temperature but the feel temperature for users are going to be different as far as other effective factors should be considered in calculation. From the extract chart it is clear which time of the year and which part of the date users will feel thermally comfortable and the scenarios should be done according to which period and for how long in order to have proper strategy. Terminologies are defined according to time of the day on the vertical direction in figure below.

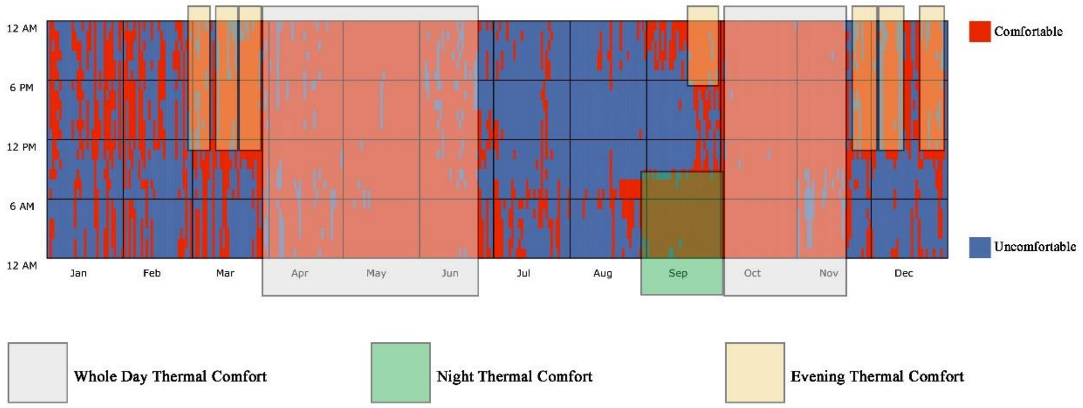


Figure 21: Hourly comfortable or not (Exported from grasshopper for Magusa).

3.1.2 Adaptive Thermal Comfort

The assumption of users to adapt their thermal condition according to situation is the main theory based for adaptive thermal comfort which is directly related to individual expectation. Generally, it is possible to assume users will accept conditions closer to they inhabit which will have effect on their evaluation, thus it is critical that how it is possible to generalize acceptable range (Nicol, Humphreys, & Roaf, 2012). Factors broke down in the relapse models were resolved based on three gatherings as input data collection including a thermal questionnaire; determined records including arrived at the midpoint of physical factors and warm files; and open-air meteorological perceptions (de Dear, Brager, & Cooper, Developing an Adaptive Model of Thermal Comfort and Preference. Final Report on ASHRAE RP-884, 1997); (de Dear, 1998). The versatile guideline suggests the capacity to adjust as indicated by the circumstance; henceforth, thermal reactions of the subjects could be fluctuated and abstract in every condition. Based on de Dear conduction individual variables for each person and indicates calculations can be standardized. The overall aim for adaptive thermal comfort calculation is clarifying the numerical relation between indoor thermal comfort (T_{comf}), measured outdoor temperature (T_{out}), and free run or conditioned variable (b). The linear equation is going to be "$T_{comf} = T_{out} + b$".

3.1.3 Climate Analysis According to Wind

It is essential to recognize wind behavior for the specific place and study how it is possible to improve the impact of natural ventilation for having higher level of energy efficiency in building construction. On one hand understandable graphical charts such as wind rose and wind height and on the other hand physical barriers effects like wind mask effect are important to be considered. The graphic tools which presents the short view to explain the wind is coming from which direction and how much will be the speed in specific location named wind rose. The polar coordinate system has been applied for gridding to show the direction and colors will represent the wind speed range. The greatest frequency will present as the longest spoke following the direction in the wind rose. the circular form arrangement in wind rose shows the recurrence of winds blowing from a specific direction over a predefined time. As it is clear in Figure 22 the length of each spoke around the circle is identified with the recurrence that the wind blows from a specific direction for every unit time. Each concentric circle speaks to an alternate recurrence, radiating from zero at the middle to expanding frequencies at the external circles (Curstin, 2020). Red arrow represents the summer breath and blue one is for winter wind.

According to climate analysis based on thermal condition, the period for defining prevailing wind which there will be benefit from natural ventilation which is going to be helpful for indoor thermal comfort improvement will be defined as useful summer breath and also the wind direction which should be avoided specially during winter Perion which will have disturbing effect should be clarified as well. This information will help to understand the angle which is going to be more successful in order to have higher indoor thermal comfort from prevailing wind point of view.

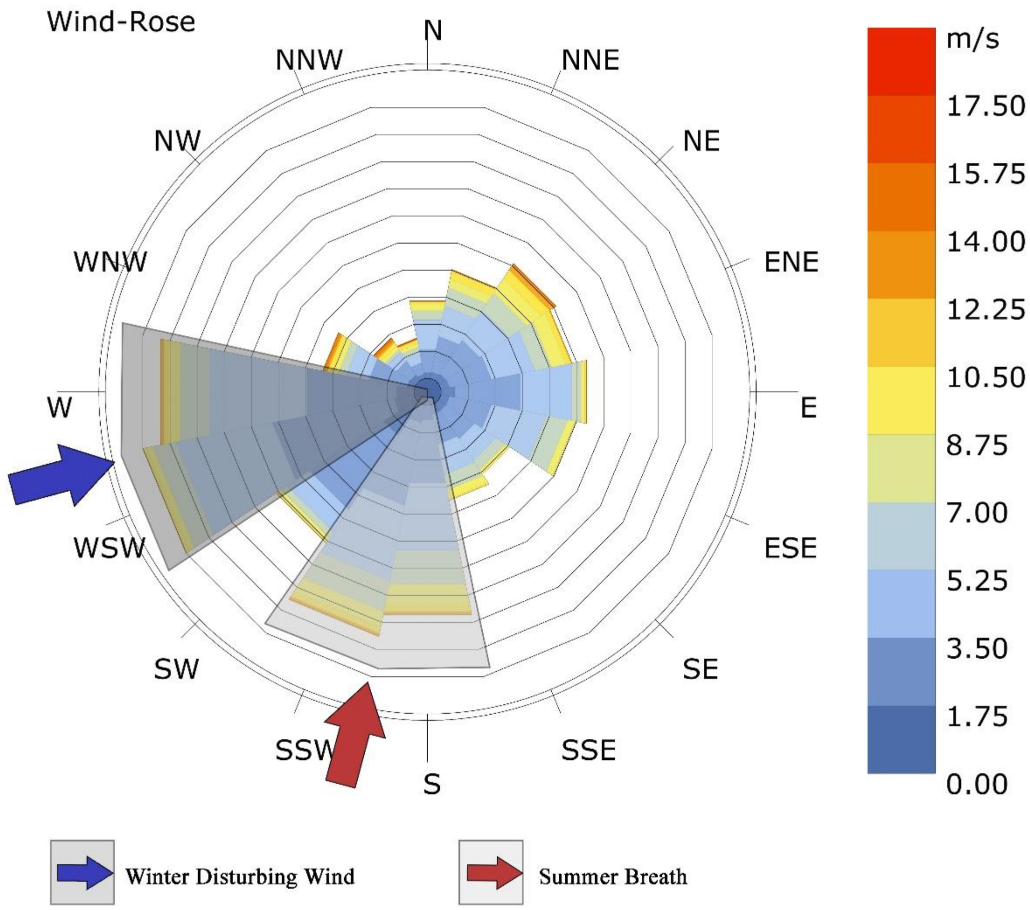


Figure 22: Wind Rose (Exported from grasshopper for Magusa).

Wind speed is not the single variable and the speed changes according to the height. As high as we go the wind speed increase accordingly. So, in order to make the simulations possible there should be a limitation for these wind speed changes. Internationally it is accepted to consider 10m height as a standard for energy simulations (Bay & Ong, 2007). The graphical expression on wind and height change relation is presented in Figure 23. In case the architect decides to have more accurate result specially in case of high-rise building design it is possible to find the wind speed in any height coming from weather data so the input number for wind speed will insert to calculation formula accordingly.

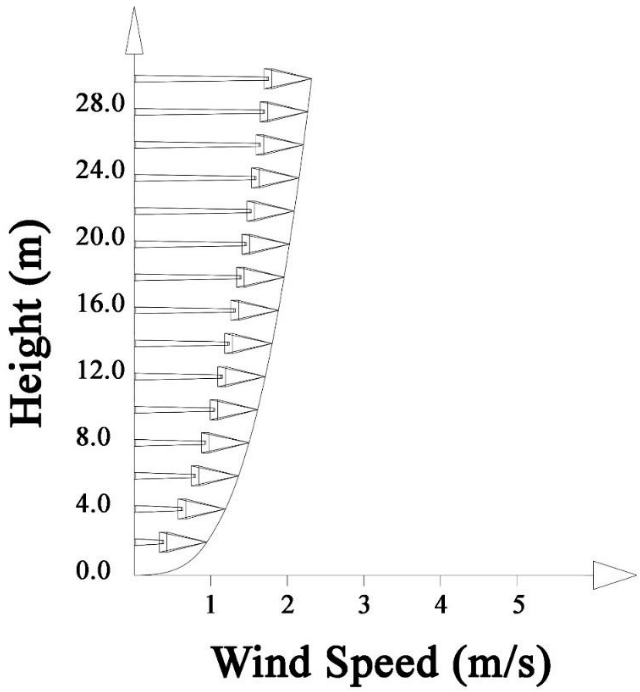


Figure 23: Wind speed change according to height (Exported from grasshopper for Magusa).

3.2 Stage 2: Defining Design Scenario

The issue in most thermal comfort calculation is considering building in a free run condition with no nearby built environment in calculation process according to weather data wind properties while there is a magnificent change based on surrounding on air movement. In order to understand complete ventilation in building it is possible to cover most parts by "Natural Ventilation in Building; Architectural Concepts, Consequences and Possibilities (Kleiven, 2003)". In this thesis calculations are going to be done by use of computer software in order to reach the outcome following dynamic energy calculation method. For building design four main categories are defined which are: existing building in existing context thermal comfort calculation, new building design in existing context, new building design with context (design stage), and pre-design stage which is more related to urban development. After defining the category accordingly and the requirements for each design definition, different scenarios will be created. Figure 24 illustrate the general division which means existing context and design with its context accordingly and under each grouping category will be located. This system will help to make the math in the process clear to follow and go to the next stage.

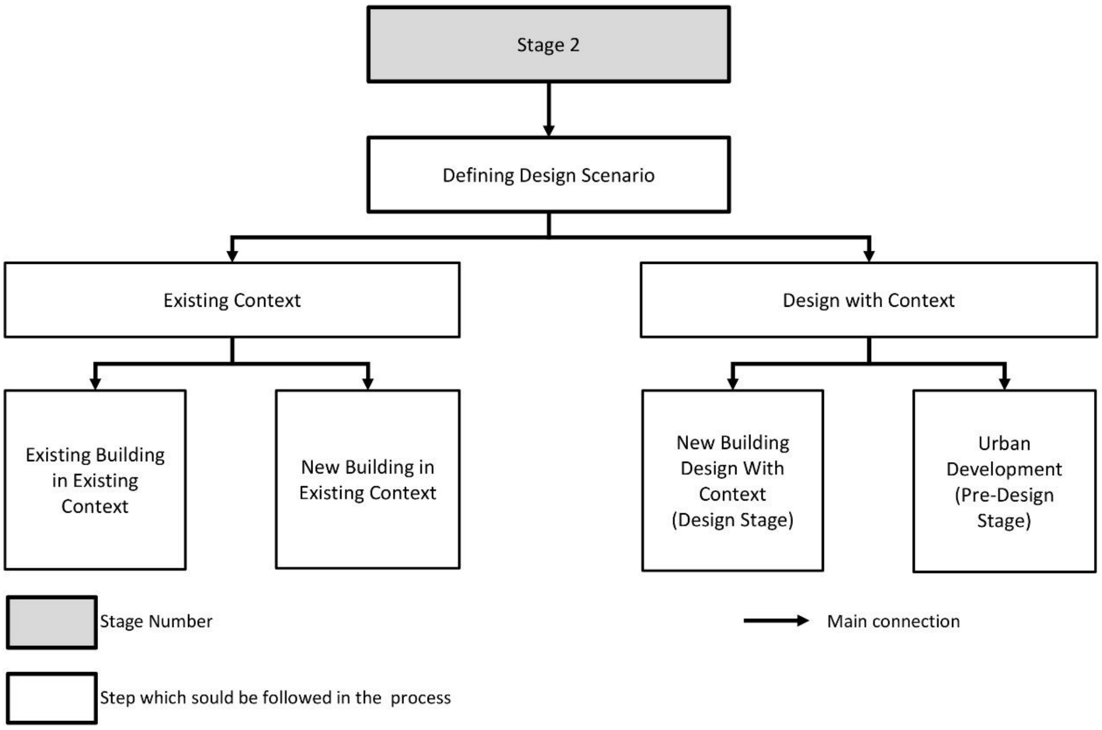


Figure 24: Stage 2; Defining design scenario (Designed by author).

3.3 Stage 3: Nearby Built Environment Configuration According to Design Scenario

For analyzing the nearby built environment, the path is going to be different for existing context and design with context. When the context is existing, estimation of wind mask is going to be directed from the neighborhood and its properties. The variables which are going to define the wind mask are location of the site, plot shape, plot proportion, street direction, street width, and surrounding buildings proportion. Based on these information wind mask will be calculated for further steps. On the other hand, the design with context should pass through different steps in order to define the wind mask. As the first step, which type of pattern is going to be suitable for design site and accordingly the streets will be located will be studied. Street dimension and orientation are very important factors during the thermal comfort calculation as far as they will define the air movement and behavior plus the building plot will be define after these decisions are done. It is very important to mention during the general process after evaluation of each section in order to prepare the outcome for another scenario architects should come back and start from this stage. If the project will be related to existing building design as far as the wind mask effect is going to be same, they may scape this stage and follow the process otherwise changes will start happening from here. Figure 25 is presenting stage 3 process and steps.

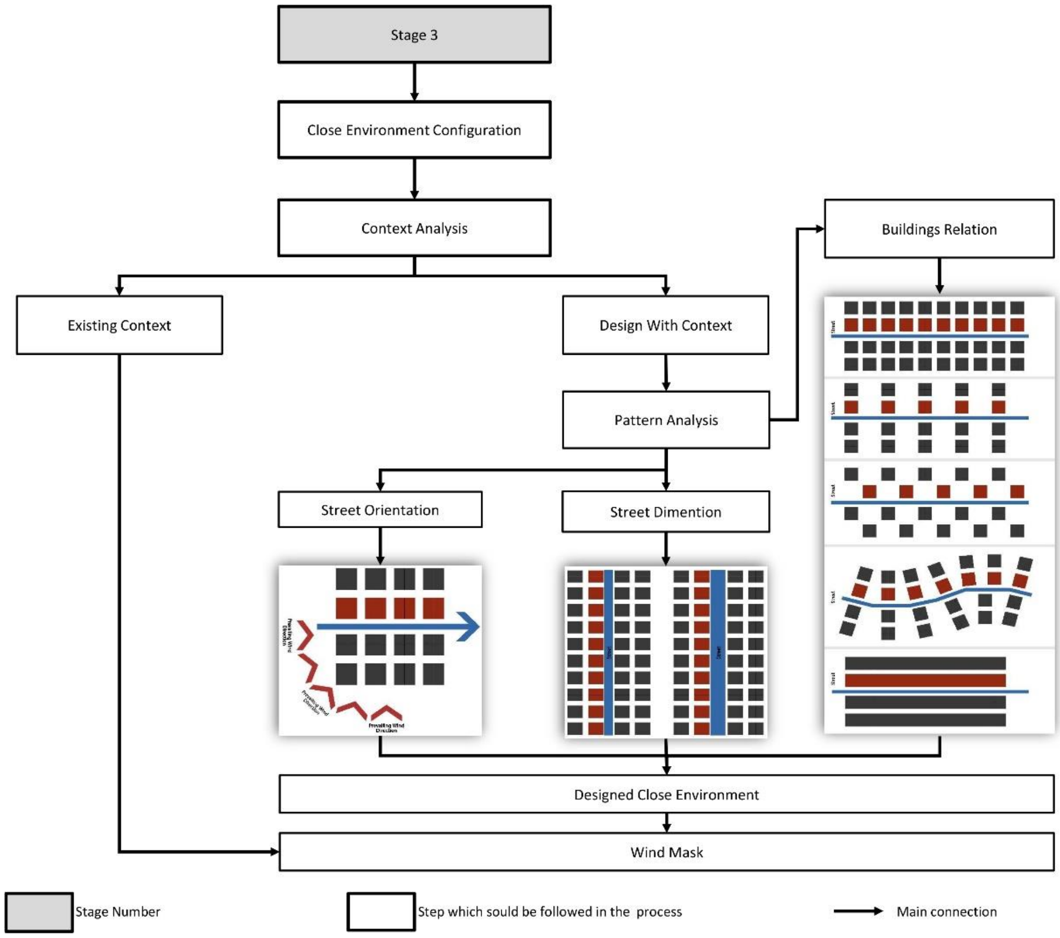


Figure 25: Stage 3; Nearby built environment configuration (Designed by author).

3.4 Stage 4: Variables Based on Physical Parameters

Designing the process, new building can be modeled after extracting the boundaries dictated from the local construction regulation. Before filtering the project from construction regulation, decision based on project functions and occupancy condition should be clear. In building design stage some variables like: building shape, building physic, building orientation, and window properties can be changed based on project description and goal which will require different approaches. Each scenario should be calculated in order to find the optimized solution for the new building construction for having maximum benefit from natural ventilation on user indoor thermal comfort (Figure 26).

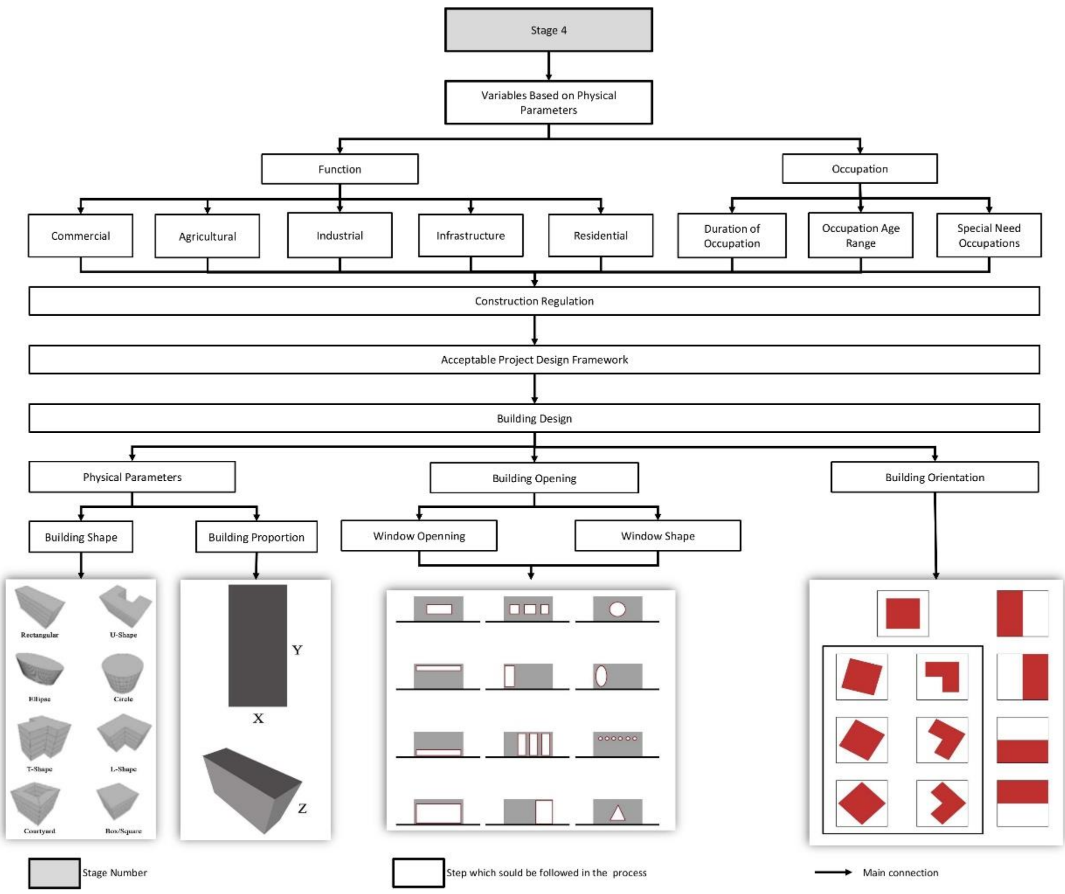


Figure 26: Stage 4; Variables based on physical parameters (Designed by author).

3.5 Stage 5: Calculation Method of Building and Nearby Built Environment Performance Based on Thermal Comfort

As it is mentioned in Chapter 2 there are two main energy calculation methods and for this method the dynamic method is suitable while dives more flexibility to find the result, they need.in order to be able to do the calculation 3D model of the building with nearby built environment is mandatory. For building thermal comfort calculation findings from each step should insert to the process to be able to have accurate outcome. From stage 1 the information related to beneficially wind duration in the year, wind direction, wind temperature, wind speed, and wind temperature are going to act as input while from stage 2 design scenario will be defined to the process. Wind mask which is one of the most important factors will be exported from stage 3 and finally from stage 4 occupation and function we will have clothing level, metabolic rate, comfortable humidity range, and comfortable temperature rate. From stage 3 and 4 together the mentioned 3D will be created which will cover other sections in those stages.

During the process of this thesis the computer program which can run the CFD simulation based on required data in order to help us go further. Some software has been examined to find if they are covering the needs for all aspects of natural ventilation calculation in this study but it is important to mention there are other software which exist and according to the preference they might be used. Each CFD software is useful individually base on the input data output expectation according to the goal.

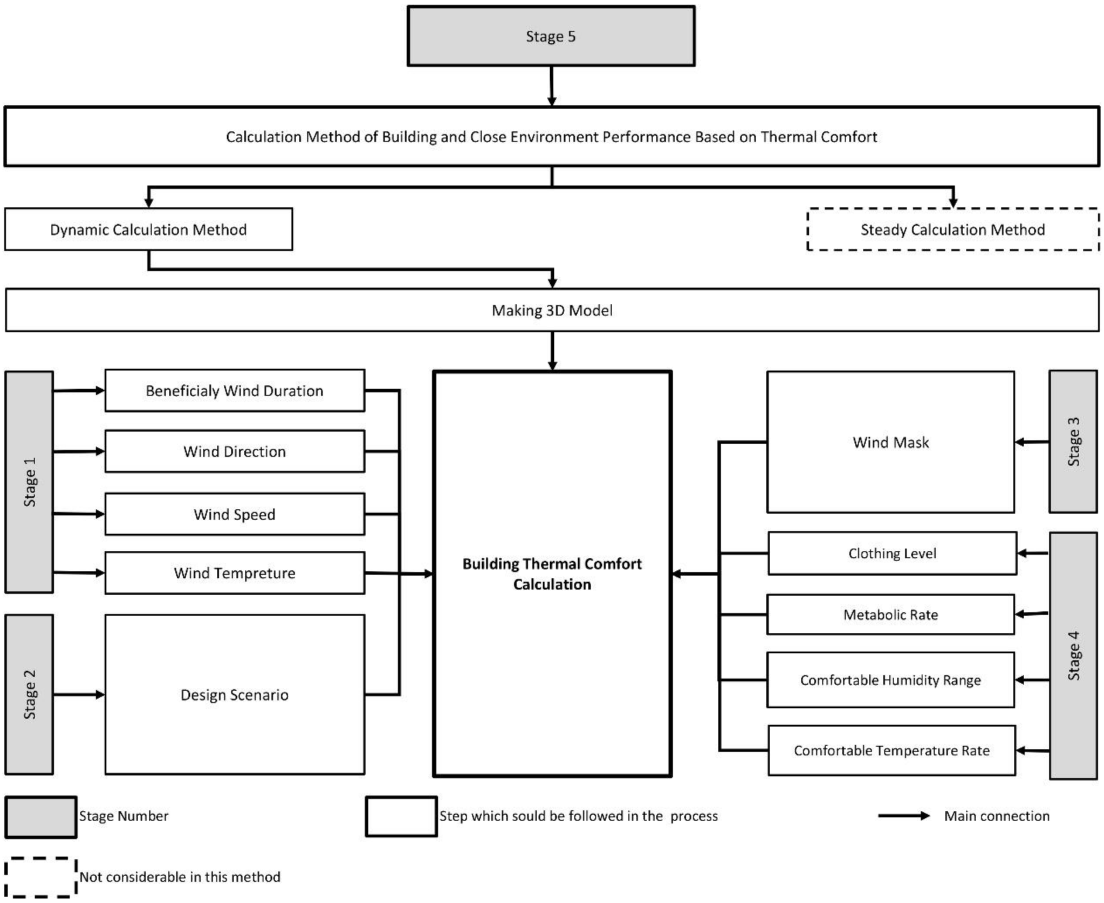


Figure 27: Stage 5; Calculation technique (Designed by author).

List of tested software for this thesis are mentioned below:

- Autodesk Flow design (very easy and basic software to estimate the general wind behavior according to the readymade setting).
- Autodesk CFD software (very useful and categories in advanced group of software but in many sections).
- Ansys Fluent (basically it is possible to put Fluent and Acad CFD in the same category but Ansys fluent is slightly better and gives more freedom to the user specially in messing system).
- TAS (hourly based simple and strong software with many building and components for the energy analysis).

- Rhinoceros 3D also known as "Rhino 3D", is computer-aided design software with many additional plugins. Grasshopper is the open scoured mathematic base plugging which created the platform for easy use for component connection and run the calculation in between. Also, there are several energy calculation external plugins which will create the option for CFD simulation calculation.

3.6 Stage 6: Thermal Comfort Analysis Outputs

Running the simulation according to the weather data and variables which explained in previous stage, outcome will be exported. In this stage the important factor is what kind of information extracted from the calculation and how it will guide us towards optimized result for the project. Indoor thermal comfort as the aim for the process should be evaluated and be clear, thus according to outcome subsets there will be two groups of data which may use in different paths. Thermal comfort based on natural ventilation is going to have input from air flow volume, relative humidity, air heat gain rate, heat lost and gain based on natural ventilation (Figure 28).

Important factor which should be explained in this section is in total thermal comfort calculation based on various regulation in each country according to their climate condition is going to be calculated parallel to natural ventilation effect analysis, so within the process of air flow affected by close built environment and indoor thermal comfort it is possible to attach the other result and gather more detailed information. It is possible to merge all mathematical result in this stage and follow the model in order to find the optimized result for each scenario.

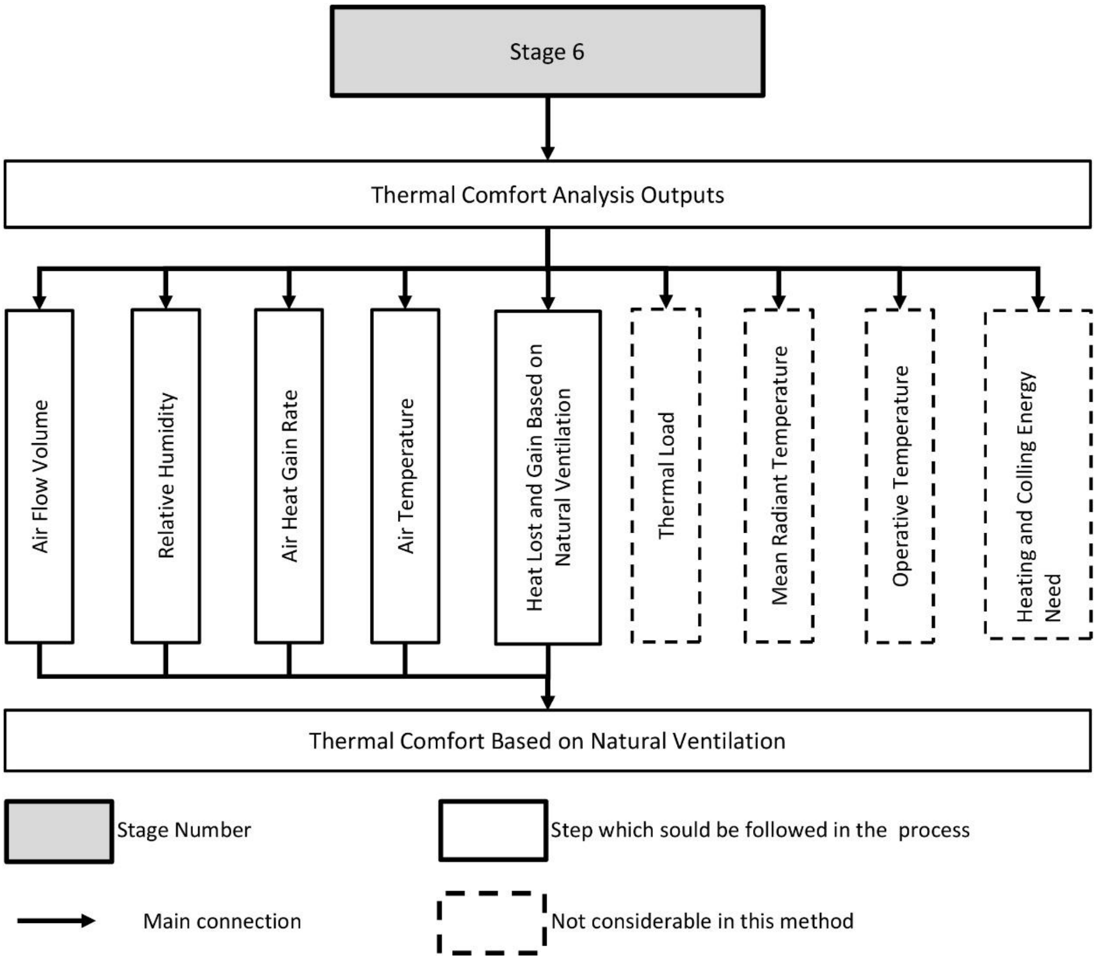


Figure 28: Stage 6; Thermal comfort analysis outputs (Designed by author).

3.7 Stage 7: Evaluation of Thermal Comfort Results Based on Nearby Built Environment from Natural Ventilation Point of View

Calculation outcome might be exported in required detail according to architect's need like hourly, monthly even yearly thermal comfort as percentage. Information about duration and percentage according to context, and total building thermal comfort as average will be defined as floor by floor, thus accordingly the building average will be calculated. Within this step optimization analysis based on scenario is going to take place. Building orientation in the site and building physic which consist of building shape, proportion, and height are going to be main variables for defined scenarios within existing context organization in order to complete optimization process as long as other factors are fixed in existing context. Design with context will cover all factors mentioned for existing context condition also other variables should be evaluated in optimization process. Distance between buildings, street dimension, and street orientation towards prevailing wind are flexible and designed by architect thus it is must to find the optimized variables for them in order to find the best result based on scenario.

According to exported graphs the outcome should be evaluated again in order to see if there is a significant result to apply in construction or it is better to follow another scenario. If the result is not significant for projects with designed context; architects should go back to stage 3 as far as with any change in pattern design the wind mask effect will be different and the result of it has direct effect on calculation process. Incase of existing context condition, Process should be followed with new scenario from stage 4 as long as the wind mask effect will be same based on existing close built environment. All results from different scenarios will be calculated and compared with each other to finalize the process with optimized result for specific climate and design condition. By following Figure 29 which illustrate the steps to be followed the last step in method will finalized by optimized scenario for design project. The outcome of this process will clarify the result which is going to be more realistic and closer to the outcome after project construction, thus architects will approach with trustable data and find better solution for other periods of the year with other strategies in order to improve the level of indoor thermal comfort.

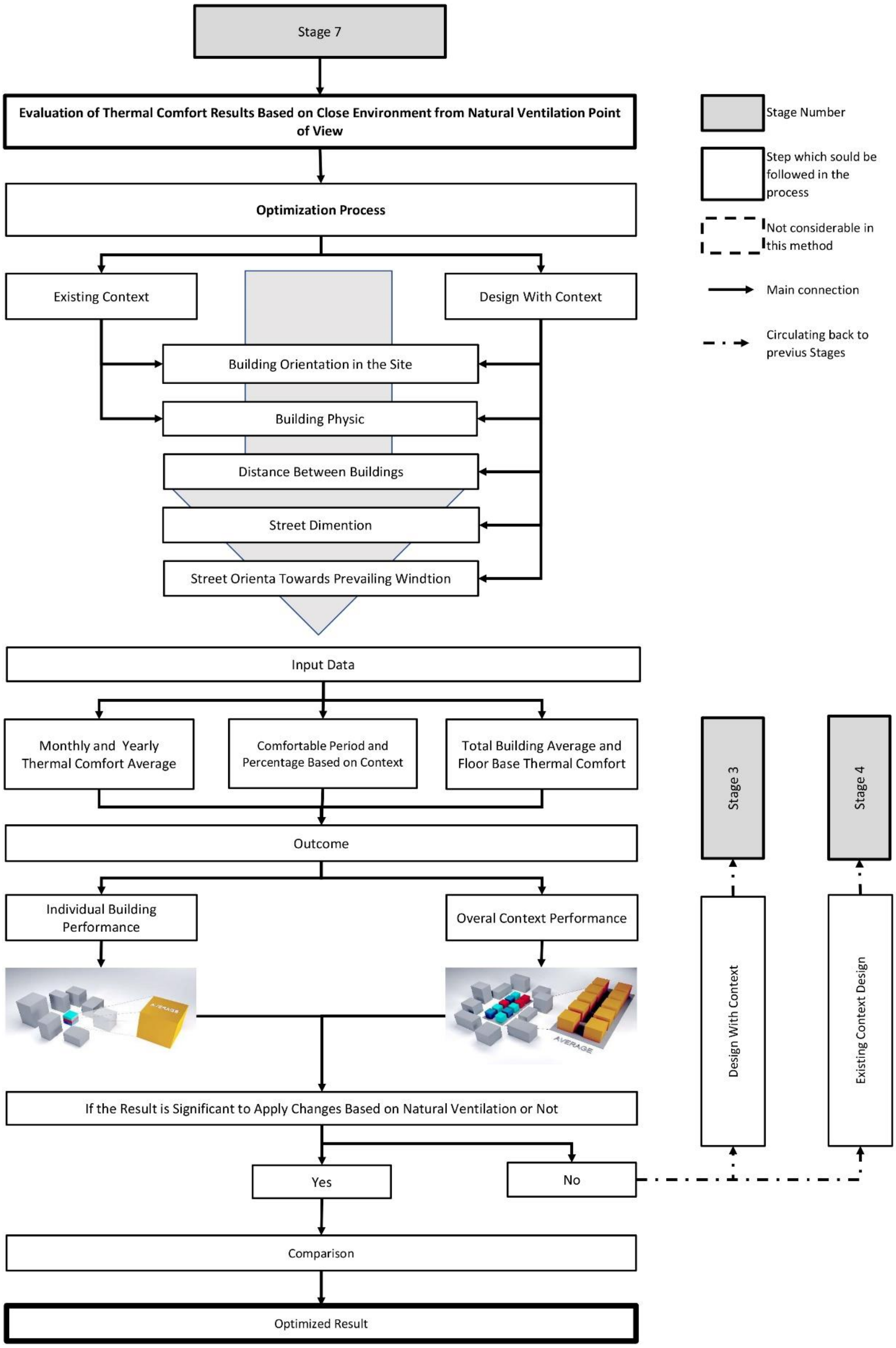


Figure 29: Stage 7; Evaluation of thermal comfort results based on close built environment from natural ventilation point of view (Designed by author).

The section which needs extra attention is how the evaluation should be done to have the useful answer for comparison and optimization process. According to scenario related to existing context the building average of indoor thermal comfort should be calculated while for design with context it is important to have the overall thermal comfort duration for the complete site with designed context. It is worth noting that the measurement of indoor thermal comfort is carried out independently for each house, but the primary goal is to view the actual complex thermal comfort percentage throughout the year. In Figure 30 the left picture represents the existing context and the right one is for design with context situation.

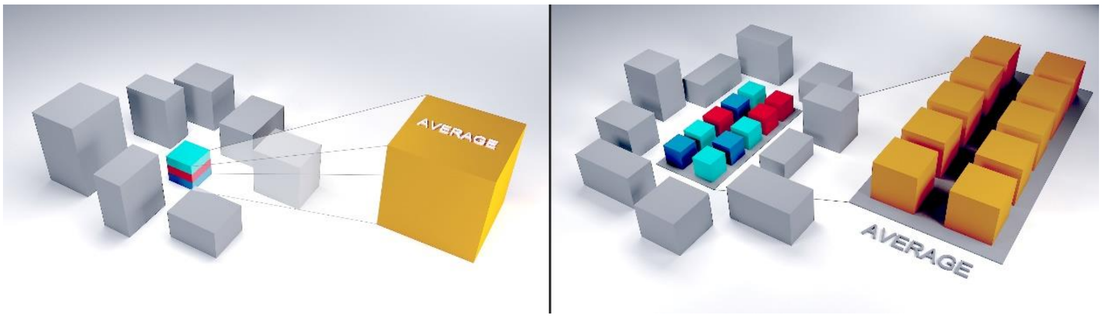


Figure 30: Overall needed result of calculation for existing context and design with context (Designed by author).

3.8 Chapter 3 Overview

Chapter 3 present the detailed information for designed method in order to consider natural ventilation effect on indoor thermal comfort based on nearby built environment and each stage has been presented in detail and clarify the process to have optimized result for passive building design. In following chapter, designed method is going to be tested on the thesis selected case to check the accuracy and find the result for the specific climate condition based on the location. Step by step process are going to be formulated according to study case regulation and mentioned software and plugins to find out the accuracy of the method and illustrate how the system works and which type of results will be exported from the process. Also, it will be clear which factors during the design process will have more effect on improvement of indoor thermal comfort level.

Chapter 4

TESTING THE PROPOSED MODEL IN A CASE

During chapter 4 after explanation of the method and the process in previous section it is time to apply the method and go through the process with mathematical calculation in order to examine the method and see how it is going to help and define the effect of natural ventilation on indoor thermal comfort also, highlight the improvement by following the path of maximizing the benefit of wind in passive building design. The framework for selected location is going to be generated and analyzed to illustrate based on existing condition how much improvement we may have and the difference between free run simulation without nearby built environment into consideration which is happening in most energy regulation calculations now a days and with integrating the nearby built environment into calculation simulation. Also, the design stage strategies based on the scenarios are going to be explained and will be tested to have the perspective of how the process will work and define which factors are more effective in the design according to natural ventilation and designing the nearby built environment.

4.1 Stage 1 Climate Analysis for Selected Case

The method and the model design have been done in chapter 3 is going to examine on. Turkish Republic of Northern Cyprus, Magusa city has been selected as a city which is going to be analyzed and tested. This city selected according to the author personal experience and knowledge of the city, life style and construction method in order to have more realistic result and compare it with reality of Cyprus. Person experience and living more than 10 years in this region and climate helps the pre-estimation of the result expectation and see how the simulation response the expectation from the current condition of the city.

The Turkish Northern Republic of Cyprus is an authorized express covering the northeast side of the island of Cyprus. Northern Cyprus stretches from both the northeastern tip of the Karpaz to the Kokkina throughout the west (Figure 31). A security region under UN control exists between Northern Cyprus and the rest of the island and divides Nicosia into part the island's largest state and is the capital of both sides (Alipour & Kilic, 2005). Cyprus is the third large island located within the Eastern Mediterranean Sea the Cypress is surrounded by Turkey on the north, Syria and Lebanon on the east, Israel on the south east, Egypt on South, and Greece is located on the west as the island neighbors. Cyprus is 240 kilometers long and 100 kilometers wide at its widest point. Geographic placement of Cyprus is latitudes 34° and 36° N, and longitudes 32° and 35° E. from approximately 10th millennium BC the beginning of the life traces in island have been found. Because of its very strategic location, many powerful countries have occupied Cyprus island in the history (Kypros, 2013).

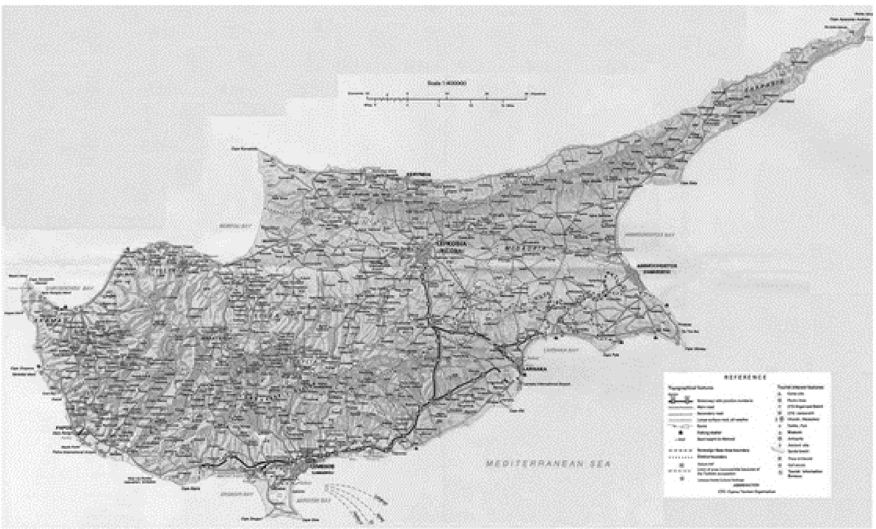


Figure 31: Cyperus map (http://www.intercyprus.com/maps/map-of-cyprus.jpg)

- **Magusa City**

There is a port city on the eastern shore of the island of Cyprus with a very rich heritage called Magusa. It is placed on the east side of Nicosia and has the most profound harbor of the island. During the medieval era, Magusa has been a very important port city upon this island as well as an entrance to the coasts of European nations from where merchandise of the Silk Road dealers was transported. The old walled city and parts of the cutting-edge city directly fall inside the Turkish Republic of Northern Cyprus in Magusa district (Walsh, Kiss, & Coureas, 2014).

This city, with a population of about 54,000 (Lotfabadi & Hancer, 2019), is Northern Cyprus's third-largest city and it is situated at 35 ° 7′ N and 33 ° 55′ E, at an altitude of 25 meters with seasonally moderate and warm subtropical Mediterranean climate, according to the Köppen classification. In other words, it is hot and dry in summer due to the subtropical high-pressure system, and has rainy and cool conditions due to the polar front. The average hot season maximum temperature is about 33 ° C in the city and the average cold season minimum temperature is about 17 ° C (Famagusta Climate & Temperature, 2019).

Magusa is generally divided in two main section in the urban characteristics. First one is the historical pattern which it is possible to see streets with arcs and turns which basically contains the historical area in the city. The other pattern is the modern approach to the city with land division and cross road connection between vehicle path. In order to realize the DNA of the city pattern it is easier to follow the city streets and study them. Thus, streets and their direction plus the thickness of the roads are highlighted in the next Figure.

As far as the Magusa is limited by the sea on the east, the city growth towards the coast continuation which means mostly to the north and north west. The expansion of the new settlements is following the modern urban style and natural ventilation is just considered only for city scale which means ventilating the air pollution from the city. Focusing on the south west of the map and surroundings it is visible how urban pattern change from the historic and natural development to the modern style (Figure 32). There should be more control over new settlement areas by architect in order to improve the possibility of building passive design in Magusa case.

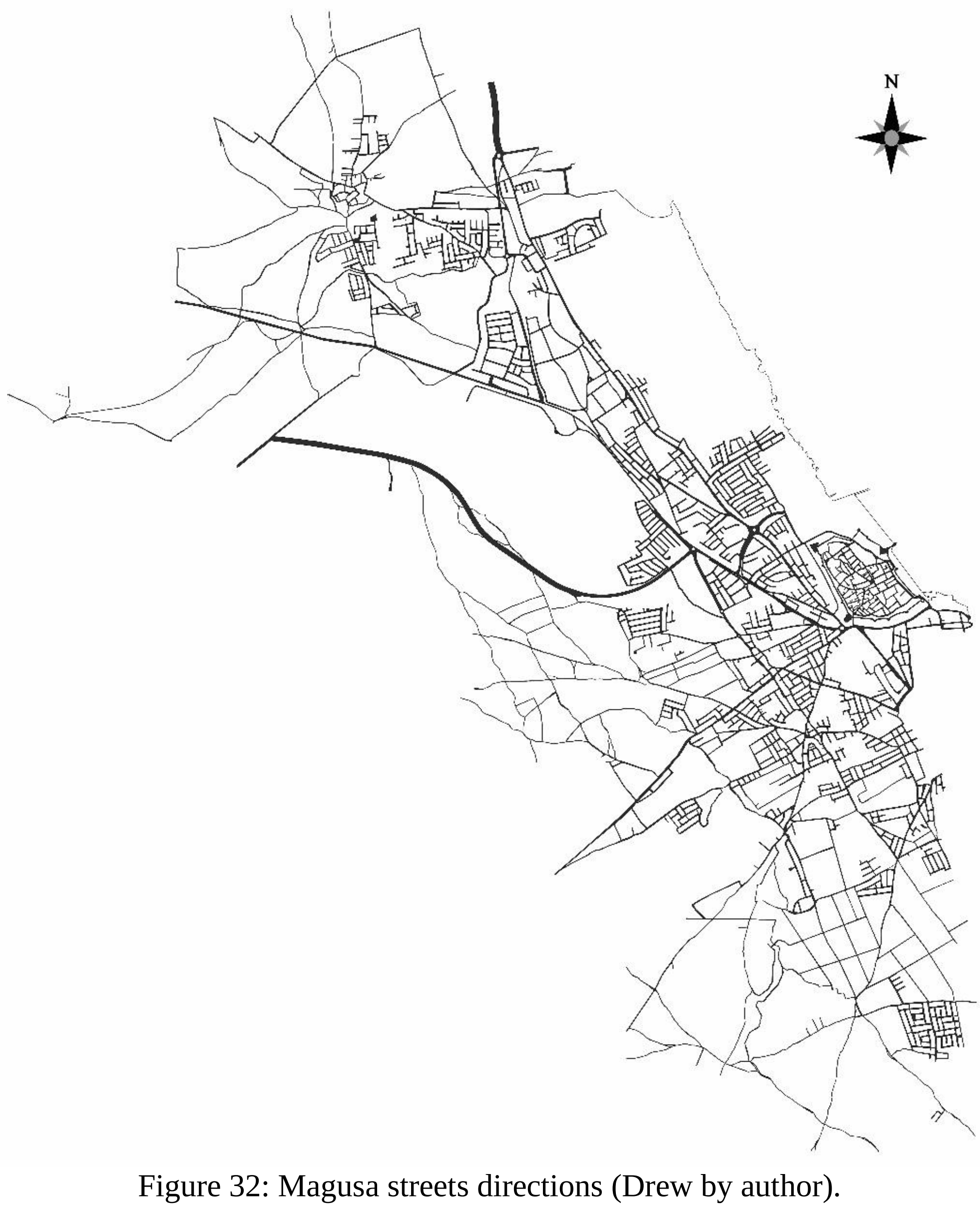


Figure 32: Magusa streets directions (Drew by author).

In the modern part of the city generally it is possible to find two construction patterns in the neighborhoods. Most of the city is following individual plots and separated building construction and in small part there is row housing style.

- **Row Housing**

In row housing pattern there will be only one opening direction which will face to the street direction but the building dimension will be same and only analysis will be done for two story building as a copy from the existing area in the Magusa. There will be estimation for upcoming construction if it will be beneficial if they use this type of construction or not. This neighborhood is called Sakarya in Magusa (Figure 33).

Figure 33: Sakarya neighborhood in Magusa (Exported from Google earth).

- **Individual Building Pattern**

Individual pattern is mainly selected for villa areas with two story buildings, four story buildings in apartment residentials, and ten story buildings as an average for dwellings which need to consider elevators in their buildings based on Northern Cyprus municipality regulation. Each sets of buildings will be analyzed from three different orientation according to the wind direction which the result will be helpful for existing neighborhoods and also for the new development areas as a guideline in order to have their buildings in a location based on passive design factors with the focus of natural ventilation (Figure 34).

Figure 34: Example of separated neighborhood pattern in Magusa (Exported from Google earth).

Test case located in the Mediterranean Sea where the subtropical climate has hot-humid and semi-arid region. Mountain in the middle of the island of Northern Cyprus, creates climate differences happen in several towns. Girne is to the high mountain in a hot-humid climate with low rainfall. Due to the distance from the sea, the variation between hot and humid and mixed climate is linked to Magusa and Guzelyurt. Nights and early mornings mentioned cities are facing higher percentage of the humidity, but it reduces during the noon tome. Lefkosa faces a hot-dry climate in the center of the island, due to the distance from the sea (Hancer, 2005). Hot summer and mild winter are Cyprus general climate identity. Thus, snowing is rarely happening in mountains, tropical rains are appearing in winter and spring generally and then dry hot summer began (MOA, 2013). with 60% of annual rainfall is the percentage calculated for Cyprus winter. These rains produce winter torrents that fill most of the rivers, which typically dry up as the year progresses. The short spring is characterized by unstable weather, occasional heavy storms and the "meltem", or westerly wind. Parts of the island experience the "Poyraz", a north-westerly wind, or the sirocco, a wind from Africa, which is dry and dusty.

4.1.1 Climate Analysis According to Temperature for Selected Case

After dealing with wind information it is necessary to see how comfortable is Magusa. It is possible to measure the percentage of the year that is comfortable based on annual weather data and how people believe that the temperature that just indicates the air temperature is not equal to the temperature they experience. Alternatively, it must be subject to speed and humidity factors.

In Figure 35 first chart shows the universal thermal climate index for Magusa and based on the information hot and cold periods which is going to have effect on the calculation scenarios and clothing levels in formula and by comfortable or not chart will be defined also, during which hours in a year it is needed to have strategies for having benefit from natural ventilation and clarify if it is beneficial or not will be illustrated. In comfortable or not we can see red color stands for comfortable time and blue color shows uncomfortable time in Cyprus Magusa. Almost five months a year people seem to feel relaxed in this environment, which demonstrates the value of a new systemic way and managing the microclimatic conditions to design the systematic approach. The third chart stand for outdoor feeling comfort which has been categorized into 5 different levels. -2 stands for very cold and 2 is very hot. Understanding till now we are not facing any steam coldness or warmness about 60% of the year. During analyzing third chart we can find how many hours outdoor condition is pleasant and these hours windows can be open and have totally comfortable condition with air flow.

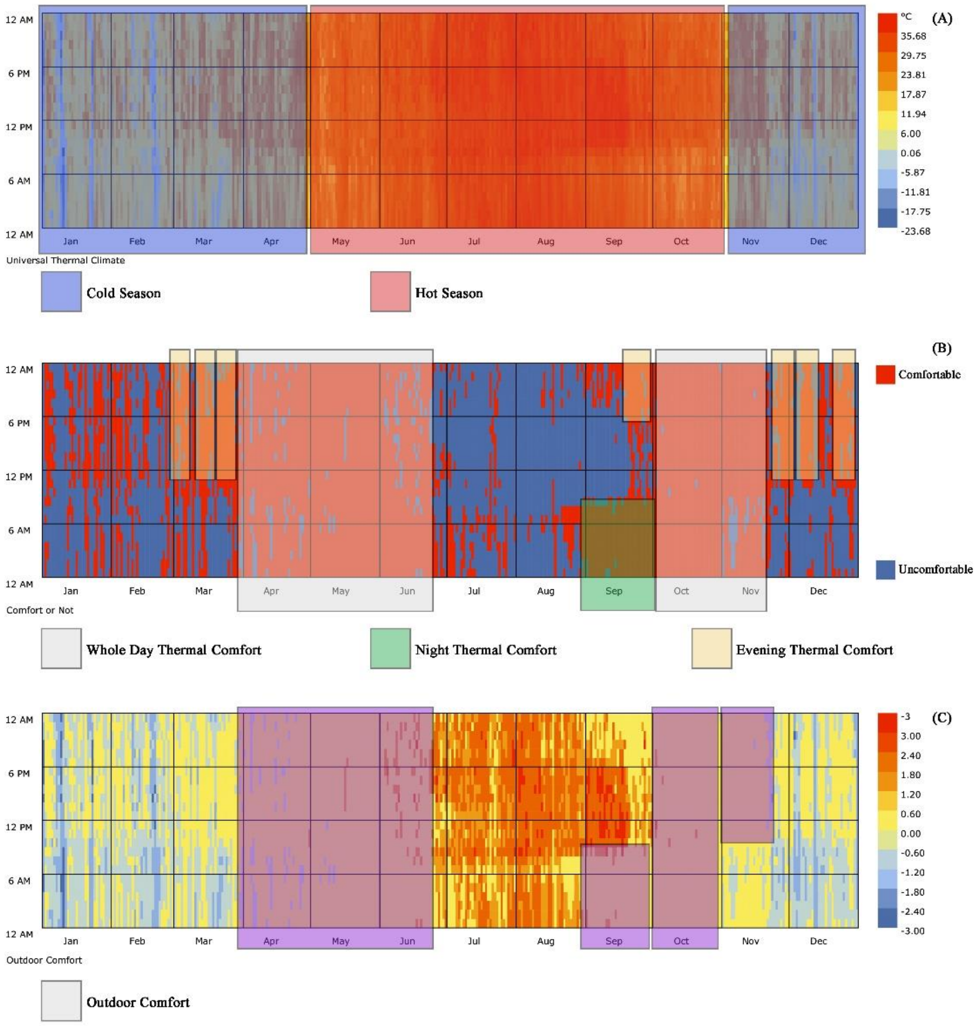


Figure 35: (a) Cold and hot seasons, (b) Duration for benefiting from wind, and (c) Comfortable period for outdoor (Exported from grasshopper for Magusa and modified by author).

❖ Humidity and Sun Path

The other climatically effective factor which is one of the base variables to make people feel comfortable or not is the sun location and level of humidity during that time. In this thesis we are not focusing on this issue but by following exported graphs we can understand that in which time of the year and which hour according to sun location and if the humidity percentage in the air is in the comfort limits or not it is needed to have ventilation. Following charts are limited by some factors like the time period and also percentage of the humidity which is mentioned in Figure 36. Collective data and visualization of them will be helpful to put the design in the correct path and make more effective decision according to each scenario. So, it became necessary to have the pick on the sun and the relation of it to the needed ventilation or not criteria.

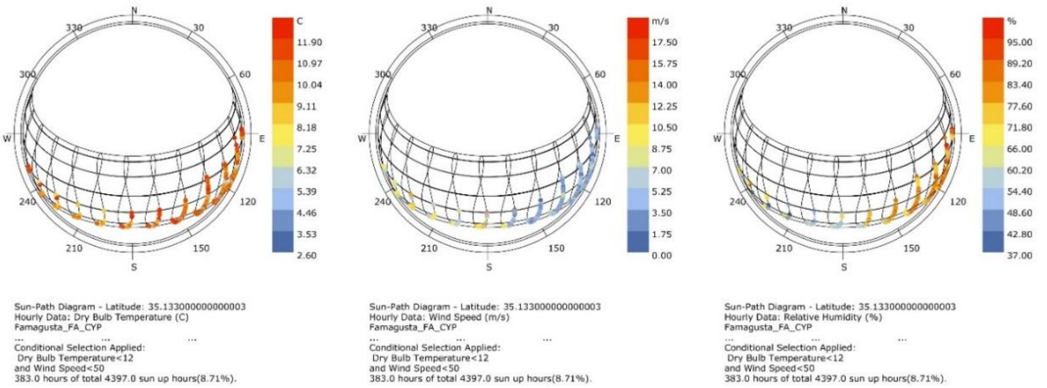


Figure 36: Magusa sun path with dry bulb temperature, wind speed, and relative humidity (Exported from grasshopper for Magusa).

- ❖ **Adaptive Thermal Comfort Calculation**

In the following section the most important and effective components is going to be introduces. Adaptive comfort and psychometric chart. After all the study these two elements should pave the way for comparison and understand the situation. We also offer the ability to export the numerical results to functional and easy-to understand graphs so that anyone can benefit from the analysis. It is to be illustrated in the adaptive comfort chart that there are three different criteria which are: when people feel cold, hot or comfortable in the chosen climate. This zoning is going to be the base for the solvation strategy. For this thesis only information from natural ventilation effect results are going to be counted in psychometric chart but it is possible to have other outcomes from energy calculation considered as well to have all together result and presentation. Thus, in this step the level of success for the scenario will be clear and it can be compared with other results from different scenarios.

4.1.2 Climate Analysis According to Wind for Selected Case

During the year Cyprus is facing to the wind from South till North west as a main direction of the wind. It is necessary to see how the wind affects the environment in specific months of the year to find the right simulation path involved in real cases and to act accordingly to increase the degree of thermal satisfaction for indoor and outdoor environments with minimal need for any other form of energy, apart from natural and renewable energy. In Figure 37 the separated wind rose of Magusa sorted by the month of the year proves the annual data based on the wind direction basically for the whole duration of the year.

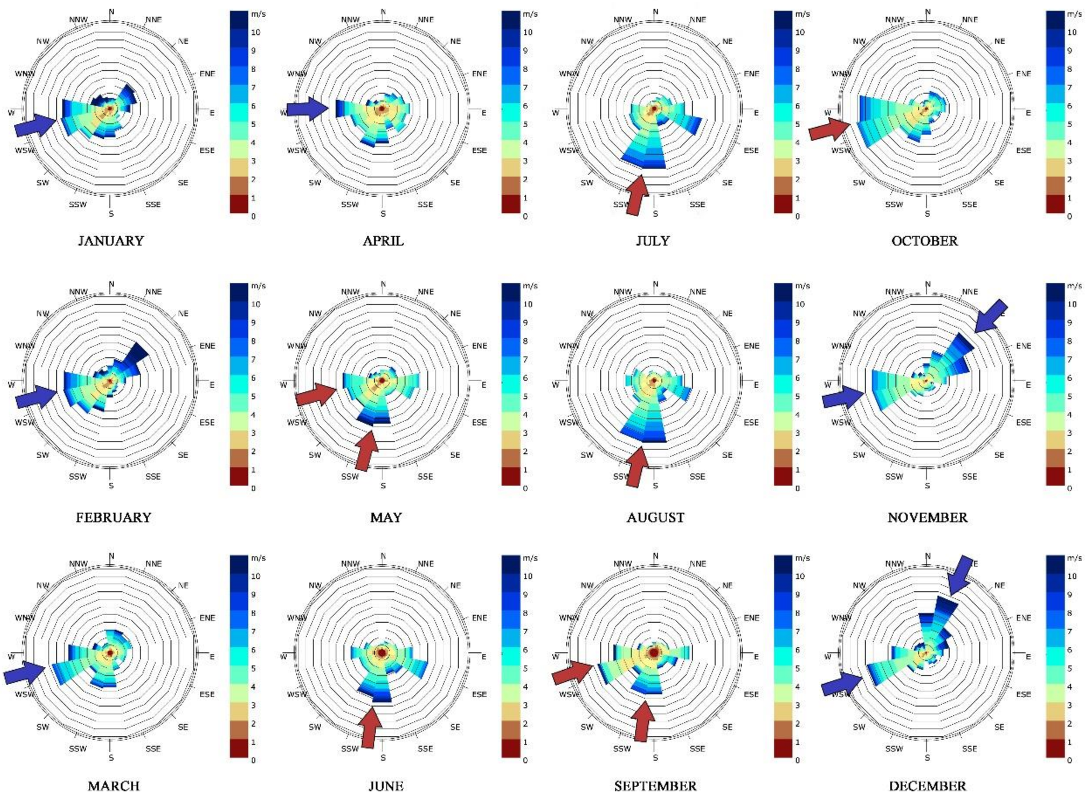


Figure 37: Magusa monthly wind rose (Exported from grasshopper for Magusa and modified by author).

After understanding the general wind and parameters monthly it is time to check the average of the year and also added information from temperature. With this system we can find out that in which time of the year and how long we need to ventilate the outdoor space or even naturally ventilate indoor area. In Figure 38 left side is the yearly average of Magusa wind rose in winter which shows stronger wind with less temperature is directed from west while the right graph represents summer breath from south, south-west and west. Based on this information there will be more successful result if building orientation will be towards south and the west side should have very controlled and careful opening design as far as it will be beneficial during summer with cooler breath but it should clock disturbing cold heavy wind in winter time.

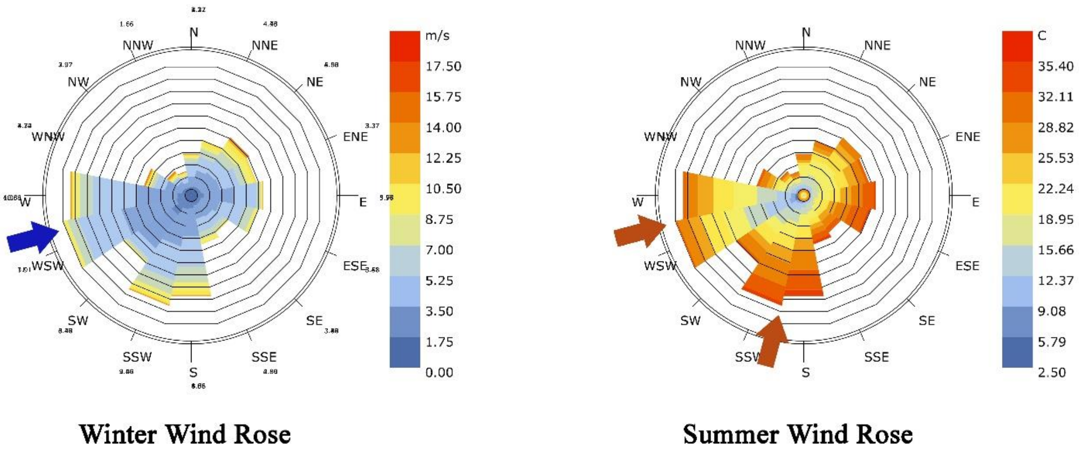


Figure 38: Magusa wind rose for winter and summer (Exported from grasshopper for Magusa and modified by author).

4.2 Stage 2 Defining Design Scenario

Two categories are selected to be simulated in scenario section: new building design in the existing context and new building design with context. Existing building in existing context and urban development are not going to be simulated based on flexible variables which are not matching with thesis limitation and they are suggested for further studies. The detailed information which will create different subset scenarios are going to be explained in coming headings and thermal comfort calculation will be done on each of them in order to test the method.

4.3 Stage 3 Nearby Built Environment Configuration for Selected Case

For testing the formula in nearby built environment configuration, it is important to define the existing context case and also different scenarios for design with context to be able to calculate the wind mask condition. During the process for both categories there will be the simulation run with no nearby built environment and then the context will be added to illustrate the level of change in comparison with existing calculation techniques and following the thesis method. It is important to mention for existing context wind mask estimation the site and surrounding should be defined in other to be able to have the simulation. On the other hand, strategies for design with context is going to be explained and followed in sections below. There will be limitation for pattern selection in order to make the simulations achievable based on the time limit.

4.3.1 New Design in Existing Context

For the existing context simulation author selected walled city of Magusa as the area in order to illustrate the effect of nearby built environment on indoor thermal comfort as far as the walled city is surrounded by manmade wall. Historical settlement located on the south east part of Magusa is selected as attesting neighborhood pattern for the designed formula. Walled city of Magusa is surrounded by manmade wall around the area and it creates unique environment in order to test the effect of built nearby built environment on user’s indoor comfort level based on natural ventilation. In this section detailed information about the walled city of Magusa and history of it is going to be explained in order to get familiar with the testing area (Figure 39).

Figure 39: Walled city of Magusa (Exported from Google earth).

The strongholds of Magusa are a progression of guarded dividers and different fortresses which encompass the city of Magusa in Northern Cyprus. The splitter walls were built by the Lusignan Kingdom of Cyprus in the fourteenth century and finished by the Republic of Venice in the 15th and 17th centuries before the attack of the Ottoman Empire in 1571 (Hill, 2010). This manmade structure hugged the historical settlement and create unique condition which will support the aim of this thesis.

- **Medieval Period**

During the thirteenth century, Magusa's harbor was safeguarded by a pinnacle, and it is conceivable that some type of stronghold existed before. then on the fourteenth century, the Lusignans constructed the Othello Castle to guard the city and port Magusa tumbled to the Genoese in 1373, and in 1489 it was occupied over by the Republic of Venice alongside the remainder of Cyprus (Cypnet, 2019).

- **Venetian Rule**

While Venetian were ruling Magusa, it is possible to call the city as an army base. modernization of the Othello Castle started to be built (Romeartlover, 2019). The military architects designed the strongholds which were structured by various. the Martinengo Bastion design which filled in as a model for different strongholds became as a reference building for many constructions in Europe and America (Walsh, Edbury, & Coureas, 2012).

- **Ottoman Rule to Present Day**

Damaged pieces of the wall fixed by Ottomans, but they didn't make any significant changes. The city started to extend outside in the late Ottoman time frame. after Cyprus fell under British principle and the city began to grow even faster. Numerous nearby built environments inside the old city of Magusa is in a condition of deterioration, the fortresses are still in generally great condition (EARTH Lab, 2008).

The walled city of Magusa is an important, special historically protected location. Since this thesis seeks on the nearby built environment, the impact of surrounding walls beside structures on thermal stability indoors is important. To explain the rationale for selecting a two-story residential building for this study, this settlement follows applicable rules that forbid any building from raising the wall height and most of the community is residential, and this provision has the highest time-counting function for daily living activities. In Figure 40, Listed simulation locations are outlined based on the surrounding volume and the street connections which serve as direction of the wind guidance. The first location will be within the Namik Kamal street stretch of the main city walk path, demonstrating the impact on natural ventilation in combination with low-density surroundings and the second building site is deeper in the historical urban pattern in Yeni Belediye Eclari street. Results of both buildings' mathematical simulations are contrasted with the single building with the same specifications without conditions of nearby built environment.

Figure 40: Introdicing site location in Magusa walled city (Drew by author).

In order to find the air movement changes nearby built environment should be design which can be modeled by any 3-dimensional software and according to the selected program it can import to Rhino. Author decided to have the simplistic design with in the thesis limitation by the grasshopper plugin itself based on information and proportion of the existing pattern. Based on 3D and weather data information related to natural ventilation it is possible to import all to butterfly plugin to have the free run for wind behavior according to the existing condition and accordingly there will be information for wind mask creation as a result and wind changes in the way to the site which new design is going to be applied for it. In order to run the simulation, there is need for virtual wind tunnel as well which should be defined in this step.

The wind tunnel has been defined as 5-meter offset from each side of the model and 12 meters for the extension towards the wind direction to have complete air movement reaction after passing through the neighborhood pattern. also, the wind tunnel created with 5meter offset from the model highest level to have the result in the Z direction as well and the proportion will not have effect on the free run wind situation. The other variables which should be define for the software is the grid system which means for each cell program will calculate the wind speed, direction, and temperature and record the information for further steps. As far as butterfly is running based on tile limit thus, the simulation has been done for 1000-time unit in order to reach the consistent result because for the process the ventilation start from the input slot and continues till it pass from the obstacles designed virtually and will be affected by them. It is possible to have the result directly from software but author used "para view" software for more detailed export data.

4.3.2 Design with Context

At the beginning the pattern for construction from design scenario point of view is going to be discussed means how the vehicle circulation width and direction will be located in the site. As the general step this is the most critical stage as far as the pattern will define the plot size and orientation and linked with the wind mask creation as the result. Architects can act more freely as far as the site dimension gives the opportunity but the responsibility for have optimized passive building design will be higher while the nearby built environment effect should be considered for the calculation as well.

Simulations are going to follow the individual building construction neighborhood patter for this section based on climate condition and how it is possible to improve the level of thermal comfort inside of the building. The pattern is going to be limited by

10 rows (within 10 rows it is possible to estimate the level of success in each scenario and understand what will be the optimized distance if the pattern is going to expand) residential flats and there will be two-way street located in between the building's as the neighborhood vehicle and pedestrian circulation. The model will keep the building dimension as a fix parameter but the height is going to be change based on thesis limitation. In order to show the simulation result and process and make the outcome simpler and more comparable for new construction in existing neighborhood pattern the average of all floors thermal comfort will be considered and for the first simulation the detailed results are going to be presented with various presentation technique.

Models for the simulation have been categories in three different pattern which at the beginning all limited by 2story building and then simulations will be done for 4 story and 10 story. Each category represents different type of residential buildings. Two story is defining villa type construction while four story is low ride residential building. Based on construction regulation in Northern Cyprus more than four story building the elevator in design should be integrated thus, many owners prefer to keep the building height in this range and ten story represent high rise residential block as an average building height. The information will be exported for the second column of each model in order to prepare the base for comparison between all types and buildings will be in proximity with street. Also, it is needed to mention in each simulation, each floor has been simulated separately based on the month and the average of them will be calculated. In Figure 41 these patterns are shown and clarified based on each scenario the calculation process will be followed to find the optimized result for each one. Before going into simulation details, explanation for each pattern is needed. above three main patterns as a base for all separated building neighborhood is shown. From left to right they are going to be numbered, pattern A, pattern B, and pattern C.

- **Pattern A**

This pattern is following the existing condition for buildings in Northern Cyprus. There is two-way street at the middle and building has 3-meter offset from the site boundary. In the model we have 10 sets of rows and street location is shown by the arrow. After 10nth row the site is considered finished while it is possible to expand the model as larger design according to site limitation. Distance between building and street dimension is going to be defined after following optimization process.

- **Pattern B**

After analyzing the existing condition, new urban strategy is going to be tested. In this model after each construction area, breathing section with greens and landscape is located. The aim of pattern B is understanding the percentage changes if the distance between buildings are going to be increased.

- **Pattern C**

In third design strategy, areas are located as a zigzag connection from the beginning till the end of model. It means instead of complete connected green zone; it has been given to each building from the side. Also, there is distance difference between sites but at the same time it will illustrate the effect of pattern change on indoor thermal comfort percentage by only considering the natural ventilation.

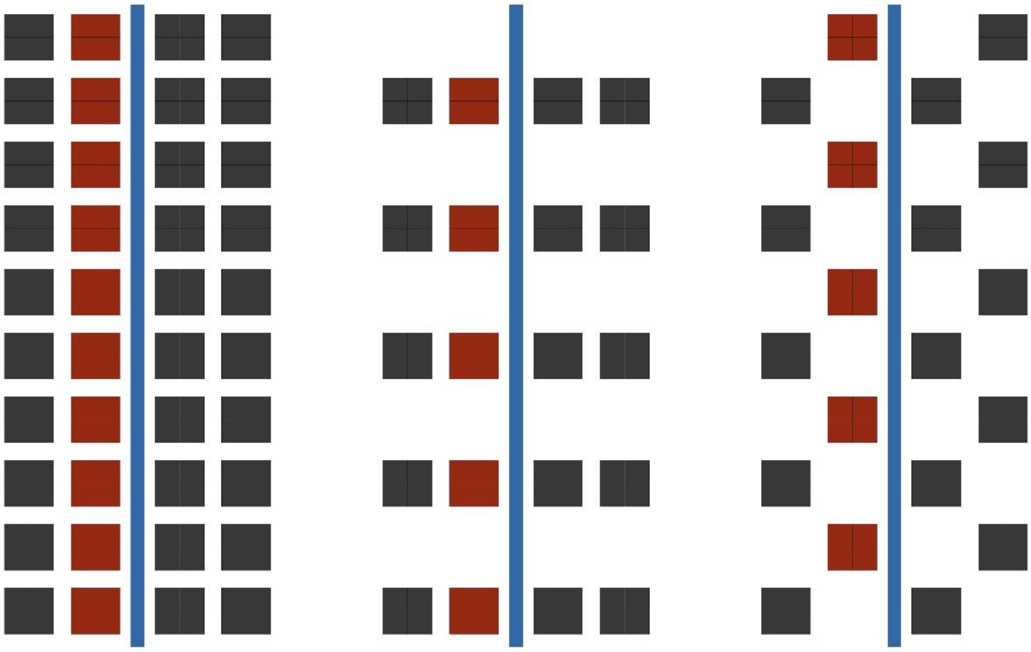


Figure 41: Neighborhood patterns. Order from the left: Pattern A, Pattern B and pattern C (Designed by author).

4.4 Stage 4 Building Design Configuration

As the first step in building configuration it is important to analyze the project based on construction regulation after considering function (in this thesis residential) and occupation (adult person for daily stay at home). The simulation model was created based on the Northern Cyprus construction regulation. Building proportion defined as 17 m and 16 m. 3.5 m has been considered for floor height, as the rectangular building shape. Cross-ventilation windows designed in accordance with the opening rule usually indicate that they will cover at least 5% of the floor area in square meters, that is to say 20% of the floor area based on the model built in Z direction. 100% openable windows will be considered during the simulation. For building orientation 0, 45, and 90-degree angle from prevailing wind have been selected for simulations. Then, the entire opening percentage in each facade is built as three windows. The separation distance is 1.3 m offset from the ceiling and 1 m offset from the floor will be the window definition with the overall height of 1.2m.

Also, it is important to study the wind behavior inside of the building. As far as there will be empty flat with thus, there is no barrier to change the wind behavior. So, there is very simple cross ventilation style air flow between two windows. In further study section the future of this section is explained that there will be a need of time and simulation which is not fitting in the thesis limitation and time table. In this example the front surface is straight open with no division and it contain twenty percent of the floor surface. Height of the floor is considered four meter and the building dimension is seventeen by sixteen meters. The reason behind the dimension is to show the general wind behavior. In Figure 42 the bottom part of the picture is inlet which the wind will enter to the building and the top part is the exit which creates the cross-ventilation effect. It is important to mention this system is the best-case scenario while the other types of natural ventilation systems will have lower percentage as the overall outcome. Thus, the simulations should be done based on each design and the selected method for natural ventilation system.

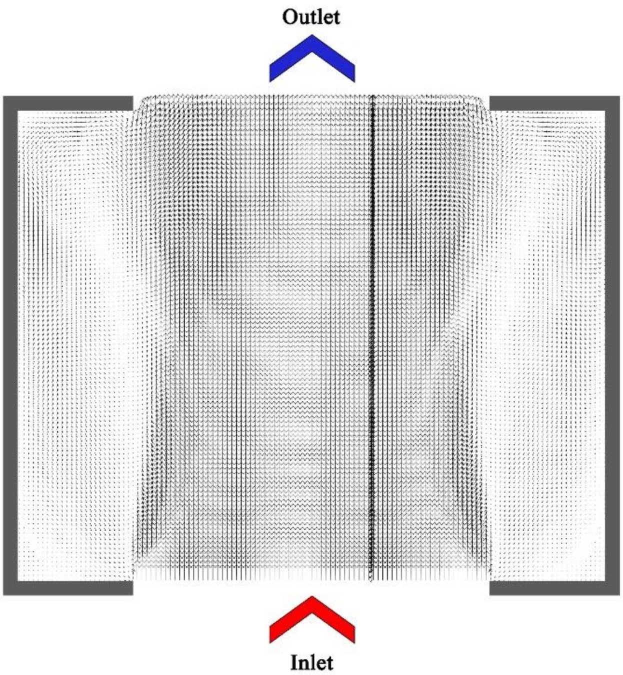


Figure 42: Indoor air flow for cross ventilation (Exported from grasshopper butterfly).

4.5 Stage 5 Calculation Technique for Selected Case

As far as building proportion is going to be defined from the site boundaries, the simulation location has been decided with identical dimension to have same building for further comparisons in the key formula is attached to the Honeybee background segment, surface parameters which reflect the other buildings in the neighborhood. This set will describe the program as an immediate environment with a windbreak effect. To provide accurate details, an hourly time stage is chosen for the simulation output. This ensures that the prevailing wind is in a different direction for each month but eventually the result would be the same with different angles. Energy Plus calculates the whole set as a supporting software connection to Grasshopper Honeybee during this section. The generic data imported from the climate data file is used as a basis for approximating the equation. The observations for all situations will be obtained from the complex statistical models.

In the following section the process of computing simulation will be explained and also detailed introduction of used software for this study will define. The main reasons behind selecting this specific software are need of open source system and the support it has from well-known international energy calculation companies with accepted algorithm for energy calculation. Also, it is important to mention this software will create the opportunity to have design by ant program and import it to the software. Figure 43 software explanation will be explained in Appendix 1.

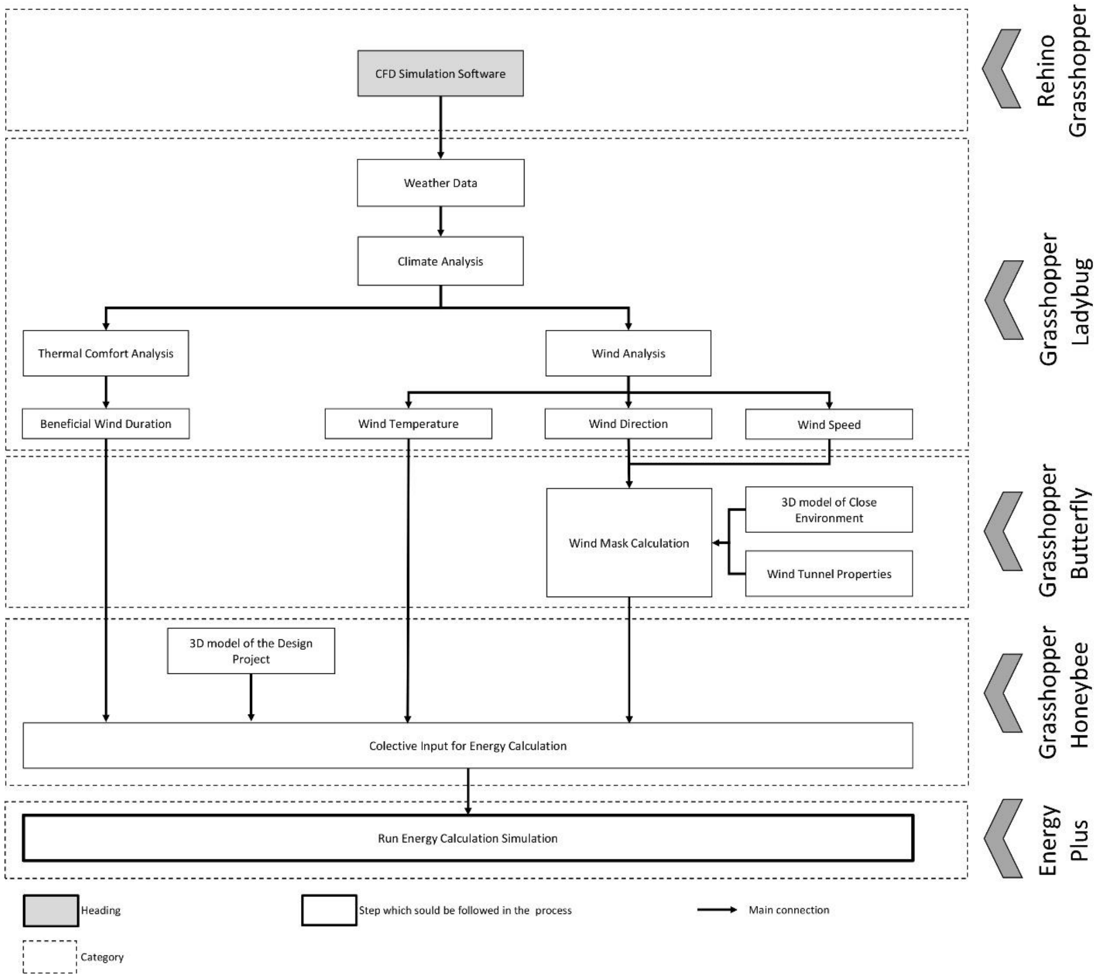


Figure 43: Energy calculation process (Designed by author).

In each simulation floors are been separated for each level to have individual height result. Window opening is possible when (each number is Celsius) minimum indoor temperature > 21, maximum indoor temperature < 30, minimum outdoor temperature > 15, and maximum outdoor temperature < 30. Simulations are done by Energy plus software as a supportive engine and Results are done based on sitting as an activity for metabolic rate. One factor which should be highlighted before running simulation which is possible to increase or decrees the clothing. Within the process the relative humidity defined as 0.012 as the higher limit based on ASHRAE standard which defines upper number will not fill comfortable even if the temperatures will be in acceptable level. On the other hand, for personal factors the clothing level is changing between hot season and cold season. during the summer clothing defined as 0.6 which means light two-piece clothing and in winter it is 1 which stand for three-piece clothing in order to create more realistic condition for users. metabolic rate which is directly define by the user activity for all simulation set for sifting position in all simulations and for wellbeing the healthy condition for adult has been defined.

4.6 Stage 6 Thermal Comfort Analysis Outputs

Running the simulation will gather numerical result as an outcome and this information will be used as input for thermal comfort realization based on natural ventilation and also these data might be used for other thermal comfort calculations. As far as this study is focusing on natural ventilation, for indoor thermal condition during the year we are going to use values from air flow volume, relative humidity, and air heat gain. Based on these numbers it is possible to understand how the wind is going to be affected by the nearby built environment and simulation setting for each scenario. Also, it is important to see the level of heat lost and heat gain based on natural ventilation which is directly change the thermal feel for the user.

4.7 Stage 7 Evaluation of Thermal Comfort Results Based on Nearby Built Environment from Natural Ventilation Point of View for Selected Case

Following the calculation outcome, it is time to check each category scenario selection based on indoor thermal comfort level. As the first section the new design in existing context is going to be study in the walled city of Magusa in two different location. The free run building result also will be compared with each condition and the optimized condition for each site based on simulation result and building orientation in the site will be decided. Then the process will apply to new project with context according to categories which are explained and find out what are the most effective factors to make the decision for design project and how much it will have effect on the indoor thermal comfort level. Results are going to be detailed for comparison and for the first category they will be presented. The larger graphs are going to be added into appendix for more clear evaluation in any case, but the rest of results are going to be summarized and last outcomes will be presented.

4.7.1 New Building Design in Existing Context According to Selected Case

Results have been exported after simulations and gathered in charts for easy understanding. The horizontal bar represents the months of the year in Figures and the vertical bar shows the percentage of thermal comfort within each month. Color codes will show different building results for making the comparison easier. In the sections below different results according to the building orientation are explained. Building angles are defined according to the prevailing wind for the selected case. In each section preliminary comparison will be done and after all information gathered the main comparison for each case is going to be analyzed. Based on the last comparison the optimized design for each site will be illustrated. The same process should apply for design process with unique scenarios and conditions to improve the level of success in passive building design.

- **Result for Zero-Degree Angle**

Outcome produces the data for simulation while free run model illustrated by blue line indicating that the weather data information was inserted into the simulation without a nearby built environment effect on natural ventilation. During this process it is clear that the average internal temperature in the neighborhood pattern of surrounding buildings that covers the comfort zone is higher than that of the other contexts. The orange line represents the outcome of the first building on the Magusa walled town's main path with a more open area surrounding nearby built environment, which has a lower thermal percentage than the individual building simulation. The gray line at the end shows the higher density second apartment, deep within the neighborhood.

The percentage is close to nothing during January, February, August and December. The explanation for this is that the windows will automatically close when the ambient temperature is out of the maximum range, ensuring there will be no natural ventilation during these times. This occurs mostly during the winter, when the weather outside is very cold, and due to high temperatures in the middle of the summer. In addition, the percentage during March and July are below 10 percent and the HVAC system will be required in that period. In April, the free run model achieves higher than 10%, but according to user satisfaction, the virtual models with nearby built environment are still below 10%. Low percentage during summer affected by high level of humidity which will be considered out of comfort boundaries, means exceeds 0.012 according to the ASHRAE guidelines, even though the temperature is within the correct range (Figure 44).

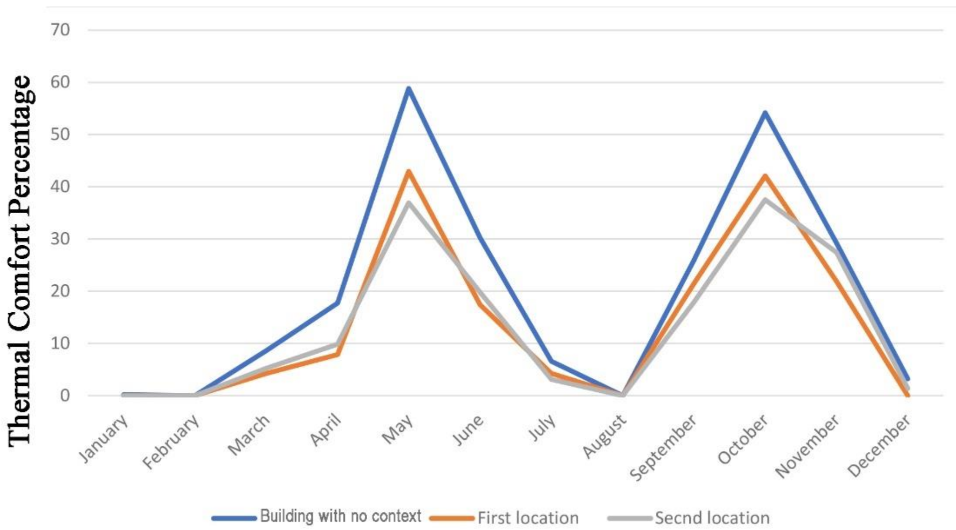


Figure 44: 0-degree oriented building witought surounding and different locations with close built environment thermal comfort percentage comparison chart (Summeried from Energy Plus calculation results).

Regards to hourly measured thermal comfort percentage for all scenarios, the average of free run example with no surroundings measurements is 19.56% as a yearly average. First place is followed at 13.51% with a wide-open field. It suggests that the wall constructed around the ancient settlement itself affects the movement of air, and the only route for the breeze appears to be from the top of the wall and three main gates for the passage to the fortification. The third construction site reveals an even lower level of indoor thermal comfort, 13.02 percent year-round (Figure 45).

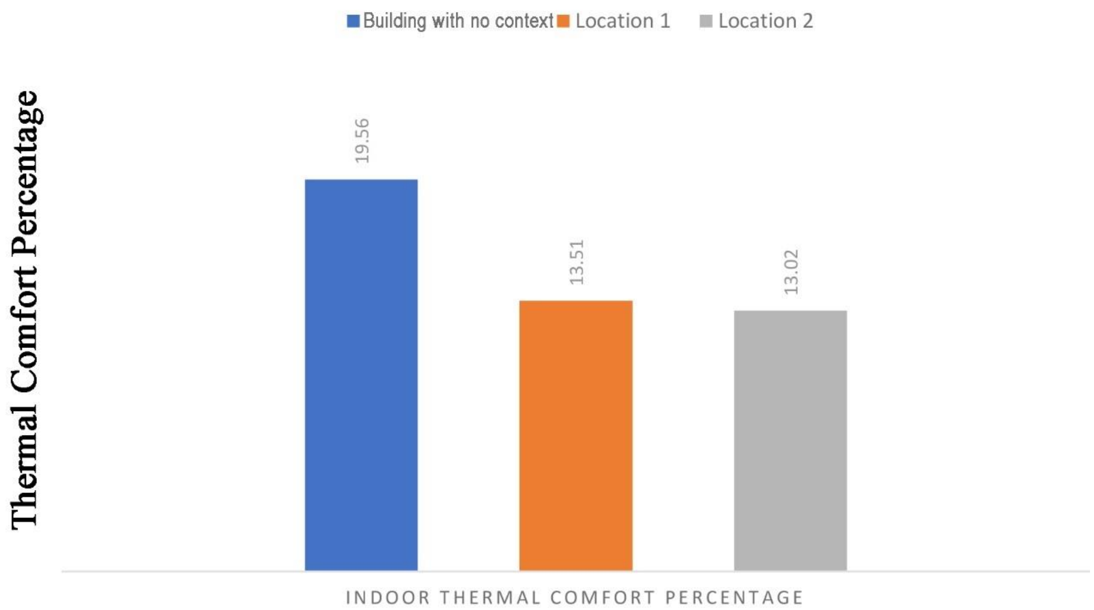


Figure 45: Yearly building thermal comfort percentage comparison (Arfaei & Hancer, 2019).

❖ **Result for 45 and 90-Degree Angle**

The same process happened for other orientations according to prevailing wind as well in order to gather the information for the conclusion and final comparison. Figure 46 represent the graphical expression of the outcome based on different angles and showing the differences within the design process.

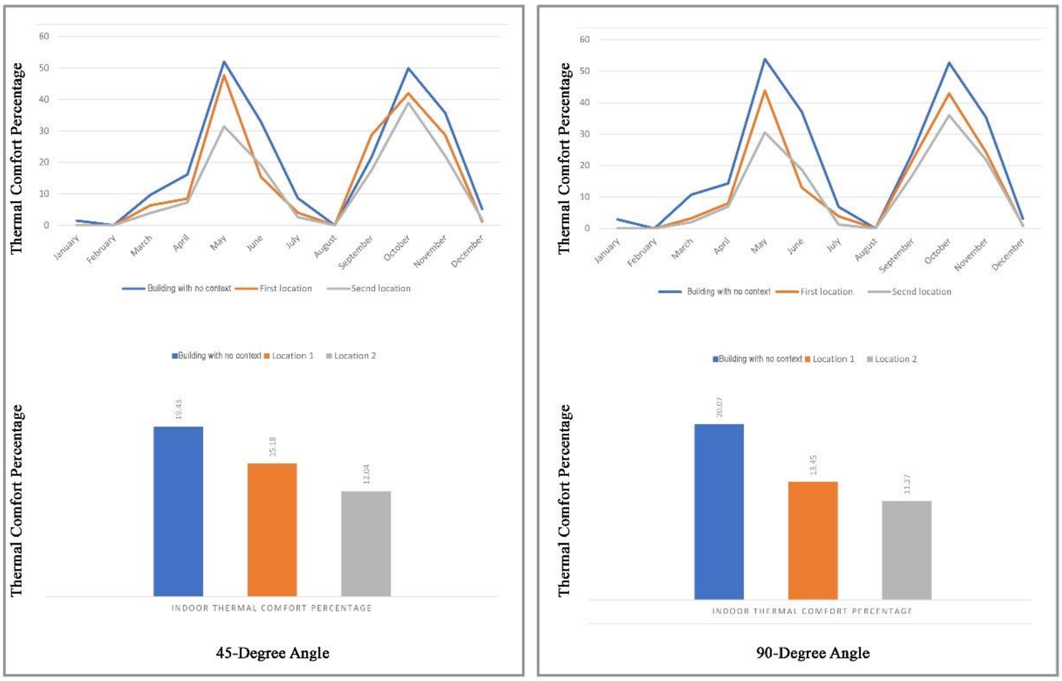


Figure 46: Existing context simulation result for 45-degree and 90-degree angles (Summeried from Energy Plus calculation results).

- ❖ **Optimized Result**

Following the findings, it is clear that the percentage of thermal comfort for the single building without a closed area is higher than for the buildings in the current system that are influenced by the local environment. The percentage is measured only on the basis of natural ventilation, and it became apparent that a decrease in thermal comfort of about 6.05 percent occurred when contrasting the simulation of free run building and the first neighborhood building with a nearby built environment. If the first construction site is substituted by the second, which is further in the area, this difference rises to 6.54 percent. Such percentage variations will be protected by mechanical indoor HVAC systems, meaning that the energy usage in the passive building design phase may vary and can surpass the appropriate limits. Thus, in calculating energy standards, consideration should be given to the effect of the nearby built environment on natural energy ventilation calculations.

For the building in the first site location 45-degree angle with 15.18% is the optimized result and for second site 0-degree angle with 13.27% is more promising. In Figure 47 both selected scenarios for each site highlighted by purple color in order to differentiate it from other building orientations. These results proved the difference between calculation with nearby built environment consideration and free run and on the other hand, for the same building condition just with different locations also there will be other affective factors which define the optimized result for each scenario in building design process for existing context.

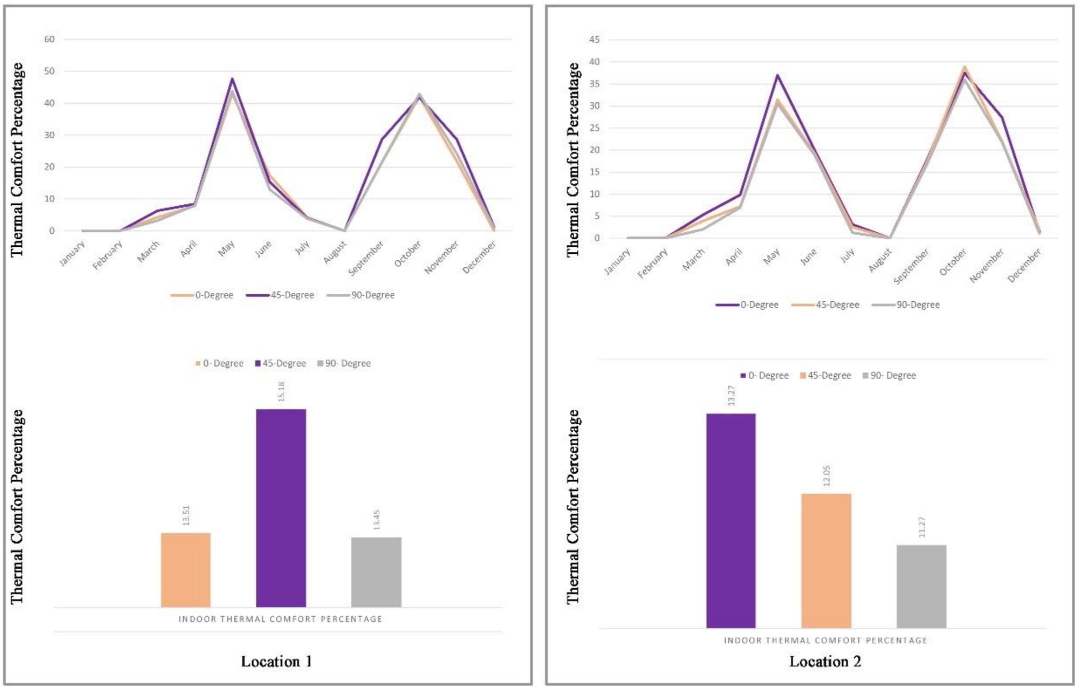


Figure 47: Optimized result for each location (Summeried from Energy Plus calculation results).

4.7.2 Design with Context According to Magusa Condition

At the beginning the 2-story building simulations are going to be presented and will follow by 4-story building simulation and complete by 10-story building condition for all different selected patterns. During pattern A the wind mask effect and optimized distance between buildings and design orientation will be presented graphically in order to clarify which type of information will be possible to export from the simulation software. Graphical presentation will be helpful for better understanding and sharing with other colleagues, thus for further projects there is no need to go through all complicated process and formulas in order to simplify the steps and reach the outcome faster. This process will be possible specially for architects and companies which they are working in the same climatic condition otherwise the first and most important variable will be changed and all steps should be followed.

4.7.2.1 Optimized Street Direction Towards Prevailing Wind and Wind Mask Creation

Design orientation towards prevailing wind also creates different wind mask area. According to wind mask the air input to the building is going to be different thus the result for indoor thermal comfort will be affected. In Figure 48 three different angles which are defined in the thesis limitation are going to be presented and illustrate the change on wind mask according to the complex orientation towards prevailing wind. It is clear the 0-degree wind mask is the minimum which created the opportunity to have more benefit from natural ventilation in this scenario. According to this result the optimized calculation outcome will be covered by the selected orientation which will be 0-degree. For having solid response to designed scenario, it is important to find the opening direction to have maximum cross ventilation effect for indoor environment in order to calculate changes in user thermal comfort condition.

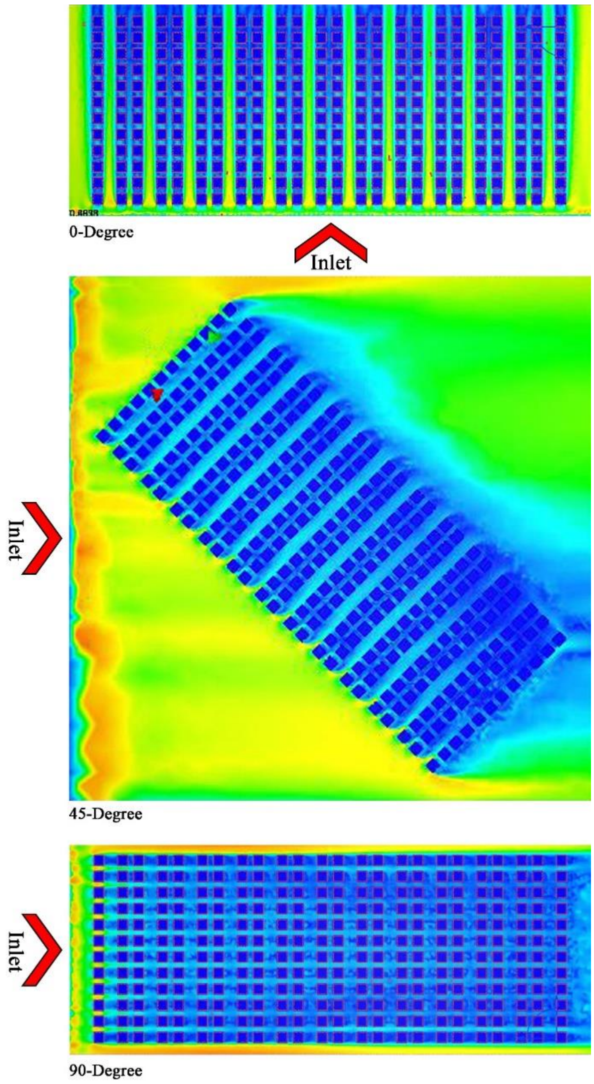


Figure 48: Wind mask shape based on design orientation towards prevailing wind (Visualized by Autodesk CFD).

4.7.2.2 Optimized Building Orientation in Site According to Context Angle with Prevailing Wind

For different angle towards prevailing wind, the optimized building orientation and distance between each row has been calculated, to show which scenario has better result for this pattern. As the overall outcome comparison, the 0-degree angle is more promising than other orientations as far as the model will provide higher possibility to achieve indoor thermal comfort. The optimized option for 0-degree angle is if the building distance extend to12 meters and the window opening locate towards the street

(270-degree rotation) while in 45-degree and 90-degree angle 10 meters distance with 184 to186 degree rotation will give the maximum percentage (Figure 49). In all simulations, building height is considered same for all locations for simplifying the result.

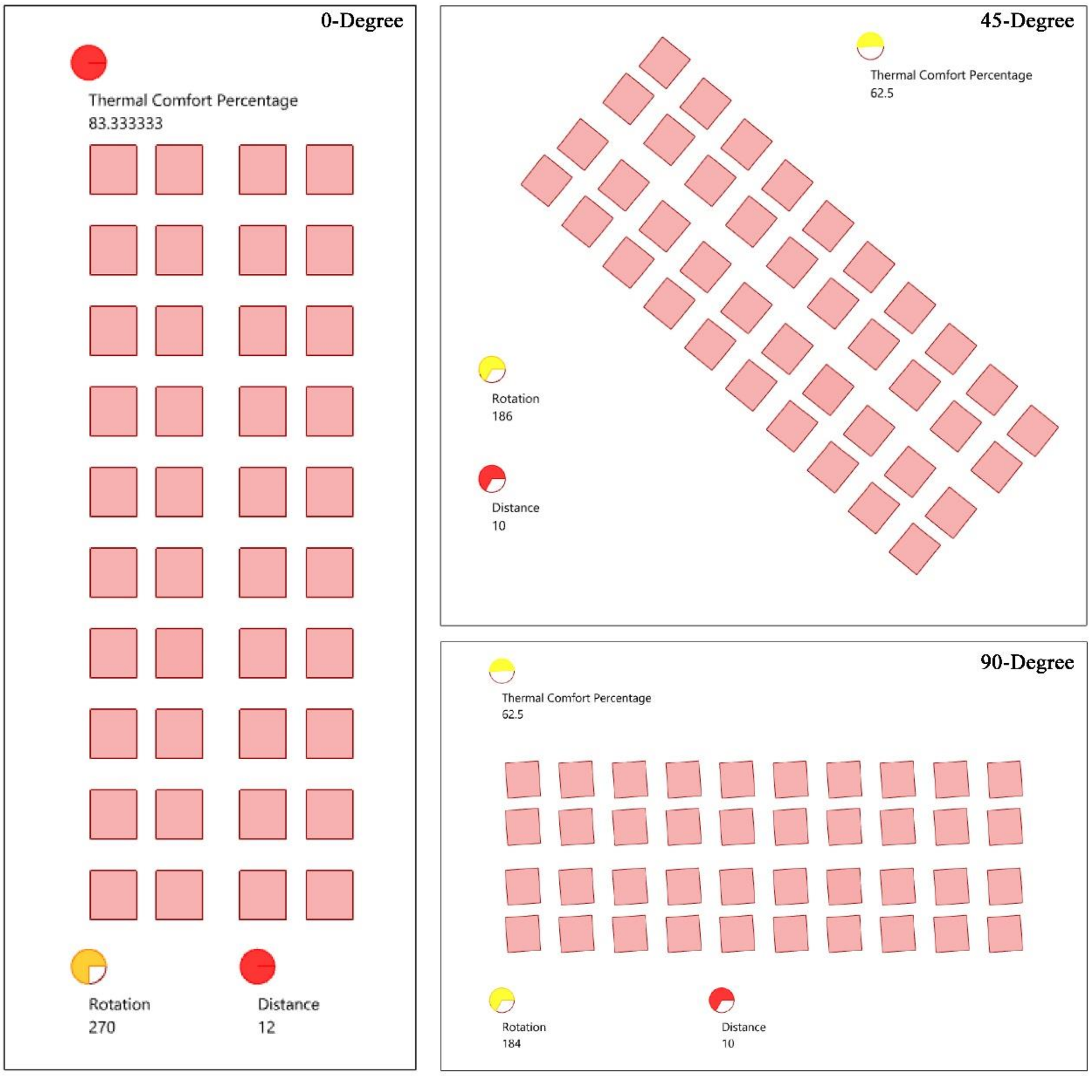


Figure 49: Optimized distance and orientation based on angle from prevailing wind (Visualized by grasshopper honeybee).

Based on discussion in this section, the optimized orientation between prevailing wind and designed context is clear also, distance between buildings and optimized window location for having best cross ventilation effect is concluded. Based on this information the rest of scenarios and simulations will be followed. As it is presented in Figure 50 as an example of 4story building, detailed calculation result for all rows in the pattern is exported and presented with different colour code based on the thermal coverage percentage during the year. These types of graphics will be helpful for architects to understand the condition based on context design and improve their design accordingly to achieve optimum result, but in this thesis the general average of all building is going to be calculated and consider during comparison. The important factor is overall thermal comfort as far as the unit percentage is changing according to the location and height, so it is not logical to have the analysis based on each floor outcome. Percentages in figure below are defined based on simulation results exported from energy plus calculation.

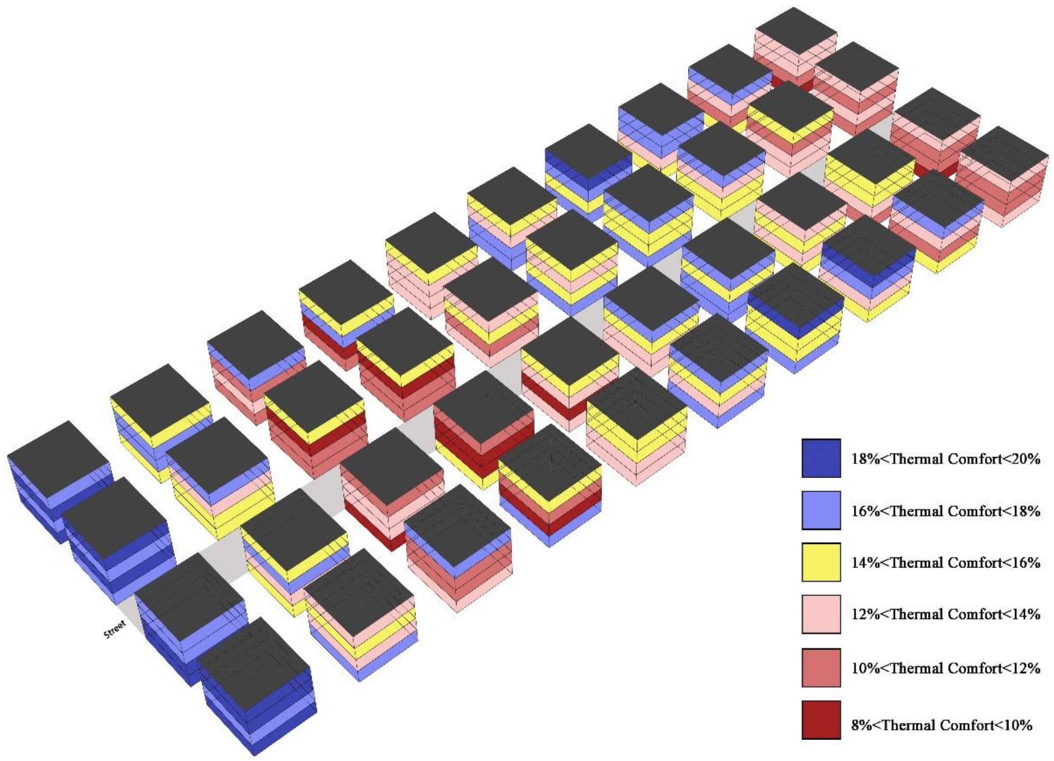


Figure 50: Separated detailed indoor thermal comfort percentage based on context design and building location (Designed by author based on Energy Plus calculation results).

4.7.2.3 Pattern A: Building Relation Based on Selected Case Plot Dimension

The first pattern is design following description in previous section distance between buildings. As far as the modern city planning is reputative system, so it is possible to expand the model from sides but there should be the public circulation in-between if the model is going to be extended from the length. The reason behind the second-row selection is the building is going to be affected from both surroundings. Figure 51 is representing the model which used in the simulation.

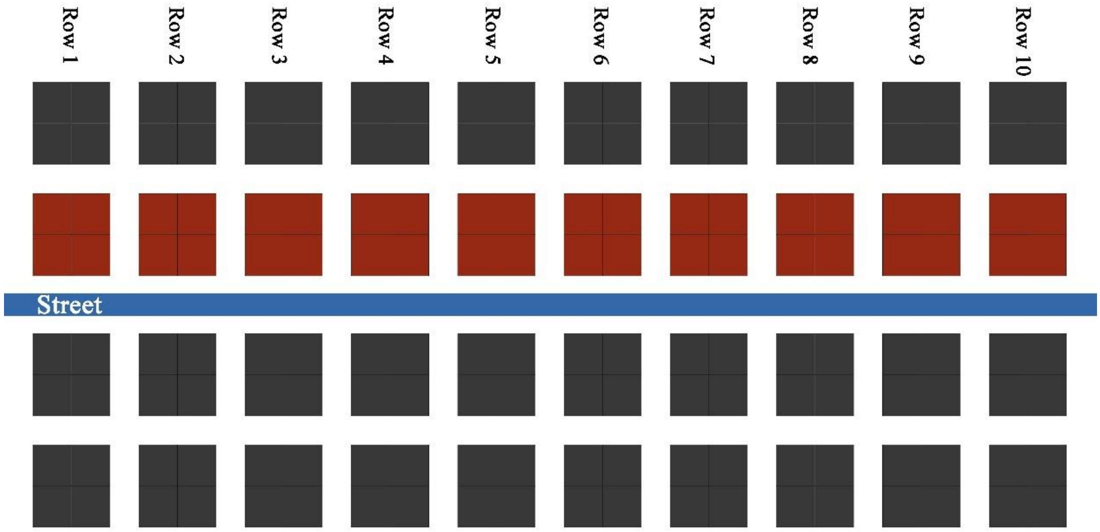


Figure 51: Model designed for pattern A (Designed by author).

- ❖ **2 Story Height**

For pattern A scenario for 2 story height all steps for outcomes will be presented in different graphs in order to clear the systematic result and evaluation system based on various focuses like monthly, monthly average, or yearly comparison, also the results calculated for each floor separately to have more clear understanding for indoor thermal comfort based on the residential unit location in the Z direction which represent the height. But for the rest the last result is going to be presented as the summary of the process. For each scenario the same system has been followed. At the end the average percentage is going to be counted in order to finding the common ground with similarities to make the comparison possible.

In the first row it is clear that during the year there are 3 months (January, February, and August) which the thermal comfort percentages are close to 0 as an average. The reason behind this result is either these months are cold or very hot days. Thus, the outdoor temperature is out of the explained boundaries for the simulation. In that case software will consider the windows closed which makes the natural ventilation impossible. During March, July and December the average of thermal comfort is very low which in both these sections with insolation and sun direction the average will be different but as far as these factors are illuminated from the simulation, we can find less than 10% of the month in thermal comfort zone. During April, June, September, and November thermal comfort percentage rise up to 30% in the month and the most comfortable month are May and October which we have higher level of indoor comfort between 60 to 70 percent. The first row is more similar to free run building with no nearby built environment from windward direction as far as there is no barrier Infront of it but it has been affected from units located on the sides and leeward direction pressure difference according to surrounding.

During the year for the second row we can see the small reduction in thermal comfort percentage in most of the month but during May and October we have higher average for the thermal comfort specially in second floor. The reason behind this increase is the third-dimension effect on the wind behavior after reaching the first row of the neighborhood. We will be able to see the higher floor thermal level is increasing mostly because of the wind direction changes in section and also the speed increase. Based on wind mask effect also the pressure at the back of the building in higher levels decrease and make the cross-ventilation process faster. In the third row all percentages during the year is going down. These buildings started to get the effect from the wind behavior changes more than the previous. Mainly from here architects and urban designer should have strategies based on natural ventilation effect from nearby built environment. It is possible to see the surroundings began to have more dramatic effect on the indoor feeling thermal comfort level. In the fort row the eye-catching change is belongs to October which both floors and average of them is reaching 50% thermal comfort. After the fourth row again the percentage for October will start going up which can be the pick pint of natural ventilation behavior change towards positive effect on month October. It is not possible to generalize all the data based on one-month result changing but we shouldn't pass through this fact lightly. As it is mentioned previously October comfort level start going up again from fifth row. But on the other hand, December comfort percent is reducing almost to zero in this location.

From the sixth row December level is going to be exact zero and illuminate from the low percentage months till row 8 which again slowly start to have very low level of thermal comfort in December. Generally during December, we are not going to have any percentage above 5 in the year. There are not many differences between sixth and seventh row as a general feeling thermal comfort. So, we can say between fourth to seventh row is the main area which we are going to have the maximum effect from the natural ventilation in building. After the seventh row the data shows comfort is begin to go back to towards the higher comfort level. It is important to mention that it will never reach the same number but it will start to make the gap smaller. From the eighth row the level of thermal comfort is starting to rise up again. The highlight of the ninth row is same as the second row the indoor feeling thermal comfort on the second floor is going to be more that the seventy percent again. During the year based on simulation model only in mentioned building locations we are going to see this level of comfort. At the end of the neighborhood model we have the result which almost identical to the third row only with the December percent reduce to zero again. It is possible to mention in this stage that the wind behavior is acting as sinus shape in mathematics for each row. It is starting strong from the first wind contact to the building which is close to the individual simulation following the energy standards and then thermal comfort percentage begin to reduced till fifth and sixth row and ageing go up. This effect is repeating itself for the whole separated pattern neighborhood even with changed distance, design change or even the height differences.

In Figure 52 each row result has been gathered for each floor separately and the average which represent the building thermal comfort has been presented as well. In each graph the Y direction represent the percentage of thermal comfort and X direction shows month of the year. First floor result brought to graph with blue colour while orange represent second floor and gray is the 2-story building as an average between 2 floors and is the main result which will be considered in further comparisons as far as the aim is finding the thermal comfort percentage and time for the building. Other important factor here to mention is the result exported based on square meter calculation for floors and for the average accordingly (larger Figures are in Appendix for more detail).

Figure 52: Monthly result based on the row number for free run building, first floor, and second floor in 2-storu building example for pattern A (Exported from grasshopper based on energy plus calculation).

- ❖ **Pattern A First Floor Monthly Comparison**

In order to make the comparison possible we need to have the data for all simulations next to each other. In further Figures; each month thermal comfort level differences based on the outcome is going to be presented. thus, process will follow by discussion and comparison section will take place in the next chapter. In the first-floor result it is possible to see the difference between the first-row simulation and the change level with the other steps in the neighborhood pattern. In some cases, we can see even the further layer is going to achieve the higher thermal comfort percentage specially on October which the most dominant one. This shows the wind behavior changes is going to have both negative and positive effect on indoor conditions. But it makes the fact clear we have to follow the natural ventilation path in order to have better estimation and calculation for passive building design. The result is comparable in Figure above but it is difficult to understand and outcome clearly because of many variables shown. Thus, the second way of presenting data is designed to simplify the data for comparison. In the following Figure merged information based on the month is shown which means during the year which month is going to have maximum percentage of thermal comfort in the hole neighborhood pattern with two story building and on the other hand which ones are going to be the minimum.

After this discussion we can see October is the most comfortable month following by May and June. During the year January, February and August are going to be counted as zero because of the outdoor temperature is not in the formula range that’s why the window will be considered close during these periods which makes the natural ventilation impossible. Also, December is shown as zero because of the very low comfort percentage in comparison with other months.

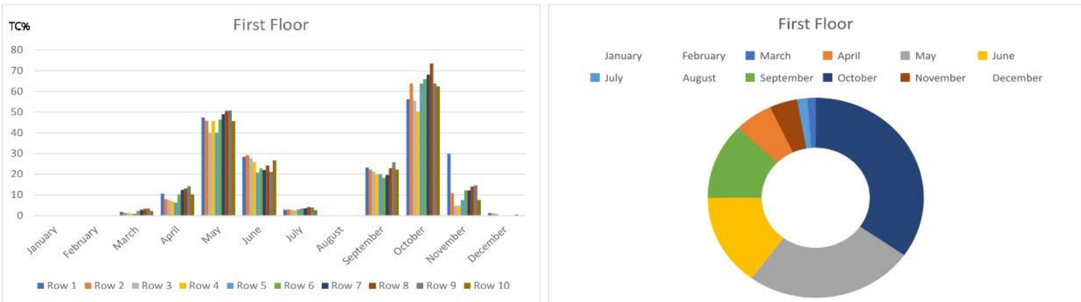


Figure 53: Pattern A, all rows in month, first floor (Exported from grasshopper based on energy plus calculation).

- ❖ **Pattern A Second Floor Monthly**

Same as the first-floor process, the second floor also is going to follow the same path. The main difference realized in-between first and second floor is the changes during the May which is dramatically raised and October which seems to be much lower that the first-floor result. This happens because the third dimension of the wind circulation is going to affect the higher floor more than the first floor. Both it is possible to have the air flow coming from above or based on wind direction change it might be blocked and we are going to experience less speed for the air entering to the level. In the second-floor result as it is mentioned above the most comfortable month is going to be May following by October, June, November, and April. It is clear to find the changes which are happened in September, April, and November in comparison with the first floor. Now it is time to check the average and find out which building is going to have the highest thermal comfort percentage and location of it (Figure 54).

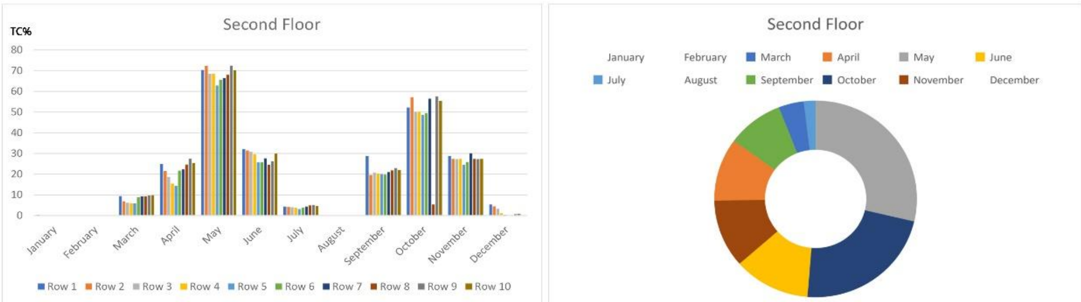
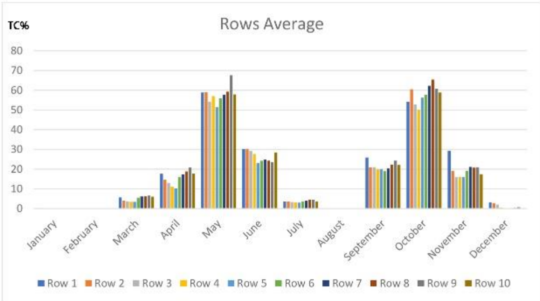


Figure 54: Pattern A, all rows in month, second floor(Exported from grasshopper based on energy plus calculation).

- ❖ **Pattern A 2-Story Building Monthly**

As it is expected the average of both May and October is so close to each other in the first model simulation result. Also, it is clear the average thermal comfort percentage has less difference according to the location in comparison with each floor separately. Normally in Turkish Republic of Northern Cyprus villa design in two story both are belongs to the same building. So, the average is going to be more pleasant that the middle ground outcomes for the buildings which they have different owners for each floor. That means the benefit of the natural ventilation for two story building design as a villa might be even more when there is the interior air wall which makes the flow between two floors. In the merged chart the final average of each month thermal comfort percentage is concluded for two story villas. It is starting from higher to lowest as October, May, June, September, April, November, March, and July. Obviously, January, February, August, and December are going to be counted as not suitable periods for naturally ventilated zone. The reason has been explained in the section above already (Figure 55).



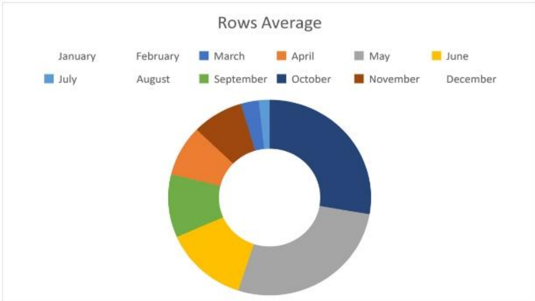


Figure 55: Pattern A, all rows in month, average (Exported from grasshopper based on energy plus calculation).

❖ **Pattern A Yearly Average**

In this step we have complete data exported from the simulation software based on thermal comfort percentages but author need to have the summary data in order to make the comparison possible. Thus, all information from detailed analysis in two story building are gathered in the Figure below as a simple linier graph. Also, it is possible to understand all complete comments during each floor analysis. Each floor percentage is shown separately and the average is taken as well. It is possible to follow the thermal comfort reduction from the beginning till the end of the simulation model. Around the fifth row the wind behavior is going to change and start rising till the ninth row. Thus, this result brings the limitation for the mentioned neighborhood pattern into the awareness. This section will be discussed more carefully in the conclusion section.

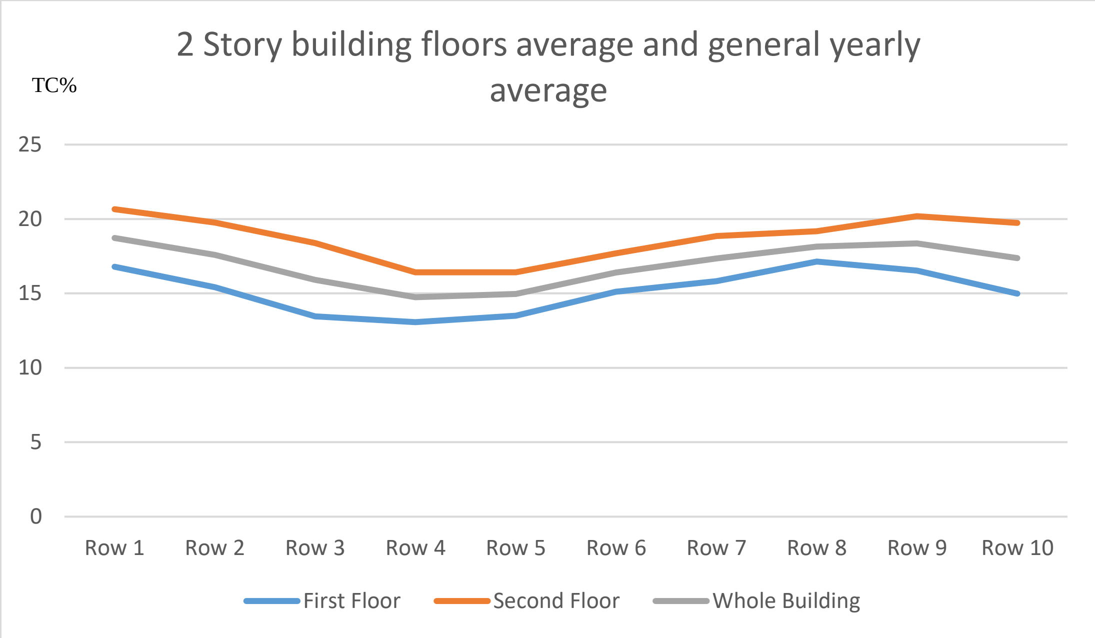


Figure 56: Pattern A, yearly average 2-story building (Exported from grasshopper based on energy plus calculation).

From this point forward the detailed Figures are provided but attached to the thesis as an appendix. The analyzing system will be the same as the first case. Thus, we will go directly to the linear graph which shows the general information about each case to save time and make the process simpler.

- **4 Story Building**

The same process has been done for 4 story building. The thermal comfort percentages collected from the simulation result for each floor and then the average has been calculated for each month of the year and the yearly graph visualized in order to make the comparison possible. Each floor calculation Illustrate different reaction to the indoor thermal comfort based on natural ventilation with nearby built environment consideration but in order to prepare the general result for comparison Figure 57 has been developed. The important point which is possible to extract from yearly average is there is a dramatic reduction on thermal comfort percentage till fourth row and then the percentage start rising again while in 2 story building design we are facing much smoother curve for thermal comfort level. In this case increasing the distance between rows might be the solution for optimization process.

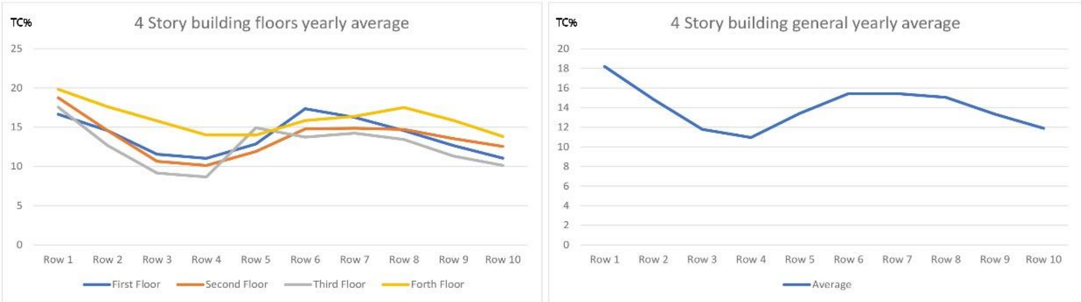


Figure 57: Pattern A, 4-story building floor by floor and complete building thermal comfort level (Exported from grasshopper based on energy plus calculation).

❖ **10 Story Building**

Based on comparison between floors after sixth floor the level of thermal comfort increases and the last floor has the best result. The reason behind is the air movement effect from the top in the calculation process. The yearly average exposed in Figure 58 illustrate the rise after fifth row which might be proper location for having the cross-vehicle street in order to have increase the thermal comfort level for deeper units. Also, the distance between building should be increased and examined to reach optimized result for 10 story building in pattern A.

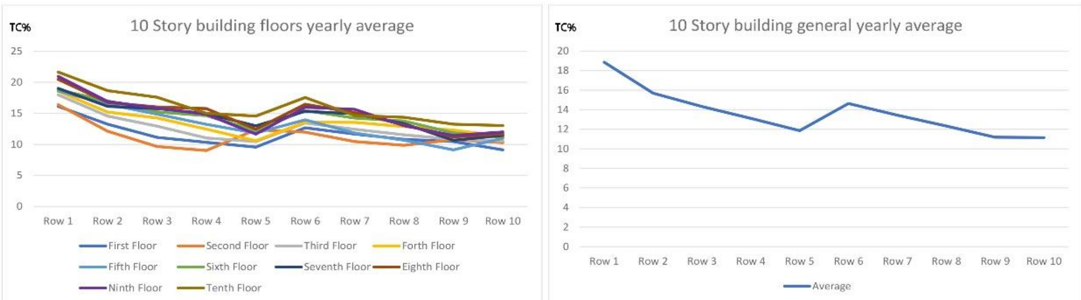


Figure 58: Pattern A, 10-story building floor by floor and complete building thermal comfort level (Exported from grasshopper based on energy plus calculation).

- **Pattern A Comparison**

In this stage it is possible to gather the general yearly average data from all simulations for neighborhoods with different floor heights in one simple chart which shows the difference between thermal comfort percentages between them. Figure 59 illustrate the fact that the same plot size and floor differences decrease the level of indoor user thermal comfort. Both information based on building location in pattern and building yearly thermal comfort have been presented. As an overall view two-story building is covering more time of the year following by four-story building design covers wider time range for indoor thermal comfort but between four story and ten-story building design there is not much differences. The other important fact in first pattern is in between fifth and sixth row the wind behavior has increasing effect in all floor's simulations. This information will be helpful for the finding the more convenient location for cross circulation network and how far there should be street location.

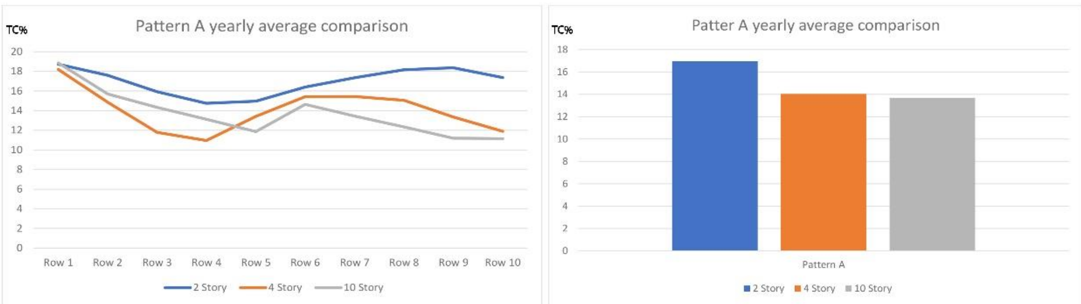


Figure 59: Pattern A, Thermal comfort for each row and yearly average (Exported from grasshopper based on energy plus calculation).

4.7.2.4 Pattern B: Building Relation Based on Selected Case Plot Dimension with Common Landscape Zones in Between

The second pattern is design in order to have more distance between buildings. As far as keeping the proportion will create comparison ground between different scenarios, the even rows are given to the neighborhood green and landscape area which means the distance between rows are double in this example. Same as first category the second row has been selected for simulation calculation to have the maximum effect from nearby built environment. The plan of the second patter is shown in the Figure below and the arrow is representing the street location.

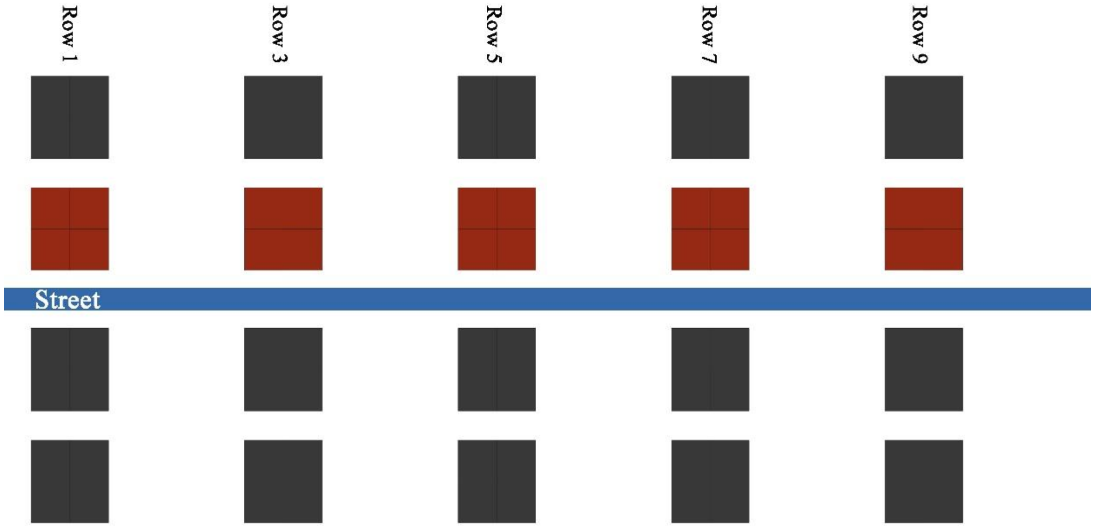


Figure 60: Model designed for pattern B (Designed by author).

- ❖ **2 Story Building**

Same steps are followed and the result exported from the simulation software. After analyzing the detailed information, the summary chart is provided. The interesting section is the huge change in the floors and average thermal comfort percentage. As it is shown in Figure below the general percentage for all rows are lifted and after the third row this time, we are experiencing increasing indoor thermal comfort percentages.

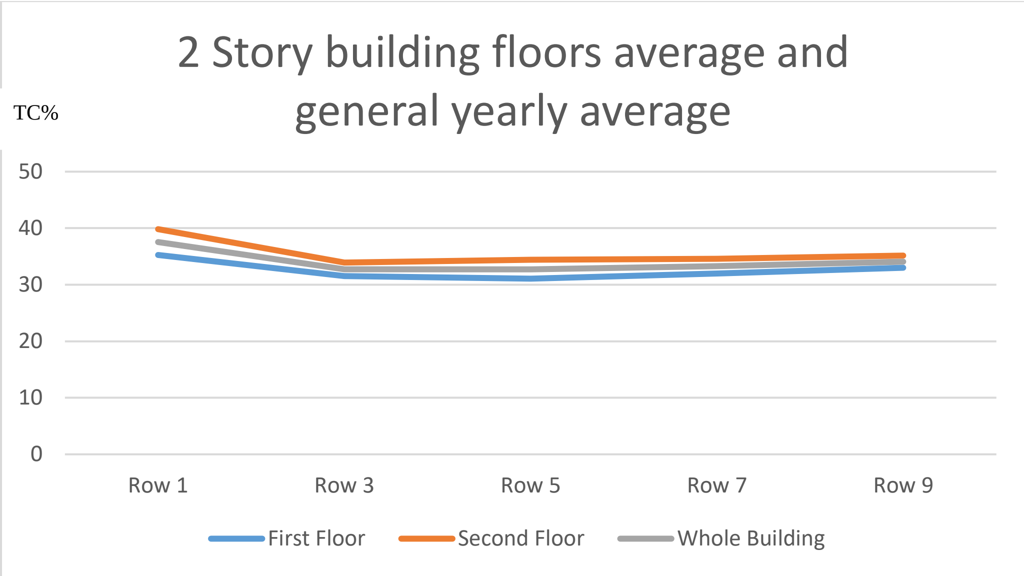


Figure 61: Pattern B, yearly average 2-story building (Exported from grasshopper based on energy plus calculation).

❖ **4 Story Building**

In second pattern four-story building the fourth floor has the best performance for having better air movement which reach the building from the top. The second floor has the minimum performance as far as it is the most affected floor in this model from natural ventilation. Dramatic reduction based on indoor thermal comfort level in four story building yearly average (Figure 62) is clear but generally the complete chart is showing more promising result in comparison with same level in pattern A. the lowest row is still above 31% while in the other example the highest average is about 18% of the year. This shows how important is the pattern decision consideration at the beginning.

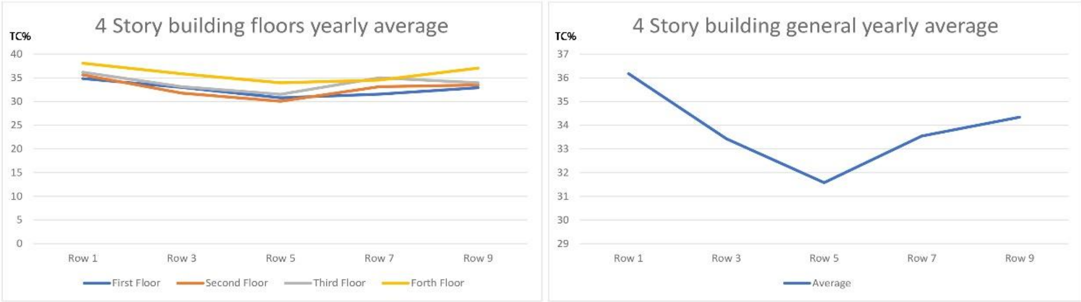


Figure 62: Pattern B, 4-story building floor by floor and complete building thermal comfort level (Exported from grasshopper based on energy plus calculation).

❖ **10 Story Building**

In this section based on floor there is not much difference in between but it is clear the higher levels are having better performance generally and as an overview this patter is much more successful that the first systematic model. The middle fifth floor has the worst thermal level in comparison with other levels and it is because the minimum air speed will reach the opening according to nearby built environment. The yearly average chart (Figure 63) represent the result for odd numbers of rows in comparison with patter A and it is clear the general average of thermal comfort percentage for indoor area has been improve. It is important to mention that the green area in pattern B is going to have positive effect on air movement.

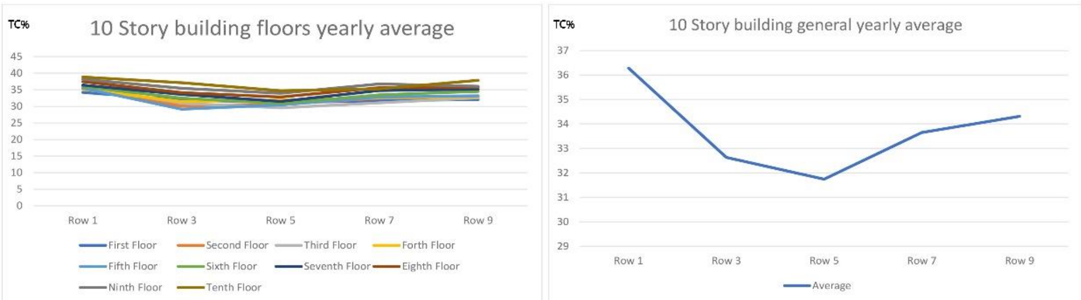
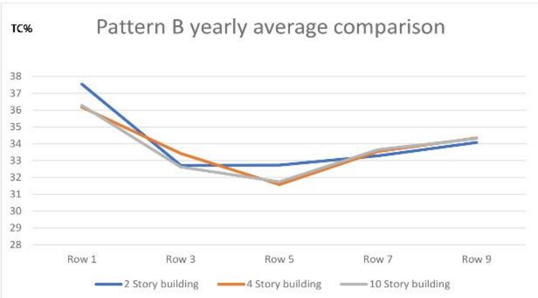


Figure 63: Pattern B, 10-story building floor by floor and complete building thermal comfort level (Exported from grasshopper based on energy plus calculation).

❖ **Comparison of Pattern B**

After analyzing each height and compare the results with each other; in Figure 64 it is clear that the two-story building has the best outcome and highest level. This fact s similar with pattern A result as well but we can perceive that the other floor heights are more similar with each other which shows the improvement in general approach. Overall thermal comfort percentage is much higher than previous scenario, thus the more important factor on success in passive building design when the architect is responsible for the nearby built environment design as well as the building characteristic is going to start from the pattern design than the building height, proportion, shape, and other factors. Based on this discovery, the priorities with in the calculation process begins by definition of building relations and distance with each other and pattern circulation



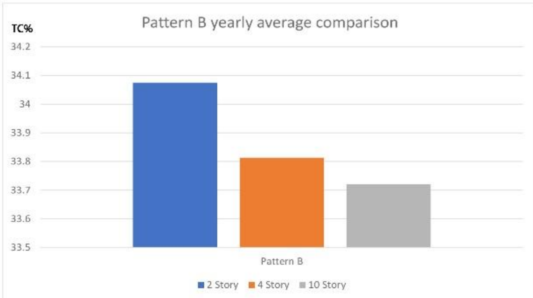


Figure 64: Pattern B, Thermal comfort for each row and yearly average (Exported from grasshopper based on energy plus calculation).

4.7.2.5 Pattern C: Building Relation Based on Selected Case Plot Dimension as Zigzag with Landscape Zones In-Between

The third neighborhood design for two story building simulation is decussated empty space from each sets of building which created zigzag shape for the model. This pattern is following the same distance from pattern B but the building location will be different. The aim of this simulation is illustrating the effect of land boundaries and building location on indoor thermal comfort percentages (Figure 65). The empty plot might consider as green area or landscape which might belong to each residential building or even the neighborhood.

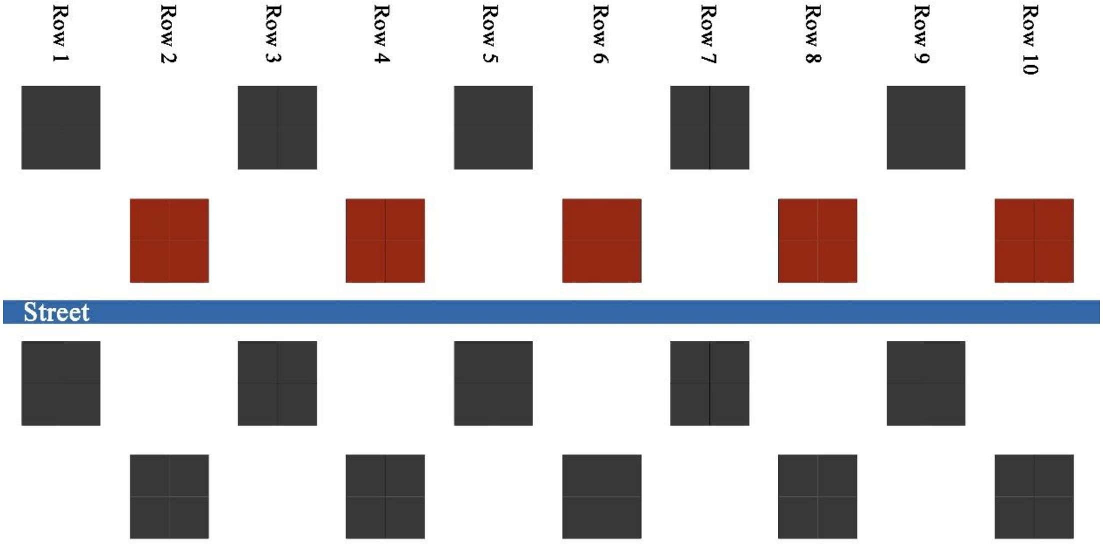


Figure 65: Model designed for pattern C (Designed by author).

- **2 Story Building**

The yearly average of new pattern design simulation which presented in Figure below is illustrating the fact that the percentage between rows reduce smoothly and they are so close to each other which is very positive outcome. This system is counted as the straight and steady system which is helpful for simplifying the conclusion of the graph. This type of neighborhood can be the solution to unsteady percentages for the buildings order which are affected by the natural ventilation factors changes constantly according to the building distance and wind mask effect. It is clear that in this study there is the minimum wind mask at the back of each building because of the guided air flow from the other buildings in that environment.

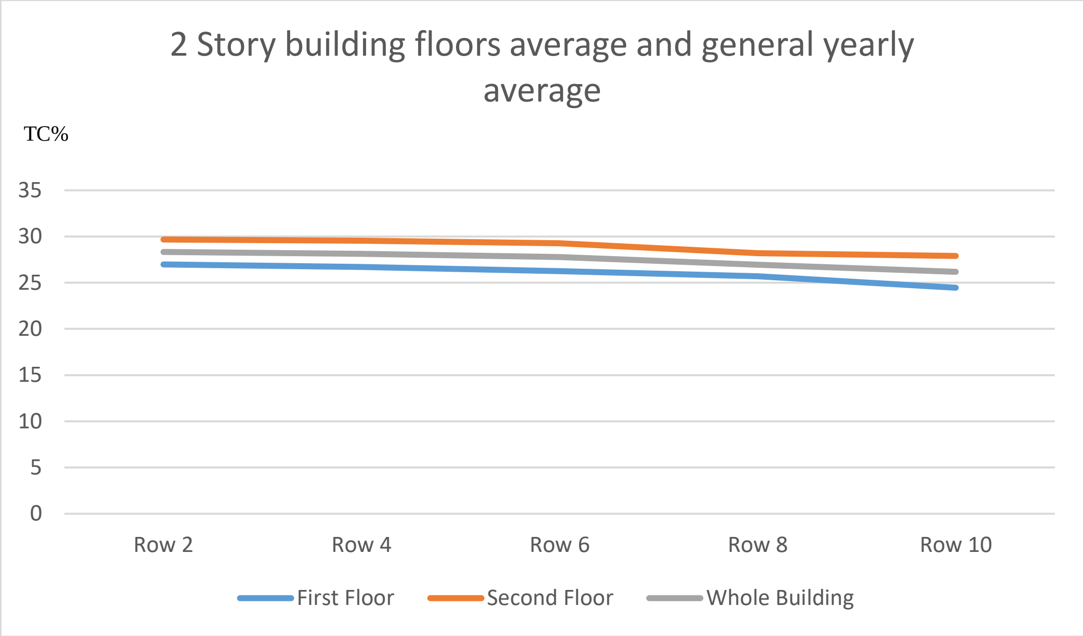


Figure 66: Pattern C, yearly average 2-story building (Exported from grasshopper based on energy plus calculation).

❖ 4 Story Building

In 4-story rather than fourth floor, the others are almost in the same condition according to thermal comfort level based on natural ventilation according to each floor. So, this information shows in this section rows are not having very special role. As the building performance for this scenario illustrate in Figure 67 the level of thermal comfort fluctuation is almost 4% between highest and lowest level so in this case it is possible to illuminate the row base calculation consideration and focus on building height in comparison section.

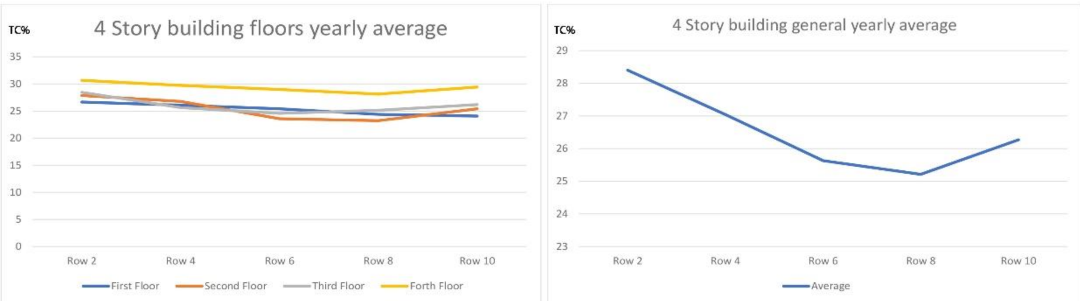


Figure 67: Pattern C, 4-story building floor by floor and complete building thermal comfort level (Exported from grasshopper based on energy plus calculation).

❖ **10 Story Building**

In pattern C between floor thermal comfort percentage there is not much differences, but based on Figure 68 the eighth floor achieves more thermal comfort in comparison with other floors. The reason id in zigzag pattern solution the air circulation changes according to the other building location plus the wind increase speed from the top creates more successful inlet for this height. Generally, between floors they cover thermal comfort range between 14% and 33%, but in the average, it is obvious that the total building thermal comfort is dropping from first row till 8th row and then rise again. As the general building average according to building location the thermal range is between 25.2% till 29.2%.

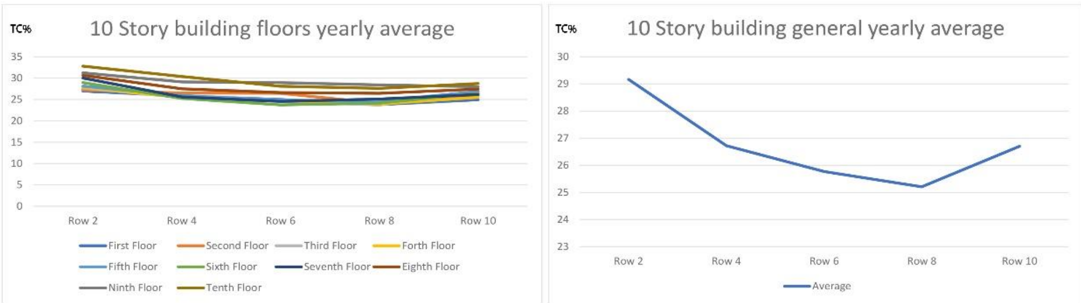


Figure 68: Pattern C, 10-story building floor by floor and complete building thermal comfort level (Exported from grasshopper based on energy plus calculation).

❖ **Comparison of Pattern C**

As the yearly average thermal comfort percentage, Figure 69 illustrate that there is not much difference between building height and location in the pattern, thus we can conclude that if this scenario is selected for the project overall design can be more flexible with height changes and the effect will be very little so the result will be almost same in-between. Thermal comfort percentage difference between different height simulation in pattern C is 2-story building is higher with 1% better result from 4-story and 0.8% from 10-story building design.

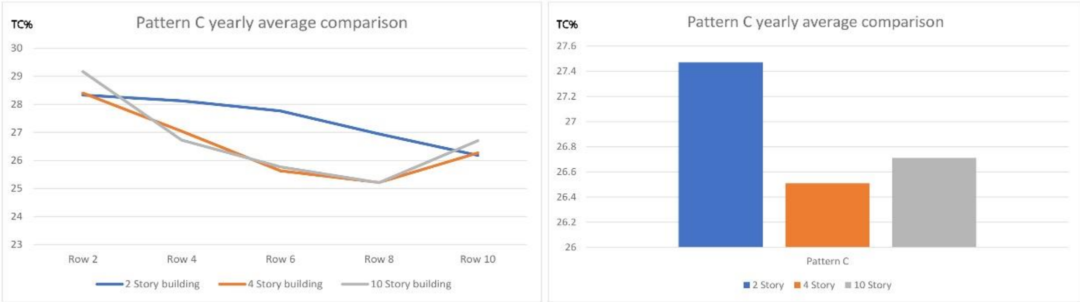


Figure 69: Pattern C, Thermal comfort for each row and yearly average (Exported from grasshopper based on energy plus calculation).

4.7.2.6 Comparison Between Patterns

Simulation results illustrate the changes and differences according to nearby built environment on natural ventilation and indoor thermal comfort percentage. In this section main comparison between all data is going to be done in order to find the optimized result. Analyzing the result of comparison will be the base for the thesis conclusion.

- **Two-Story Buildings Comparison**

The simulation results show the difference between each pattern and the thermal comfort percentage changes. The existing pattern which is the pattern A in the Figure 70 is located as the weakest organization as far as the highest percentage in the model is belong to the first row which is 19% of the year. The comfort level is going down from the first row till the fifth one. After sixth step we can see the percentage grow and after ninth one it starts to reduce again. The second pattern which is the most successful one is doubled space between building which is about 37% of indoor thermal comfort as the highest level. The reason behind higher percentage of even first row is the wind mask effect and pressure difference at the back of the building as the air flow behavior is changing. As the beginning this model is 18% higher than the existing pattern and as an average it is possible to say 15% improvement on indoor thermal comfort level. It is important to mention after the third site location percentage begin to increase and gradually continues.

The last pattern for two story building simulation is decussated empty space from each sets of building which created zigzag shape for the neighborhood. This model result is located in between previous models. The first-row percentage as a base is 28% which is 9% more than first model and 9% below the second pattern. The interesting fact in this model is the smooth reduction of thermal comfort level till the end of neighborhood.as an average this design is 4% worst that second model and 11% better than the existing situation.

In the chart below, graphic expression of all three patterns are brought together to make the visualization for two story building different urban neighborhood design. All percentages and discussions in chapter four and comparison section is readable in the Figure and it will be an easy and understandable graph to present to architects and urban designers in order to improve the success of passive building design by takin nearby built environment into consideration.

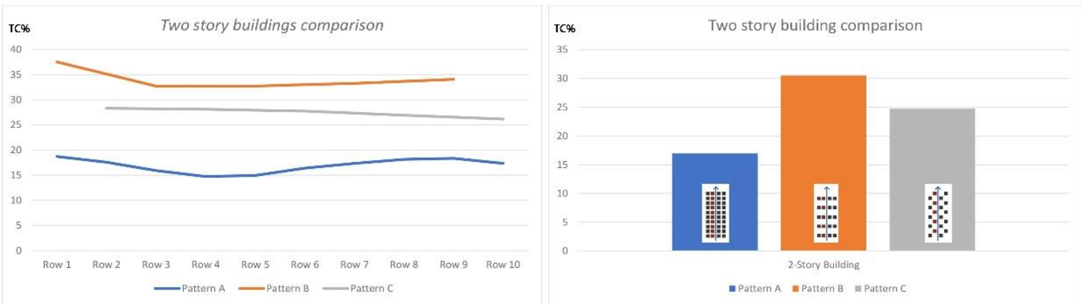


Figure 70: 2-story separated building pattern with 0-degree rotation comparison (Exported from grasshopper based on energy plus calculation).

❖ Four-Story Buildings Comparison

In four-story height comparison as well, the weakest result belongs to pattern A followed by patter C and the most successful outcome belongs to pattern B. Indoor thermal comfort percentage for the complete building in the year for first pattern is 24% while in second one is 34% and third pattern shows 26% success. According to findings based on selected case weather data and step by step simulation for different scenarios if the architect based on any reason decide to follow the first pattern it is suggested to locate the cross path road after sixth row in order to have better and more successful passive building design from natural ventilation point of view, but in the other scenarios there is not much difference for indoor thermal comfort changes. In pattern B the gap between highest and lowest percentage is 5 and in pattern C this number reduced to 3%, thus it will be more flexible to design the general nearby built environment context if these strategies will be selected (Figure 71).

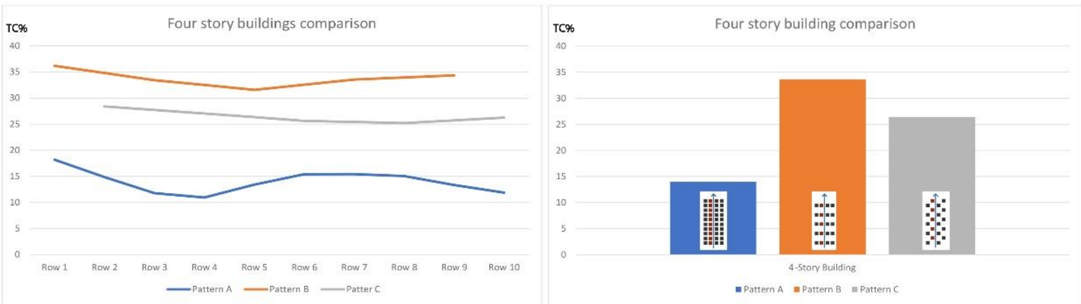


Figure 71: 4-story separated building pattern with 0-degree rotation comparison (Exported from grasshopper based on energy plus calculation).

❖ Ten-Story Buildings Comparison

Same as other patterns comparison result in then-story height also pattern A has the minimum thermal comfort percentage as the building during the year. This information clears that pattern design should be on top of the design decision at the beginning of the process as far as it has more effect that the other variables on passive building design. For selected height thermal comfort percentage in the firs scenario 24% of the year will be covered followed by the third scenario which is 37% and the highest will be second pattern with 34% in order from low to high.in pattern A 10 story difference is only happening between rows 5 and 6 and during the rest the graph shows reduction for indoor thermal comfort. Change is not significant in other patterns scenario based on the building location in the site (Figure 72).

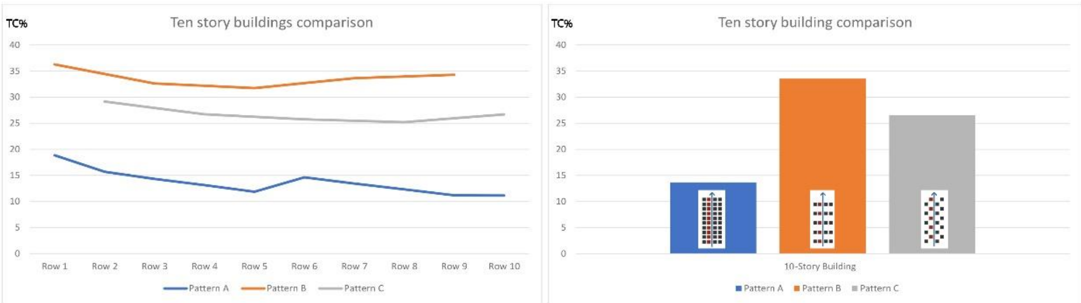


Figure 72: 10-story separated building pattern with 0-degree rotation comparison (Exported from grasshopper based on energy plus calculation).

4.8 Chapter 4 Overview

As the general overview for chapter 4 for each scenario graphical presentation have been created to have the last comparison between simulation outcomes and selection of optimized result for the best indoor thermal comfort percentage during the year based on consideration of natural ventilation and the effect of nearby built environment. Based on the main categories first the new design in existing context has been simulation and during the calculation process the method explained in chapter 3 has been followed step by step. To show the differentiation between free run building and calculation with surrounding three main scenarios has been developed. First is the building simulation with no nearby built environment following by two selected sites in historic settlement located in the selected case with hot climate condition. Also, cases simulated according to 0-degree, 45-degree, and 90-degree angle towards prevailing wind to reach the comparable outcome and after analyzing them the optimized result selected according to each building condition. Figure 73 represent each scenario result all together.

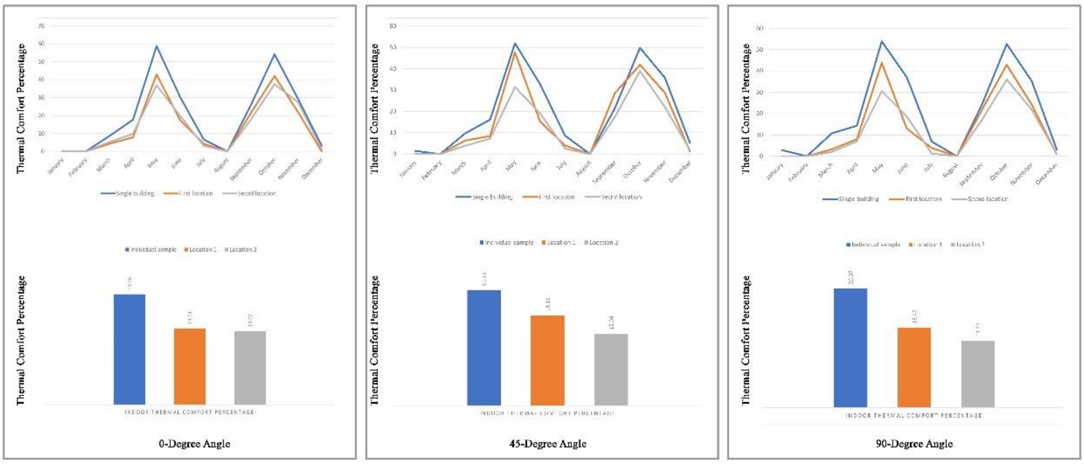


Figure 73: New building design in existing context results categories by the orientation from prevailing wind (Exported from grasshopper based on energy plus calculation).

On the other hand, in new design with context followed more scenarios in order to find the optimized result for each pattern defined within the process. For preparing the data for comparison there should be same general condition between patterns which covered with ten rows by four with the 6m street located at the middle of each pattern. In each category the wind mask has been calculated and floor by floor thermal comfort percentage realized based on the building location within the pattern. Also, different heights as 2-story, 4-story, and10-story buildings simulated. Figure 74 shows the building thermal comfort based on each pattern and the location of them in the designed pattern.

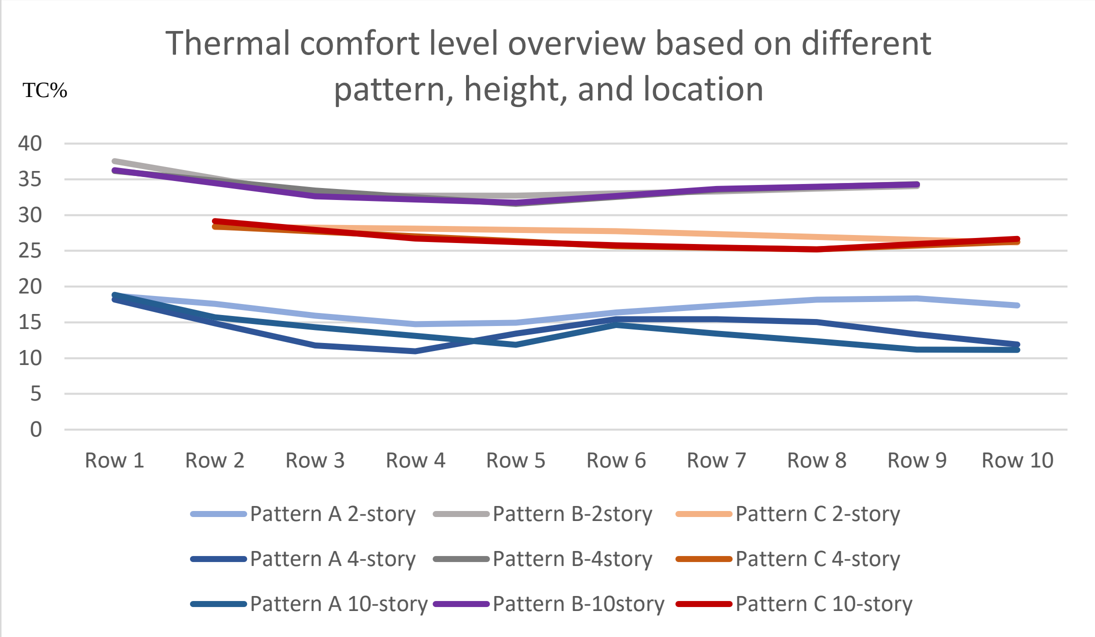


Figure 74: Thermal comfort level based on different pattern, height, and location (Exported from grasshopper based on energy plus calculation).

In order to have the general overview for each scenario the overall yearly thermal comfort percentage for each pattern based on the height differences gathered in Figure 75. Analyzing the graph from the best to worst categories illustrate that pattern B which has construction and green landscape in between them has the best thermal comfort performance and covered more duration in the year followed by pattern C which is the zigzag construction combination with landscape. The lowest thermal comfort level is for pattern A which is about 15% of the year as average. Pattern B thermal comfort percentage average is about 34% and pattern C is 27%.

It is clear that the most important variable in context design and accordingly indoor thermal comfort level is the design pattern. Based on the design condition specially for pattern A the height is acting as second important variable on thermal comfort while in other scenarios the height effect is very small which can be eliminated from the effective factors.

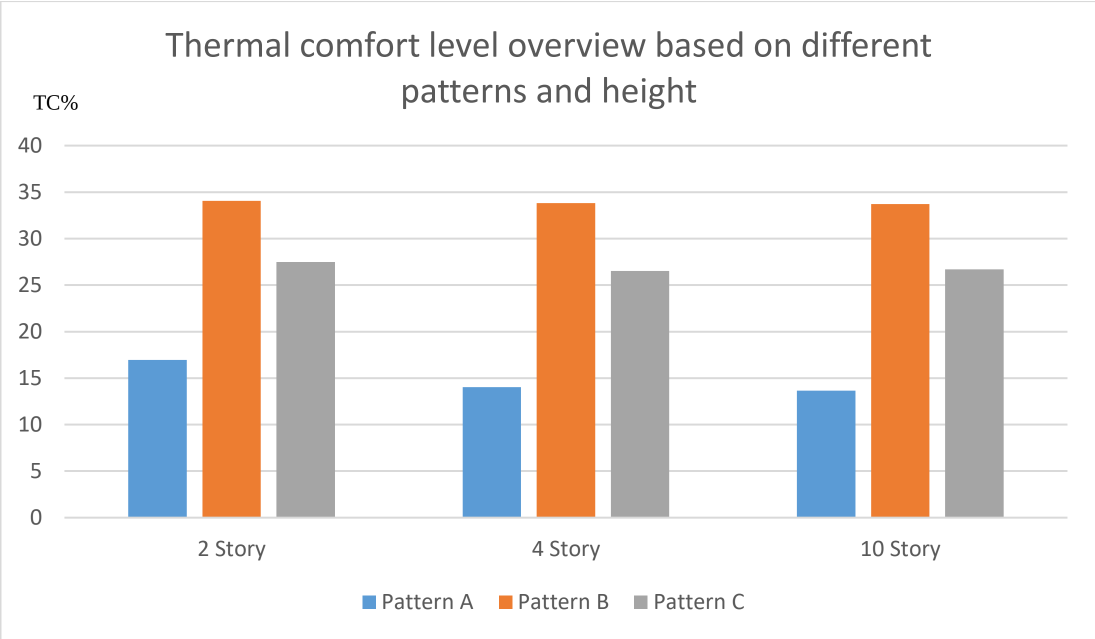


Figure 75: Thermal comfort level based on different patterns and heights (Exported from grasshopper based on energy plus calculation).

Chapter 5

CONCLUSIONS

Thesis conclusion is going to be counted as the foundation for updating and regulating for thermal comfort codes to full fill very important existing gap in passive building design and urban development strategies from natural ventilation point of view and taking nearby built environment into consideration. This field needs more time, expertise, attention, and focus in order to be designed as a part of the building energy standards but as the fundamental aspect of the method to be followed is missing. This study clarifies the missing knowledge based on natural ventilation and indoor thermal comfort based on nearby built environment and illustrate the unrealistic calculation result based on free run simulation according to existing methods. The approach taken for method creation stands on existing knowledge and clarification of natural ventilation in energy calculation methods in current regulations around the world. Classification of steps as the outcome of the data collection gathered and analyzed to find the logical and clear stages in order to be followed by architects as well as having flexible enough system to be adaptable for different countries and locations.

Within the stages, detailed process and needed variables in every section has been clarified and presented as graphical expressions for better understanding during the method explanation. For having the trustable result and giving example of how the systematic approach will guide to have the optimized result for the project; the method tested on familiar selected case for author to be able to examine the simulated outcome with personal experience of the location. Because of the vast topic field, there has to be limitation in order to create achievable platform according to time frame. During the method description these limitations have been mentioned and future steps are grouped in further studies to show how the method can be developed and upgraded accordingly.

5.1 Thesis Conclusion

As the statement for thesis outcome each stage in designed method is going to be analyzed and summarized in order to illustrate the approach clarification and contribution to indoor thermal comfort based on theory and selected case test result. Main factor which is going to define as the main variable for method which is going to have direct effect on all steps during the calculation process is the climate condition. Climate analysis at the beginning in order to find fundamental information to define the strategies should take place. Wind and thermal analysis have overall contribution in thermal comfort calculation exported from weather data. In wind analysis information like wind speed, wind temperature and prevailing wind direction will be clear and thermal analysis is going to define which time of the year it is possible to have benefit from natural ventilation and for what duration architect should consider other strategies for reaching indoor thermal comfort in passive building design.

In second stage the general design condition and accordingly main scenarios are prepared for calculation process. As general categories there are projects which are going to be designed in the existing context or already constructed and thermal comfort is going to be estimated for them in order to have improvement strategies or the other categories that located under designing with context proposing the building will give the flexibility to design the building context as well.

Approach to stage three is going to be based on the design category. If the project for indoor thermal calculation exist in context, the 3D model and examine the wind mask effect from existing nearby built environment should be prepared for the site which the project is located or going to be constructed, but if the context is going to be designed by the architect detailed scenarios should be prepared in this step. First the pattern should be decided from the overall three main categories which are separated building, row housing, and historical pattern. For each set there is chance to make various changes in the outline for calculation. Street dimension and orientation towards prevailing wind at the beginning and according to that the plot shape, proportion and direction will be defined. The wind mask which is the main goal of stage 3 then the calculation process is going to apply for each scenario and used in the main method.

Building configuration in stage 4 should be done after making the function and occupation condition of the project clear in order to find the constructible frame work by checking the result with local construction regulation. There might be energy consumption code section within the regulation or in some countries only the construction limits will be defined. In building configuration section generally, the design orientation in the site plus building shape and proportion are going to be designed and accordingly the window shape and opening percentages will be classified. As the last step the 3D model of the designed project should be prepared for further step.

Stage 5 dedicated to main indoor thermal comfort calculation. Dynamic calculation method has been selected over steady calculation method as far as the flexibility on variables input and more realistic results are achievable within this system. For simulating the thermal comfort needed input data from each stage should be imported as fundamental criteria in calculation process. In this section definition of thermal comfort according to user preference based on location and design goal are going to be defined as well.

Calculation outcomes will be gathered and act as input for indoor thermal comfort calculation based on natural ventilation while the nearby built environment considered during the process. based on natural ventilation related results the thermal comfort level and time table is going to be illustrated in stage6. Evaluation of all results is going to be done in stage 6 according to main scenario. The result can show overall yearly average or monthly outcome, even hourly result in order to find the building performance during night or day is possible. For existing context, the whole building thermal comfort percentage is going to be collected. There is percentage difference between floors according to height which it might be helpful in some cases but the aim is calculating the complete building thermal performance in this category. For design with context the overall thermal comfort for the complete project is the goal while there is detailed information for each building in different location and also separate floors result individually.

These outcomes should be evaluated to realize if the result is significant or the scenario is failed. If the result is not significant for existing building the existing context, other scenarios from stage 4 should be followed and if the result has been extracted for design with context the setback for scenario should go back to stage 3. Outcomes of all scenario for indoor thermal comfort are going to be compared with each other and the optimized result is going to be selected.

Figure 76 represent the graphical preview of the proposed model as the main achievement of this thesis. From top towards button, all stages are listed from 1 to 7 and how the relation between variables are working with each other are illustrated. It is important to mention that there is no limit for this model according to climate condition and function selection. Architects can define any scenario based on the design aim and follow the process in order to reach the optimized thermal comfort level for their design project. Detailed information for each stage has been explained in chapter 3.

The calculation can be done by any convenient method, but in this thesis computing fluid dynamic program has been used in order to create digital model and define the setting for finding the level of indoor thermal comfort. Used software here is rhino grasshopper which is the open source program and supported by climate and energy related plugins. Havin different tools which are adaptable with each other during the process was helpful to gather and run all simulations in one place. Climate analysis is done by ladybug plugin while changes in wind and its behavior according to nearby built environment covered by butterfly tools. The setting for building and limits for thermal comfort variables plus defining the window opening position created by honeybee and as far as the link between grasshopper and energy plus, all settings imported to energy calculation software and imported again for comparison and visualization of numerical outcomes.

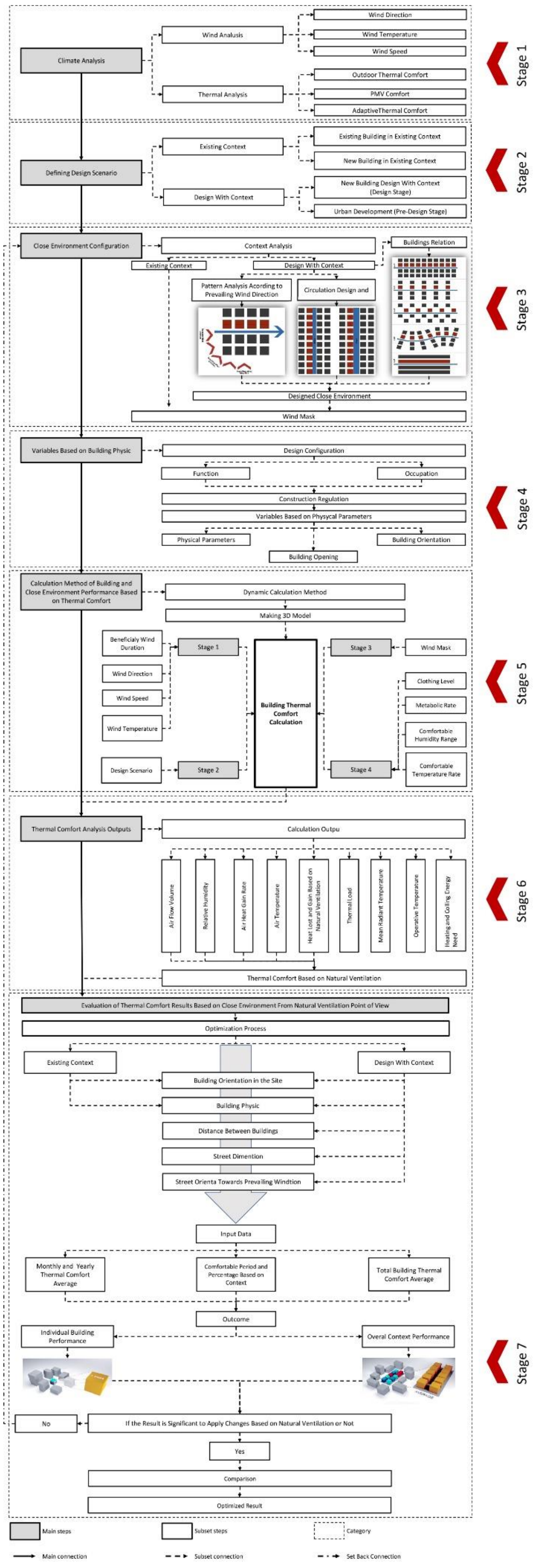


Figure 76: Proposed model (Designed by author).

Based on the outcome from simulations done for each scenario we have to conclude the optimized result based on context situation. in existing context scenario, it is clear there is a huge difference between free run building with no surrounding and taking nearby built environment into consideration. Also, comparison between different site locations illustrate the effect of density and site location on indoor thermal performance. During the evaluation it became clear that building orientation in the site will have significant change on thermal comfort percentage as well.

Results of simulations for design with context clarified the important factors from maximum to minimum impact. The highest effective factor is buildings relation and distance with each other and street. With wider space architects will create better natural ventilation condition for indoor thermal comfort improvement. After that the design orientation towards prevailing wind is acting as very important factor. Site orientation, street direction and building able itself according to wind direction should be considered as different scenarios and tested for the project. After orientation building shape has very important roll and at the end building height. If the distance between buildings in designed context will be sufficient the height is not going to have significant change in the overall result, but in case the buildings are close to each other the height will have effect on wind circulation and wind mask creation. It is suggested to define scenarios from the higher effective factors for finding optimized result.

Figure 77 shows the systematic approach for each scenario in order to have simplified decision making in order to have optimized building. Each column represents different pattern and from bottom to top the process will be followed. As it is clear in the legend thermal comfort percentages are differentiated by 5% and presented by different color code. The minimum boundaries are between 0 to 15% and the maximum is above 35%

in this Figure according to scenarios. Fixed variables in each level is the pattern orientation towards prevailing wind as 0-degree, 45-degree, and 90-degree on the right side and the left side is going to change based on other variables with in the simulation process.

In the first row, building height and the effect of it according to pattern is presented based on research limitation which means 2-story, 4-story, and 10-story building followed by distance between plots in the second row. For general understanding and simplifying the second step 3-meter increase between buildings are presented which means for each height 3,6, and 9 meters distance are selected to make the comparison and calculation easier. The third row is clarifying the building orientation in the site as 0-degree, 45-degree, and 90 degree to provide the thermal comfort changes in this section. The last row is decision-making level which based on thermal comfort color code, architect can select the most optimized configuration for the selected scenario according to project location.

For the decision-making process in this thesis based on defined patterns and explained variables it is clear that for design with context, pattern B gives more options to architect in order to have optimized design while pattern C is more limited and the level of thermal comfort is less. Pattern A has the minimum indoor thermal comfort based on natural ventilation which means the general organization is not successful and if architect want to achieve more successful passive building design should follow the model steps in order to change the design variable in order to improve the outcome and act accordingly to evaluate the new result and find the optimized solution.

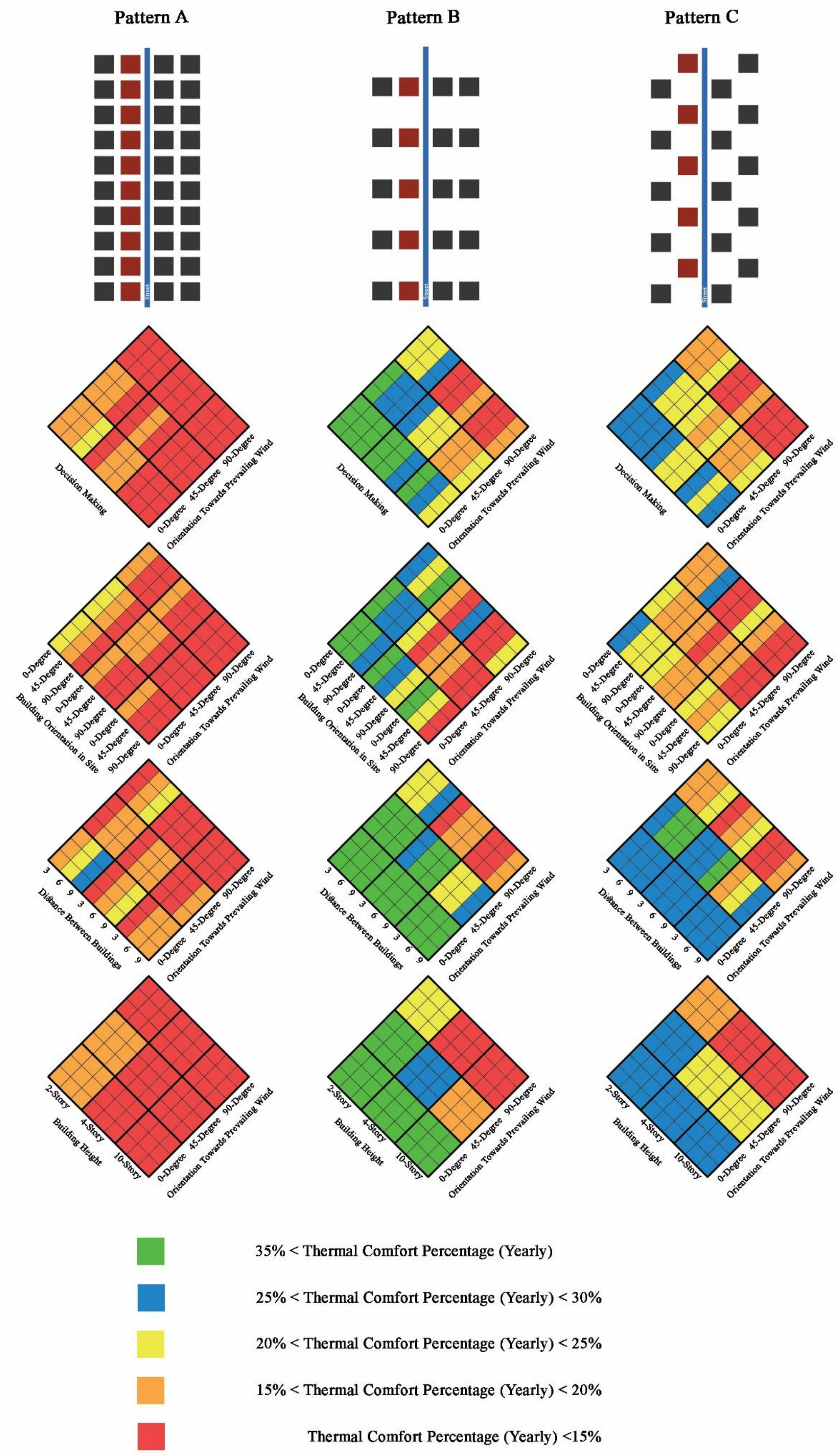


Figure 77: Optimization and decision-making diagram (Designed by author).

5.2 Further Studies

This study is the preliminary step towards the exact calculation and complete systematic approach for reliable calculation of the natural ventilation effect on indoor thermal comfort from natural ventilation and close nearby built environment condition. As a first step this study shows the effect of nearby built environment on wind behavior and changes on wind factors in the path to the building. This study conclusion can be adaptable for any condition in order to have more realistic calculation for passive building design. Also, it can be the base for other cases with different climate condition to find the applicable strategies for improving the level of indoor thermal comfort in passive building design. As a further study, following list is proposed as a guidance in order to complete the findings in this systematic method. Created platform can be considered as a piece of puzzle and should be upgraded with right fitting extensions, thus author illustrate the upcoming stage in this field of study below.

- **Effect of Natural Environment on Natural Ventilation**

Same as nearby built environment, the nature itself will have effect on the air movement and behavior, so close natural environment effect should be counted in to consideration as well. Natural environments might be existing such as ocean, sea, forest, land height, mountains, and etc. or it might be designed as landscape and constructed via humans which each of them will have undeniable effect on wind behavior. The manmade natural elements such as landscaping, parks, city plaza, and etc. needs more study and there should be a strategy according to location for improve the effect of natural ventilation on thermal comfort. Selection of ever green or seasonal trees also the location of them will have wind break effect for the direction which the natural ventilation should be controlled according to the climate and site, also it will define the amount of shadow creation in different seasons for other energy calculation techniques. It is very important and time consuming to have reliable method as a simplified systematic approach for natural elements effect on thermal comfort based on building surrounding greeneries. It seems the CFD software experts are the only solution with existing level of knowledge and technology.

- **Building Height**

This study limited by examining three different building height based on the selected case evaluated the proposed method, but knowledge should be expanded for all buildings with all height. The formula should be edited according to mathematical equation which will be adaptable and simplified for scenarios defined based on any floor numbers.

- **Building Function**

Residential buildings are selected as a focused for this thesis but it is possible to expand the simulation for any type of building like commercial, offices, short term accommodation, industrial buildings, and health related facilities. Each type of building has its own requirement and boundaries according to the function need and local construction regulation, thus natural ventilation should be considered in calculation process according to the function needs. Generally, for each category the method should apply and missing variable should be defined. These information for the unique condition of specific function should place carefully in method and the calculation process in order to maximize the use of natural ventilation on indoor thermal comfort. It is crucial to have the experts to group other buildings and categorize them according to the need of ventilation in space.

- **Building Shape and Proportion**

Building shape and proportion have direct effect on natural ventilation. Both new building design in existing context and new building design with context have to be studied based on building shape and dimension based on their function. Same as manmade natural environment and city landscape, this topic is unique according to the city location and pattern, thus it is not possible to generalize the applicable method. It is needed to be done by experts for each case and find the result accordingly, but still it is possible to simplify the path and bring it in to the method in order to estimate higher level of thermal comfort level in building from building shape point of view.

- **Ventilation method**

This study focused in driven ventilation system with cross ventilation method and the results are calculated according to this limitation, but the method should be capable of covering other ventilation technique and system. In order to find the approach and integrate it in the model, other ventilation methods should be examined and based on their effect on indoor thermal comfort they should be categories and located in the systematic process. In all categories different window shape and their location should be examined as well to clarify the relation between window and level of thermal comfort success.

- **Indoor Plan Organization**

Indoor plan and divisions are directing the air movement and movable indoor elements like doors and furniture location are going to effect the natural ventilation circulation inside the building, so it is important to study and categories these elements to have systematic approach to have the indoor condition according to the user need and natural ventilation effect on user thermal comfort.

- **Wind Mask**

Equation between building factors and wind mask is still vague. The cooperation between architects and mathematician might be the solution for illustrating the answer of the knowledge gap in between. This answer will be helpful to estimate the proper dimension between buildings and city blocks in order to reduce wind mask effect and gives the opportunity to buildings located at the back to have maximum benefit from natural ventilation as a simple chart in order to improve the possibility of natural ventilation usage in passive building design.

- **Indoor Air Quality**

In order to full fill all aspects of natural ventilation in building it is important to analyses the indoor air quality parallel with thermal comfort and model should be updated for having single process to achieve the general result to achieve optimized result which covers all aspects based on natural ventilation in building.

REFERENCES

Akbar Gill, M. J. (2019, 09 14). *Wind Measurements*. Retrieved from Quora: https://www.quora.com/What-is-the-unit-measurement-of-wind.

Alipour, H., & Kilic, H. (2005). An Institutional Appraisal of Tourism Development and Planning: the Case of the Turkish Republic of North Cyprus (TRNC). *Tourism Management*, 79-94.

Alvarez, S. (1998). *Natural Ventilation in Buildings: A Design Handbook.* London: James & James.

Arfaei, A. (2014). *Critical Approach to the Process of Energy Efficient Building Constructing.* (P. Hancer, Ed.) Gazimagusa, Turkish Republic of Northern Cyprus, Turkey: Eastern Mediterranean University.

Arfaei, A., & Hancer, P. (2019, October 31). Effect of the Built Environment on Natural Ventilation in a Historical Environment: Case of the Walled City of Famagusta. *Sustainability*(Building and Urban Energy Prediction-Big Data Analysis and Sustainable Design), 6043. Retrieved from https://doi.org/10.3390/su11216043.

ASHRAE. (2017). *Thermal Environmental Conditions for Human Occupancy*. Washington DC: ANSI.

Atmacha, I., Kaynaki, O., & Yigit, A. (2007, September). Effects of radiant temperature on thermal comfort. *Building and Environment, 42*(9), 3210-3220.

Babin, S. M. (2019, 09 10). *Atmus*. Retrieved from Water Vapor Myths: https://www.atmos.umd.edu/~stevenb/vapor/.

Baker, N. V. (1987). *Passive and Low Energy Building Design For Tropical Island Climates.* London: Commonwealth Secretariat.

Bandarin, F., & Oers, R. V. (2014). *Reconnecting the City: The Historic Urban Landscape Approach and the Future of Urban Heritage.* West Sussex: John Wiley & Sons.

Bates, C. G. (1911). *Windbreaks: Their Influence and Value, Volumes 82-89.* Washington DC: U.S. Department of Agriculture, Forest Service.

Bates, P. D., Lane, S. N., & Ferguson, R. I. (2005). *Computational Fluid Dynamics: Applications in Environmental Hydraulics.* New Jersey: John Wiley & Sons.

Bay, J. H., & Ong, B. L. (2007). *Tropical Sustainable Architecture.* Abingdon: Routledge.

BREEAM. (2018). *Home Quality Mark One, Technical Manual SD239, England, Scotland & Wales.* Bracknell: BRE.

BREEM UK. (2018). *BREEAM UK Consreuction; Non-domestic Buildings (United Kingdom) Technical Manual SD5078.* Watford: BRE Global LTD.

Burke, S. (1998). *Windbreaks.* Houston: Gulf Professional Publishing.

Buyantuyev, A., & Wu, J. (2009). Urban Heat Islands and Landscape Heterogeneity: Linking Spatiotemporal Variations in Surface Temperatures to Land-Cover and Socioeconomic Patterns. *Landscape Ecology*, 17-33.

Carrer, P., Wargocki, P., Fanetti, A., Bischof, W., Fernandez, E. D., Hartmann, T., . . . Seppanen, O. (2015). What does the Scientific Literature Tell Us about the Ventilation-Health Relation in Public and Residential Buildings? *Building and Environment*, 273-286.

Chakraborty, T., & Lee, X. (2019). A Simplified Urban-Extent Algorithm to Characterize Surface Urban Heat Islands on a Global Scale and Examine Vegetation Control on their Spatiotemporal Variability. *International Journal of Applied Earth Observation and Geoinformation*, 269-280.

Chen, H., Ooka, R., Huang, H., & Tsuchiya, T. (2009). Study on Mitigation Measures for Outdoor Thermal Environment on Present Urban Blocks in Tokyo Using Coupled Simulation. *Building and Environment*, 2290-2299.

Cohen, S. (2017). *The Sustainable City.* New York: Columbia University Press.

Collins, G. R., Sitte, C., & Crase, C. (2006). *Camillo Sitte: The Birth of Modern City Planning.* Limassol: Courier Corporation.

Curstin, J. (2020, 01 05). *Wind Rose Resource*. Retrieved from Natural Resource Conservation Service: https://www.wcc.nrcs.usda.gov/climate/windrose.html

Cypnet. (2019, 09 08). *Cypnet*. Retrieved from Othello's Tower and Citadel: http://www.cypnet.co.uk/ncyprus/city/famagusta/othello.htm

Da Rosa, A. V. (2009). *Fundamentals of Renewable Energy Processes*. Oxford: Academic Press.

Davidson, S. (2019, October 25). *Rhino developers docs*. Retrieved from Rhino3d Developer: https://developer.rhino3d.com/guides/rhinopython/your-first-python-script-in-grasshopper/.

de Dear, R. J. (1998). A global database of thermal comfort field experiments. *ASHRAE Transactions*, 1141-1152.

de Dear, R. J., Brager, G., & Cooper, D. (1997). *Developing an Adaptive Model of Thermal Comfort and Preference. Final Report on ASHRAE RP-884.* Sydney: Macquarie University.

Dekay, M., & Brown, G. Z. (2014). *Sun, Wind & Light Architectural Design Strategies.* New Jersey: John Wiley and Suns.

DIRECTIVE 2009/28/EC. (2009). *DIRECTIVE 2009/28/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC.* Official Journal of the European Union.

Djamila, H., Chu, C. M., & Kumaresan, S. (2014). Effect of Humidity on Thermal Comfort in the Humid Tropics. *Journal of Building Construction and Planning Research*, 109-117.

Donald, W., & Kenet, L. (1983). *Climatic Design.* New York: McGraw-Hill Inc.

Donald, W., & Labs, K. (1983). *Climatic Design: Energy-Efficient Building Principles and Practices.* New York: McGraw-Hill Inc.

EARTH Lab. (2008). *Elevating and Safeguarding Culture Using Tools of the Information Society: Dusty traces of the Muslim culture.* Athens: Earthlab.

Elmualim, A. A. (2006). Effect of Damper and Heat Source on Wind Catcher Natural Ventilation Performance. *Energy and Buildings*, 939-948.

Environmental Monitor. (2019, 09 14). *Fondriest*. Retrieved from Environmental Monitor: https://www.fondriest.com/news/airtemperature.htm

Erlandso, T., Cena, K., De Dear, R., & Havenith, G. (2014, March 12). Environmental and human factors influencing thermal comfort of office occupants in hot—humid and hot—arid climates. *Ergonomics, 46*(6), 616-628. doi:https://doi.org/10.1080/0014013031000085707.

Famagusta Climate & Temperature. (2019, 08 11). *Famagusta Climate & Temperature*. Retrieved from www.famagusta.climatemps.com.

Gonzalo, R., & Habermann, K. J. (2012). *Energy-Efficient Architecture: Basics for Planning and Construction.* Berlin: Walter de Gruyter.

Goodland, R., Daly, H. E., & Serafy, S. E. (1992). *Population, Technology, and Lifestyle: The Transition to Sustainability.* Washington D.C.: Island Press.

Grammenos, F., & Lovegrove, G. R. (2015). *Remaking the City Street Grid: A Model for Urban and Suburban Development.* Bakersfield: McFarland.

Great Britain: Parliament: House of Commons: Environmental Audit Committee. (2010). *The role of carbon markets in preventing dangerous climate change.* London: The Stationery Office.

Guillaume FABRE. (2010). *he Low-Carbon Buildings Standard 2010.* Parris: Guillaume FABRE.

Hancer, P. (2005). *Thermal Insulations of Roofs for Warm Climates.* Famagusta: EMU.

Hegger, M., Fuchs, M., Stark, T., & Zeumer, M. (2012). *Energy Manual: Sustainable Architecture.* Berlin: Walter de Gruyter.

Hegger, M., Matthias, F., Stark, T., & Zeumer, M. (2008). *Energy Manual: Sustainable Architecture.* Munich: Birkhäuser Architecture.

Heisler, G. M., & Dewalle, D. R. (1988). Effects of windbreak structure on wind flow. *Agriculture, Ecosystems & Environment*, *22-23*, 41-69.

Hensen, J. L., & Lamberts, R. (2012). *Building Performance Simulation for Design and Operation.* New York: Routledge.

Hill, G. (2010). *A History of Cyprus, Volume 2.* New York: Cambridge University Press.

Hiyama, K., & Glicksman, L. (2015). Preliminary Deaign Method for Naturally Ventilated Building Using Target Air Change Rate and Natural Ventilation Potential Map in the United State. *Energy*, 655-666.

Hordeski, M. F. (2003). *New Technologies for Energy Efficiency.* Lilburn: The Fairmont Press.

HSE. (2020, March 01). *Thermal Comfort*. Retrieved from Health, safety and environment: https://www.hse.gov.uk/temperature/thermal/index.htm.

Huang, W., Cui, S.-h., Li, F., Huang, L., & Lin, J.-y. (2017). Carbon Footprint and Carbon Emission Reduction of Urban Buildings: A Case in Xiamen City, China. *Procedia Enineering*, 1007-1017.

ISC-Audubon. (2013, January 29). *The Koppen Climate Classification System*. Retrieved from The Sustainability Council: https://www.thesustainabilitycouncil.org/the-koppen-climate-classification-system/the-dry-climate/.

ISO. (1995). *ISO 10551:1995 Ergonomics of the thermal environment — Assessment of the influence of the thermal environment using subjective judgement scales.*

ISO. (2004). *ISO 9886:2004 Ergonomics — Evaluation of thermal strain by physiological measurements.*

ISO. (2005). *ISO 7730:2005 Ergonomics of the thermal environment — Analytical determination and interpretation of thermal comfort using calculation of the PMV and PPD indices and local thermal comfort criteria.*

ISO. (2008). *ISO 13790:2008 Energy performance of buildings — Calculation of energy use for space heating and cooling.*

ISO. (2019). *ISO 10551:2019 Ergonomics of the physical environment — Subjective judgement scales for assessing physical environments.*

Kalz, D. E., & Pfafferott, J. (2014). *Thermal Comfort and Energy-Efficient Cooling of Nonresidential Buildings.* New York: Springer.

Karmer, C., Gerhardt, H. J., & Scherter, S. (1979). Wind Pressure on Block-Type Buildings. *Journal of Wind Engineering and Industrial Aerodynamics*, 229-242.

Kennedy, W. J., & Smith, M. G. (2015). *The Art of Natural Building.* Gabriola Island: New Society Publisher.

Khan, N., Su, Y., & Riffat, S. B. (2008). A review on wind driven ventilation techniques. *Energy and Buildings, 40*(8), 1586-1604.

Kleiven, T. (2003). *Natural Ventilation in Buildings: Architectural Concepts, Consequences, Possibilities.* Trondheim: Norwegian University of Science and Technology.

Kottek, M., Grieser, J., Beck, C., Roudolf, B., & Rubel, F. (2006, June). Woels Map of Koppen-Geiger Climate Classification Update. *Meterologische Zeitschrift, 15*, 259-263.

Kubba, S. (2012). *Hand Book of Green Building Design and Construction.* Oxford: Elsevier.

Kypros. (2013, 09 02). *kypros*. Retrieved from history: http://www.kypros.org/Cyprus/history.html.

Levermore, G. (2013). *Building Energy Management Systems: An Application to Heating, Natural Ventilation, Lighting and Occupant Satisfaction.* New York: E & FN Spon.

LI, Y., & Chen, Z. (2003). A Balance-Point Method for Assessing the Effect of Natural Ventilation on Indoor Particle Concentrations. *Atmospheric Environment*, 4277-4285.

Li, Y., & Nelsen, P. V. (2011). CFD and ventilation research. *Indoor Air, International Jurnal of Indoor Environment and Health*.

Lotfabadi, P., & Hancer, P. (2019). A Comparative Study of Traditional and Contemporary Building Envelope Construction Techniques in Terms of Thermal Comfort and Energy Efficiency in Hot and Humid Climates. *Sustainability*.

Lou, M., Wang, Z., Ke, Z., & Cao, B. (2018). Human metabolic rate and thermal comfort in buildings: The problem and challenge. *Building and Environment* , 44-52.

Lowe, S. A. (2016). An Energy Morality Impact Assessment of the Urban Heat Island in the US. *Environment Impact Assessment Review*, 139-144.

Lyndon, D., Olgyay, V. W., Reynolds, J., & Yeang, K. (2015). *Design with Climate, Bioclimatic Approach to Architectural Regionalism.* New Jersey: Princeton University Press.

Manabe, S. (1969). Climate and the Ocean Circulation; The Atmospheric Circulation and the Hydrology of the Earth's Surface. *Monthly Weather Review*, 739-774.

Management Association, Information Reso. (2018). *Smart Cities and Smart Spaces: Concepts, Methodologies, Tools, and Applications: Concepts, Methodologies, Tools, and Applications.* Pennsylvania: IGI Global.

Migliore, M., Talamo, C., & Paganin, G. (2019). *Strategies for Circular Economy and Cross-sectoral Exchanges for Sustainable Building Products: Preventing and Recycling Waste.* Berlin: Springer Nature.

MOA. (2013, September 02). *Meterological service*. Retrieved from Metological report: http://www.moa.gov.cy/moa/MS/MS.nsf/DMLclimet_reports_en/DMLclimet_reports_en?OpenDocument&Start=1&Count=1000&Expand=1.

Morris, C. J., Simmonds, I., & Plummer, N. (2001). Quantification of the Influences of Wind and Cloud on the Nocturnal Urban Heat Island of a Large City. *AMS*.

Mostafaeipour, A., Sedaghat, A., Dehghan-Niri, A. A., & Kalantar, V. (2011). Wind Energy Feasibility Study for City of Shahrbabak in Iran. *Renewable and Sustainable Energy Reviews*, 2545-2556.

Motalaei, N., & Ranjbar, E. (2015). Climate-Friendly Urban Design Process in Old Towns. *ICUC9 - 9th International Conference on Urban Climate jointly with 12th Symposium on the Urban Environment* (p. 4). Toulouse: ICUC9.

Muller, D. G. (2002). *Sustainable Architecture and Urbanism.* Basel: Birkhauser.

National Geographic. (2019, 09 14). *National Geographic*. Retrieved from Atmospheric pressure: https://www.nationalgeographic.org/encyclopedia/atmospheric-pressure/print/.

Nicol, F., Humphreys, M., & Roaf, S. (2012). *Adaptive Thermal Comfort: Principles and Practice.* London: Taylor and Francis group.

Oke, T. R. (1982). The Energetic Basis of the Urban Heat Island. *Royal Metorological Society*, 1-24.

Oliver, J. E. (2004). *Encyclopedia of World Climatology.* Dordrecht: Springer.

Parker, J., & Teekaram, A. (2005). *Wind-driven Natural Ventilation Systems.* Berkshire: BSRIA.

Passerini, F., Albatici, R., & Frattari, A. (2013). Quasi-steady state calculation method for energy contribution of sunspaces: a proposal for the European standard improvement. *Building Simulation Applications* (pp. 141–150). Bolzano: BSA 2013.

Perillo, G., Wolanski, E., Cahoon, D. R., & Hopkinson, C. S. (2019). *Coastal Wetlands An Integrated Ecosystem Approach.* Maryland Heights: Elsevier.

Peronato, G., Kämpf, H. J., Rey, E., & Anderson, M. (2017). Integrating urban energy simulation in a parametric environment: a Grasshopper interface for CitySim. *PLEA 2017 Edinburgh - Design to Thrive.* Edinburgh.

Peters, B., & Peters, T. (2018). *Computing the Environment: Digital Design Tools for Simulation and Visualisation of Sustainable Architecture.* New Jersey: John Wiley & Sons.

Pourvahidi, P., & Hancer, P. (2019). *Scrutinizing Solar Gain and Ventilation in Traditional Iranian Architecture Based on Graph Theory and Matrix Analysis.* Basel: Sustainability.

Rafferty, J. P. (2016, March 14). *Humid Continental Climate*. Retrieved from Britannica: https://www.britannica.com/science/humid-continental-climate.

Reis, J. (2017, April 24). *Sciencing*. Retrieved from What Is the Meaning of Tropical Climate?: https://sciencing.com/meaning-tropical-climate-8722483.html.

Rhea, P. (2001, July 25). *Polar Climates*. Retrieved from Lumen Learning: https://courses.lumenlearning.com/geophysical/chapter/polar-climates-group-e/.

Romeartlover. (2019, 09 08). *Romeartlover*. Retrieved from The Walls of Famagusta: http://romeartlover.tripod.com/Cipro1.html.

Rudlin, D., & Falk, N. (1999). *Building the 21st Century Home: The Sustainable Urban Neighbourhood.* Oxford: Architectural Press.

Sabnis, G. M. (2011). *Green Building with Concrete: Sustainable Design and Construction.* Florida: CRC Press.

Sadeghipour Roudsari, M., & Pak, M. (2013). Ladybug: a Parametric Environmental Plugin for Grasshopper to Help Designers Create an EnvironmentAlly-Conscios Design. *13th Conference of International Buildings Performance Simulation Association.* Chambery.

Sailor, D. J. (2011). A Review of Methods for Estimating Anthropogenic Heat and Moisture Emissions in the Urban Environment. *International Journal of Climatology*, 189-199.

Santamouris, M. (2014). On the Energy Ompact of Urban Heat Island and Global Warming on Buildings. *Energy and Buildings*, 100-113.

Sayigh, A. (2013). *Sustainability, Energy and Architecture: Case Studies in Realizing Green Buildings.* Oxford: Academic Press.

Seppänen, O., Brelih, N., Goeders, G., & Lițiu, A. (2012). *HealthVent Health-Based Ventilation Guidelines for Europe (Deliverable 5: Summary of European ventilation standards, their implementation and ventilation systems used in European buildings).* Brussels: European Union.

Shinichi, T., & Kenichi, K. (1994). Effects of air temperature, humidity, and air movement on thermal comfort under hot and humid conditions. *U.S. Department of Energy*.

Smith, M. P. (1992). *After Modernism: Global Restructuring and the Changing Boundaries of City Life.* New Jersey: Transaction Publishers.

Solecki, W. D., Rosenzweig, C., Parshall, L., Pope, G., Clarck, M., Cox, J., & Wiencke, M. (2005). Mitigation of the heat island effect in urban New Jersey. *lobal Environmental Change*, 39-49.

Staff, F. (2010, August 12). *Air Tempreture*. Retrieved from Environmetal Monitor: https://www.fondriest.com/news/airtemperature.htm.

Sullivan, P. O. (2003). *Passive Solar Energy in Buildings: Watt Committee: Report Number 17.* New York: Routledge.

Taleb, H. M. (2015). Natural Ventilation as Energy Efficient Solution for Achieving Low-Energy Houses in Dubai. *Energy and Building*, 284-291.

Thomas, W. D., & Duffy, J. J. (2013). Energy Performance of Net-zero and Near Net-zero Energy Homes in New England. *Energy and Buildings*, 551-558.

Thullner, K. (2010). *Low-Energy Buildings in Europe - Standards, Criteria and Consequences.* Lund: Lund University.

Tu, J., Yeoh, G. H., & Liu, C. (2012). *Computational Fluid Dynamics: A Practical Approach.* Oxford: Butterworth-Heinemann.

United Nations Economic Commission for Europe. (2018). *Mapping of Existing Energy Efficiency Standards and Technologie in Building in the UNECE Region.* Geneva: UNECE.

VanGeem, M. G. (2016, 10 24). *REnergy Codes and Standards*. Retrieved from Whole Building Design Guide: https://www.wbdg.org/resources/energy-codes-and-standards.

Venkatarama Reddy, B. V., & Jagadish, K. S. (2003, February). Embodied energy of common and alternative building materials and technologies. *Energy and Building, 35*(2), 129-137. Retrieved from https://doi.org/10.1016/S0378-7788(01)00141-4.

Walsh, M. J., Edbury, P. W., & Coureas, N. S. (2012). *Medieval and Renaissance Famagusta: Studies in Architecture, Art and History.* Surrey: Ashgate.

Walsh, M. J., Kiss, T., & Coureas, N. S. (2014). *The Harbour of all this Sea and Realm: Crusader to Venetian Famagusta.* Budapest: Central European University Press.

Ward, S. V. (2004). *Planning and Urban Change.* Thousand Oaks: SAGE Publishing.

Wiel, S., & McMahon, J. E. (2003, October). Governments should implement energy-efficiency standards and labels—cautiously. *Energy Policy, 31*(13), 1403-1415.

Wight, B. (1988). Farmstead windbreaks. *Agriculture, Ecosystems & Environment, 22-23*, 261-280.

Williamson, T., Radford, A., & Bennetts, H. (2003). *Understanding Sustainable Architecture.* London: Spon Press.

Wong, N. H., & Heyanto, S. (2004). The Study of Active Stack Effect to Enhance Natural Ventilation Using Wind Tunnel and Computational Fluid Dynamics (CFD) Simulations. *Energy and Buildings*, 668-678.

Yang, L., & Xinyi, Z. (2012). An Empirical Study of the Impact of Human Activity on Long-Term Temperature Change in China: A Perspective from Energy Consumption. *Journal of Geophysical Research Atmospheres*.

Yap, E. H. (2017). *Energy Efficient Buildings.* Norderstedt: BoD – Books on Demand.

APPENDICES

Appendix 1: Simulation Software Technical Explanation

Figure 43 create the guidance to be followed based on their preference in simulation software but the steps will be same.at the beginning the weather data input is mandatory and comfortable period time table will be extracted after analyzing the climate condition. The wind analysis also illustrates needed information such as: wind temperature, prevailing wind direction, and wind speed which are important for calculation process. In this study the software and each plugin which has been used step by step is clarified. Wind mask calculation based on weather data outcome and nearby built environment with the limit of wind tunnel is going to be the next step. The information from weather file, wind mask, and design project will prepare the base for wind analysis will input to energy calculation software at the end in order to have energy analysis. Grasshopper is a visual programming language and environment that runs within the Rhinoceros 3D computer-aided design application. Grasshopper is primarily used to build generative algorithms, such as for generative art. Many of Grasshopper's components create 3D geometry. Programs may also contain other types of algorithms including numeric, textual, audio-visual and haptic applications. Advanced uses of Grasshopper include parametric modelling for structural engineering, parametric modelling for architecture and fabrication, lighting performance analysis for eco-friendly architecture and building energy consumption (Peronato, Kämpf, Rey, & Anderson, 2017). For the CFD simulation software in this study grasshopper as the open source program seems suitable. Figure 78 represent different tools for grasshopper and the relation between them and also with supportive software. These relations illustrate the systematic approach for Figure 43.

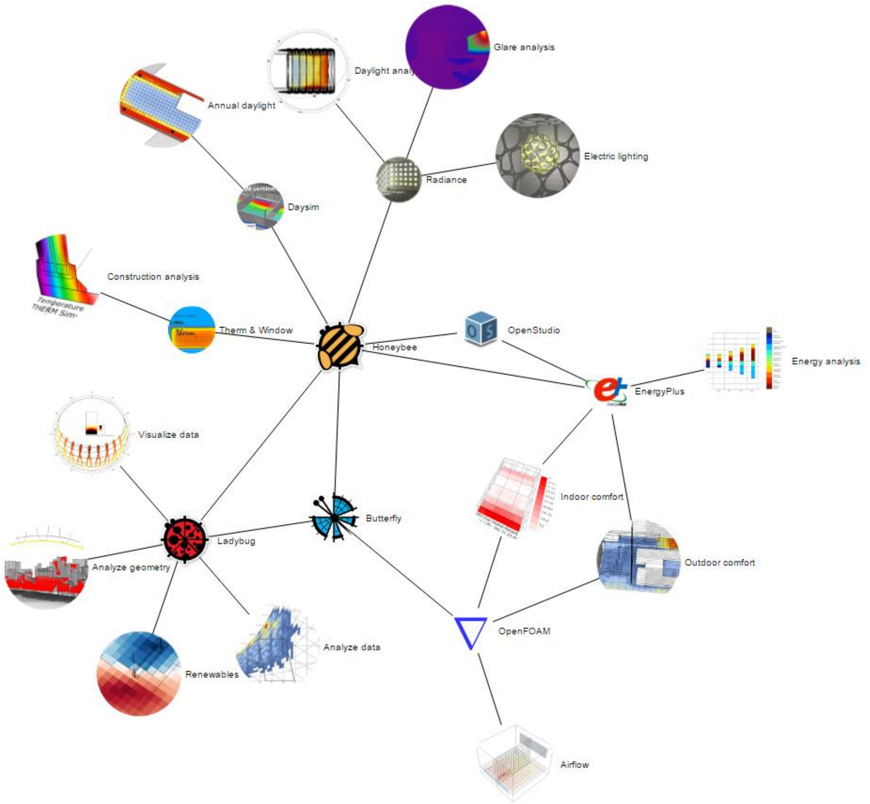


Figure 78: Grasshopper plugins relation (Static.food4rhino.com).

Ladybug Tools is a collection of free computer applications that support environmental design and education. Of all the available environmental design software packages, Ladybug Tools is among the most comprehensive, connecting 3D Computer-Aided Design (CAD) interfaces to a host of validated simulation engines. This plugin creates the opportunity to have access to the updated mainframe which everyone can download the related weather data file for any location they need (Sadeghipour Roudsari & Pak, 2013). With this plugin general climate data analysis will be simulated and it is possible to export them as a graphical chart, thus it can cover the weather data needs and analysis which create basic climate condition information for strategy selection can cover with ladybug plugin (Figure 79).

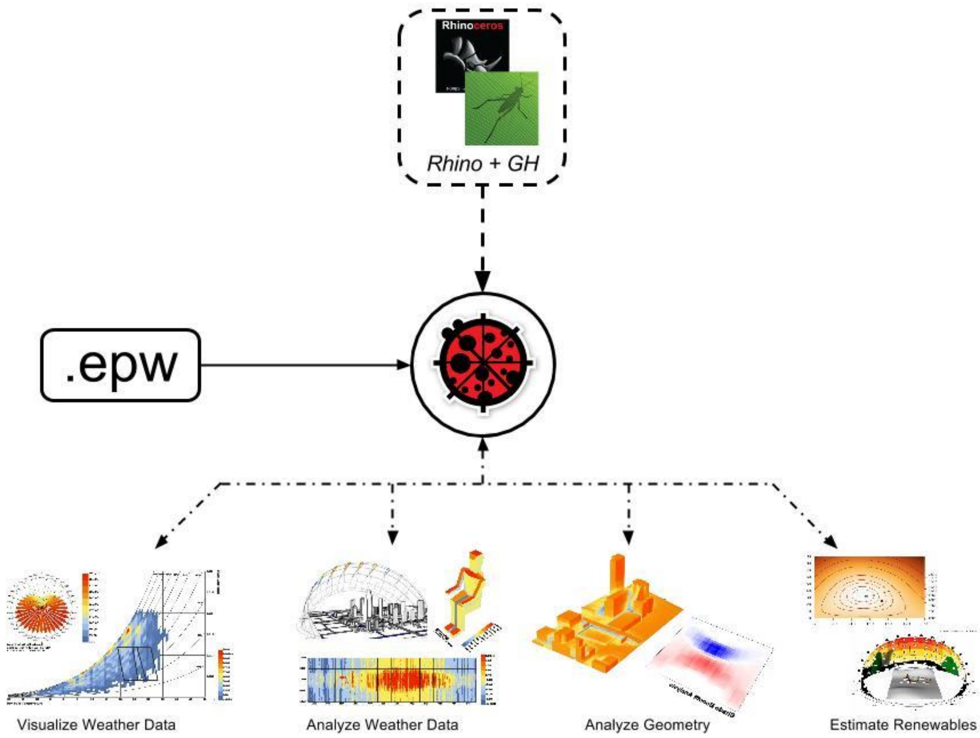


Figure 79: Grasshopper Ladybug Plugin (Static.food4rhino.com).

Honeybee supports detailed daylighting and thermodynamic modeling that tends to be most relevant during mid and later stages of design. Specifically, it creates, runs and visualizes the results of daylight simulations using Radiance, energy models using Energy Plus, Open Studio, and heat flow through construction details using Berkeley Lab Therm. It accomplishes this by linking these simulation engines to CAD and visual scripting interfaces such as Grasshopper and Dynamo/Revit plugins. It also serves as an object-oriented Application Programming Interface (API) for these engines. For this reason, Honeybee is one of the most comprehensive plugins presently available for environmental design, so the design condition can be clarifying by honeybee components and be prepared for next step (Figure 80).

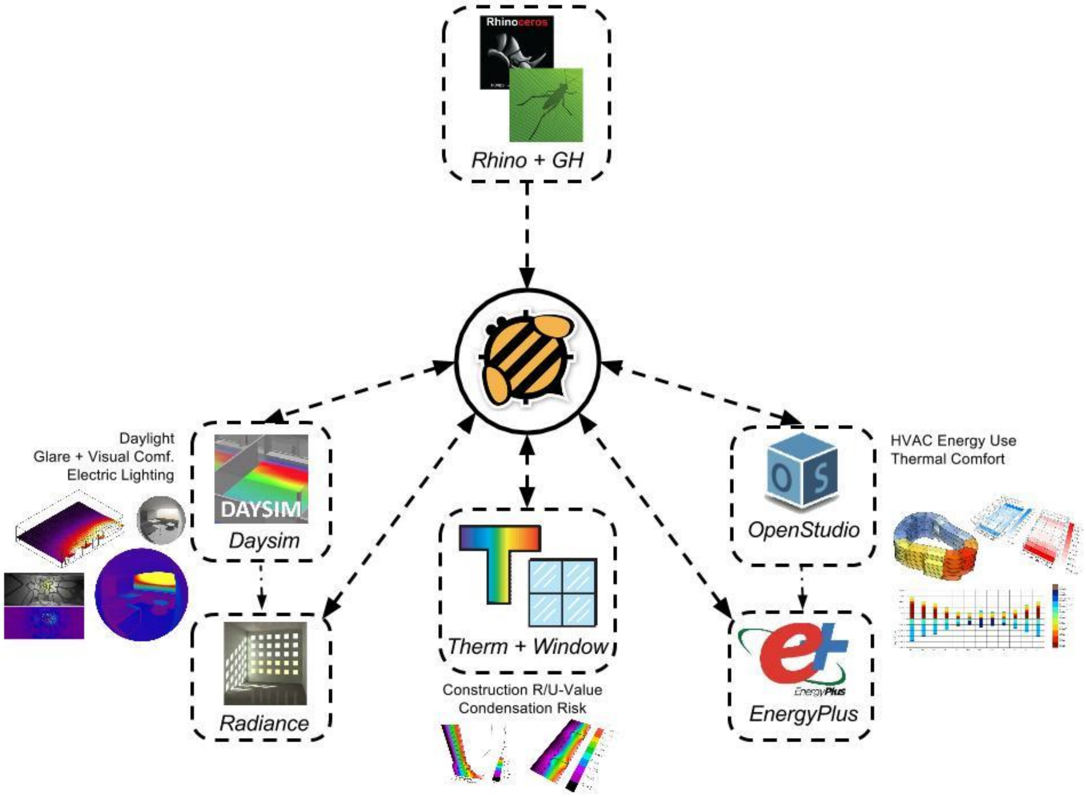


Figure 80: Grasshopper Honeybee Plugin (Static.food4rhino.com).

Butterfly is a Grasshopper/Dynamo plugin and object-oriented python library that creates and runs computational fluid dynamics (CFD) simulations using Open FOAM. At the present time, Open FOAM is the most rigorously-validated open source CFD engine in existence and is capable of running several advanced simulations and turbulence models. Butterfly is built to quickly export geometry to Open FOAM and run several common types of airflow simulations that are useful to building design. This includes outdoor simulations to model urban wind patterns, indoor buoyancy-driven simulations to model thermal comfort and ventilation effectiveness, and much more. Butterfly is going to take care of wind analysis and air flow in the calculation process. Scripting segments fill in as an incorporated of GH file. They can get info and produce harvest from and to other standard GH parts. They can be utilized to make specific practicality that opens up colossal potential past the standard parts. In any case, the GH Python part bolsters Rhino Script Syntax capacities. The Rhino Script Syntax capacities can be set to produce geometry within Grasshopper that doesn't live in the Rhino archive (Davidson, 2019).

On the left side of each component in grasshopper there are several numbers of pines according to the formula input data requirement which are categorized into three different types. Firs category has dash line located on the left side of the pin name which means the data is mandatory for the formula and it should be attached. The second type is having dash line on both side of the pin name which means it is recommended to have the input information for the specific panel and if the dash line located on the right side means it is optional to have the data. The middle line that normally contains the panel that displays the component calculation formula. The right side after the mathematical equation represents the measured performance data exported to the operator from the method to be able to use them depending on the need for the rest of the process. Calculate the percentage of thermal comfort for the time span picked. In this section the important factor is to properly determine the quality of clothing based on the data exported. For final measurement from the Energy Plus results list, dry bulb temperature, relative humidity, mean radiant temperature, and wind speed are attached to the associated pins. After the calculation, biometric pressure is also defined, and several outcomes are to be exported from which usefulness and percentage of indoor thermal comfort are gathered as the main results.

Appendix 2: Simulation Result in Detail

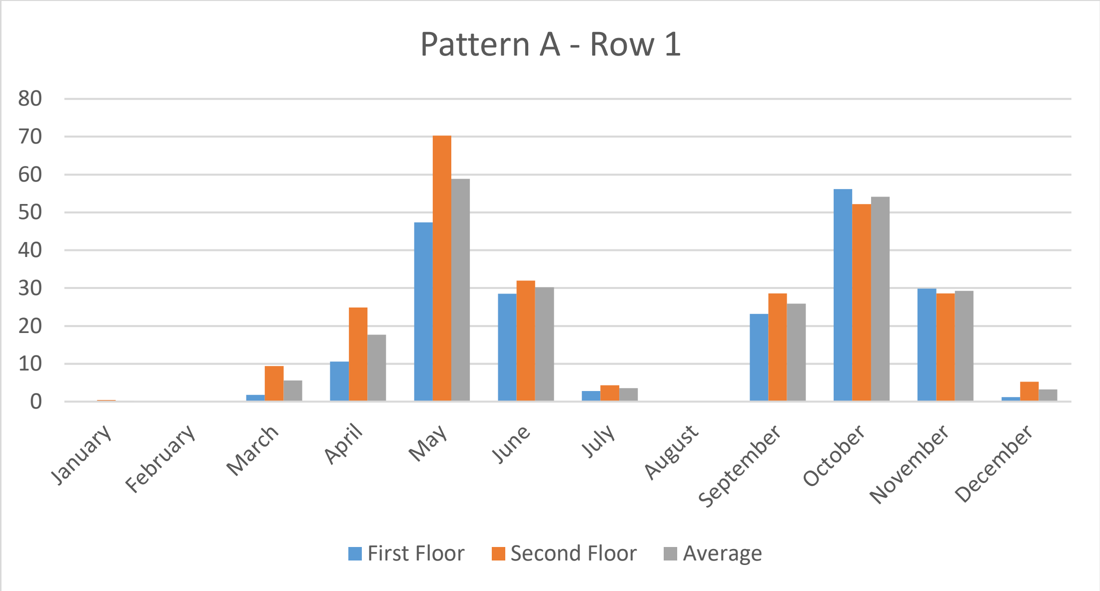


Figure 81: Pattern A, 2-story building, row 1 monthly result (Exported from grasshopper based on energy plus calculation).

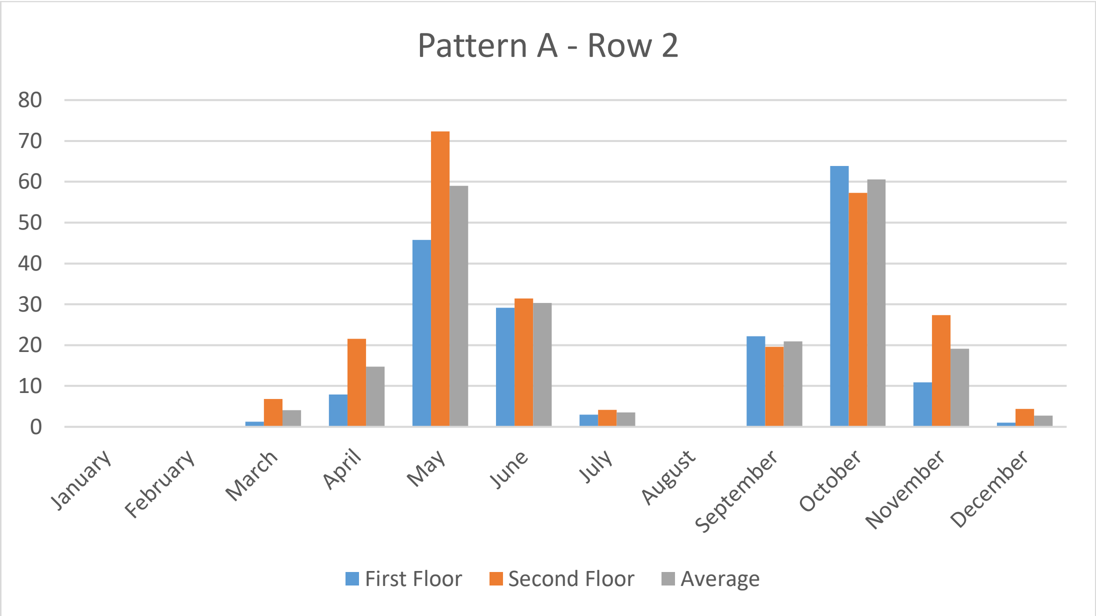


Figure 82: Pattern A, 2-story building, row 2 monthly result (Exported from grasshopper based on energy plus calculation).

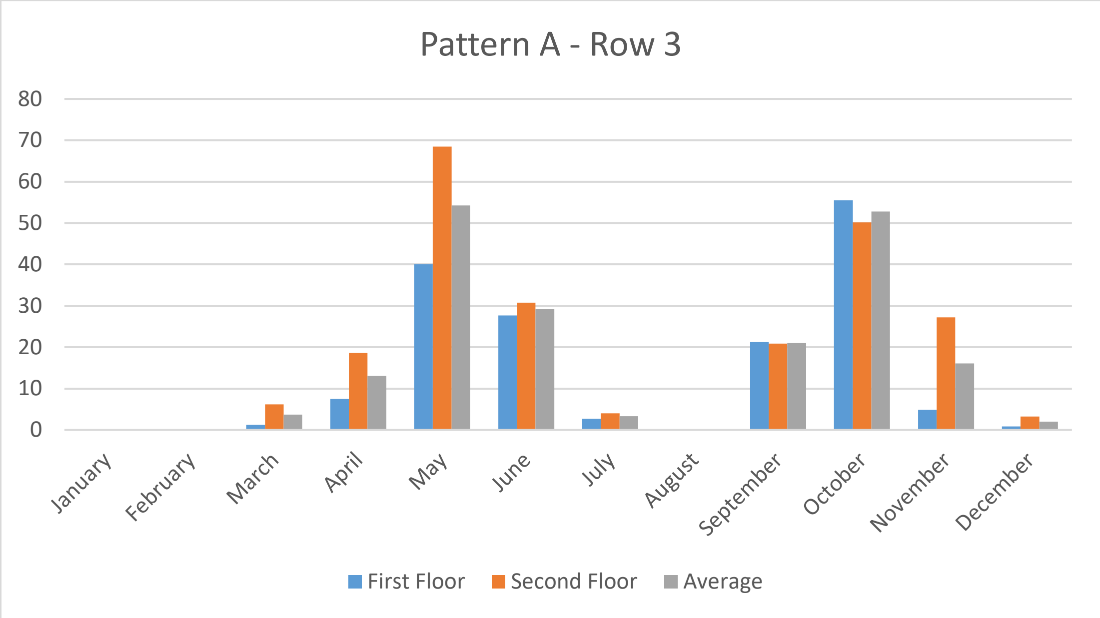


Figure 83: Pattern A, 2-story building, row 3 monthly result (Exported from grasshopper based on energy plus calculation).

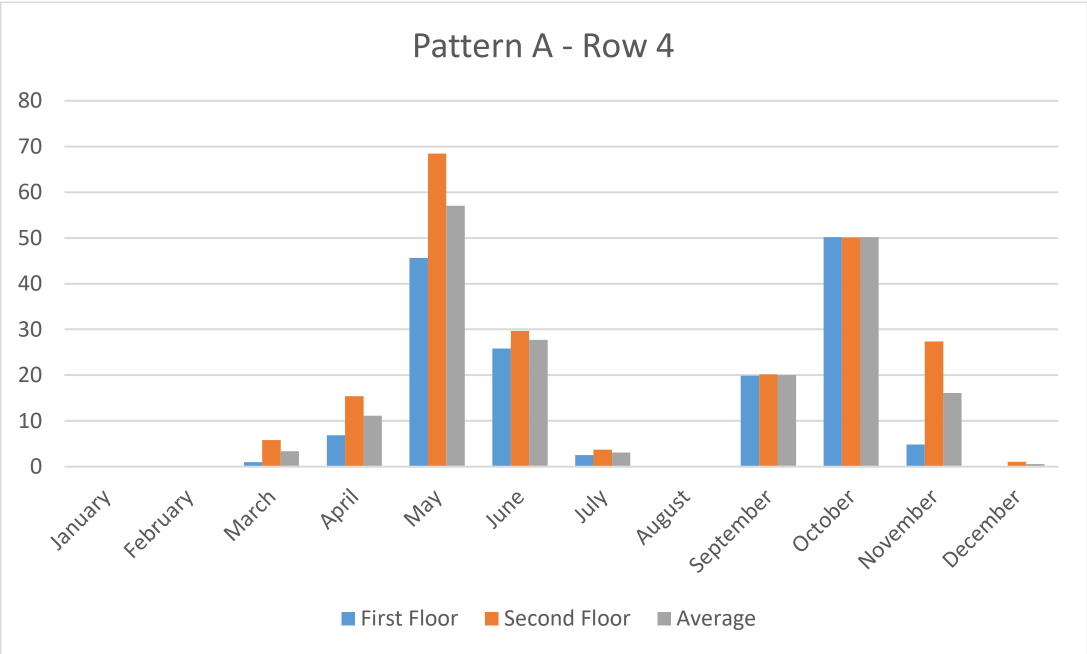


Figure 84: Pattern A, 2-story building, row 4 monthly result (Exported from grasshopper based on energy plus calculation).

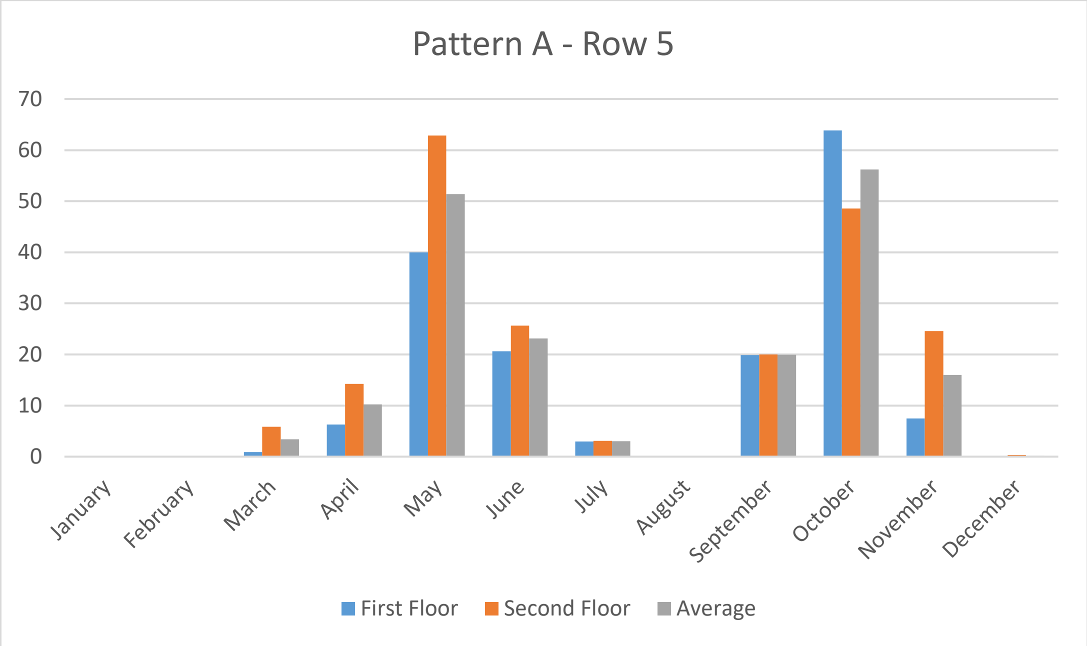


Figure 85: Pattern A, 2-story building, row 5 monthly result (Exported from grasshopper based on energy plus calculation).

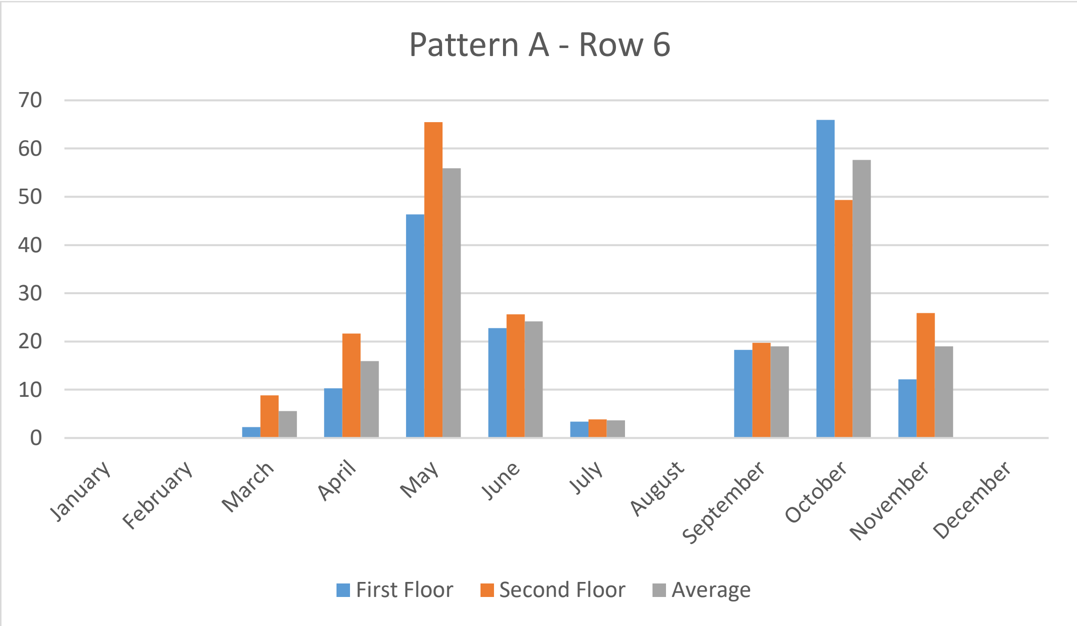


Figure 86: Pattern A, 2-story building, row 6 monthly result (Exported from grasshopper based on energy plus calculation).

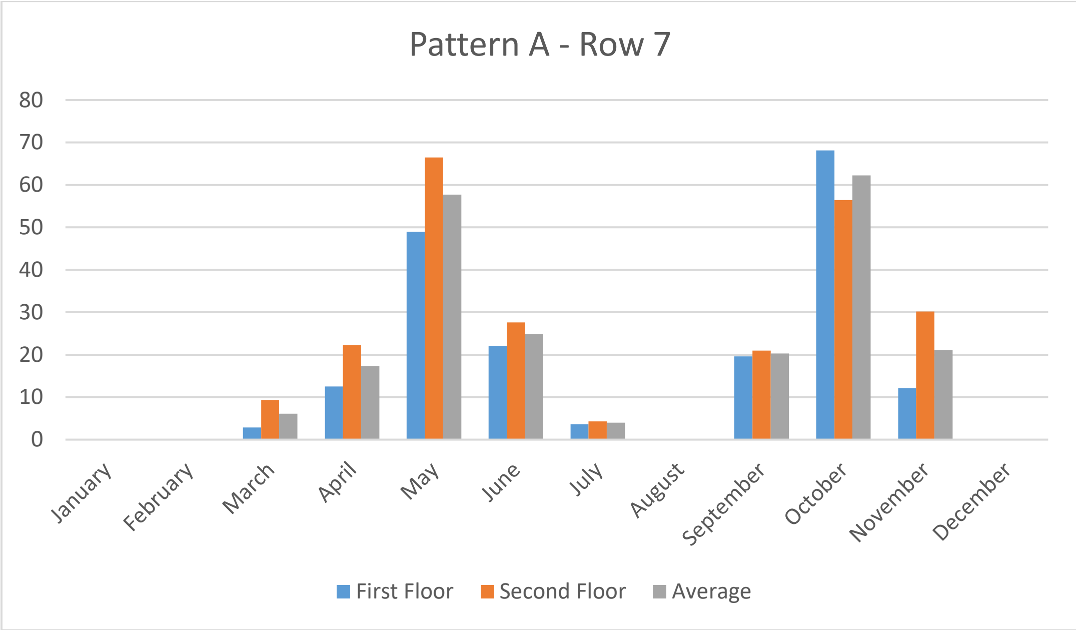


Figure 87: Pattern A, 2-story building, row 7 monthly result (Exported from grasshopper based on energy plus calculation).

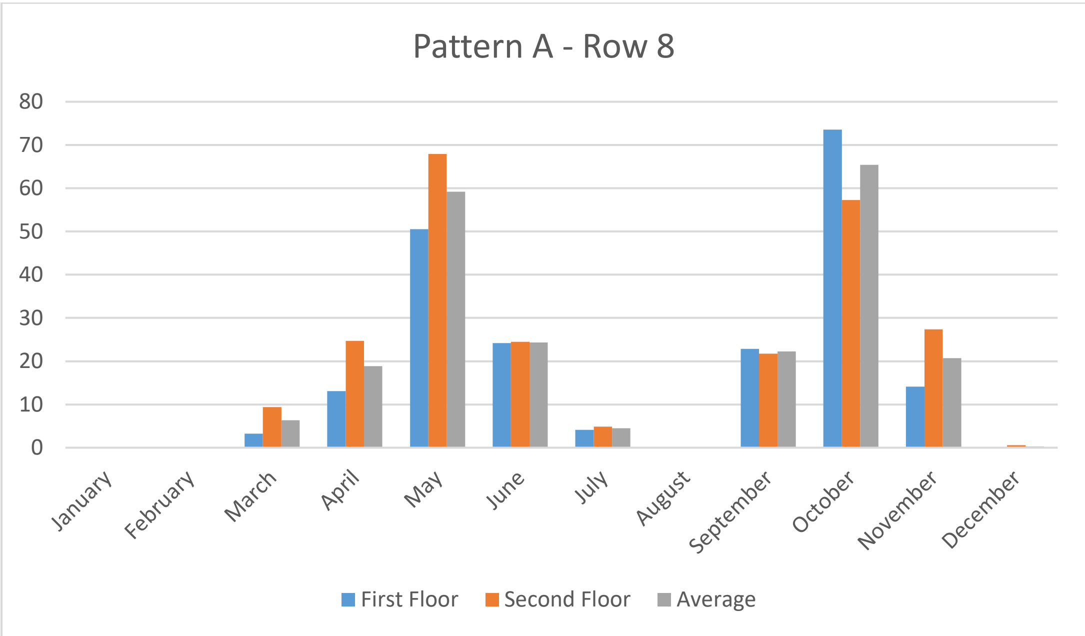


Figure 88: Pattern A, 2-story building, row 8 monthly result (Exported from grasshopper based on energy plus calculation).

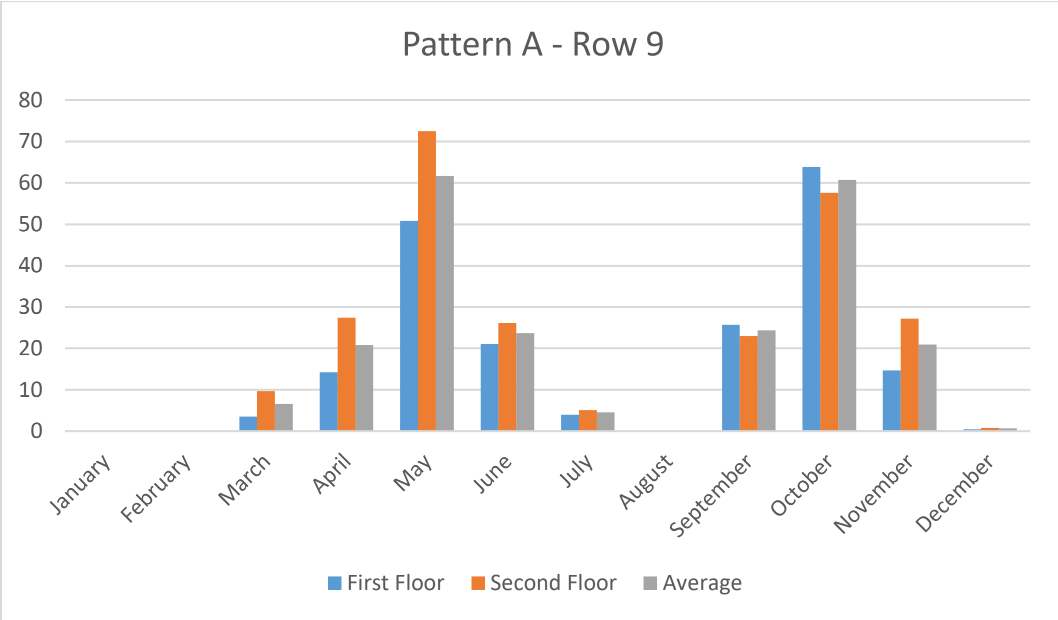


Figure 89: Pattern A, 2-story building, row 9 monthly result (Exported from grasshopper based on energy plus calculation).

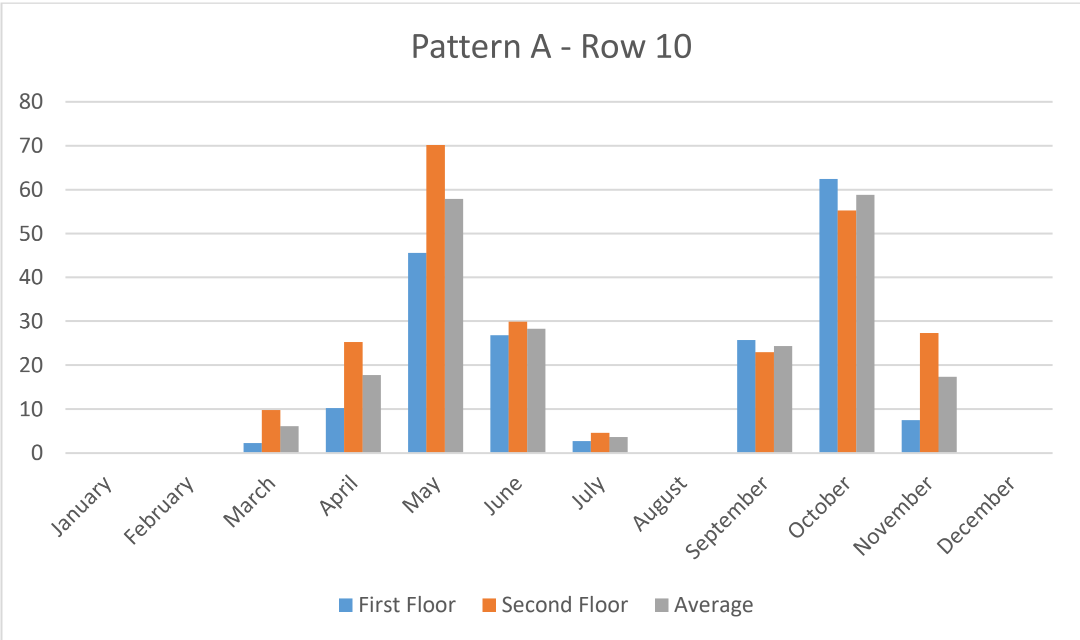


Figure 90: Pattern A, 2-story building, row 10 monthly result (Exported from grasshopper based on energy plus calculation).

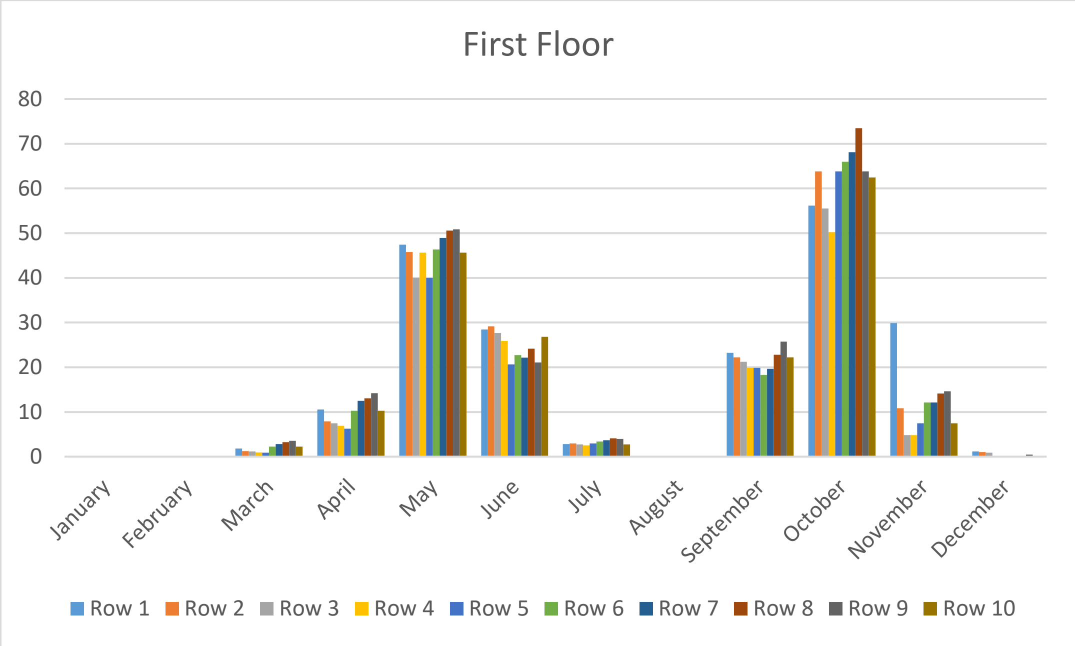


Figure 91: Pattern A, 2-story building, all rows in month, first floor detail (Exported from grasshopper based on energy plus calculation).

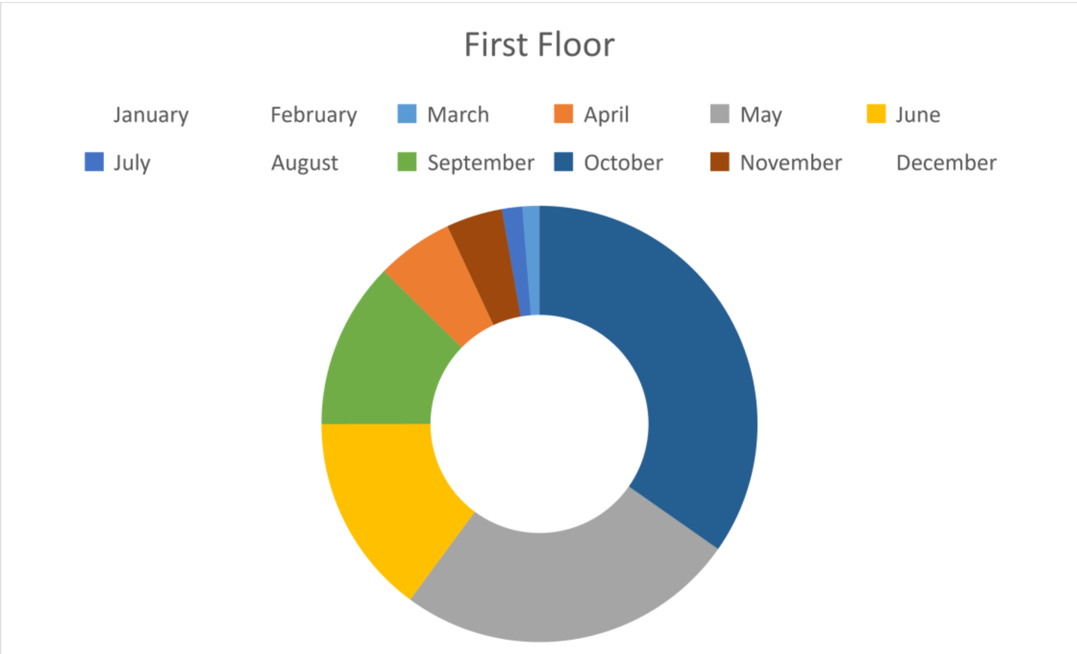


Figure 92: Pattern A, 2-story building, all rows in month, first floor (Exported from grasshopper based on energy plus calculation).

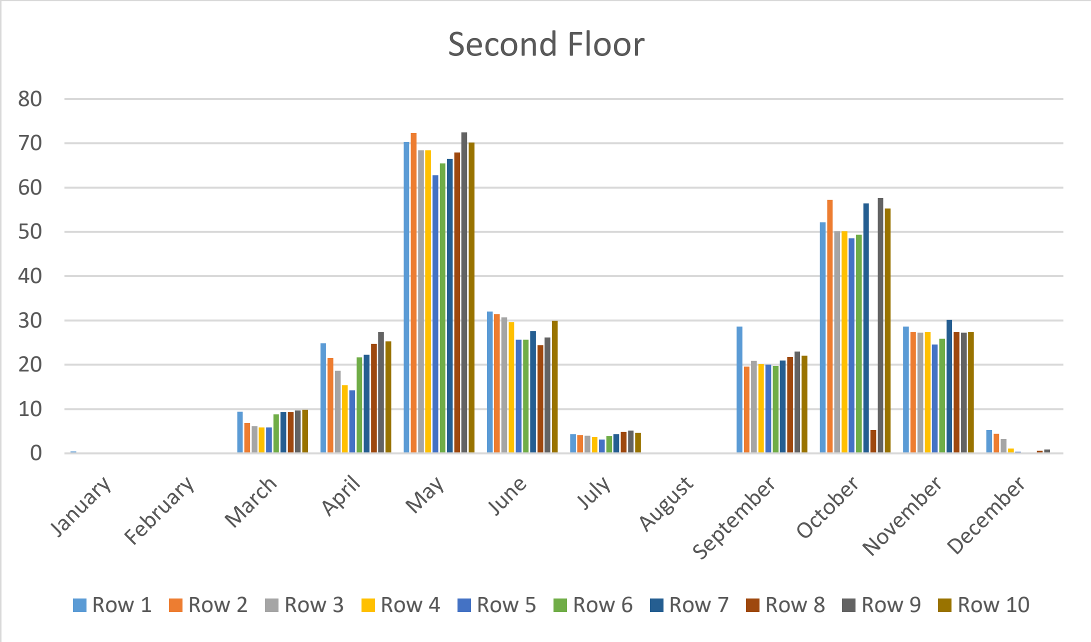


Figure 93: Pattern A, 2-story building, All rows in month, Second floor detail (Exported from grasshopper based on energy plus calculation).

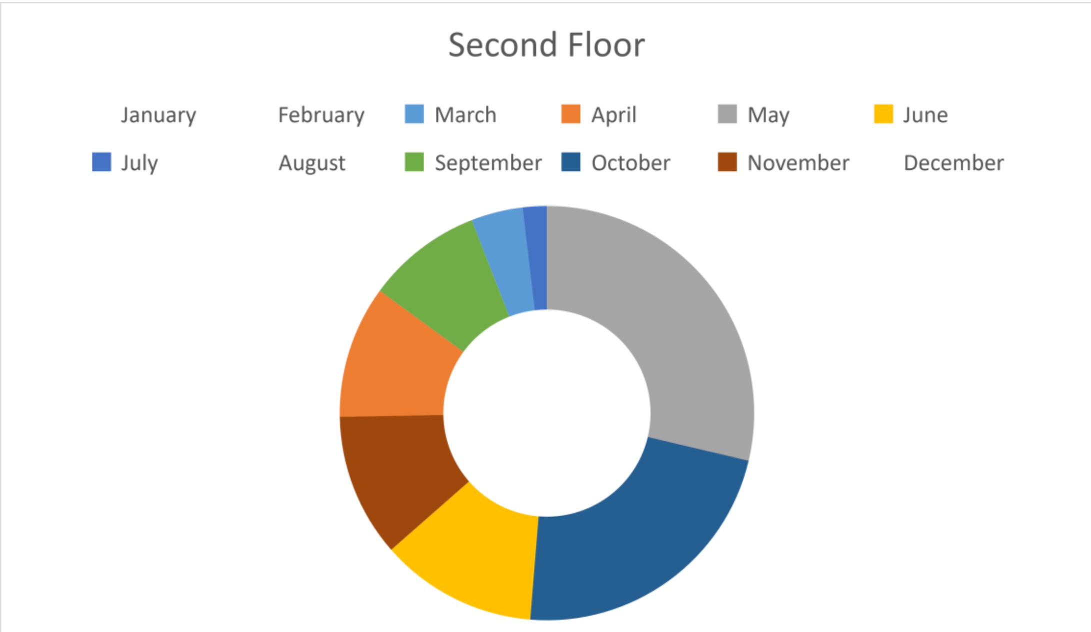


Figure 94: Pattern A, 2-story building, all rows in month, Second floor (Exported from grasshopper based on energy plus calculation).

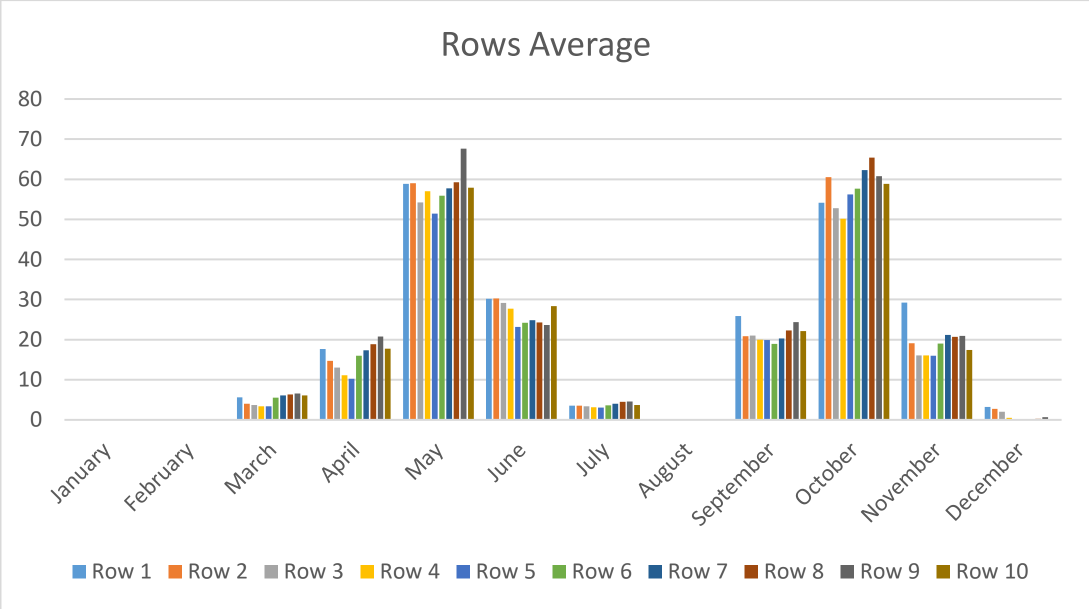


Figure 95: Pattern A, 2-story building, all rows in month, average detail (Exported from grasshopper based on energy plus calculation).

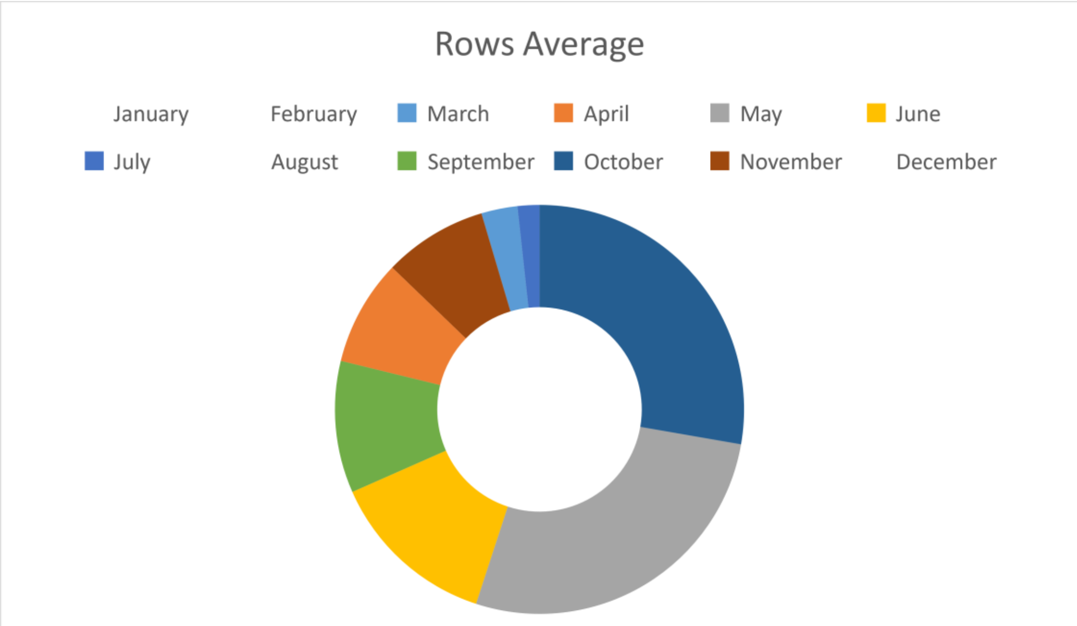


Figure 96: Pattern A, 2-story building, all rows in month, average (Exported from grasshopper based on energy plus calculation).

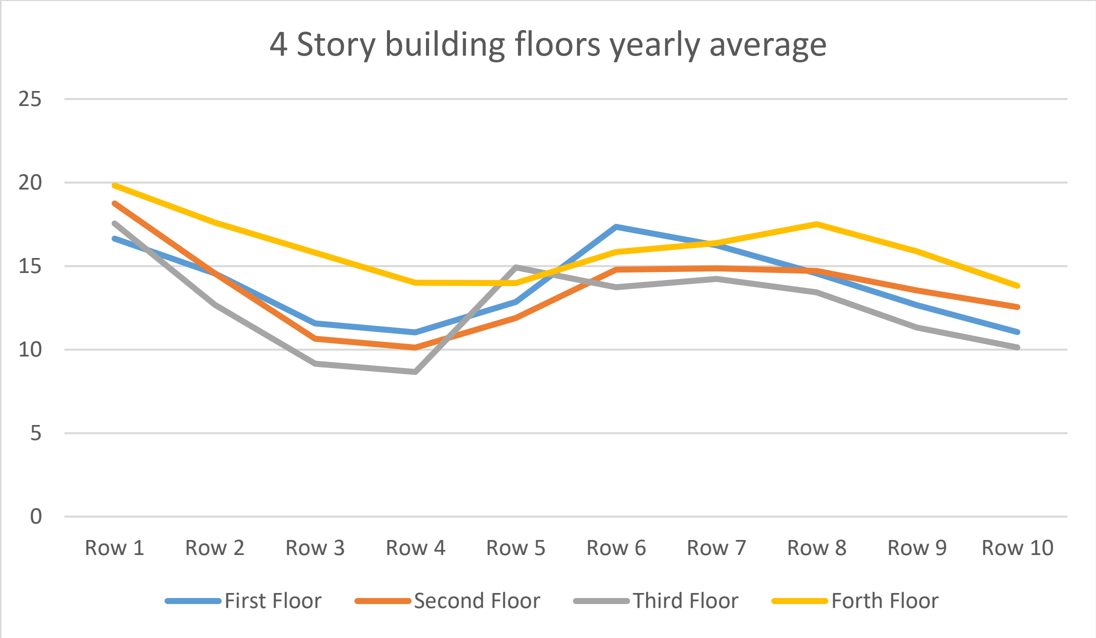


Figure 97: Pattern A, yearly average for each floor in 4-story building (Exported from grasshopper based on energy plus calculation).

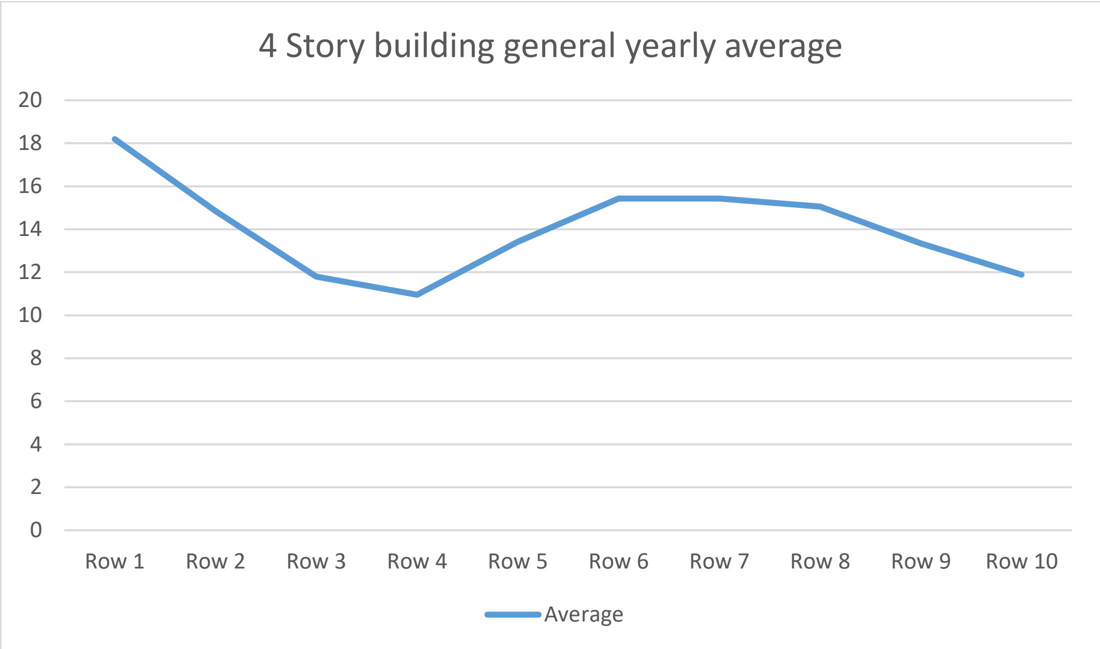


Figure 98: Pattern A, yearly average 4-story building (Exported from grasshopper based on energy plus calculation).

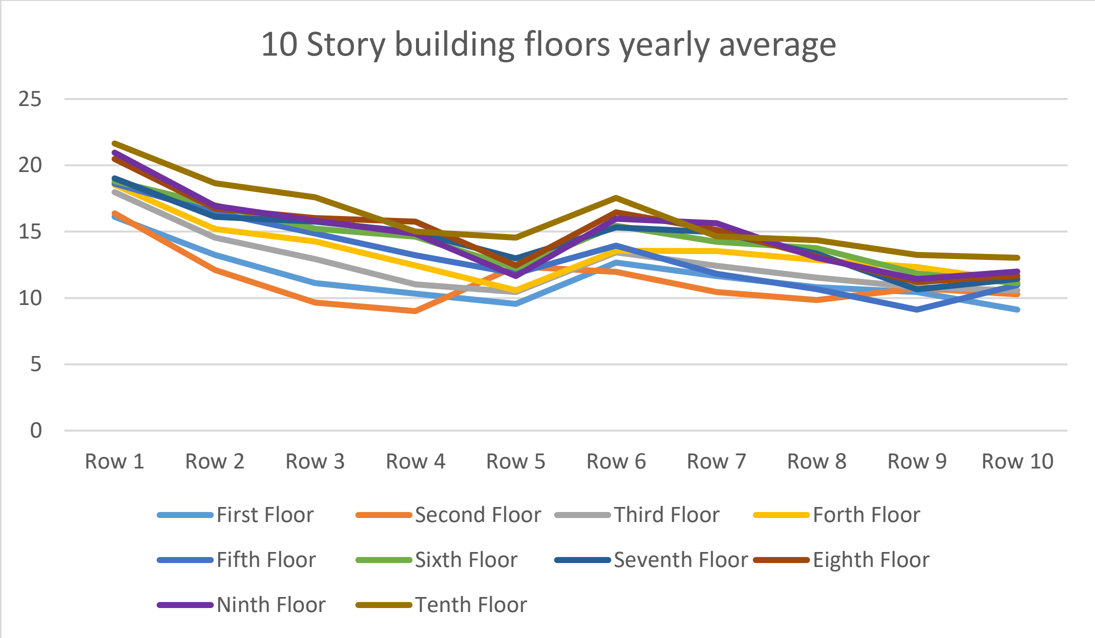


Figure 99: Pattern A, yearly average for each floor in 10-story building (Exported from grasshopper based on energy plus calculation).

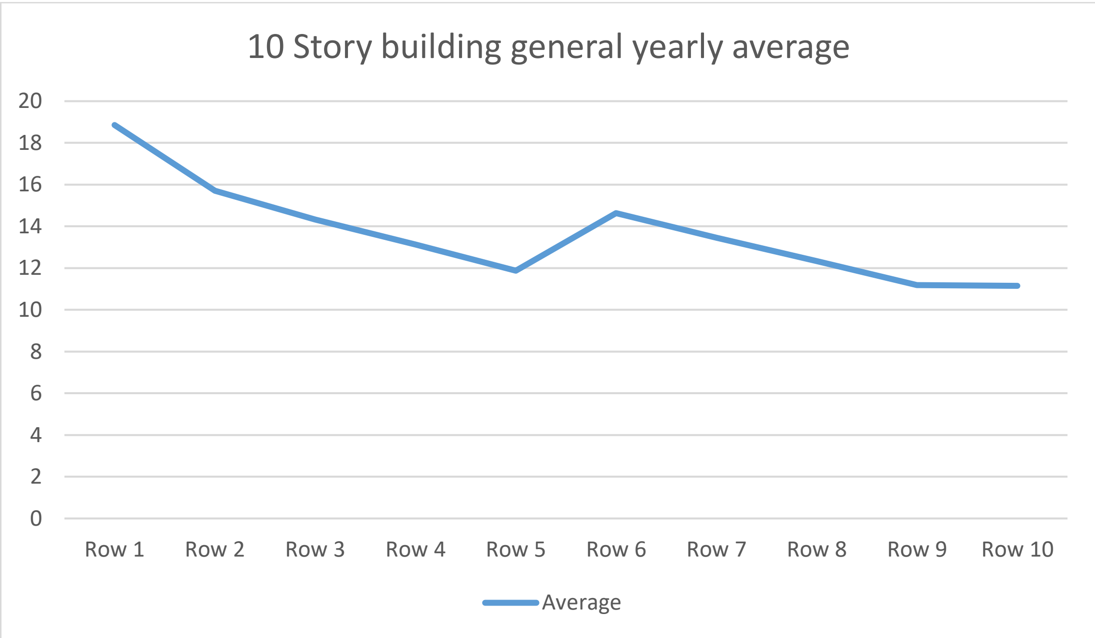


Figure 100: Pattern A, yearly average 10-story building (Exported from grasshopper based on energy plus calculation).

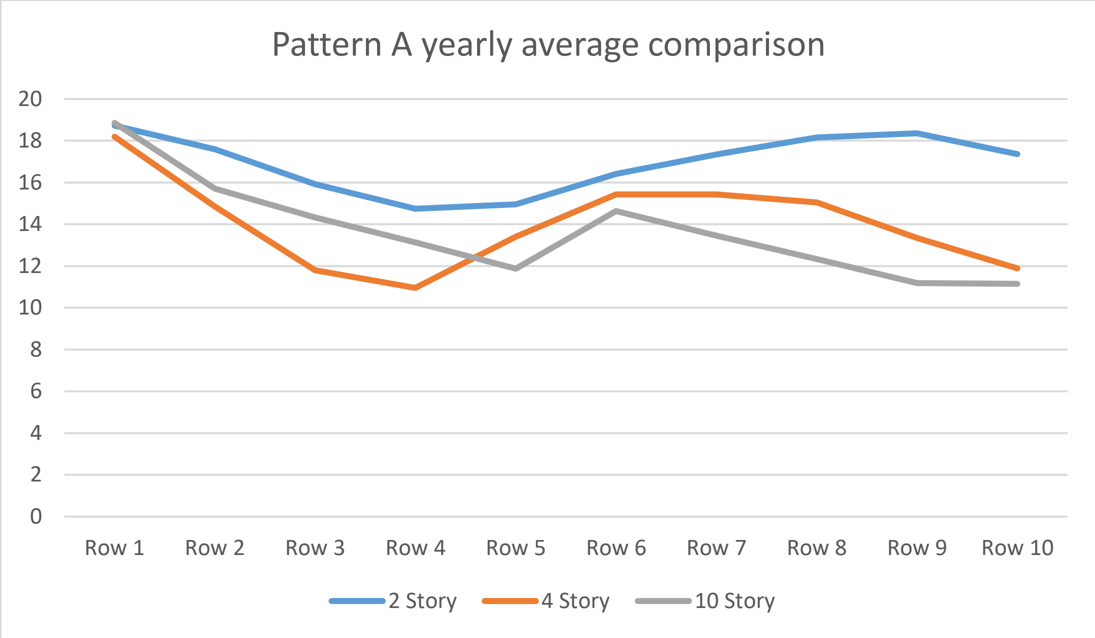


Figure 101: Comparison between all categories for pattern A base on row (Exported from grasshopper based on energy plus calculation).

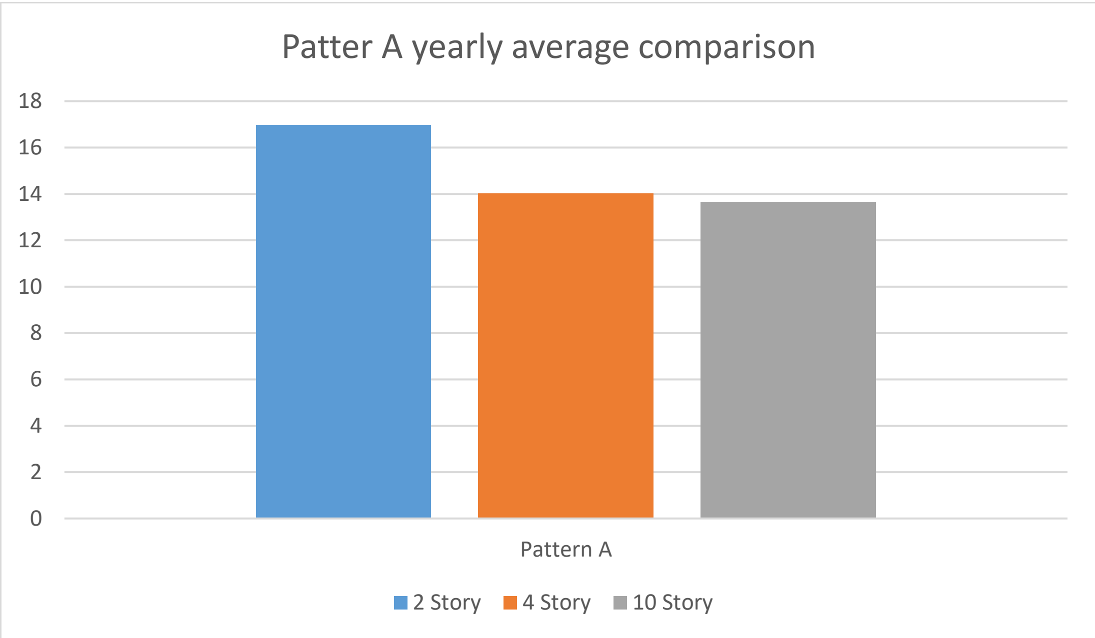


Figure 102: Comparison between all categories for pattern A (Exported from grasshopper based on energy plus calculation).

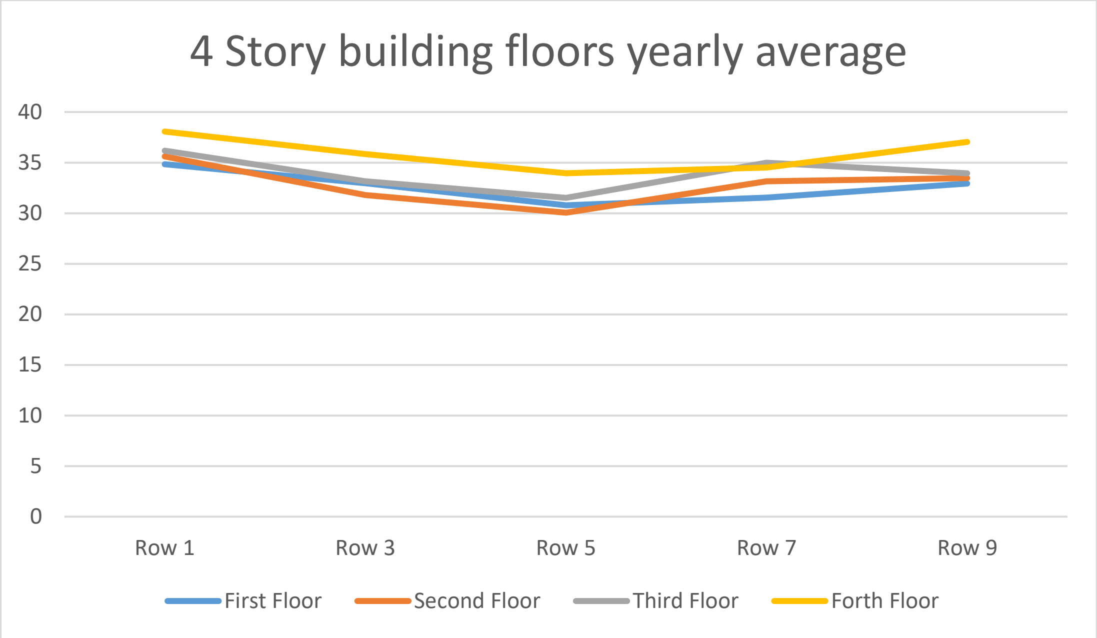


Figure 103: Pattern B, yearly average for each floor in 4-story building (Exported from grasshopper based on energy plus calculation).

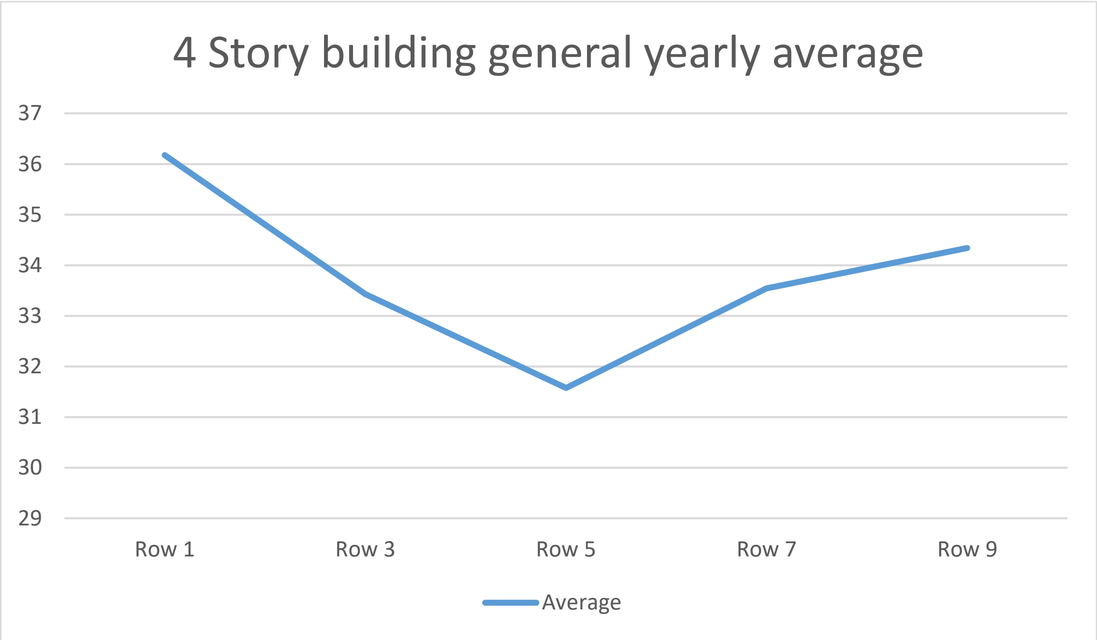


Figure 104: Pattern B, yearly average 4-story building (Exported from grasshopper based on energy plus calculation).

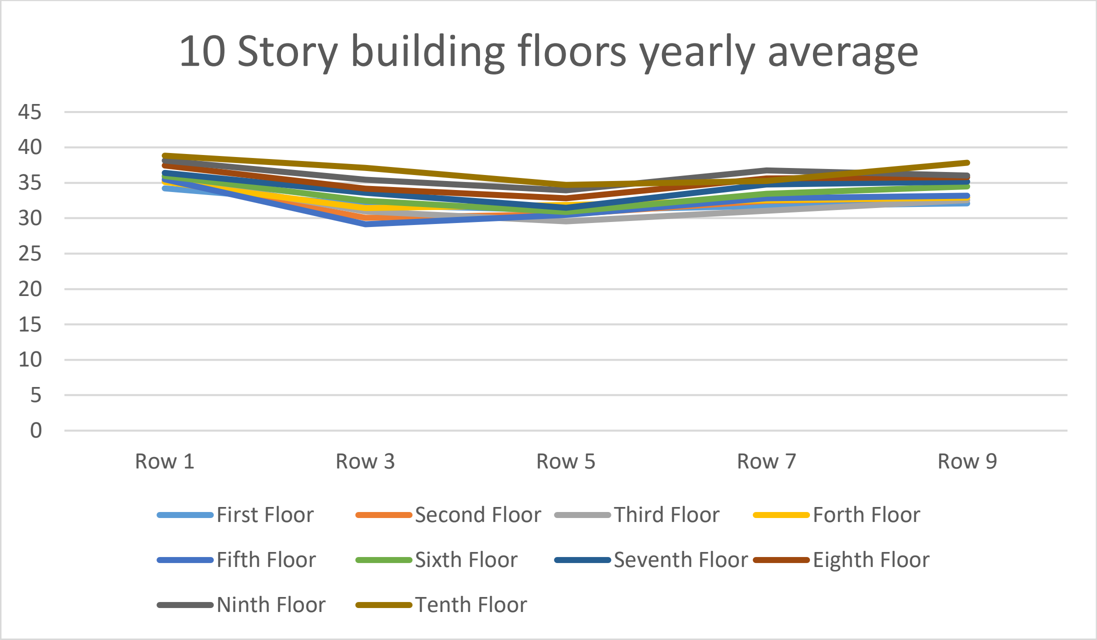


Figure 105: Pattern B, yearly average for each floor in 10-story building (Exported from grasshopper based on energy plus calculation).

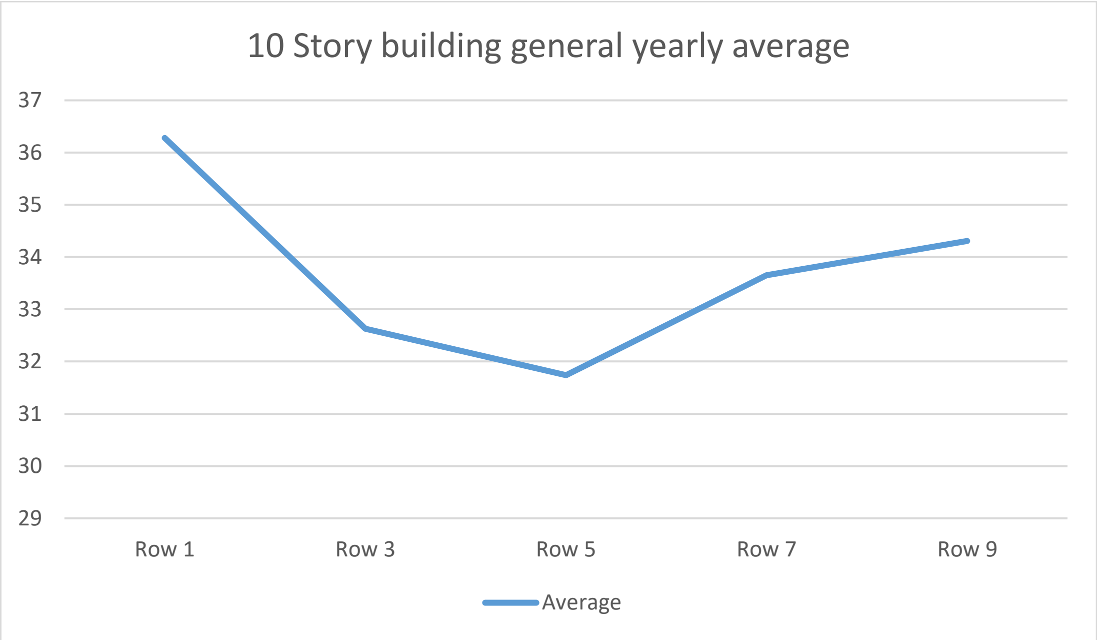


Figure 106: Pattern B yearly average 10-story building (Exported from grasshopper based on energy plus calculation).

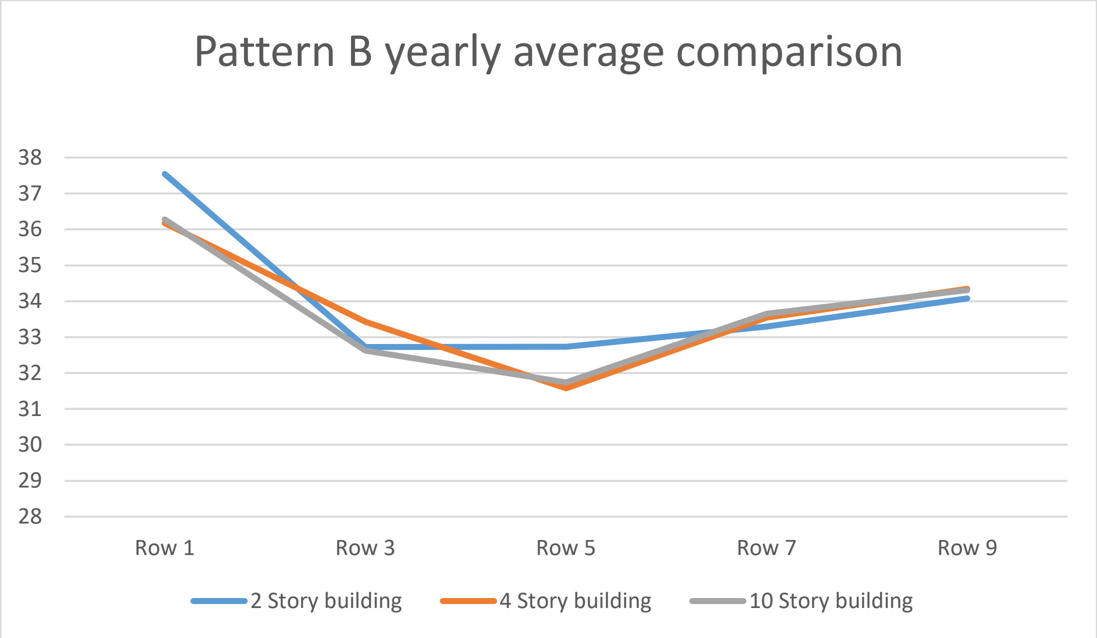


Figure 107: Comparison between all categories for pattern B based on row (Exported from grasshopper based on energy plus calculation).

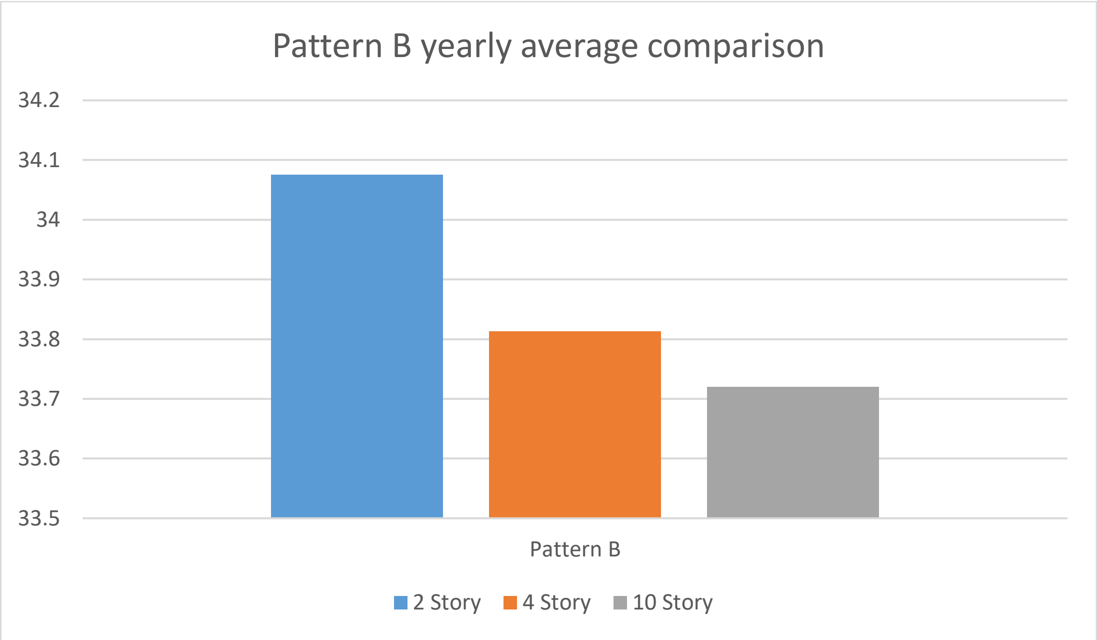


Figure 108: Comparison between all categories for pattern B (Exported from grasshopper based on energy plus calculation).

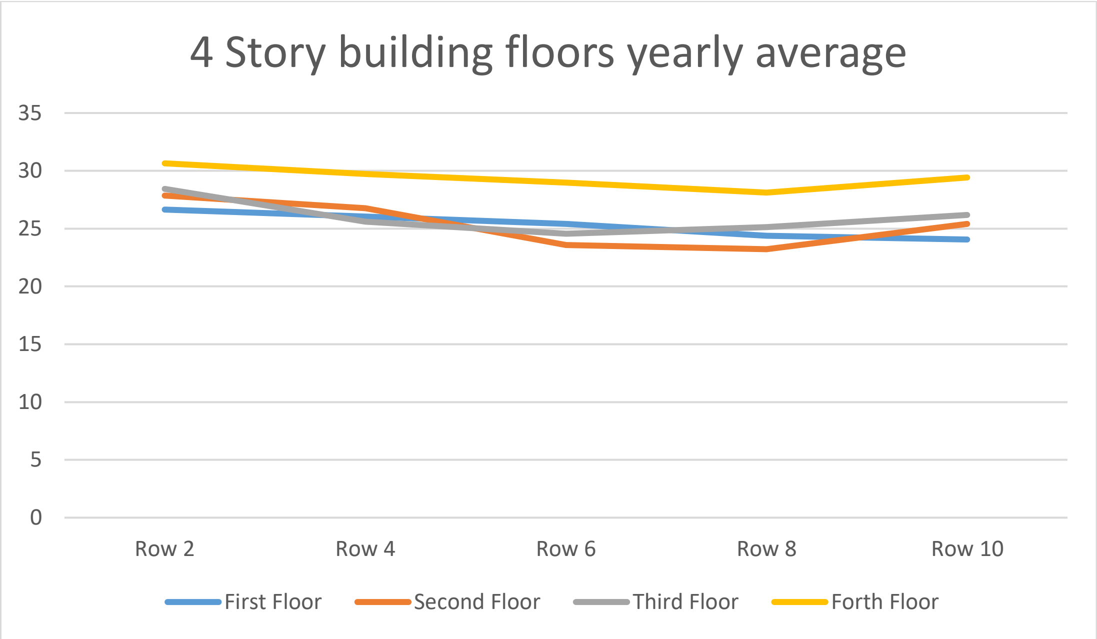


Figure 109: Pattern C, yearly average for each floor in 4-story building (Exported from grasshopper based on energy plus calculation).

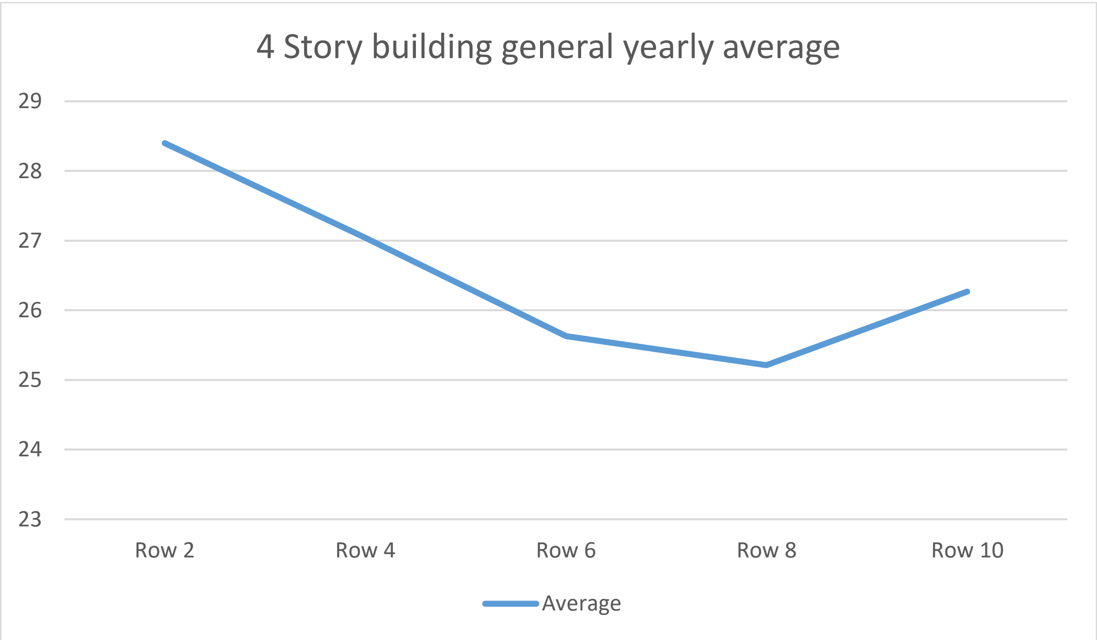


Figure 110: Pattern C, yearly average 4-story building (Exported from grasshopper based on energy plus calculation).

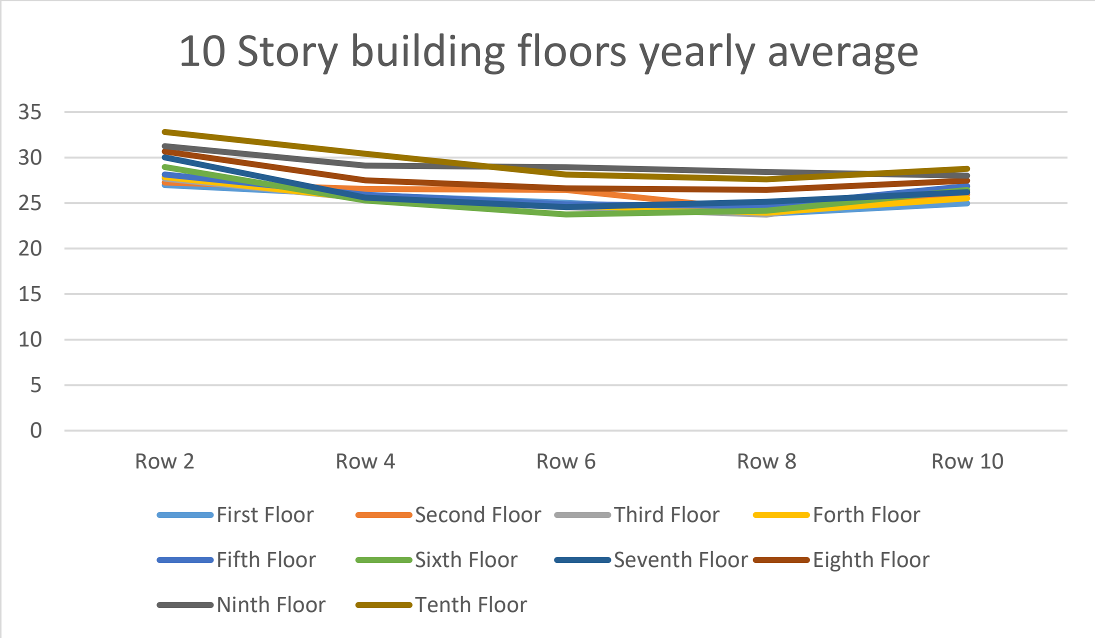


Figure 111: Pattern C, yearly average for each floor in 10-story building (Exported from grasshopper based on energy plus calculation).

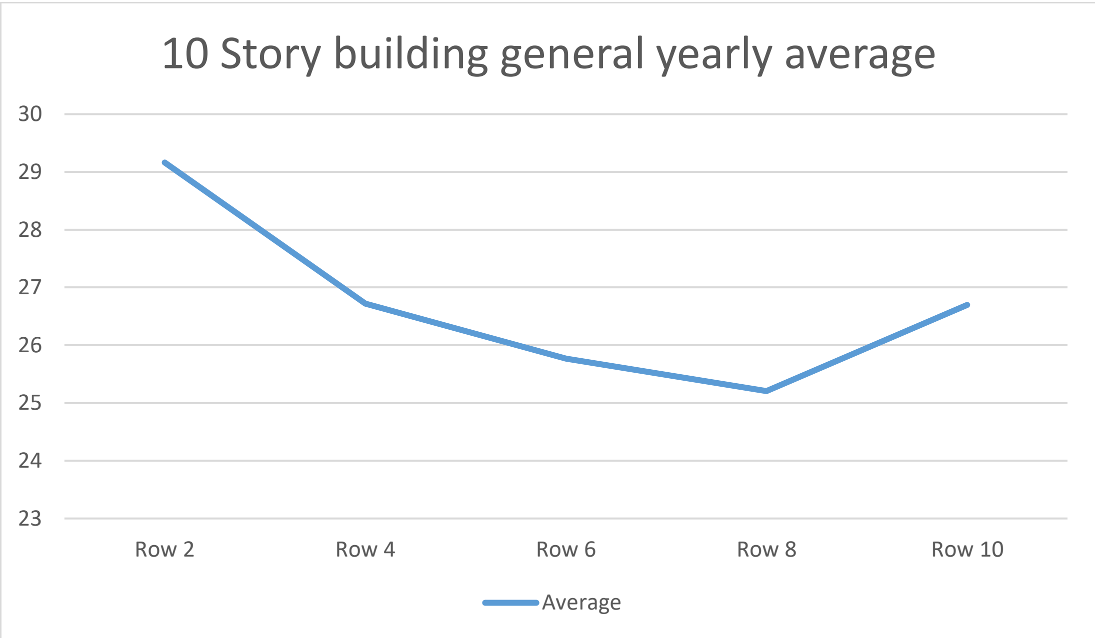


Figure 112: Pattern C yearly average 10-story building (Exported from grasshopper based on energy plus calculation).

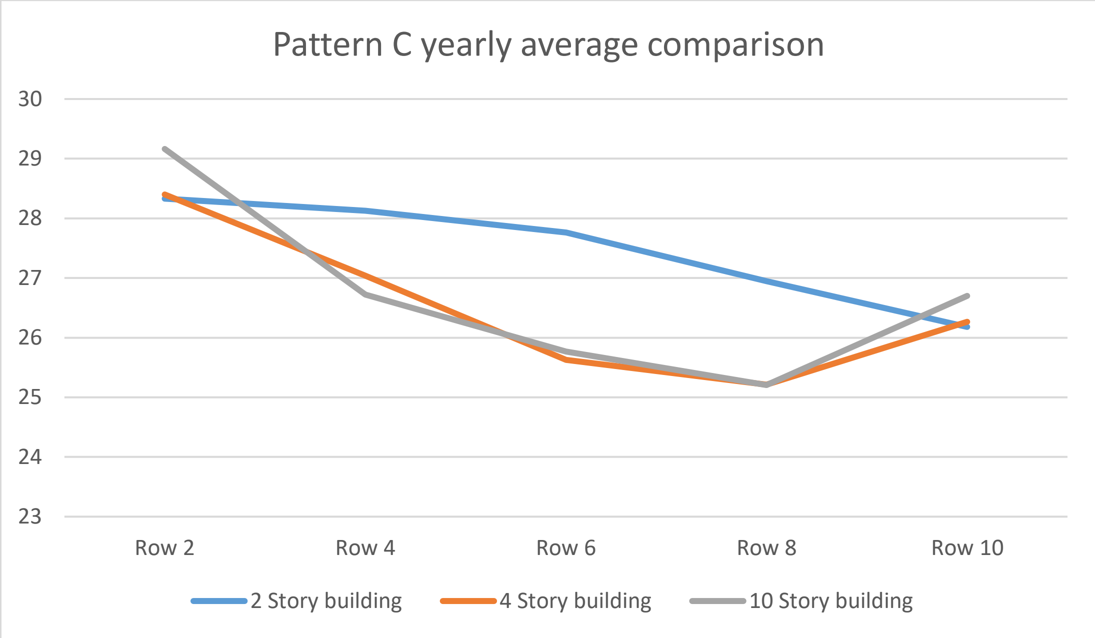


Figure 113: Comparison between all categories for pattern C based on row (Exported from grasshopper based on energy plus calculation).

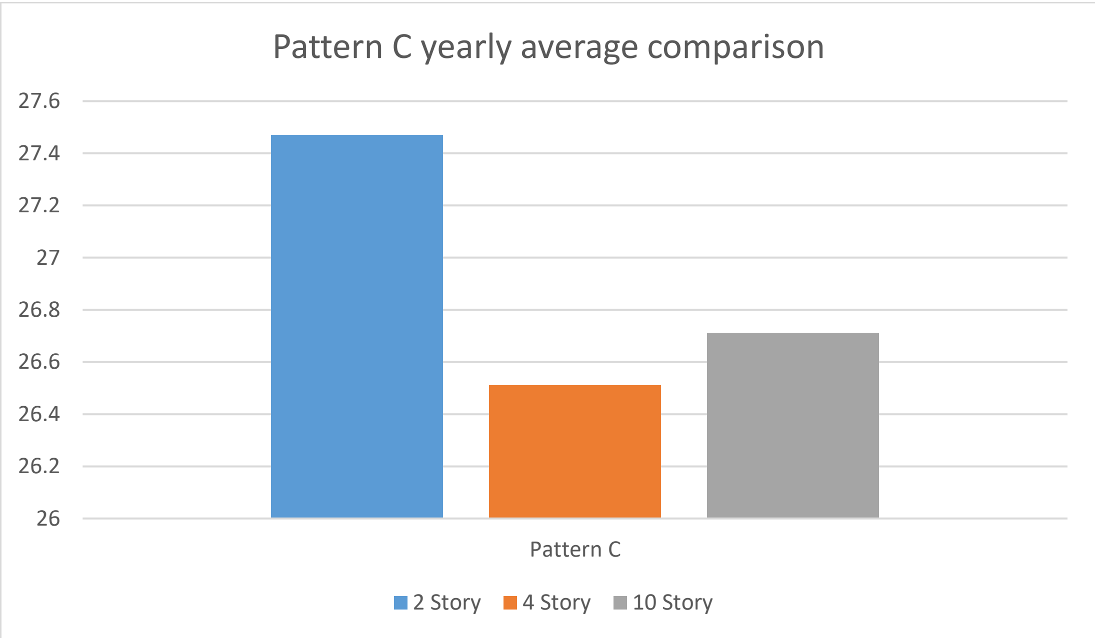


Figure 114: Comparison between all categories for pattern C (Exported from grasshopper based on energy plus calculation).

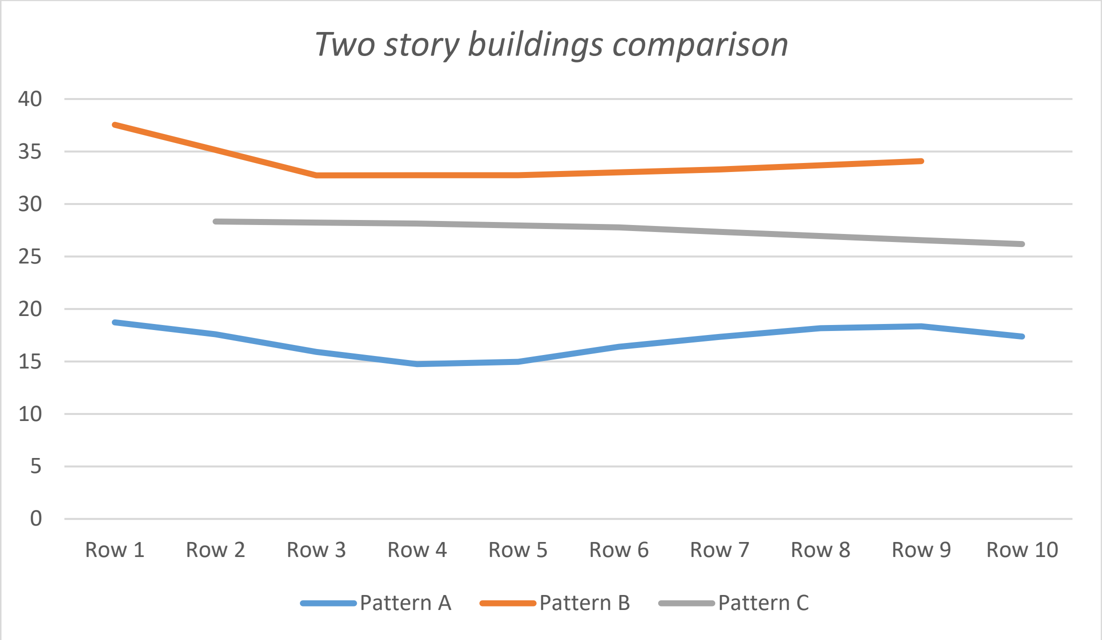


Figure 115: 2-story separated building pattern comparison based on rows (Exported from grasshopper based on energy plus calculation).

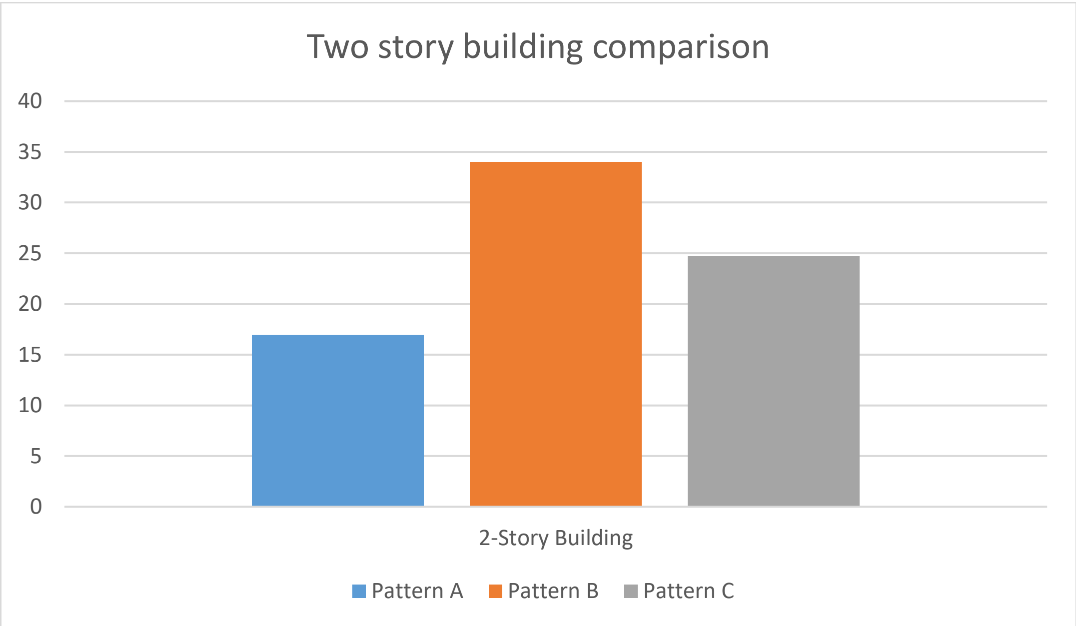


Figure 116: 2-story separated building pattern comparison (Exported from grasshopper based on energy plus calculation).

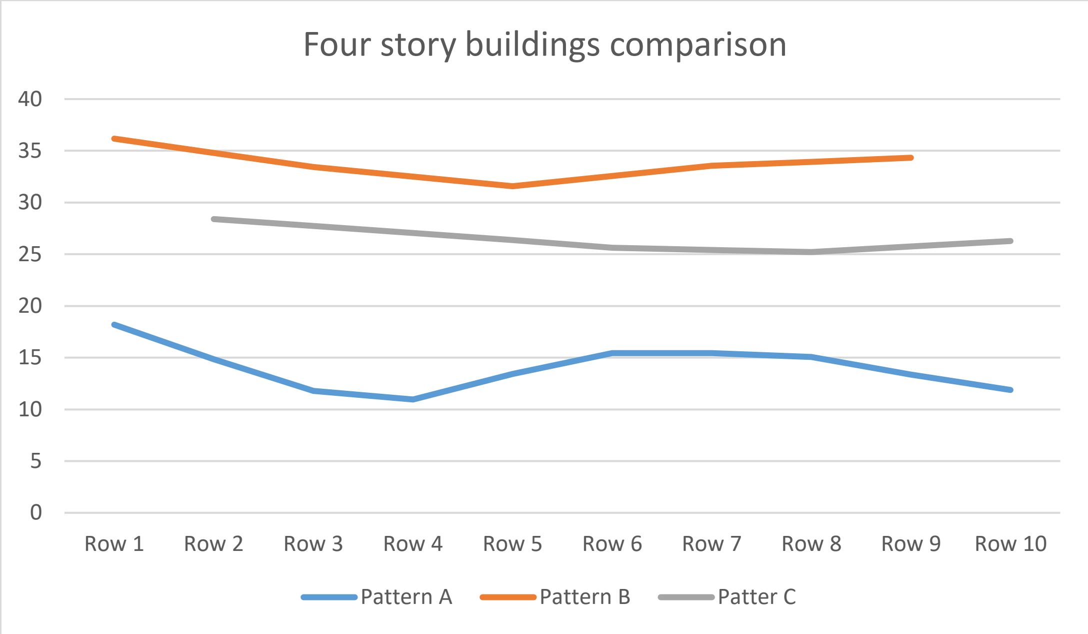


Figure 117: 4-story separated building pattern comparison based on rows (Exported from grasshopper based on energy plus calculation).

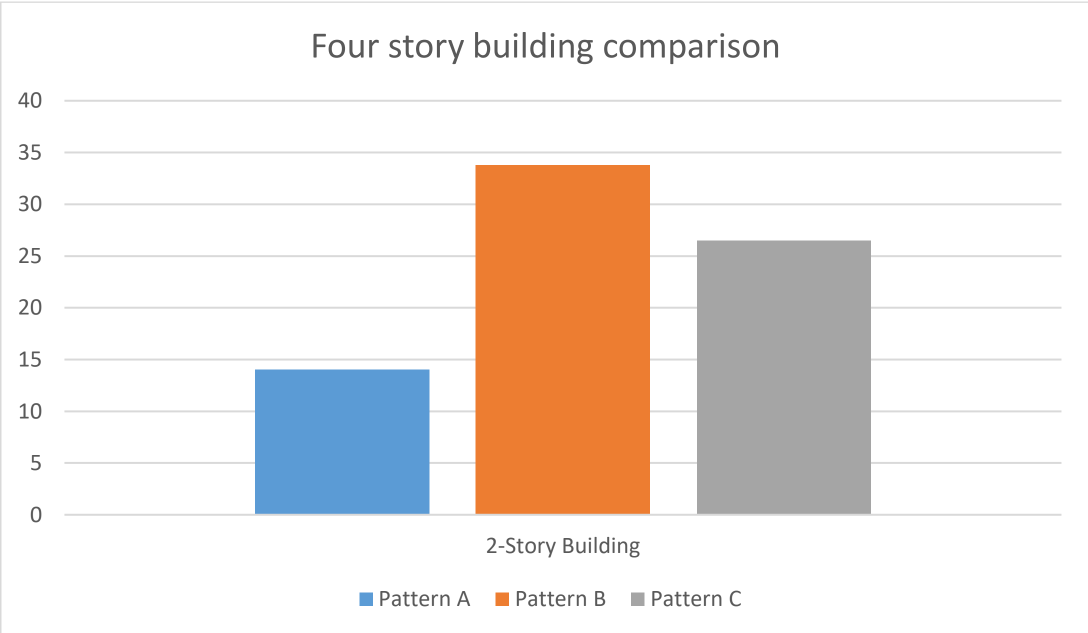


Figure 118: 4-story separated building pattern comparison (Exported from grasshopper based on energy plus calculation).

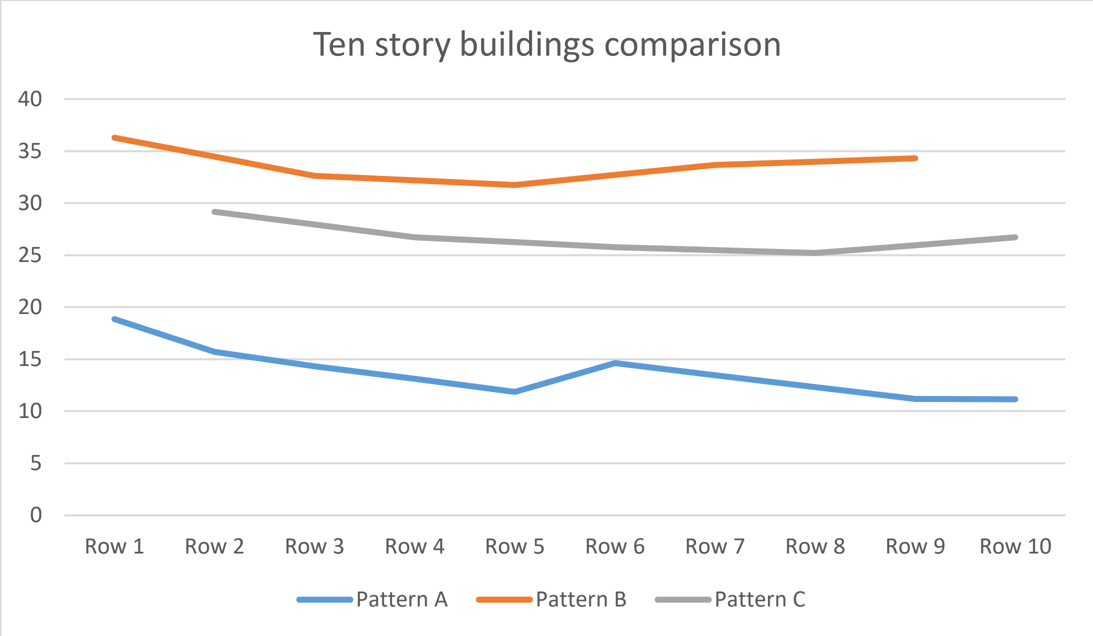


Figure 119: 10-story separated building pattern comparison based on rows (Exported from grasshopper based on energy plus calculation).

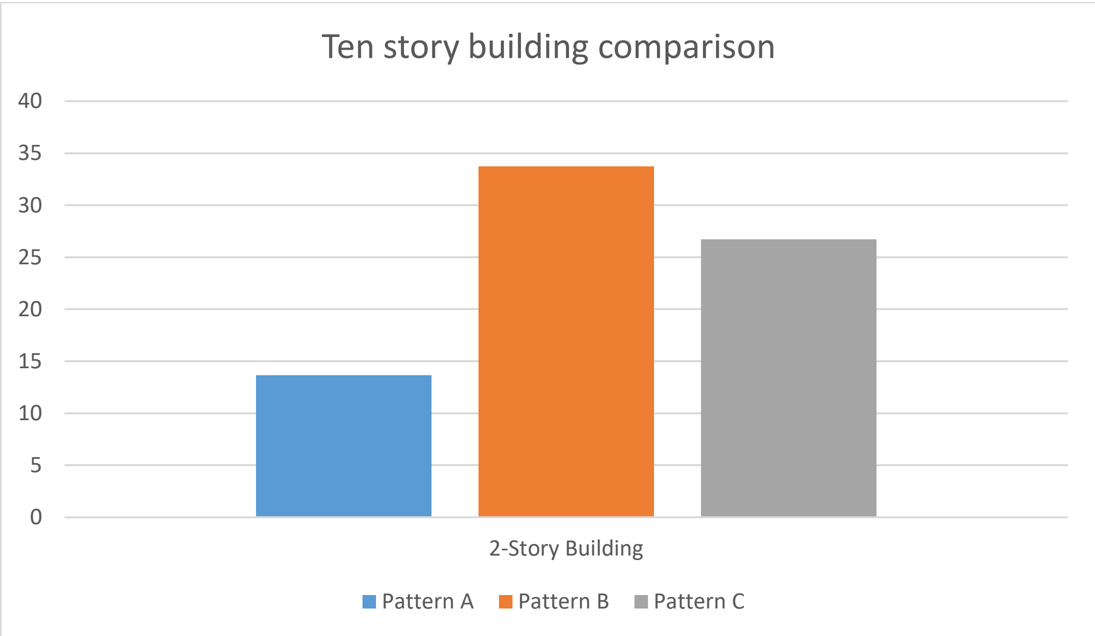


Figure 120: 10-story separated building pattern comparison (Exported from grasshopper based on energy plus calculation).