THE EFFECT OF THE ROOF AND GLAZING TYPE OF TRADITIONAL COURTYARD HOUSES ON ENERGY EFFICIENCY. A CASE OF ERBIL CITY, IRAQ

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SHAD SHERZAD JAWHAR: THE EFFECT OF THE ROOF AND GLAZING TYPE OF TRADITIONAL COURTYARD HOUSES ON ENERGY EFFICIENCY. A CASE OF ERBIL CITY, IRAQ

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To My Father...

ABSTRACT

Energy efficiency is considered as a significant factor in architectural design, particularly in the modern era which is transforming due to the rapid acceleration of changes that have occurred in modern life.

The main problem of this research can be described as overheating on traditional houses in flat roofs, and the Loss of a vast amount of energy from the windows.

The main research aim is to study the effect of the roof and glazing type of traditional courtyard houses on energy efficiency. In order to achieve the aim, the following objectives were pursued: a) To study the traditional courtyard buildings and their environmental elements. b) To study the context in Iraq generally and the city of Erbil specifically. c) To visit Erbil city and choose a group of traditional courtyard houses for collecting data about roofs and windows. d) To Investigate the effects of solar radiation on the roofs using a computer model for analysing. e) Comparing the existing glazing used with standards and specifications of recent glazing F) To draw out key results and make recommendations.

A group of courtyard houses in the old district of Erbil got for a case study, and in this research used a quantitative method to collect and analyse the data. Also, for analysing the roof used the computer model, after for analysing the different glazing type used the Comparison with standards.

The results of research demonstrated that the average of kilowatts that can be produced by solar panels on the roof of studied traditional houses in Erbil city is 200-kilowatt per one year for one square meter. Another benefit can be got is providing shadow on the roof in addition to protecting the environment by reducing emissions. Furthermore, triple HR glazing has the highest insulation, as it retains internal heat gain and loss about seven times of single glass which is used in traditional houses.

Also, using the solar panel on the top of the roof and exchanging the old type of glazing system in traditional houses could reduce the consumption and provide renewable energy.

Keywords: Energy Efficiency; Traditional Courtyard Houses; Roof and Windows.

ÖZET

Enerji verimi, mimari tasarımda, özellikle de modern yaşamda meydana gelen değişimlerin hızlı ivmesi nedeniyle değişmekte olan modern çağda önemli bir faktör olarak görülmektedir.

Bu araştırmanın başlıca sorunu, geleneksel evlerin düz çatılarındaki aşırı ısınma ve pencerelerden çok miktarda enerji kaybı olarak tanımlanabilir.

Bu araştırmanın başlıca amacı, çatı ve cam tiplerinin geleneksel avlu evlerinde enerji verimi üzerindeki etkisini incelemektir. Bu amaca ulaşmak için aşağıdaki hedefler takip edilmiştir: a) Geleneksel avlulu yapıların ve çevresel unsurlarının incelenmesi b) Özellikle Erbil şehrindeki ve genel olarak Irak'taki durumun incelenmesi c) Erbil şehrini ziyaret etmek ve çatı ve pencereler hakkında veri toplamak için bir grup geleneksel avlu evi seçilmesi d) Analiz için bilgisayar modellemesi kullanarak güneş ışınlarının çatılara etkisinin araştırılması e) Kullanılan mevcut camlar ile yeni camların standartları ve özelliklerinin karşılaştırılması f) Çözüm sonuçları çıkarmak ve tavsiyelerde bulunmak.

Eski Erbil semtindeki bir grup avlu evlerine örnek olay incelemesi yapıldı ve bu araştırmada, verileri toplamak ve analiz etmek için nicel bir yöntem kullanıldı. Ayrıca, bilgisayar modelinde kullanılan çatıyı analiz etmek için, farklı cam türlerinin analizinden sonra standartlarla karşılaştırma kullanıldı.

Araştırma sonuçları, Erbil şehrinde incelenen geleneksel evlerin çatısında güneş panelleri tarafından üretilebilecek kilovat ortalamaları, bir metrekare için her yıl 200 kWh olduğunu göstermiştir. Elde edilebilecek başka bir fayda ise, emisyonları azaltarak çevreyi korumanın yanı sıra çatıda gölge sağlamaktır. Ayrıca, üçlü HR camlar, geleneksel evlerde kullanılan tek camın yaklaşık yedi katı kadar iç ısı kazancı ve kaybını muhafaza ettiği için en yüksek yalıtıma sahiptir.

Çatı üzerinde güneş paneli kullanmak ve geleneksel evlerdeki eski tip cam sistemini değiştirmek, tüketimi azaltabilir ve yenilenebilir enerji sağlayabilir.

Anahtar Kelimeler: Enerji Verimliliği; Geleneksel Avlu Evleri; Çatı ve pencereler.

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INTRODUCTION

This chapter provides a clear introduction to courtyard houses in hot dry zones. Although traditional buildings have the highest level of sustainability, in the modern era, the most essential factor in sustainability is energy efficiency.

The city of Erbil has a hot dry climate and there is an absence of studies about energy efficiency in this area. Also, in Erbil, most traditional houses have a courtyard inside; these houses provide the best solution to environmental problems and the courtyard also offers a higher level of privacy for family life.

1.1. Background

The courtyard house is one of the traditional architectural forms and courtyard buildings transcend regional, historical and cultural boundaries.

In traditional courtyard buildings, the environmental system achieves an optimal balance among construction, ventilation, social and family structures and this design continue to use in architectural works. Sustainability refers to conserving developments for the future by protecting natural resources and conserving energy.

Energy consumption has become an important subject and energy efficiency has been prioritised in recent years. As a result, there has been a universal shift to transform design strategies towards energy consumption in buildings.

Promoting increased awareness regarding environmental architectural design is one of the best solutions for preserving the future of the world. Passive solar structures result in increased requirements in the traditional houses; however, courtyard systems are capable of reducing the cost of the extra heating and cooling way that is used in buildings without sacrificing thermal comfort.

The courtyard house has evolved as the best system, mainly in response to specific climate requirements. Design can create challenges in terms of controlling the temperature, glare and energy consumption for the future.

This research presents the benefits of traditional courtyard houses in hot, dry zones, in general, using the city of Erbil as the specific context. Furthermore, consideration of the environment is important for environmental design.

Elements and materials used in the courtyard houses enable designers to devise the most effective strategies for getting the best environment inside the buildings.

The knowledge of the construction of environmental buildings focuses on the ability to integrate environmental and climatic standards within the design, by considering space characteristics and thermal comfort.

1.2. Problem Statement

From ancient times, people built their houses according to traditional styles and using traditional methods. Many traditional houses have been constructed in Erbil, especially by using the courtyard system. Such schemes allow people to take into account most characteristics of the local climate. However, less attention is given to saving energy and reducing the effects of climate on roofs and windows.

The main problem of this research can be described as overheating on traditional houses in flat roofs, and the Loss of a vast amount of energy from the windows.

1.3. The Aim and Objectives

The main research aim is to study the effect of the roof and glazing type of traditional courtyard houses on energy efficiency. In order to achieve the aim, the following objectives were pursued:

I. To study the traditional courtyard buildings and their environmental elements.

II. To study the context in Iraq generally and the city of Erbil specifically.

III. To visit Erbil city and choose a group of traditional courtyard houses for collecting data about roofs and windows.

IV. To Investigate the effects of solar radiation on the roofs using a computer model for analysing.

V. Comparing the existing glazing used with standards and specifications of recent glazing.

VI. To draw out key results and make recommendations.

1.4. Importance of the Study

Erbil, like many traditional cities, has an ambitious plan for housing production in order to meet in the rapid growth in demand. Nowadays, an increased amount of money is spent on housing in order to achieve increased environmental efficiency. However, there is less study about the positive elements and functions used in traditional houses. The research tries to study the best climate performance of traditional houses through studying, glazing, roofing, and provide renewable energy.

Using the solar panel in the top of the roof and exchanging the old type of glazing system in traditional houses could improve the level of energy used beside the courtyard in traditional buildings. Also, the research tries to fill the knowledge gap regarding the study of roofing and glazing of traditional courtyard houses.

1.5. Methodology

This study adopts a quantitative research approach in order to understand the energy efficiency of the courtyard system in dry-hot zones. The study contains two scientific levels:

- Part one: the literature review will examine the different environment of courtyard houses, the inspiration of international architecture on the sustainability of vernacular architecture from a different perspective, and the efforts devoted to the development of modern buildings in order to make them more sustainable.

Part two: the author travelled to Erbil many times and visited traditional houses in the city for collecting data and making observations in selected houses, taking notes and photos on the process. However, it was difficult to obtain all data about the houses, such as surveying the areas for preparing architectural drawings. For this reason, the author obtained information about the five traditional houses from another researcher, which included architectural drawings shown in Figures 4.3, 4.5, and others.

The collected data and drawings reveal the practical and scientific experiences of courtyard houses; based on this process, suggestions will be made for solar panels and modern glazing, which will maximise the level of energy efficiency in the hot dry zones.

After selecting the group of traditional courtyard houses for the case study, the models were created for analysis using the Autodesk Revit 2018 software, which is used for experimentation, restatement, and parametric analysis. By using the energy model, it can help to understand more clearly the critical energy efficiency measurements. The energy model is useful for researchers for answering questions about more spatial cases, Also, the energy model can be used for scaling for previewing the buildings using depth energy analysis.

The method involves the use of multiple sources and techniques in the data collection process Figure 1.1 and Table 1.1 illustrate the multiple methods used for gathering and analysing the research information and the data required in the case study.

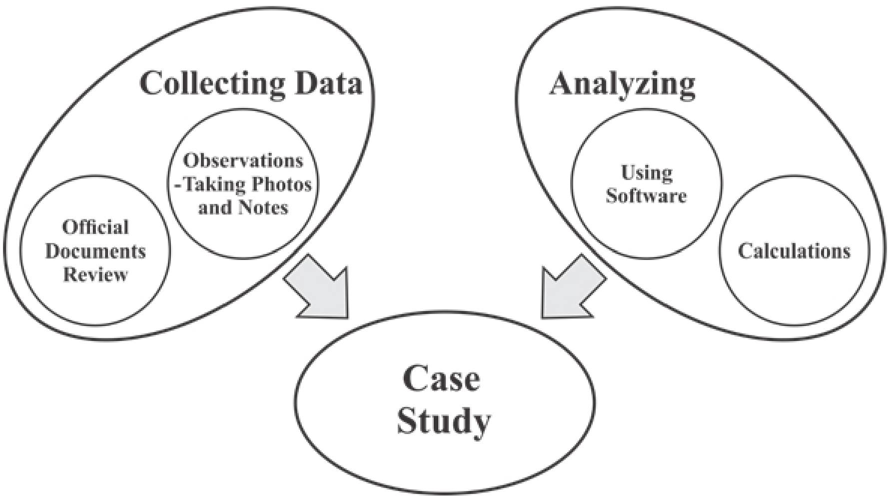


Figure 1.1: Multiple methods for collecting data to study case.

Table 1.1: The Connection of the Research Objectives to the Research Method.

Research objective	Research methods: Literature Review	Observation	Official Document Review and	Software
Study of the traditional courtyard buildings and their environmental elements.	✓			
Study the research context and clarify the effect of the courtyard in hot dry zones.	✓	✓		
visit Erbil citadel after choosing a group of traditional courtyard houses in the buffer zone around the citadel and for collecting data about the type of the different types, measurements and direction of roofs and windows.		✓		
Investigate the effects of solar radiation on the roofs using building information modelling to analyse the solar panels.			✓	✓
Comparing the existing glazing used with new standards and specifications to suggest new solutions.			✓	

1.6. Research Structure

Chapter One started with the introduction, which identified general information about the environment of courtyard houses, the research problems, aims, importance, scope, and methodology frameworks.

Chapter Two assesses the diversity of the concept of courtyard houses, the various disadvantages/criticisms and the design features that impact energy efficiency.

Chapter Three presents the context of the research with a precise definition of the conditions in Erbil, with a focus on the evolution of courtyard houses and the elements used besides courtyard to increase energy efficiency.

Chapter Four presents a study case.

Finally, conclusions and limitations on the theoretical and practical aspects of the research will be presented (Chapter Five).

CHAPTER 2 TRADITIONAL COURTYARD BUILDINGS & THEIR ENVIRONMENTAL ELEMENTS

2.1. Courtyard Buildings

The Oxford Dictionary defines a courtyard as an unroofed area that is entirely or partially enclosed by walls or buildings, typically forming part of a castle or a large house. The Cambridge Dictionary defines a courtyard as an area of flat ground located outside which is either partly or fully by the walls of a building. (Taleghani, Tenpierik, & van den Dobbelsteen, 2012) The courtyard is the best architectural tool for protection and privacy. It is like a dome that has its own self-contained ecosystem. (Taleghani, 2014)

Courtyards can be defined as non-built spaces that are formed by the interior facades of buildings, or those spaces within the interior contours of a plot. (Myneni, 2013)

Throughout the world, traditional houses represent the country's traditions, reflect the traditional forms and values and also are an indication of the culture of the people of that country. They generally have distinct characteristics in terms of design and the materials used. Traditional architecture in Iraq is designed by trained professionals. (Ragette, 2003)

Architects or people who design traditional homes have recognised the need for effective design and planning. According to the specific needs of the era, buildings have been constructed using suitable designs. However, the majority of traditional buildings were by built by labourers and master builders with no architects. (Barnes, 2002)

The continuity of tradition requires planning, design regulations, and guidelines, as well as the development of a code of practice to regulate and control the correct effects, considering new technology with traditional housing functions. (Rasdi, 2005)

Nowadays, architects are currently researching a vast number of traditional buildings in order to make improvements to the energy sources of buildings. In order to mitigate the energy requirement, the design and construction techniques can be developed based on the analysis of traditional buildings to understand the climate response techniques in different climatic zones. Many researchers have investigated traditional climate-responsive structures in their own regions. In order to obtain explicit knowledge in this field, some of the significant results from around the world will be reviewed. (Oliver, 2003)

The courtyard is an ancient system used in the design of houses, and its history dates back more than 5,000 years. Courtyard homes can be found on different continents around the world, such as in North Africa, the Mediterranean, Asia, and Europe, as shown in Figure 2.1. It is possible to distinguish between the courtyard and other transitional spaces such as atriums. For example, an atrium is a large open space within a building that is usually covered by a permanent structure made of glass. Atriums are less preferred in hot areas as they operate like greenhouses that cause more heating, which subsequently has an impact on the cooling power needed for the home. (Taleghani, 2014) Figure 2.1 shows the geographical distribution of houses built around the world.

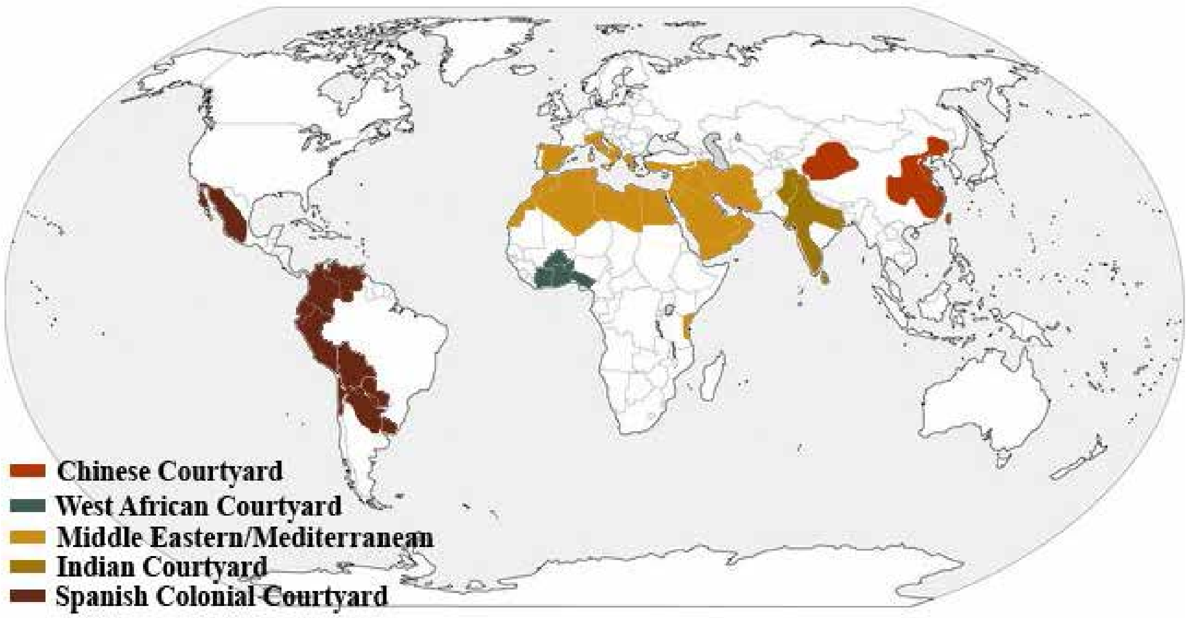


Figure 2.1: Courtyard buildings in different zones around the world. (Taleghani, 2014)

2.2. Different Functions and Types of Courtyard

The courtyard is a characteristic feature of architecture that repeatedly appears in different cultures with different performance. In modern times, design processes use elements of the concepts of courtyard buildings through a series of processes that always contain the central element of traditional courtyard building similar to the original models. Inside traditional houses, the yard is mostly located in the middle area, and the rooms are situated around the yard. It is an influential style function that acts as a dynamic heart for internal spaces in the courtyard and provides a sense of privacy from external disturbances. However, researchers have explored variations on the concept of the courtyard house that extend the courtyard concept (Forés, 2004), in Figure 2.2 shows the different types of the courtyard.

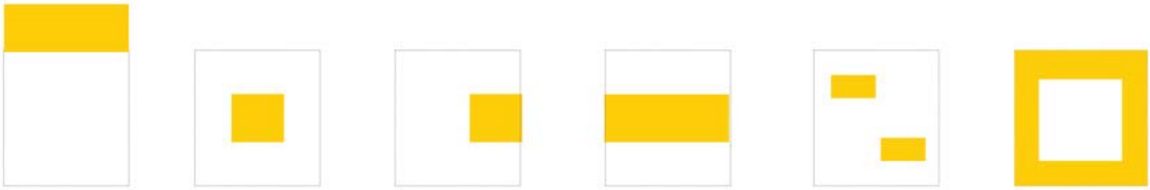


Figure 2.2: Different types of courtyards in buildings. (Forés, 2004)

The courtyard is in the primary element in the design process of Islamic architecture. The origins of the courtyard can be traced to ancient civilisations like the Mesopotamians, whose land was subsequently into Islamic regions. The courtyard is also a significant element of Sumerian architecture. In Islamic architecture, the courtyard is a multi-functional element of the building. It acts as a social space in which the family can gather. (Almamoori, 2018)

The philosophy of the courtyard is that it is an internal meeting space for all users, according to the different function of the building. Many types of Islamic buildings have courtyards for increased privacy and protection, such as houses, schools, mosques, and hospitals (Almamoori, 2018), Figure 2.3 shows the building that created by courtyard system in the ancient Mesopotamian city.

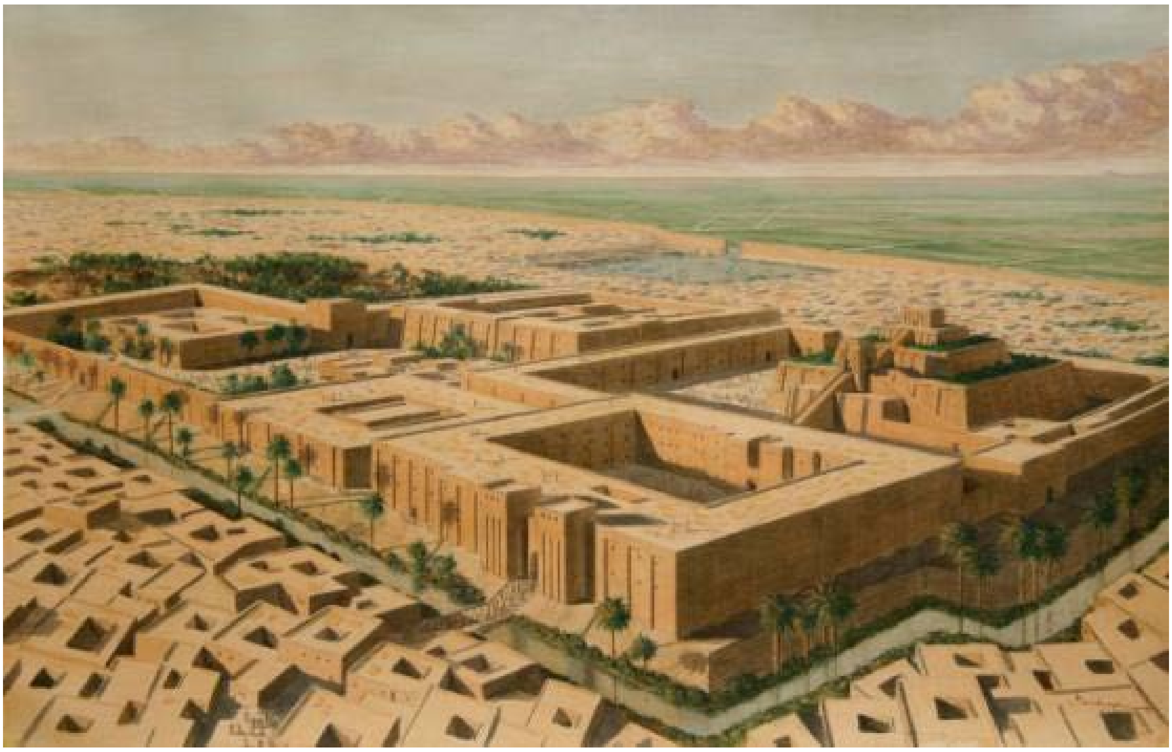


Figure 2.3: Ancient courtyard buildings in a Mesopotamian city. (Almamoori, 2018)

Building design in Islamic culture is directly connected with the beliefs of Islam. The principles of modesty, hospitality, and privacy are the guiding elements of the religion and these principles not only have a significant impact on home design but also for the organisation and usage of space for social interaction within each home. (Almamoori, 2018)

Although they are commonly used for increasing privacy, courtyard houses are designed for providing hospitality in the Muslim home. People in different countries are affected by different cultural factors in their respective countries. All factors help to improve building design by using the space within the home in various ways. Architects have created designs that adequately meet the needs of residents over the centuries (Othman, Aird, & Buys, 2015), Figure 2.4 shows the level of privacy with a courtyard system in the traditional Muslim houses.

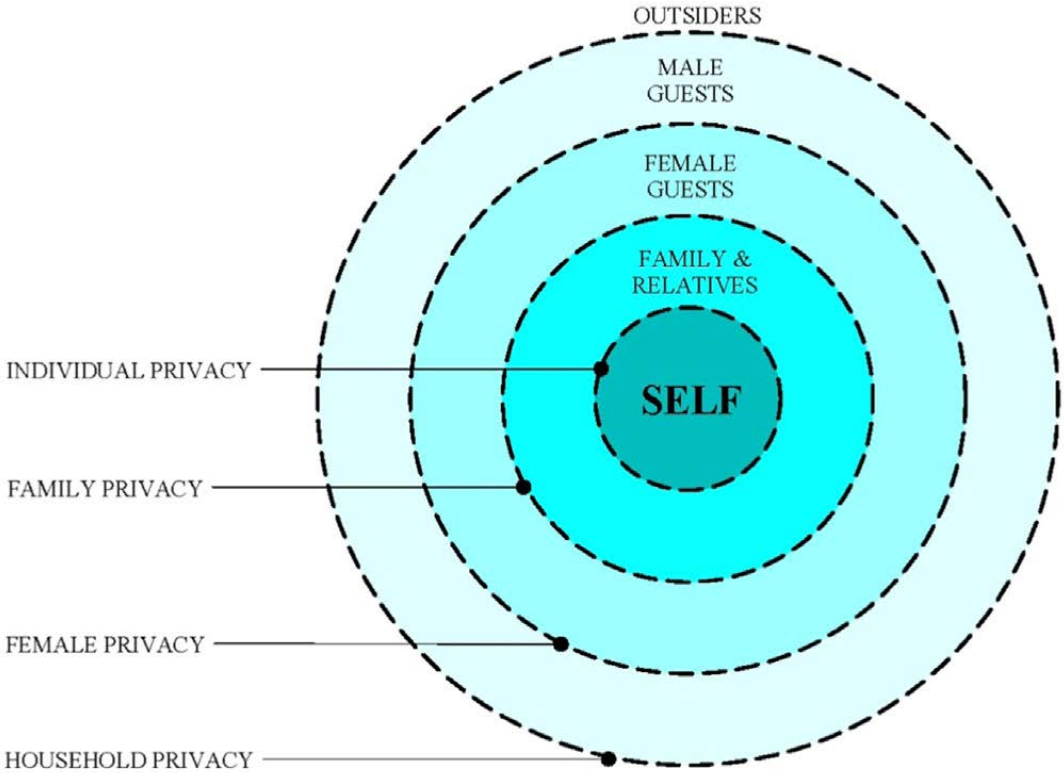


Figure 2.4: The level of privacy in the traditional Muslim house. (Othman et al., 2015)

2.3. Energy Efficiency of the Built Environment

People and governments around the world are becoming increasingly concerned about the problem of global warming and how to reduce the carbon emissions that are causing the rising temperatures the increased energy usage in daily life and the continually increasing global oil prices have led to the necessity to devise methods of improving energy efficiency inside buildings. Climate change strategies are being devised to promote an internal environment that serves the earth and the human population. (Givoni, 1994)

In the light of this growing problem, construction and materials are seen as a significant contributor to the increased energy consumption, which is impacting the future of humans and the global climate. It is expected that the level of energy consumption will continue to increase, thus leading to higher temperatures in the coming years. (Yan-ping, Yong, & Chang-bin, 2009)

Around the world, people are experiencing improved living conditions and there has been rapid urbanisation. Consequently, there has been a significant increase in the amount of energy used by appliances like air conditioners and thinking about converting the buildings to environmental. Buildings in the UK account for half the energy used, compared with 36% in America and 41% in Europe. Energy efficiency is an important aspect of urban life and the built environment and it is reducing and presenting more challenges due to the changing world climate, broader environmental issues, and resource constraints. (Steemers, 2003) Today, most of the design of most buildings do not consider natural ecological control. With modern materials and technology, the structures of the current architectural style lead to high energy consumption due to the desire to provide thermal comfort to the occupants inside. Designing without giving adequate consideration to the suitable design for building a form with orientation and insulation can subsequently lead to significant increases in heat gains and the energy consumption. Several specific issues related to the problem are analysed in adjacent zones such as courtyards or patios. For example, courtyards can provide a pleasant outdoor environment and can also improve internal thermal conditions through natural means. Courtyard buildings provide improved climatic conditions and can upgrade the indoor air quality due to the insulation properties of the walls; furthermore, the use of a shading device can reduce air temperature. (Givoni, 1994)

2.4. Changing Seasonal in Hot Dry Areas

On average, climate conditions are changing in hot, dry climates and the environment has a direct effect on people's lifestyles, particularly in urban areas; consequently, through a process of trial and error, traditional houses have frequently been designed with courtyards as an effective system of combatting the adverse effects of transforming climatic conditions. Local engineers have developed environmental designs such as courtyards, which enables people to adapt their lifestyle in accordance with the particular season. Experiments to achieve the desired thermal environmental have been conducted using mechanical devices; the architectural design concepts of form, building plans, shapes, facades, heights and, sections along with other details have expanded to make them compatible with the environment. (Al-Azzawi, 1996)

2.5. Natural Ventilation and Thermal Comfort in Hot Dry Zones.

The presence of an internal courtyard, particularly in older buildings, can provide better sustainable and comfortable temperatures due to the use of flowered basins, trees, fountains, water surfaces and the moderate natural air ventilation in the summer nights. Therefore, many researchers around the world, especially those in hot, dry regions, have increasingly studied passive control methods in traditional buildings. (Ahmad, Khetrish, & Abughres, 1985)

The courtyard ventilation functions changing during three different times:

First: the cool air in the night time moving into the courtyard and the surrounding rooms., floors Walls, columns, ceilings, roofs, even furniture are cooled at night and remain so late afternoon. In addition, the courtyard loses heat quickly by radiation to the clear night sky: it is used often for sleeping during the summer time.

Second: in the middle time of the day, the sun directly attacks the courtyard. A part of the cool air moves to rise and also leaks out of the surrounding rooms this induces convection rents currents which may afford further comfort.

The courtyard now begins to act as a chimney during this time when the outside temperatures are highest. The thick adobe walls and roof do not permit the external heat to immediately penetrate to the interior the time delay for this wall thickness is as much as 12 hours.

Third: the courtyard floor and the inside of the house get warmer and further convection currents are set up by late afternoon most of the cool air trapped within the rooms spill out by sunset. During the afternoon, the courtyard, building, and street are further protected by adjacent structures. As the sun sets in the desert, the air temperature rapidly flies to the courtyard, completing the cycle, Figure 2.5 shows the various types of natural ventilation inside the courtyard house. (Moore, 1993)

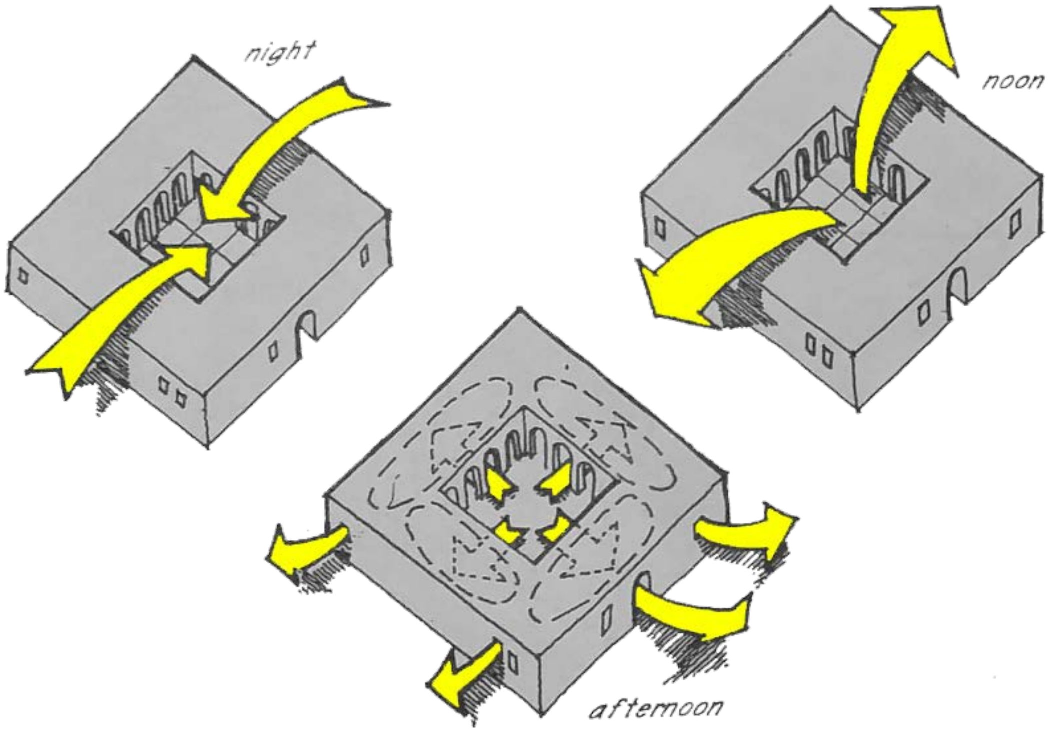


Figure 2.5: The air movement inside the courtyard at different times. (Moore, 1993)

Many researchers have compared the traditional courtyard houses with modern houses in new urban development in terms of the effect of hot and dry seasons. Research has shown that the courtyard system changes the natural ventilation. Environmental factors are affecting the fabric of urban areas and highlights the need for effective planning at modern or traditional urban fabric in hot, dry zones. (Mousli & Semprini, 2016)

The combination of adequate window openings and the building's thermal mass increases the efficiency of the ventilation technique and increases the thermal comfort. Many studies have investigated traditional buildings in the hot-arid regions and have revealed the significant potential for the adaptation of the occupant's habits with the severe climate and weather conditions during all seasons. The courtyard is able to create an effective balance between the indoor and outdoor areas; furthermore, the temperature control and ventilation provided by the courtyard system enable the interior to be cool in the summer. The courtyard system helps the designers to select the proper thermal capacity for the building, and researchers have identified future opportunities to improve energy efficiency. (Mousli & Semprini, 2016)

2.6. The Effect of Roof Covering for Courtyard Buildings

As a result of the combined effect of air temperature, humidity and the lack of air movement, this can have an impact on comfort limits; therefore, passive modification of the indoor air temperature through the design of the buildings is an approach that conserves energy by minimizing cooling and heating loads and improves indoor thermal comfort inside the buildings. (Rajapaksha & Hyde, 2002)

The best solution is to achieve internal thermal comfort by designing with positive methods. In severe climates characterized by cold, dry winters and hot summer, mixed responses are observed throughout the year. The architectural design tries to find a solution to all the building problems by using natural resources such as the wind and by preventing solar radiation at different times of the year. More strategies have emerged that adopting designs that favour full enclosure to benefit from a solar gain in the winter. strategies used for climate modification in buildings in moderate climates can be interpreted and applied in courtyard buildings. (Rajapaksha & Hyde, 2002)

One approach to enhancing comfort within homes is to ensure adequate adjustment of indoor air temperatures by effectively designing the buildings. Reducing indoor air temperature below ambient levels in the summer may reduce the sense of thermal discomfort caused by the combined effect of high temperatures and relative humidity. Also, when ambient temperatures are lower than comfort levels in the winter, elevated indoor air temperatures may promote internal thermal comfort. Consequently, the formation of the courtyard in the building can alter the internal thermal environment, but it requires specific conditions and design details and treatment of design variables. (Hyde, 2013)

Further studies have been conducted regarding thermal behaviour in the courtyards of hot, dry regions, and it has been suggested that shading and ventilation within the courtyard can offset increases in air temperature. (Meir, Pearlmutter, & Etzion, 1995)

A high thermal mass, aided by shading and nocturnal ventilation, can provide a surface that can act as a heat regulator with a large surface area and ample depth. A field investigation on the behaviour of indoor air temperature examined the effect off airflow access points in a partly roofed courtyard building on the passive modification of indoor air temperature for thermal comfort in a moderate climate. (Rajapaksha & Hyde, 2002)

The use of courtyards for climate modification in moderate environments is a challenging task. Some studies have suggested the potential for using courtyards for passive cooling and passive heating in mild climates. However, the use of courtyards for climate modification requires a greater understanding of architectural design regarding the layout and local characteristics for manipulating daytime and nocturnal ventilation during summer as well as solar gain in winter. (Rajapaksha & Hyde, 2002)

2.7. The Effect of Courtyard Buildings Like a Bioclimatic Form

Courtyard housing is offered in geographically, climatically and culturally different areas around the world; consequently, there is a diverse volume of literature on this subject in the fields of architecture and urban planning. (Taleghani, 2014)

Many discussions and academic research have concentrated on courtyards as urban forms that react to the changing climate. For instance, found that courtyards with introversion satisfied different functions for hot, dry zones. (Fathy, 1986) Courtyards create an open protected area that is effective at providing cooling in a natural way. (Bahadori, 1978)

It also protects the building from dusty and sandy winds, while reducing the effects of solar radiation. Based on the literature, the courtyard appears to be the most active object for many architectural fields. Persons residing in severe desert climates attempt shading through orienting and adequately narrowing the street, and evading the hot winds by making the roads winding with closed vistas. (Taleghani, 2014)

However, conflicting and different claims about the environmental properties of courtyards exist, such as discussions about vernacular architecture throughout Norway, Sweden and Switzerland and claims that courtyards have the ability to make ‘pockets of solar gain, this balancing the harshness of cold northern climates. Therefore, it is apparent that the courtyard can act as a sun protector or a sun collector. (Mänty & Pressman, 1988)

Many of the climatic properties of courtyard spaces depend on their proportions, so either of these declarations might be acceptable and reasonable based on the given circumstances. Another problem is that the claims found in the architectural literature remain unsubstantiated, as they are largely based on qualitative observation and common sense. (Taleghani, 2014)

2.8. Main Elements Around the Courtyard

A design incorporating a courtyard provides the best effect according to a comprehensive understanding of the influencing elements and factors. The courtyard is the best environmental strategy and it has the best relationship with thermal performance. It is based on integrated strategies: Maintaining natural ventilation and protecting the buildings from direct solar radiation. In the summertime, the goal is to increase the shading level to reduce the heat gain and to subsequently decrease the temperature. During the winter time, the goal is to raise the heat gain. (Al-Hafith, Satish, Bradbury, & de Wilde, 2017)

Natural ventilation helps to reduce the impact of hot weather by allowing the hot and cold air to flow, thus providing cooling to the building. Partially adequate ventilation is an approach based on pressure differentials between a shaded system with the sun for moving the air. During the day buildings are protected from solar radiation; according to the different time of day, the courtyard system performs different functions. For example, in the daytime, it absorbs the heat from the solar radiation has it hits the surfaces. However, at night, the surface releases the stored energy, thus changing the atmosphere of the house. The natural ventilation is moved by the pressure change between the tropical yard, the surrounding spaces and the cold exterior. (Al-Hafith et al., 2017)

In the hot, dry zones, houses with courtyards consistently provide the best natural ventilation with fresh air. This mechanism helps to reduce the temperature of the entire building at night when it is not able to extract energy from the sunlight. Also, the figure below shows some elements used around courtyards in traditional houses. These elements include wind catchers, plants built-in urban fabric, thick walls, among others. All elements work to achieve the optimal level of energy efficiency, Figure 2.6 shows the different environmental elements that used beside the traditional courtyard. (Al Jawadi, 2011)

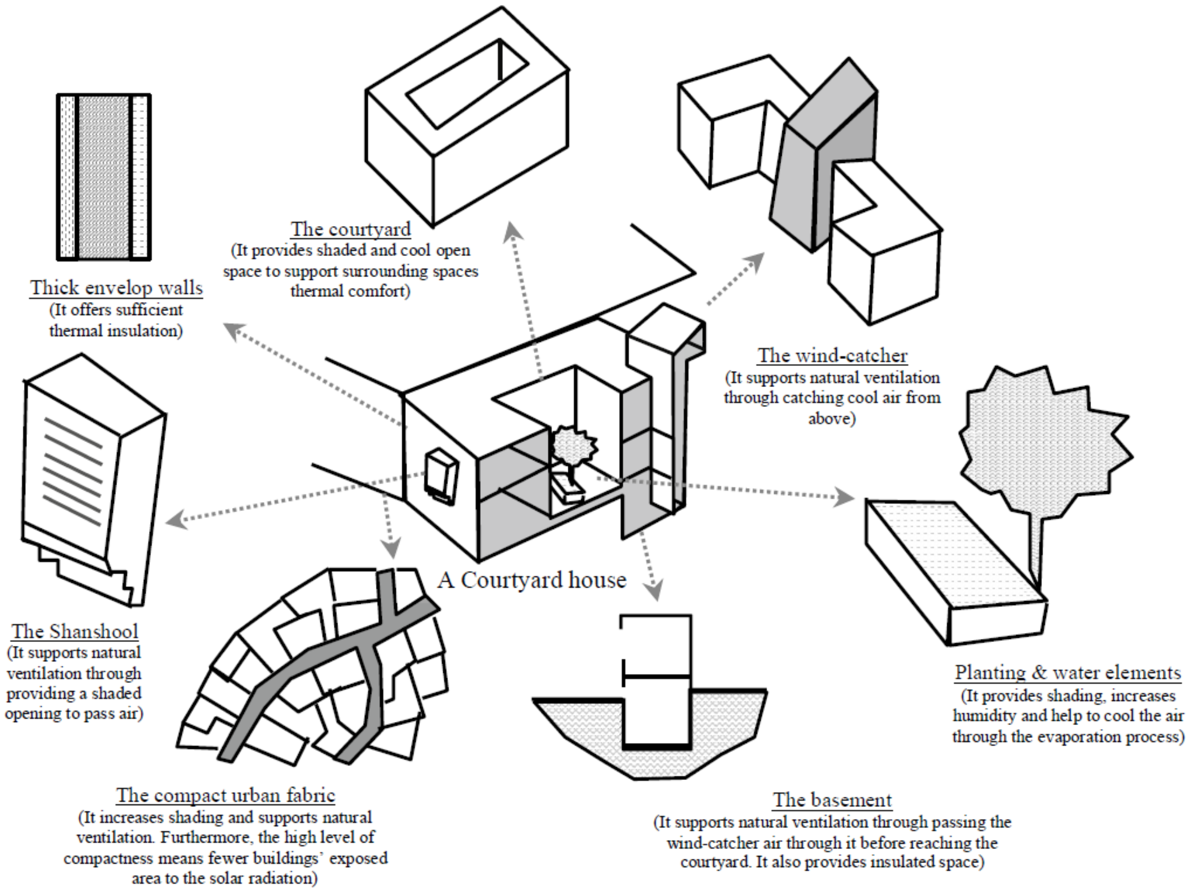


Figure 2.6: The courtyard and environmental elements. (Al-Hafith et al., 2017)

Each component displayed in Figure 2.6 has different parameters which have an effect on the thermal conditions inside the traditional courtyard buildings. With these essential factors, the influential issues are the geometry of courtyard and the orientation of the building, the mass volume to the exterior zone, the interior area, proportions, size of the openings, the building location and the urban pattern. (El-deep, El-Zafarany, & Sheriff, 2012), Table 2.1 shows the main effective factors on courtyard buildings' performance.

Table 2.1: Main Affective Factors on Courtyard Performance. (Al-Hafith et al., 2017)

Buildings elements or features	The effective parameters	The direct impact
The courtyard	Geometrical properties (Width, length and height) Orientation (the orientation of the courtyard long axis)	Heat gain and natural ventilation
The internal spaces	Size and location of open spaces	Natural ventilation
The wind - catcher	Orientation and geometrical properties	Natural ventilation
The building envelope	Envelop thermal mass (construction materials U-value)	Heat gain
The water & planting elements	The ratio of the area of these elements to the courtyard area	Heat gain and natural ventilation and humidity
The building forms	Building volume to external surfaces area	Heat gain
The building urban context	Building adjutancy and urban fabric compactness	Heat gain and natural ventilation

The effects of courtyard design parameters and the shading system can, therefore, have a significant impact on the thermal properties of the courtyard buildings in hot, dry zones. Furthermore, many variables can affect the level of shading in the courtyard:

First: External factors that are linked to the position of the sun in the sky and this situation can vary between different locations and at different times.

Second: The are different variables influenced by internal factors, namely the courtyard proportion and the building's direction. There are two main parameters related to courtyards, namely the sun and the sunrise to provide effective shading; these criteria must be determined considering the efficiency in both summer and winter. (Muhaisen, 2006)

The shading of the courtyard is influenced by its various properties and directions, which all have different degrees of influence. However, as a general rule, in order to achieve a higher level of shading, courtyards are designed with broad and narrow forms. In terms of the relative effect of the courtyard design parameters on shading, the shading of the patio is mostly influenced by the ration of the width of the patio to the height, while the courtyard direction is the least useful factor. (Meir et al., 1995)

2.9. Cooling Courtyard Houses with Shading Concept

The spatial relationship between the inside and outside limits the number of openings inside the walls; thus, when any light penetrates the homes. a connection is made between the inside and outside. The open spaces are covered by a comprehensive ceiling, according to the combination of light and extensive shade, which is an essential aesthetic factor necessary in these buildings. (Al-musaed, Almssad, Harith, Nathir, & Ameer, 2007)

The direct light from the sun can generate heat gain. It creates radiation across all surface. As a result, shading can prevent up to 90 per cent of this temperature increase. The most important problem is the heat of the sun and the direct light, and the radiant heat from the sun passes through the glass and becomes immersed in the different parts and furniture of the house, which is then re-radiated. Radiation radiates at a different wavelength and cannot go outside through the windows as fast. In most climates, radiative heat is restricted to winter heating but should be avoided in summer. Shading of the roof and wall surfaces is necessary to reduce summer heat gain and can be mainly achieved if they are darker in colour and heavyweight. To address this cooling factor, the most important consideration is the direction of the aperture that is shaded. Windows and south-facing heights are easy to cover, because in the summer months when shading is necessary, the sun's angle is high. However, east and west facing windows are significantly more difficult to shade because the sun is much lower in the sky. (Al-musaed et al., 2007)

The existing shading on the house structure or outer spaces is not enough for cooling in the house. Shading can reduce the temperature by between 5-10ºC. Therefore, the solution is to combine cooling systems like evaporative cooling by water or trees and earth inertia cooling, ventilate cooling, etc.; consequently, shading can help to create the optimal level of efficiency with a cooling system. Also, plants can be used for shading the house, particularly around windows, in order to reduce unwanted gain heat and glare. The shading on the top of the roofs surface and walls is essential for reducing summer heat gains. Light or coloured shading devices appear warmer. Internal shading will not prevent heat acquisition unless it is reflected. (Al-musaed et al., 2007)

2.10. The Effect of Shading Device in Courtyard Houses

Humans inside the buildings need energy for the heating and cooling process, and energy costs are continually increasing. The energy required to provide comfortable living conditions within a given area depends on the prevailing weather conditions in that area.

The architectural components like shading devices can work as the primary tool to increase energy efficiency in a building, especially in hot, dry climates. In the summertime, a shading device can protect the windows from extreme solar radiation; while allowing maximum solar radiation in the winter.

Shading is used in different buildings. Different types of shading devices improve the energy performance of buildings, such as exterior shading, interior shading, overhangs, canopies, and curtains. (Eskandari, Saedvandi, & Mahdavinejad, 2017)

One of the best energy saving strategies in buildings is the use of passive solar energy inside the building.

Traditional architecture has provided effective solutions for the optimal use of solar energy. These characteristics can be found in building elements such as Windcatcher and Courtyards as well as in other spaces. Most of them are used for cooling purposes in arid zones. Shading against solar radiation plays a vital role in reducing cooling loads for the buildings. In traditional architecture, the Iwan is recognized as a semi-open room, a traditional style that is used in houses with a unique structure. Investigations have been conducted into the different types in different climatic conditions. (El-Shorbagy, 2010)

In the courtyard houses in hot-dry climatic, although most of the architectural functions are used as individual devices for shading the buildings, the Iwan uses an outer shaded space and is a form integration between vertical and horizontal shading devices. The Iwan also has the best thermal performance because it acts as a large shading device, which focuses more on solar gains through external openings. In addition, the Iwan provides shading for external openings. (Eskandari et al., 2017)

In terms of heating and cooling improvements, the impact on the comfort of building residents is analysed through experimentation and simulation. In ancient times in the traditional houses, Iwan was used correctly, where the geographical direction was clear and it was an effective energy-saving strategy for buildings. Therefore, the optimum depth and geometric shape of Iwans have been explored, and the best geographical direction for the Iwan has been investigated in order to improve energy efficiency. Consequently, in the future, the Iwan can be used by contemporary architects for improving energy efficiency in buildings. (Mohamed, 2010)

2.11. Human Life Requirements for More Energy Efficiency

People around the world dream of living eco-friendly homes, old buildings that were made from natural resources such as wood, stone, and brick. The world now dreams of moving away from industrial sources and is trying to establish economic homes and live clean lives based on renewable energy; thus, homes are being designed in an innovative way that takes nature into account and benefits from their natural resources. (Pacheco-Torgal, Cabeza, Labrincha, & De Magalhaes, 2014)

People are looking for more natural and efficient resources to get natural lighting and heating, using heat insulation materials in construction, lighting and solar heaters. The external facades provide shade, as some depend on organic farming to provide their vegetable needs, and others depend on industrial canopies to reduce water use and give the area an aesthetic appearance. (Morel, Mesbah, Oggero, & Walker, 2001) The houses are eco-friendly, long-term investment, distinctive in design and self-comfort, especially with natural lighting, using an internal courtyard that interacts with sunlight without producing heat, which contributes to reducing electricity consumption, such as fountains that facilitate the evaporation process and increase moisture. Also, these houses have been demonstrated to be friendlier to the environment. (Buys, Barnett, Miller, & Bailey, 2005)

Building designers experience challenges in determining a balanced relationship between windows and the level of energy use in high-rise buildings. Orientation and the location of windows has a significant effect on energy consumption in the building. (Al-Sallal, Al-Rais, & Dalmouk, 2013)

Traditional building regarding the contribution of glazing systems to thermal insulation. The best practice in window incorporates design to improve the light level as well as the thermal insulation properties for traditional and new houses in remote mountain regions. (Huys, 2012)

2.12. Summary

The elements around the courtyard have a positive effect on the environmental level in the traditional buildings have been explained, such as Windcatchers, Basement, insulating wall and others.

Also, this chapter discussed benefits of courtyard building, including the advantages in different seasons, the effect of courtyards on family life, and the bioclimatic courtyard effect in which the heat of the sun is collected during the day and expelled during the night time.

In traditional buildings, some overlooks act like shading devices and the courtyard also functions as the best shading device because it protects more areas inside the buildings from the sun’s rays, especially in the hot dry zones.

Also, This chapter defined the concept of the courtyard and displayed a map of different zones around the world that use courtyard buildings, There are different types and models of courtyards.

To solve the problem of global warming, it is necessary to identify the level of energy used. Consequently, people try to live inside buildings that more sustainable and the courtyard offers the best level of energy efficiency, therefore, the best solution for a more sustainable life.

The literature review demonstrated that some subjects were not studied including the effect of the solar radiation on the flat roof surface, and the heat loss and gain in traditional buildings through the windows area in hot dry zones.

CHAPTER 3
RESEARCH CONTEXT

3.1. Geography, Environment and Traditional Houses in Iraq

3.1.1. The location of Iraq with historical background

Iraq is a country that is located in western Asia and shares borders with Iran, Jordan, Kuwait, Saudi Arabia, Turkey and Syria. (Oluic & Army, 2009) Figure 3.1 shows the Iraq location inside the world map.

Figure 3.1: Location of Iraq on the world map. (Tablet, 2018)

The capital of Iraq is Baghdad, and it is the largest city in Iraq, and it has a total population of 30,399,572 other large cities in Iraq include Mosul, Basra, Irbil, and Kirkuk and the country's population density is 179.6 people per square mile or 69.3 people per square kilometre (Briney, 2017), Figure 3.2 shows Iraq map.

Figure 3.2: Borderline map of Iraq. (Maps, 2018)

Iraq, also known as Mesopotamia, was home to the world's most ancient civilisation, the Sumerian culture. This culture was the first to produce many things, including writing, philosophy, mathematics, cities, beer, the wheel, and the world's early works of literature, the Epic of Gilgamesh. Iraq was also home to the world's first empire, the Akkadian Empire, and its successor states of Babylon and Assyria. Babylon, in particular, is famous for its artistic achievements and scientific advances, in areas such as mathematics, medicine, astronomy, and architecture. (Oppenheim, 2013)

3.1.2. Climatic in Iraq

Iraq has a hot, dry climate characterised by long, hot, dry summers and short, cold winters. The environment is influenced by Iraq's location between the subtropical aridity of the Arabian desert areas and the subtropical humidity of the Persian Gulf. January is the coldest month, with temperatures ranging from 5°C to 10°C, and August is the hottest month with temperatures rising to 50°C and more (A’zami, 2005), Figure 3.3 shows Iraq temperature for each month.

In most of the areas, summers are warm to hot with frequent sunshine, but there is high humidity on the southern coastal areas of the Persian Gulf. Daily temperatures can be scorching; on some days, temperatures can easily reach 50°C or more, particularly in the Iraqi desert areas that have dangerous levels of heat. (Abbood, Al-Obaidi, Awang, & Rahman, 2015)

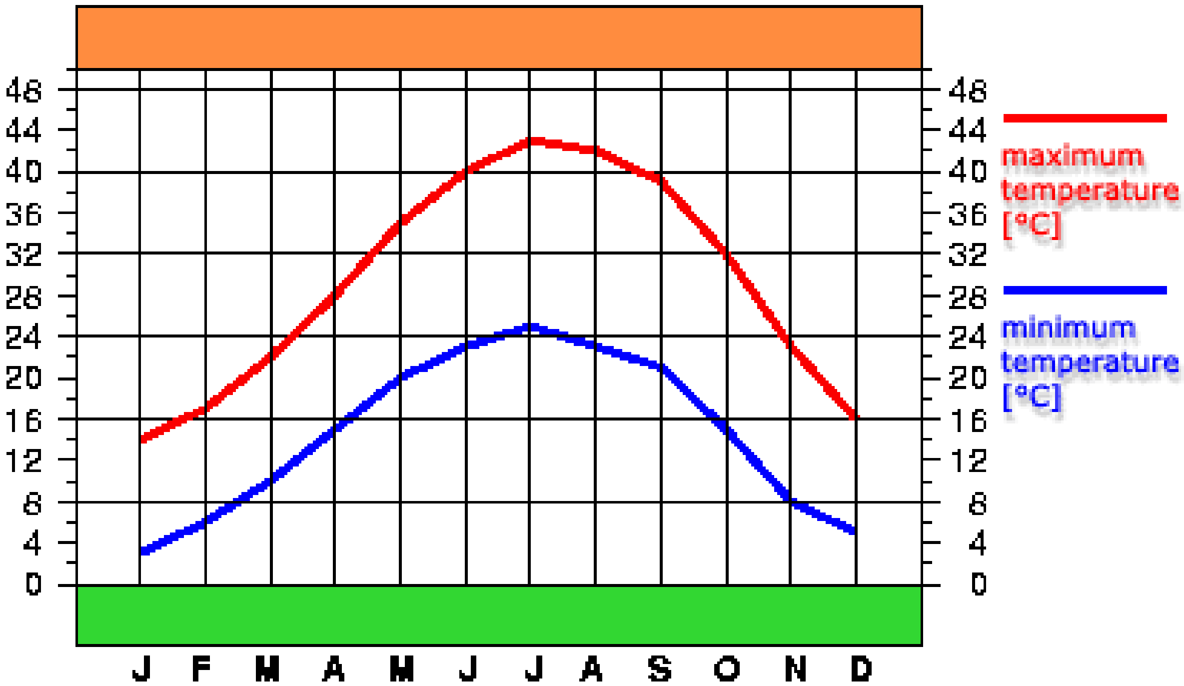


Figure 3.3: Iraq temperature. (Weatheronline, 2018)

Hot, desert winds can sometimes be extreme and can cause exhaustion. About 70 per cent of the average rainfall in the country falls between November and March; June through August often have no rain. Rainfall varies from season to season and from year to year.

Precipitation is sometimes concentrated in local, but violent storms, causing erosion and local flooding, especially in the winter months, Figure 3.4 shows Iraq precipitation for each month. (WWO, 2017)

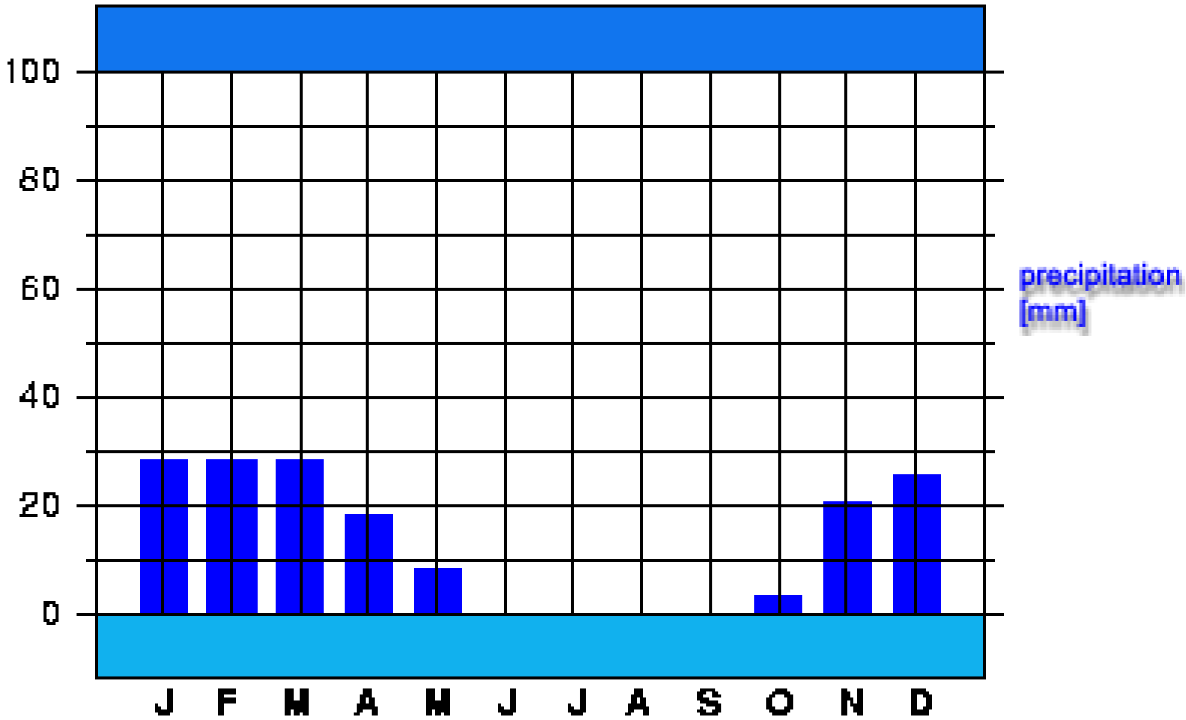


Figure 3.4: Iraq precipitation. (Weatheronline, 2018)

Iraq can be divided into three different climate zones. The climate of the Western and southwestern areas can be classified as hot desert climates: a hot, desert climate with annual average temperatures above 18°C. A small zone between the Persian Gulf and the Turkish Border in the east of Iraq can be classified as hot semi-arid climates, a hot, dry Climate with an annual average temperature above 18°C. Finally, the mountainous regions of northern Iraq can be classified as dry summer continental climates: a cold snowy climate with dry summers and wet winters with the warmest month over 22°C and the coldest month below -3°C (WWO, 2017), Figure 3.5 shows different Temperature degrees in Erbil for each month.

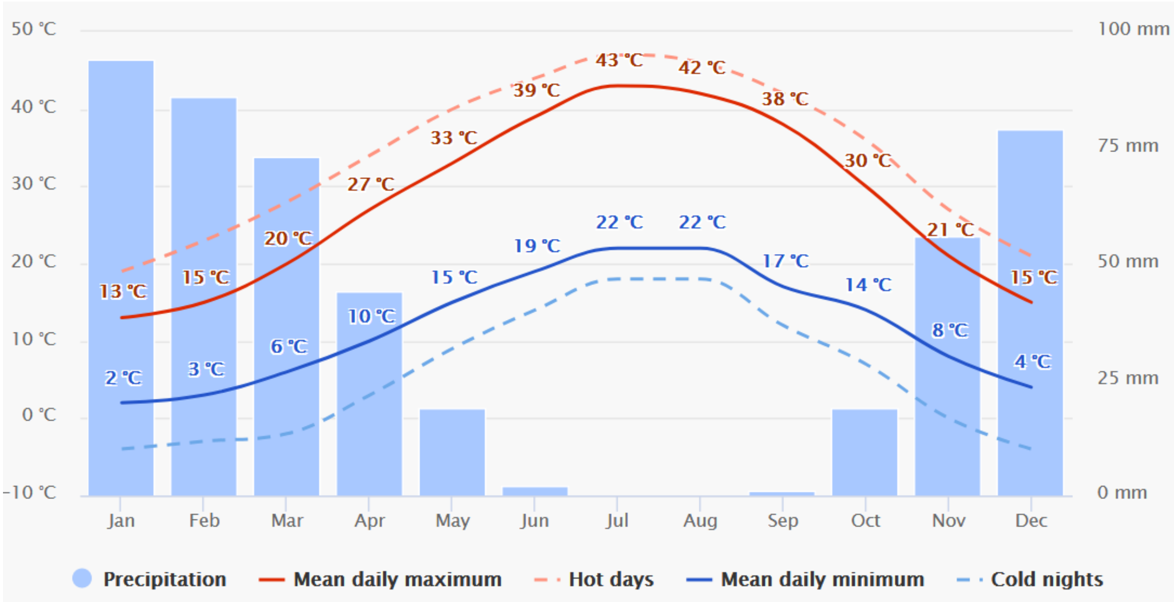


Figure 3.5: Max, min, and the average temperature in Erbil. (Meteoblue, 2018)

3.1.3. Family environment in Iraq

In Iraq, family life changes in the winter and summer seasons and the weather conditions have an impact on daily lifestyle; climatic conditions distinguish the character of the different seasons like winter and summer as well as the transitive season's spring and autumn. Baghdad and other cities in Iraq experience a similar climate. Consequently, residents of these cities find it necessary to adapt their household lifestyle at least twice a year, mainly because of the changing climatic conditions. (Salman, 2017)

First, in the summer and winter, most people give up living outdoors as they are required to live in fully-enclosed rooms that have the best indoor air quality provided by mechanical devices.

Second, in winter, the first process is reflected. This means that at the beginning of the spring and autumn seasons, most people move from the interior of the house to the patio spaces to enjoy the natural climate. Naturally, people like to change their lifestyles at different times, especially in the houses that have a courtyard. (Salman, 2017)

The residents of Baghdad who live in original courtyard houses move from one level to another, and from one room to another looking for the best indoor thermal environment; they do so to avoid extreme micro-climatic conditions, mainly through the hot and dry summers. In general, during different seasons, residents move towards the sun in the winter and people like the shade in the summer. The transferal of household activities from spaces or between different rooms occurs in the summer in order to avoid being in the outdoor environment and this is also observed in the winter because of the colder temperatures. (Al-Azzawi, 1996)

3.1.4. Traditional houses in Iraq

Traditional houses in Iraq are based on necessities and reflect the essential components required for environmental efficiency and thermal comfort. The removal of ceilings around the yard is affected by the level and the integrated form of units using the roof for shading is a better concept and raise the concept of the house to a more vital level. (Knowles, 2003)

The relationship between living spaces inside and outside houses can be seen as the necessity to maintain consistent shading and to upgrade the energy efficiency and natural ventilation capacity. (Sadafi, Salleh, Haw, & Jaafar, 2011)

Traditional houses are influenced by the homes of past civilizations in Iraq, such as the oldest Sumerian city of Ur, and they have buildings with huge facades. With simple ideas and conceptions, using modern and traditional materials can produce more efficient energy houses, which exist in the traditional areas of Iraq. As can be observed in the houses of the poorer residents of Iraq, there is an art in creating closed spaces through the use of walls to preserve the interior spaces. The opposition of shading and lighting concept have a significant impact on different elements such as in the structure of the walls. (Almamoori, 2018; Postgate, 1994)

3.2. Erbil City

3.2.1. Location of Erbil

Erbil located in Iraq with the GPS coordinates of 36° 11' 28.0068" N and 44° 0' 33.0012" E. (Latlong, 2017) Figure 3.6 shows a map of Erbil.

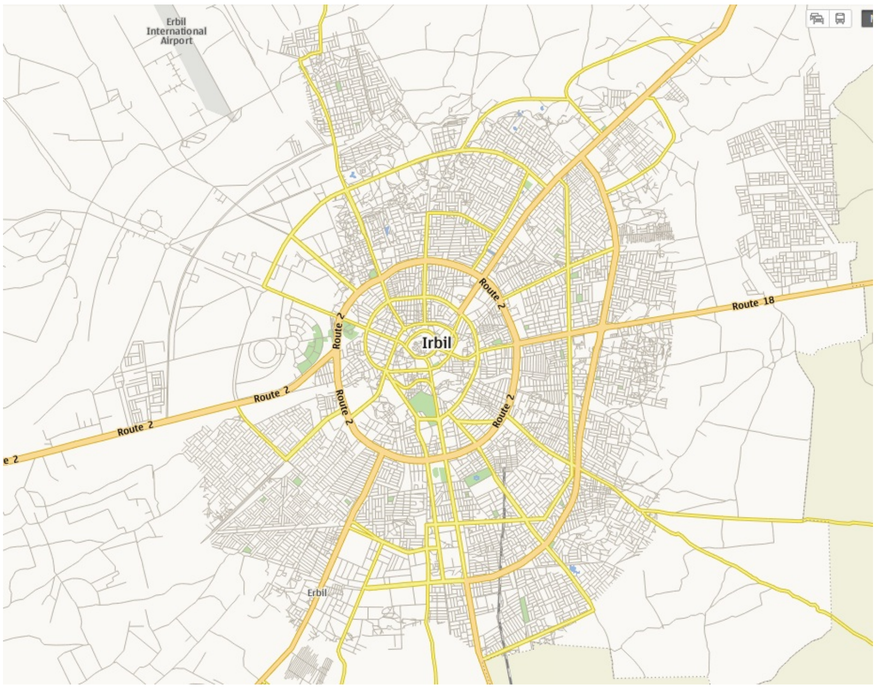


Figure 3.6: Map of Erbil city. (Erbil, 2011)

One of the largest cities in northern Iraq, it is located approximately 350 kilometres (220 miles) north of Baghdad. It has about 850 thousand inhabitants, and its governorate had a permanent population of 2,009,367 as of 2015. The latitude of Erbil, Iraq is 36.191113, and the longitude is 44.009167. Erbil, Iraq located in Iraq country in the Cities place category with the GPS coordinates of 36° 11' 28.0068" N and 44° 0' 33.0012" E. (Latlong, 2017)

All countries around the world have a different style that defines their traditional spatial architecture, it reflects the originality and depth of the civilisation of that nation or is an indication that it has no creativity and progress. Traditional architecture represents the spiritual symbol of the nation's identity in thought and culture, which often reflects all aspects of life (social, historical, economic, artistic, environmental, political) that belonging to nations or places in which native people live. (Navrud & Ready, 2002)

Erbil is a cradle of civilisations and has a tradition that is comparable to countries that boast a rich history and an example of this ancient cultural tradition is the city of Erbil. This city is one of the earliest inhabited settlements with evidence of the citadel of Erbil that was built more than 6,000 years ago. (Akram, Ismail, & Franco, 2016)

In this era, the urban traditions of the ancient city of Erbil suffer from multiple factors that threaten its destruction. Therefore, it requires both national and global intervention to control and preserve its traditions. Thus, many successful experiments must be conducted with competent bodies into the adaptive reuse of traditional buildings (Akram et al., 2016), Figure 3.7 shows old Erbil city.

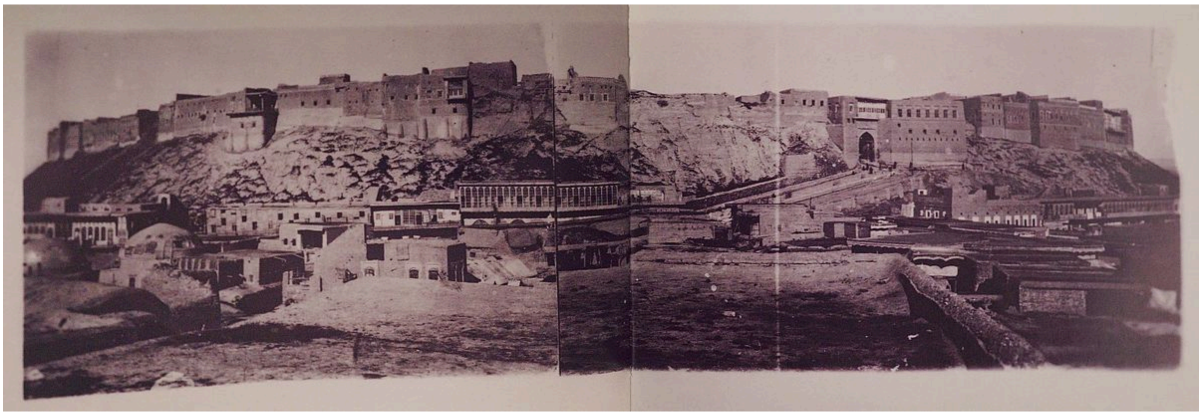


Figure 3.7: Old photographs of Erbil in the year 1900. (Alaa, 2014)

In the Middle Ages, Erbil was on the major commercial route between Mosul and Baghdad, and that role is still maintained by the main highway that connects to the main square of Erbil. (Britannica, 2016)

3.2.2. Theories about the old citadel

The city of Erbil is strategically located at the foot of Zagros mountain range and thus constitutes a natural gateway between Iran and Mesopotamia. Moreover, the plains in the west provide a thriving agricultural base, so the rise of a city in this area was inevitable. The castle was founded approximately 3,000 years ago during the Assyrian period from 1365 to

612 BC. Some archaeologists assume that the original site arose during the Neolithic to the Middle Bronze Age from 6000 until 1500 BC.

There are many theories on how Erbil was founded and how it evolved into its present form:

1. Gradual extension: This theory presupposes that the rise of the hill gradually increased and was built on the remnants of previous settlements. The layers slowly rose to the present height of 28-32 meters. If one assumes that the origin of this castle dates back to about 6,000 years ago, this means that it rose at a speed of 1 meter per 200 years. This seems reasonable given the relevant archival evidence. (Abbas, 2017)

2. Assyrian Settlement: This theory assumes that the fortress was an Assyrian settlement with a ziggurat in the centre and surrounded by temples. It concludes that this settlement was destroyed and abandoned, leaving only remains. When the materials on the site were compressed, they were found to be very useful and for the hillock was defensible for human settlements, Figure 3.8 shows Erbil Citadel in ancient time. (Abbas, 2017)

3. Manmade Mound: According to this theory the hill was created artificially by people living in the fertile area who needed stronghold. This may have required an intensive human effort, unparalleled in the history of human settlements in Mesopotamia. This theory assumes that the hill formed naturally. (Abbas, 2017)

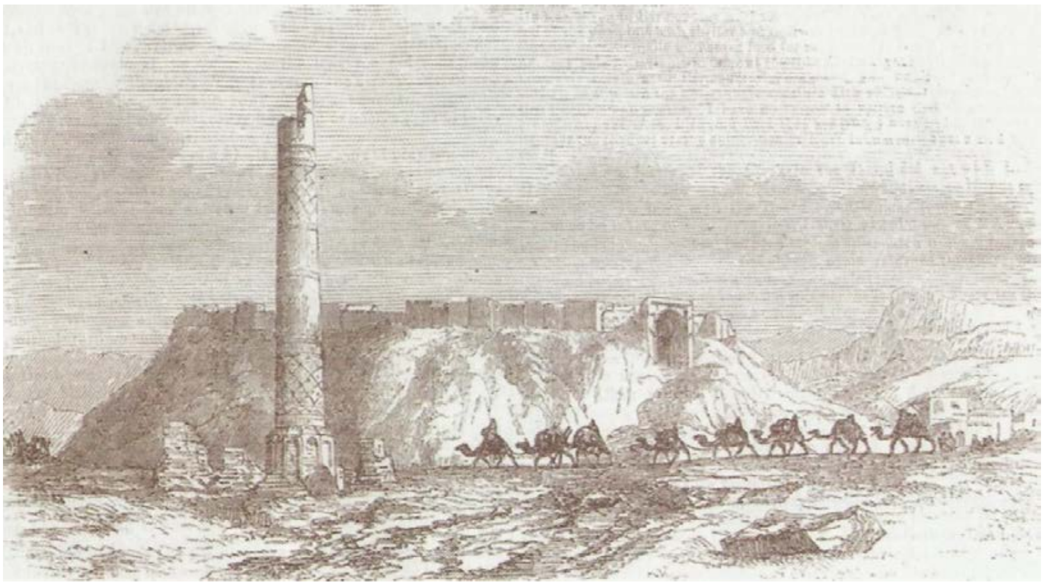


Figure 3.8: Citadel in an engraving by Eugène Flandin in the 1840s. (Abbas, 2017)

3.2.3. The citadel inside heritage world

The Erbil Citadel (Iraq), a rare and unique example of an ancient urban settlement, is listed as a UNESCO World Heritage site. The integration process was preceded by multiple studies designed to bring about the revitalisation of the citadel as a residential, tourist and cultural centre for Erbil. A further study of the area surrounding the castle has been initiated to enhance the integration of the castle and surrounding areas and to provide an additional layer of protection. (Unesco, 2014)

Archaeological surface studies have brought to light potshards dating from the Ubaid period, 5500-4000 BC. Because of its past as a citadel and its steep hill, the city has survived a myriad of vicious attacks and sieges. The slope surrounding the castle ranges from 35 to 60 degrees, with the northwestern slope more severe than other aspects. The remaining parts of the city date back 'only' a few hundred years (Abbas, 2017), Figure 3.9 shows citadel perspective from above.

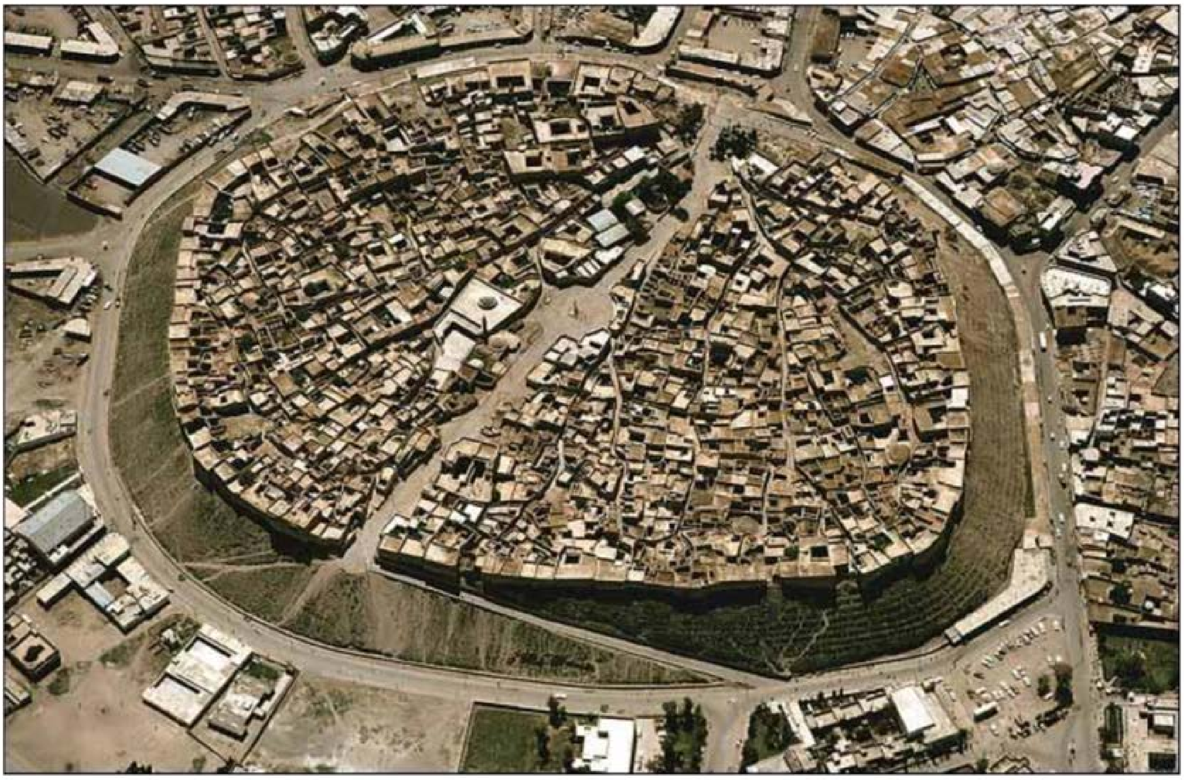


Figure 3.9: Aerial view of the citadel. (Osman, 2014)

3.2.4. Old citadel with buffer zones

The traditional method for has an important role in saving energy in the most famous houses in Erbil city. In the area shown in Figure 3.10, Courtyard Houses within the traditional fabric built to increase the energy efficiency in the buffer zone. The eco-efficiency of the castle houses and the Arab area secluded in the buffer zone around the Citadel bring new life into traditional places in order to develop the sustainable conservation of energy used in the courtyard houses. (Abbas, 2017)

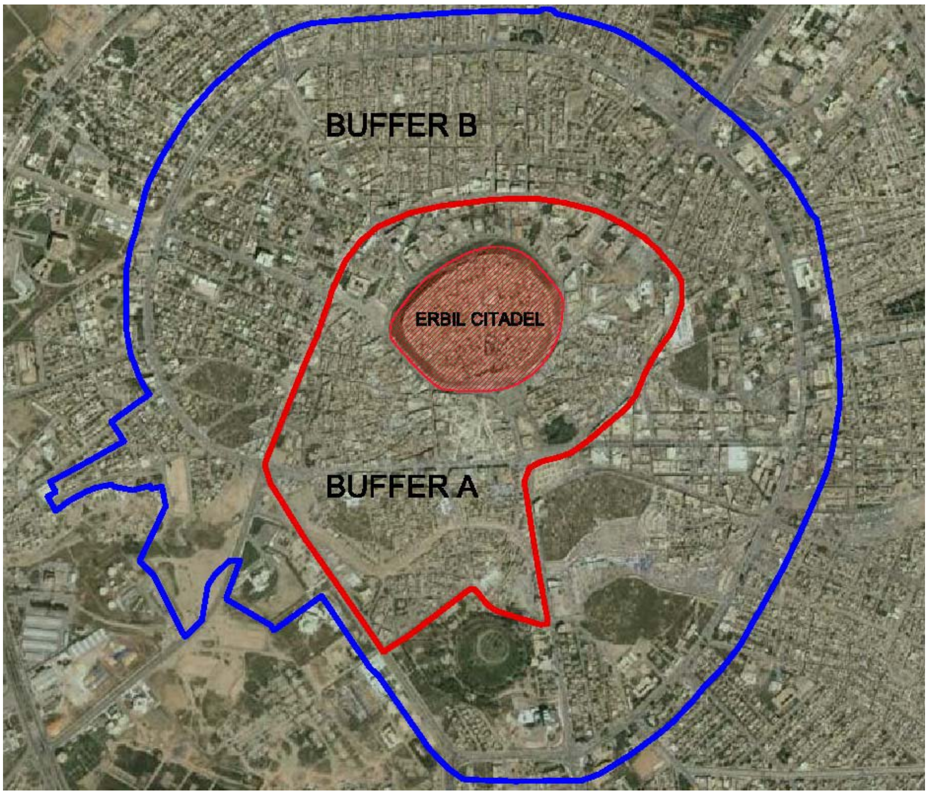


Figure 3.10: Site plan of citadel and buffer zones. (SPA, 2011)

In the buffer zones around the Erbil Citadel, the majority of people use courtyard systems. In traditional buildings, courtyards are used for the benefits of the residents. This includes health benefits, such as protection from the sun and other challenging conditions. In addition to security interests and the proximity of houses to each other, the convergence of the biosphere of each house facilitates the defence process in the event of external damage. (Baper & Hassan, 2010) Most of the windows in the houses are inside and overlook the courtyard. (Khayat & Khaznadar, 2002)

3.3. Materials Used in Tradition Houses in Erbil

Traditional houses can be recognized by the building materials used in their construction. The primary building materials are mud bricks with clay mortar. (Sahni & Chahal, 2014)

It has been shown that of the different types of clay materials used to preserve moisture, cold and heat in traditional houses and is also decorative methods. (Al-Shwani, 2011; Khayat & Khaznadar, 2002) Clay is one of the oldest building materials known to the residents of the area that is used to construct homes, especially on the top of ancient Erbil citadel. (Al-Shwani, 2011) The need to search for natural materials as alternative materials in the construction process is increasing day by day because of the environmental and physical costs of modern building materials. Clay construction is based on the selection of suitable soil due to the nature and climate of the region (Morel et al., 2001).

Natural resources also have some essential environmental potential, which can be summarised as follows:

Clay is natural and environmentally friendly, so clay construction helps to reduce the depletion of natural biogenic resources and carbon emissions by using the minimum amount of manufactured materials. (Morel et al., 2001)

Energy saving is due to the availability of mud in most of the implementation sites. Furthermore, the provision of power during the construction of mud buildings creates an environmental structure similar to those created in traditional houses in Erbil on the citadel and buffer zones. Also, for more efficiency, solar panels can be used for clean energy that can be produced directly from natural sources. (Maleki, 2011)

3.4. Functions and Components Used in Traditional Building for Energy Efficiency

3.4.1. Inner courtyard

In the past, people learned to close their homes from the outside and open them inward by opening an inner courtyard, which was exposed to the sky. (Nejadriahi & Dincyurek, 2015) This mode reduces the temperature by a significant amount in the mild cold nights coming from the top. (Al-Hemiddi & Al-Saud, 2001) The fresh air collects in the yard and then flows into the surrounding rooms to provide a cooling effect (Moosavi, Mahyuddin, Ab Ghafar, & Ismail, 2014). In the morning, the air that envelopes the four walls of the courtyard and the atmosphere of the surrounding chambers begins to heat slowly and slowly but their coolness remains moderate until late in the day when the sun shines directly inside the courtyard. In this way, the inner courtyard acts as a reservoir for the air. The courtyard an active element in natural ventilation and has worked in these areas as a regulator of heat through its ample shade (Moosavi et al., 2014), Figure 3.11 shows courtyard house on the citadel.

Figure 3.11: Courtyard house on the top of the old citadel. (Rudaw, 2015)

3.4.2. Fountain

The fountain is an architectural design that comes in several sizes, and its function is to pump water to levels above the ground for aesthetic purposes or to increase the distribution of water within a given area (Fathy, 1986). It also helps to maintain cleanliness and more in the courtyards of houses. The fountain helps to moisten the air in the inner courtyard because of the process of evaporation. The process for exchanging the air quality with water needs to heat from the fountain and this helps to moisturise and cool the air; the fountain also has a symbolic value as it is generally in the middle of the square with an octagonal or hexagonal shape (Petersen, 1996; Steele, 1997). Fountains are placed in the middle of the inner courtyards of Islamic houses. The Iwan and the living spaces opened to the fountain and it helps to moisten the air in the inner courtyard. Fountain helps to moisturise and cool the air in places where there is not enough pressure to spray the water. The marble panelled wavy appearance of fountains is inspired by the movement of water. The properties of the fountain in the inner courtyard provide better evaporation, which increases the moisture of the surrounding air in the courtyard houses (Petersen, 1996), Figure 3.12 shows Fountain in courtyard house on the citadel.

Figure 3.12: Fountain in a courtyard house in the citadel. (Citadel, 2013)

3.4.3. Windcatcher

One of the most common uses of windcatchers is for cooling inside the dwelling. It is commonly used in traditional courtyards and domes and is the best strategy for ventilation and thermal level. It is a tower, crowned with one open face at the top. This open side faces the prevailing wind and thus "holding" it out, which cools the building and the inner courtyard (Abdaei & Azami, 2014). This simple, functional tool acts as a clever environmental trick to change a significant amount of air, and it has been used for centuries (A'zami, 2005). It creates a pressure gradient that allows hot air, which is less dense, to rise and escape from the top. It is also hugely exacerbated by a daily cycle, trapping cold air below. When combined with thick clay that exhibits excellent resistance to heat transfer, it can cool low-level spaces in homes that are exposed to extreme midday temperatures (Maleki, 2011). Ventilation above the building is achieved through a hole corresponding to the direction of the prevailing winds, which catches the air passing over the structure, which is usually colder and pushes into the building. Furthermore, it serves to reduce the dust and wind traditionally carried by the wind that blows in hot regions. The size of the structure depends on the external air temperature. If the heat at the entrance of the collector is low, the area of its horizontal section should be significant. (Abdaei & Azami, 2014) If the temperature is higher than the maximum comfort of the thermal circumference, the area of its horizontal section should be small. The air can be cooled through wet charcoal boards placed between two sheets of metal mesh, and air flowing over a water element such a fountain can be directed to increase its moisture content (Abdaei & Azami, 2014; Fathy, 1986), Figure 3.13 shows windcatcher in a courtyard house in the buffer zone.

Figure 3.13: Windcatcher in Chalabi's house in the buffer zone. (Abbas, 2014)

3.4.4. Iwan

The ceiling covers a three-walled hall, with the fourth side fully open to like a public gallery overlooking the courtyard or the inner courtyard. It may rise from the highest part of the interior building to exchange air in hot and stressful times of the summer, with the fountain moving cool air with small water droplets directly to the Iwan. (Edwards, 2006)

It is used as a reception area, an excellent outdoor seating area and a place used for evening events with traditional music. The Iwan is usually on the northern façade of the courtyard and is used for entertaining during the summer time. The Iwan consists of two adjoining rooms facing each other with a stone arch in front of the courtyard. A multi-coloured marble floor characterises the transition from the courtyard to the Iwan area. The Iwan faces the main reception hall used for special ceremonies and celebrations such as Eid. (Edwards, 2006)

For different seasons, the walls facing the inside protect against solar radiation and gaining excess heat. One way to reduce thermal gain is to find a sufficient balance between the surface exposed to solar radiation and shade. Natural ventilation has a role to play in heat gain and loss (Feroz, 2015), Figure 3.14 shows Iwan in the courtyard house on the citadel.

Figure 3.14: Iwan in a traditional house above the citadel. (Aaron, 2012)

3.4.5. Basement

Many traditional houses have basements, especially for the wealthy. There are two types of vaults: one kind of basement is under the house and has windows, a part of the windows is overlooking the courtyard, and the other kind built completely underground. (Edwards, 2006) The original purpose of the basement is to provide cooling in the summer, where the temperature drops significantly below the temperature outside, thus making it fresh. (Agha, 2015)

The basement is often connected to the windcatcher, making the basement an ideal place to sit and sleep during the summer, whereas it is used for storage during the winter. In Iraq, the use of the vaults on a large-scale date back to the Abbasid period, while the cellar is used for storage. (Petersen, 1996) A single house may contain a basement, one or more subterranean basements, and louvres will illuminate the basement in the courtyard. The basement is not one of the elements that are repeated from traditional homes in general, but its design and use depend on the nature of the climate, terrain, and customs in the region. (Edwards, 2006) The basement acts to achieve an equilibrium temperature throughout the year. It is, therefore, an attractive living space during periods of extremely high or summer temperatures. The basement works as a thermal manager during the hot, dry season, allowing the hot air collected by the windcatcher to be cooled and moisturised before being released into the courtyard (Edwards, 2006), Figure 3.15 shows basement function with courtyard.

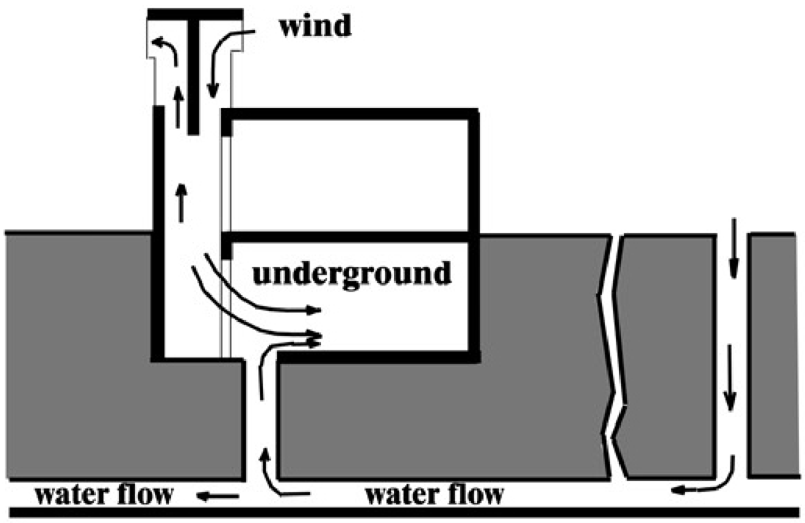


Figure 3.15: Basement functionality. (Behbood, Taleghani, & Heidari, 2010)

3.5. Summary

Iraq is located in the hot dry zone. for studying of context got Iraq country and Erbil city, the old citadel in Erbil was the focal point for the development of the current city. Around the citadel had buffer zones that contain traditional houses and in the same location a group of traditional houses selected for a case study.

Generally, Erbil city has a hot climate in the summer temperature by average raise to forty degrees Celsius, and the cold season is limited in the winter season the temperature drops to sixteen degrees, in spring and autumn had the nice climate Compared with two other seasons.

Traditional houses can be recognized by the building materials used in their construction. The primary building materials are mud bricks with clay mortar.

In Erbil, besides the courtyards that used in traditional houses, people used other functions and components such as fountains, windcatchers, Iwans, and basement in order to optimise the energy efficiency.

CHAPTER 4
CASE STUDIES

4.1. Descriptive Analysis for Case Studies

In this chapter as shown in the Figures 4.2 – 4.10 the traditional houses chosen for the case studies are located in Iraq, Erbil, an Arab neighbourhood, because the Arab Buffer zone is a representative of the oldest type of houses in Erbil, in environmental and social aspects. All houses used in the case study are traditional. A descriptive analysis will explain by quantitative and locative analysis has been conducted for each case, Figure 4.1 shows the locations of the case study houses.

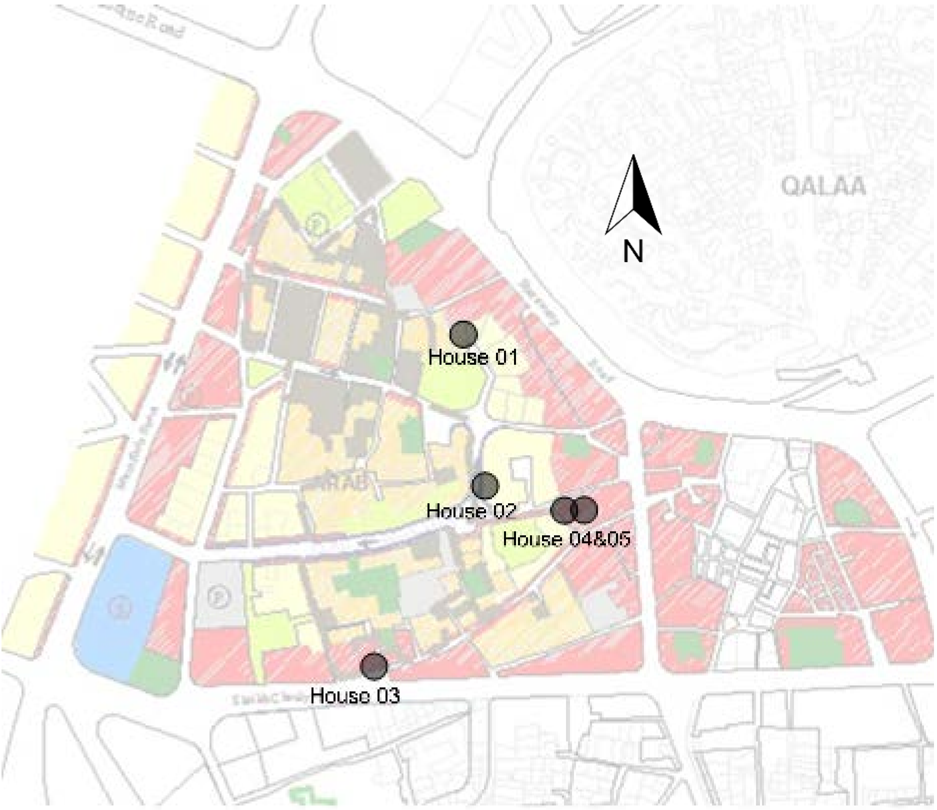


Figure 4.1: The locations of the case study houses.

4.2. Case Studies

4.2.1. Case study 1 – House 01

It is located in the Arab region of Erbil. The plot area is 225 m². The house is one storey, the courtyard is about 40 m² and the open to built-up ratio is about 1:1.8. Although the house is small, it contains the main required spaces such as Reception, Rooms, Kitchen, Store, and Bathrooms. The house is designed on the introvert concept, where all areas open onto the central courtyard. The construction system is load-bearing walls with a thickness of 0.5 meters, with steel beams in the roof using, brick for the walls, mud as the mortar, and concrete used for the roof. Four old columns in the North elevation embellish the main entrance, figure 4.2 shows exterior view for case study 01.

Figure 4.2: Chalabi’s house. (Author 2018)

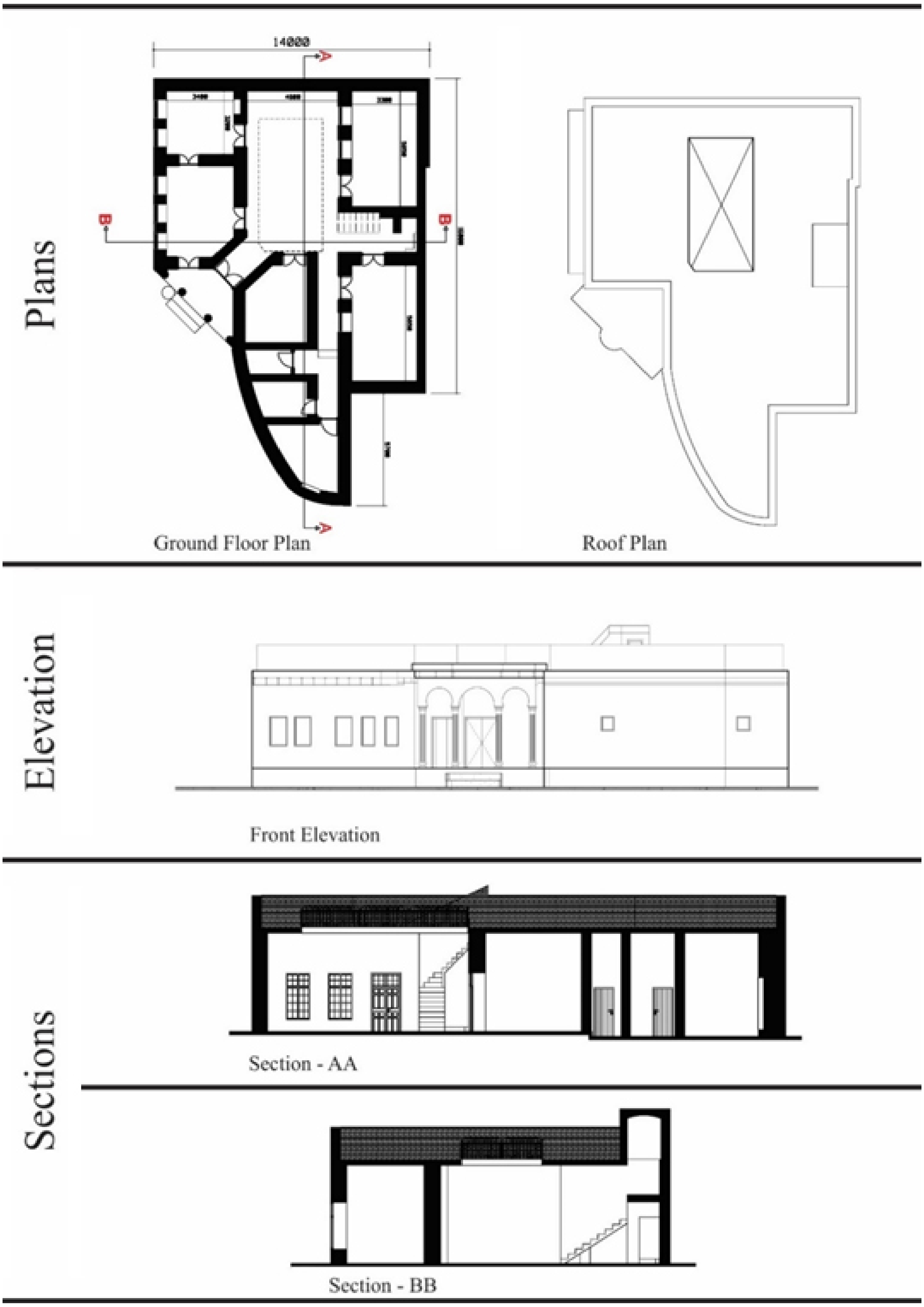


Figure 4.3: Plans, elevation and sections of house 01. (Abbas, 2015)

4.2.2. Case study 2 – House 02

It is located in the Arab district. The plot is almost square (10.6 m* 15.4 m) and the house has three levels, with a total area for all levels of 290 m^2. The ground floor area is 160 m^2, the basement level 102.08 m^2 and the first floor 27.4 m^2. The courtyard is about 36 m^2 all and all rooms open to the courtyard; the depth-width ratio of the courtyard is about 1:1.75. The main entrance is in the South facade. The ground level has a Small lobby, Reception, Living Room, Kitchen, Store, Toilet, and Bathroom. Two staircases in the right and left sides lead to the basement. The basement level has two small rooms and two other large rooms which are used in different hot or cold seasons due to the temperature difference; the basement may also be used as a store at different times. The first floor of the house has two rooms. The construction system is load-bearing walls with a thickness of 0.80 m and partitions (0.25 m), stones are used for the foundation, clay brick and mud mortar joint for the walls and concrete with iron steel for the Roof. Figure 4.5 illustrates more architectural details for the analysis of case study two, figure 4.4 shows exterior view for case study 02.

Figure 4.4: House 02 from the exterior. (Author 2018)

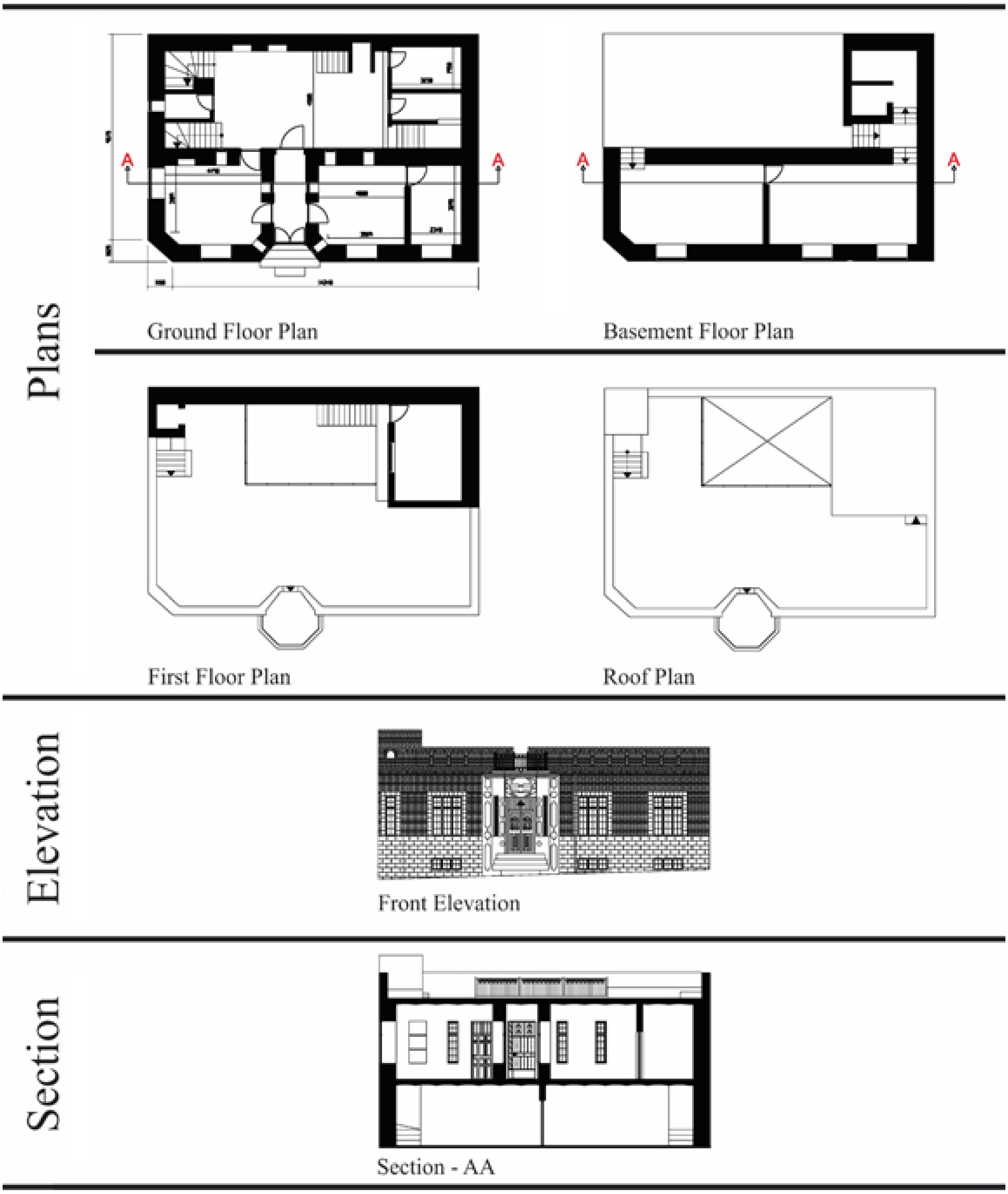


Figure 4.5: Plans, elevation and section of house 02. (Abbas, 2015)

4.2.3. Case study 3 – House 03

It is located in the Arab district. The plot area and total area is 286 m^2. The house is all at the ground level and all rooms open to the central courtyard. The width to depth ratio for the yard is about 1:1.15, the main entrance is in the South facade. The ground level has a Reception, Living Room, Kitchen, Bedroom, Toilet, and Bathroom. Two staircases go to the first floor and there are two windcatchers above the stairs for natural ventilation. The construction system is load-bearing walls with a thickness of 0.70 m, partition walls (0.2 m and 0.4 m), clay brick and mud mortar joint are used for the walls and concrete with iron steel for the roof also stone materials are used for the foundation. Figure 4.7 illustrates more architectural details for the analysis of case study three, figure 4.6 shows exterior view for case study 03.

Figure 4.6: House 03 from the exterior. (Author 2018)

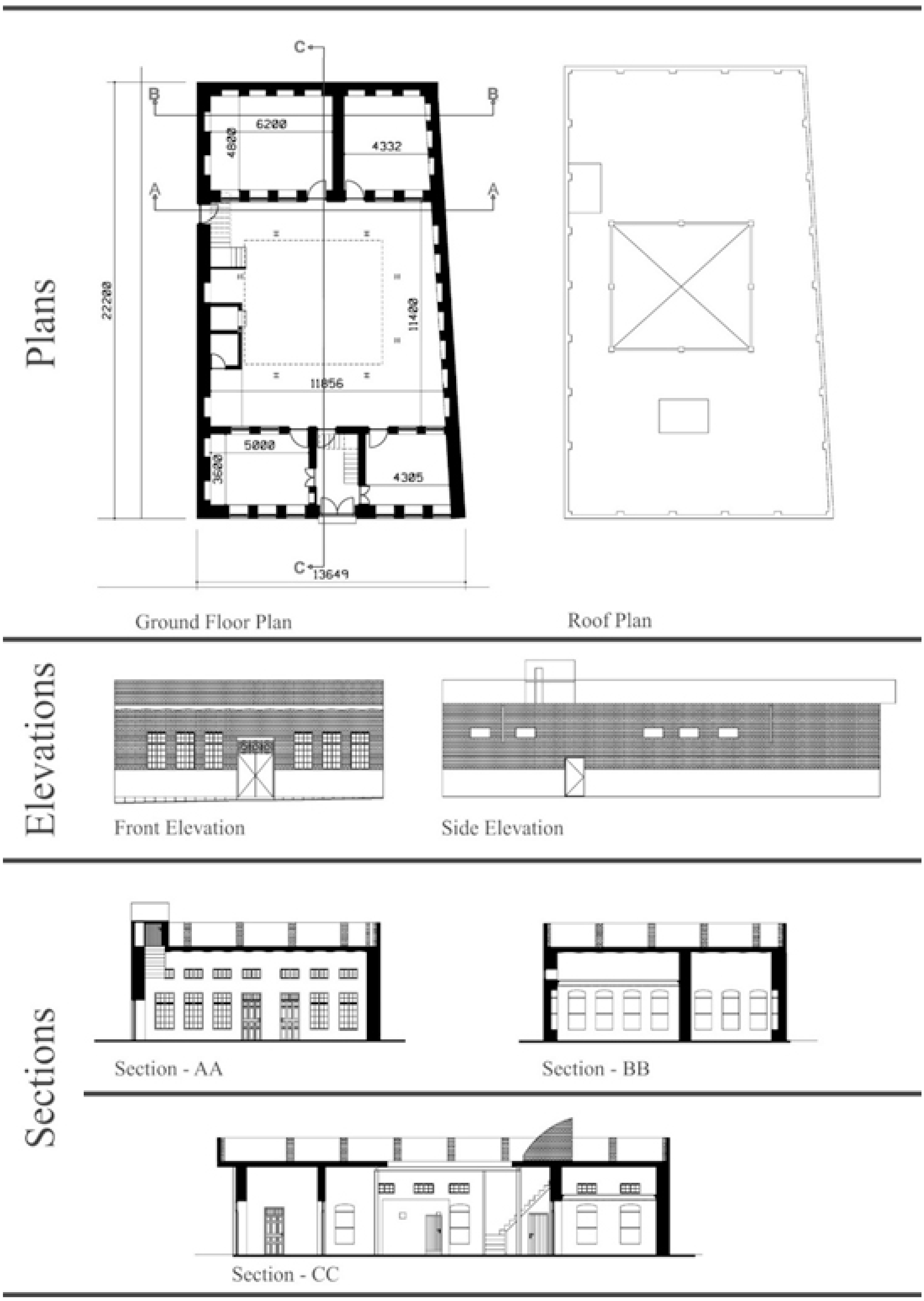


Figure 4.7: Plans, elevations and sections of house 03. (Abbas, 2015)

4.2.4. Case study 4 – House 04

It is located in the Arab district. The total area for two levels is 199.5 m^2, and the ground level has a Reception, Living Room, Kitchen, Bedroom, Toilet, and Bathroom; the first floor has storerooms. The width to depth ratio of the courtyard is about 1:1.45, the main entrance is in the North facade. The construction system is load-bearing walls (0.45 m and 0.65 m), partition walls (0.25 m, 0.4 m and 0.45 m), clay brick and mud mortar joint are used for the walls and concrete with iron steel for the roof. Figure 4.9 illustrates more architectural details for the analysis of case study four, figure 4.8 shows exterior view for case study 04.

Figure 4.8: House 04 from the exterior. (Author 2018)

Figure 4.9: Plans and sections of house 04. (Abbas, 2015)

4.2.5. Case study 5 – House 05

It is located in the Arab district of Erbil. The total area for the two levels is 158.7 m², where the ground floor level is 141 m², and the courtyard is 40 m². The house has rooms on two levels: the ground floor contains the Living Room, Reception, Kitchen, Toilet and Bathroom, whereas the first floor has one storeroom. The courtyard is in the centre and the main entrance is on the north side; the ratio of the courtyard is 1:1.25. The construction system is load-bearing walls with a thickness of 0.70 m and partitions 0.30 m, with the use of bricks for walls and concrete for roofing. Figure 4.10 illustrates the quantitative and spatial analysis for case study 5.

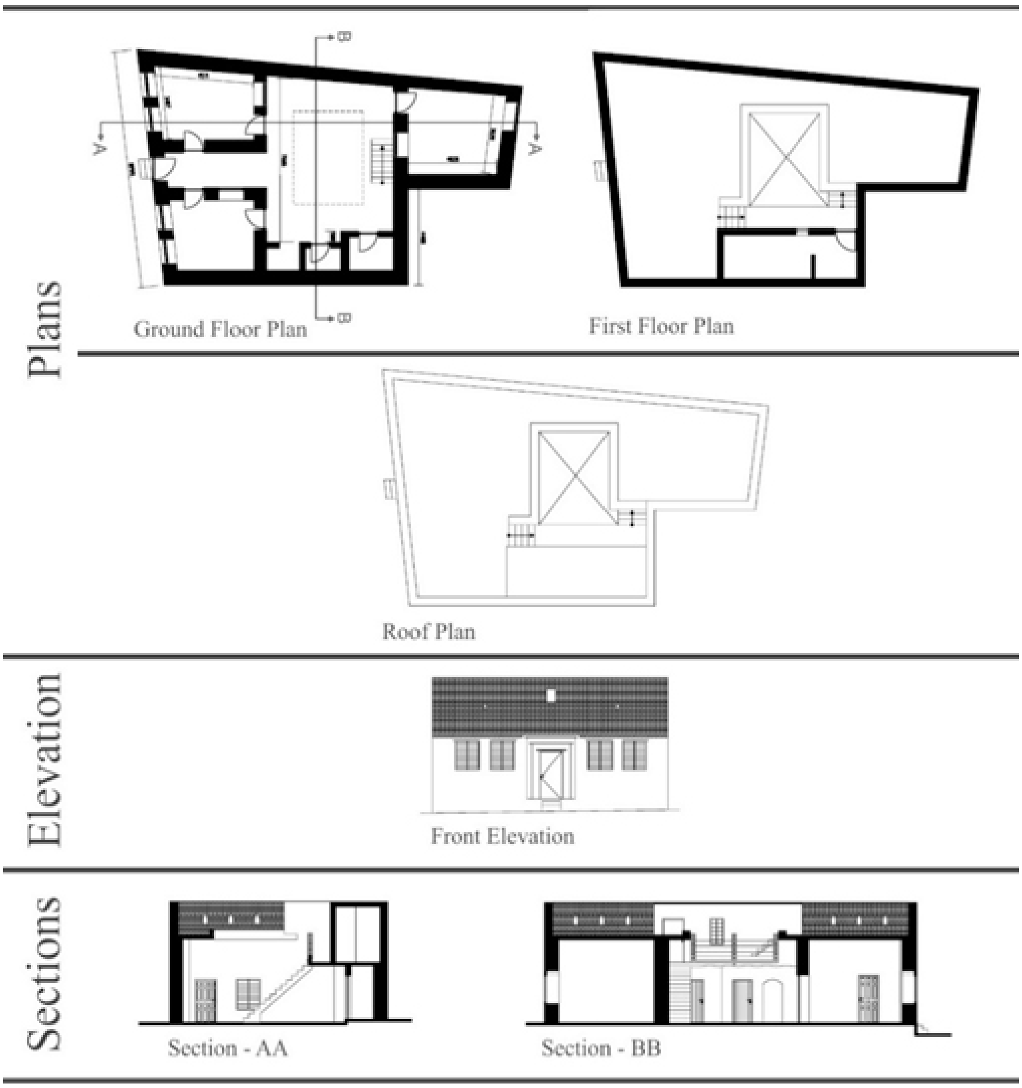


Figure 4.10: Plans, elevation and sections of house 05. (Abbas, 2015)

4.3. Working Courtyard System with Energy Efficiency

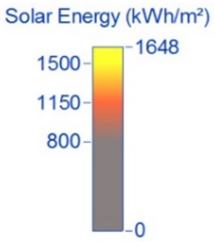
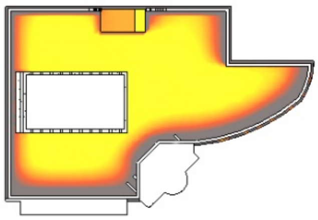
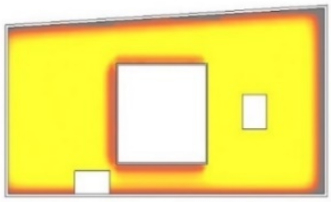
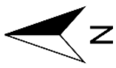
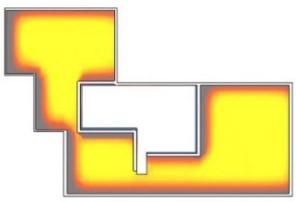
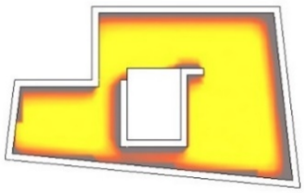
The Hot dry Climate in Erbil has a significant impact of on the performance of the traditional buildings and their energy consumption. There is a lack of water and energy resources in these areas, expenses load people to build their homes using strategies based on minimal energy consumption. Heating and cooling strategies are normally used for controlling the temperature in buildings. Therefore, builders tried to use natural climate strategies to deal with the extreme conditions. Additional factors have an impact on the built environment, such as the building direction, the distance between buildings, the orientation and shape of the buildings, climatic elements, windcatchers, courtyards, and more. The research presents basic principles and changes in their use that may be beneficial for sustainable design. also, the design strategies will be examined, modern and traditional methods will be assessed regarding design criteria.

4.4. Energy Efficiency with Solar Panel

4.4.1. Analysing solar energy for study cases

The selected traditional houses have flat roofs and one of the ways of solving the overheating problems is by using solar panels, which act like shading device because they protect the roof from the direct sun; therefore, the top of the roofs represent the best alternative factor for obtaining energy. In this research, the analysis part of the Revit Program version 2018 will be used to study the roofs, all the roofs are flat, and Erbil experiences hot sun throughout the year, apart from several days in winter. In Table 4.1, the amount of energy gained by solar panels in a year is shown. Also, in the Figures 4.3, 4.5, 4.7, 4.9 and 4.10 showing all selected houses, there are parapet walls above the roof level at least one-meter high; therefore, the use of solar panel with minimum height will not have an effect on the traditional shape as viewed from the outside. In traditional houses materials that cover flat roofs typically allow the water to run off from a slight inclination or camber into a gutter system. Water from some flat roofs such as on garden sheds sometimes flows freely off the edge of a roof, though gutter systems are of advantage in keeping both walls and foundations dry. Gutters on smaller roofs often lead water directly onto the ground, or better, into a specially made soakaway. Gutters on larger roofs usually lead water into the rainwater drainage system of any built-up area, however, flat roofs are designed to collect water in a pool, usually for aesthetic purposes, or for rainwater buffering. (Britannica, 2017)

Table 4.1: The Amount of Energy Gained by Solar Panels in a Year.

Case Studies	Area (m^2)	Solar Energy (kWh/Year)	North Direction	
House 01	173	35,479		
House 02	133	28,642		
House 03	240	55,691		
House 04	129	26,961		
House 05	130	23,829		

4.4.2. Solar panel and current uses

Solar energy is the source of life on Earth. Plants harness this through the process of photosynthesis. This generates heat which can be harvest and then converted to electricity. When sunlight hits the surface, some solar energy is absorbed. The sun heat is converted into another type of energy it can be subsequently used for heating and cooling the buildings. Sun energy varies seasonally, and as a result of daily weather changes, meaning it is not always reliable. However, solar energy can be stored and used when the sun is not bright. Solar panels can range from simple flat panels without glass, glass boxes or tubes, to intricate mirrors. Solar collectors are usually found on rooftops but can also be installed on vertical walls and handrails or installed on the ground. Solar devices are traditionally installed to face in one direction but can also be rotated to follow the movement of the sun's path in the sky. (Omer, 2008)

4.4.3. Calculation of solar panel angle

The solar panel angle for the solar system is different it is depending on the sun angle and It changes from a different part of the world. Solar panels give the highest energy output when they are directly facing the sun**.** The sun moves across the sky and it will low or high depending on the time of the day and the season. For that reason, the ideal angle is better not fixed. To get the most solar energy the panel throughout the day, need to determine the best direction for the panels it should face and calculate an optimal tilt angle. (Moore, 1993)

This will depend on the different geographical location and the different time of the year that people need the most energy from the solar panel, figure 4.11 shows sun path diagram with a solar panel for case study 01. To calculate the optimal solar panel angle, As a thumb rule, solar panels should more vertical during winter to gain most of the low winter sun, and more tilted during summer to maximize the output. (Handbook, 2017) Table 4.2 shows the calculation of solar panel angles for each month. That formula for calculating approximate solar panel angle according to latitude degree. (Moore, 1993)

The noon solar altitude for the summer solstice is $\alpha_{Summer} = (90^\circ - \text{latitude}) + 23.5^\circ$

The noon solar altitude for the winter solstice is $\alpha_{winter} = (90^{\circ} - \text{latitude}) -23.5^{\circ}$. (Moore, 1993)

Acoording to section 3.2.1. the latitude angle of Erbil is 36°, $\alpha_{Summer} = (90^{\circ} - \text{latitude}) + 23.5 = (90^{\circ} - 36^{\circ}) + 23.5^{\circ} = 77.5^{\circ}$, and $\alpha_{winter} = (90 - \text{latitude}) - 23.5^{\circ} = (90^{\circ} - 36^{\circ}) - 23.5^{\circ} = 30.5^{\circ}$.

Table 4.2: Calculation of Altitude Angles for Each Month. (Handbook, 2017)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
38°	46°	54°	62°	70°	78°	70°	62°	54°	46°	38°	30°

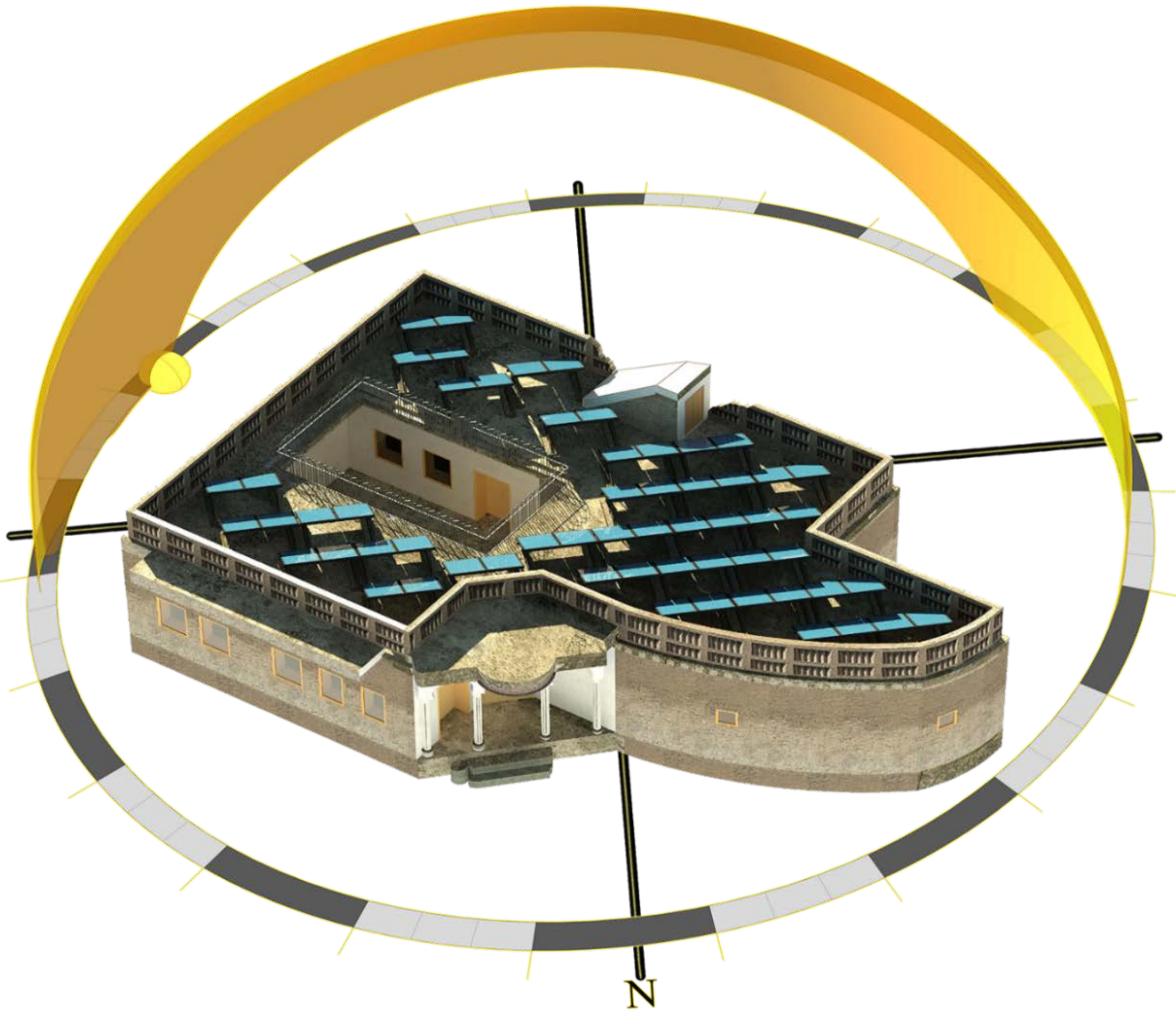


Figure 4.11: Sun path with a solar panel for house 01, created by Autodesk Revit 2018.

The modern world is characterised by overlapping and contradicting complex requirements with different activities. This has become a feature of the development of civilisation. Architecture as an activity is a social art with complex functions. It is directly affected by the processes of public life, which is reflected in its design problems. It has designed for various purposes according to different methods as result of development, growth and the need to meet the new job requirements has led to the increase in energy consumption around the world, thus increasing the usage of fossil fuels. Consequently, the idea of energy-efficient buildings has emerged. (Campbell, 1996)

It is possible to move towards conserving energy in architecture through two dimensions. The first is to increase the technical efficiency and use it to serve the architectural work, which is known as an active system, such as the emergence of modern air conditioners that consume less energy compared to previous devices; the second is the reduction in the need to use energy. (Omer, 2008)

Architecture is specific to certain regions and environments, and the area in which it is established plays an essential role in influencing energy-efficient building design strategies. Architecture tries to interact with its settings, to preserve the safety of this environment by limiting the negative aspects. The construction of the surrounding environment, in turn, provides the needed architecture from energy sources within these regions. Architects and planners must take responsibility to help stimulate the intellectual emergence of a new type of design that attaches responsibility to the environment while providing the functional efficiency appearance of the building. (Baker & Steemers, 2003)

4.4.4. Solar panel functionality

Nowadays, solar panels are one of the best components of renewable energy. They can help to save energy and can generate excellent financial returns. While the initial costs may be somewhat high, the payback period is relatively short. (Tsoutsos, Frantzeskaki, & Gekas, 2005)

4.4.5. Environmental benefits of solar panels

Cut off energy: Using solar panels means reducing the amount of energy used from the grid. Solar energy can even involve the use of batteries to keep the home powered at night, thus saving energy and reducing the number of pollutants released on a daily basis. (Hub, 2018)

No emissions: Solar energy depends on capturing sunlight and converting heat into electricity or heating for the home. This means that any greenhouse gases or harmful emissions that contribute to global warming can be reduced. Even the carbon footprint can be reduced by up to 80% in one year. Renewable: Solar energy is a form of renewable energy. This means that until such point that the sun is extinguished, the energy will not run out. Fossil fuels are the most frequently used at present, but they are not a source of renewable energy. The world is running out of fossil fuels, and their use is causing damage to our planet as well. (Hub, 2018)

No maintenance: When gas boilers or other conventional forms of conventional heating break down break down, repairs are required. This can contribute to the harmful emissions that are produced every day, and this is not good for the environment. The process of manufacturing solar panels is not perfect because of the presence of some harmful waste, but the fact that they do not need any maintenance means that they do have ecological value. (Hub, 2018)

4.4.6. Solar panel disadvantages for the environment

There are a few disadvantages for the environment that come with using solar panels. People can take up a lot of lands. Solar farms are incredibly large structures and ones that take up entire fields. Unlike wind farms, people cannot be shared with agricultural pursuits because they are mounted on the ground. However, it is possible to try and minimise the impact that solar farms have by placing them on brownfield sites or investing in floating solar panels for reservoirs. The use of water is a little high. During the manufacturing process for solar PV panels, water is used. This is not a significant amount for concern, however. Instead, the focus shifts to thermal solar panels. Concentrating solar thermal plants require large quantities of water for the cooling systems that have been installed. (Hub, 2018)

Unfortunately, many of the areas in the world with the highest potential for solar efficiency also have some of the driest climates, making this a difficult obstacle to overcome. The manufacturing process isn’t entirely clean. The disappointing part of solar panels is the fact that the manufacturing process does cause some pollution as well as produces hazardous materials. Monocrystalline solar cells produce a lot of silicon waste and use additional energy, while some layers in solar cells contain toxic materials that can cause environmental harm. However, most manufacturers are responsible for the safe disposal of this waste, and more companies are following suit. (Hub, 2018)

4.4.7. Installing solar devices in traditional buildings

Changes in energy production and consumption made at all levels. traditional buildings have demonstrated a higher level of efficiency as a symbol of sustainability. At the same time, governments throughout the world are trying to protect the traditional places by advocating appropriate positioning for renewable energy systems in a traditional context. (Florides, Tassou, Kalogirou, & Wrobel, 2002) Energy use directly affects the safety of public and private lands. Most governments support the removal of unreasonable regulatory barriers restricting the use of solar panels in traditional sites, buildings, and structures. (Yılmaz, 2007) The addition of contemporary energy conservation equipment has no traditional-visual equivalent and therefore has a substantial impact on existing buildings. The goal of heritage preservation and energy conservation is important, and care should be taken to ensure that one is not achieved at the expense of the other. (Clarke, 2007)

4.5. Energy Efficiency with Windows Glass

4.5.1 Old glass and window frames used in study houses

Through the analysis of the existing problems, it is possible to make improvements. By comparing the data with other studies, this part of the research will continue to display the development of the current windows glass by using high-quality glass. The tables below display all dimensions and directions for all windows. The existing windows have different shapes and sizes according to the specific houses, and there are many similarities between them. All window frames are made from wood or iron, and the thickness of glass used in the studied cases houses is 4 millimetres. Based on the measurements of the width and the height of the windows, a new type of glazing will be suggested to improve the window quality by showing the heat reduction and gains according to the different seasons, in the Figures 4.12, 4.13, 4.14,4.15, and 4.16 shows all study case windows with tags.

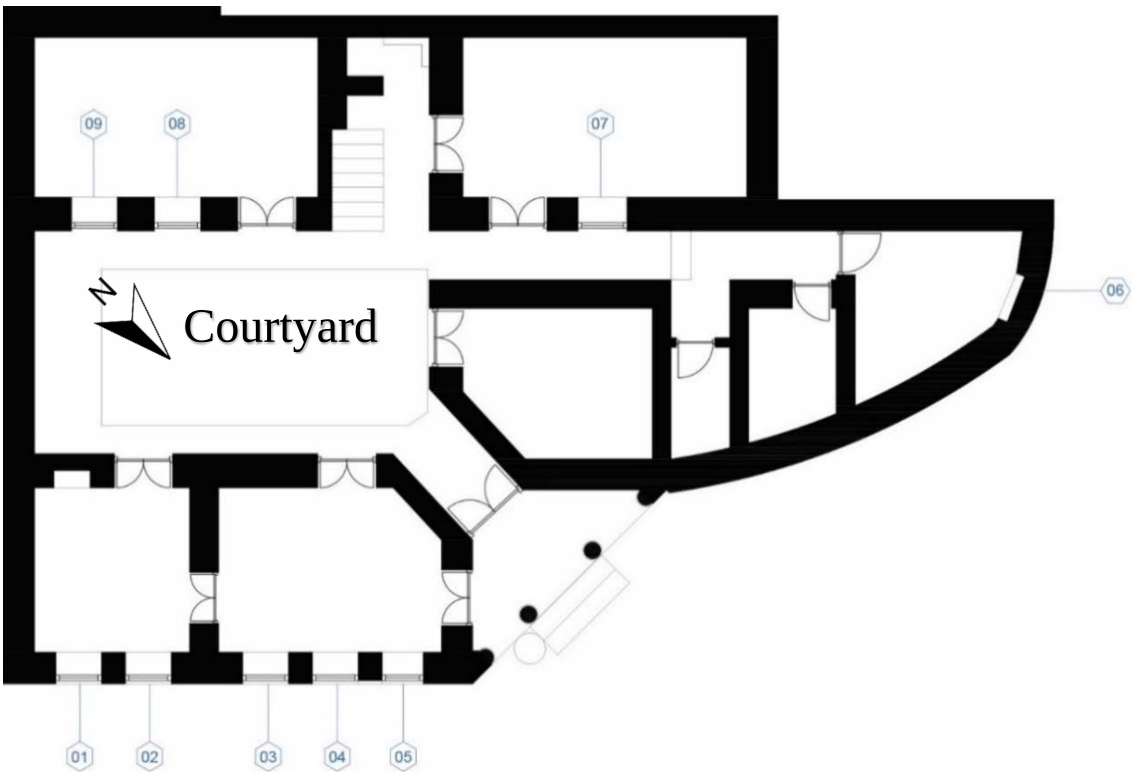


Figure 4.12: Case study house 01, windows with tag.

Table 4.3: Case Study House 01, Windows Calculation.

Windows no.	**Width** (m)	**Height** (m)	**Area** (m^2)	Orientation
01	0.94	1.50	1.41	Northeast
02	0.94	1.50	1.41	Northeast
03	0.94	1.52	1.42	Northeast
04	0.94	1.50	1.41	Northeast
05	0.94	1.50	1.41	Northeast
06	0.94	0.80	0.75	Northwest
07	1.00	1.88	1.88	Northeast
08	0.95	1.88	1.78	Northeast
09	0.95	1.88	1.78	Northeast
			Total = 13.25	

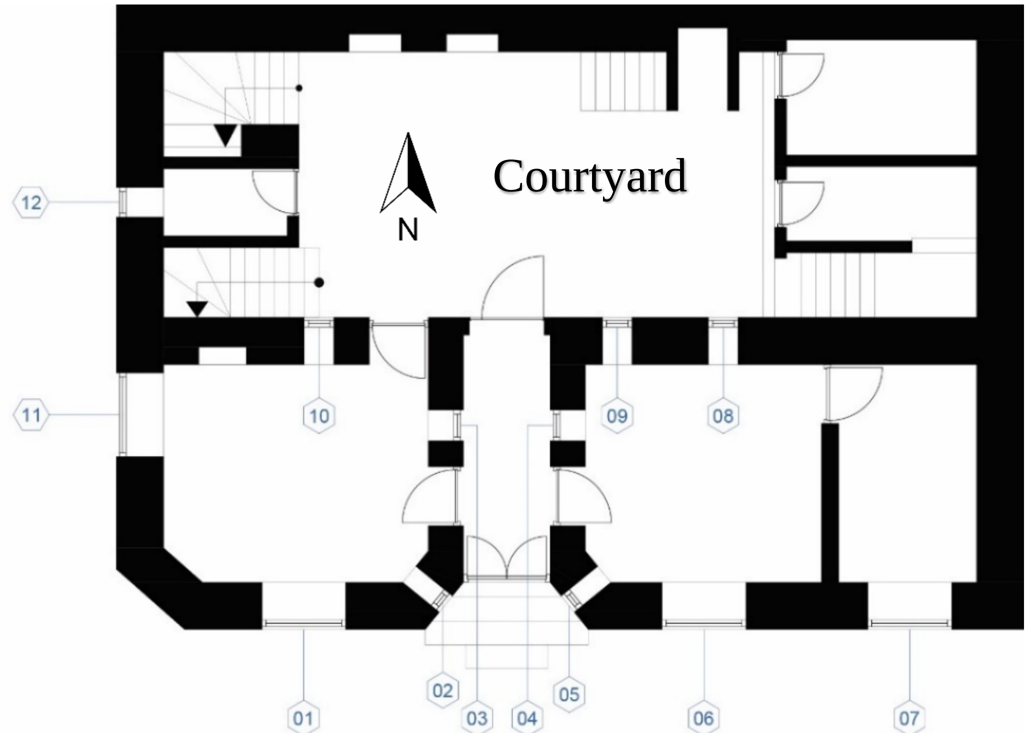


Figure 4.13: Case study house 02, windows with tag.

Table 4.4: Case Study House 02, Windows Calculation.

Windows no.	**Width** (m)	**Height** (m)	**Area** (m^2)	Orientation
01	1.42	2.10	2.98	South
02	0.35	2.10	0.73	Southeast
03	0.52	1.88	0.97	West
04	0.52	1.88	0.97	East
05	0.35	1.50	0.52	West
06	1.42	0.80	1.13	South
07	1.42	1.88	2.66	South
08	0.50	1.96	0.98	North
09	0.50	1.96	0.98	North
10	0.50	1.96	0.98	North
11	1.42	2.00	2.84	West
12	0.50	2.00	1.00	West
			Total = 16.74	

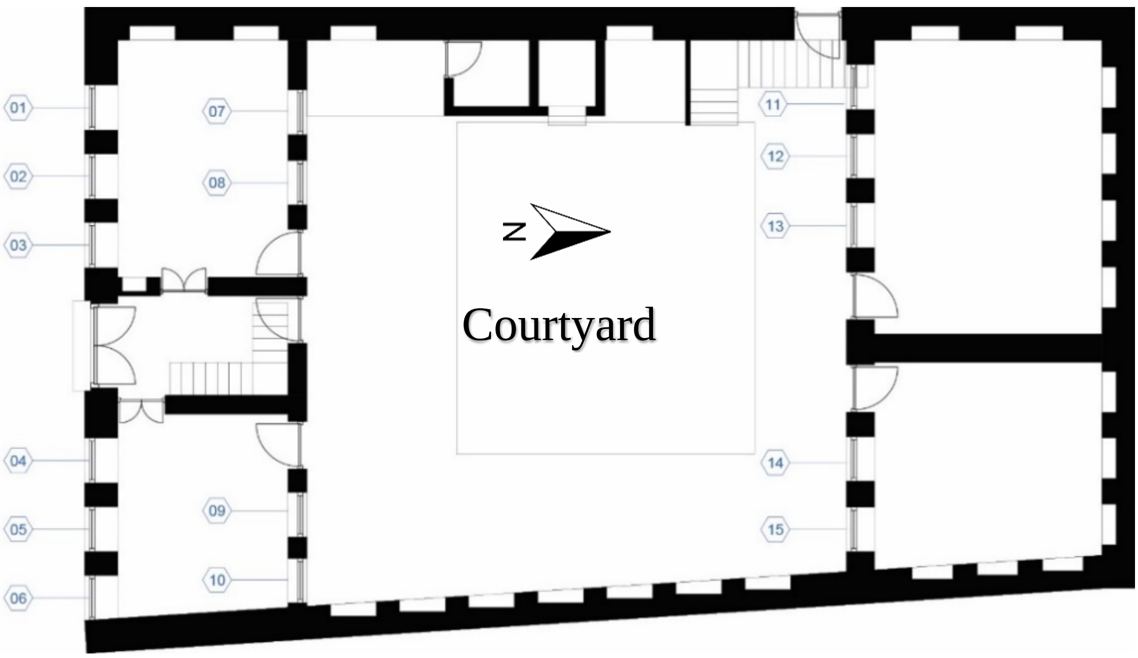


Figure 4.14: Case study house 03, windows with tag.

Table 4.5: Case Study House 03, Windows Calculation.

Windows no.	**Width** (m)	**Height** (m)	**Area** (m^2)	Orientation
01	0.95	1.88	1.78	South
02	0.95	1.90	1.80	South
03	0.98	1.85	1.81	South
04	0.95	1.88	1.78	South
05	0.95	1.88	1.78	South
06	0.98	1.90	1.86	South
07	0.94	1.88	1.76	North
08	0.94	1.92	1.80	North
09	0.90	1.88	1.69	North
10	0.94	1.88	1.76	North
11	0.94	1.90	1.78	South
12	0.94	1.90	1.78	South
13	0.90	1.90	1.78	South
14	0.94	1.88	1.76	South
15	0.90	1.86	1.67	South
			Total = 26.59	

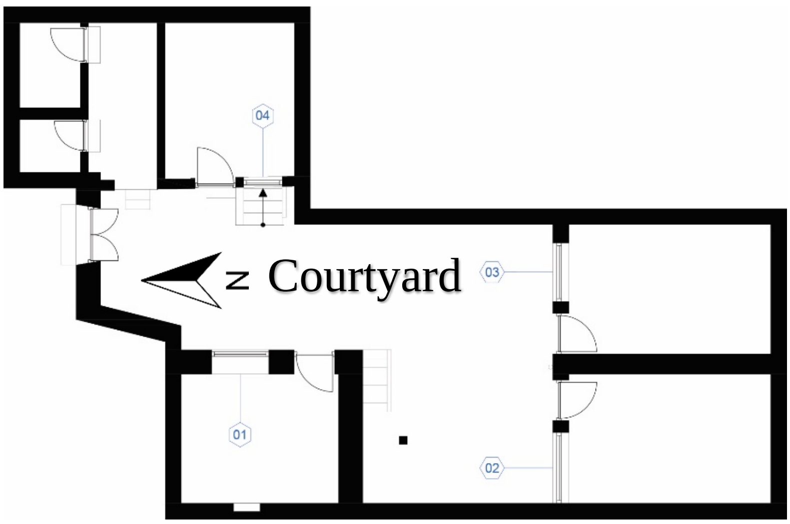


Figure 4.15: Case study house 04, windows with tag.

Table 4.6: Case Study House 04, Windows Calculation.

Windows no.	**Width** (m)	**Height** (m)	**Area** (m^2)	Orientation
01	1.42	2.00	2.84	East
02	1.75	1.95	3.41	North
03	1.45	2.00	2.9	North
04	2.00	1.50	3.00	West
			Total = 12.15	

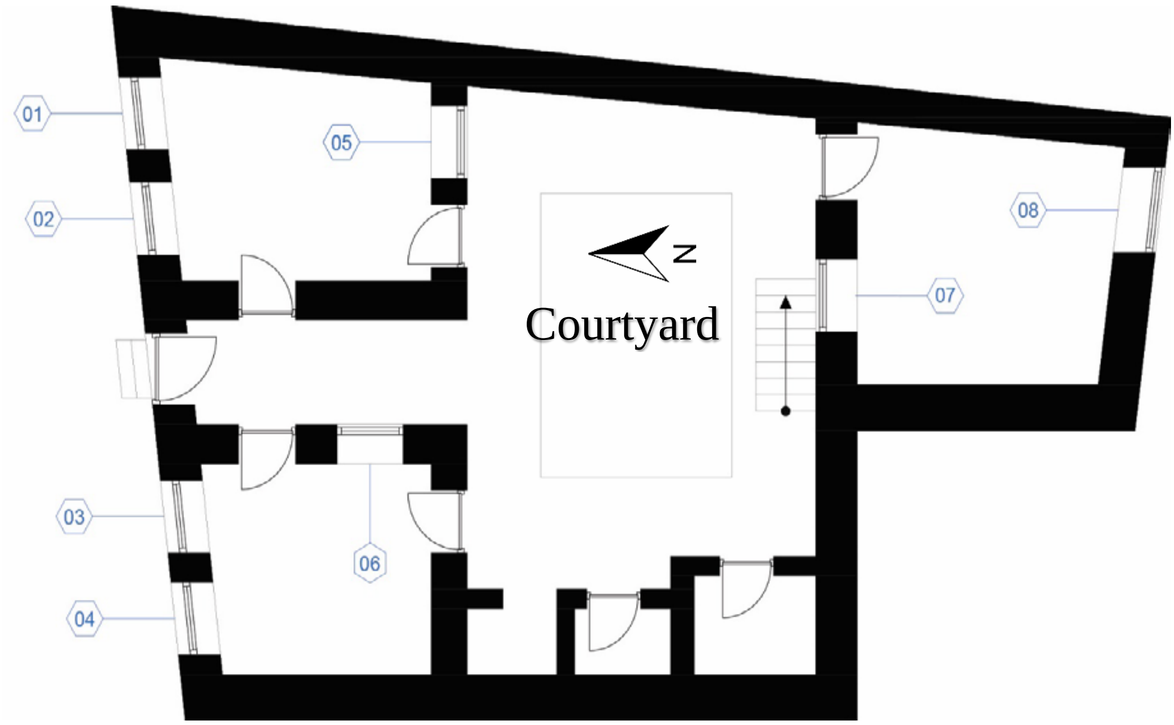


Figure 4.16: Case study house 05, windows with tag.

Table 4.7: Case Study House 05, Windows Calculation.

Windows no.	**Width** (m)	**Height** (m)	**Area** (m^2)	Orientation
01	1.10	1.34	1.78	West
02	1.12	1.35	1.80	West
03	1.10	1.34	1.81	West
04	1.08	1.40	1.78	West
05	1.10	1.83	1.78	East
06	1.12	1.92	1.86	South
07	1.10	2.00	1.76	West
08	1.31	1.52	1.80	West
			Total = 14.37	

4.5.2. Using HR glass in the world

More houses in the United States and Europe have converted to HR glass because it is one of the most effective types of experimental glass. Also, HR systems offer the best levels of energy efficiency. Therefore, people are choosing to replace their glazing. Frequently, this involves replacing outdated windows, which requires an extra investment. The popularity of HR type glass comes primarily from the favourable price, with best quality and ratio. People who install HR glass also have reduced heating costs. The HR glass is used more because of the existence of insulation properties, which means that little heat from the inside loss or gain. This implies that in the room where the glass is installed, the energy can be retained more efficiently than a room with single or ordinary double glazing. (Bosschaert, 2008)

The advantage is that people need to use less energy in order to keep warm. In this way, people will save the level of energy uses as the cost of energy depends on the type of glazing placed in all the windows, and whether there are other forms of insulation and energy saving materials, such as roof covering, floor wadding, insulation of walls, using solar panels and others. On balance, HR glazing is an effective long-term investment for occupiers. Therefore, it is possible to see the financial benefits compared to other insulation improvements. Glazing with HR properties has more advantages, such as sun defence, fire protection, sound-proofing, injury prevention, burglary protection and self-cleaning properties. (Bosschaert, 2008)

4.5.3. HR glazing system

The abbreviation HR stands for High Efficiency. HR glass works according to the energy conservation principle, similar to double glazing (it is also named glass with insulation). The only difference with double glazing is the metal layer (coating) and the cavity is filled with a noble gas (argon or krypton), instead of dry air. The HR++ windows are effective in hot and cold weather. Also, it blocks noise from the outside. HR++ glass is beneficial for the climate, consumes less energy and therefore produces less CO2. The metal layer allows the solar radiation to pass through and reflects the longwave radiation. The more active the metal layer, the better the insulation. Hence, less energy is needed to warm the indoor rooms. (Bosschaert, 2008)

The plus signs in the name define these types from other types of glass HR. HR ++ glass insulates better than HR + glass and HR+++ is better than all others. For making HR++ or HR+++ systems, two or three sheets of glass are separated from each other by a layer of noble gas. The noble gas insulates better than the modest air contained in standard double glazing. Besides, specific HR ++ or HR+++ glass is fitted with an extra coating (invisible metal coating), which further enhances insulation properties. (Bosschaert, 2008)

HR+++ glass can be found in a variety of products. Usually, it is like an HR++ standard and unit with an extra sheet in the cavity between the two other sheets. The extra chamber is created for convection and enables the level of insulation to be higher than the double layer in the HR++ structure. It is important to understand that the triple glazing in HR+++ does not necessitate extra thickness in comparison to the double glazing in HR++, but it may have considerably more weight. Furthermore, there are significant costs involved in the fabrication, transportation, storage, placement and handling of double glazing which is used in HR++ systems (Bosschaert, 2008). Figure 4.17 shows the differences between HR++ and HR+++ glass.

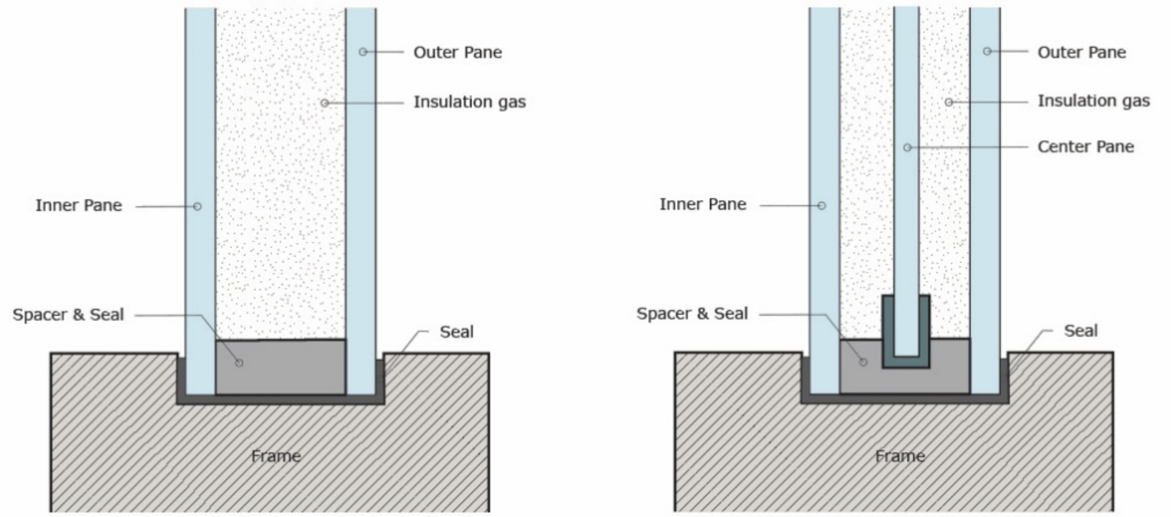


Figure 4.17: The differences between HR glasses. (Bosschaert, 2008)

4.5.4. Insulation and value transmission value

Many types of glass are used for energy efficiency; the figure below shows the values of insulation and transmission for five commonly used types of glass. To achieve the best level of energy efficiency in traditional houses, the best two types are HR++ and HR with triple glazing, Table 4. 8 shows the windows types and different U-Value.

U Glass: insulation value

Table 4.8: Type of Windows with U Factor.

Windows type	**Single**	**Double**	**Triple**	**HR**	**HR +**	**HR ++**	**HR +++**	**HR+++ (triple glazed)**
U-Value (W/m^2K)	5.8	2.8	1.21	2	1.6	1.2	1	0.78

4.6. Window Retrofits

Retrofitting windows means upgrading the existing windows to those that have better insulating properties. Windows are one of the major sources of heat leakage from a building since they are constructed from a different material than the rest of the building envelope and act as thermal bridges. Building element where a significant change in the thermal resistance occurs compared to that of the envelope, due to the presence of materials with a higher thermal conductivity. This means that there is a sudden increase in the heat loss due to an increase in the thermal conductivity of the window compared to the rest of the building envelope. Consequently, the larger the window area, the higher the heat loss. (Sundaram, 2013) The main factor determining the effectiveness of a window in terms of heat loss prevention is the U-value or the thermal conductivity. This is a measure of the heat transmission through the window – the higher the U-value, the more the heat loss. Consequently, the aim is to keep the U-value of the windows as low as possible. Window specifications generally involve two U-values: one for the glass and one for the frame. This is applicable when the entire frame along with the glass is replaced. This is because the frame is made of a different material – and also contributes to the loss of heat. However, in this case, we shall consider only replacing the window panes (glass). (Sundaram, 2013) The energy savings for each type of available glass are calculated. The assumptions made in this calculation are as follows:

- U-factor for each type of windows shown in Table 4.8.

- To find the total area of the windows, the average dimensions of a window are needed to calculate the total number. Tables 4.3, 4.4, 4.5, 4.6, and 4.7 show the total area of each study case.

- Constant indoor temperature is set at 25 °C, and for the average outside temperature is set according to Erbil City weather shown in Figure 3.5, and the difference between the two values is then calculated (Δ T).

By multiplying the U-value, the total area of the windows, and the different indoor with outdoor temperature, the Heat loss or gain of each kind of window can be calculated. (Sundaram, 2013) The basic formula used to calculate transmission loss is: Heat Loss and gain = U-value * Area * Δ Temperature

Table 4.9: Heat Loss & Gain Calculation for Case Study 01.

Month	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Average heat loss** (kWh)	**Average heat gain** (kWh)
Ex T. °C	13	15	20	27	33	39	43	42	38	30	21	15		
In. T. °C	25	25	25	25	25	25	25	25	25	25	25	25		
Δ T. °C	12	10	5	2	8	14	18	17	13	5	4	10		
Single	922	769	384	154	615	1076	1383	1306	999	384	307	769	630	845
Double	445	371	186	74	297	519	668	631	482	186	148	371	304	408
Triple	192	160	80	32	128	224	289	273	208	80	64	160	131	176
HR	318	265	133	53	212	371	477	451	345	133	106	265	217	292
HR +	254	212	106	42	170	297	382	360	276	106	85	212	174	233
HR ++	191	159	80	32	127	223	286	270	207	80	64	159	130	175
HR +++	159	133	66	27	106	186	239	225	172	66	53	133	109	146
HR +++ (t.g.)	124	103	52	21	83	145	186	176	134	52	41	103	85	114

Table 4.10: Heat Loss & Gain Calculation for Case Study 02.

Month	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Average heat loss** (kWh)	**Average heat gain** (kWh)
Ex T. °C	13	15	20	27	33	39	43	42	38	30	21	15		
In. T. °C	25	25	25	25	25	25	25	25	25	25	25	25		
Δ T. °C	12	10	5	2	8	14	18	17	13	5	4	10		
Single	1165	971	485	194	777	1359	1748	1651	1262	485	388	971	796	1068
Double	562	469	234	94	375	656	844	797	609	234	187	469	384	516
Triple	243	203	101	41	162	284	365	344	263	101	81	203	166	223
HR	402	335	167	67	268	469	603	569	435	167	134	335	275	368
HR +	321	268	134	54	214	375	482	455	348	134	107	268	220	295
HR ++	241	201	100	40	161	281	362	341	261	100	80	201	165	221
HR +++	201	167	84	33	134	234	301	285	218	84	67	167	137	184
HR +++ (t.g.)	157	131	65	26	104	183	235	222	170	65	52	131	107	144

Table 4.11: Heat Loss & Gain Calculation for Case Study 03.

Month	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Average heat loss** (kWh)	**Average heat gain** (kWh)
Ex T. °C	13	15	20	27	33	39	43	42	38	30	21	15		
In. T. °C	25	25	25	25	25	25	25	25	25	25	25	25		
Δ T. °C	12	10	5	2	8	14	18	17	13	5	4	10		
Single	1851	154 2	771	308	1234	2159	2776	2622	2005	771	617	154 2	1265	1696
Double	893	745	372	149	596	1042	1340	1266	968	372	298	745	611	819
Triple	386	322	161	64	257	450	579	547	418	161	129	322	264	354
HR	638	532	266	106	425	745	957	904	691	266	213	532	436	585
HR +	511	425	213	85	340	596	766	723	553	213	170	425	349	468
HR ++	383	319	160	64	255	447	574	542	415	160	128	319	262	351
HR +++	319	266	133	53	213	372	479	452	346	133	106	266	218	292
HR +++ (t.g.)	249	207	104	41	166	290	373	353	270	104	83	207	170	228

Table 4.12: Heat Loss & Gain Calculation for Case Study 04.

Month	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Average heat loss** (kWh)	**Average heat gain** (kWh)
Ex T. °C	13	15	20	27	33	39	43	42	38	30	21	15		
In. T. °C	25	25	25	25	25	25	25	25	25	25	25	25		
Δ T. °C	12	10	5	2	8	14	18	17	13	5	4	10		
Single	846	705	352	141	564	987	1268	1198	916	352	282	705	578	775
Double	408	340	170	68	272	476	612	578	442	170	136	340	279	374
Triple	176	147	74	29	118	206	265	250	191	74	59	147	121	162
HR	292	243	122	49	194	340	437	413	316	122	97	243	199	267
HR +	233	194	97	39	156	272	350	330	253	97	78	194	159	214
HR ++	175	146	73	29	117	204	262	248	190	73	58	146	120	160
HR +++	146	122	61	24	97	170	219	207	158	61	49	122	100	134
HR +++ (t.g.)	157	131	65	26	104	183	235	222	170	65	52	131	107	144

Table 4.13: Heat Loss & Gain Calculation for Case Study 05.

Month	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Average heat loss** (kWh)	**Average heat gain (**kWh)
Ex T. °C	13	15	20	27	33	39	43	42	38	30	21	15		
In. T. °C	25	25	25	25	25	25	25	25	25	25	25	25		
Δ T. °C	12	10	5	2	8	14	18	17	13	5	4	10		
Single	1000	833	417	167	667	1167	1500	1417	1083	417	333	833	683	917
Double	483	402	201	80	322	563	724	684	523	201	161	402	330	443
Triple	209	174	87	35	139	243	313	296	226	87	70	174	143	191
HR	345	287	144	57	230	402	517	489	374	144	115	287	236	316
HR +	276	230	115	46	184	322	414	391	299	115	92	230	189	253
HR ++	207	172	86	34	138	241	310	293	224	86	69	172	141	190
HR +++	172	144	72	29	115	201	259	244	187	72	57	144	118	158
HR +++ (t.g.)	135	112	56	22	90	157	202	191	146	56	45	112	92	123

4.7. Summary

The selected traditional houses have flat roofs for dealing with the overheating problem using suggested solar panels, which act like the shading device because they protect the roof from the direct sun; therefore, the tops of the roofs have the best alternative factor for getting energy.

All selected houses have parapet walls above the roof at least had one-meter high; hence using the solar panel with minimum height will not affect the traditional shape from the outside. However, low-level panels will affect using the roof Sun energy is the source of life on Earth.

The modern world is characterized by overlapping and contradicting its complex requirements with different activities. Solar panels are one of the best components for renewable energy. By average with the solar panel in Erbil city for one square meter get near 200 kWh/Year.

Another subject that was considered is glazing the current single glass had the big U Value and other types of double of the HR glazing system had small U Value, heat gain and loss Reverse changes with U Value, HR+++ had smallest U value by Comparing HR+++ with triple glass with the single types that had greatest U Value, the new system retain internal heat gain and loss about seven times.

CHAPTER 5
CONCLUSION

5.1. Conclusions

Erbil city had a hot climate in the summer temperature by average raise to forty degrees Celsius, and the cold season is limited in the winter season, the temperature drops to sixteen degrees, in spring and autumn had the nice climate Compared with two other seasons. Erbil city characterized by traditional style the courtyards houses had a good level of natural ventilation due to the courtyard space act like is an essential location inside the house.

The literature review demonstrated that some subjects were not studied including the effect of the solar radiation on the flat roof surface, and the heat loss and gain in traditional buildings through the windows area in hot dry zones.

In this research group of traditional courtyard houses in Erbil City have been studied. The first suggestion for study case studies using solar for collecting energy from the sun lighting, while at the same time, the functions of the panel as a shading device, it also has benefit for achieving a higher level of energy efficiency, the second suggestion is using a new glazing system for traditional houses.

The key result of the research is revolving for the roof and window areas in traditional courtyard houses in Erbil. Regarding the roof, the average of kilowatts that can be produced by solar panels on the roof of studied traditional houses in Erbil city is 200-kilowatt per one year for one square meter (kWh/year). Another benefit can be got is providing shadow on the roof in addition to protecting the environment by reducing emissions. However, solar panels could affect the cultural value of the facades if the level of solar panels is hight, and if the level of solar panels is low might affect using the roof by residents. Another subject is regarding glazing. The current single glass which used in traditional houses has low insulation. Whereas triple HR glazing has the highest insulation, it retains internal heat gain and loss about seven times of single glass which is used in traditional houses. However, with the new glazing system, the frame of the windows should be changed because of the different thickness and it may affect the traditional frames that used with the single glass type.

5.2. Limitations

It was under these constraints that the research was planned and implemented in order to not only address the existing problem but also to create a new strategy for traditional buildings via an understanding of the local climate and occupants' needs.

It is important to highlight some obstructions that affected the progression of this research and affected the initial stages, which are listed below;

I- The absence of energy data; the researcher had to build an energy model in Revit software to be used at the computer modelling stage. Forgetting the correct and accurate results.

II- Lack of research about traditional buildings that were built with a courtyard system in Erbil city.

5.3. Recommendations

From old time until this century Builders, designers, and Architects usually thought about suitable solutions that had the best environmental results. In the previous era of designing the designers took benefit of the different atmosphere and they used natural materials like wood, mud and dried clay.

Erbil is located in a hot dry zone the most ancient part of Erbil is the old citadel, it is containing a noticeable number of houses that follow the courtyard system of designing which is the best solution for dry hot weather places. This research focuses on two main points beside the courtyard system to obtain the highest level of energy efficiency.

Additionally, the adaptation configurations which exist in traditional architecture could be an inspiration for contemporary houses. Regardless of the old-style accommodation, the designs have been planned with great respect for the environment. Also, for the future design, this research recommends those points:

I. Erbil government encourage its citizens to use local building materials because they are natural and they have the heights insulation and they had no bad impact on the environment.
II. People of Erbil have to go back to using the courtyard system and their elements as the best environmental solution for hot dry zones.
III. Flat roof using for gaining energy to get the benefit from the sunny weather of Erbil at the same time the solar panels could be used as insulation to protect the roof from the solar energy
IV. To control the interior atmosphere would be better to use new insulated window systems like HR because most of the heat lost or gained with the outer environment.

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APPENDICES

APPENDIX 1 BUILDING INFORMATION MODELING

There is a common misconception that BIM means 3D design. In fact, it's much more. BIM is a process for creating and managing all of the information on a project, before, during and after construction. The output of this process is the Building Information Model, the digital description of every aspect of the built asset.

The use of BIM in construction and engineering is not new, but the rate of growth becomes clear when Designer looks at the number of BIM files stored on the Aconex collaboration platform. In 2009, fewer than 10,000 models were being managed on Aconex. By the start of 2013, clients were managing over 270,000 models – a growth of 2,600% in just three years. And it's not just that more project teams are adopting BIM. The size of the average model has almost doubled to 54MB over the past five years.

Doing BIM is much more than just model creation and using BIM software: communication and collaboration are equally important. The volume of information created and managed on BIM projects can create confusion if participants are not connected in a meaningful way. And like any construction or engineering project, a project that uses BIM requires an audit trail of every exchange, every decision and every approval point.

BIM is as much about process as it is about technology. When we think of BIM, we often think of better design coordination and improved constructability. But the real value can come after the handover when the owner or facility manager receives a complete and accurate set of information.

Even more than that, BIM provides a set of interrelated and cross-referenced information. For example, objects in the model are linked to related information including manuals, specifications, commissioning data, photos, and warranty details. This allows the owner or facility manager to efficiently and accurately manage the asset. Since 75% of the cost of a facility is incurred after the handover, it's clear that the benefits of BIM continue to accrue after design and construction have been completed.

For all its benefits, BIM brings new challenges around creating and collaborating on models:

Taking the model beyond the design team, The true value of BIM can only be realized when it is taken beyond the design team: to subcontractors, the owner and facility manager. Providing access to the model and allowing them to contribute and link other information are key.

Viewing the model (including in the field) – How can a subcontractor be given a view of a particular part of the model

Linking models to other data: A lot of project information, like drawings, RFIs and spec sheets, live outside the model.

Tracking approvals and audit trails: Models are generated by different authoring tools and constantly changing, making it difficult to obtain and record approvals. With hundreds of decisions made around the model during its life, maintaining an audit trail of who did what and when can be almost impossible.

Managing large file sizes: When BIM models can easily reach 50MB or more, distributing files securely and efficiently can be difficult, if not impossible. E-mail can’t handle the file sizes and FTP sites don’t provide the access control or audit trail.

Model management: Typically, people on a project work with different authoring tools. The BIM Manager then compiles and distributes the federated model. This might happen on a weekly cycle, which can be too slow for a fast-moving project. Allowing each party to contribute its model as needed, while others access the information in real time, makes BIM more valuable to everyone.

Dealing with long review cycles: Clash resolution usually takes place at set intervals, such as weekly or twice a month. But this creates a lag, where somebody addressing a clash has to wait for a whole cycle to complete before knowing whether it has been fixed or not. Immediate, real-time resolution of clashes is required.

Publishing slices of models: No matter how advanced 3D modelling is, there is still the requirement to publish, distribute and track the 2D plans which are needed for set-out and construction.

Archiving point-in-time models: Even when a 3D software package can track changes, there still needs to be a way to save point-in-time models for sign-off and approval purposes.

Handover of a complete and accurate model: Owners want to receive a full set of information to run their facility. And contractors and consultants want to be sure they have met their contractual requirements in order to get paid. So, understanding when this point has been reached is in everyone's interest.

Doing BIM is much more than just model creation and using BIM software: communication and collaboration are equally important. The volume of information created and managed on BIM projects can create confusion if participants are not connected in a meaningful way. And like any construction or engineering project, a project that uses BIM requires an audit trail of every exchange, every decision and every approval point. BIM is as much about process as it is about technology. (Aconex, 2018)

APPENDIX 2 AUTODESK REVIT & ENERGY ANALYSIS

Perform energy analysis on the building design through all stages, from the earliest conceptual phase through detailed design, to ensure that Designers are constantly working towards the most energy-efficient building possible.

Energy simulation can help Designer analyse the movement of energy in, out, and through the rooms and volumes in a building model. This information can help designers make better informed, cost-effective decisions that improve the performance and reduce the environmental impact of buildings.

Whole building energy simulation measures expected energy use (fuel and electricity) based on the building's geometry, climate, building type, envelope properties, and active systems (HVAC & Lighting). It takes into account the interdependencies of the building as a whole system.

Green Building Studio is Autodesk's core whole building energy simulation engine. This flexible cloud-based service uses the DOE2 simulation engine. It allows running building performance simulations to optimize energy efficiency and to work toward carbon neutrality earlier in the design process. Green Building Studio helps extend the ability to design high-performance buildings at a fraction of the time and cost of conventional methods.

Use Energy Analysis for Autodesk Revit to perform energy simulation for conceptual forms and detailed architectural models created in Revit. Use the simulation results to understand building energy use. Then iterate the designs to improve their sustainability ratings.

The energy model created from the Revit building model can be displayed in Revit, so it can view and validate the energy model used for analysis. The energy model can also be exported to third-party applications for further analysis in a variety of common formats: gbXML, DOE2, and EnergyPlus. (Autodesk, 2017)

APPENDIX 3 U-VALUE CALCULATIONS

A U-value is a measure of the rate of heat transfer through a structure, with a lower U-value meaning a better insulator. In terms of SAP assessments, U-values relate to all exposed:

Floors, Walls, Roofs, Doors, Windows, and Roof-lights

U-value information for openings (doors, windows and roof lights) will need to come from the supplier or manufacturer. In terms of glazed openings, the required U-value is that of the whole opening including the frame, and not just the glass itself.

For floors, walls and roofs, a U-value calculation is required to demonstrate the achieved value. These must be provided as evidence before an EPC can be lodged for a dwelling.

The U-value of an element depends on all materials contained within it. For example, with a cavity wall, this would include the plaster, plasterboard, blockwork, insulation, cavity and brickwork. Each of these materials will have a thickness and conductivity value, which combine to make a thermal resistance value. All of these materials' resistance values are added up to give the total thermal resistance for that element. Dividing 1 by this total resistance gives us the U-value. Therefore, a larger total resistance will give a smaller U-value, meaning less heat loss.

The thermal resistance of a material can be improved by making it thicker or by using a lower thermal conductivity. Therefore, when specifying insulation, a lower thermal conductivity will lead to a lower U-value for a given thickness of insulation. Most insulation boards achieve a conductivity of 0.020 – 0.022 W/mK but Kingspan's Kooltherm K100 range has a conductivity of 0.018 W/mK, allowing lower U-values to be achieved for a given thickness

Sometimes a developer will want to change the specified installation during the design. If the insulation being used has the same conductivity and thickness, it will achieve the same U-value and therefore not affect the SAP calculation. If either of these two things gets worse it's best to check with the assessor to see if it affects things.

In the figure appendix, 1.1 shows the example of what a U-value calculation looks like. The example is a cavity masonry

wall using full fill Celotex K106 insulation, achieving a U-value of 0.16.

Wall Construction								
		Main Element			2 Bridging Element		
No	Description	Thickness	1 λ	R-value	λ	R-value	Fraction
-	Internal Surface Resistance	-	-	0.13	-	-	-
1	Plasterboard Standard	12.5	0.21	0.06	-	-	-
2	Plaster Dabs Cavity (15 mm)	15	-	0.17	0.43	0.035	0.2001
3	Concrete Block (Low Density)	100	0.18	0.556	0.88	0.114	0.0667
4	Kingspan Kooltherm K106	90	0.018	3 5	-	-	-
5	10mm cavity	10	-	0.15	-	-	-
6	Brickwork Outer Leaf - BRE	102.5	0.77	0.133	0.94	0.109	0.1712
-	External Surface Resistance	-	-	0.04	-	-	-
		Σ=330mm		Σ=6.238			

Resistances		
Lower Limit	Upper Limit	Average
6.045	6.175	4 6.11 m²K/W

Wall U-value Corrections	
Corrective Description	Correction Value
Mechanical Fasteners	0.003
	Σ=0.003

Wall U-value	
U-value uncorrected	0.161
Total U-value Corrections	0.003
U-value	0.164
U-value rounded	5 0.16 W/m²K

Figure appendix 1.1: Ville project. (Buildenergy, 2018)

I. λ is the symbol for conductivity
II. Bridging elements are other materials that bridge the main element, such as mortar in the blockwork and brickwork
III. The insulation material make up the vast majority of the thermal resistance
IV. This is the total thermal resistance of all the elements
V. This is the calculated U-value

After finding that architects will calculate U-values themselves. Alternatively, the designer can request U-value calculations from the insulation manufacturer. An architect can use their online calculator if they have one or contact them directly such as (Celotex and Kingspan websites online calculators).

SAP Assessor should be able to carry out U-value calculations for the scheme if required. The designer will need to provide details of the materials used including thicknesses, make and model of insulation, and whether any insulation layers are bridged by other materials such as timber studs or joists.

Some further information:

These are the U-values used in the notional SAP assessment which determines the target CO2 emissions that designer need to meet for compliance. The designer should always aim to meet or improve these values or will need to be compensated elsewhere.

Floors: 0.13 W/m2K, Walls: 0.18 W/m2K, Roofs: 0.13 W/m2K, Opaque doors: 1.0 W/m2K, Half glazed doors: 1.2 W/m2K, Windows/glazed doors/roof lights: 1.4 W/m2K. (Energy, 2018)