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The Effect of Housing Density on Energy Efficiency in Buildings: The Case of the Gaza Strip

تأثير الكثافة السكنية على كفاءة الطاقة في المباني : قطاع غزة كحالة دراسية

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Dedication

This Research is lovingly dedicated to my husband who have been my constant source of inspiration. Also, it is dedicated to my parents who have given me the drive and discipline to tackle any task with enthusiasm and determination. Without their love and support this research would not have been made possible.

Acknowledgement

Firstly, I would like to thank my supervisor Dr. Omar Asfour for his important and helpful guidance from the beginning to the end of this research. I also want to thank him for his patience of teaching me scientific research techniques. Secondly, I owe many thanks to the Islamic University, which gave me the opportunity to study and to increase my knowledge. It provided many facilities which helped me greatly in this study. Lastly, I offer my regards and blessings to all of those who supported me in any aspect during the completion of the research

ABSTRACT

The current global research efforts pay a significant attention to the application of strategies that improves sustainability in our built environment. There are several studies in the field of sustainable urban planning, and energy-efficient design and the impact of urban pattern on energy consumption. Housing density is one of the important elements that affect urban planning of residential neighborhoods. Residential buildings are considered the most architectural structures consuming energy in the world. Thus, this study examines the effect of housing density on energy efficiency of buildings considering the conditions of the Gaza Strip, Palestine. Gaza is characterized by the shortage of energy resources and the scarcity of residential land. Thus, the main aim of this study is to highlight the impact of housing density on energy consumption considering different configurations of residential buildings in an attempt to detect the most efficient urban configurations.

This is carried out through an analytical approach that reviews the current situation, compares it to similar cases, and draws out conclusions and recommendations. In this regard, the study assumes that the residential density of different forms of buildings in residential neighborhoods significantly affect the thermal performance of the housing unit and the resulting heating and cooling loads. Hence, the study seeks to evaluate the energy consumption of different types of housing units in urban configurations with a variety of residential densities. The research is carried out using quantitative assessment based on the implementation of two simulation tools: the ECOTECT, as a basic tool and the Design Builder, as a validation tool.

The research concludes a set of results. Firstly, the impact of residential density on energy consumption is dependent on the type and height of housing unit. The study also found that the row housing type offers a reduction in energy consumption per square meter by about 50% compared to the apartment buildings in the case of isolated buildings. In the urban situation, the observed reduction ceased to 14% as a result of the reduced surface area and higher cooling loads. This mean that in some cases the horizontal expansion of residential buildings is more energy efficient than the vertical one. The research recommends to apply the energy-efficient strategies in buildings including optimum housing density and to consider this in the relevant building regulations.

ملخص الدراسة

يوجد اليوم جهد بحثي كبير وتوجه واضحنحو تطبيقالاستراتيجياتالتي تعمل على تحسينالاستدامة فيالبيئة المبنية، حيث توجدالعديد من الدراساتفي مجالالتخطيط الحضريالمستداموالتصميممن أجل الكفاءة في استخدام الطاقة. ومدىتأثيرنمطالمناطق الحضريةعلى استهلاك الطاقة. لذلك تعد الكثافة السكنية أحد العناصر الهامة والمؤثرة على التخطيط الحضري للمجاورات السكنية ، والتي بدورها ترتبط ارتباطا وثيقا باستهلاك الطاقة في المباني السكنية خاصة، والذي ينعكس ايجابا أو سلبا على الأداء الحراري داخل تلك المباني. تحتل المباني السكنية النصيب الأكبر من استهلاك الطاقة عن غيرها من أنواع المباني المختلفة، إذ يقدر استهلاكها للطاقة ما يقرب نصف متطلبات الطاقة. يشكل القطاع السكني الأكثر استهلاكا للطاقة في العالم بصفة عامة وفي قطاع غزة بصفة خاصة، حيث تأتي هذه الدراسة في محاولة لدراسة تأثيرالكثافة السكنيةعلىكفاءة استخدام الطاقة فيالمبانيمع الأخذ بالاعتبارظروف قطاع غزةبفلسطين، و مايعانيهمن نقص فيموارد الطاقةوندرةالأراضي السكنية. وبالتالي، فإن الهدف الرئيسي من هذه الدراسةهو تسليط الضوء علىأثرالكثافة السكنية في مختلف أنواع المباني السكنيةفيمحاولة للكشف عن أفضل أنواع المباني السكنية الموفرة للطاقة للتصدي لهذا النقص الشديد للطاقة ونقص الأراضي في المناطق الحضريةفي قطاع غزة.

وفي هذا السياق تفترض الدراسة أن الكثافة السكنية لأشكال المباني المختلفة في المجاورات السكنية تؤثر تأثيرا كبيرا على الأداء الحراري للوحدة السكنية وبالتالي طاقتي التدفئة والتبريد. ومن هنا فإن الدراسة تسعى إلى تقييم استهلاك الطاقة لأنواع الوحدات السكنية المختلفة في تجمعات ذات كثافات سكنية متنوعة. ويتم ذلك منخلال منهجتحليلييستعرضالوضع الراهنللاسكان في قطاع غزة، وبالاستفادة من برامج التحليل الحراري ECOTECT وDesign Builder وصولا إلى نموذج محقق لأقل استهلاك للطاقة يصلح استخدامه في قطاع غزة.

يختم الباحث هذه الدراسة بمجموعة من النتائج أهمها مدى تأثير الكثافة السكنية على استهلاك الطاقة باختلاف نوع الوحدة السكنية واختلاف الارتفاع فيما بينها. كما توصلت الدراسة إلى أن المباني المتصلة (Row house) تساهم في تخفيض ما يقرب من ٥٠% من استهلاك الطاقة في المتر المربع الواحد مقارنة بالعمارات السكنية في حالة المباني المنعزلة. أما في حالة التجمعات الحضرية للمساكن فإن الدراسة تؤكد انخفاض ما يقرب ١٤% من استهلاك الطاقة في الحالات الدراسية المختلفة نتيجة انخفاض مساحة السطح وأحمال التبريد العالية. كما أكدت الدراسة أن التوسع الأفقي للمباني السكنية في بعض الحالات أكثر توفيرا للطاقة من التوسع الرأسي. ويوصي البحث إلى تطبيق بعض الاستراتيجيات الخاصة بكفاءة استخدام الطاقة في المباني السكية ولاسيما تلك التي تتعلق باستخدام الكثافة السكنية الأمثل وربطها بأنظمة البناء المتعددة في تنظيم المجاورات السكنية المختلفة.

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LIST OF ABBREVIATIONS

ARIJ: Applied Research Institute

PCBS: Palestinian Central Bureau of Statistics

UNRWA: United Nations Relief and Works Agency

MPWH: Ministry of Public Works and Housing

PHC: Palestinian Housing Council

UDD: Urban Demographic Density

ULD: Urban Land-use Density

UMD: Urban Mass Density

URD: Urban Resource Density

GHG: Greenhouse Gas

DU: Dwelling unit

Upa: Unit per area

MOLG: Ministry of Local Government

CIBSE: Chartered Institution of Building Services Engineers

FAR: Floor Area Ratio

CHAPTER1

INTRODUCTION

1.1 Background

> "*Architects have a larger share of responsibility for the world's consumption of fossil fuel and global warming gas production than any other professional group*" (Edwards, 1996)

Energy is one of the most fundamental needs of our universe. Nowadays, energy consumption of non-renewable fossil fuels has increased significantly across the world with the continued growth of the population. This use of fossil sources to produce energy has adverse impacts on the environment as well as on the human health such as global warming, ozone depletion and acid rain.

There is a global trend to promote the effective use of energy in housing sector through sustainable design and urban planning. For example, the orientation of buildings, urban densities, layout and landscaping. There are several solutions for energy efficiency in buildings like the compact city which includes many strategies that aim to create compactness and density that can reduce the problems of energy demand (Thomas, 2003).
Density is a useful tool in determining sustainable urban forms. It is the ratio of people or dwelling units to land area. Density and dwelling type affect sustainability through differences in the consumption of energy; materials; and land for housing, transportation and urban infrastructure. Building energy consumption is accordingly going up year after year. Statistics on total energy consumption and building energy consumption shows that the proportion of building energy consumption to the total energy consumption in the world is rising. According to the European Commission (2005), the building sector is responsible for more than 40 % of EU energy consumption (Karasu, 2010).
Gaza Strip is one of the highest populated areas in the world. According to the Palestinian census carried out in 2007, total population of the Strip was about 1.42 million compared with 1.02 million in 1997(Palestinian Central Bureau of Statistic, 2007). On the other hand, the problem of housing land shortage, considering the ever rapidly growing human population. In addition, the Gaza Strip suffers from a serious problem in energy. It has almost no conventional energy sources except the recent

exploration of the gas field near the Gaza Strip beach. In addition, it has been suffering from a lack of fossil fuels and cut of electricity supply for several years as a result of the (Israel) occupation procedures (Muhaisen, 2007). In the Gaza Strip, the residential buildings consume the large part of the overall energy consumption, which is estimated to be 70% of the total amount of energy consumption (Asfour, 2011). Thus, this sector should be the field of study for researchers in an attempt to rationalize energy consumption through integrating passive and active energy efficient techniques in the design of buildings. Thus, the research seeks to find solutions that strike a balance between dense housing patterns and energy use.

The research aims to highlight the situation of the residential buildings in the housing sector in the Gaza Strip, especially with regard to the type of the housing unit as well as the form of urban configurations. The research used energy simulation software which appeared in recent years as useful tools in simulating buildings performance. They provide significant contribution in dealing with climate adaptation in regard to energy responsible planning (Karasu, 2010). A computerized simulation program called ECOTECT has been used as a tool for investigating the thermal performance of housing types. Then the Design Builder program has been used as a validation tool. General housing types, such as single detached houses, duplex houses, row houses, low-rise apartments, mid-rise apartments and high-rise apartments have been simulated and the heating, cooling and total loads have been determined in each type in order to estimate the effect of housing types on the energy consumption. Also, various urban configurations based on different housing types have been simulated and the energy requirements have been determined.

1.2 Research importance

The Gaza strip is characterized by the shortage of energy resources and the scarcity of residential land and high population. So the research highlights the low energy planning of residential buildings in Gaza Strip in an attempt to find solutions for improving the residential environmental design and enhance energy efficiency.

The research helps to get better understanding about the interactive relationship between the housing density on the energy consumption in buildings. Thus, The main output of this study is a developed an approach for lowering the energy of housing project in Gaza Strip taking into account the shortage of energy resources, the scarcity of residential land and high population.

1.3 Problem Statement

Gaza Strip is one of the highest populated areas in the Palestinian territories. Population density of the Palestinian territories is high in general and in Gaza Strip in particular. The Palestinian population of the West Bank including East Jerusalem grew by 25.4% to 2,350,583, while the Gaza Strip increased by 38.5 % to 1,416,543, during the decade prior to the 2007 census. Average annual population growth in the West Bank was accordingly about 2.5 % while that in the Gaza Strip was 3.8 % (Ajluni, 2010). Housing types in the Gaza Strip vary between single family houses, multi-story buildings and high-rise buildings. On the other hand, the large consumption of energy by the housing sector in the Gaza Strip coupled by the shortage of nonrenewable energy resources and growing human population. The electricity consumption of the Gaza Strip was increased by 80% during the period 1999 to 2005, and at about 10% average annual increasing rate (Abu-Hafeetha, 2009). In this context, this research investigates the relationship between housing types and energy consumption with reference for density. This aims to find out solutions that are efficient in terms of land and energy saving.

1.4 Hypothesis

This study assumes that there is a relation between housing density and energy consumption. This relation is more critical considering the case of Gaza Strip, where urban land and natural resources are limited. Thus, the research determines the effect of this relation on the thermal performance of buildings positively or negatively. In this context, several housing types are examined under the assumption that horizontal compact patterns can be effective in terms of energy saving as well as vertical compact patterns.

1.5 Research Aim

To identify the relationship between the housing density and the energy efficiency in residential buildings at Gaza Strip.

1.6 Research Objectives

1- To study the current situation of housing density and the consumption energy in the Gaza Strip

2- To identify the relationship between housing type and energy consumption.

3- To identify solutions for more energy efficiency patterns in the urban fabric.

1.7 Methodology

The adapted approach is both quantitative and qualitative which includes the following steps:

1- Literature Review:

Recent relevant publications were reviewed in order to look into other countries experiences in analyzing the effect of housing density on energy efficiency in buildings. A summarized literature review on the thermal performance and the climate responsive buildings design is carried out as theoretical background. It depends on theoretical sources such as researches, conference papers and previous studies.

2- Studying the local situation in housing and energy:

Study and analyze housing projects experiences to understand the impacts of residential buildings on the energy efficiency.

3- Parametric study:

Also the research has carried out parametric simulation using computerized programs, namely ECOTECT and Design Builder which provide quantitative results. Residential buildings with different types and in different urban configurations have been analyzed energetically. The heating and cooling loads have been calculated for each model. The results have been evaluated in order to quantify energy consumption of the models.

ECOTECT software is a comprehensive, concept-to-detail sustainable design analysis tool, providing a wide range of simulation and building energy analysis functionality that can improve performance of existing buildings and new building designs. Online energy, water, and carbon-emission analysis capabilities integrate with tools visualize and simulate a building's performance within the context of its environment. It calculates heating and cooling loads for models and analyze effects of occupancy, internal gains, infiltration, and equipment. Also, it visualize incident solar radiation on windows and surfaces, over any period. It displays the sun’s position and path relative to the model at any date, time, and location (Autodesk Ecotect Analysis, 2010).

Design Builder is a unique software tool for creating and assessing building designs. It has been specially developed so it can be used effectively at any stage of the design process. From the concept stages where just a few parameters are needed to capture the building design to much more detailed building models for established designs.

Design Builder is suitable for use by architects, building services engineers, energy consultants, and university departments (Design Builder website,2013). Some typical uses are:

- Evaluating a range of façade options for the effect on overheating, energy use and visual appearance.
- Checking for optimal use of natural light, Modeling lighting control systems and calculating savings in electric lighting.
- Calculation of temperature, velocity and pressure distribution in and around buildings using CFD
- Visualization of site layouts and solar shading.
- Thermal simulation of naturally ventilated buildings.
- HVAC design including heating and cooling equipment sizing.

1.8 Research Limits

This thesis focuses on residential buildings in the Gaza Strip, that consumes the largest part of energy, which is estimated to be 70% of the total amount of energy consumption (Asfour, 2011). It focuses on the modern housing projects and studies the effect of housing density on energy efficiency considering the climatic conditions of the Gaza Strip.

1.9 Sources of Information

The Research depends on several sources of information varied between the theoretical sources for the scientific information, the field study and computer simulation, these sources can be listed as follows:

- Journal papers.
- Conference papers.
- Books that deal with similar subjects.
- Internet.
- Related Reports and Statistics from governmental and private institutions.
- Field visits to collect information and data.
- Computer simulation of the selected models using the analysis program ECOTECT and Design Builder.

1.10 Structure of the Thesis

This research consists of two main parts. First part is the literature review, which focuses on the concept of housing density and its effect on energy efficiency. Then it discusses housing and energy situation in the Gaza Strip. The second part includes a parametric study to examine the impact of housing density on the energy consumption. Figure (1.1) summarizes the main structure of this research.

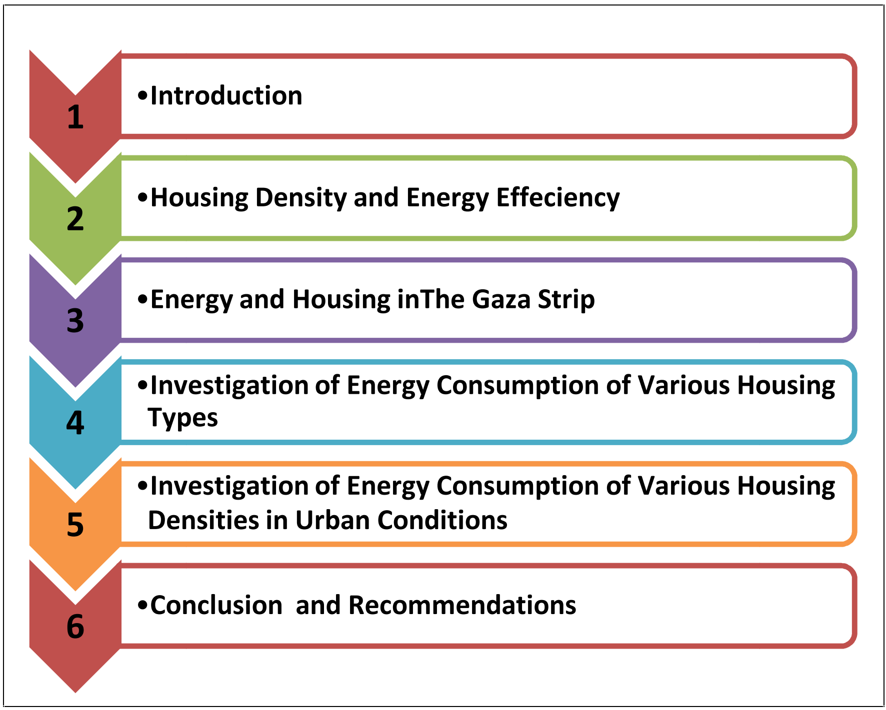


Figure (1.1): Structure of the reseach

The research is presented in six chapters. The first chapter which is a general introduction is composed of the research problem, hypothesis, importance, objectives, sources of information, methodology and an overview of previous studies that dealt with the similar subjects.

Chapter 2 introduces a literature review about housing density and energy effeciency. It describes the concepts of housing density, methods of controlling housing density and its effect on the energy consumption. It overviews the energy efficiency in housing, its environmental effects and its strategies.

Chapter 3 presents a literature review about the energy and housing situation in the Gaza Strip. It summarizes the energy use in housing and the electricity situation in the Gaza Strip. It presents the situation of the housing situation, types of resedential buildings and the current housing needs in the Gaza Strip. It presents some housing projects and some observations about them in general.

Chapter 4 discusses the effect of housing type on its thermal performance by simulating different types of buildings using a simulation tools (Ecotect and Design Builder) then calculate the thermal performance of each model in terms of the heating and cooling loads to determine the desired type.

Chapter 5 discusses the energy consumption of different housing types in the urban configurations by simulating different urban pattern. Then it identifies the effect housing density as a floor area ratio on energy consumption using a simulation tool (Ecotect and Design Builder). It simulated different configurations to determine the desired configuration.

Chapter 6 gives a conclusion about the best housing type and urban configuration of energy efficiency. Some recommendations are provided in this chapter as well.

1.11 Previous Studies

Several Studies have investigated the effect of housing density energy efficiency in residential buildings, for example:

Holloway & Bunker (2006) addressed on planning, housing and energy use. This research enhanced policy debates surrounding energy use in different forms of housing through a review of recent research into the issue. The research aimed to add to debates surrounding current metropolitan planning strategies that promote particular sustainable urban development forms. The main sources of energy used by urban residents are in the form of gas, electricity and fuel for vehicles. There are other forms of energy such as heating oil, wood and bottled gas, although these are not used extensively in our towns and cities. Households that lived in houses (defined as detached houses, semi-detached dwellings and town houses) used 74 per cent more electricity than those in multi-unit dwellings. Interestingly, the research concluded that detached houses should be targeted by initiatives and strategies that encourage lower energy use by these households.

Another research by Sivam and Karuppannan (2008) addressed Density Design and Sustainable Residential Development. Urban growth in the last few decades has led to a number of physical problems. Many factors responsible for this unprecedented growth of urban areas have also contributed to the acute shortage of building space and rise in the price of urban land. Cost of land and infrastructure is increasing continuously. In spite of this, people are generally in favor low density housing with the implicit assumption of its positive effects on the living environment. It is often assumed that high densities are inherently evil and that low densities are inherently good It is, however, quite likely that in spite of high housing densities, living conditions are better than in the low-density areas. The cost of development may also be high for low-density housing.

Another research by Wright (2010) addressed on the relationship between housing density and built-form energy use. This research seeks on the relationship between housing density and built-form energy use and looks at the need for more research to better inform urban planning policies as well as the design of individual buildings for reduce energy demand in buildings. The researcher provide different levels between four case studies which include energy use measurement, unit of measurement, sample size and composition, definition of density and variable selection. The research shows that a high-density housing contributes to higher built form energy use than low or medium-density housing. The general evidence indicates that while increasing housing density may reduce transport energy use when combined with other elements such as employment density and activity intensity, it does not automatically result in decreased operational energy use for buildings. The research indicates that planning, design, and construction decisions should give greater consideration to the energy sources and energy provision for developments if operational energy, and hence greenhouse gas emissions, are to be reduced.

Another research by Stupka and Kennedy (2010) addressed on Impact of Neighborhood Density on Building Energy Demand and Potential Supply via the Urban Metabolism. This study demonstrates how the density of a neighborhood affects its energy demand, metabolism (energy and material flows) and its ability to produce its own energy. Single-family detached houses and row townhouses were each modeled using passive solar housing guidelines with the Design Builder building energy simulation software. Energy demand is then modeled within neighborhoods at two densities based on south facing windows fully un-shaded at 9:00 am, and 12:00 pm solar time on Dec. 21. The neighborhood metabolisms were then calculated based on location and density. The potential energy supply was evaluated from the spatial characteristics of the neighborhood (for solar) and the metabolism (municipal solid waste and wastewater flows). The energy demand for the modeled buildings was 77% to 82% less than the average Canadian single family house. Energy consumption at the neighborhood scale was 15% to 19% greater for the detached house and 3.5% to 5.7% greater for the townhouse than when modeled in isolation. Density varied by 50% in both detached house and townhouse scenarios between the high and lower solar access cases yet heating and cooling loads increased only 11% in the detached house and 8% in the townhouse scenarios.

1.12 Conclusion

This chapter presented the problem of the increasing energy consumption in residential buildings which appears as a result of the relative absence of sustainability principles in architectural design and planning. The importance of this problem increases with the shortage of energy which is linked with the increasing in using heating and cooling energy. The chapter focused on the housing type with different housing density as it considered one of the first decision in the design process which determine the urban configurations. This chapter assumed that the housing density in the urban morphology has a great influence on the thermal performance of the indoor environment and thus the energy consumption. So, simulation processes using the thermal analysis programs have been proposed to evaluate this assumption.

This chapter clarified some previous studies which dealt with similar subjects. Variations in the urban morphology according to variations in the housing types didn't studied with regard to the energy consumption. It is concluded that there is a lake of studies which dealt with the impact of housing density on efficiency energy in the Gaza Strip.

CHAPTER 2

HOUSING DENSITY AND ENERGY EFFECIENCY

2.1 Introduction

Rapid populations growth leads to the growing of built-up areas which cause a number of problems of modern cities. Most of the time, this problem is solved with high-rise buildings or compact settlement structures, instead of expanding the city boundaries. Density is a critical tool in determining urban forms. The number of people within a given area becomes sufficient to generate the interactions needed to make urban functions or activities viable. Density and dwelling type affect sustainability through differences in the consumption of energy; materials; and land for housing, transportation, and urban infrastructure. High density and integrated land use not only conserve resources but provide for compactness that encourages social interaction. Buildings are responsible for at least 40% of energy use in most countries (Forsyth, 2003).

Energy use in the housing sector includes energy for heating, cooking, cleaning, washing, drying, lighting, cooling and for entertainment. Knowledge of the patterns of energy consumption and energy flow in the urban settlement structure are essential for the energy management of urban areas. Population density and building characteristics are important factors which are strongly correlated with residential energy demand. Spatial variation in residential energy demand is accounted for by a variety of factors including climatic variation and building age, size and type. Significantly lower residential energy demand can be achieved in newer, higher density residential apartment developments (Montgomery, 2003). Many studies show that there is a relationship between housing density and energy use. However, this has not been investigated considering the Gaza Strip conditions.

This chapter is carried out to introduce a literature review about the housing density and its effect on the energy consumption and micro climate. Then, the chapter discusses the issue of energy efficiency in housing and its economic and environmental effects. At the end of the chapter, it discusses several strategies to solve the problem of energy demand in housing projects through design low energy building which is known as energy efficient building design. As well as through proper planning of residential densities in residential neighborhoods. Also the chapter shows the principles of passive design in buildings and planning principles for energy efficiency in housing projects.

2.2 Overview of Housing Density

Density plays very critical role in creating built environment. Density is one of many design parameters such as orientation, mass, volume etc. This section gives an overview of density, energy consumption and their relationship. The main objective of this section is to identify the term of housing density. Then, it discusses the methods to determine density in urban areas. Also, this section deals with the types of residential density and their environmental and economic impacts. Finally, it identifies the relationship between density and energy consumption.

2.2.1 Definition of Housing Density

Density is a term that represents "relationship between a given physical area and the number of people who inhabit or use the area". It is expressed as a ratio of population or number of dwelling units to area. Density is a critical typology in determining sustainable urban forms. It is the ratio of people or dwelling units to land area(Cuthbert, 2006).

There has been varying perceptions among scholars and authors to the concept ‘density’. These perceptions stem from the varying fields of discipline from which density draws its meaning. Density has been studied extensively from many perspectives including – physical, psychological, social and environmental (Gomez Arenas, 2002). In the field of planning, a misunderstanding arises because of the several kinds of density used such as neighborhood density, net density, gross density etc. Another ambiguity arises from the use of the concept without clearly defining it. Mitrany and Churchman argue that in many studies, density has been referred to as “high” or “low”, without a definition of what is a high or a low one. As a result these studies have not built up a sufficient body of knowledge or a comprehensive theory about the meaning of residential density (Lupala,2002).

Urban density has many dimensions that can be measured include (Roberts, 2007):

- Urban Demographic Density(UDD) is a measure of population concentration in an area (usually people/households but can include other species).

- Urban Land-use Density(ULD) is a measurement of the ratio of the intensity of use of land-use features for a geographic area. ULD may include the measure of the intensity of dwellings, structures or ground surface cover.

- Urban Mass Density(UMD) is a volumetric measurement of urban structures. It is a three dimensional measure of land-use intensity, usually measured as the floor space ratio of site.

- Urban Resource Density(URD) is a measurement of the resource concentration, especially demand for and waste generated spatially by land-use activities.

2.2.2 Methods of Controlling Residential Density

An analysis of international practice indicates that in general, the methods for controlling density fall into three principal categories (Skinner, 2006):
a. Plot coverage.
b. Plot Ratio (i.e. total amount is the most common in other European countries, of floor space over total site area) such as Belgium, France, Germany, Italy, Sweden and also USA. To a lesser extent, habitable rooms or bed spaces per hectare are used but are not widespread.
c. Dwellings per hectare is the most common in the UK and Ireland.

The most widely used method to determine density is dwelling unit (DU) per hectare. DU sounds much better because it is constant, whereas population is variable based on household size. Gross and net residential density is typically expressed as dwelling units per hectare. Floor area ratio (FAR) is a more precise way of measuring commercial or mixed-use density. In housing studies, however, crowding is measured generally as number of people per room, per bedroom, or square foot (Pont and Haupt, 2007). Obviously, density and crowding are different and are not even always related.

Density has often been referred to as a degree or intensity of development or of occupancy. Conventionally, urban densities have been defined from two perspectives; of population and physical density. While population density has been referred to as the number of persons per unit ground area of development, physical density (sometimes referred to as objective density) has been examined as land use ratios. In housing and urban design, density has been measured in terms of floor area ratios, plot coverage and dwelling units per specified area (Lupala, 2002). Accommodation density in housing has been expressed as the number of inhabitants per unit of habitable space.

1. Plot Coverage

Site coverage is a control for the purposes of preventing the adverse affects of overdevelopment and thus safeguarding sunlight and daylight within or adjoining proposed layouts or buildings. The site coverage index is determined by dividing the total area of ground covered by buildings by the total ground area within the cartilage of the buildings, excluding any land lying between the building line and the public street.
Site coverage is probably only directly relevant in inner urban locations, where open space and car parking may not be contributing factors and where indicative site coverage layout controls are required to ensure that over-development is avoided. In such cases, a range of between 70% to 80% is considered appropriate (Khan,2008).

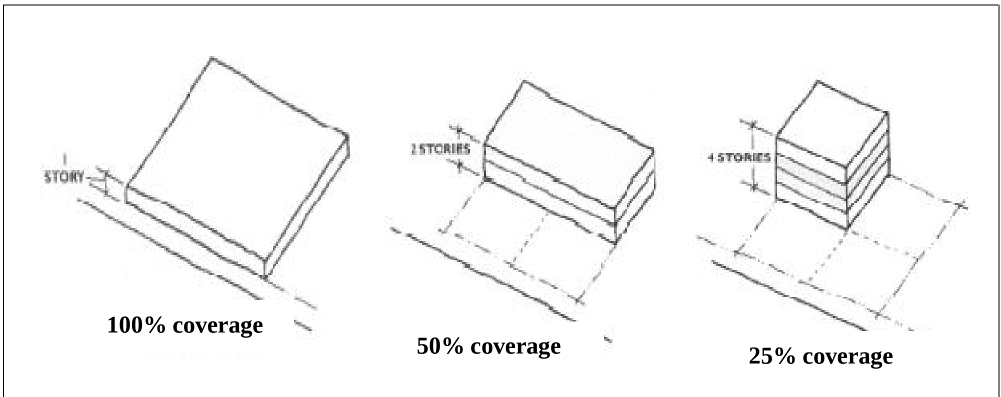


Figure (2.1): Forms of plot coverage
Source: (Khan,2008)

2. Floor Area Ratio

The FAR is the total building square footage (building area) divided by the site size square footage (site area). Thus, an FAR of 2.0 would indicate that the total floor area of a building is two times the gross area of the plot on which it is constructed.
Thus, FAR = (Total covered area on all floors of the building on a plot)/(Area of the plot). This simply means that, if the area of the plot is 100 square meters, then 100 square meters of gross floor area has been built on the plot. The illustration above

shows a 4story building covering 1/4 of the site, giving a FAR of 1.0. Four floors of 25 square meters each are built on a site of 100 square meters (Khan,2008).

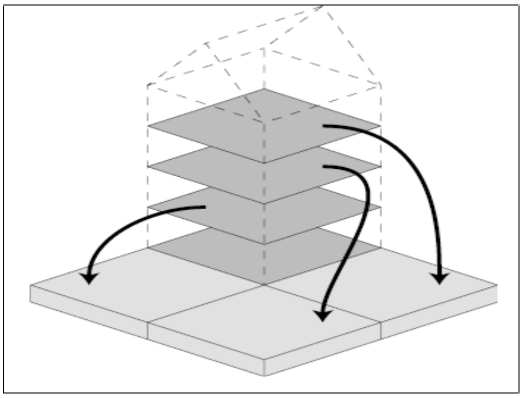
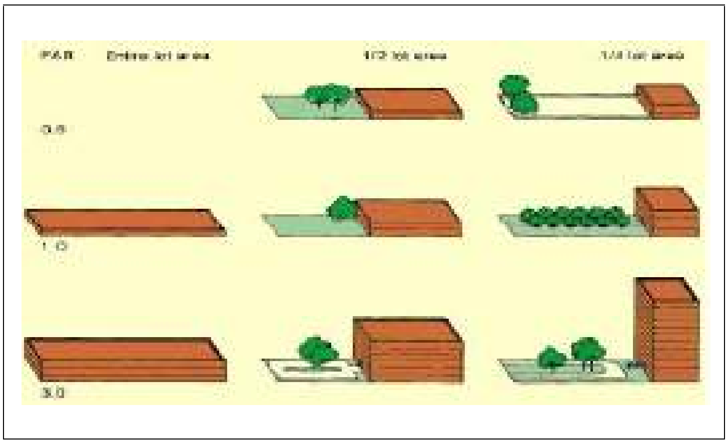


Figure (2.2): Floor area ratio of 1.0
Source: (Carwford, 2002. Available at: http://www.carfree.com/far.html)

Another instance, an area has the planning decision of having FAR of 1.5 and here are some ways to get a FAR of 1.5:

· Build a 2story building on 75% of the site (2 x 0.75 = 1.5)
· Build a 3story building on 50% of the site (3 x 0.5 = 1.5)
· Build a 4story building on 37.5% of the site (4 x 0.375 = 1.5)

Building coverage will be half of the plot when FAR value of an area is 0.5. Plot can be used 1 floor at half of the area of the plot or 2 floors at one fourth of the plot either. Building coverage will be full when FAR value of an area is 1.0. Plot can be used as 1 floor covering the whole lot or 2 floors at half of the plot or 4 floors at one fourth of the lot(Khan,2008).



Figure(2.3): Theoretical explanation of FAR
Source: (Khan, 2008)

3. Dwelling units per specified area

Research carried out by the Department of the Environment, Transport and the Regions in the UK indicate that of the various methods employed for measuring density, dwellings per hectare is the most appropriate measure for estimating development land requirements, making housing land allocations, monitoring completions/take up and in providing a broad indication of the intensity/form of development envisaged on a site or area. However, dwellings per hectare is not effective in predicting or controlling the form of development on a site - planning standards or plot ratio are more effective. In large measure the lack of predictability and consistency of the other methods results from the fact that average size of dwellings and average area per habitable room can vary substantially (i.e. terraced townhouses versus large family houses). Dwellings per hectare is the most appropriate measure for estimating the gross or net yield of existing or future housing, but should be used in conjunction with other planning standards and with plot ratio in particular when controlling development form (Forsyth, 2003).

2.2.3 Types of housing density

Gómez has defined physical densities in relation to urban planning and design. He discusses four categories of density, these are explained in brief as follows (Gómez, 2002):

Town or overall density: that refers to population related to all urban activities and uses of the whole town.

Gross density: This is the population or built space or floor area divided by all the land covered by dwellings and gardens, roads, local shops, primary schools and most open spaces but excluding urban uses such as secondary schools, town parks, and town centers.

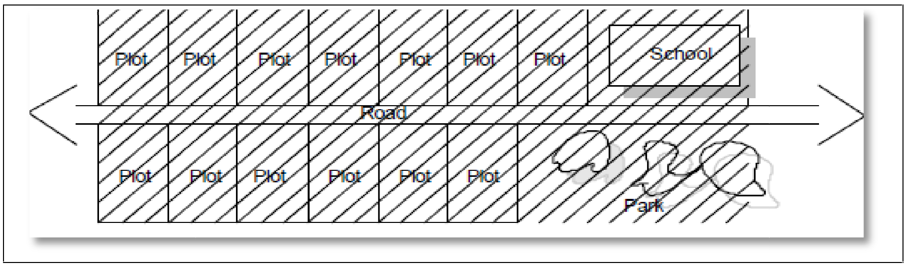


Figure (2.4): Gross Density
Source: (Gómez, 2002)

Net density: This is the population or built space (in terms of houses, habitable floor areas spaces) divided by the land covered by dwellings and their gardens, any incidental open space (e.g. children's play spaces, or parking space for visitors) and half the width of surrounding streets but excluding local shops, primary schools, open spaces and other types of. When the total built up area is divided to the land covered by buildings, the result is a Floor Area Ratio (FAR). In a similar way land coverage at block level can be established.

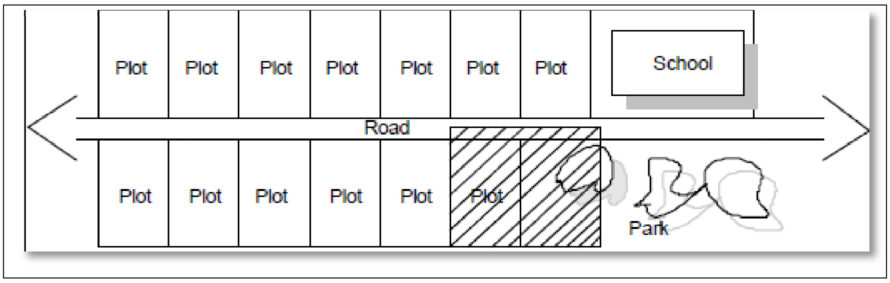
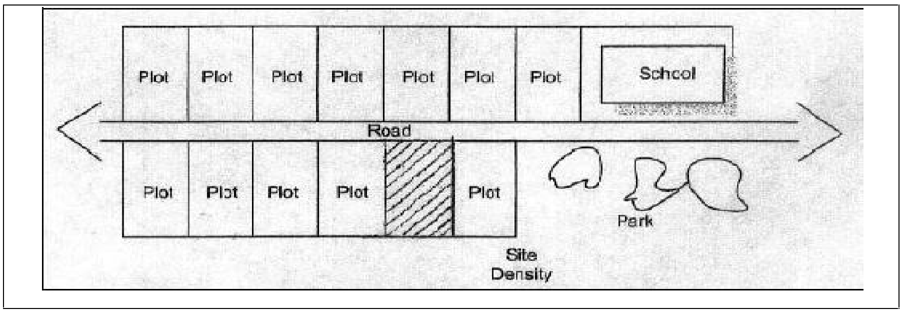


Figure (2.5): Net density
Source: (Gómez, 2002)

Site/ plot density: This refers to the density on a specific site excluding public roads and public open space (Units/hectare).



Figure(2.6): Site Density
Source: (Gómez, 2002)

Asfour (2011) mentioned some examples on housing density levels. Some recommended figures were as follow:

- The net density in low-rise, medium-density housing should not exceed 38 dwellings per hectare based on their observations in America and Western Europe.

- The Department of Environment in Ireland (1999) recommended net housing density of up to 50 dwellings per hectare in the case of housing projects established on peripheral sites.

- In Egypt, for example, the law of Urban Planning allows for a maximum urban density of 100 persons per feddan (4200 m^2).

In China, the rapid population increase necessitates the adoption of land containment strategies that help concentrating urban growth in planned areas using compact developments. As a result, the average gross housing density in Beijing has been raised from 44 to 53 dwellings per hectare in the period from 1990 to 2009 (Zhao, 2011).

Singapore is also known for its densely populated state. Thus, gross new town density reaches 92 dwelling units per hectare without compromising housing environment quality even for low-income groups who cannot afford the cost of privately built housing (Yuen, 2004).

In Hong Kong, housing density is usually controlled using the plot ratio indicator. Plot ratio ranges between 3 and 10, where housing towers are used in mass possible to achieve very high densities with spacious apartments without crowding, and conversely it is possible a detached farmhouse is crowded in terms of having many people per room(Yuen, 2004).

2.2.4 Levels of Housing Density

The following section provides an overview of housing forms and related densities according to Lupala (2002):

1. Suburban Residential (1- 4 unit per acre)

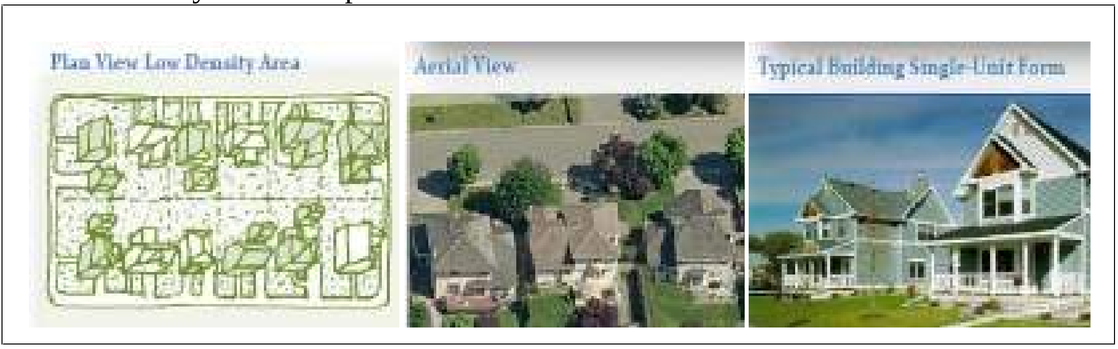
In keeping with the objective of providing a variety of housing types and sizes, some large Single-family detached homes on one acre or half-acre lots up to a maximum density of 4 units per acre may still be maintained.

Figure (2.7): Suburban residential

Source: (Lupala, 2002)

2. Low Density Urban Residential (6-10 upa)

Low density housing is generally associated with Single-family homes and duplexes on lots of approximately 371.6 m^2 to 414 m^2 up to a maximum of 557.4 m^2. These can be developed with and without lanes at densities between 6 and 10 units per acre, with a desirable density of 8 units per acre or above.



Figure(2.8): Low Density Urban Residential

Source: (Lupala, 2002)

3. Medium Density Urban Residential (10-15 upa)

Medium density can consist of single-family residential homes in more compact neighborhoods and two-family dwellings (i.e., duplexes) on narrow 270 m^2 to 360 m^2 lots with service lanes at densities between 10 and 15 units per acre, with a desirable density of 12.5 units per acre or above. Coach houses and Secondary units may also be part of this range of housing types.

Figure (2.9): Medium Density Urban Residential

Source: (Lupala, 2002)

4. Medium- High Density (15-25upa)

Medium-high density development can comprise semi-detached single-family duplexes, triplexes, and fee-simple row houses. At the higher density range, integrated townhouse developments are permitted between the ranges of 15 and 35 units per acre, with a desirable average density of 20 units per acre. Ground-oriented units can be promoted in this form of development.

Figure (2.10): Medium-High Density Residential

Source: (Lupala, 2002)

5. High Density Urban Residential (25-45upa)

High-density residential development would likely be in the ranges of 25 and 45 units per acre with a desirable average density of 35 units per acre. High-density areas are comprised of stacked townhouses, row houses, and/or garden apartments.

Figure (2.11): High Density Urban Density Residential

Source: Lupala, 2002

6. Mixed-Use Main Street Special Residential (25-45 upa)

High-density residential units of densities between 25 and 45 units per acre are permitted within the context of a mixed-use neighborhood and with desirable average densities of 35 units per acre and commercial floor area. A Main Street district may serve as the "heart". In a main street residential village area, residential units are designed to visually and functionally integrate with commercial uses. The external design of buildings is oriented to the pedestrian realm, with a direct and close connection to the public sidewalk. All parking is typically provided via rear lanes, underground, or on the street.

Figure(2.12): Mixed-Use Main Street Special Residential

Source: (Lupala, 2002)

Table (2.1) shows different types of density according to the City of Surrey and the Citizens Advisory Committee.

Table (2.1): Different types of density
Source: (Lupala, 2002), adopted by the author

Land use Designation	Typical housing form	Density (upa)	Average lot sizes (m^2)
Suburban residential	Acre residential	1-2	4046
	Half- Acre transitional residential	2-4	2023
Low density urban residential	Traditional single family	6-8	557 or less
	Single family with secondary unit	8-10	371-418
	Single family and coach house	8-10	371-418
	Semi detached (duplex)	8-10	371-557
Medium density urban residential	Compact single family	10-12	278-371
	Two- family dwelling (duplex)	12-15	278-371
Medium- high density urban residential	Multi- unit with single family appearance	15	371-418
	Row houses	15-25	185
	Town houses	15-25	2972.8
High density residential	Multifamily walk-up flats	25-45	2972.8
	Ground oriented apartments	25-45	3716
Mixed- use main street residential	Row houses with ground level commercial (live work)	25-35	More 3716
	Ground- floor commercial with residential walk- up apartment above	25-45	More 3716

2.2.5 Effect of Housing Density

The effects of urban density on the total energy demand of a city are complex and conflicting. Highly concentrated load centers and compactness of land use patterns will bring benefits to energy distribution and transport system design, but crowded conditions may create congestion and undesirable local microclimate. Table (2.2) gives a summary of the positive and negative effects of urban density (Sam,2001).

Table (2.2) Effects of urban density on city's energy demand
Source: (Sam, 2001)

Positive effects	Negative effects
Transport : promote public transport and reduce the need for trips by cars.	Transport: congestion in urban areas reduces fuel efficiency of vehicles.
Infrastructure : reduce street length needed to accommodate a given number of inhabitants and shorten the length of infrastructure facilities.	Vertical transportation: high-rise buildings involve lifts, thus increasing the need for electricity for the vertical transportation
Thermal performance: multistory, multiunit buildings could reduce the overall area of the building's envelope and heat loss from the buildings.	Ventilation: a concentration of high-rise and large buildings may impede the urban ventilation conditions.
Energy systems: district cooling and heating system is usually more energy efficiency when density is higher.	Urban heat island: heat released and trapped in urban areas may increase the need for air conditioning.
Ventilation: a desirable air flow pattern around buildings may be obtained by proper arrangement of high-rise building blocks.	Use of solar energy: - roof and exposed areas for collection of solar energy are limited

1. Density and Energy Consumption

An inverse relationship is found between residential population density and energy consumption; lower residential population densities are associated with higher energy consumption patterns, and higher densities with lower energy consumption patterns. Density and dwelling type affect sustainability through differences in the consumption of energy; materials; and land for housing, transportation, and urban infrastructure. High density and integrated land use not only conserve resources but provide for compactness that encourages social interaction. Newman and Ken worthy conclude that some policies can save significant amounts of energy, mainly by increasing the urban density; strengthening the city center; extending the proportion of a city that has inner-area land use; providing a good transit option; and restraining the provision of automobile infrastructure (Sam,2001).

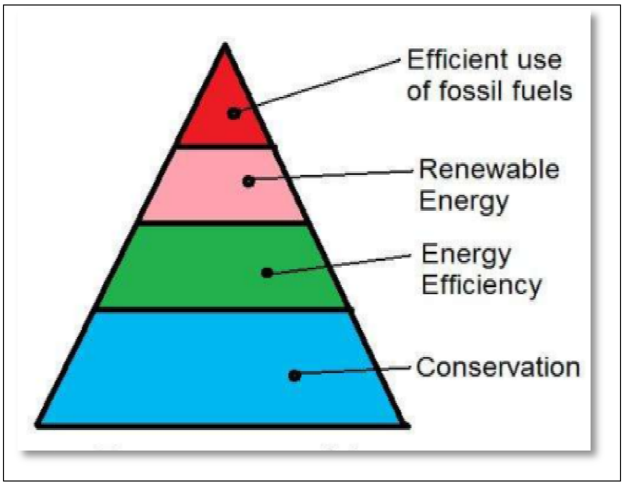
2. Density and Microclimate

There is a general perception that low-density development of Middle Eastern housing has a significant advantage in terms of microclimate. Johansson (2006) found that housing in Morocco with tight streetscapes had street temperatures 6 – 10 degrees lower than exposed locations. On the other hand, Skinner (2006) in a study of

Melbourne found that higher urban density has negative impacts on the microclimate and the hydrology of the city. There are strategies to minimize these adverse effects, including the widespread use of roof top gardens. Roof-top gardens are now actively promoted as part of sustainability planning policy (Skinner,2006). The change in urban form resulting from the increase in average house size and ground surface cover is having an impact on the microclimate of suburban areas. This increase in surface cover, combined with the decline in tree and vegetation cover, has increased the level of thermal radiation per hectare (Roberts, 2007).

2.3 Energy efficiency in housing

Energy efficiency is the reduction of the amount of energy required to provide products and services. Energy conservation is directly related to energy efficiency. It refers to efforts made to reduce energy consumption. It can be achieved by simply switching off a light when not in use. It is directly related to people's habits and behavior. It can also be achieved through passive building strategies that reduce the need for electricity. Energy efficiency together with energy conservation are the basis of a sustainable energy strategy (Jaber, 2011). Figure (2.13) shows Energy pyramid.

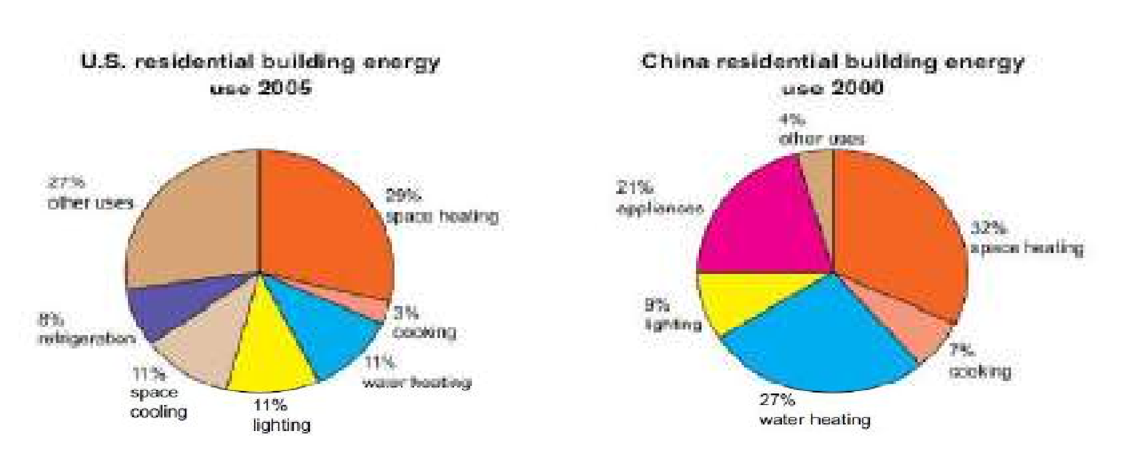


Figure(2.13):Energy pyramid
Source: (Jaber, 2011)

2.3.1 Energy Use in Housing

One of the most important topics related to contemporary architecture is the energy using in buildings which contributes to achieve thermal comfort for occupants (Karasu, 2010). Commercial and residential buildings consume roughly 40% of the primary energy and 70% of the total electricity used each year in the United States. It is expected that electricity consumption in the commercial building will increase 50% by 2025 (Zain et al. 2007). mentioned that more than 45% of the total electricity consumption in Hong Kong is used to provide air-conditioning in commercial buildings.

The cooling requirements is estimated to consume about 65% of the electrical energy generated in the Kingdom of Saudi Arabia. According to the European Commission (2005), the building sector is responsible for more than 40 % of EU energy consumption (Karasu, 2010). Figure (2.14) presents a breakdown of energy end-use in the residential sector for the United States and China. As shown in the figure, the space heating is the largest user of energy in both regions. It followed by water heating in China and other uses – primarily electric appliances in USA (Abed, 2012).



Figure(2.14):Breakdown of residential sector energy use in United States (2005) and China (2000)
Source: (Abed, 2012)

2.3.2 Benefits of Energy Efficiency in Housing

Improving energy efficiency in housing is a great opportunity to promote economic development, quality of life and social equality and environment. Some of these benefits are explained below **(**Janssen, 2004).

1. Environmental Benefits

Better energy efficiency reduces the pressure of energy use and on climate change. Furthermore, improving the energy efficiency of housing constitutes a climate change adaptation measure by better shielding homes from adverse weather conditions. There are also financial opportunities related to carbon trade possibilities due to reduced carbon dioxide (CO)emissions.

2. Energy Security

Improving energy efficiency in housing permits more energy for alternative uses or for growing "structural" energy demands in the housing sector itself. It also reduces the risks of political instability which may arise due to energy shortages or energy price inflation for households. It is widely acknowledged that investing in energy efficient homes provides quicker and cheaper results than alternatively increasing capacities for energy supply.

3. Economic Benefits

Better efficiency offers savings of operational costs for tenants. Service providers benefit from the more efficient transportation of energy services. The development of the sector also has positive influences for research and innovation, business development, employment and investment. It therefore offers an effective tool to stimulate economic growth and to boost economic competitiveness.

2.4 Principles of energy efficient building design

The previous sections discussed the density, energy efficiency and their relationship in housing. Thus, the issue of energy is becoming more and more important. Because of housing sector is one of the most significant energy consumers, there are several strategies to solve the problem through design low energy building which is known as energy efficient building design. There is no global definition for low-energy buildings, but it generally indicates a building that has a better energy performance than the standard alternative/energy efficiency requirements in building codes (Brussels,2009). Table (2.3) shows some examples of definitions for low energy buildings.

Table (2.3): Examples of definitions for low energy building standards
Source: Brussels,2009

Country	Official definition
Austria	· Low energy building = annual heating energy consumption below 60-40 KWh/m² gross area 30 % above standard performance. · Passive building = passive house standard (15 kWh/m² per useful area (Styria) and per heated area (Tyrol).
Belgium	· Low Energy Class 1 for houses: 40 % lower than standard levels, 30 % lower for office and school buildings. · Very low Energy class: 60 % reduction for houses, 45 % for schools and office buildings.
Germany	· Residential Low Energy Building requirements = kfW60 (60kWh/(m²•a) or KfW40 (40 kWh/(m²•a)) maximum energy consumption. · Passive House = KfW-40 buildings with an annual heat demand lower than 15 kWh/m² and total consumption lower than 120 kWh/m².
England	Graduated minimum requirements over time: · 2010 level 3 (25% better than current regulations). · 2013 level 4 (44% better than current regulations and almost similar to PassivHaus).

Generally, energy efficient buildings can be achieved through two approaches which are active and passive. The active system employ hardware and mechanical equipment to collect and transport heat. In contrast, the passive system collect and transport heat by non-mechanical means. In the other words, the specific different between two systems is that the passive system operates on the energy available in its immediate environment while the active system imports energy, such as electricity, to power fans and pumps which make the system work (Dabboor, 2011).

2.4.1 Building envelope principles

The building envelope includes everything that separates the interior of a building from the outdoor environment, including the windows, walls, foundation, ceiling, roof, and insulation. Some specific envelope measures include:

1. Insulation

Envelope insulation should have a thermal value optimized for the microclimate zone of the home and encapsulates the entire occupied space that is air-conditioned – either by entirely filling the cavity between the structural system or through the use of an exterior-applied insulation system that also reduces air leakage. Stud framing can be omitted entirely with Structural Insulated Panels comprised of a foam-core sandwich panel, and have been shown to save 10-15% more in the winter than conventional wood framing assemblies, and have as much as 15 times less air leakage. Doors should have weather stripping and windows should be caulked (Lam,2005).

2. Fenestration

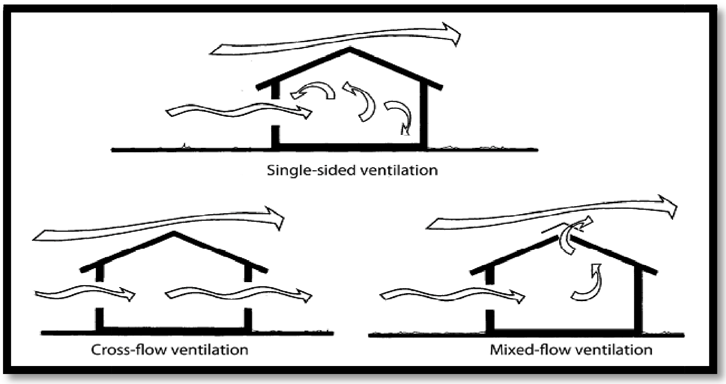
High performance windows, glazed doors and skylights reduce heating and cooling energy costs; improve occupant comfort and enable greater utilization of floor areas on perimeter zones; improve noise control and condensation resistance; minimize fading of interior furnishings; and increase the resale value of a property. Spectrally-selective glazing use a low-emissivity coating to minimize ultraviolet transmission, maximize the visible light admitted, and reduce solar heat gain in the summer and heat loss in the winter. This type of glazing typically lowers solar gain and heat loss by 25-45% with only a 10-15% reduction in visible light transmission – while tinted glass or reflective coatings can also be used for additional solar control (Yu et al,2008).

Exterior shading systems such as fixed overhangs, fins, awnings and operable, louvers, shutters, awnings or weave screens block the solar gain before it enters the fenestration assembly, while integral and interior shading systems are secondary options for solar gain, glare and heat loss control. Solar screens resemble standard window screens and can block up to 85% of the sun's heat from entering the home. Such shading control can lower the space temperature in spaces adjacent to windows by as much as 20 degrees Fahrenheit on a hot day (Datta,2001).

3. Natural ventilation

Natural ventilation systems rely on pressure to move fresh air through buildings. Pressure difference can be caused by wind (cross ventilation) or the buoyancy effect created by temperature differences or differences in humidity (stack effect). In both the cases the amount of ventilation critically depends on design of openings, their size and placement. Natural ventilation unlike forced ventilation uses natural sources like wind and buoyancy to deliver fresh air into the building (Aynsley,2007).

In the Cross Ventilation, a pressure is generated on a surface whenever moving air is obstructed or deflected. The distribution of pressure depends upon the wind direction and the geometry of the surfaces. Pressures will generally be positive on the windward sides of buildings and negative on leeward sides. The lateral pressure distribution gives rise to cross-ventilation; that is airflow from the windward to the leeward side of the building. This requires that the interior of the building is not sealed by dividing walls, or that where rooms are double banked, openings at high level are provided. Cross ventilation was assisted by having high level openings in the internal walls and over doors in traditional houses (Liping et al,2007).



Figure(2.15) :The most common methods used in natural ventilation
Source : Dabboor, 2011

4. Daylight

Daylight is a natural source of light, which meets all the requirements of good lighting. Daylight provides a dynamic environment inside the buildings in consonance with the nature outdoors. Windows in buildings establish contact with nature through a direct view and admit daylight inside. Adequate provisions of daylight in buildings through a proper planning for windows in respect of the position, area and shape, are therefore an important aspect of a good building design. Daylight integration helps reduce dependence on artificial lighting and thus help reduce electricity consumption of the building (Majumda, 2002).

According to Majumda (2002) Many factors should be taken into consideration to achieve good daylight system in building:

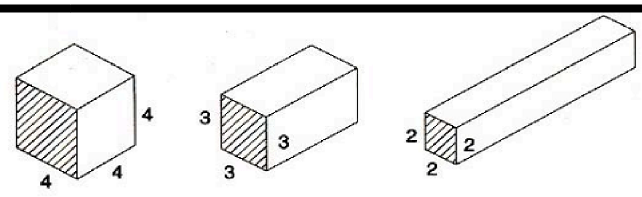
- Orientation, space organization, and geometry of the space to be light.
- Location form, and dimensions of the fenestrations to allow entering of daylight.
- Location and surface properties of internal partitions that affect daylight distribution by reflection.
- Location, form, and dimensions of shading devices that provide protection from excessive light and glare.
- The Light and thermal characteristics of the glazing materials.

2.5 Principles of energy efficient building planning

It is not only the technological attributes of buildings and their interiors that contribute to the reduction of energy use, but also the very spatial and density attributes of communities and cities at large. Town planning and land use zoning can therefore make a big difference, particularly as far as new building sites are concerned. Certain levels of residential density, mixed-use developments, and good public transit provision are believed to be important considerations for energy efficiency and reduced greenhouse gas (GHG) emissions, since such measures typically reduce vehicle use, bring more efficiency to energy consumption, and reduce municipal infrastructure requirements. Planning strategies study the macro and microclimate of the site to avoid the adverse conditions, and taking advantage of the desirable conditions (Reinhart et al, 2001).

2.5.1 Building form/surface-to-volume ratio

Building form is one of the most important principles due to the fact that it determines the amount of heat loss or heat gain through the building envelope. Building form can be defined by the shape factor (the ratio of building length to building depth), height and roof type. As shown in figure (2.16), there is possible to determine a lot of building forms that have same volume, but different facade area. Thus, The ratio of total facade area to building volume (A/V) is the best indicator describing the building form. Also, the building form determines the airflow pattern around the building, and affect its ventilation. Additionally, The depth of a building determines the requirements for artificial lighting, so the greater depth needs more artificial lighting (Oral, 2003).



Solid shape type	Surface area (S)	Volume (V)	Ratio (S/V)
a	96	64	1.5
b	103.2	64	1.61
c	136	64	2.13

Figure(2.16) : Surface-to-volume ratio

Source : Krishan, 2006

2.5.2 Orientation

Building orientation is an important design consideration, mainly with regard to solar radiation and wind. In hot humid climates, buildings should be oriented to minimize thermal impact from solar radiation and maximize effectiveness of ventilation. This can be achieved by lying the longer axis of building along east-west direction. That because the longer sides of the buildings should face the prevailing winds (north direction) and the shorter sides should face the direction of the strongest solar radiation (east and west directions) (Mathur, 2003).

2.5.3 Landscaping

By strategically placing vegetation and trees immediately adjacent to the building envelope, incoming solar heat gain and glare through fenestration is reduced and cold prevailing winds are obstructed, thereby lowering cooling and heating costs while improving occupant comfort. Deciduous trees offer one of the best year-round ways to save energy by blocking the summer sun for solar control and dropping their leaves in the winter to admit more solar gain through fenestration. This practice in conjunction with light colored landscape elements and reflective Cool Roof materials also reduces the "Urban Heat Island Effect" that raises the overall average air temperature of the region (Chenvidyakarn, 2007).

2.6 conclusion

This chapter investigated the density in the world and its effect on energy consumption. The conclusion emphasized that an inverse relationship is found between residential population density and energy consumption; lower residential population densities are associated with higher energy consumption patterns, and higher densities with lower energy consumption patterns.

The buildings sector are considered the large consumer of energy. Thus, many principles to design low energy buildings are also discussed in this chapter including planning, building envelope, passive cooling and passive heating. It has been concluded that these principles can easily integrated into building design and can contribute effectively to reduce the energy consumption.

CHAPTER 3

ENERGY AND HOUSING IN THE GAZA STRIP

3.1 Introduction

The Gaza strip has almost no conventional energy sources, wherefore it is almost totally dependent on the electricity and fossil fuel imported from Israel. The Gaza Strip has been suffering from a serve energy deficit and a worsening balance between supply and demand in recent years. It is evident that using fossil fuel to produce energy has adverse impacts on the environment and human health through emission of greenhouse gases.

Housing is one of the critical problems facing the Palestinian people in general and in particular the Gaza Strip. It has been developed in several stages, including from the UNRWA camps to modern housing projects implemented by the Housing Council and the Palestinian Ministry of Housing. Residential buildings are considered the main construction subsector in Gaza. Detached buildings are the most commonly used style in residential complexes. The attached style is only found in the old town in Gaza city. Building's density, height, area and spacing are determined according to the local municipalities regulations.

This chapter is carried out to identify the energy situation in the Gaza Strip especially in the housing sector. It is carried out to introduce a literature review about the housing in the Gaza Strip. Then, the chapter discusses the term of housing density in several housing projects and introduces some observations in those housing projects.

3.2 Overview of the Gaza Strip

3.2.1 Location and Geographical Boundaries

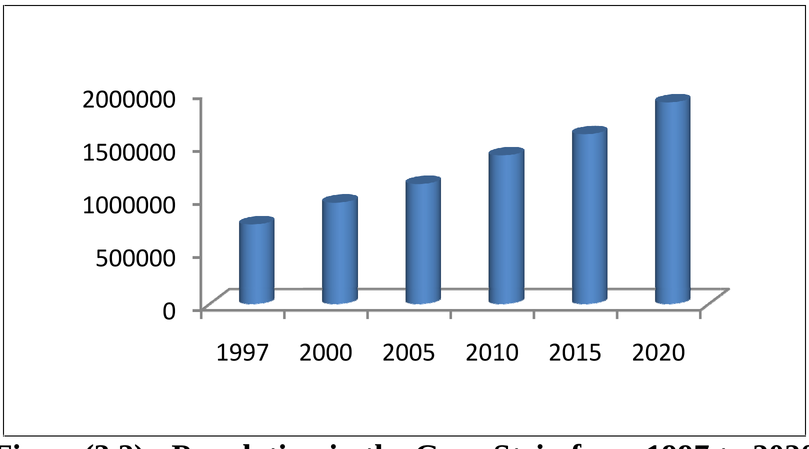
The Gaza Strip is about 1.33% of the area of historical Palestine. It is a coastal area along the eastern Mediterranean Sea, within the Middle East (at 31º 25' N, 34º 20' E). It is about 42 kilometers long and between 6 and 13 kilometers wide, with a total area of 365 square kilometers. The area forms a transitional zone between the sub-humid coastal zone in the north, the semiarid losses plains of the northern Negev Desert in the east and the arid Sinai Desert of Egypt in the south. The Gaza Strip has a Mediterranean dry summer subtropical climate with mild winters. The territory takes its name from Gaza city, its main city and administrative center (ARIJ, 2006).

Figure (3.1): The Gaza Strip map
Source: (ARIJ, 2007)

The population is distributed in the Gaza Strip on seven major cities, in addition to twenty villages and eight camps. Gaza Strip consists of five governorates which are the north Gaza, Gaza, Deir al-Balah, Khanyounis and Rafah. It consists of eight camps which are Jabaliya refugee camp, the beach camp, Rafah, Khanyounis, Bureij, Maghazi, Nuseirat and Deir al-Balah (Ministry of Local Government, 2004).

3.2.2 Urban Population and Density

According to the Palestinian Central Bureau of Statistics (PCBS), the estimated palestinian population of the Gaza Strip increased by 38.5 % to 1,416,543 during the decade prior to the 2007 census (PCBS, 2007). Average annual population growth in the Gaza Strip was accordingly about 3.8 %. The Gaza Strip was 35.4% of the 1997 population but was responsible for 45.3% of the growth in the intervening period (PCBS, 2007). Figure (3.2) shows population in the Gaza Strip from 1997 to 2020.



Figure(3.2): Population in the Gaza Strip from 1997 to 2020

Source: : (PCBS, 2007)

Gaza Governorate was shown to have the second highest population after Hebron Governorate in the West Bank, which amounts to 13% of the total population in all of the governorates in the West Bank and the Gaza Strip. In the Gaza Strip, The total recorded population growth was 38.5%. Population growth was more rapid in the far north and far south, with the Gaza North and Rafah governorates experiencing above average growth (47.3% and 41.1%, respectively) (Ajluni S, 2010). Figure (3.3) shows the population growth by Gaza Strip governorates between 1997 and 2007.

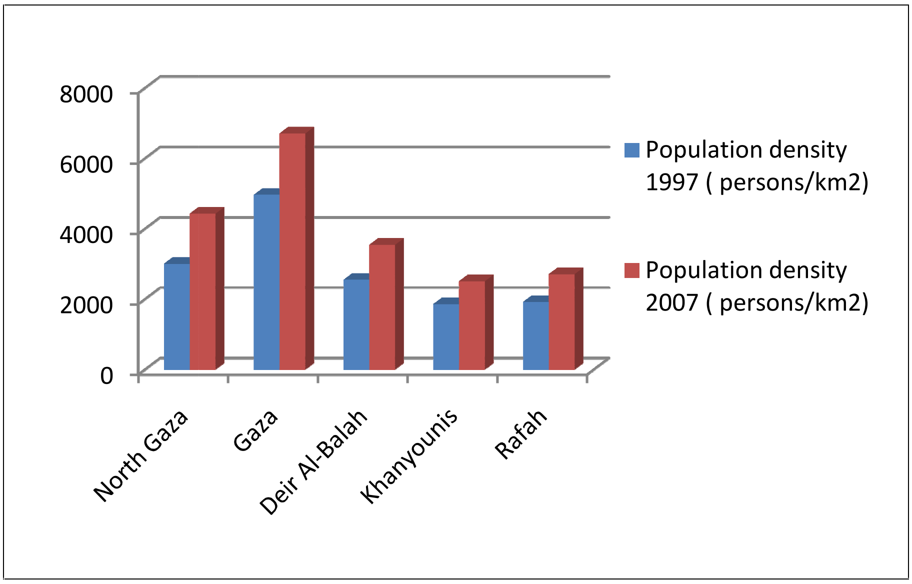


Figure (3.3): Population growth by Gaza Strip governorates, between 1997 and 2007

Source: (PCBS, 2007)

While the area of Gaza Strip is only 365 square kilometers, population density renowned as among the highest in the world which was about 38.5 % between 1997 and 2007 to an average of 3,880.9 persons per square kilometer which about 9.3 times the average density of the West Bank. Figure (3.3) shows that the Gaza governorate is the most dense with 6708.3 persons per square kilometer in 2007. While the North Gaza and Rafah governorates grew faster than average while density in the Gaza and Khanyounis governorates grew less than average. The Gaza governorate remained, by far, the most dense and there was no change in the rankings with Khanyounis remaining the least dense governorate (PCBS, 2007).

According to the Palestinian Central Bureau of Statistics (PCBS), the number of Palestinian private households totaled 213,710 households. The average size of Gaza Strip households is 6.5. The average housing density in the Palestinian Territory amounted to 1.6 person per room in 2009; while the average for the West Bank reached 1.6 person per room compared with 1.8 person per room for the Gaza Strip.

Table (3.1) shows that the number of households in the Gaza Strip in 2007 was 219,220 households. The number of housing units in the Gaza Strip was 245,623 housing units with an increase of 50.4% in housing units from Census 2007 to Census 1997.

Table (3.1): Number of households and dwellings, buildings, and the average family size in the Gaza Strip.
Source: PCBS, 2007

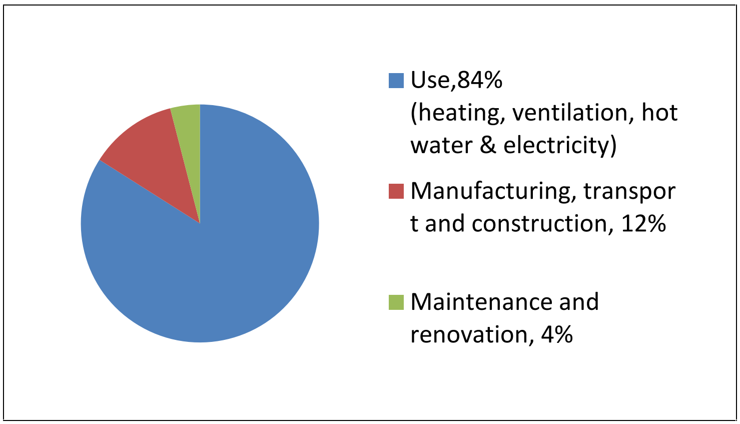
Governorate name	The number of households	The average size of households	The number of buildings	The number of housing units
North Gaza	40,262	6.7	26,368	43,322
Gaza	76,809	6.5	41,527	90,390
Deir Al-Balah	32,082	6.4	24,901	34,633
Khanyounis	43,203	6.3	34,267	48,177
Rafah	26,864	6.5	20,374	29,101
Gaza Strip	219,220	6.5	147,437	245,623

3.3 Energy Situation in the Gaza strip

The Gaza strip has almost no conventional energy sources, wherefore it is almost totally dependent on the electricity and fossil fuel imported from Israel. The Gaza strip has been suffering from a serve energy deficit and a worsening balance between supply and demand in recent years. It is evident that using fossil fuel to produce energy has adverse impacts on the environment and human health through emission of greenhouse gases Therefore there is a tendency globally to improve energy efficiency in buildings where possible and reduce the dependence on conventional types of energy in favor of renewable energy resources. The Gaza strip is rich in solar energy, which is abundant during the entire year as a result of the territory's location near the hot dry region of the world. It is believed that solar energy can be used in different applications in buildings, which may contribute to overcome the energy problems, especially in the residential sector, currently facing Gaza (Muhaisen,2007).

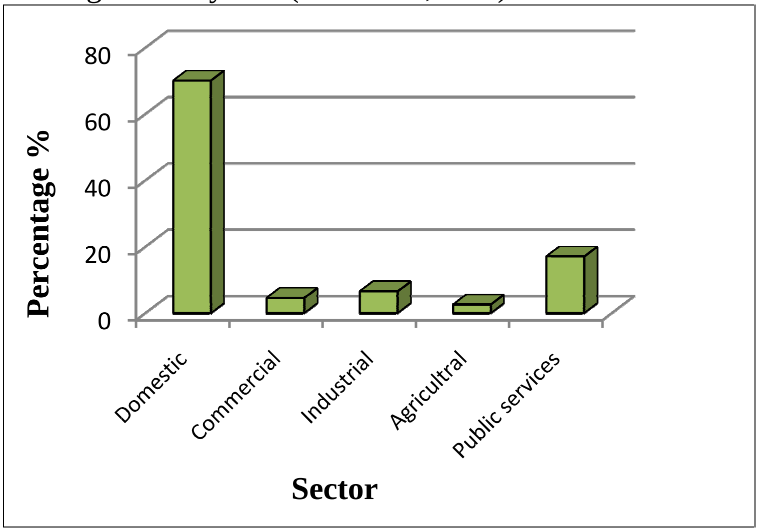
3.3.1 Energy Use in the Gaza Strip in Housing

Energy use varies among residential buildings, but lighting and water heating are substantial components in most regions.



Figure(3.4):Life cycle energy use in buildings
Source: Jaber, 2011

Most energy in existing residential buildings is consumed for space and water heating. In the Gaza Strip, the main forms of energy in housing sector are electricity and natural gas. The distribution of the total manual electricity consumption in the Gaza Strip among various sectors clearly reveals that the domestic and residential sector consumes the main bulk of electricity; about 70 % of the total consumption. The public services sector consumes the second biggest amount with an average of 17 %, while the industrial sector only uses 6.5% of the total consumption, and the commercial and the agricultural sectors significantly less (Muhaisen,2007).



Figure(3.5):The electricity consumption of the different sectors in the Gaza strip
Source: Muhaisen,2007

3.3.2 Energy Resources in the Gaza Strip

The Gaza strip depends on three main sources of electricity supply including (Israeli) Electricity Company, Egyptian Electricity Company, and local Gaza Power Plant. Also, it imports the fossil fuels by two ways either directly from Israel or indirectly (by tunnels) from Egypt. Figure (3.6) obviously shows the electricity load required for the Gaza strip from 2001 to 2010. It's clear that the electricity needs increase by about 10-15 MW annually, as a result of the natural population growth and the expansion in the different sectors requiring electricity supply (Muhaisen, 2007).

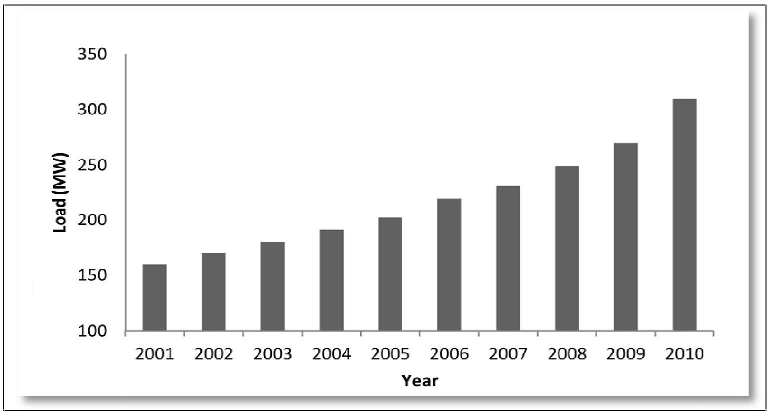


Figure (3.6) : The electricity load required for Gaza strip from 2001 to 2010

Source : Muhaisen, 2007

The significant exploration of the gas field near the Gaza strip beach can play important role in the development of energy sector in the Gaza strip. There are a positive indicators for existence of approximately 50-60 billion m^3 of natural gas in this field. This massive amounts of natural Gas is enough to meet the Palestinians requirements of gas for 30 years, while the surplus will be exported. Unfortunately, the project has not been implemented yet due to the bad political status (Muhaisen, 2007).

Unfortunately, the main problem of energy in the Gaza strip is that it has almost no conventional energy sources. This problem becomes worse by the high density pollution of the Gaza strip and the difficult political status caused by (Israel) occupation. According to Kandeel (2010) the Gaza strip needs (270) MW of electricity. The available supply is (197) MW. The large share of this supply about (60%) with an average load (120) MW is provided by (Israeli) Electricity Company. Locally, about (32%) with an average load (60) MW is provided by Gaza Power Plant. In addition, about (8%) with an average load (17) MW is provided by Egyptian electric company.

In the light of previous statistics, the Gaza strip has been suffering from a real shortage in electricity supply estimated by 25%. The result is cutting of electricity supply for several hours per day which affect negatively on all aspects of the Palestinians life. This shortage rate of electricity supply will be increased by the time if other options is not found. One of the available and considerable options in the Gaza strip is renewable energy sources, particularly solar and wind energy.

Abu-Hafeetha (2009) presented that the energy consumption increased by 2% from 2001 to 2002 and by 9% from 2002 to 2003. The electricity consumption of the Gaza Strip was increased by 80% during the period 1999 to 2005 and about 10% average annual increasing rate (Abu-Hafeetha, 2009). The Gaza Strip consumes other forms of energy such as kerosene, gasoline and diesel. As shown in table (3.2) the Gaza Strip consumes 216 KWh of electricity. It is seems to be a large quantity comparing with other Palestinian territory regions although the small area of the Gaza Strip. This is due to the high population density. As well as, the Gaza Strip consumes a large amount of wood as an alternative resource of energy under the electricity crisis.

Table (3.2): Average Household Consumption of Energy from the Households that Use Energy in the Palestinian Territory by Region, July 2011
Sources: (Palestinian Central Bureau of Statistics, 2011)

Region	Average Household Consumption of Energy					
	Electricity (KWh)	Wood (Kg)	LPG (Kg)	Kerosene (Liter)	Gasoline (Liter)	Diesel (liter)
Palestinian Territory	243	49	15	6	49	66
West Bank	257	42	15	20	80	74
North of West Bank	241	36	15	25	91	89
Middle of West Bank	318	21	15	15	91	83
South of West Bank	214	96	17	25	57	55
Gaza Strip	216	58	15	5	26	23

3.4 Housing situation in the Gaza Strip

3.4.1 Historical Background

The housing sector in the Gaza Strip is a major challenge in the Palestinian situation which requires concerted efforts of all governmental and private institutions. Since Al-Aqsa Intifada in September 2000, the growing demand for housing have increased the need for housing. As well as that population growth rates in the Gaza Strip is the highest rates of population increase in the world. The Gaza Strip need 123106 housing units annually to meet the deficit in the housing sector. We can distinguish four phases to identify the history of housing in the Gaza Strip (Salha, 2003):

1. The first phase: during the British Mandate (1917-1948):

The British government carried out the first survey of the territory of Palestine. It did not have any urban activity except the implementation of a housing scheme in 1934. The total planned area was 3000 dunum, nearly 1000 acres for housing. The residential land divided into different areas with one acre. this plan adopted on the grid planning with wide and regular streets. On the other hand, the British government distributed many of the government land on a number of people in different parts of the provinces of Gaza, but not for housing projects.

2. The second phase: during the Egyptian Administration (1948-1967):

The Egyptian administration began planning housing in the early sixties from 1959 to 1962. Housing projects were adopted on the grid planning. Each project area was two acres which led to the depletion of government land. Then the space reduced to half acre and provided the necessary services to the population in these projects.

3. The third phase: during the Israeli occupation (1967-1994):

The Israeli housing policy adopted on the establishment of several different projects. It distributed land to citizens and built houses or distributed land to the owner of the house or distributed land to build building and demolished the house in the camp.

The main reasons for the housing projects during the Israeli occupation:

- emptying the refugee camps of the population to end the refugee issue.
- reducing overcrowding in the camps to absorb the despair that drives resistance to the occupation.

The main housing projects carried out by the occupation are Sheikh Radwan housing project in Gaza, Al Amal housing project in Khanyounis and Al Brazil project in Rafah.

4. The fourth phase: during the Palestinian National Authority (1994-to date):

The Ministry of Public Works and Housing has constructed housing projects for about 16% of households since 1995. The most important projects carried out by MPWH are Alnada Towers, Sheikh Zayed city, Alkarama project in the northern Gaza Strip, Al-Zahra city in the center of the Strip, and Almashtal, Al Awda city , Tel al-Hawa project in Gaza, Alkalaa and Austrian neighborhood in Khanyounis. Also housing cooperatives have been introduced as one of the solutions developed by MPWH. The most important projects is Tel al-Hawa Housing with multi-story buildings. Figure (3.7) shows some examples of housing projects in the Gaza Strip.

A: Sheikh Zayed city

B: Alkarama project

Figure (3.7): Examples on the mass housing projects in the Gaza Strip

Source: MPWH, 2009

3.4.2 Main Housing Actors in the Gaza Strip

The Ministry of Housing and Palestinian Housing Council are the most important institutions interested in the field of housing which depend on vertical multi-storey buildings in their projects to cope the land scarcity. They implemented several housing projects, while the Ministry of Housing reduced the gap between supply and demand for private housing through land grants and put apartments according to specific criteria.

1. The Ministry of Public Works and Housing (MPWH)

The ministry created in 1994 as a part of the structure of the Palestinian National Authority. It aims to provide housing units available to the citizen in health and social conditions in both urban and rural areas. As well as it contribute to the development of industry and technology building and construction in Palestine. Some of housing projects undertaken by the Ministry such as Alnada project neighborhood, al-Zahra city, Almashtal project, Tel al-Hawa housing project, Alshorouk housing project , Sheikh Zayed City, Alawda city and Alsalam housing project (Al-Isawi, 2008).

Figure (3.8): Tel al-Hawa housing project

Source: MPWH, 2012

2. The Palestinian Housing Council (PHC)

The Council could to recruit more than 168 $ million to help solving the housing problem in Palestine. It contributed to prepare plans and strategies and studies in the field of housing for solving the housing problem. The most important of housing projects in the Gaza Strip are Tel Al Sultan neighborhood in Rafah, Al Kalaa project in Khanyounis, Ain Galout towers in alnasirat and Al Karama housing project (Al-Isawi, 2008)

Figure (3.9): Al Qalaa project in Khanyounis

Source : (PHC, 2012)

3. United Nations Relief and Work Agency (UNRWA)

UNRWA established several settlements after the second Palestinian intifada in September 2000. It established five communities in each of the Deir al-Balah, Khanyounis, Al Fokhary region near to the European Hospital, and Tel Sultan in Rafah in collaboration with UNDP (Al-Isawi, 2008).

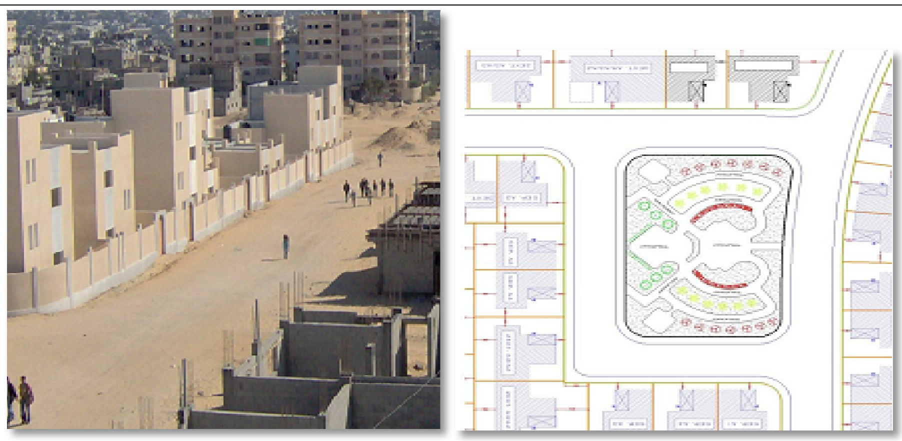


Figure (3.10): Al Amal Housing project

Source: (Al-Farra, 2010)

4. Cooperative housing associations

The Ministry of Housing established a cooperative housing associations in 1997, which is the most achievement project in housing in the Gaza Strip. This system includes some conditions as follows (Al-Sadawi, 2005):

- Forming groups of middle-income for employees, each group of 21-32 families.

- Each group enable to own a piece of land for a nominal fee be paid over a five-years with an area of 1000 square meters and build on 60% of them according to plans of the ministry.

- The associations built around 1340 housing units in the period from 1997-1999, was completed about 40% of them and the rest is not completed.

3.4.3 Types of Residential Buildings

Residential buildings are considered the main construction sub-sector in Gaza. Detached buildings are the most commonly used style in residential complexes. The attached style is only found in the old town in Gaza city and it doesn't used in the present architecture of the Gaza Strip. Building's density, height, area and spacing between them are determined according to the zoning district regulations. The maximum built site coverage ranges between 50% in multi story buildings and 60% in zoning district (b) and 80% in zoning district (c). The minimum area of parcel range between 250 m^2 in zoning district (b) and (c) and 1000 m^2 in multi story buildings. Spacing between buildings is determined according to the side and rear setback. Table (3.3) illustrates the main zoning district regulations in the Gaza Strip (Alkahloot, 2001).

Table (3.3): Zoning district regulations in the Gaza Strip
Source: Alkahloot (2006)

Area	The maximum built site coverage	Number of floors	Top	The minimum area of parcel	The front setbacks	The side and rear setbacks
Zoning district (b)	60%	6	3	250	3m	2/2/2m
Zoning district (c)	80%	6	4	250	2m	1/1/1m
Multi-storey buildings	50%	1.5* street's width	0.5*1.5* street's width	1000	3m	Side back= 10% of height and 15% of height

According to the Palestinian Central Bureau of Statistics (PCBS, 2007), the percentage of separate buildings and villas constitute 39.7% in the Gaza Strip while the percentage of apartments reach to 59.6%, this confirms that the dominant type in the Gaza Strip are apartments which appears in low-rise residential buildings and high residential buildings.

Table (3.4) shows that the number of different housing types in the Gaza Strip in 2011. It indicates that the percentage of apartment buildings in Gaza City up to 75.5%, while the percentage of villas and detached buildings is the highest in the city of Deir al-Balah, where up to 56.1%.

Table (3.4): Percentage Distribution of households in Gaza Strip by types of housing unit. Source: (PCBS, 2011)

Governorate/Region	Type of housing unit		
	Villa/ House	Apartment	Other*
Gaza Strip (average)	39.7%	59.6%	0.7
North Gaza	41.6%	58.4%	-
Gaza	24.5%	75.5%	-
Deir Al-Balah	56.1%	43.4%	0.5
Khanyounis	52.0%	46.3%	1.7
Rafah	40.5%	57.2%	2.3

*Other: Includes Independent Room, or Tent, or marginal

According to Hadid, (2002) residential buildings can be classified into two main types which are detached house and apartment building:

a. Detached House

The separate house is a popular style in the cities, towns and campus of the Gaza Strip. The area of this style can be determined according to the owner ability and to accommodate the main functions which are 2-3 bedrooms, 1-2 bathrooms, kitchen, guest room, setting room, and balconies. Simple forms are using and the main materials are the concrete and hollow blocks walls, which are plastered and painted from both sides with light colors. Ventilation is the most characteristic of this style as the building is exposed to the environment from the four facades. Due to the absence of insulation, the upper floor usually gains much heat in summer time and losses heat in winter. A villa house is another type of this style for rich families. The area of such type is variable starting from 200 m^2 up to 500 m^2. Different forms can be utilized to create shades on the elevations.

b. Apartments Buildings

Residential apartment is a new concept in the Palestinian society. The needs of housing increased especially in cities and some villages. The areas for building purposes is small comparing to the demand of housing needs, especially in cities. This is another reason for the vertical expansion in apartments which can be classified as low-apartment building and tower-apartment. The areas of apartments vary from $80m^2$ up to 180 m^2 with the same functions as in the separate house functions.

The design and form varies depending on number of apartments in the same floor. In most of the low-apartment buildings, 1, 2, or 3 apartments in the same level is the typical example, while the number of floors can reach 6 floors. Each apartment has three facades open to the natural environment in the best cases for ventilation and natural lighting. The building material is concrete. The number of floors can reach more than 15 floors in the tower apartments. Generally, The tower buildings are cool (with humidity) and windy (open to the west – the sea) in summer time, and cold in winter. Figure (3. 11) shows a view of residential building in Gaza city.

Figure (3.11): Arial view of Gaza city

Source: (Hadid,2002)

3.4.4 Current Housing Needs

1. Current Housing Needs

The Gaza Strip suffers from a shortage of housing units in general. In 1994, there was an unnatural increase due to the return of some families. Statistics that calculate the deficit in the number of housing units are based on three criteria (PCBS, 2007) which are the average family size, the rate of marriages and families and the percentage of family members.

As for the first method, the required number of housing units is based on the division of the population on the average family size. The results showed a deficit of 101078 units until the year 2015. While the second method adopted on the rate of family formation and the proportion of new marriages. The results showed a deficit of 158537 units until the year 2015. The third method based on average household size which showed a deficit of 109,703 units until 2015. Finally the total deficit in housing units until 2015 based on average deficit from the previous criteria is 123106 units, See Table (3.5).

Table 3.5: the deficit in housing units in the Gaza Strip from 2004 to 2015 (based on average deficit). Source: PCBS, 2007

Governorates	Household number											
	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
North Gaza	1585	1640	1698	1757	1819	1882	1948	2016	2087	2160	2235	2314
Gaza	2978	3083	3191	3302	3418	3537	3661	3789	3922	4059	4201	4348
The middle	1222	1264	1309	1354	1402	1451	1502	1554	1609	1665	1723	1784
Khanyounis	1640	1697	1757	1818	1882	1947	2016	2086	2159	2235	2313	2394
Rafah	1006	1041	1078	1116	1155	1195	1237	1280	1325	1371	1419	1469
Total	8431	8726	9031	9347	9675	10013	10364	10726	11102	11490	11892	12309

2. Future Housing Needs

According to the future expectations of the population, the average family size in the Gaza Strip and the housing units needs for the returnees. According to the regional plan for the Gaza Strip (2005-2020) which has been considered 1% for renewal consumed houses and 20% for the rehabilitation of housing units in the refugee camps. The housing units needed for normal growth until 2020 will be 4,320,660 units. While the housing units to accommodate the returnees will reach 63,000 units. The housing units needed for the rehabilitation of the refugee camps would amount to 5263 units. The units required for the renewal of damaged buildings will amount to 2423 units.

3.4.5 Future Land Uses in the Gaza Strip

There are different life styles distributed in Gaza Strip as urban, rural and refugee camps. Moreover, the housing types vary between house, multi-story building, high building and township. Land holdings classified in the Gaza Strip into four main categories as shown in table (3.6).

Table 3.6: Land uses in the Gaza Strip

Source: (Ministry of Planning - the regional plan 2005-2015)

Land type	Percent %
Private land	63.9
Waqf land	2.1
Beersheba land	18.7
Governmental land	15.3

The Gaza Strip consists of five Governorates: North Gaza, Gaza, Deir al Balah, Khanyounis and Rafah, according to the current administrative divisions. According to (PCBS, 2007) the definitions for the three types are stated as follows:

. **Urban:** Any locality whose population amounts to 10,000 persons or more. This applies to all governorate/district centers regardless of their size. Besides, it refers to all localities whose populations vary from 4,000 to 9,999 persons provided they have, at least, four of the following elements: public electricity network, public water network, post office, health center with a fulltime physician and a school offering a general secondary education certificate.

. **Rural:** Any locality whose population is less than 4,000 persons or whose population varies from 4,000 to 9,999 persons but lacking for the aforementioned elements.

. **Camps:** Any locality referred to as a refugee camp and administered by the United Nations Refugees and Work Agency in the Near East.

Distributed population in the Gaza Strip was residing in urban areas by 81.5% of the total population in the Gaza Strip, and 38,056 individuals residing in rural areas by 2.7% of the total population In the Gaza Strip, and 219,048 individuals residing in the camps by 15.8% of the total population in the Gaza Strip. In the census 1997, the percentage of the population in the Gaza Strip residents in urban areas about 63.8%, and the percentage of the resident population in rural areas, about 5.3%, while the proportion in the camps, reaching 30.9% of the total population living in the Gaza.

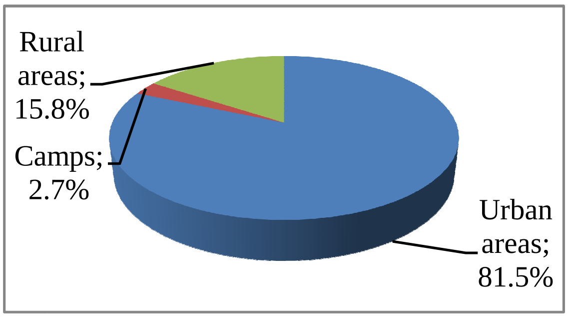


Figure (3.12): Distributed population in the Gaza Strip

Source: Adapted by the author

3.5 Housing Projects in the Gaza Strip

Several institutions implemented many housing projects over the Gaza Strip such as the Ministry of Public Works, Palestinian Housing Council and United Nations Relief and Work Agency. They implemented large housing projects like El-Zahra, Austrian, El-Nada, EL-Fara, Deir-El-Balah, Sheikh Zayed, El-Karma, Ain-Jalout, and Tal-El-Soltan housing projects. In this section, the research shows some previous and future housing projects in the Gaza Strip with a special focus on housing density.

3.5.1 Previous Housing Projects

1.The Ministry of Public Works and Housing Projects:

The Ministry of Public Works and Housing (MOWH) is working in implementing relative large scale housing projects. Table (3.7) shows some housing projects.

Table 3.7: The Ministry of Public Works and Housing projects

Source: (MPWH, 2009)

SN	Project	Planed No. of flats	Actual No. of flats	Project area (dunum)	Density (DU/Dunum)
1	El Nada Neighborhood Housing Project	1500	450	150	10
2	El Zahra Township	Serves 1500 capita		334	4
3	El Mashtal Housing Project	2000	On going	280	7
4	Deir El Balah Housing Project	125	80	5	25
5	Tal El Hawa Housing Project	4160	80	420	10
6	El Namsawi Housing Project	206	170	20	10
7	El Sheikh Zayed Housing Project	3500	527	527	7
8	El Awda Housing Project	650	357	50	13
9	El Salam Housing Project	410	410	32	13

2. Palestinian Housing Council (PHC) Projects:

The Palestinian Housing Council works many housing projects. The most important of these projects is Al Karama towers housing project, where is located in the north of Gaza City which contains 416 residential units (Al-Sadawi, 2005).

Figure (3.13): Al Karama towers housing project

Source: PHC, 2008

3.5.2 Current and Proposed Housing Projects

1. Al Israa neighborhood project

The project is located in the territory of editors within the influence of Khanyounis municipality in the northeast of Asdaa city. The total area is 517 acres of the neighborhood. The project is a residential neighborhood consists of two adjacent residential . It consist of 4784 residential housing units with a population of 31.096 people. The maximum population density is about 60.15 persons / acre (MPWH, 2012).

Figure (3.14) : Al Israa project plan
Source: (MPWH, 2012)

2. Al Buraq neighborhood project

The project is located in the territory of editors at the west of the Austrian, Amal neighborhood and on the borders of the Western camp. The area of the project is864.40 acres. The project's land is divided into two parts separated by Ahmed Yassin street. The project is a residential neighborhood contains five residential neighborhoods, including 8987 residential units and a population of 55,276 people. The residential density of the project is about 63.5 persons / acre (MPWH, 2012).

Figure (3.15): Al Buraq project plan
Source: MPWH, 2012

3. Bissan Housing Project

The project is located in Beit Lahiya at the north of Gaza Strip. The area of the project is 606 acres. The project is a residential neighborhood consists of two residential neighborhood. The number of housing units is 6400 with a population of 41.600 in habitants. The population density is 68.61 persons / acre(MPWH, 2012).

Figure (3.16): Bissan project plan

Source: (MPWH, 2012)

4. Al-Firdaws Housing Project

The project is located within the boundaries of the town of Beit Lahiya in the voucher number (36) of Plot No. 1742. The project covers an area of about 179.716 acres. The project is a residential neighborhood containing 1162 apartments and a population of 6972 inhabitants. The population density of the project is 39 persons/acre (MPWH, 2012).

Figure (3.17) : Al-Firdaws project plan

Source: (MPWH, 2012)

3.5.3 Comments and Observations

Because of the acute shortage of housing in Gaza, resulting from a high birth rate and the returnees of Palestinian after the peace agreement between Palestinian Liberation Organization (PLO) and Israel in 1993, a number of housing programs have been launched since 1994, providing the urban population with dwellings and housing facilities outside and inside the existing urban perimeters.

There are similar features of the residential projects in the Gaza Strip which is mostly due to economic reasons and these features can be summarized as described by Salah Al-Sakka in the Journal of Development Affairs as the following:

1. The economic difficulties as well as the low level of per capita income compared with the high cost of living that have affected the form and style of urban sprawl in the Gaza Strip.
2. Overcrowding building on the parcel which has been divided into a number of small parcels to a larger number of owners due to high land prices.
3. Most housing units dispenses with aesthetic elements within the houses, without the external finishing due to high construction costs significantly in recent times.
4. Neglect the historic and old buildings, where the phenomenon of demolition of old buildings without the attention of any official or popular or the imposition of laws to protect and preserve them.
5. There is no real planning for the cities and villages in the Gaza Strip . Village councils and Municipalities issued permits depend on old foundations which are not suitable with the current situation of housing sector.

In General, the present picture of housing status seems hard and complex. The housing sector is getting more crucial. This can be related to the following difficulties:

1. The concentration of whole Gaza Strip population in narrow and restricted areas due to x-settlements and occupation.
2. The limited financial resources of the PNA to rehabilitate the infrastructure required to the development and expansion of infrastructure. This is reflected by the lower number of housing units constructed yearly by the PNA to solve the housing projects.
3. The Israeli rule on the raw material needed for construction through directing Gaza Strip entry points and delaying the port establishment.
4. The high growth rate, companied with escalating in the family size and youth contribution to the population pyramid, are a prevalent condition in all areas in Gaza Strip.
5. The bad economical conditions and high unemployment levels as a result of Israeli actions, intrusions and occupation.

As for housing density, It can be seen that the housing projects in the Gaza Strip is dominated by high-density residential per dunum. In addition, there is a lack of diversity in the types of residential buildings during each project which is a problem in energy consumption.

3.6 Conclusion

The chapter addressed the reality of the housing sector in the Gaza Strip, which it was clear that it is suffering from various problems especially the land scarcity for housing construction in light of the rising population and the high cost of construction due to poor economic conditions. The chapter mentioned the most important actors for the housing sector in the Gaza Strip such as the Ministry of Works and Housing and the Council of Palestinian housing in addition to cooperative housing societies. It identified the most important projects implemented by those actors in order to know the problems that should be avoided in new housing projects. Also it mentioned the most important current and future needs in the housing sector in order to the growing numbers of people quickly. Also, the researcher showed the most common features between the housing projects in the Gaza Strip and most of the problems. The main problems are the high housing density, the lack of land and the lack of organized planning. In addition, most projects neglected component of energy conservation through regular population densities. At the end of chapter, the researcher showed the situation of the energy in the Gaza Strip and the potential of using renewable energy in the Gaza Strip. Thus the next chapter will show the relationship between population density and energy conservation in future housing projects in the Gaza Strip which depends on the housing types.

CHAPTER 4

Investigation of Energy Consumption of Various Housing Types

4.1 Introduction

Planning for new communities should encourage the development of a variety of housing types, densities and more compact housing forms that will provide a variety of housing options while still promoting a strong and unified residential character. Basically, the house type is one of the main parameters which determines the urban character and its relationship with the outdoor environment. Moudon argues that in order to characterize house forms, inventory on house forms should aim at observing and documenting house types in terms of their shapes, the major building elements and where necessary their decorative elements (see: Lupala, 2002). Formal characteristics also include whether houses are detached, semidetached, row, or high-rise buildings. The number of storeys, roof type, building materials, house sizes, and building uses are essential elements that characterize house forms. Hence, It can affect the received amounts of solar radiation, the rate of air infiltration and as a result the indoor thermal conditions.

In order to provide a full understanding of these integrated parameters, this chapter is divided into two sections. The first section introduces a study of 23 different housing types with different heights in order to examine the relationship between those types and the increasing in both heating, cooling and total loads comparing with the reference house type. The second section studies the previous types in different urban configurations. The study then correlates the effect of changing the type house configuration on the urban with the total, heating and cooling loads. It evaluates the effect of changing the building height with the same plot ratio on energy efficiency.

4.2 Tools and validity

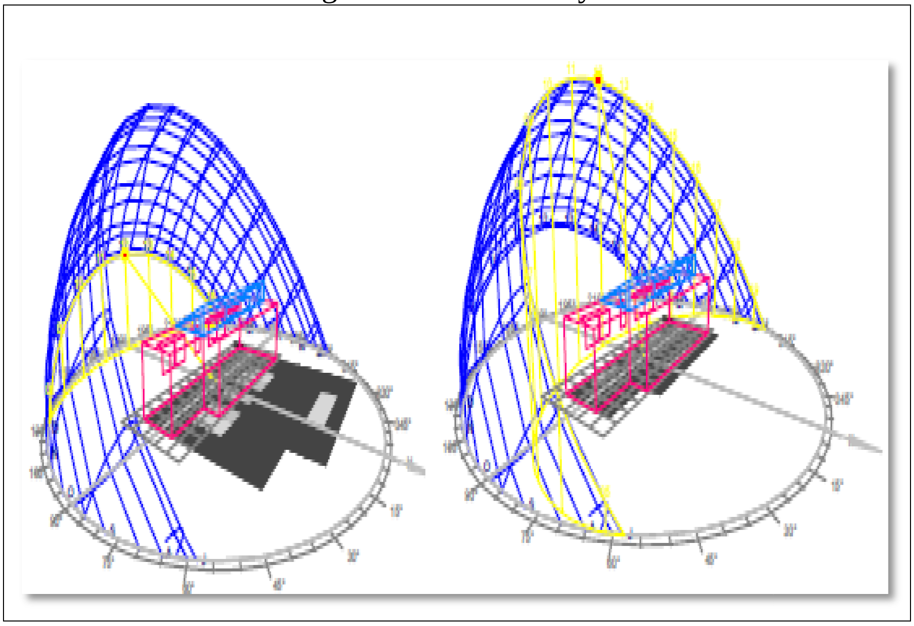
The research has been carried out simulation processes using computerized program namely ECOTECT and Design Builder which provides the required results in this study. Residential buildings with different forms and in different urban configurations have been analyzed energetically. The heating and cooling loads have been calculated for each model. The results have been evaluated in order to optimize the thermal behavior of the models.

4.2.1 ECOTECT program

Ecotect is a software package with a practical approach to conceptual building design. It couples an intuitive 3-D design interface with a comprehensive set of performance analysis functions and interactive information displays. ECOTECT offers a wide range of internal analysis functions which can be used at any time while modeling. These provide almost instantaneous feedback on parameters such as sun penetration, potential solar gains, thermal performance, internal light levels, reverberation times and even fabric costs (Marsh, 2003). ECOTECT has the ability to calculate the total amount of solar radiation falling on selected surfaces for each month of the year. Geometric overshadowing, reflective effects and available radiation are calculated separately for each day within the month (see figure 4.1).

Ecotect is used to do the following:

- Display and animate complex shadows and reflections,
- Generate interactive sun-path diagrams for instant overshadowing analysis,
- Calculate the incident solar radiation on any surface and its percentage shading,
- Work out daylight factors and artificial lighting levels either spatially or at any point,
- Calculate monthly heat loads and hourly temperature graphs for any zone,
- Generate full schedules of material costs and environmental impact,
- Export to the Radiance Lighting Program for physically accurate lighting analysis,
- Read and write a wide range of CAD and analysis file formats.



Figure(4.1): An example of ECOTECT analysis tools (Shadow Analysis)

Source: Marsh, 2006

ECOTECT provides a range of thermal performance analysis options. At its core is the Chartered Institute of Building Services Engineers (CIBSE) Admittance Method used to determine internal temperatures and heat loads. This thermal algorithm is very flexible and has no restrictions on building geometry or the number of thermal zones that can be simultaneously analyzed. Most importantly, with only a few pre-calculations for shading and overshadowing, it is very quick to calculate and can be used to display a wide range of very useful design information(Marsh, 2003).

The underlying assumption of the Admittance Method is that the internal temperature of any building will always tend towards the local mean outdoor temperature. Any fluctuations in outside temperature or solar load will cause the internal air temperature to fluctuate in a similar way, though delayed and dampened somewhat by thermal capacitance and resistance within the building fabric. When the total of all heat losses become equal to the total of all gains, then internal temperatures stabilize As with any calculation method, it is necessary to strike a balance between accuracy and simplicity / flexibility. The Admittance Method is widely used around the world and has been shown to be an extremely useful design tool. It is not as physically accurate as some of the more computationally intensive techniques such as the response factor or finite difference methods, however for the purposes of design decision-making, the Admittance Method is by far the best choice (Beattie and Ward, 2012).

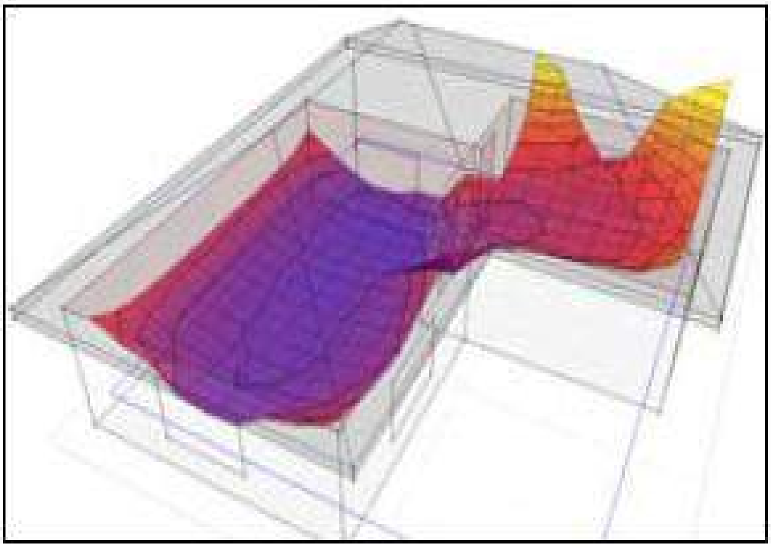


Figure (4.2): Thermal performance in ECOTECT
Source: Marsh, 2006

4.2.2 Design Builder

Design Builder is a powerful software tool for creating and assessing building designs. It has been specially developed so it can be used effectively at any stage of the design process. From the concept stages where just a few parameters are needed to capture the building design to much more detailed building models for established designs (Design Builder web site, 2013).

Design Builder is suitable for use by architects, building services engineers, energy consultants, and university departments. Some typical uses are:

- Evaluating a range of façade options for the effect on overheating, energy use and visual appearance.
- Checking for optimal use of natural light, modeling lighting control systems and calculating savings in electric lighting.
- Calculation of temperature, velocity and pressure distribution in and around buildings using CFD
- Visualization of site layouts and solar shading.
- Thermal simulation of naturally ventilated buildings.
- HVAC design including heating and cooling equipment sizing.

Design Builder uses the latest Energy Plus simulation engine to calculate the energy performance of the building. Output data may be selectively graphed or exported in table format for use in other applications. Energy Plus is the building energy simulation program for modeling building heating, cooling, lighting, ventilating, and other energy flows. Energy Plus is a stand-alone simulation program without a 'user friendly' graphical interface. Design Builder creates an elegant and easy to use interface for Energy Plus.

Data templates allow the users to load common building constructions, activities, HVAC & lighting systems into the design by selecting from drop-down lists. They can also add their own templates if they often work on similar types of buildings. This, combined with data inheritance, allows global changes to be made at building, block or zone level. They can also control the level of detail in each building model allowing the tool to be used effectively at any stage of the design process.

A comprehensive range of simulation data can be shown in annual, monthly, daily, hourly or sub-hourly intervals:

- Energy consumption broken down by fuel and end-use.
- Internal air, mean radiant and operative temperatures and humidity
- Comfort output including temperature distribution curves, ASHRAE 55 comfort criteria.
- Site weather data
- Heat transmission through building fabric including walls, roofs, infiltration, ventilation etc.
- Heating and cooling loads.
- CO_2 generation.
- Heating and cooling plant sizes can be calculated using design weather data.

Data can be displayed graphically or in tabular form and can be exported in a range of formats to spreadsheet and custom reports.

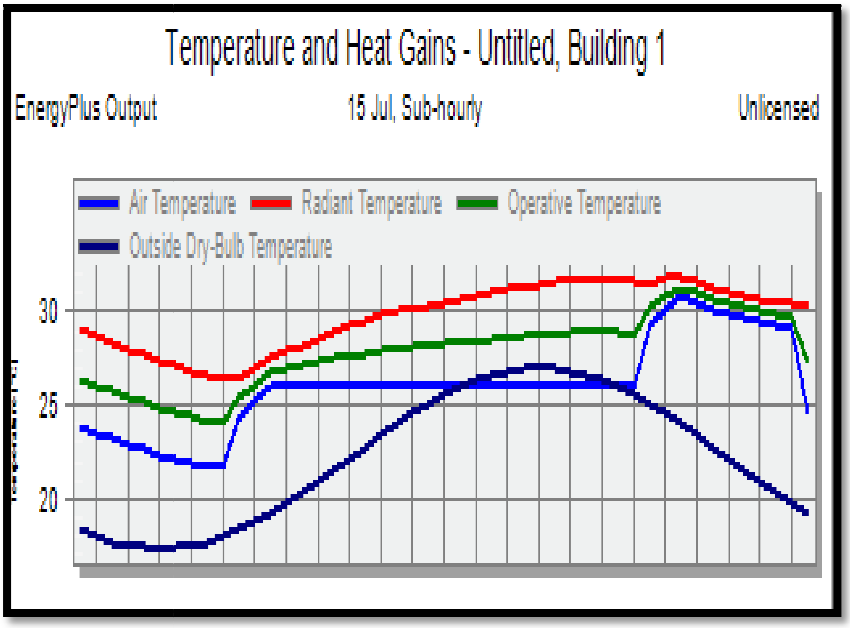


Figure (4.3): Hourly temperature and heat gains in Design Builder
Source: Design Builder web site, 2013

4.3 The Effect of House Type on Energy Consumption

Basically, this study examines the relation between the energy consumption and the house type with different height. For this reason, 25 house types which are single detached house, row house, duplex house, low rise apartment, mid rise apartment and high rise apartment were examined. The area (A) for each dwelling is assumed to be 130 m^2 as it represents the average of residential units areas in Gaza (Asfour, 2011). It has been provided to accommodate six members, which reflects the average Palestinian family size (PCBS,2007). The height is assumed to be 3 m for each storey.

The most common construction system in the residential buildings of Gaza strip is the structural system (reinforced concrete foundations, columns and ceilings). In this study, building materials are defined to match the most common ones in the Gaza strip. Thermal properties of these materials have been obtained using the thermal properties calculator integrated in ECOTECT, Design Builder and the Palestinian Code of Energy Efficient Buildings (MOLG,2004).

The following is a description of the several materials used in the reference modeling building:

1. Most commonly, walls in the Gaza Strip are made of hollow concrete blocks and thin layer of cement plastering. Thermal properties of walls are as follows: U-value:2.3 W/m^2K, admittance: 4.4 W/m^2K, decrement factor: 0.3, time lag: 7.4 hrs.
2. Most commonly, ceilings in the Gaza Strip are made of reinforce concrete, hollow concrete blocks and thin layer of cement plastering. Thermal properties of ceilings are as follows: U-value:2.6 W/m^2K, admittance: 4.9 W/m^2K, decrement factor:0.4, time lag: 6.8 hrs.
3. Windows are single-glazed type with aluminum frame, its thermal properties are as follows: U-value:5.5 W/m^2K, admittance: 5.5 W/m^2K, solar heat gain coefficient: 0.9.

To specify the sensible gains due to lighting and appliance should be estimated. As for lighting it is estimated in residential buildings that heat gains due to energy efficient lighting is about 11W/m^2(CIBSE,1998). As for appliances, table(4.1) shows an assumption of the appliances that are usually used in residential buildings in addition to their operation times. The total heat emission due to these electric equipment is 520 W. Given that each dwelling unit area is 130 m^2, heat gains due to these equipment is 4 W/m^2.

Table (4.1): Heat emission due to equipments.

Source: CIBSE,1988

Equipment	No.	Watts	Operation time	Total(W)
Refrigerator	1	60	75%	45
Washing machine	1	1000	10%	100
Oven	1	2000	5%	100
Kettle	1	2000	5%	100
T.V	1	150	50%	75
P.C	1	200	50%	100
Total(W)				520

Thus, sensible heat gains should be defined as: heat gains due to lighting + heat gains due to appliances = 4 +11 = 15 W/m^2.

To carry out any thermal analysis using ECOTECT and Design Builder, it is essential to specify the city in which the building located. The climate data of this city should be download from the program directories. As there is no climatic data file for Gaza, it is possible to rely on Al-Arish climatic data file due to the similarity between these two cities. Al-Arish is a coastal city in Egypt that is close to Gaza. Both cities are located on latitude 31 N. Table (4.2) compares temperature averages for both cities.

Table (4.2): Average monthly temperature in Al-Arish and the Gaza Strip

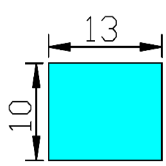
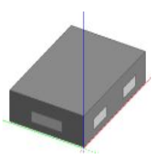
Source: www.weatherbase.com, 2013

Average temperature in Al-Arish												
	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
C°	13	14	16	18	21	24	25	26	25	22	20	16
Average temperature in the Gaza Strip												
	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
C°	13	14	15	18	20	23	25	26	25	22	19	15

The optimum orientation for the Mediterranean climate is which provide both heating and cooling. The solar access is the most important parameter for heating requirements. Hence, it will be appropriate to orientate the building to the south. This south-west orientation would be worse in summer, instead the building have to orientate to provide breeze and shading. In general, the best orientation for the reference building is north-south direction.

All house types were considered as isolated buildings without overshadow from any adjacent buildings. The description of the base case reference for generic residential building is clarified in table (4.3).

Table (4.3): Description of the Base Case used as a Reference in the modeling study

Location	**Floor area(m^2)**	**Height**	**Windows to wall(%)**	**People number**	**Plan**	**Perspective**
Gaza city 31° N, 34° E	130	3	15	6		

4.3.1 Parametric Investigation

The study investigates the effects of house types with various heights on the heating, cooling and total loads. The study analyzed different house types such as single detached house, duplex house, row house, low-rise apartment, mid-rise apartment and high-rise apartment. The study used a methodology to develop abbreviation codes for the house types within the study to understand and deal with them during the analysis of the results. The method gives the house type a special code which contains three items; the first refers to the house type, the second refers to the number of floors and the third refers to the number of apartments in each floor. Table (4.4) is clarified the method for determining the abbreviation codes of some house types are showed in the study.

Table (4.4): Description of the method is used for determining the abbreviation codes in the modeling study

House types	Item1 House type	Item 2 number of floors	Item 3 number of apartments in a floor	abbreviation code
Single Detached house	D	1	1	D.1(1)
Duplex house	Du.	2	-	Du.2
Row house	R	1	2	R.1(2)
Low- rise apartment	Al	3	4	Al.3(4)
Mid- rise apartment	Am	5	4	Am.5(4)
High- rise apartment	Ah	10	4	Ah.10(4)

The study investigates four types of houses with different heights, as the following:

1. Single Detached House:

Because of the detached houses constituted 22.7% of housing types in the Gaza Strip (PCBS,2007), the study offers 4 types of these buildings. Each floor contains one apartment (130 m^2) with height from 1 floor to 4 floor as shown in figure (4.4).

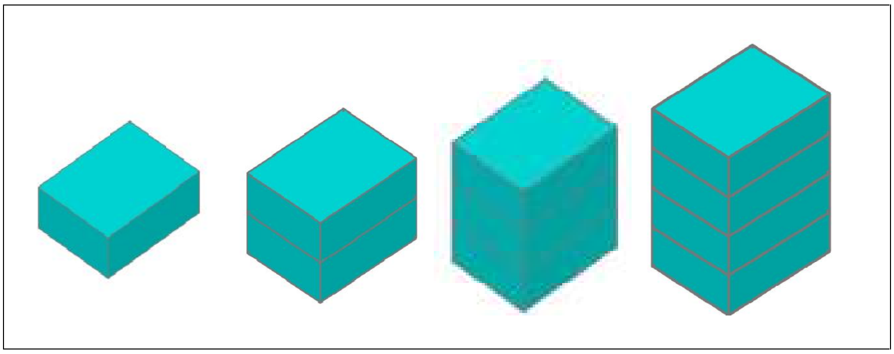


Figure (4.4): Perspective models of single detached house

2. Duplex House:

Because of the duplex houses constituted about 17% of housing types in the Gaza Strip (PCBS,2007), the study offers a duplex house model which contains two floors with 65 m^2 as shown in figure (4.5).

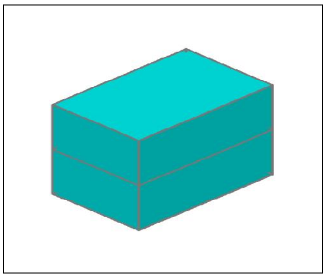
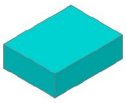
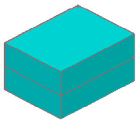
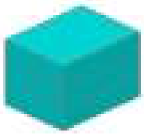
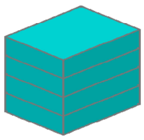
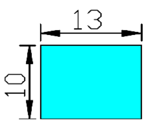
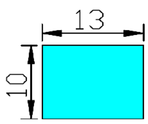
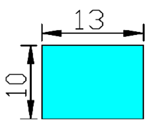
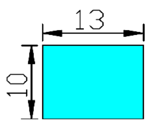
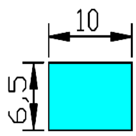


Figure (4.5): Perspective model of duplex house

Table (4.5) summarized parameters of single detached and duplex house which are analyzed in the study.

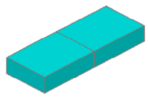
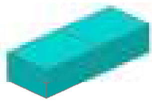
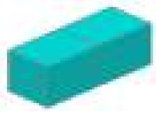
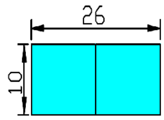
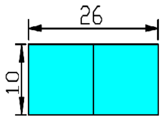
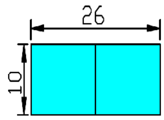
Table (4.5):Geometrical Parameters of Detached and Duplex Modeling Cases

House Type	**Single detached house**				**Duplex house**
House Code	**D.1(1)**	**D.2(1)**	**D.3(1)**	**D.4(1)**	**Du.2**
Perspective					
Plan					
Height(m)	3.3 (1floor)	6.6 (2 floors)	9.9 (3floor)	13.2 (4 floors)	6.6 (2 floors)
Plan area/dw. (m^2)	130	130	130	130	130
Surface area (m^2)	411.8	823.6	1235.4	1647.2	477.8
Number of dwelling	1	2	3	4	1
Number of people	6	2*6=12	3*6=180	4*6=24	6

3. Row house:

The study offers 3 types of these buildings. Each floor contains two apartment (130 m^2) with height from 1 floor to 3 floor as shown in table (4.6).

Table (4.6): Geometrical Parameters of Row House Modeling Cases

House Type	Row house		
House Code	**R.1(2)**	**R.2(2)**	**R.3(2)**
Perspective			
Plan			
Height(m)	3.3 (1 floor)	6.6 (2floors)	9.9 (3 floors)
Plan area/dw. (m^2)	130	130	130
Surface area (m^2)	823.6	1647.2	2470.8
Number of dwelling	2	4	6
Number of people	2*6=12	4*6=24	6*6=36

4. Apartment Houses:

Because of the apartment houses constituted 59.6% of housing types in the Gaza Strip (PCBS,2007), the study offers 3 types of these buildings which are low- rise, mid – rise and high- rise apartment as the following:

a. Low- Rise Apartment:

The study offers 5 types of these buildings. In 3 types, each floor contains two apartment (130 m^2/ ap.) with height from 2 floor to 4 floor. In the others, each floor contains four apartment (130 m^2/ ap.) with height from 3 floor to 4 floor.

b. Mid- Rise Apartment:

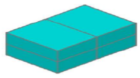
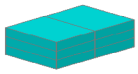
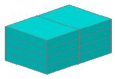
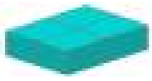
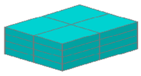
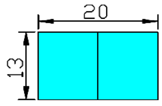
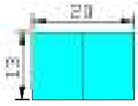
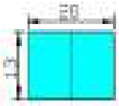
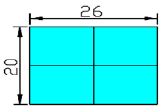
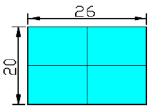
The study offers 3 types of these buildings. Each floor contains four apartment (130 m^2/ ap.) with height from 5 floor to 7 floor.

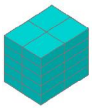
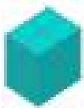
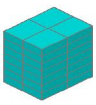
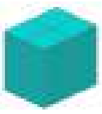
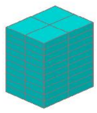
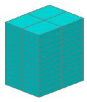
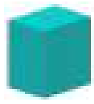
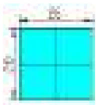
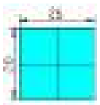
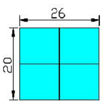
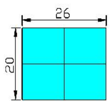
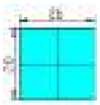
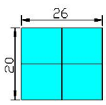
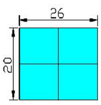
c. High- Rise Apartment:

The study offers 3 types of these buildings. Each floor contains four apartment (130 m^2/ ap.) with height from 5 floor to 7 floor.

Table (4.7) summarized parameters of low- rise, mid- rise and high rise apartment which are analyzed in the study.

Table (4.7):Geometrical Parameters of Low-Rise, Mid-Rise and High Rise Apartment Modeling Cases

House Type	Low – Rise Apartment				
House Code	**Al.2(2)**	**Al.3(2)**	**Al.4(2)**	**Al.3(4)**	**Al.4(4)**
Perspective					
Plan					
Height(m)	6.6 (2 floors)	9.9 (3 floors)	13.2 (4 floors)	9.9 (3 floors)	13.2 (4 floors)
Plan area/dw. (m^2)	130	130	130	130	130
Surface area (m^2)	1647.2	2470.8	3294.4	4946.1	6594.8
Number of dwelling	4	6	8	12	16
Number of people	4*6=24	6*6=36	8*6=48	12*6=72	16*6=96

House Type	Mid-rise apartment			High-rise apartment			
House Code	**Am.5(4)**	**Am.6(4)**	**Am.7(4)**	**Ah.8(4)**	**Ah.10(4)**	**Ah.12(4)**	**Ah.15(4)**
Perspective							
Plan							
Height(m)	16.5 5floors	19.8 6floors	23.1 7floors	26.4 8floor	33 10floor	39.6 12floor	49.5 15floor
Plan area/dw. (m^2)	130	130	130	130	130	130	130
Surface area (m^2)	8240.5	9889.2	11536.4	13182.1	16476.5	19772.5	24712.5
Number of dwelling	20	24	28	32	40	48	60
Number of people	20*6= 120	24*6= 144	28*6= 168	32*6= 192	40*6= 240	48*6= 288	60*6= 360

4.3.2 Simulation Results of different house types

Simulations were performed using ECOTECT software. Also, Design Builder software was used to validate the results. The simulation results were expressed in terms of annual heating loads, annual cooling loads and annual total loads in KWh. These loads have been normalized by dividing them by the total floor area of the building, so that modeling cases with different building volumes can be fairly compared. Fig. 4.6 shows that the total loads estimated in D.1(1) is 82.05 KWh/m^2, in D.2(1) is 104.85 KWh/m^2, in D.3(1) is 106.26KWh/m^2 and in D.4(1) is 109.56 KWh/m^2 in the ECOTECT software. Thus, it shows an increase of 21.7 % from D.1(1) to D.2(1). In general, the observed increase between D.1(1) and D.4(1) is inconsistent with the common trend that increasing housing density leads to a reduction in energy consumption per housing unit. Thus, a detailed investigation of each floor has been carried out using ECOTECT to find out the reason. It has been found that the observed increase between D.1(1) and D.2(1) is mainly related to the cooling load, which increased by 33%. This can be related to the decrease of the surface area which limits heat loss by convection. However, this can be a matter of further investigation.

It is also clear from Fig. 4.6 that there is a slight increase of 1.3% from D.2(1) to D.3(1) and 3.1% from D.3(1) to D.4(1) in the ECOTECT software. This explains the increasing in the total loads with increasing the height and the occupancy. The results show that the total loads estimated in D.1(1) is 82.05 KWh/m^2 in the ECOTECT software. In the case Du.2, the total load increased up to 121.75 KWh/m^2 which show an increase of 39.7% in the ECOTECT software. This mean that the duplex house consumes more energy than the detached house because of the increasing in the surface area by 16.2% from the duplex house to the detached house. It is also clear that there is a decline in loads by 79% from Du.2 to R.1(2) in the ECOTECT software. This means that the horizontal plan of the row house consumes less than the vertical design of the detached and duplex house. Also, the results indicate that the total loads estimated in Al.2(2) is 104.06 KWh/m^2 in the ECOTECT software which shows an increase of 48.3% from the row houses. This mean that the increasing of height increases the total loads in the simulated cases. It is clear that there is almost a linear relationship between low-rise, mid-rise and high-rise apartment buildings. The row house type offers the lowest energy consumption. On the other hand, the duplex house presents the highest energy consumption. Figure (4.6) shows the effect of house type on the total loads per m2 throughout the year using the ECOTECT.

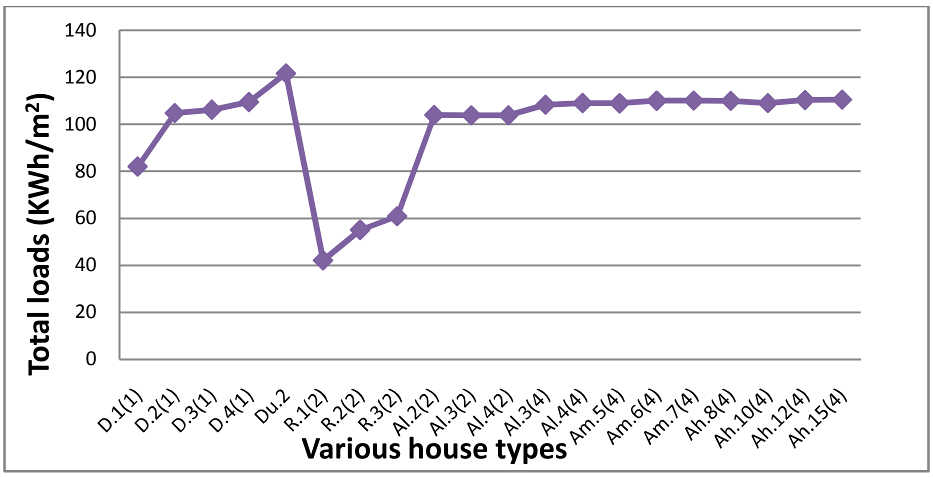


Figure (4.6): Annual total loads in house types (KWh/m^2) by ECOTECT

In the Design Builder software, it can be noticed the same trend of increasing in the total loads. The results show that the total loads estimated in D.1(1) is 90.81 KWh/m^2, in D.2(1) is 107.61 KWh/m^2, in D.3(1) is 115.62 KWh/m^2 and in D.4(1) is 116.89 KWh/m^2. Thus, it shows an increase of 16.8 % from D.1(1) to D.2(1). It is clear that there is a slight increase of 5.6% from D.2(1) to D.3(1) and 2.1% from D.3(1) to D.4(1).

In the case Du.2, the total load increased up to 129.51 KWh/m^2 which show an increase of 35.7% from the detached houses. It is clear that loads decreased by 70.4 % from the duplex house to the row houses. Also, the results indicate that the total loads have an increase of 41.5% from the row houses to the apartment houses.

The discrepancy in results between ECOTECT and Design Builder can be explained as a result of different load calculation techniques and assumptions. ECOTECT uses the worst case annual design load while the ASHRAE load calculator uses a worst month scenario (January) for heating loads and 5 months (May-September) for cooling loads. The simulation engine and load calculation methods are different in the two programs. While ECOTECT uses the CIBSE 'admittance method' for calculating thermal loads, the Energy Plus simulation engine uses to calculate the energy performance of the building in Design Builder (Marsh, 2003).

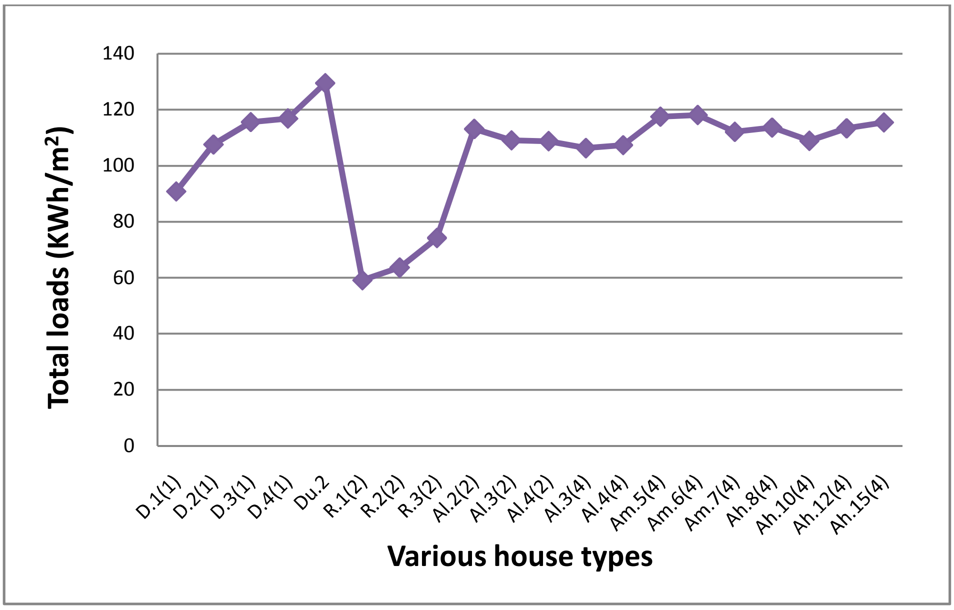


Figure (4.7): Annual total loads in house types (KWh/m^2) by Design Builder

In the ECOTECT software, the same trend of increasing in the total loads can be noticed in the heating loads from the single detached house D.1(1) to the duplex house Du.2 which is about 21.7%. It is evident that there is a strong difference between the row house R.1(2) and the single detached house D.1(1) which decreases to about 65% in the heating loads. This mean that the row house consume less heating loads than the detached houses because it has more surface area which increases by 50% from the surface area of D.1(1). In the low-rise apartment models, the heating loads decreases from Al.4(2) to Al.4(4) by 56.3 % . There is a slight difference between mid –rise and high-rise apartment which decreased by 1.3% in the heating loads. In general, this mean that the heating loads decrease with the increasing of height. This is because heat loss from one apartment becomes heat gain from the upper one. This effect is more effective as the height increases. Figure (4.8) shows the effect of house type on the heating loads per m^2 throughout the year using the ECOTECT.

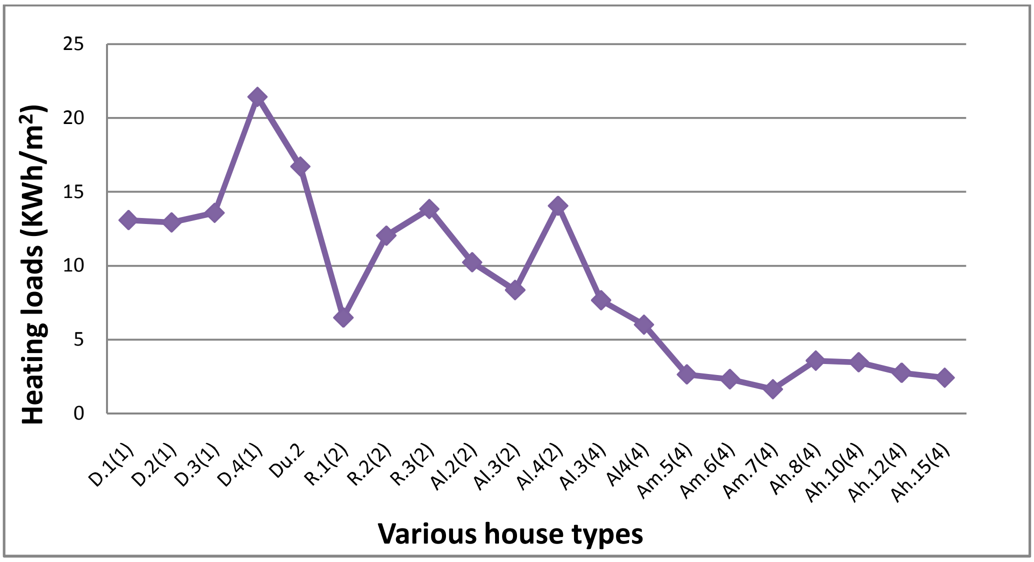


Figure (4.8): Heating loads in house types (KWh/m^2) by ECOTECT

In the Design Builder software, the same trend of increasing in the total loads can be noticed in the heating loads from the single detached house D.1(1) to the duplex house Du.2 which is about 33.6%. It is evident that there is a decrease by 35.2% from the duplex house Du.2 and the row house R.1(2).It is clear that the heating loads decrease in the low-rise, mid-rise and high-rise by about 51.2% from the row houses. Figure (4.9) shows the effect of house type on the heating loads per m^2 throughout the year using the ECOTECT.

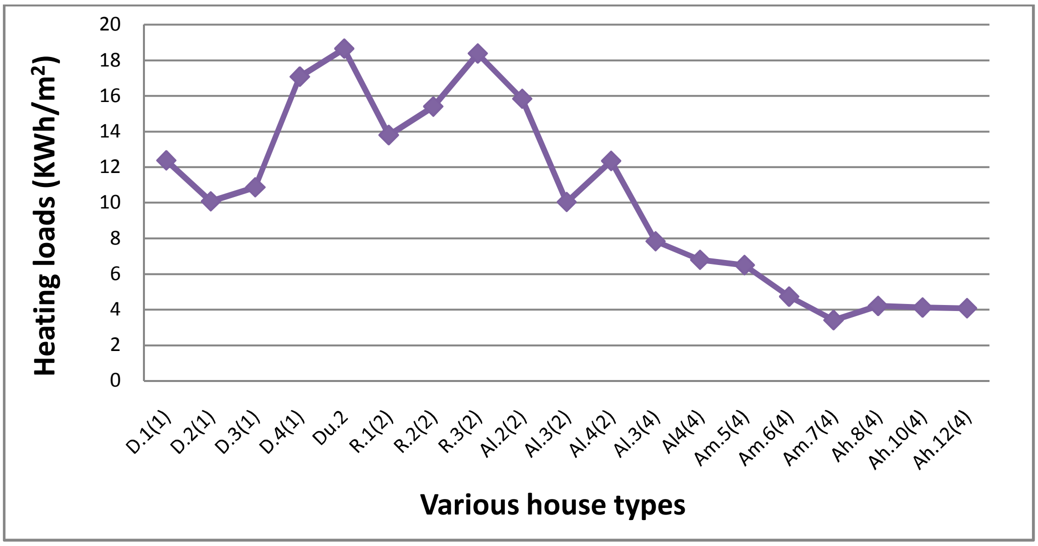


Figure (4.9): Heating loads in house types (KWh/m^2) by Design Builder

The same trend of increasing in the total loads can be noticed in the cooling loads from the single detached house D.1(1) to the duplex house Du.2 which is about 23.7% in the ECOTECT software. This mean that the increasing in the height and the occupancy increases the cooling loads. It is evident that there is a strong difference between the row house R.1(1) and the single detached house D.1(1) which decreases to 33.2% in the cooling loads because of decreasing in the height. As the largest portion of buildings especially the high rise apartment can be considered as the highest thermal option in the cooling loads. Also, the low rise apartment presents similar behavior to high-rise apartment buildings, where increasing density doesn't result in a significant saving in energy. Figure (4.10) shows the effect of house type on the cooling loads per m^2 throughout the year using the ECOTECT.

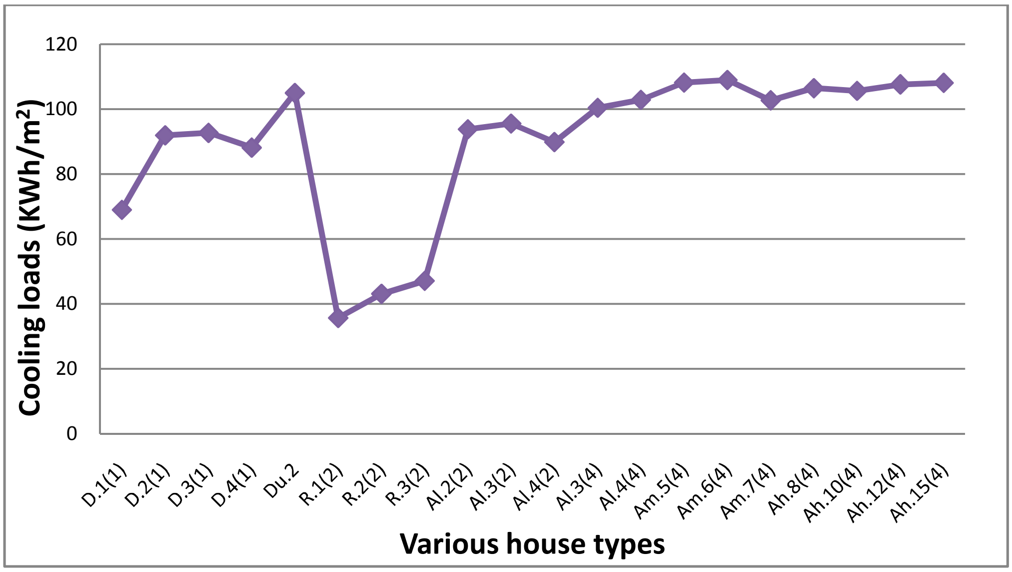


Figure (4.10) : Cooling loads in house types (KWh/m^2) by ECOTECT

In Design Builder software, the same trend can be noticed in the cooling loads which emphasizes the increasing in cooling loads with the increasing of height and occupancy. The row houses achieve the lowest energy consumption in the cooling loads, while the high-rise apartment acheives the highest energy consumption in the cooling loads. Figure (4.11) shows the effect of house type on the cooling loads per m^2 throughout the year using the Design Builder.

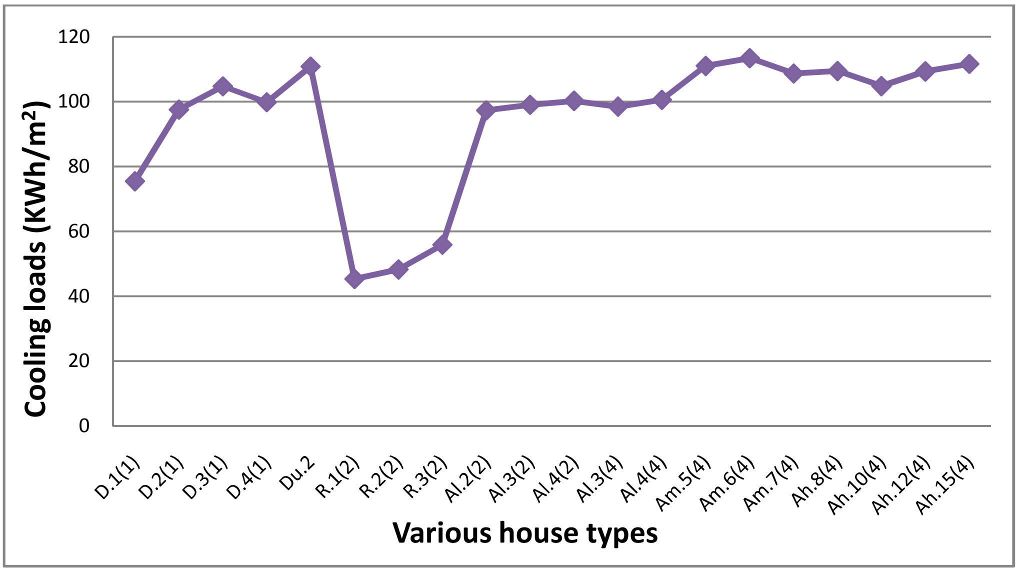


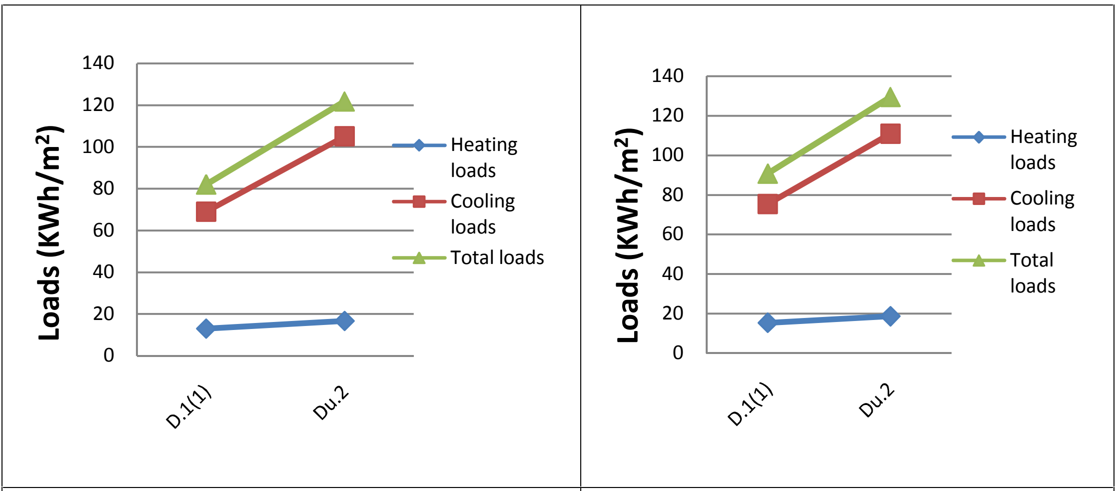
Figure (4.11): Cooling loads in house types (KWh/m^2) by Design Builder

4.3.3 Simulation results of different house types with the same occupancy

The single detached house D.1(1) and the duplex house Du.2 have the same occupancy (6 persons each dwelling). The results indicate that the total loads estimated in Du.2 is higher than D.1(1) by 39.6%, 3.6% and 36.04% in terms of total, heating and cooling loads respectively by ECOTECT.

Also the results indicate that the total loads estimated in Du.2 is higher than D.1(1) by 38.7%, 3.27% and 35.43% in terms of total, heating and cooling loads respectively by Design Builder.

So, the single detached house type presents the lowest energy consumption so it was taken as a reference type. On the other hand, the duplex house presents the highest energy consumption because of its vertical layout and increasing its surface area from D.1(1) by about 15.8%. It is clear that cooling loads are larger than heating loads in the two models. Figure (4.12) shows the effect of D.1(1) and Du.2 on the total, heating and cooling loads per m^2 throughout the year using the ECOTECT and Design Builder.



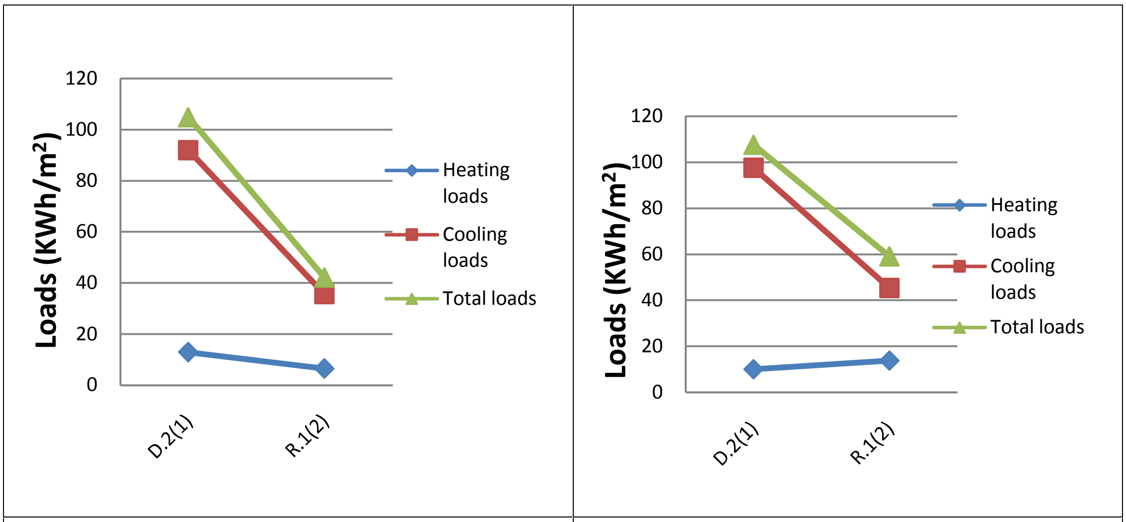
A: ECOTECT results	B: Design Builder results

Figure (4.12): Loads in D.1(1), Du.2 (KWh/m^2) by ECOTECT and Design Builder

The single detached house D.2(1) and the row house R.1(2) have the same occupancy (12 persons). The results indicate that the total loads estimated in D.2(1) is higher than R.1(2) by 62.7%, 6.4% and 56.3% in terms of total, heating and cooling loads respectively by ECOTECT.

Also the results indicate that the total loads estimated in Du.2 is higher than D.1(1) by 48.5%, 3.7% and 52.2%in terms of total, heating and cooling loads respectively by Design Builder.

So, the row house R.1(2) achieves the lowest energy consumption. On the other hand, the single detached house D.2(1) achieves the highest energy consumption. This mean that the horizontal arrangement of apartment is better thermally than vertical arrangement. Figure (4.13) shows the effect of D.2(1) and R.1(2) on the total, heating and cooling loads per m^2 throughout the year using the ECOTECT and Design Builder.



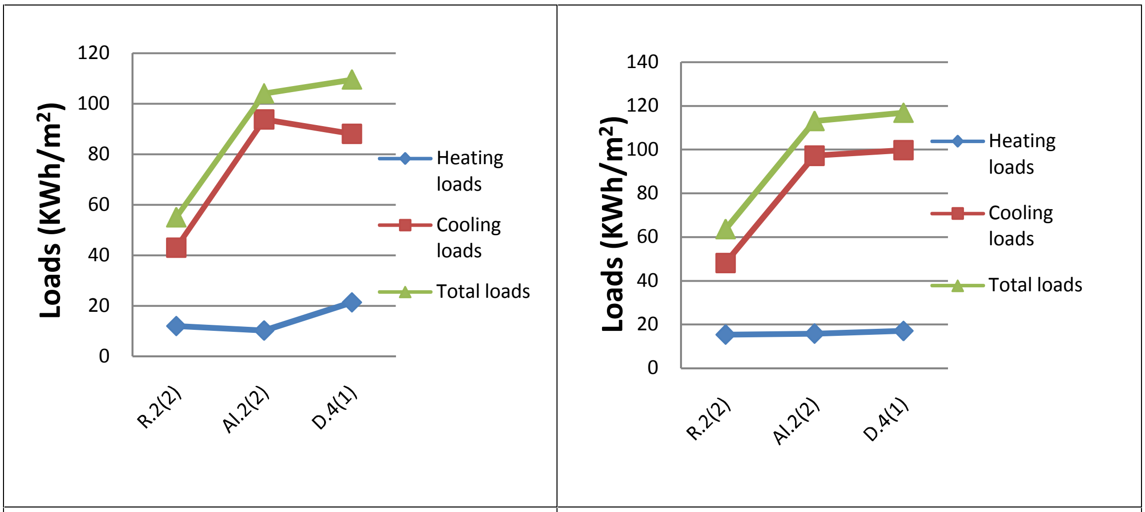
A: ECOTECT results	B: Design Builder results

Figure (4.13): Loads in D.2(1), R.1(2) (KWh/m^2) by ECOTECT and Design Builder

The single detached house D.4(1), the row house R.2(2) and the low-rise apartment Al.2(2) have the same occupancy (24 persons). The results indicate that the total loads estimated in Al.2(2) is higher than R.2(2) by 49.3%, 2.6% and 51.4% in terms of total, heating and cooling loads respectively by ECOTECT and by 52.6%, 1.6% and 49.4% in terms of total, heating and cooling loads respectively by Design Builder.

It is evident that there is a slight increase between the low-rise apartment Al.2(2) and the single detached house D.4(1) by 6.4%, 18.3% and 6.1% in terms of total, heating and cooling loads respectively by ECOTECT and by 3.2%, 8.6% and 2.4% in terms of total, heating and cooling loads respectively by Design Builder.

So, the row house R.2(2) achieves the lowest energy consumption. On the other hand, the single detached house D.4(1) achieves the highest energy consumption. This mean that the increasing of height with the same occupancy increases the energy consumption. Figure (4.14) shows the effect of R.2(2), Al.2(2) and D.4(1) on the total, heating and cooling loads per m^2 throughout the year using the ECOTECT and Design Builder.



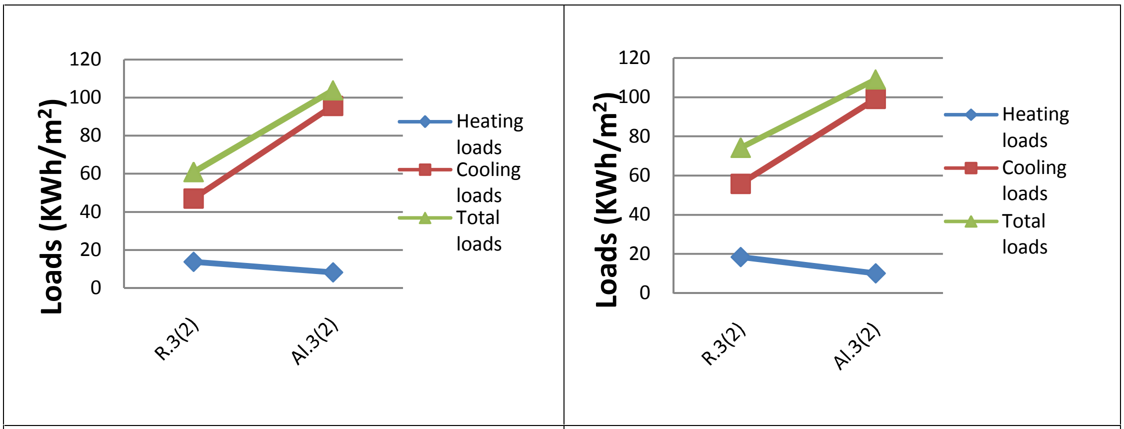
A: ECOTECT results	B: Design Builder results

Figure (4.14): Loads in R.2(2),Al.2(2) and D.4(1) (KWh/m^2) by ECOTECT and Design Builder

The row house R.3(2) and the low-rise apartment Al.3(2) have the same occupancy (36 persons). The results indicate that the total loads estimated in Al.3(2) is higher than R.3(2) by 43.1% and 48.5% in the total and cooling loads respectively, but it decreases by 5.5% in the heating loads by ECOTECT.

Also the results indicate that the total loads estimated in Al.3(2) is higher than R.3(2) by 34.8% and 43.2% in the total and cooling loads respectively, but it decreases by 8.3% in the heating loads by Design Builder.

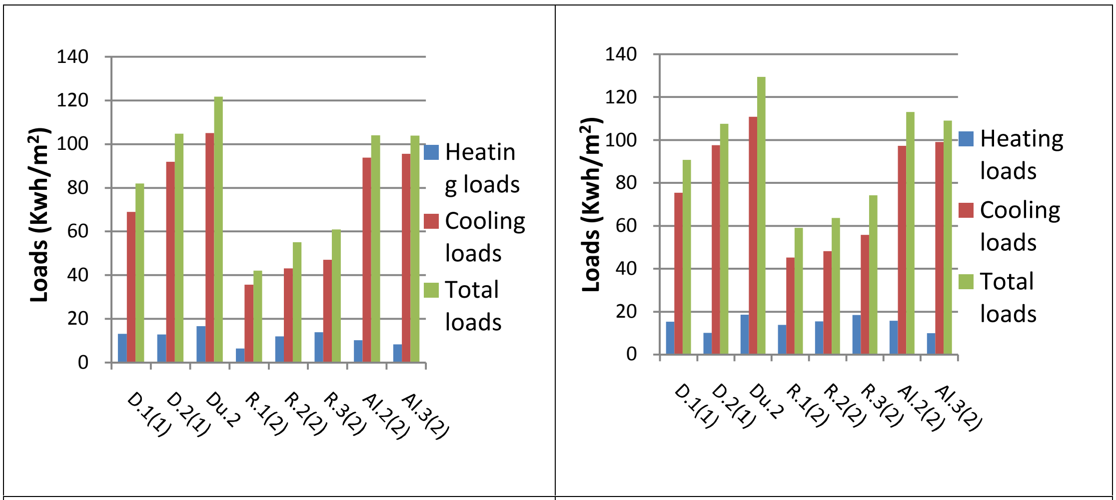
So, the row house R.3(2) achieves the lowest energy consumption. On the other hand, the low-rise apartment Al.3(2) achieves the highest energy consumption. This mean that the decreasing of the surface area with the same occupancy decreases the energy consumption. Figure (4.15) shows the effect of R.3(2) and Al.3(2) on the total, heating and cooling loads per m^2 throughout the year using the ECOTECT and Design Builder.



A: ECOTECT results	B: Design Builder results

Figure (4.15): Loads in R.3(2), Al.3(2) (KWh/m^2) by ECOTECT and Design Builder

It can be concluded that the row house types are more preferable for both cooling and heating requirements, even when it have more occupancy because of its small surface area. Figure (4.16) shows the effect of various house types on the total, heating and cooling loads per m^2 throughout the year using the ECOTECT and Design Builder.



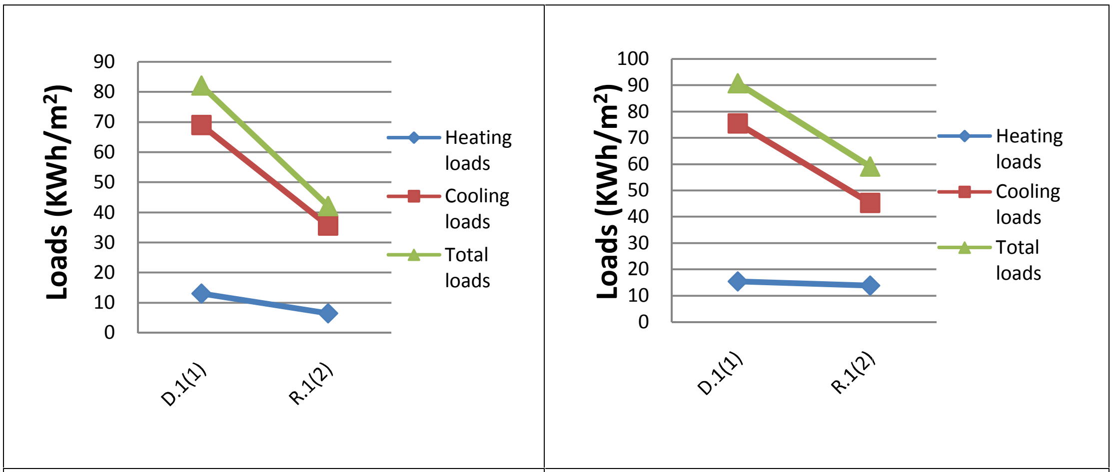
A: ECOTECT results	B: Design Builder results

Figure (4.16): Loads in various house types (KWh/m^2) by ECOTECT and Design Builder

4.3.4 Simulation results of different house types with the same height

The single detached house D.1(1) and the row house R.1(2) have the same height (3m). The results indicate that the total loads estimated in R.1(2) is lower than D.1(1) by 39.9%, 6.5% and 33.3% in terms of total, heating and cooling loads respectively by ECOTECT. Also the results indicate that the total loads estimated in R.1(2) is lower than D.1(1) by 48.3%, 2.3% and 50.2% in terms of total, heating and cooling loads respectively by Design Builder.

Figure (4. 17) shows the effect of a constant height at D.1(1) and R.1(2) on the total loads throughout the year using the ECOTECT and Design Builder. It can be noticed that the row house R.1(2) achieves the lowest energy consumption while the single detached house D.1(1) achieves the highest energy consumption. This mean that the increasing of density horizontally is more preferable than the increasing of density vertically with constant height for the energy consumption.



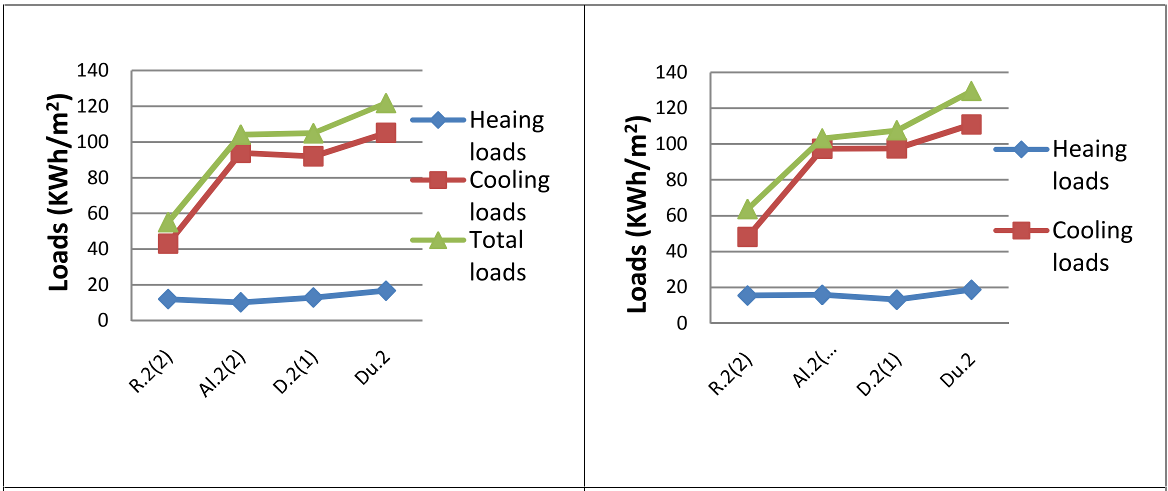
A: ECOTECT results	B: Design Builder results

Figure (4.17): Loads in D.1(1) and R.1(2) with 3 m (KWh/m^2) by ECOTECT and Design Builder

The single detached house D.2(1), the duplex house Du.2, the row house R.2(2) and the low-rise apartment Al.2(2) have the same height (6 m). The results indicate that the total loads estimated in R.1(2) is the lowest by 53.9%, 4.5% and 54.6 % in terms of total, heating and cooling loads respectively by ECOTECT. Also the results indicate that the total loads estimated in R.1(2) is the lowest by 50.3%, 5.6% and 54.1% in terms of total, heating and cooling loads respectively by Design Builder.

It is evident that there is a slight increase between the low-rise apartment Al.2(2), the single detached house D.2(1) and the duplex house Du.2 by 12.3%, 4.5% and 7.3% in terms of total, heating and cooling loads respectively by ECOTECT and by 15.4%, 5.6% and 2.5% in terms of total, heating and cooling loads respectively by Design Builder.

Figure (4. 18) shows the effect of a constant height at D.2(1), Du.2, R.2(2) and Al.2(2) on the total loads throughout the year using the ECOTECT and Design Builder. It can be noticed that the row house R.2(2) achieves the lowest energy consumption while the duplex house Du.2 achieves the highest energy consumption. This mean that the horizontal layout of buildings is better thermally than the vertical layout of buildings with constant height.



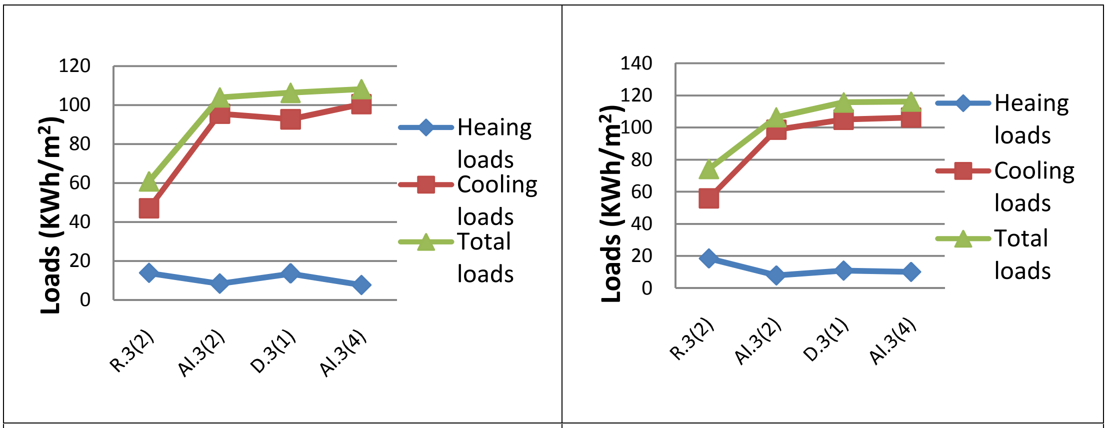
A: ECOTECT results	B: Design Builder results

Figure (4.18): Loads in various house types with 6 m (KWh/m^2) by ECOTECT and Design Builder

The single detached house D.3(1), the row house R.3(2) and the low-rise apartment Al.3(2) and Al.3(2) have the same height (9 m). The results indicate that the total loads estimated in R.3(2) is lower than the other types by 47.6%, 2.3% and 51.4 % in terms of total, heating and cooling loads respectively by ECOTECT. Also the results indicate that the total loads estimated in R.1(2) is the lower than the other types by 45.3%, 6.8% and 49.3% in terms of total, heating and cooling loads respectively by Design Builder.

It is evident that there is a slight increase between the low-rise apartment Al.2(2), the single detached house D.2(1) and the duplex house Du.2 by 9.6%, 5.8% and 5.4% in terms of total, heating and cooling loads respectively by ECOTECT and by 11.4%, 3.6% and 8.5% in terms of total, heating and cooling loads respectively by Design Builder.

Figure (4. 19) shows the effect of a steady height at D.3(1), R.3(2), Al.3(2) and Al.3(4) on the total loads throughout the year using the ECOTECT and Design Builder. It can be noticed that the row house R.3(2) achieves the lowest energy consumption while the low-rise apartment Al.3(4) achieves the highest energy consumption. This mean that the increasing of surface area in buildings increases the energy consumption with a steady height.

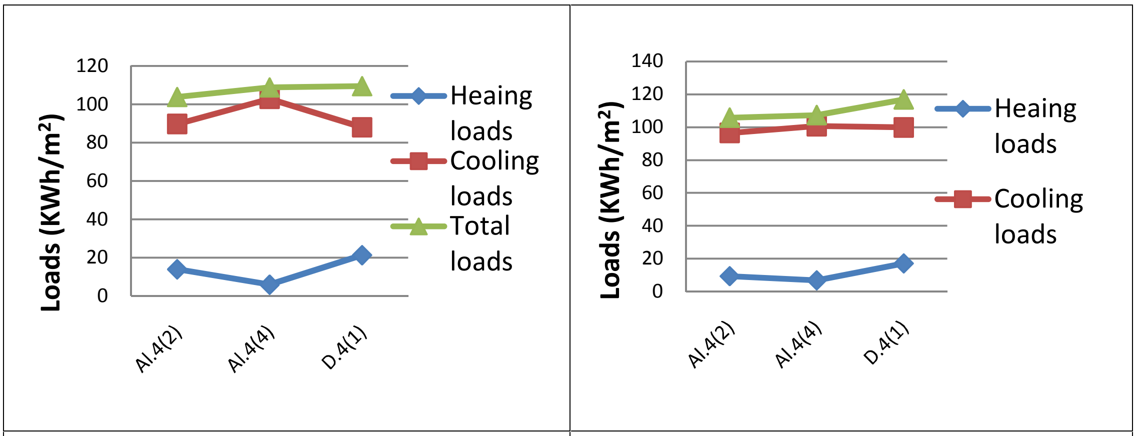


A: ECOTECT results	B: Design Builder results

Figure (4.19): Loads in various house types with 9 m (KWh/m^2) by ECOTECT and Design Builder

The single detached house D.4(1) and the low-rise apartment Al.4(2) and Al.4(4) have the same height (12 m). The results indicate that there is a slight increase between the low-rise apartment Al.4(2), Al4(4) and the single detached house D.4(1) by 5.7%, 10.5% and 13.4% in terms of total, heating and cooling loads respectively by ECOTECT and by 8.4%, 13.6% and 7.5% in terms of total, heating and cooling loads respectively by Design Builder.

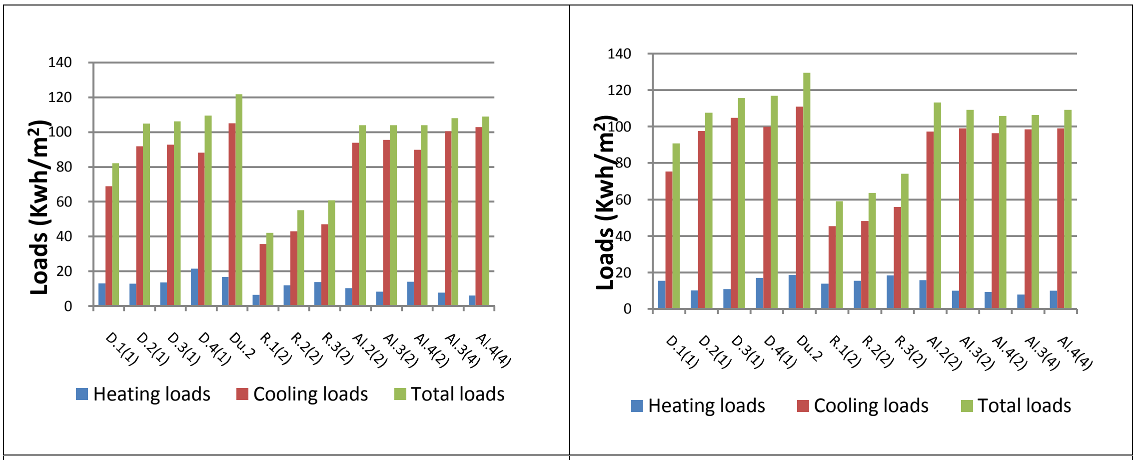
Figure (4.20) shows the effect of a steady height at D.4(1), Al.4(2) and Al.4(4) on the total loads throughout the year using the ECOTECT and Design Builder. It can be noticed that the low-rise apartment Al.4(2) achieves the lowest energy consumption while the single detached house D.4(1) achieves the highest energy consumption. This mean that configurations that allow flats to receive ventilation and sun light from three sides are preferable.



A: ECOTECT results	B: Design Builder results

Figure (4.20): Loads in various house types with 12 m (KWh/m^2) by ECOTECT and Design Builder

In general it can be concluded that the row house types are more preferable for energy requirements, because of its large surface area which decreases the heating loads by about 65%. Figure (4.21) shows the effect of various house types on the total, heating and cooling loads per m2 throughout the year using the ECOTECT and Design Builder.

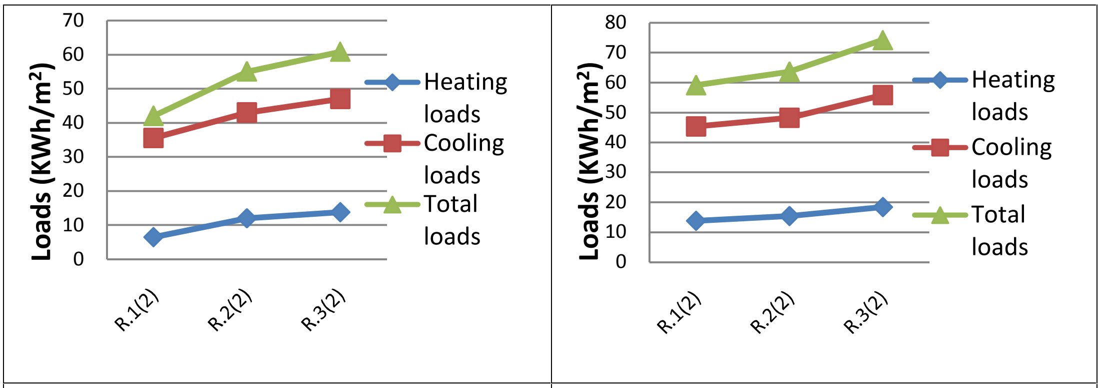


A: ECOTECT results	B: Design Builder results

Figure (4.21): Loads in various house types (KWh/m^2) by ECOTECT and Design Builder

4.3.5 Simulation results of the same house types with the different height

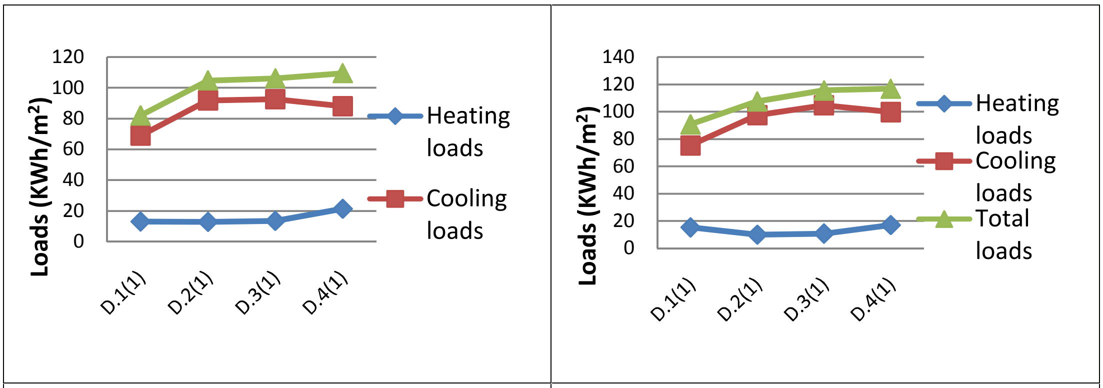
For changing heights, the results indicate that the row house types with a height of 3m, 6 m and 9 m, R.1(1) achieves the lowest energy consumption while the row house R.3(1) has the highest energy consumption. It can be noticed that as the building height increases, the total loads increases. This means that increasing the building height by one story cause the same percentage of loads increasing. Increasing the building height from 3 m to 9 m in the row house types increases loads by about 25.3%, 45.6% and 20.5% in terms of total, heating and cooling loads respectively by Design Builder and by 30.8%, 53.1% and 24.3% in terms of total, heating and cooling loads respectively by ECOTECT. Figure (4.22) shows the effect of house height on the cooling, heating and total loads respectively in row house types using ECOTECT and Design Builder.



A: ECOTECT results	B: Design Builder results

Figure (4.22): Loads in row house types (KWh/m^2) by ECOTECT and Design Builder

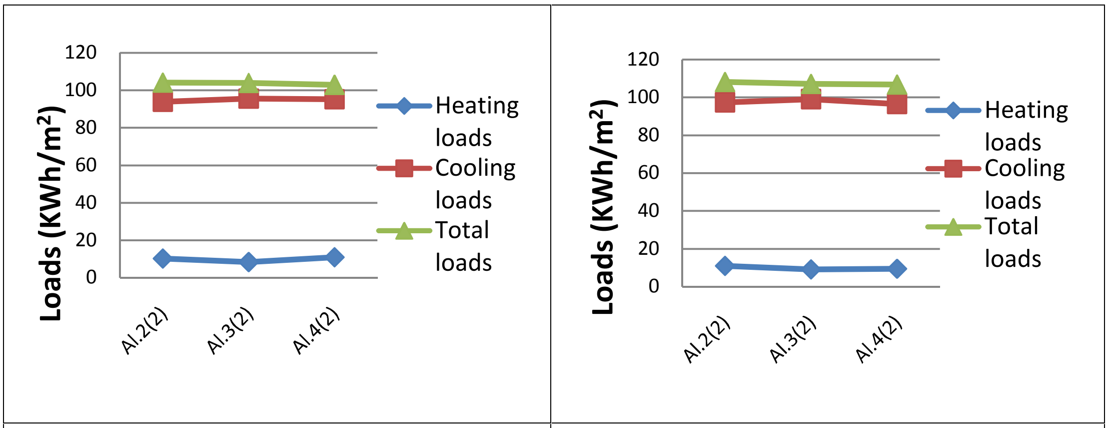
In the single detached house types, the results indicate that increasing the building height by one story causes increasing in the total and heating loads from 1 floor to 4 floors but decreasing in the cooling loads from 1 floor to 4 floors. The single detached house D.1(1) achieves the lowest energy consumption while the single detached house D.4(1) has the highest energy consumption. This means that increasing the building height from 3 m to 12 m in the single detached house types increases the loads by about 25.1%, 38.9% and 21.7% in terms of total, heating and cooling loads respectively in ECOTECT. Figure (4.23) shows the effect of house height on the cooling, heating and total loads respectively in single detached house types using ECOTECT and Design Builder.



A: ECOTECT results	B: Design Builder results

Figure (4.23): Loads in single detached house types (KWh/m^2) by ECOTECT and Design Builder

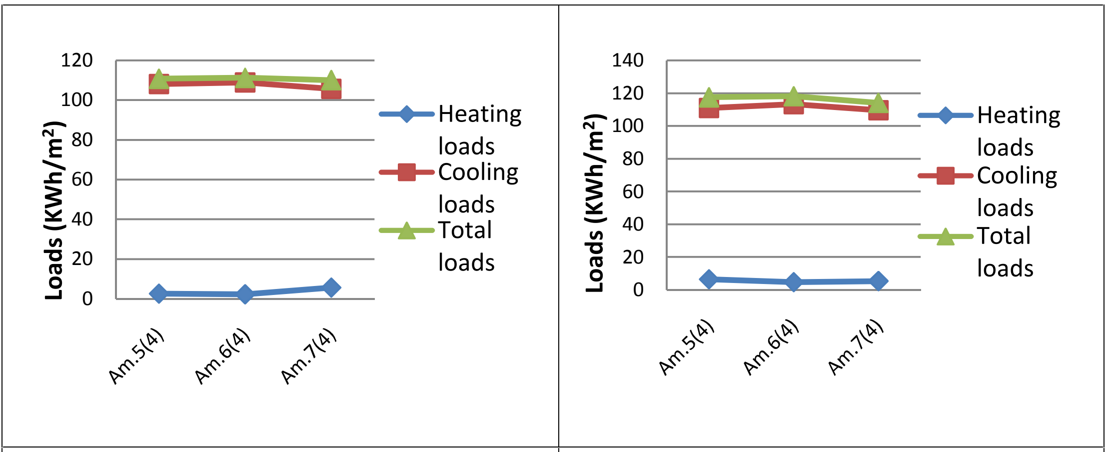
In the low rise apartment types with a height of 6 m, 9 m and 12 m, there is a slight difference between them which reach to about 4%, 5.8% and 1.7% in the total, heating and cooling loads respectively by Design Builder. This means that increasing the building height from 6m to 12 m in the low rise apartment types decreases the total loads by about 2.1% in ECOTECT. Figure (4.24) shows the effect of house height on the cooling, heating and total loads respectively in low rise apartment types using ECOTECT and Design Builder. It is clear that the increasing in the total loads is resulting from the increase in the surface area that increases by 30% from Al.2(2) to Al.4(2).



A: ECOTECT results | **B: Design Builder results**

Figure (4.24): Loads in low rise apartment types (KWh/m^2) by ECOTECT and Design Builder

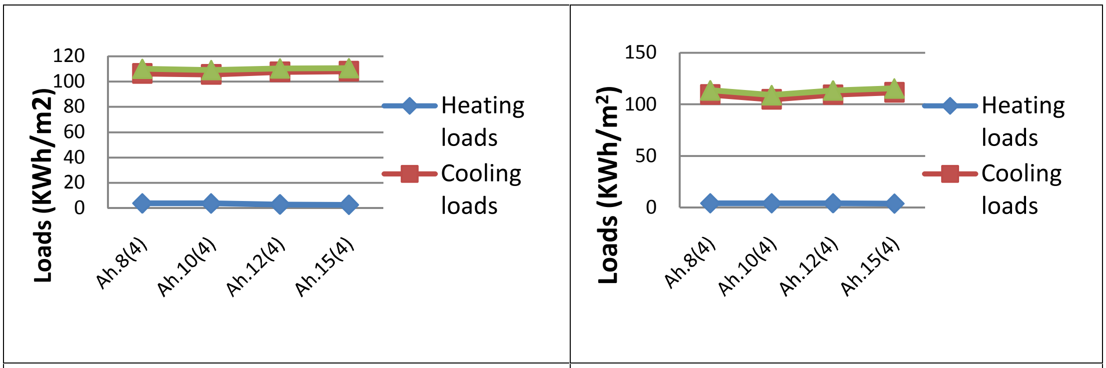
It can be is noticed that there is a linear relationship between loads resulting from the mid-rise apartments which increased by 1.4%, 4.3% and 1.8% in terms of total, heating and cooling loads respectively by ECOTECT and by 2.2%, 3.6% and 2.4% in terms of total, heating and cooling loads respectively by Design Builder. This means that the mid-rise apartment with 5, 6 and 7 storeys don't effect heavily on the total loads despite the increase in the height. This indicates that as the height exceeds 5 floors, the effect of stacking flats vertically on energy consumption becomes less effective. Figure (4.25) shows the effect of house height on the cooling, heating and total loads respectively in mid-rise apartment types using ECOTECT and Design Builder.



A: ECOTECT results | **B: Design Builder results**

Figure (4.25): Loads in mid rise apartment types (KWh/m^2) by ECOTECT and Design Builder

In the high rise apartment types with a height of 24 m, 30 m, 36 m and 45 m, there is a slight difference between those buildings which reach to about 7.2%, 0.4% and 6.8% in the total, heating and cooling loads respectively by Design Builder. This means that increasing the building height from 24 m to 45 m in the high rise apartment types increases the total loads by about 1.6% in ECOTECT. Figure (4.26) shows the effect of house height on the cooling, heating and total loads respectively in high rise apartment types using ECOTECT and Design Builder.



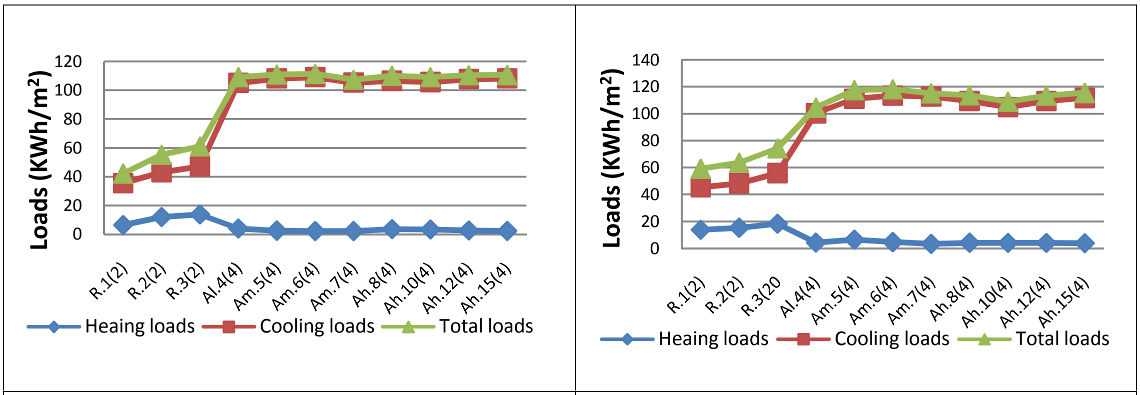
A: ECOTECT results | **B: Design Builder results**

Figure (4.26): Loads in high rise apartment types (KWh/m^2) by ECOTECT and Design Builder

In general, as shown in figure (4.27) the effect of changing height is not remarkable in the heating loads. While changing height from 4 floors to 15 floors increases the total loads, it reduces the heating loads by 3.6% in ECOTECT. The effect of changing height is more noticeable in the cooling loads. About 73.5% of the cooling loads can be increased with changing height in different house types i.e. when comparing case R.3(2) and case Al.4(4). Figure (4.27) illustrates the effect of changing the building height at different house types on the total, heating and cooling loads throughout the year using the ECOTECT and Design Builder.

The results indicate that the total loads for the simulated house types are increased by 69.2% with increasing the building height from 3 m to 45 m. It can be noticed that the highest height (7, 8, 10 and 15 floors) is more preferable for heating requirements. As the building height increased, the total loads increased.

It is evident that there is a strong difference between the row house types and the other types. They offer less loads by 43.9% and 58.4% in the total and cooling loads respectively by Design Builder.



A: ECOTECT results | **B: Design Builder results**

Figure (4.27) : Loads in various house types (KWh/m^2) by ECOTECT and Design Builder

4.4 Conclusion

This chapter dealt with the effect of housing types with different height and different housing density on the energy consumption. It dealt with individual buildings in the same area. Each unit in all the models have the same characters (materials, area plot, occupancy and orientation). It is concluded that the housing type is a crucial aspect affecting the thermal performance of buildings.

It emphases that individual row house type is the best type thermally. This is true in the case of isolation and urban conditions. In the case of isolated buildings, row house in average consumes less energy by about 50% compared to the maximum cases Detached and apartment buildings).

Hence, the housing density is an important factor to identify energy consumption in residential buildings. Thus the next chapter will show the effect of different urban configurations and the effect of floor area ratio on energy consumption in urban configurations.

CHAPTER 5

Investigation of Energy Consumption of Various Housing Densities in Urban Conditions

5.1 Introduction

Urban density as employed in this study refers to parts of settlements having a common set of physical characteristics in terms of house forms, density, spaces and plot characteristics. Density has often been referred to as a degree or intensity of development or of occupancy. Conventionally, urban densities have been defined from two perspectives; of population and physical density. While population density has been referred to as the number of persons per unit ground area of development, physical density (sometimes referred to as objective density) has been examined as land use ratios. In housing and urban design, density has been measured in terms of floor area ratios, plot coverage and dwelling units per specified area. Accommodation density in housing has been expressed as the number of inhabitants per unit of habitable space. Floor Area Ratio is a unit of density referring to the floor space in relation to plot or land area (Lupala,2002). The methods of calculating an urban density as applied in this study are summarized in Figure (5.1).

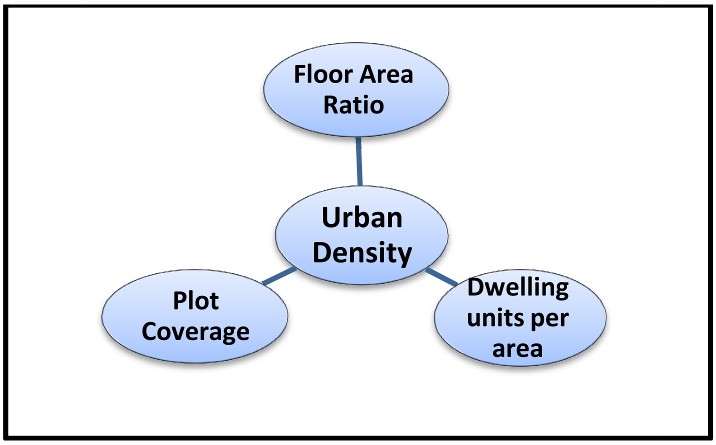


Figure (5.1): The methods of calculating an urban density

In order to provide a full understanding to the previous integrated methods, this chapter was divided into two sections. The first section studied the urban density by discussing the number of units per dunum and its effect on the energy consumption. The study focused on the housing type as it considered the main determinant of the urban

density. It also examined the vertical layout of the building configuration and its effect on the thermal response.
The second section introduced a study of the urban density by understanding Floor Area Ratio to examine the relation between the Floor Area Ratio in urban canopy and the energy consumption. It dealt basically with 64 simulated parameters with changing plot area ratio from 0.2 to 3 in different house types.

5.2 Effect of Number of Units per Dunum on Energy Consumption in Urban Configuration

Basically, this study examines the relation between the energy consumption and the house type in the urban configuration. For this reason, the study analyzed the previous 20 house types in the same block with affixed area of 3300 m^2. Similar to the previous chapter, the area (A) for each dwelling is assumed to be 130 m^2 as it represents the average of residential units areas in Gaza. The height is assumed to be 3 m for each storey.

The optimum orientation for the Gaza Strip climate is which provide both heating and cooling. Hence, it will be appropriate to orientate the building ±22.5 from the south. This south-west orientation would be worse in summer, instead the building have to orientate to provide breeze and shading. In general, the best orientation for the reference building is north-south with 25° south easterly direction (Rosenlund, 2000).

5.2.1 Effect of single detached house on the Energy Consumption in the urban configuration

The study investigates four models of single detached house with height of 1, 2 ,3 and 4 floors, each block (3300m^2) contains 10 buildings, see figure (5.2). Thus, there is 10 units with 60 persons in the first model, 20 units with 120 persons in the second model, 30 units with 180 persons in the third model and 40 units with 240 persons in the fourth model. This equivalent to 3, 6, 9 and 12 units per dunum respectively.

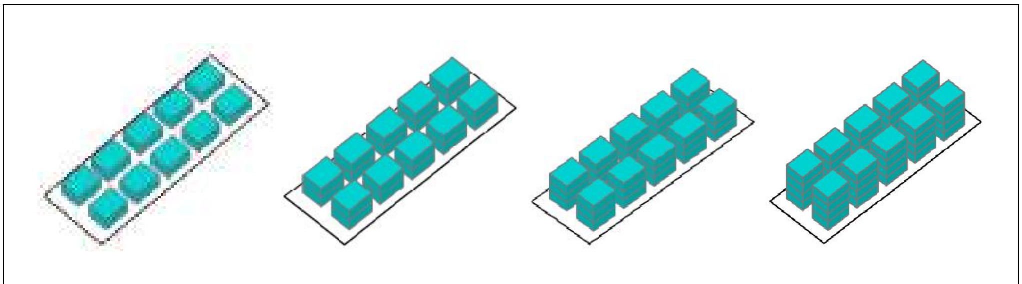
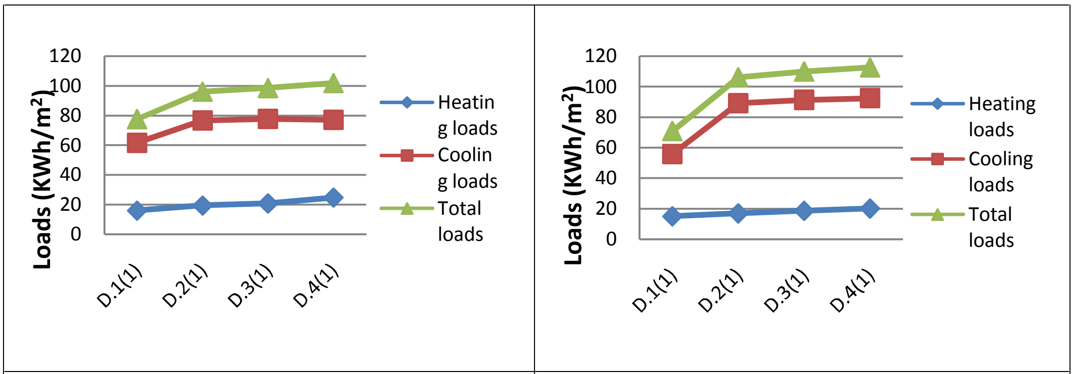


Figure (5.2): Single detached house configuration investigated in the study

In the previous models, the results indicated that increasing the building height by one storey with increasing of housing density causes increasing in the total, heating and cooling loads from 1 floor to 4 floors in the single detached house by 31.1%, 15.4% and 12.5% respectively in ECOTECT and 39.3%, 13.4% and 20.5% in Design Builder. The urban configuration with single detached house D.1(1) achieves the lowest energy consumption while the urban configuration with the single detached house D.4(1) is the highest energy consumption. This means that increasing the building housing density from 60 to 240 persons in the single detached house types in ECOTECT increases the total loads by about 31.1% and by 39.3% in Design Builder. Figure (5.3) shows the effect of increasing housing density on the cooling, heating and total loads respectively in single detached house configuration using ECOTECT and Design Builder.



A: ECOTECT results	B: Design Builder results

Figure (5.3) : Loads in single detached house configuration (KWh/m^2) by ECOTECT and Design Builder

5.2.2 Effect of duplex house on the Energy Consumption in the urban configuration

The study investigates a model of duplex house configuration with height of 2 floors, each block (3300m^2) contains 10 buildings see figure (5.4). Thus, there is 10 units with 60 persons in the model. This equivalent to 3 units per dunum.

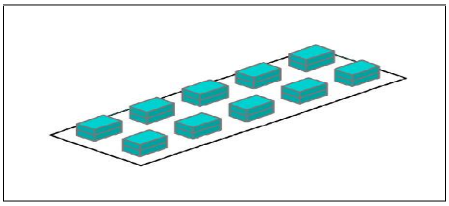
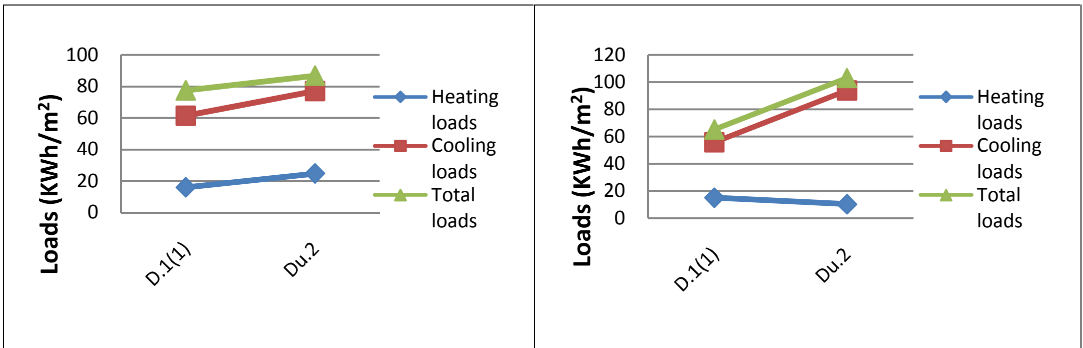


Figure (5.4): Duplex houses configuration investigated in the study

The results indicate that the duplex house configuration that are similar with single detached configuration in occupancy (60 persons) are increased by 24.5%, 8.2% and 16.3% in the total, heating and cooling loads respectively by ECOTECT and 37.5%, 5.3% and 32.2% by Design Builder. This mean that the total loads increased as the height increased with a steady occupancy. Figure (5.5) shows the total, heating and cooling loads per m^2 throughout the year using ECOTECT and Design Builder in the duplex house configuration and the single detached configuration.



A: ECOTECT results	B: Design Builder results

Figure (5.5) : Loads in single detached and duplex configuration (KWh/m^2) by ECOTECT and Design Builder

5.2.3 Effect of row house on the Energy Consumption in the urban configuration

The study investigates three models of row house configuration with height of 1, 2 and 3 floors, each block (3300 m^2) contains 14 buildings, see figure (5.6). Thus, there is 14 units with 84 persons in the first model, 28 units with 168 persons in the second model and 42 units 252 persons in the third model. This equivalent to 4, 8 and 12 units per dunum respectively.

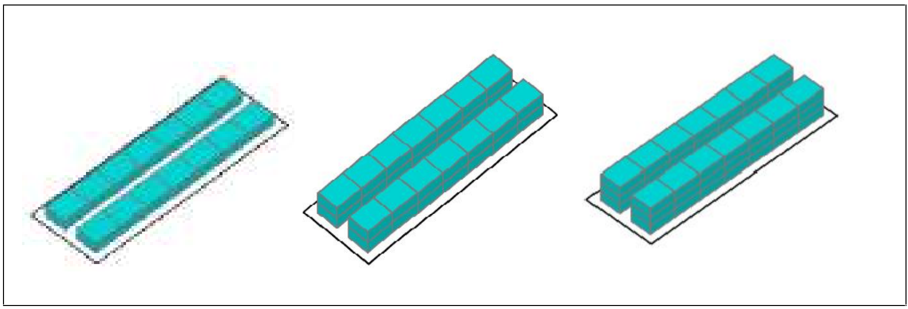
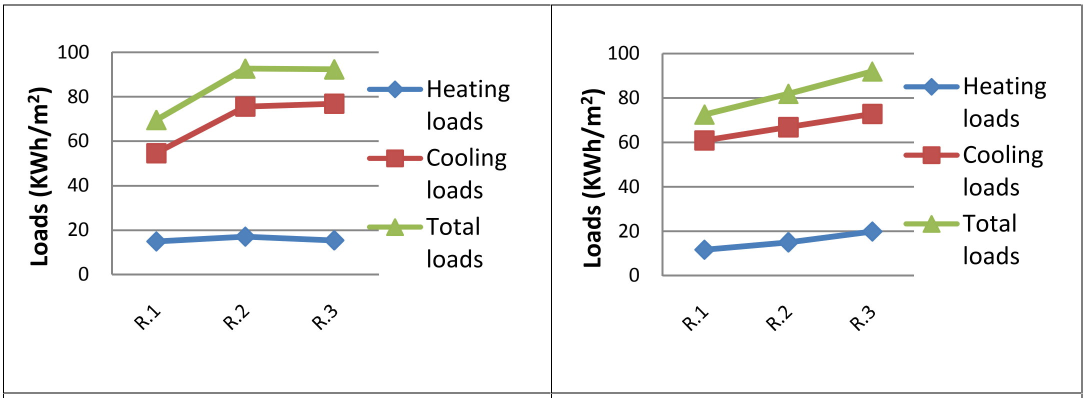


Figure (5.6): Row houses configuration investigated in the study

For changing housing density, the results indicate that the row house configuration R.1 achieves the lowest energy consumption while the row house configuration R.3 is the highest energy consumption. It can be noticed that as the building housing density increased, the total, heating and cooling loads increased by 22.7%, 3.4% and 22.2% in ECOTECT and 19.3%, 8.2% and 20.3% in Design Builder respectively. This show the negative effect of crowding on energy consumption.

Increasing the model housing density from 84 to 252 persons in the row house types increases the total loads by about 22.7% and 19.4% in ECOTECT and Design Builder. Figure (5.7) shows the effect of housing density on the cooling, heating and total loads respectively in row house configuration using ECOTECT and Design Builder. Thus, the results emphasize increasing height with increasing housing density by 84 persons increases the energy consumption in each unit by 48.2%.



A: ECOTECT results	**B: Design Builder results**

Figure (5.7): Loads in row house configuration (KWh/m^2) by ECOTECT and Design Builder

5.2.4 Effect of low-rise apartment on the Energy Consumption in the urban configuration

The study investigates five cases of low rise apartment. Three cases with height of 2, 3 and 4 floors, two units in each floor and each block (3300m^2) contains 5 buildings. Thus, there is 20 units with 120 persons in the first model, 30 units with 180 persons in the second model and 40 units with 240 persons in the third model. This equivalent to 6, 9 and 12 units per dunum respectively.

Two cases with height of 3 and 4 floors, four units in each floor and each block (3300m^2) contains 5 buildings. Thus, there is 36 units with 216 persons in the first model and 48 units with 288 persons in the second model. This equivalent to 10 and 14 units per dunum respectively, see figure(5.8).

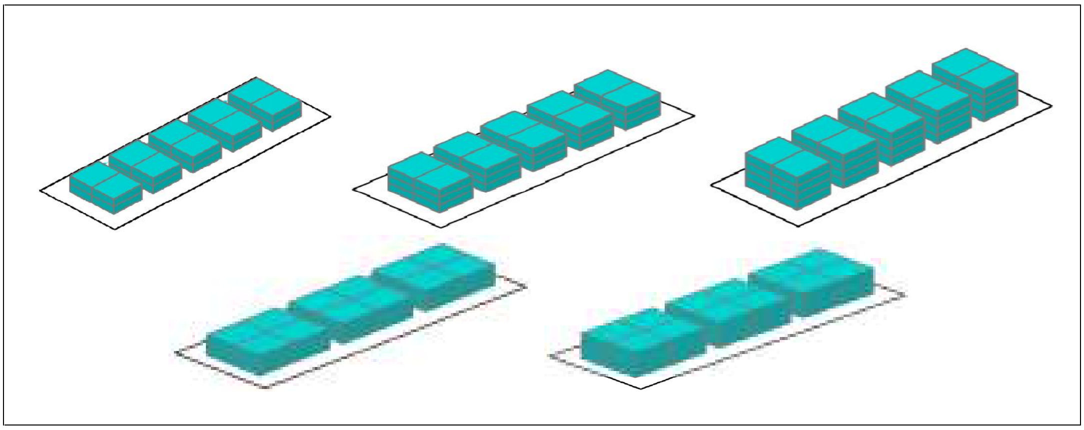
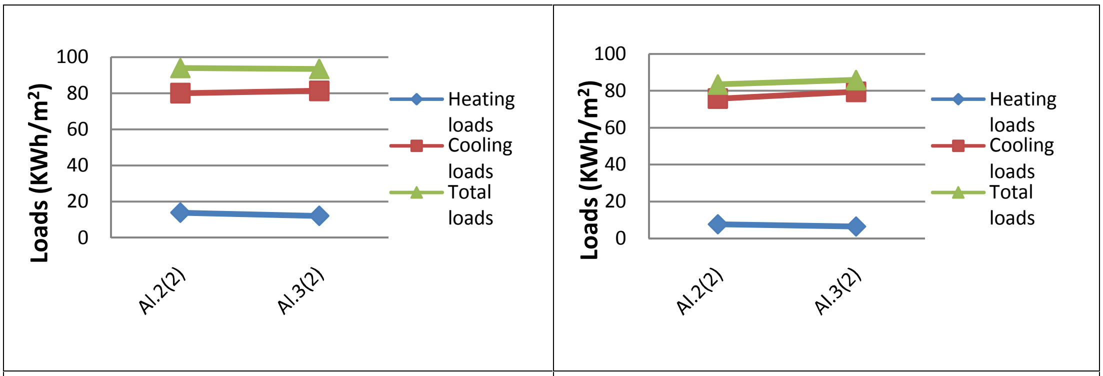


Figure (5.8): Low- rise apartment configuration investigated in the study

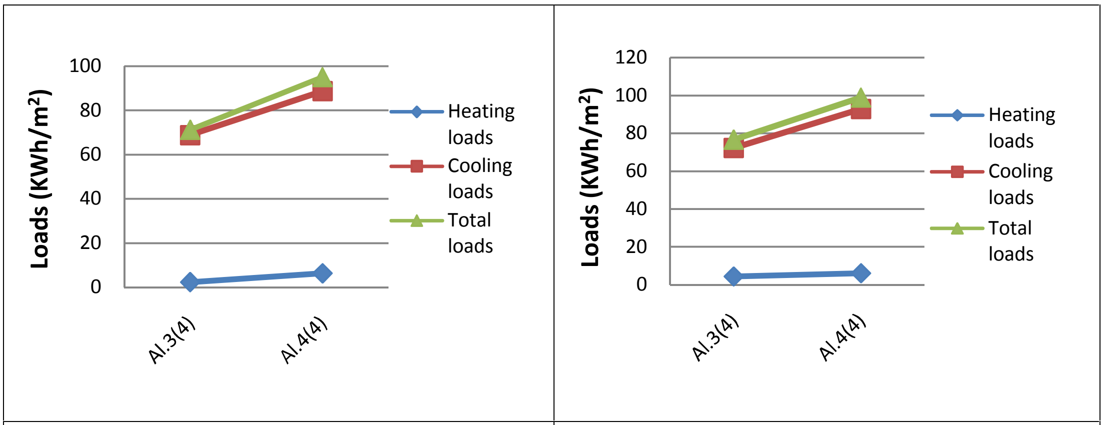
It is evident that there is a slight difference between the low-rise apartment configuration with 120 persons and the low-rise apartment configuration with 180 persons which increased to about 2%, 1.7% and 1.3% in the total, heating and cooling loads respectively by ECOTECT. Figure (5.9) shows the effect of housing density on the cooling, heating and total loads respectively in low rise apartment configuration (two units in each floor) using ECOTECT and Design Builder. This mean that there is no effect of increasing the building by one storey in the increasing of loads in those models.



A: ECOTECT results	**B: Design Builder results**

Figure (5.9): Loads in low-rise configuration (Al.2(2), Al.3(2) by KWh/m^2) by ECOTECT and Design Builder

For the two models with 3 and 4 floors (4 units in each floor), the results indicate that the second model Al.3(4) achieves the lowest energy consumption while the first model Al.4(4) is the highest energy consumption. It can be noticed that the total, heating and cooling loads increased by 26.8%, 7.1% and 19.7% in ECOTECT and 34.4%, 2.3% and 32.1% in Design Builder respectively. Figure (5.10) shows the effect of low rise apartment configuration with four units in each floor on the cooling, heating and total loads respectively in row house types using ECOTECT and Design Builder. This emphasizes that there is no effect of increasing the building by one storey in the increasing of loads in those models.



A: ECOTECT results	B: Design Builder results

Figure (5.10): Loads in low-rise configuration (Al.3(4), Al.4(4)by KWh/m^2) by ECOTECT and Design Builder

5.2.5 Effect of mid-rise apartment on the Energy Consumption in the urban configuration

The study investigates three models of mid rise apartment with height of 5, 6 and 7 floors and each block (3300m^2) contains 3 buildings. Thus, there is 60 units with 360 persons in the first model, 72 units with 432 persons in the second model and 84 units with 504 persons in the third model. This equivalent to 18, 21 and 25 units per dunum respectively, see figure (5.11).

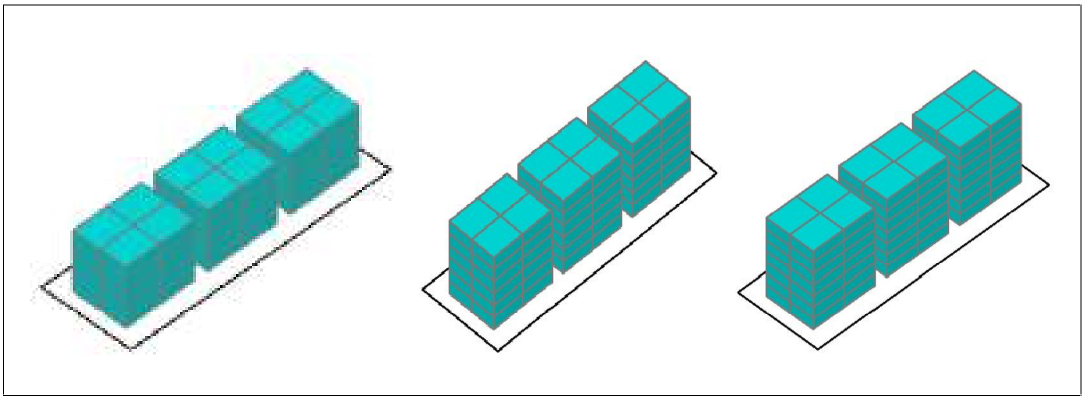


Figure (5.11): Mid-rise apartment configuration investigated in the study

For changing housing density, the results indicate that the mid rise apartment configuration Am.5(4) achieves the lowest energy consumption while the mid rise apartment configuration Am.7(4) is the highest energy consumption. It can be noticed that as the building housing density increased the total, heating and cooling loads by 26.5%, 1.2% and 25.3% in ECOTECT.

Increasing the model housing density from 360 to 504 persons in the mid rise apartment increases the total loads by about 26.5% in ECOTECT. Figure (5.12) shows the effect of housing density on the cooling, heating and total loads respectively in row house configuration using ECOTECT. Thus, the results emphasize increasing height with increasing housing density by 72 persons increasing the energy consumption in each unit by 36.5%.

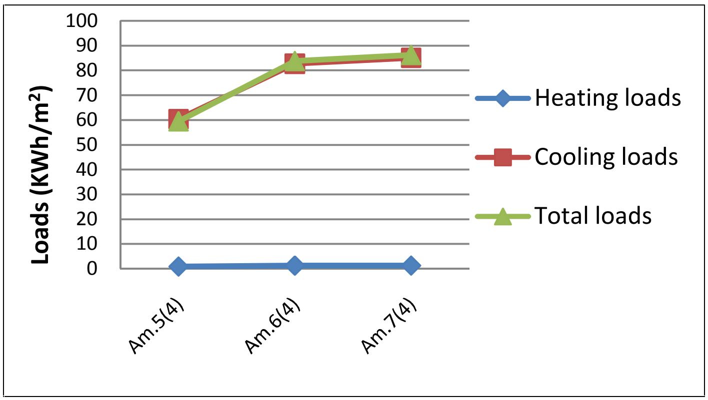


Figure (5.12): Loads in mid-rise apartment configuration (KWh/m^2) by ECOTECT

5.2.6 Effect of high-rise apartment on the Energy Consumption in the urban configuration

The study investigates four models of high rise apartment with height of 8, 10, 12 and 15 floors, each block (3300m^2) contains 3 buildings. Thus, there is 96 units with 576 persons in the first model, 120 units with 720 persons in the second model, 144 units with 864 persons in the third model and 180 units with 1080 persons in the fourth model. This equivalent to 29, 36, 43 and 54 units per dunum respectively, see figure (5.13).

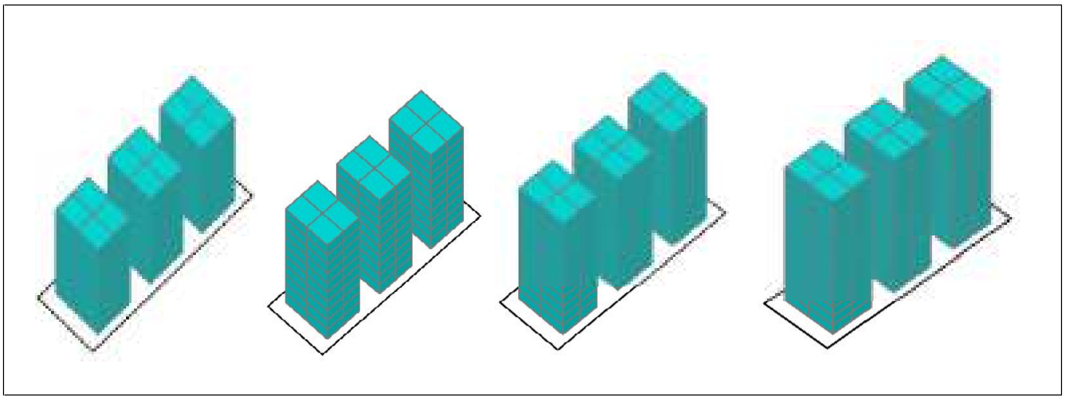


Figure (5.13): High-rise apartment configuration investigated in the study

In the previous models, the results indicate that increasing the building height with increasing of housing density causes increasing in the total, heating and cooling loads from 8 floor to 15 floors by 16.5%, 2.3% and 14.2% respectively in ECOTECT.

The urban configuration with high rise apartment Ah.8(4) achieves the lowest energy consumption while the urban configuration with the high rise apartment Ah.15(4) is the highest energy consumption. This means that increasing the building housing density from 576 to 1080 persons in the high rise apartment types in ECOTECT increases the total loads by about 16.5%.

It is evident that there is a slight difference between the high rise apartment configuration with 10, 12 and 15 floors which reach to about 0.5%, 0.2% and 0.3% in the total, heating and cooling loads respectively by ECOTECT. Figure (5.14) shows the effect of housing density on the cooling, heating and total loads respectively in high-rise apartment configuration using ECOTECT.

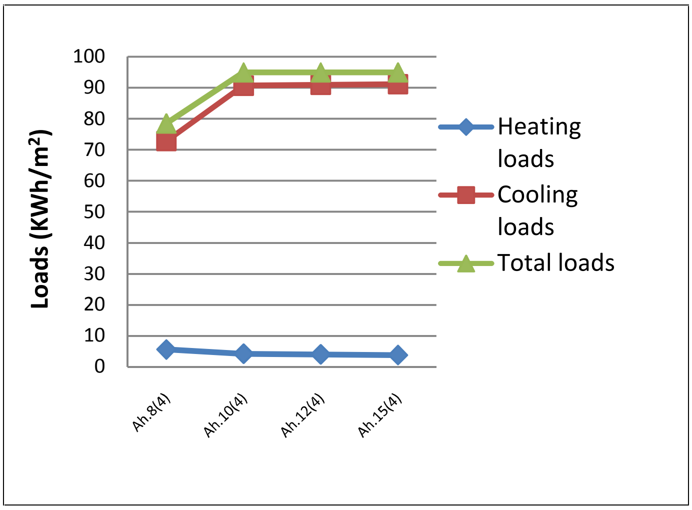


Figure (5.14): Loads in high-rise apartment configuration (KWh/m^2) by ECOTECT

5.2.7 Comparison between the effect of different house types on the Energy consumption in the urban configuration

In the previous section, the study analyzed different types of buildings in urban configurations separately. The results confirmed that the loads increase with the height of the buildings in parallel to the increasing of occupancy. While the results confirmed that the mid and high rise buildings present similar behavior despite the increase in population.

In this section, the study compared all the models and identified its behavior for the energy consumption. Table (5.1) shows the number of persons, housing units in each model upward of 60 people to 1080 people and the total energy.

Table (5.1): Total energy consumption by different house types in different urban densities

Type house configuration	number of persons	number of units	Units per dunum (density)	Total load by ECOTECT (KWh/m^2)	Average loads (KWh/m^2)
Single detached house D.1(1)	60	10	3	77.55	93.5
Single detached house D.2(1)	120	20	6	96.08	
Single detached house D.3(1)	180	30	9	98.55	
Single detached house D.4(1)	240	40	12	101.82	
Duplex house Du.2	60	10	3	86.91	86.9
Row house R.1(2)	84	14	4	69.52	84.8
Row house R.2(2)	168	28	8	92.58	
Row house R.3(2)	252	42	12	92.23	
Low rise apartment Al.2(2)	120	20	6	93.96	94.8
Low rise apartment Al.3(2)	180	30	9	93.49	
Low rise apartment Al.4(2)	240	40	12	96.22	
Low rise apartment Al.3(4)	216	36	11	95.11	
Low rise apartment Al.4(4)	288	48	14	95.06	
Mid rise apartment Am.5(4)	360	60	18	96.27	96.9
Mid rise apartment Am.6(4)	432	72	21	97.94	
Mid rise apartment Am.7(4)	504	84	25	96.64	
High rise apartment Ah.8(4)	575	96	29	94.98	95
High rise apartment Ah.10(4)	720	120	36	94.99	
High rise apartment Ah.12(4)	864	144	43	94.99	
High rise apartment Ah.15(4)	1080	180	54	94.99	

From the previous studies, The results indicate that the total loads for the simulated mid-rise apartment configurations in general have the highest energy consumption by

96.9 KWh/m^2 in the total loads by ECOTECT. While the results indicate that the row house configurations decreased by 10.3% in the total loads by ECOTECT from the single detached configurations. So, the row house configurations have lower than the single detached configuration in energy consumption. It is evident that there is a linear relationship between the low-rise, mid-rise and high-rise configurations. The loads increased by 2.3% in the total loads by ECOTECT.

Also, the results indicate that the single detached house configuration D.4(1) achieves the highest energy consumption even it has low housing density of 240 persons. This means that energy consumption increases with low housing density and decreases with high housing density in some types of houses. Figure (5.15) shows the effect of housing density on the average total loads in all urban configuration using ECOTECT.

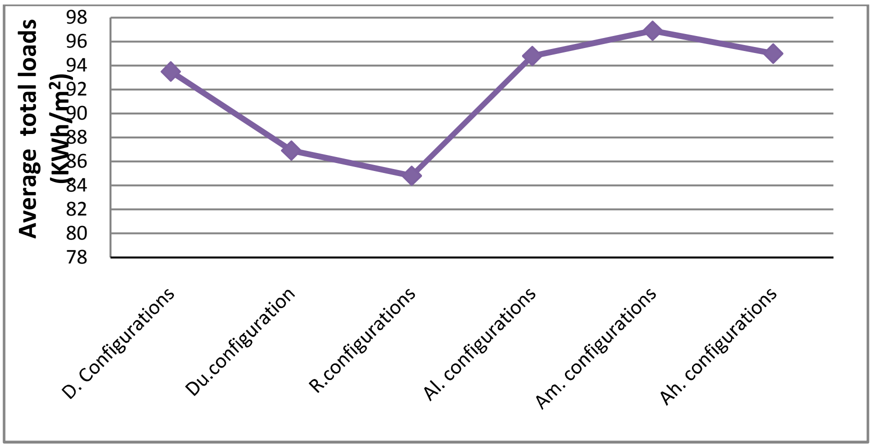


Figure (5.15): Average total loads in urban configuration (KWh/m^2) by ECOTECT

It can be noticed that the average heating loads from the low housing density to the high housing density decreases by about 23.7%. It is evident that the high rise apartment configurations present the lowest heating loads. Hence, the single detached house configurations present the highest heating loads. As the largest portion of buildings especially the high rise apartment can be considered as the optimum thermal option in the heating loads. This mean that the increasing of housing density decreases the heating loads in the urban configuration. Figure (5.16) shows the effect of housing density on the heating loads in all urban configuration using ECOTECT.

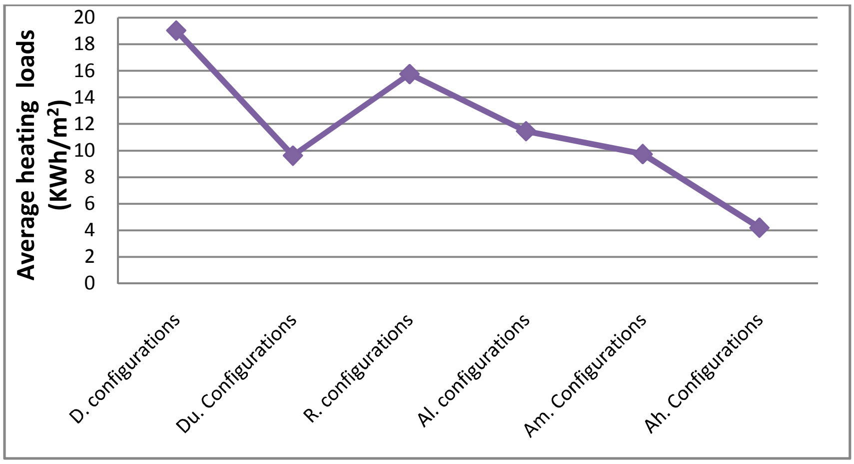


Figure (5.16) : Average heating loads in urban configuration (KWh/m^2) by ECOTECT

The different trend of increasing in the total loads can be noticed in the cooling loads from the low housing density to the high housing density which is about 29.8%. It is evident that the row house configurations present the lowest cooling loads which decreased by 29.3 % from the low, mid and high rise configurations. Hence, the high rise apartment configurations present the highest cooling loads. This mean that the cooling loads increased with the increasing of height and occupancy. Figure (5.17) shows the effect of housing density on the heating loads in all urban configuration using ECOTECT.

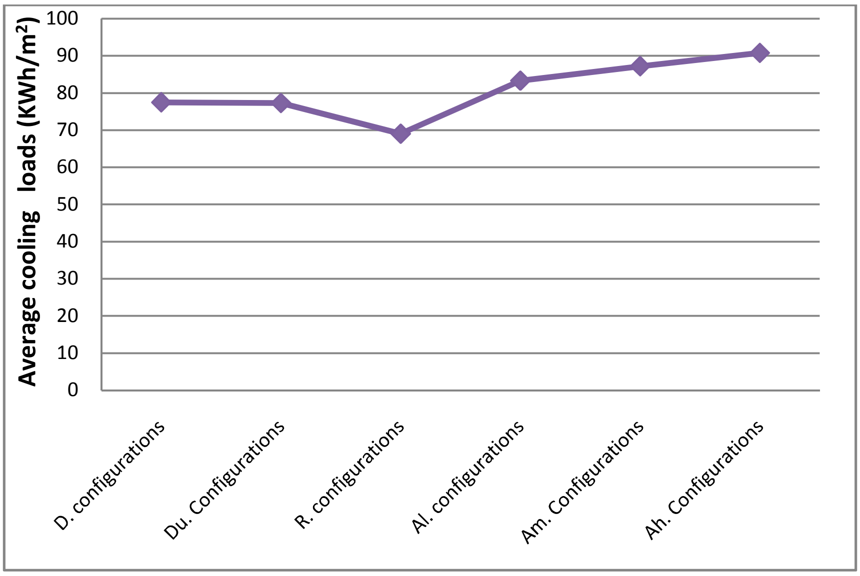


Figure (5.17): Average cooling loads in urban configuration (KWh/m^2) by ECOTECT

5.3 The effect of housing density (FAR) in urban conditions on energy consumption

Plot ratio expresses the total amount of floor space in relation (proportionally) to the site area. These indicative plot ratios should provide a mix of dwelling sizes in each case and the number of dwellings per hectare may vary significantly depending on the mix. The same area or volume can be distributed on a site in different ways to generate very different environments. This can range from larger site coverage of low bungalows or patio houses, through to high rise tower blocks.

5.3.1 Parametric Investigation

The study investigates the effects of a number of parameters on the heating, cooling, total loads with floor area ratio 0.2, 0.4, 0.6, 0.8, 1, 1.2, 1.4, 1.6, 1.8, 2, 2.2, 2.4, 2.6, 2.8 and 3 on the same simulated dwelling area (130m^2) in several parameter combinations with different housing types. Tables (5.2), (5.3), (5.4), (5.5), (5.6), (5.7) and (5.8) display the parameter combinations investigated in the study with different floor area ratio.

Table (5.2): Parameters with plot ratio 0.2 investigated in the study

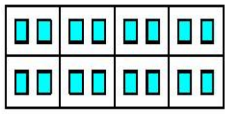
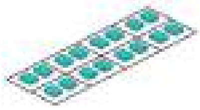
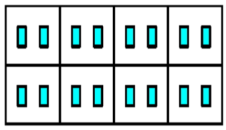
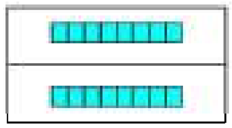
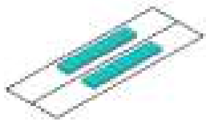
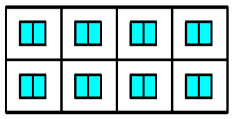
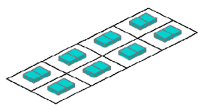
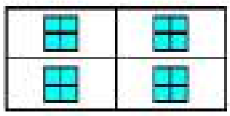
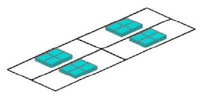
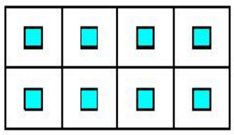
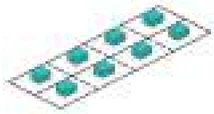
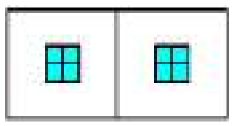
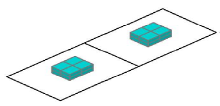
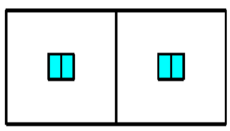
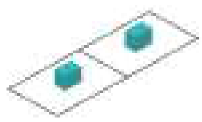
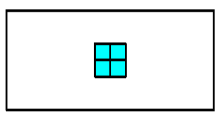
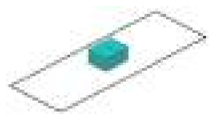
Plot ratio FAR	Urban configurations			
	Housing type	**Plan**	**Perspective**	**Height(m)**
0.2	Single detached D.1(1)			3
	Duplex house Du.2(1)			6
	Row house R.1(8)			3
	Low-rise apartment Al.1(2)			3
	Low-rise apartment Al.1(4)			3
	Low-rise apartment Al.2(1)			6
	Low-rise apartment Al.2(4)			6
	Low-rise apartment Al.4(2)			12
	Low-rise apartment Al.4(4)			12

Table (5.3): Parameters with plot ratio 0.4 investigated in the study

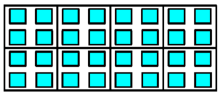
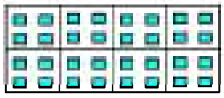
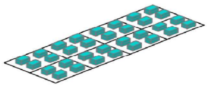
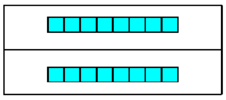
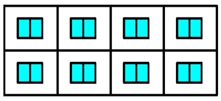
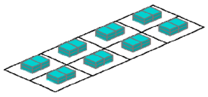
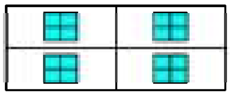
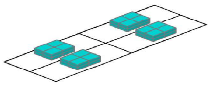
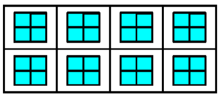
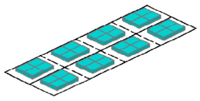
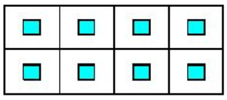
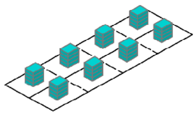
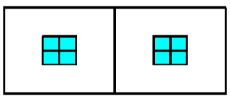
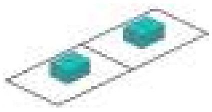
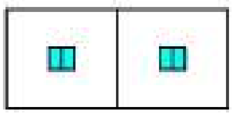
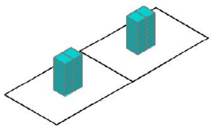
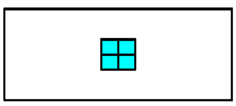
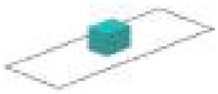
Plot ratio FAR	Urban configurations			
	Housing type	Plan	Perspective	Height(m)
0.4	Single detached D.1(1)			3
	Duplex house Du.2(1)			6
	Row house R.2(8)			6
	Low-rise apartment Al.2(2)			6
	Low-rise apartment Al.2(4)			6
	Low-rise apartment Al.1(4)			3
	Low-rise apartment Al.4(1)			12
	Low-rise apartment Al.4(4)			12
	High-rise apartment Ah.8(2)			24
	High-rise apartment Ah.8(4)			24

Table (5.4): Parameters with plot ratio 0.6 investigated in the study

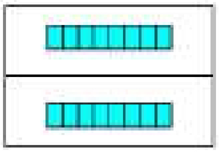
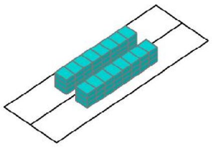
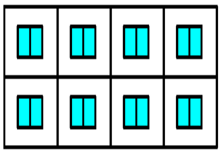
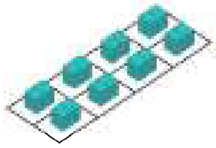
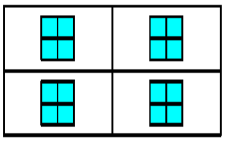
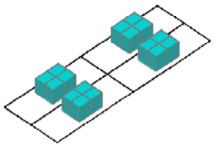
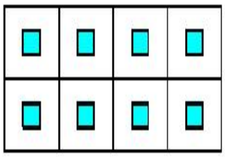
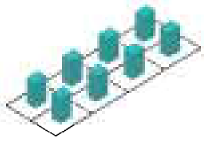
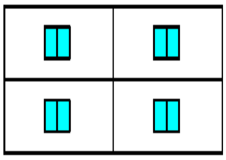
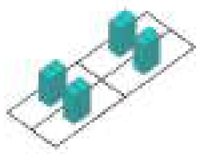
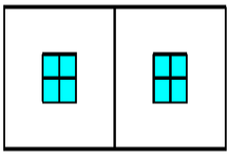
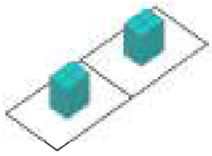
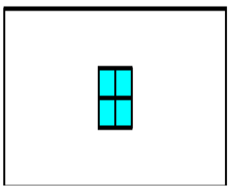
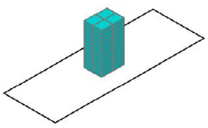
Plot ratio FAR	Urban configurations			
	Housing type	**Plan**	**Perspective**	**Height(m)**
0.6	Row house R.3(8)			9
	Low-rise apartment Al.3(2)			9
	Low-rise apartment Al.3(4)			9
	Mid-rise apartment Am.6(1)			18
	Mid-rise apartment Am.6(2)			18
	Mid-rise apartment Am.6(4)			18
	High-rise apartment Ah.12(4)			36

Table (5.5): Parameters with plot ratio 0.8 investigated in the study

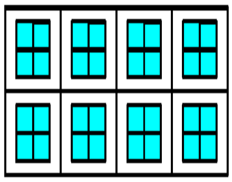
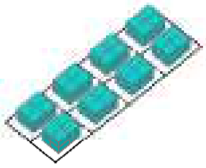
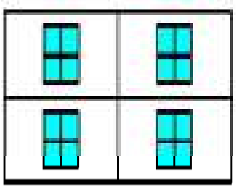
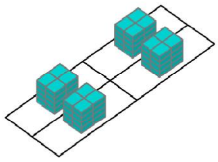
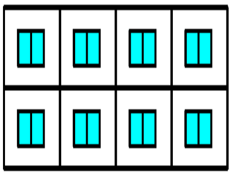
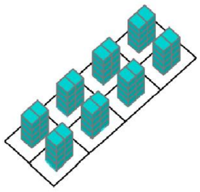
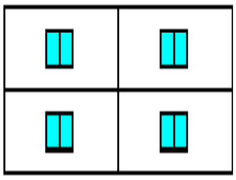
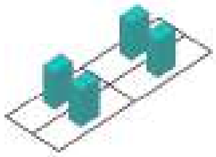
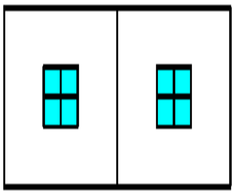
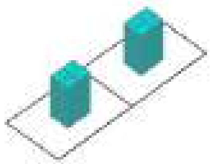
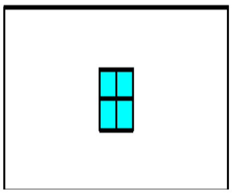
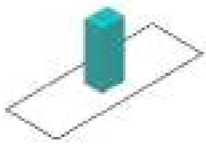
Plot ratio FAR	Urban configurations			
	Housing type	Plan	Perspective	Height(m)
0.8	Low-rise apartment Al.2(4)			6
	Low-rise apartment Al.4(4)			12
	Low-rise apartment Al.4(2)			12
	High-rise apartment Ah.8(2)			24
	High-rise apartment Ah.8(4)			12
	High-rise apartment Ah.16(4)			48

Table (5.6): Parameters with plot ratio 1 and 1.2 investigated in the study

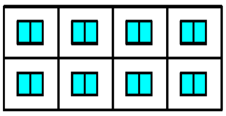
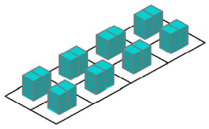
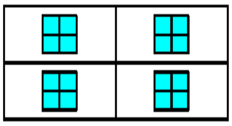
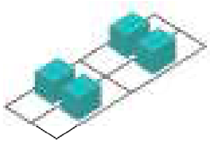
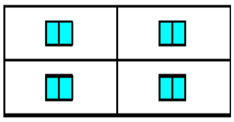
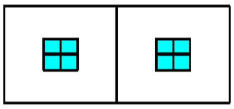
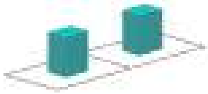
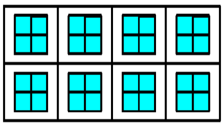
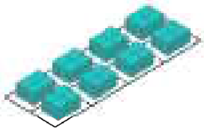
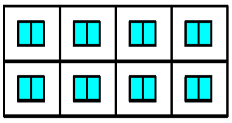
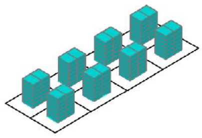
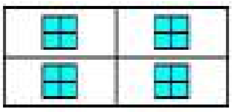
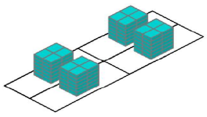
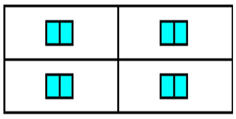
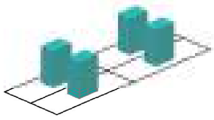
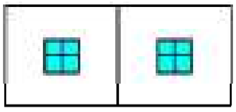
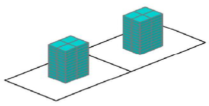
Plot ratio FAR	Urban configurations			
	Housing type	**Plan**	**Perspective**	**Height(m)**
1	Mid-rise apartment Am.5(2)			15
	Mid-rise apartment Am.5(4)			15
	High-rise apartment Ah.10(2)			30
	High-rise apartment Ah.10(4)			60
1.2	Low-rise apartment Al.3(4)			9
	Mid-rise apartment Am.6(2)			18
	Mid-rise apartment Am.6(4)			18
	High-rise apartment Ah.12(2)			36
	High-rise apartment Ah.12(4)			36

Table (5.7): Parameters with plot ratio 1.4 and 1.6 investigated in the study

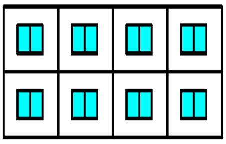
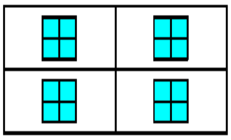
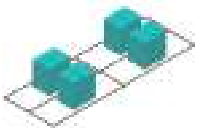
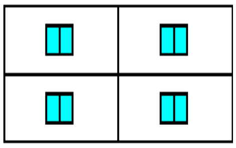
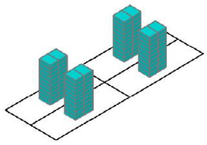
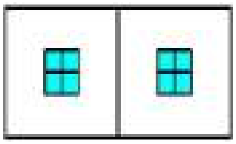
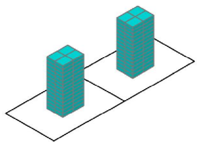
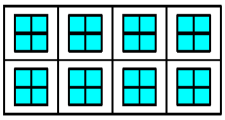
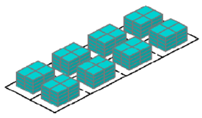
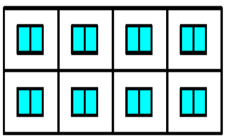
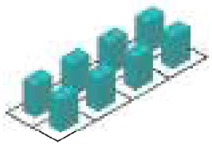
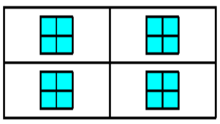
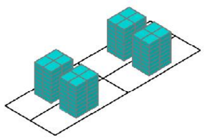
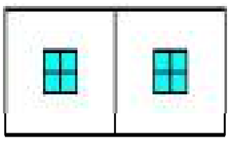
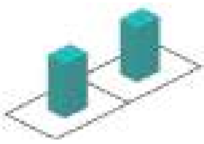
Plot ratio FAR	Urban configurations			
	Housing type	**Plan**	**Perspective**	**Height(m)**
1.4	Mid-rise apartment Am.7(2)			21
	Mid-rise apartment Am.7(4)			21
	High-rise apartment Ah.14(2)			42
	High-rise apartment Ah.14(4)			42
1.6	Low-rise apartment Al.4(4)			12
	High-rise apartment Ah.8(2)			24
	High-rise apartment Ah.8(4)			24
	High-rise apartment Ah.16(4)			48

Table (5.8): Parameters with plot ratio 1.8, 2 and 2.2 investigated in the study

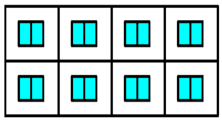
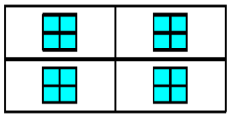
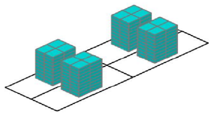
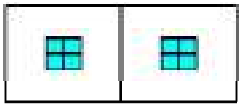
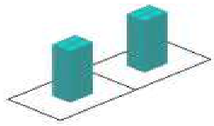
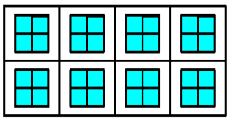
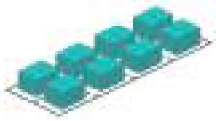
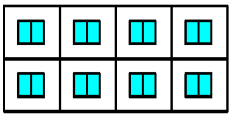
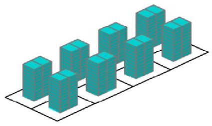
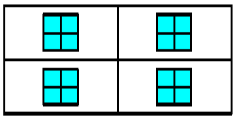
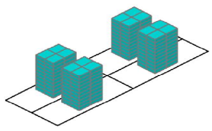
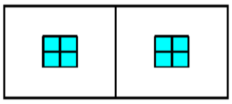
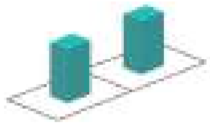
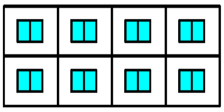
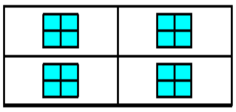
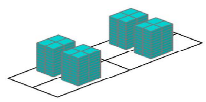
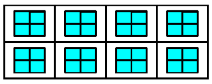
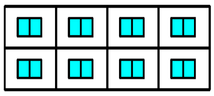
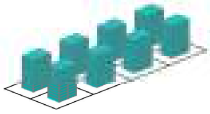
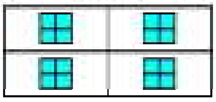
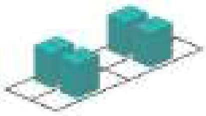
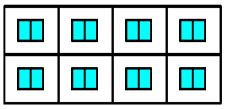
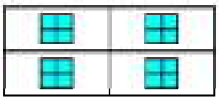
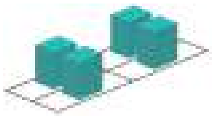
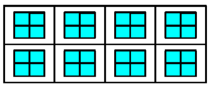
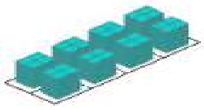
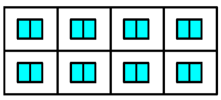
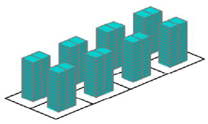
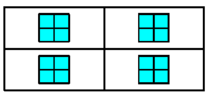
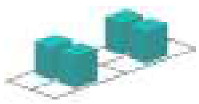
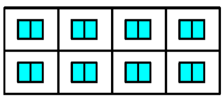
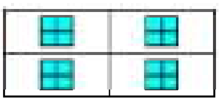
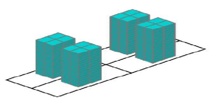
Plot ratio FAR	Urban configurations			
	Housing type	**Plan**	**Perspective**	**Height(m)**
1.8	High-rise apartment Ah.9(2)			27
	High-rise apartment Ah.9(4)			27
	High-rise apartment Ah.18(4)			54
2	Mid-rise apartment Am.5(4)			15
	High-rise apartment Ah.10(2)			30
	High-rise apartment Ah.10(4)			30
	High-rise apartment Ah.20(4)			60
2.2	High-rise apartment Ah.11(2)			33
	High-rise apartment Ah.11(4)			33

Table (5.9): Parameters with plot ratio 2.4, 2.6, 2.8 and 3 investigated in the study

Plot ratio FAR	Urban configurations			
	Housing type	**Plan**	**Perspective**	**Height(m)**
2.4	Mid-rise apartment Am.6(4)			18
	High-rise apartment Ah.12(2)			36
	High-rise apartment Ah.12(4)			36
2.6	High-rise apartment Ah.13(2)			39
	High-rise apartment Ah.13(4)			39
2.8	Mid-rise apartment Am.7(4)			21
	High-rise apartment Ah.14(2)			42
	High-rise apartment Ah.14(4)			42
3	High-rise apartment Ah.15(2)			45
	High-rise apartment Ah.15(4)			45

5.3.2 Simulation Results of plot ratio 0.2

Simulations were performed using the ECOTECT software. The simulation results were expressed in terms of annual heating loads, annual cooling loads and annual total loads (in KWh/m^2). The study compares the energy consumption of 9 configuration parameters of different housing types. Each model contains 16 units with floor area ratio 0.2 (see figure 5.18).

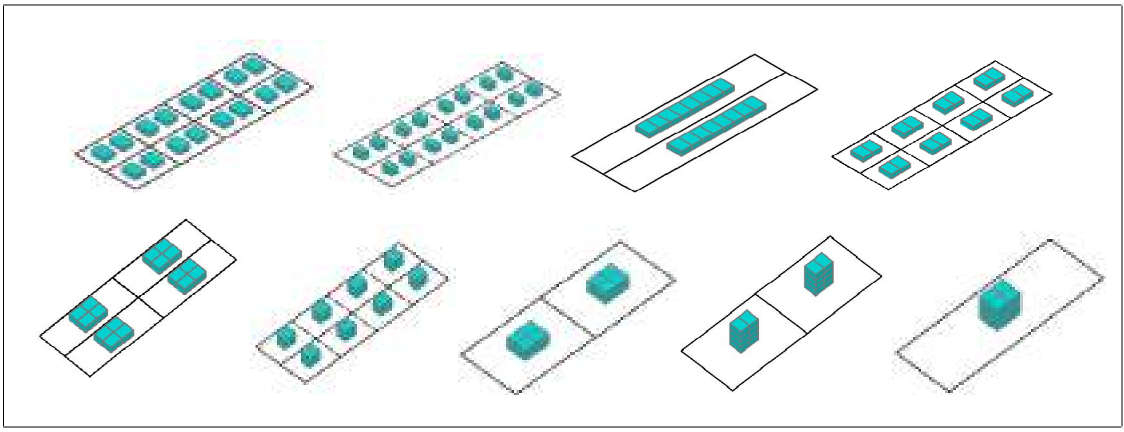


Figure (5.18): parameter combinations investigated in the study with plot ratio 0.2

On the urban scale with floor area ratio 0.2, it is clearly that model Al.4(2) presents the highest total load while the model D.1(1) presents the lowest total load. This indicate that the increasing of height increases the energy consumption by 29.6 %, 51% and 46.8 % in the cooling, heating and total loads respectively by ECOTECT between Al.4(2) and D.1(1). On the other hand, it is evident that there is a linear relationship between the model configurations Al.1(2), Al.1(4), Al.2(2) and Al.2(4). The loads increased by 2.5% 1.5%, and 2.8% in the cooling, heating and total loads respectively by ECOTECT.

As shown in figure (5.19), the model configuration Al.4(2) presents the highest heating loads while the model configuration Du.2(1) presents the lowest heating loads. This emphasizes that the horizontal configuration is better than the vertical configuration on energy consumption by about 28.5%. On the other hands the model configuration Al.4(4) presents the highest cooling loads while the model configuration D.1(1) presents the lowest cooling loads.

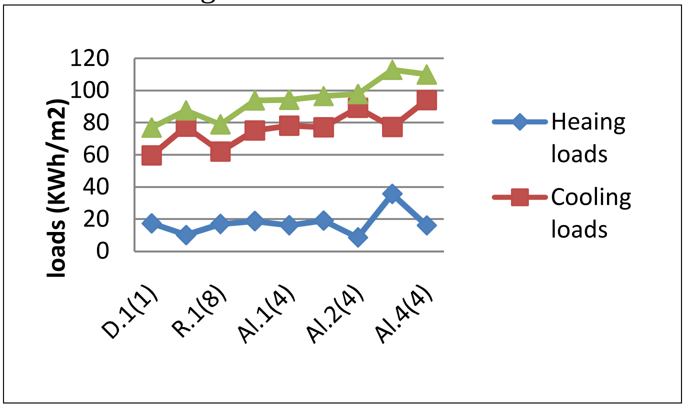


Figure (5.19): Cooling, heating and total loads in configurations with floor area ratio 0.2 by ECOTECT

5.3.3 Simulation Results of plot ratio 0.4

The study compares the energy consumption of 10 configurations parameters of different housing types. Each model contains 32 units with floor area ratio 0.4 (see figure 5.20).

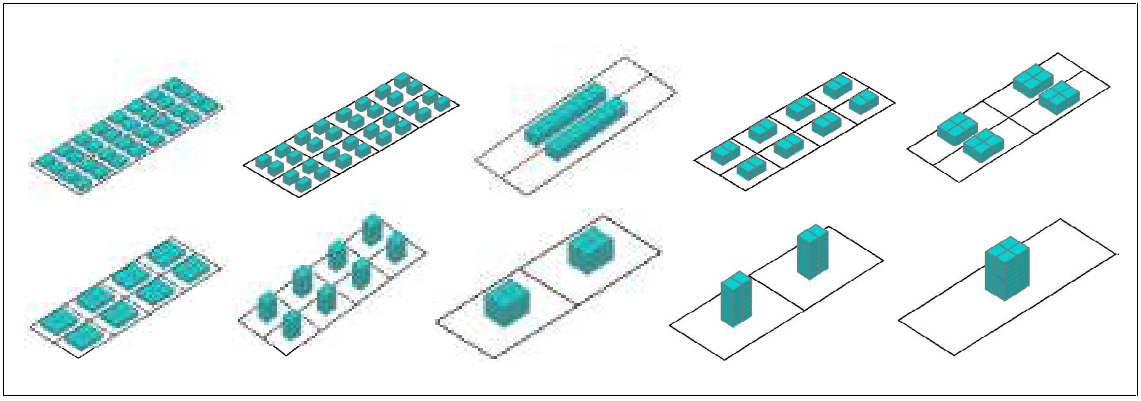


Figure (5.20): parameter combinations investigated in the study with plot ratio 0.4

On the urban scale with floor area ratio 0.4, it is clearly that model Ah.8(4) presents the highest total load while the model D.1(1) presents the lowest total load by 50.3 %, 33.1% and 46.6 % in the cooling, heating and total loads respectively by ECOTECT between Ah.8(4) and D.1(1). On the other hand, it is evident that there is a linear relationship between the model configurations R.2(8), Al.2(2) and Al.2(4). The loads increased by 1.2% 0.2%, and 0.9% in the cooling, heating and total loads respectively by ECOTECT. This is because of the constant height and occupancy between the different configurations.

As shown in figure (5.21), the model configuration Ah.8(2) presents the highest heating loads while the model configuration Du.2(1) presents the lowest heating loads. This emphasizes that the horizontal configuration is better than the vertical configuration on heating energy consumption by about 28.9%. On the other hands the model configuration Ah.8(4) presents the highest cooling loads while the model configuration D.1(1) presents the lowest cooling loads.

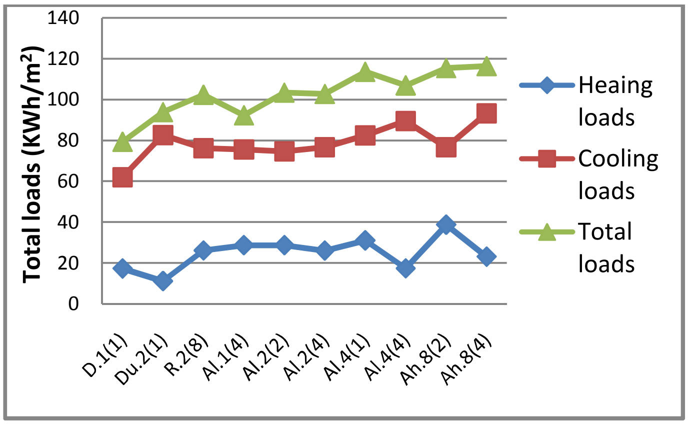


Figure (5.21): Cooling, heating and total loads in configurations with floor area ratio 0.4 by ECOTECT

5.3.4 Simulation Results of plot ratio 0.6

The study compares the energy consumption of 7 configurations parameters of different housing types. Each model contains 48 units with floor area ratio 0.6 (see figure 5.22).

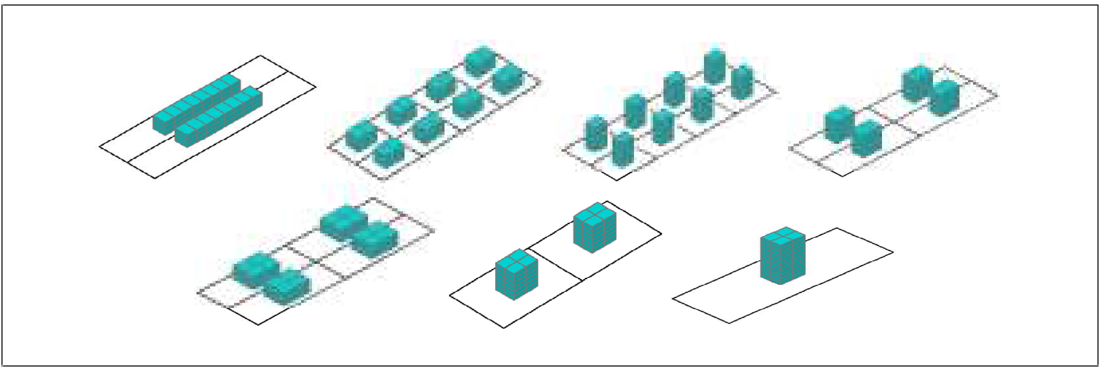


Figure (5.22): low-rise apartment combinations investigated in the study with plot ratio 0.6

On the urban scale, the results indicate that the two models Am.6(1) and Ah.12(4) presents the highest total loads while the two models Al.3(2) and Al.3(4) presents the lowest total loads. by about 8.9%, 42.5% and 18.5% in the cooling, heating and total loads respectively

As shown in figure (5.23), the model Am.6(4) presents the lowest heating loads by about 53.2%. While the model Am.6(2) presents the highest heating loads by about 53.2%

On the other hands the model Ah12.(4) presents the highest cooling loads by about 24.3% while the model Al.3(2) presents the lowest cooling loads by about 24.3%. This mean that the increasing of height increases the energy consumption in the urban configurations.

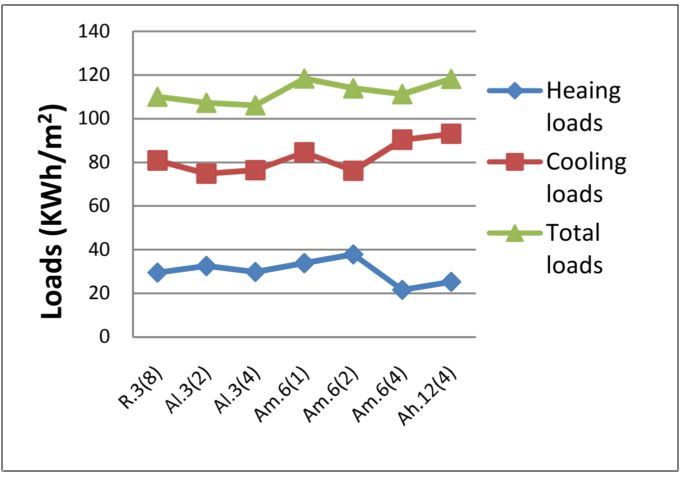


Figure (5.23): Cooling, heating and total loads in configurations with floor area ratio 0.6 by ECOTECT

5.3.5 Simulation Results of plot ratio 0.8

The study compares the energy consumption of 6 configurations parameters of different housing types. Each model contains 64 units with floor area ratio 0.8 (see figure 5.24).

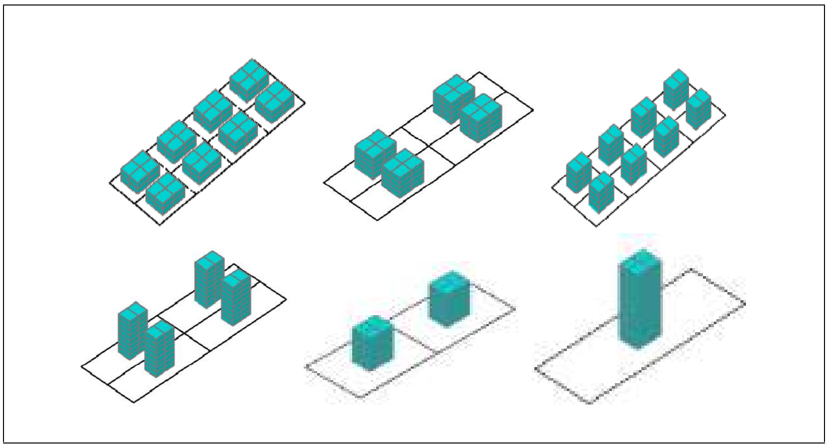


Figure (5.24): Parameter combinations investigated in the study with plot ratio 0.8

On the urban scale, it is evident that there is a slight increasing between the different models which varies by about 10.2% in the total loads.

As shown in figure (5.25), the model Ah.16(4) presents the highest energy consumption because of increasing in the cooling loads by 24.1% from the others. While the model Ah.16(4) presents the lowest energy consumption in the heating loads by 36.4% from the others. This indicate the increasing of height decreases the heating cooling but increases the cooling loads.

On the other hands the model Al.2(4) presents the lowest total loads which decreases by about 23.1%, 1.5% and 17.9% in the cooling, heating and total loads respectively from the model Ah.16(4). It can be concluded that the increasing in the cooling loads causes clearly the increasing in the total loads.

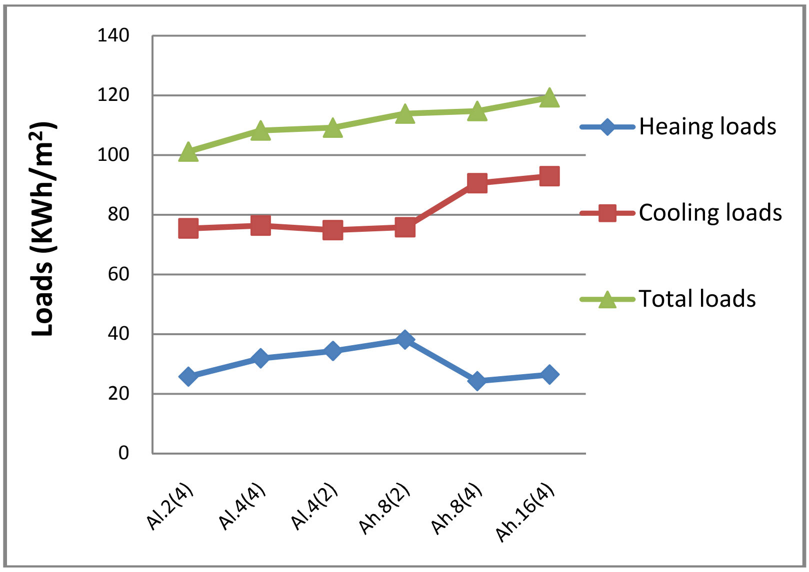


Figure (5.25): Cooling, heating and total loads in configurations with floor area ratio 0.8 by ECOTECT

5.3.6 Simulation Results of plot ratio 1

The study compares the energy consumption of 4 configurations parameters of different housing types. Each model contains 80 units with floor area ratio 1 (see figure 5.26).

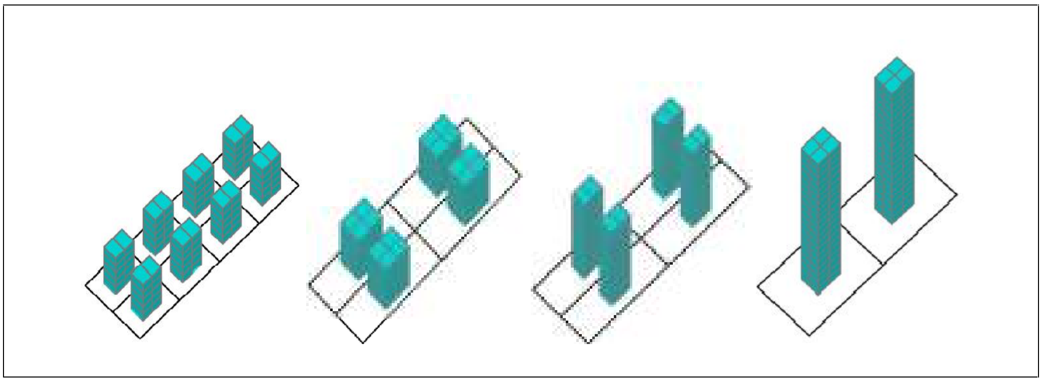


Figure (5. 26): Apartment parameter combinations investigated in the study with plot ratio 1

On the urban scale, it is evident that there is a slight difference between the different models which varies by about 4.8% in the total loads.

As shown in figure (5.27), the model Ah.10(4) presents the lowest heating loads by 57.7% but it presents the highest cooling loads by 21.6%. This mean that the increasing in the height with constant plot ratio 1 greatly affect the total energy consumption in the cooling loads but doesn't significantly greatly affects energy consumption in the case of heating loads.

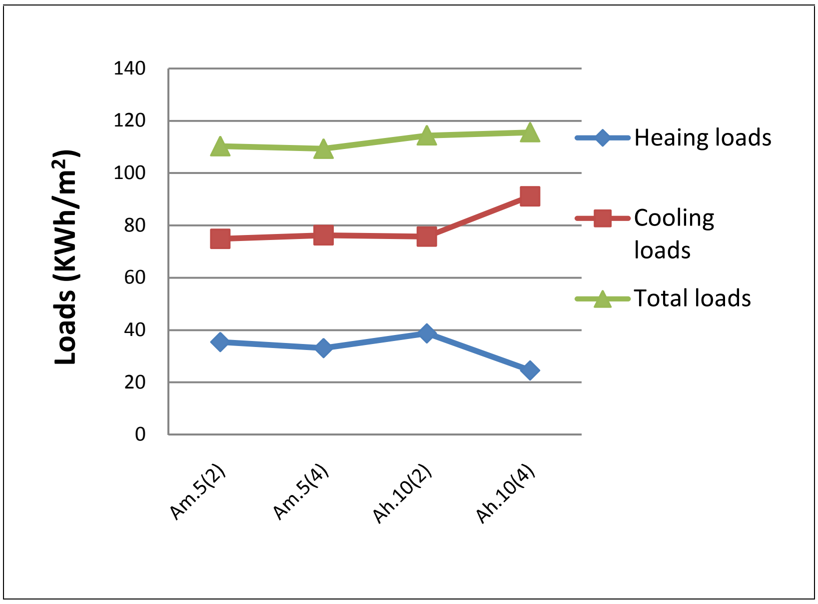


Figure (5.27): Cooling, heating and total loads in configurations with floor area ratio 1 by ECOTECT

5.3.7 Simulation Results of plot ratio 1.2

The study compares the energy consumption of 5 configurations parameters of different housing types. Each model contains 96 units with floor area ratio 1.2 (see figure 5.28).

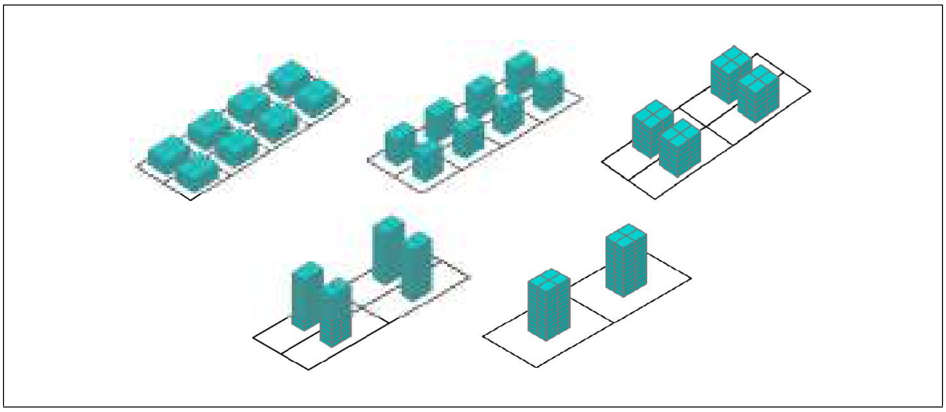


Figure (5. 28): Apartment parameter combinations investigated in the study with plot ratio 1.2

On the urban scale, it is evident that there is a slight increasing between the different models which varies by about 11.8% in the total loads.

As shown in figure (5.29), the model Ah.12(4) presents the highest energy consumption while the model Al.3(4) presents the lowest energy consumption because of increasing in the cooling loads by 20.9% between the two models. It can be concluded that the increasing in the cooling loads causes clearly the increasing in the total loads.

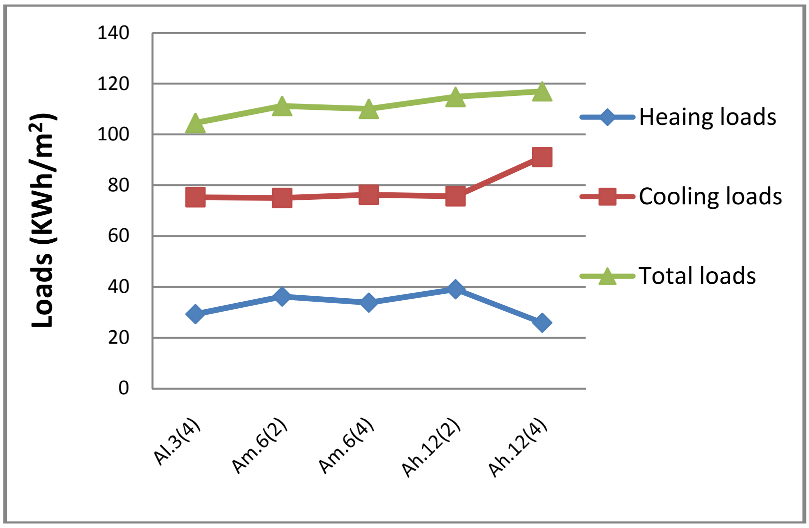


Figure (5.29): Cooling, heating and total loads in configurations with floor area ratio 1.2 by ECOTECT

5.3.8 Simulation Results of plot ratio 1.4

The study compares the energy consumption of 4 configurations parameters of different housing types. Each model contains 112 units with floor area ratio 1.4 (see figure 5.30).

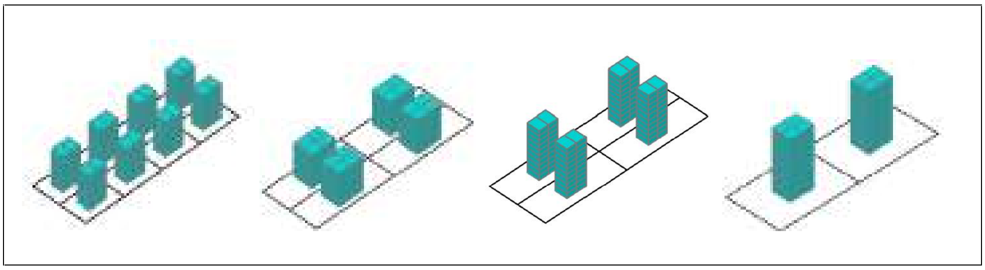


Figure (5. 30): Apartment parameter combinations investigated in the study with plot ratio 1.4

It is evident that there is a slight increasing between the different models which varies by about 5.9% in the total loads.

As shown in figure (5.31), the model Ah.14(4) presents the highest energy consumption while the model Am.7(2) presents the lowest energy consumption because of increasing in the cooling loads by 21.8% between the two models. It can be concluded that the increasing in the plot ratio doesn't significantly affect on the increasing in the total loads.

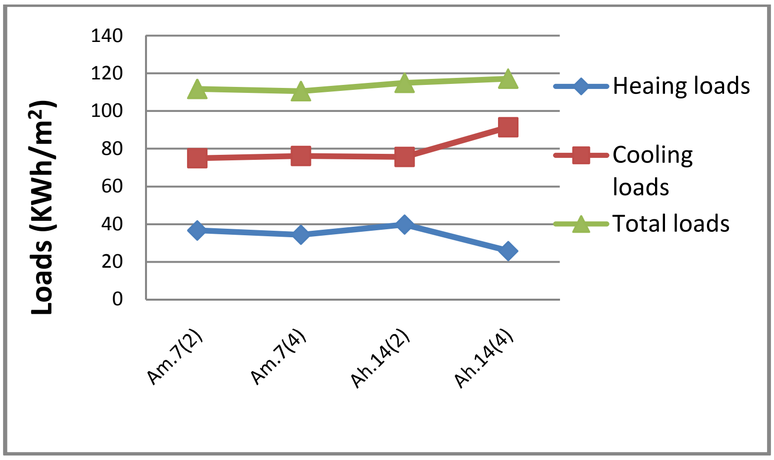


Figure (5.31): Cooling, heating and total loads in configurations with floor area ratio 1.4 by ECOTECT

5.3.9 Simulation Results of plot ratio 1.6

The study compares the energy consumption of 4 configurations parameters of different housing types. Each model contains 128 units with floor area ratio 1.6 (see figure 5.32).

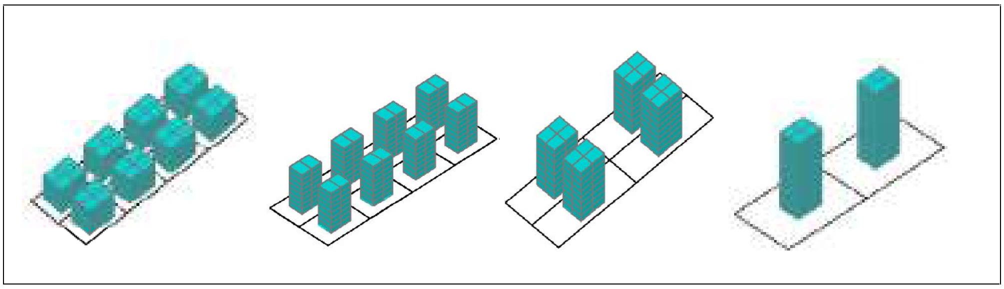


Figure (5. 32): Apartment parameter combinations investigated in the study with plot ratio 1.6

As shown in figure (5.33), the model Ah.16(4) presents the highest energy consumption by about 21.3%, 10.4% from the others in the cooling and total loads respectively but decreases by 29.3% in the heating loads.
It is a slight difference between the models Al.4(4), Ah.8(2) and Ah.8(4) by about 0.8%, 18.3% and 5.3% in the cooling, heating and total loads respectively.

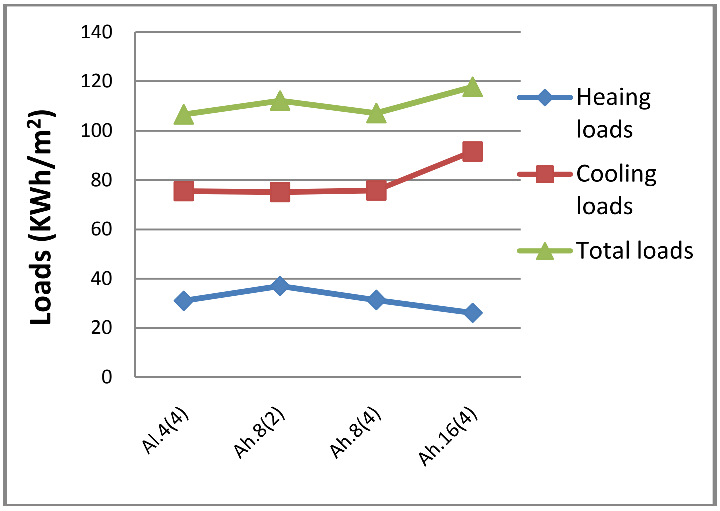


Figure (5.33): Cooling, heating and total loads in configurations with floor area ratio 1.6 by ECOTECT

5.3.10 Simulation Results of plot ratio 1.8

The study compares the energy consumption of 3 configurations parameters of different housing types. Each model contains 144 units with floor area ratio 1.8 (see figure 5.34).

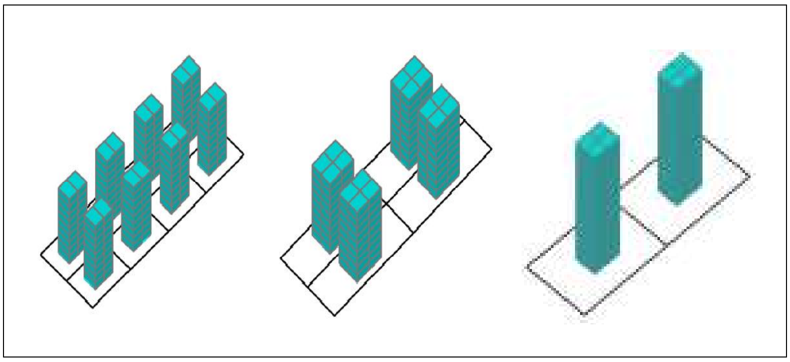


Figure (5. 34): Apartment parameter combinations investigated in the study with plot ratio 1.8

It is evident that there is a slight increasing between the two models Ah.9(2) and Ah.9(4) which varies by about 0.8%, 3.4% and 2.1% in the cooling, heating and total loads respectively. On the other hands the model Ah.18(4) presents the highest energy consumption by about 22.1%, 40.8% and 5.1% in the cooling, heating and total loads respectively. Figure (5.35) shows the effect of Ah.9(2), Ah.9(4) and Ah.18(4) on the total, heating and cooling loads per m^2 throughout the year using ECOTECT.

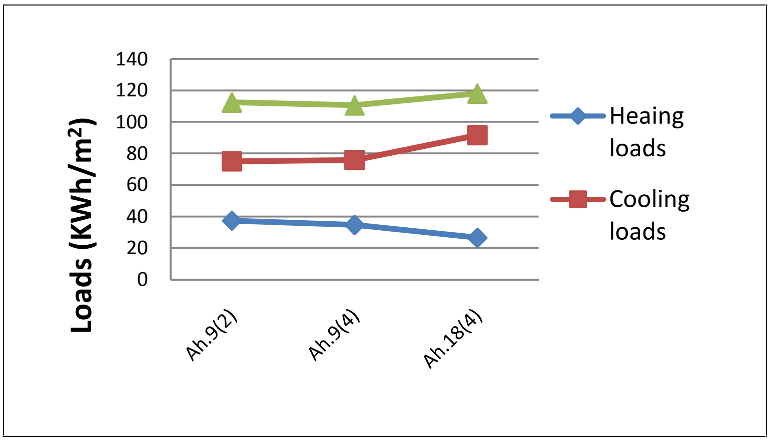


Figure (5.35): Cooling, heating and total loads in configurations with floor area ratio 1.8 by ECOTECT

5.3.11 Simulation Results of plot ratio 2

The study compares the energy consumption of 4 configurations parameters of different housing types. Each model contains 160 units with floor area ratio 2 (see figure 5.36).

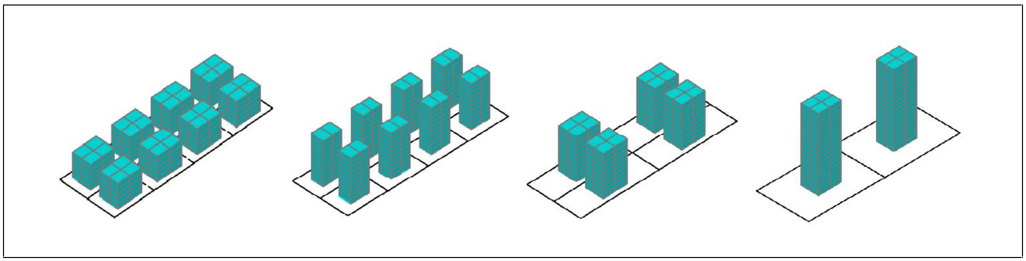


Figure (5. 36): Apartment parameter combinations investigated in the study with plot ratio 2

It is clearly that there is a slight increasing between the different models which varies by about 9.8% in the total loads.

As shown in figure (5.37), the models Am.5(4), Ah.10(2), and Ah.10(4) have the similar behavior on the energy consumption. While the model Ah.20(4) presents the highest energy consumption because of increasing in the cooling loads by 21.3% from the others but it decreases by 29.1% models. It can be concluded that the increasing in the increasing in the plot ratio greatly affect on the decreasing in the heating loads.

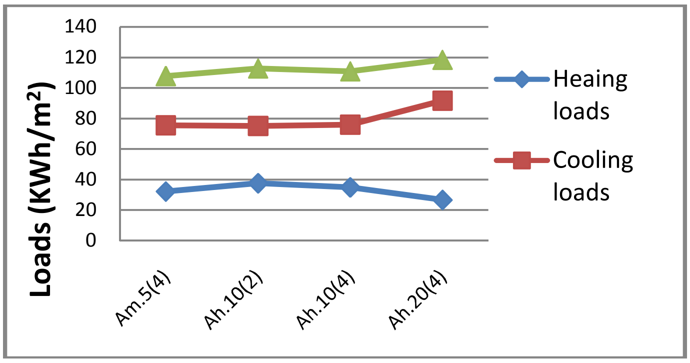


Figure (5.37): Cooling, heating and total loads in configurations with floor area ratio 2 by ECOTECT

5.3.12 Simulation Results of plot ratio 2.2

The study compares the energy consumption of 2 configurations parameters of different housing types. Each model contains 176 units with floor area ratio 2.2 (see figure 5.38).

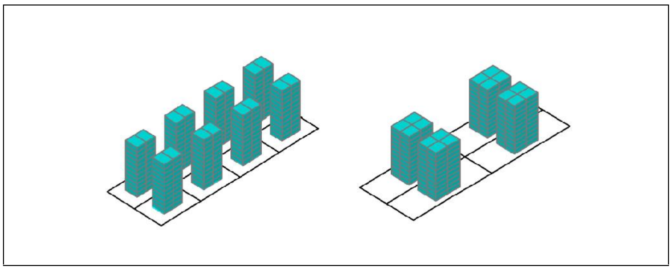


Figure (5. 38): Apartment parameter combinations investigated in the study with plot ratio 2.2

As shown in figure (5.39), it is evident that there is a slight increasing between the two models which varies by about 1.2%, 7.1% and 1.5% in the cooling, heating and total loads respectively.

It can be concluded that the increasing in the plot ratio doesn't significantly affect on the increasing in the total loads.

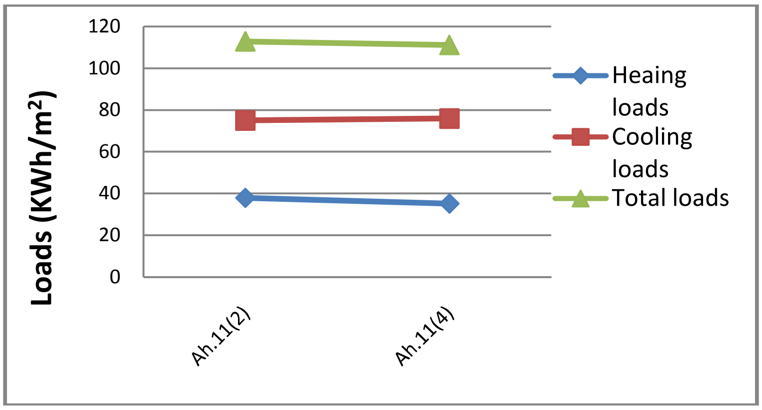


Figure (5.39): Cooling, heating and total loads in configurations with floor area ratio 2.2 by ECOTECT

5.3.13 Simulation Results of plot ratio 2.4

The study compares the energy consumption of 3 configurations parameters of different housing types. Each model contains 192 units with floor area ratio 2.4 (see figure 5.40).

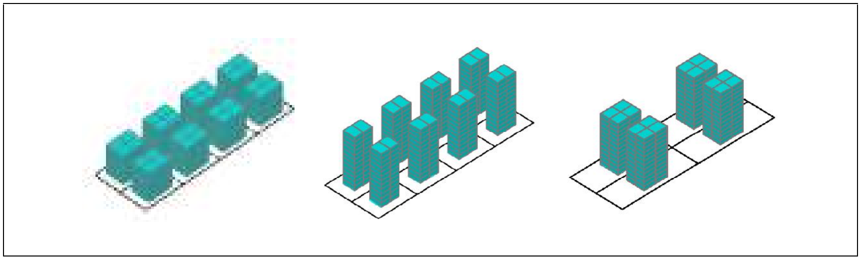


Figure (5. 40): Apartment parameter combinations investigated in the study with plot ratio 2.4

It is evident that there is a slight increasing between the different models which varies by about 1.3%, 15.3% and 2.5% in the cooling, heating and total loads respectively.

As shown in figure (5.41), the model Ah.12(2) presents the highest energy consumption while the model Am.6(4) presents the lowest energy consumption. It can be concluded that the mid rise configuration is better than the high rise configuration on the energy consumption with constant plot ratio.

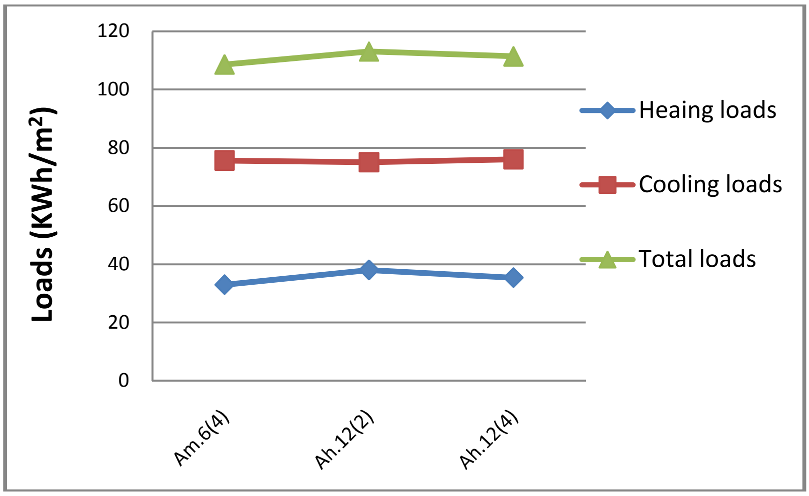


Figure (5.41): Cooling, heating and total loads in configurations with floor area ratio 2.4 by ECOTECT

5.3.14 Simulation Results of plot ratio 2.6

The study compares the energy consumption of 2 configurations parameters of different housing types. Each model contains 208 units with floor area ratio 2.6 (see figure 5.42).

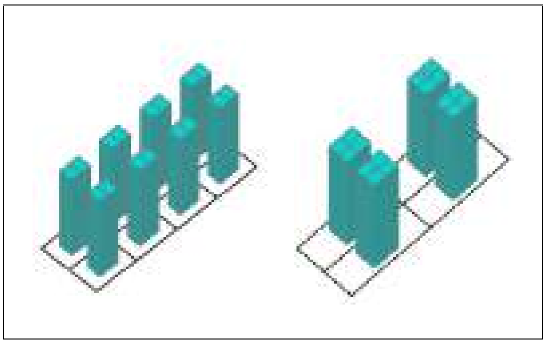


Figure (5. 42): Apartment parameter combinations investigated in the study with plot ratio 2.6

As shown in figure (5.43), it is evident that there is a slight increasing between the two models which varies by about 1.3%, 15.3% and 4.1% in the cooling, heating and total loads respectively. It can be concluded that the increasing in the plot ratio doesn't significantly affect on the increasing in the total loads.

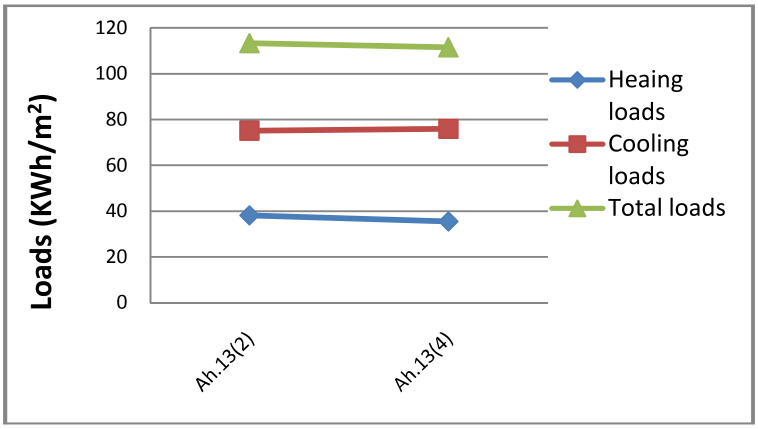


Figure (5.43): Cooling, heating and total loads in configurations with floor area ratio 2.6 by ECOTECT

5.3.15 Simulation Results of plot ratio 2.8

The study compares the energy consumption of 3 configurations parameters of different housing types. Each model contains 224 units with floor area ratio 2.8 (see figure 5.44).

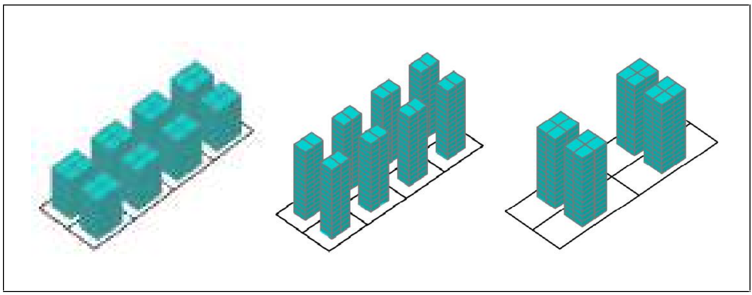


Figure (5. 44): Apartment parameter combinations investigated in the study with plot ratio 2.8

It is evident that there is a slight increasing between the different models which varies by about 2.3% in the total loads.

As shown in figure (5.45), the model Am.7(4) presents the lowest energy consumption while the model Ah.14(2) presents the highest energy consumption. It can be concluded that the increasing in the increasing in the plot ratio doesn't significantly affect on the increasing in the total loads.

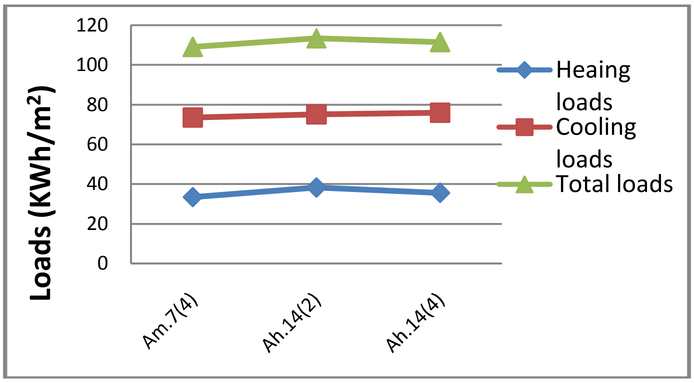


Figure (5.45): Cooling, heating and total loads in configurations with floor area ratio 2.8 by ECOTECT

5.3.16 Simulation Results of plot ratio 3

The study compares the energy consumption of 2 configurations parameters of different housing types. Each model contains 240 units with floor area ratio 3 (see figure 5.46).

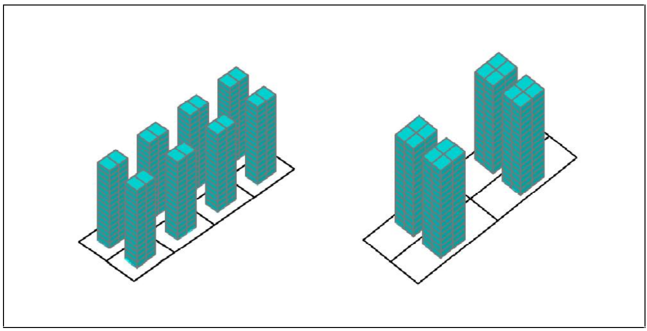


Figure (5. 46): Apartment parameter combinations investigated in the study with plot ratio 2.8

As shown in figure (5.47), it is evident that there is a slight difference between the two models which estimated by about 1. 5%, 7.3% and 1.6% in the cooling, heating and total loads respectively. It can be concluded that the increasing in the plot ratio doesn't significantly affect on the increasing in the total loads on the high rise apartments.

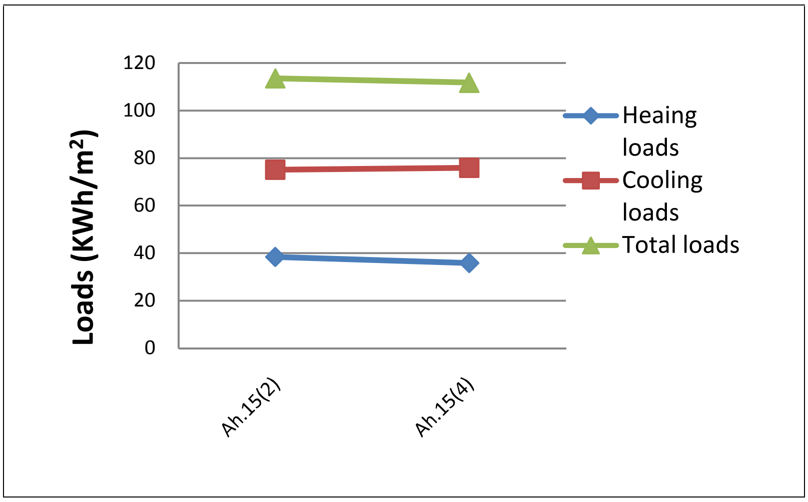


Figure (5.47): Cooling, heating and total loads in configurations with floor area ratio 3 by ECOTECT

From the previous results, table (5.9) shows the best urban configurations in different plot ratios. The results indicate that the increasing in floor area ratio from 0.2 to 3 increases the total loads by 45.3% and reduces the heating loads by 41.6% in. Figure (5.48) shows the effect of the best configurations on the total, loads per m^2 throughout the year using ECOTECT.

Table (5.10): A comparison between the different plot ratios in terms of total loads in the best case of each plot ratios (1)

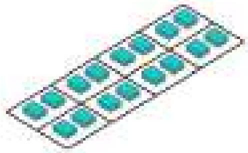
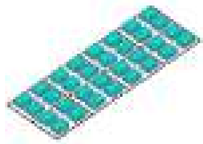
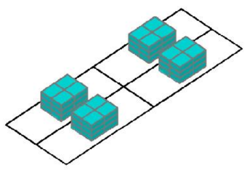
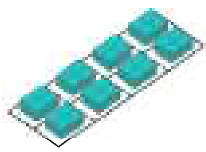
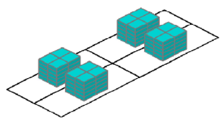
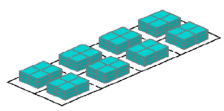
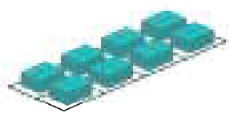
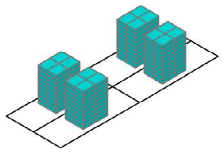
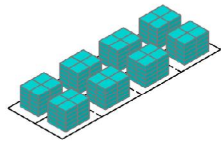
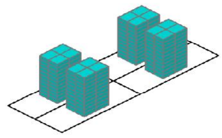
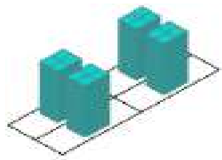
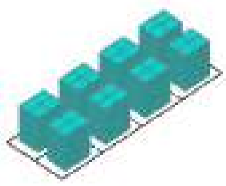
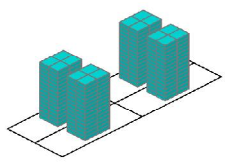
Plot ratio	Urban configuration (The best case)	perspective	Total loads(KWh/m^2)
0.2	D.1(1)		76.8
0.4	D.1(1)		79.3
0.6	Al.3(4)		106.1
0.8	Al.2(4)		101.1
1	Am.5(4)		109.3
1.2	Al.3(4)		104.6
1.4	Am.7(2)		111.7
1.6	Al.4(4)		106.6

Table (5.11): A comparison between the different plot ratios in terms of total loads in the best case of each plot ratios(2)

Plot ratio	Urban configuration (The best case)	perspective	Total loads(KWh/m^2)
1.8	Ah.9(4)		110.6
2	Am.5(4)		107.7
2.2	Ah.11(4)		111.1
2.4	Am.6(4)		108.6
2.6	Ah.13(4)		111.5
2.8	Am.7(4)		109.1
3	Ah.15(4)		111.7

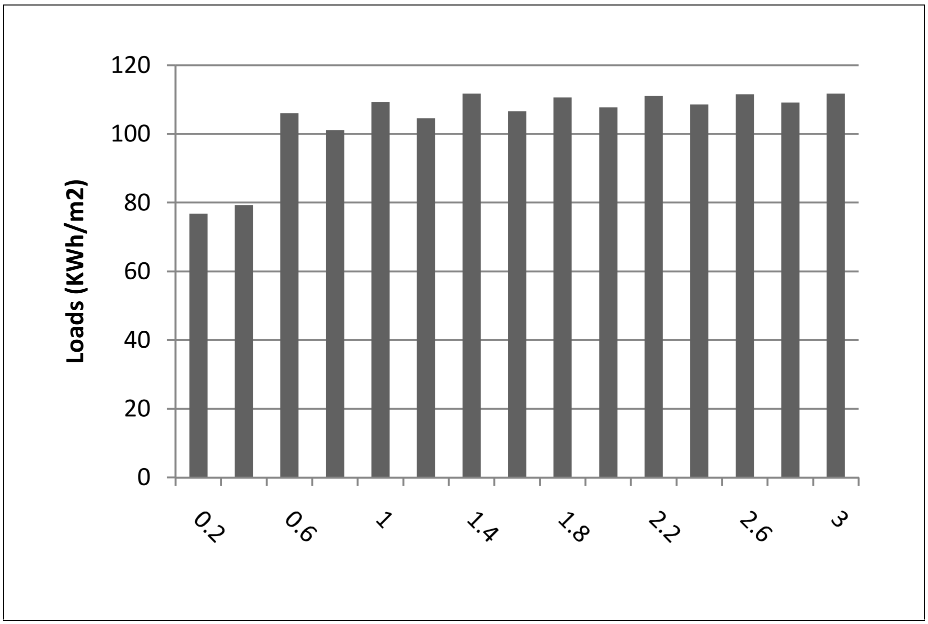


Figure (5.48): total loads in best configurations with different floor area ratio (KWh/m^2) in ECOTECT

5.4 Conclusion

This chapter dealt with the housing density in the context of the urban fabric. Methods of controlling housing density like number of units per dunum and floor area ratio investigated as an essential determinate of the urban form as it affects on energy consumption.

Firstly, it investigated the effect of building types with different heights and different housing densities on energy consumption. It dealt with individual buildings, after that it discussed each type in urban configuration. Each unit in all the models had the same characters (materials, area plot, occupancy and orientation). It is concluded that the row housing type offers a reduction in energy consumption per square meter by about 14% compared to the apartment buildings in the case of urban situation. This is less than the reduction observed in the isolated cases discussed in the previous chapter, which was about 50%. This is due to the reduced surface area and natural ventilation, and thus the higher required cooling loads.

It is also concluded that increasing floor area ratio (FAR) from 0.2 to 3 leads to an increase in the total loads observed. The lower FAR in the urban configuration is the best thermally which reduced the total loads by about 39%. In each FAR, the designer has several choices in terms of building configuration. However, it is possible to achieve the required density by choosing the best configuration in terms of energy efficiency.

CHAPTER 6

CONCLUSION AND RECOMMENDATIONS

6.1 Introduction

The world is facing a significant challenge represented in the lack of the conventional energy and the environmental problems related to the ever increase in energy consumption. Climatic change and the global warming is another challenge which is linked to the CO_2 emission from the fossil fuels. Buildings contribute to these problems as they are considered the main consumers of energy. The largest portion of the energy in buildings are used for the heating and cooling requirements in order to achieve a high level of thermal comfort. Gaza Strip; as one of the developing areas in the Middle East faces a great challenge in this regard considering its limited resources.

Thus, several strategies can be used in building design including passive and active ones. However, one important strategy is the selection of housing type and density. From this standpoint, the study focused on the effect of different housing types with different housing density in the climatic conditions in the Gaza Strip on the energy consumption.

6.2 Conclusions

The main findings of the theoretical study are classified into four sections:

6.2.1 Housing Density and Energy Effeciency

There is a great relationship between Housing density and energy consumption which is concluded as the following:

- Density is a critical typology in determining urban forms.
- Density and dwelling type affect sustainability through differences in the consumption of energy; materials; and land for housing, transportation, and urban infrastructure.
- Dwellings per hectare is the most appropriate measure for estimating the gross or net yield of existing or future housing, but should be used in conjunction with other planning standards and with plot ratio in particular when controlling development form.
- An inverse relationship is found between residential population density and energy consumption; lower residential population densities are associated with

higher energy consumption patterns, and higher densities with lower energy consumption patterns.

- Housing located in wards with the highest densities (over 35 persons/ha) is associated with 29% less energy consuming commutes than the sample average.
- that higher urban density has negative impacts on the microclimate and the hydrology of the city. There are strategies to minimize these adverse effects, including the widespread use of roof top gardens.
- Building form is one of the most important principles due to the fact that it determines the amount of heat loss or heat gain through the building envelope.
- While the area of Gaza Strip is only 365 square kilometers, population density was an average of 3,880.9 persons per square kilometer which about 9.3 times the average density of the West Bank.
- In the Gaza Strip, the main forms of energy in housing sector are electricity and natural gas.
- The distribution of the total manual electricity consumption in the Gaza Strip among various sectors clearly reveals that the domestic and residential sector consumes the main bulk of electricity; about 70 % of the total consumption. The public services sector consumes the second biggest amount with an average of 17 %, while the industrial sector only uses 6.5% of the total consumption, and the commercial and the agricultural sectors significantly less.
- The electricity consumption of the Gaza Strip was increased by 80% during the period 1999 to 2005, and at about 10% average annual increasing rate.
- About 86% of households use a space heating facility while 80.7% of families used electrical devices for air conditioning and fans.
- The electricity load required for the Gaza strip from 2001 to 2010. It's clear that the electricity needs increase by about 10-15 MW annually, as a result of the natural population growth and the expansion in the different sectors requiring electricity supply.
- The Gaza strip needs (270) MW of electricity. The available supply is (197) MW. The large share of this supply about (60%) with an average load (120) MW is provided by (Israeli) Electricity Company. Locally, about (32%) with an average load (60) MW is provided by Gaza Power Plant. In addition, about (8%) with an average load (17) MW is provided by Egyptian electric company.
- The Gaza strip has been suffering from a real shortage in electricity supply estimated by 25%.

6.2.2 The Effect of Housing Type on Energy Consumption

Accordingly, a parametrical studies were hold using the simulation programs ECOTECT and Design Builder to investigate the effect of the housing type on the energy consumption. The combination of these studies result in these conclusion:

- The occupancy and height are the main responsible for the thermal response in different housing types.
- The total loads are increased by 21.7% in the single detached house with increasing the height from one floor to two floors.
- Duplex house consumes more energy than the detached house because of the increasing in the surface area by 16.2% from the duplex house to the detached house.

- The horizontal plan of the row house consumes less than the vertical design of the detached and duplex house by 79 %.
- The row house type achieves the lowest energy consumption. On the other hand, the duplex house achieves the highest energy consumption.
- It can be concluded that the row house types are more preferable for both cooling and heating requirements, although it have more occupancy because of its small surface area.
- Mid-rise apartment with 5, 6 and 7 storeys don't effect heavily on the total loads despite the increase in the occupancy.
- Increasing the building height from 24 m to 45 m in the high rise apartment types increases the total loads by about 1.6% in ECOTECT.
- The effect of changing height is not remarkable in the heating loads. While changing height from 3 m to 45 m increases the total loads, it reduces the heating loads by 3.6% in ECOTECT.
- The effect of changing height is more noticeable in the cooling loads. About 73.5% of the cooling loads can be increased with changing height in different house types.
- The results indicate that the total loads for the simulated house types are increased by 69.2% with increasing the building height from 3 m to 45 m. It can be noticed that the highest height (7, 8, 10 and 15 floors) is more preferable for heating requirements.
- It can be seen that the row house types achieves the highest heating loads. It is clearly that compact house types which are row house are the reference types. As stated above, they decreased in the total loads by 69.1% and 73.3% in the total and cooling loads respectively from the other types.

6.2.3 The Effect of Various Urban Configurations on Energy Consumption

The study concerned on understanding the relation between the housing types and the thermal performance in urban configurations . On the other hand, it was focused on the relation between floor area ratio and energy consumption. The combination of these studies result in these conclusion:

- Increasing the housing density from 60 to 240 persons in the single detached house types in ECOTECT increases the total loads by about 31.1% and by 39.3% in Design Builder.
- Duplex house configuration that is similar with single detached configuration in occupancy (60 persons) is increased by 24.5%, 8.2% and 16.3% in the total, heating and cooling loads respectively.
- It is evident that there is a slight difference between the low-rise apartment configuration with 120 persons and the low-rise apartment configuration with 180 persons which increased to about 2%, 1.7% and 1.3% in the total, heating and cooling loads respectively.
- It is evident that there is a slight difference between the high rise apartment configuration with 10, 12 and 15 floors which reach to about 0.5%, 0.2% and 0.3% in the total, heating and cooling loads respectively by ECOTECT.
- It can be concluded that the increasing in the plot ratio doesn't significantly affect on the increasing in the total loads on the high rise apartments.

- The results indicate that the increasing in floor area ratio from 0.2 to 3 increases by 45.3% in the total loads by ECOTECT. While it decreases by 41.6% in the heating loads.
- It can be concluded that the mid rise configuration is better than the high rise configuration on the energy consumption with constant plot ratio.
- It can be concluded that the increasing in the increasing in the plot ratio greatly affect on the decreasing in the heating loads.
- This mean that the increasing in the height with constant plot ratio 1 greatly affect the total energy consumption in the cooling loads but doesn't significantly greatly affects energy consumption in the case of heating loads.
- This emphasizes that the horizontal configuration is better than the vertical configuration on heating energy consumption by about 28.9%.

6.2.4 Limitations of Results

As a final remark, there are some limitations of the results:

- Gaza Strip climatic conditions.
- Assumptions associated with the use of ECOTECT and Design Builder such as internal gains and load calculation technique.
- Although two simulation programs have been used, a physical or field investigation is recommended for further validation.

6.3 Recommendations

Concerned bodies in the Palestinian housing sector, such as MPWH and Syndicate of engineers need to:

- Highlight the issue of energy and its relation to design. In this regard, awarness activities need to be organized for architects and engineers.
- Develop the existing building laws and legislations in a way that promote energy efficiency in residential buildings. This includes grantiny licenses and permits.
- Offer proper incentives to promote sustainability in the Palestinian housing sector.
- Promote the concept of compact housing due to its proven benefit in energy savings. In this regard, new designs and housing types may be introduced.

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APPENDIX1

Table (1): Default settings for ECOTECT and Design Builder

	ECOTECT	Design Builder
Location and Site Data		
Location		
Weather File Data	El_Arish file	El_Arish file
Latitude	31.08 N	31.08 N
Longitude	33.82 E	33.82 E
Altitude (m)	32.0	32.0
Site Data		
Ground reflectance	0.2	
Terrain types	Urban	Urban
Wind exposure	Normal	Normal
Thermal Condition		
HVAC System	Full Air Conditioning	Full Air Conditioning
Thermostat Range	18.00C- 26.00C	18.00C- 26.00C
Heating set point	18.00C	18.00C
Cooling set point	26.00C	26.00C
Domestic Hot Water DHW Consumption	0.0	0.0
Use of the building/ Hours of Operation	On continuously	On continuously
Model settings		
Solar reflected fraction	-	-
Furniture mass factor	-	-
Design condition		
Clothing	1.0	-
Humidity	60.0	-
Air speed	0.5 m/s	-
Lighting level	300 lux	300 lux
Occupancy		
Internal heat gain		
Sensible gain	15	15
Latent gain	-	-
Infiltration rate		
Air change rate	1	1
Wind Sensitivity	0.25	-
Construction		
Exterior walls		
U-value	2.3	2.547
Roof		
U-value	2.6	2.505
Ground-contact/exposed		
U-value	2.560	2.244
Window		
U-value	5.5	6.121

ECOTECT Setting

Location and Site Data in ECOTECT

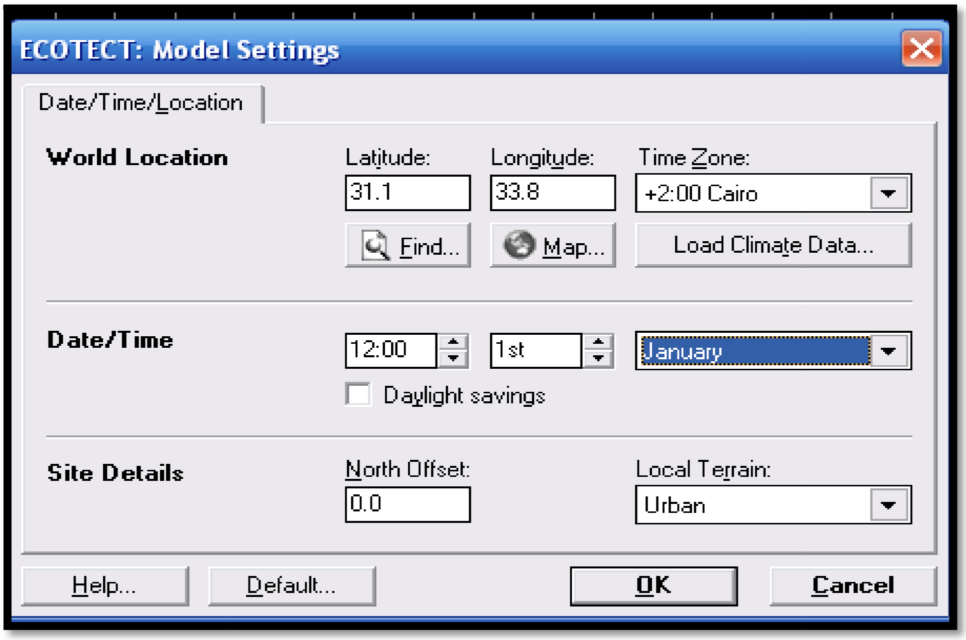

Figure (1): Location and Site Data in ECOTECT

Thermal properties for zones in ECOTECT

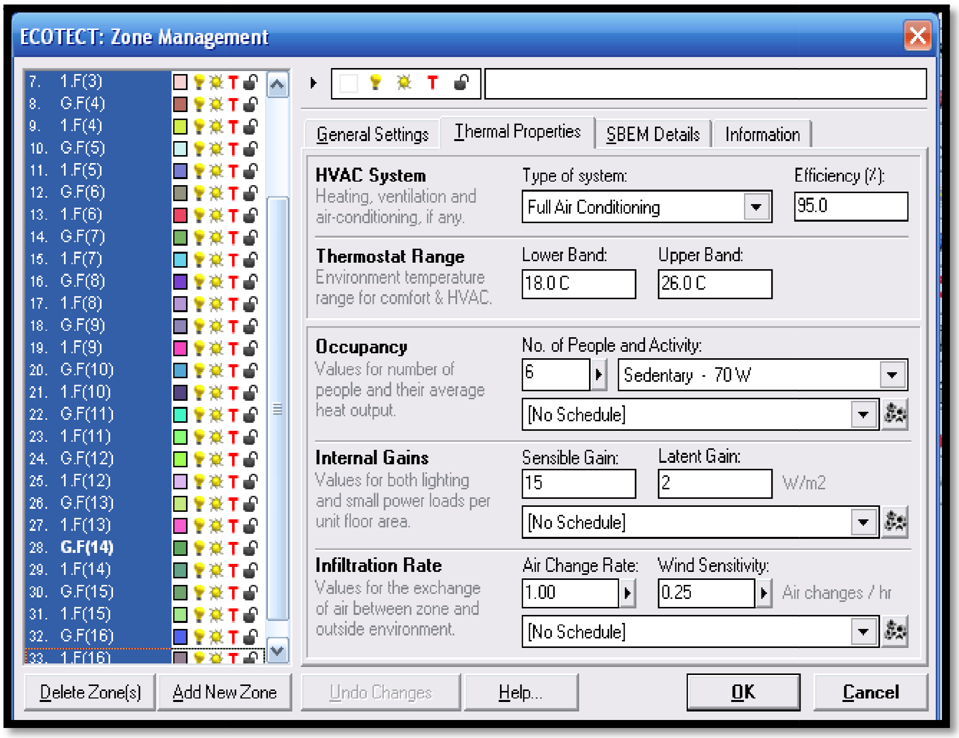

Figure (2): Thermal properties for zones in ECOTECT

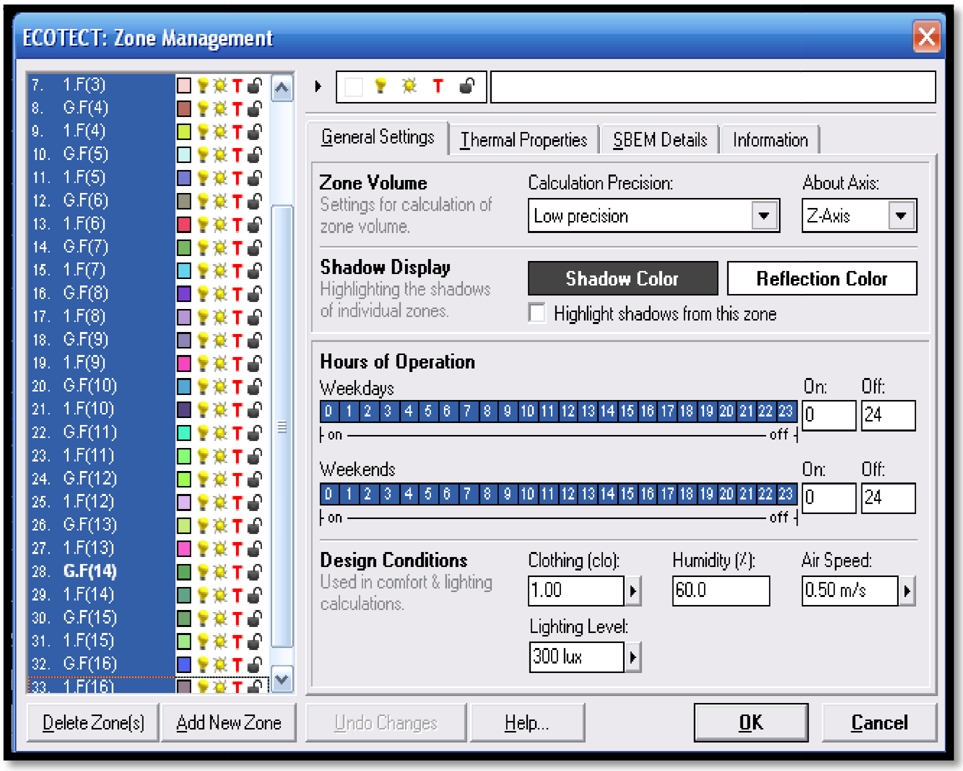

Figure (3): General Settings for Zones in ECOTECT

Materials Assignment in ECOTECT

Walls: U-value= 2.3 W/m² °K and Thermal Lag= 7.4 hrs, see figures (4) and (5).

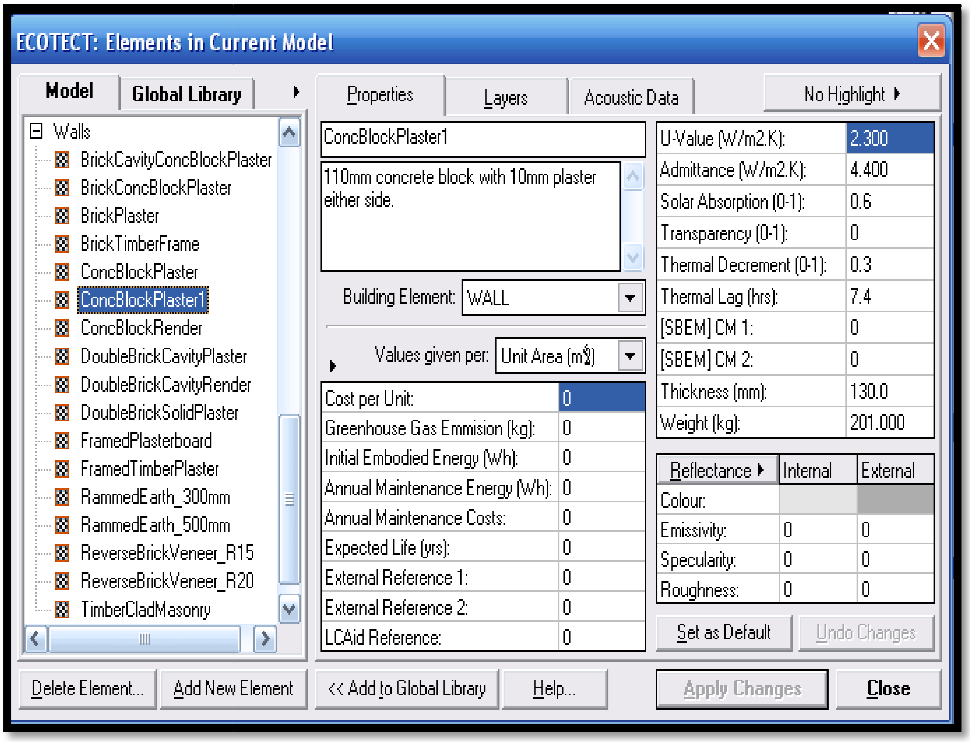

Figure (4): Properties of walls material in ECOTECT

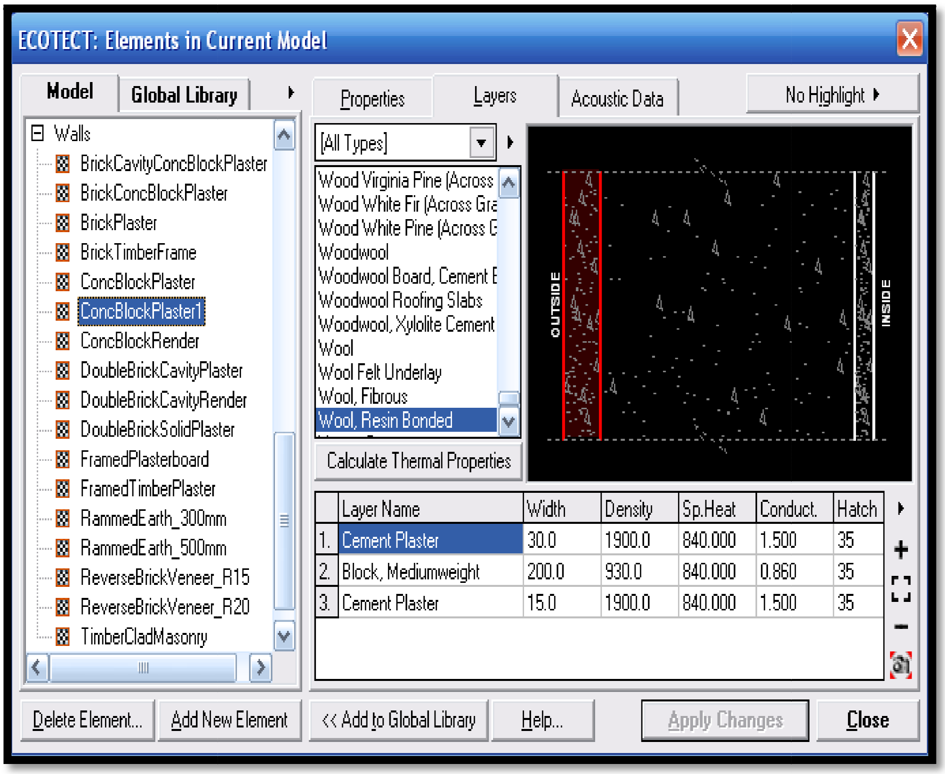

Figure (5): Layers of walls material in ECOTECT

Ceiling: Suspended Concrete Ceiling1 with U-value= 2.6 W/m² °K and Thermal Lag= 6.8 hrs, see figure (6) and figure (7).

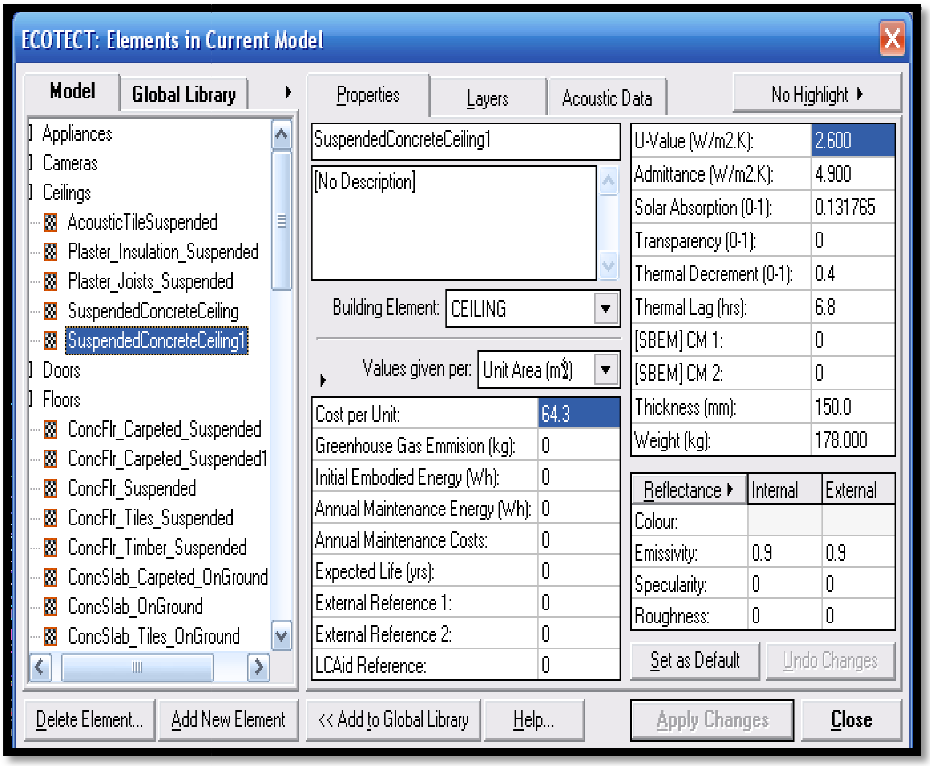

Figure (6): Properties of ceiling material in ECOTECT

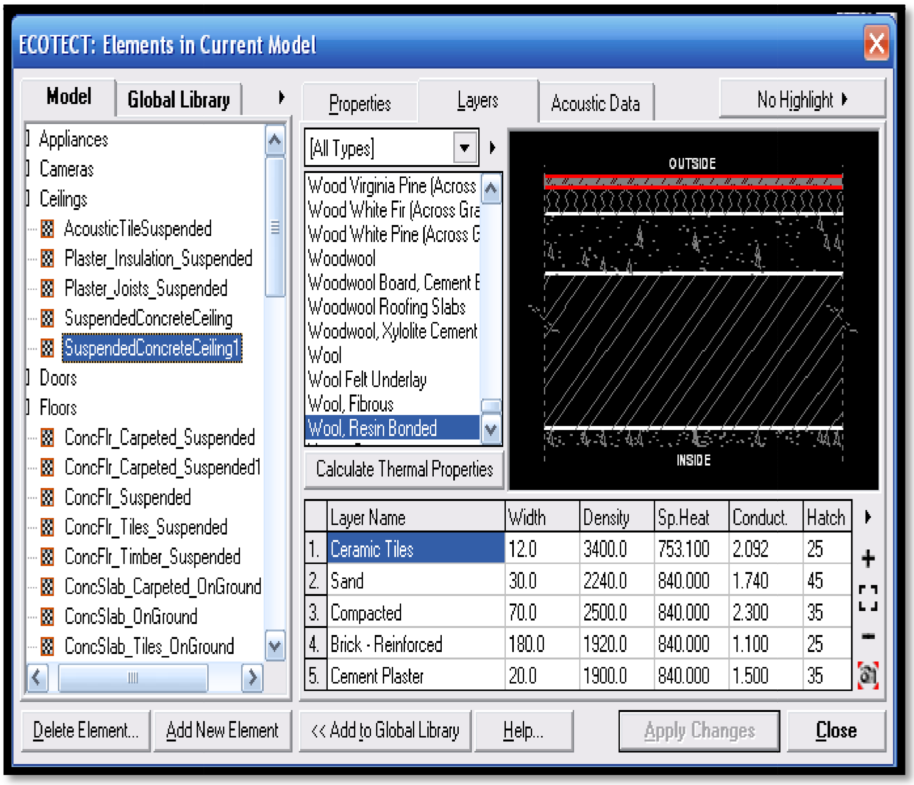

Figure (7): Layers of ceiling material in ECOTECT

Floor: ConcFlr_Carpeted_Suspended1 with U-value= 2.5 W/m² °K , see figure (8) and (9).

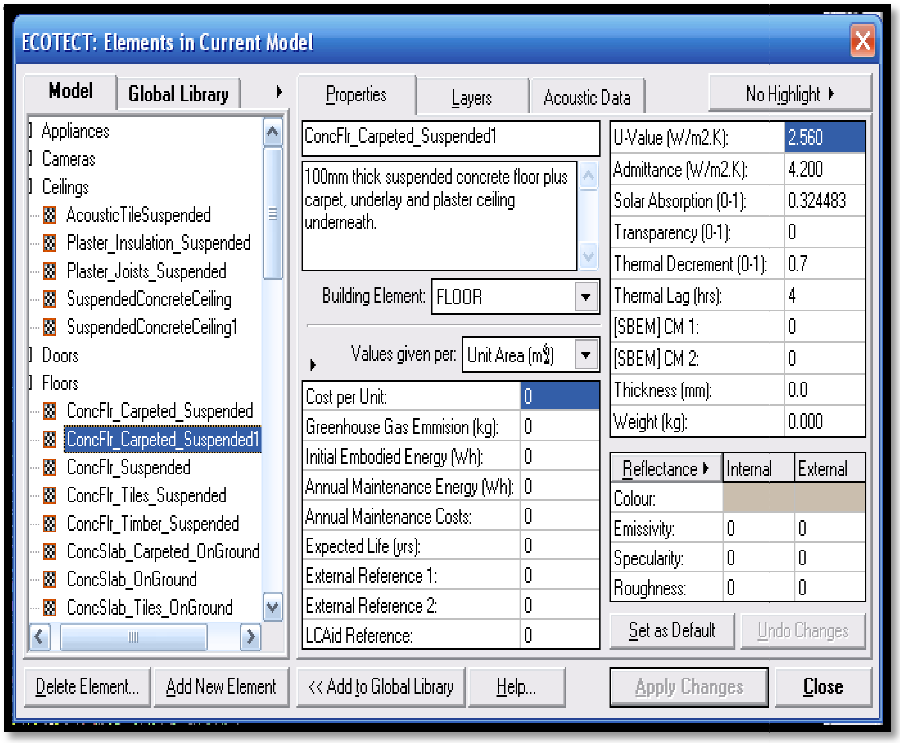

Figure (8): Properties of floor material in ECOTECT

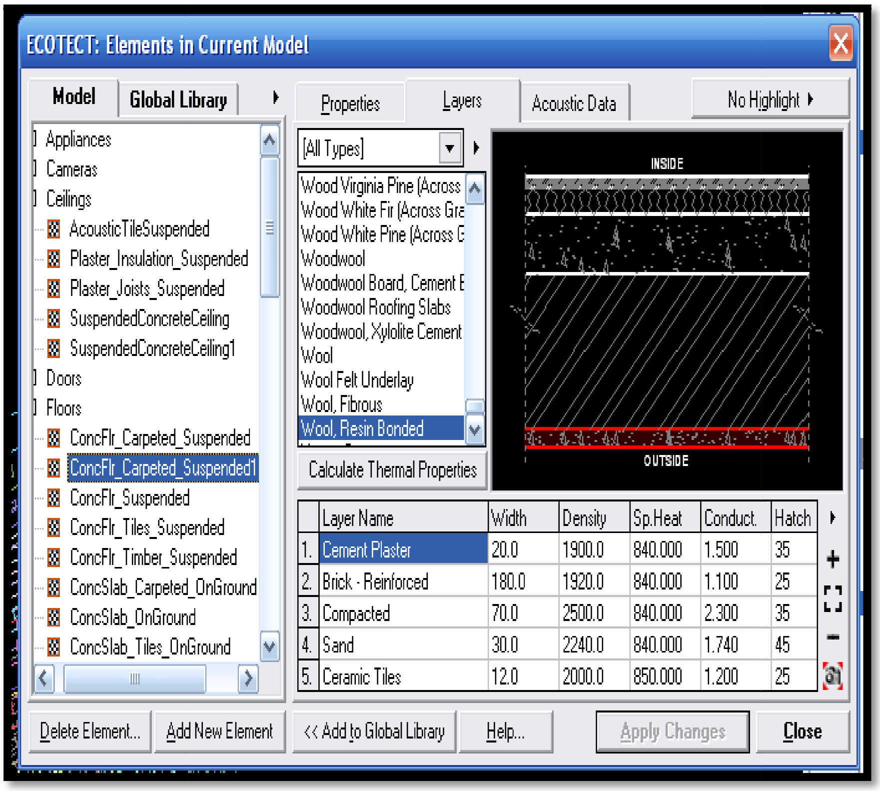

Figure (9): Layers of floor material in ECOTECT

Glass: Single Glazed with Aluminum Frame with U-value= 5.5 W/m² °K , see figure 10.

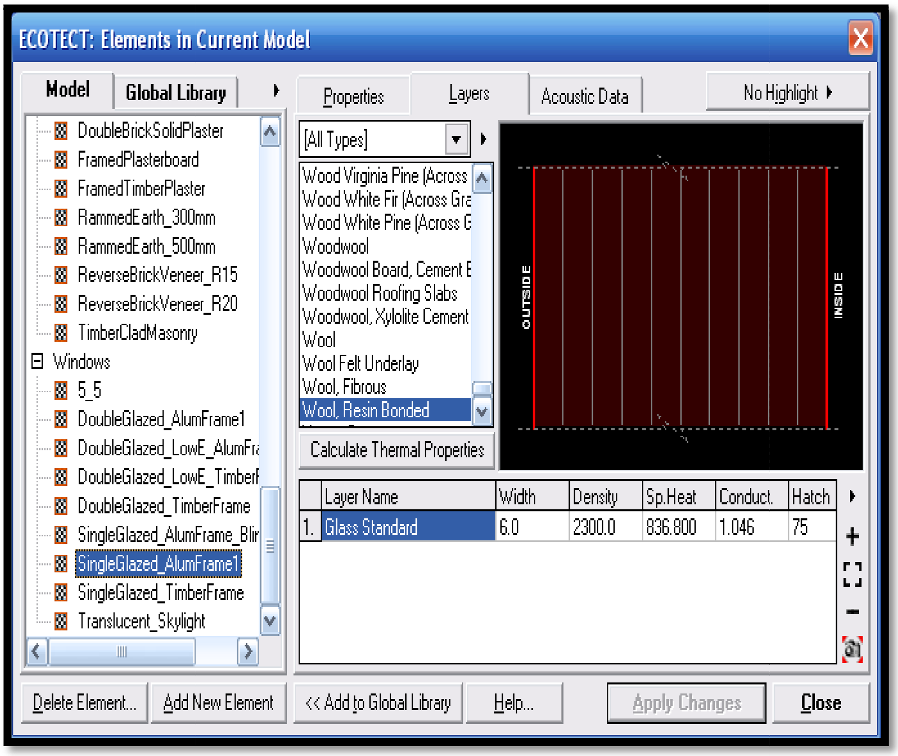

Figure (10): Layers of Glass material in ECOTECT

Design Builder Setting

Location and site data

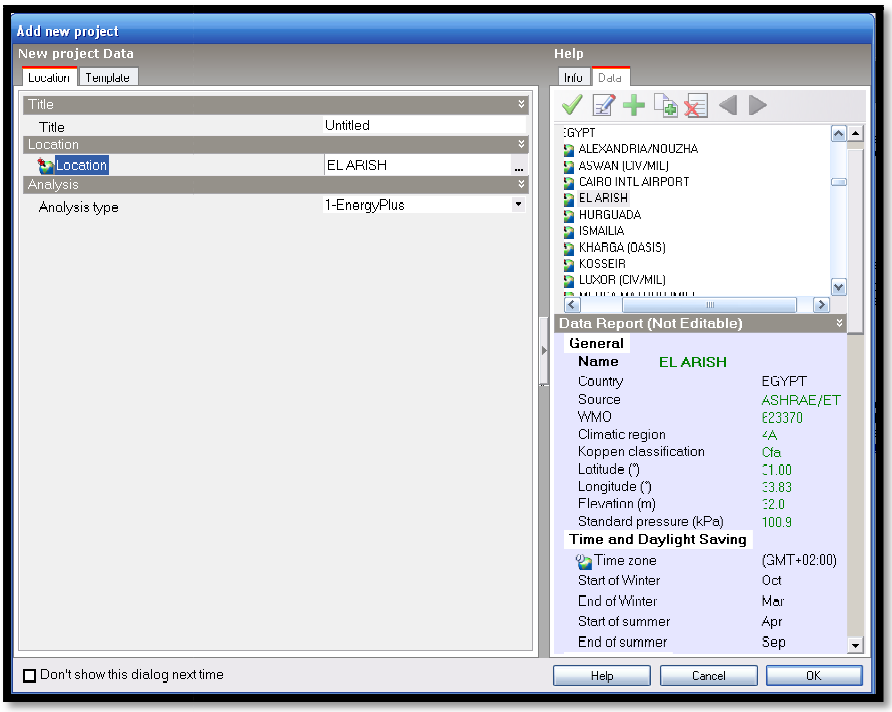

Figure (11): Location and Site Data in Design Builder

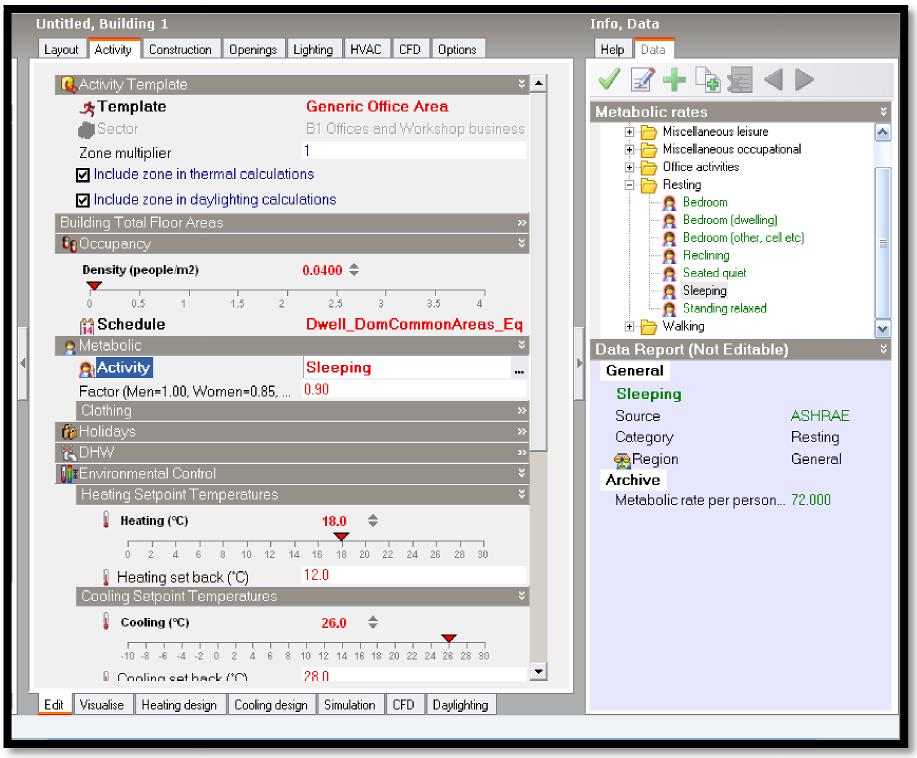

Figure (12): Occupancy and activity in Design Builder

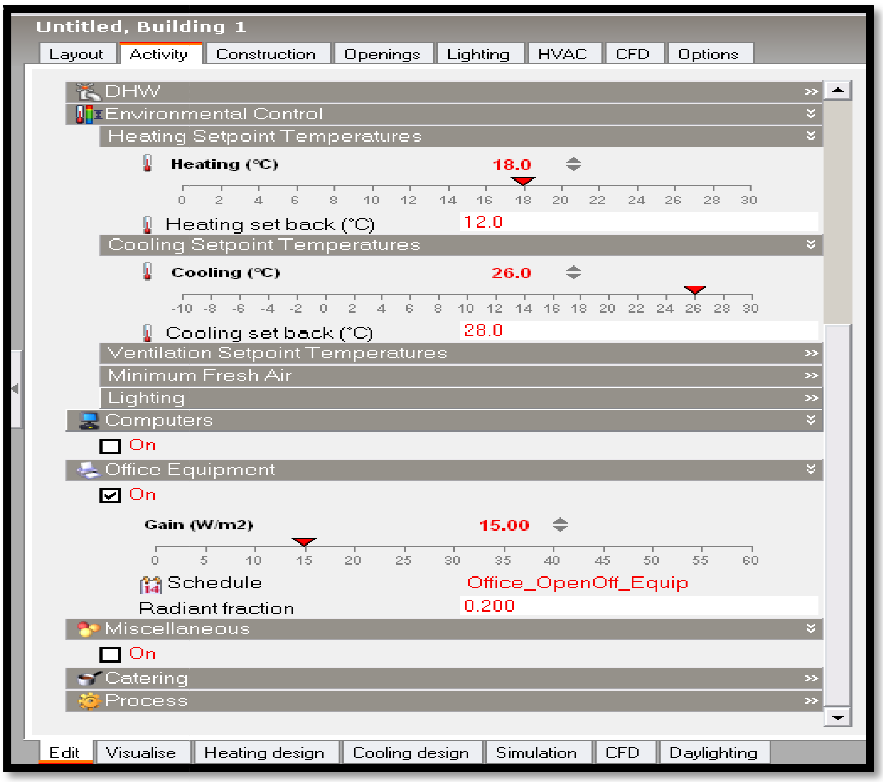

Figure (13): Heating and cooling setpoint temperature in Design Builder

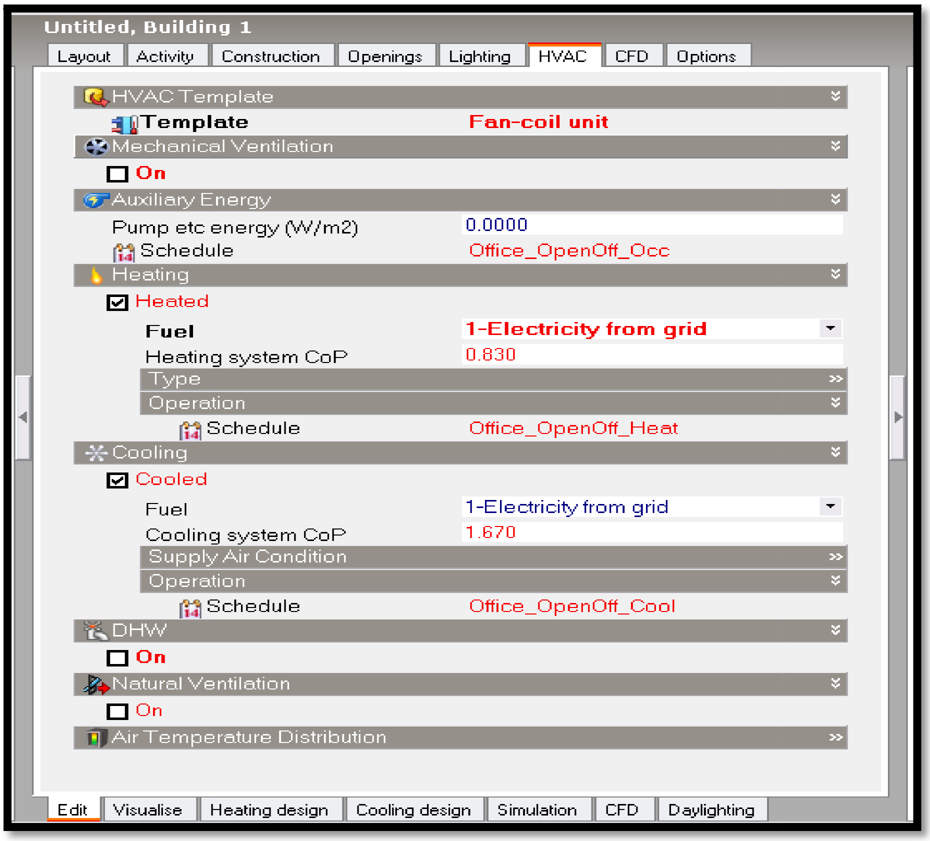

Figure (14): HVAC system in Design Builder

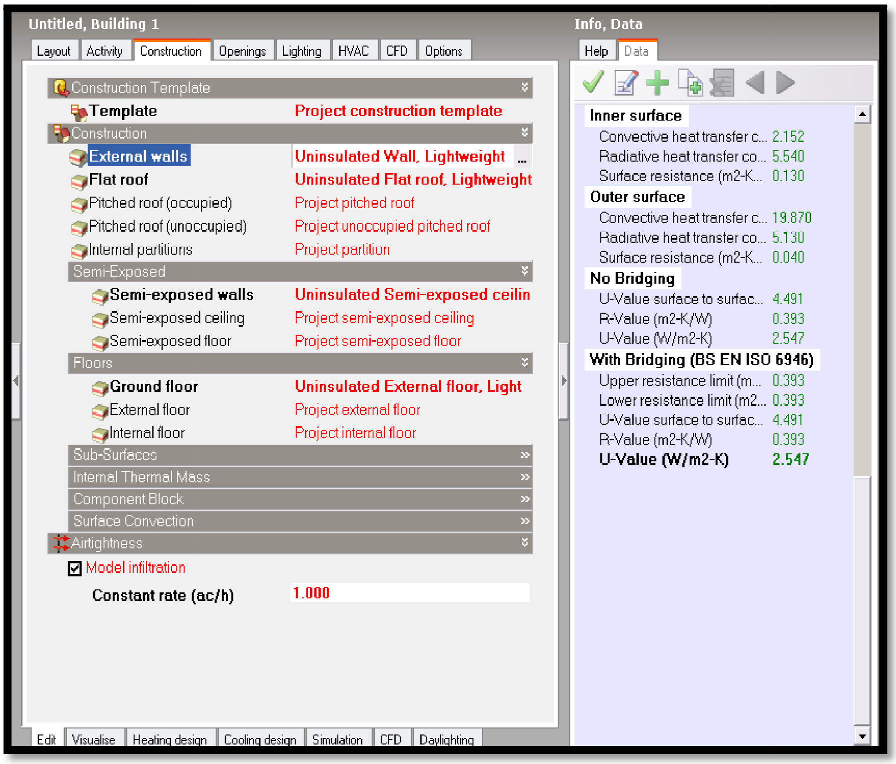

Figure (15): Properties of walls material in Design Builder

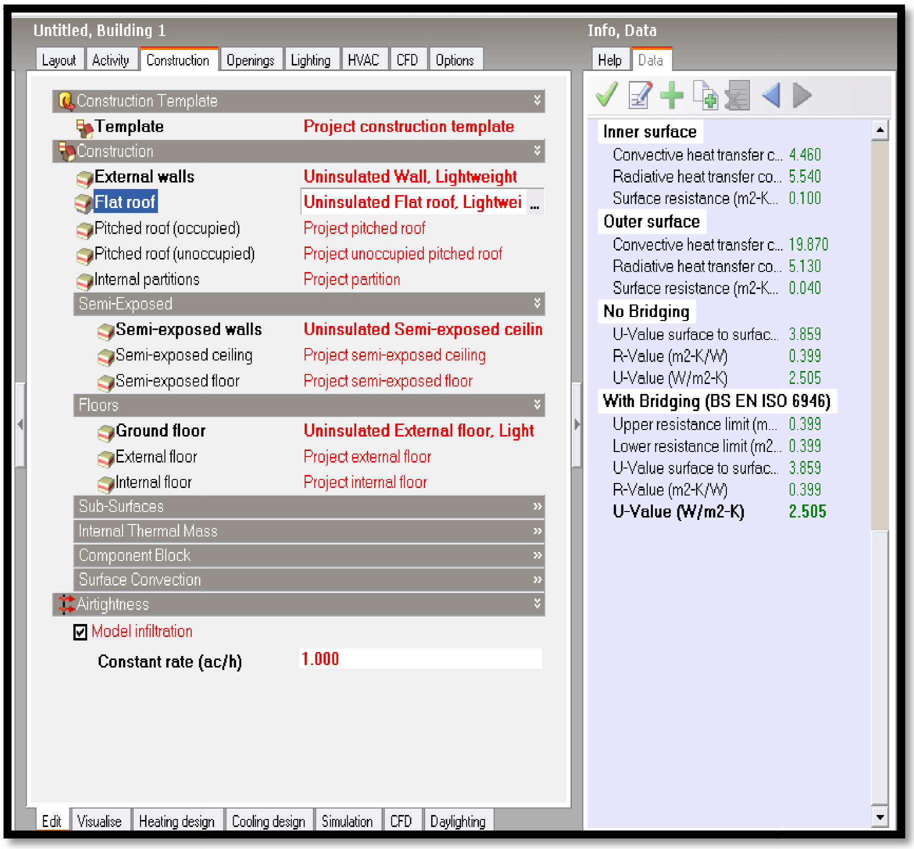

Figure (16): Properties of roof material in Design Builder

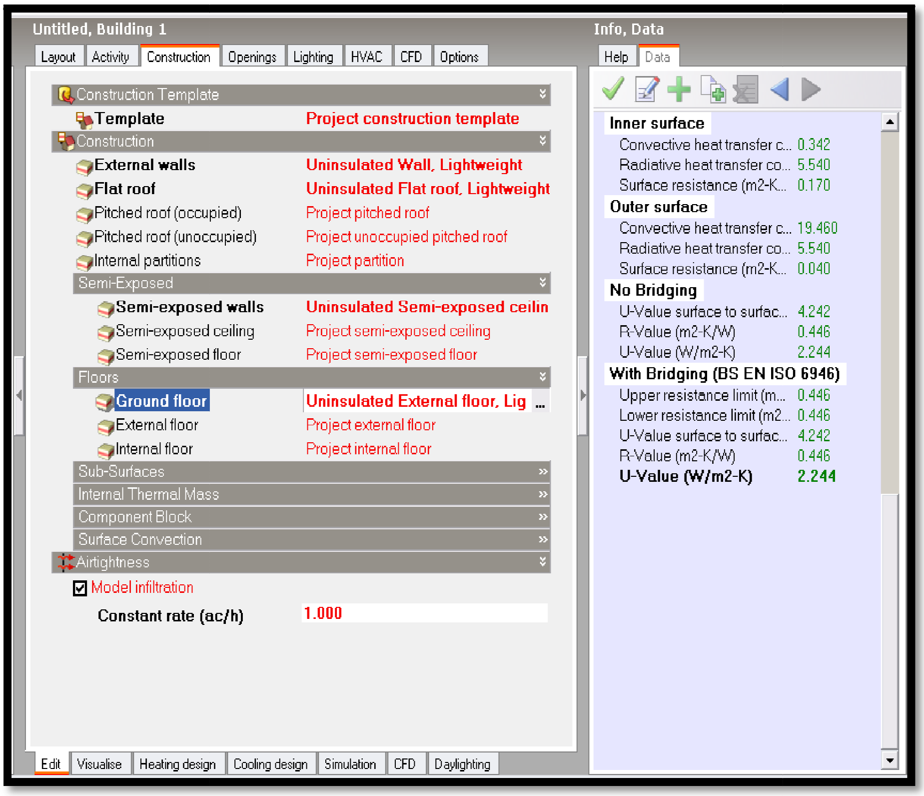

Figure (17): Properties of floor material in Design Builder

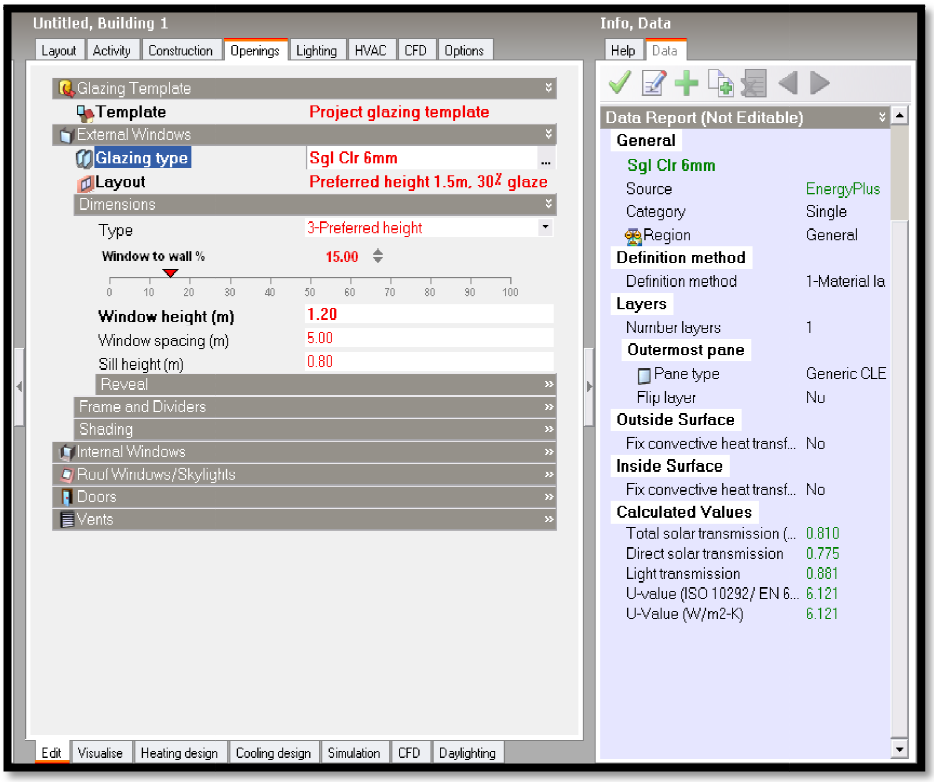

Figure (18): Properties of glass material in Design Builder