ANKARA YILDIRIM BEYAZIT UNIVERSITY

GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

ANALYZING ENERGY EFFICIENCY: A CASE STUDY OF MOSUL - A COMPARATIVE EXAMINATION OF TRADITIONAL AND CONTEMPORARY ARCHITECTURAL STYLES

M.Sc. Thesis by

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M.Sc. THESIS EXAMINATION RESULT FORM

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2024, 5 November **Iman Salah Ismail AL KHALAF**

ANALYZING ENERGY EFFICIENCY: A CASE STUDY OF MOSUL - A COMPARATIVE EXAMINATION OF TRADITIONAL AND CONTEMPORARY ARCHITECTURAL STYLES

ABSTRACT

In recent years, energy and environmental issues have attracted worldwide attention. Irreversible natural disasters may occur due to uncontrolled use of energy resources and environmental pollution. The practice of energy conservation is an important part of the design and occupancy plans for buildings and strategies in general, as studies indicate that half of the energy consumed by humans takes place inside buildings.

Residential buildings are among the types of buildings that consume energy, the largest percentage of which is to provide thermal comfort through heating and cooling devices, which leads to the consumption of large amounts of energy, and from here the research problem emerged: *how to reduce energy consumption inside buildings in Mosul?* One of the most effective and accurate ways to actually calculate and model energy in buildings before construction begins is through the universal use of computer simulation programs. The aim of this study is to present a detailed presentation of the basic features of traditional houses in the city of Mosul, as it examines building plans, features of the outer shell, materials used and construction techniques, and to find out which traditional or contemporary building strategies are more energy efficient by using Autodesk Revit and Green Building Studio programs to compare energy consumption, cost, lighting, ventilation, and annual CO_2 emissions for traditional and contemporary buildings, as the research indicates the importance of building energy modeling before starting the construction process to know the amount of energy needed in the building. The results of modeling showed that traditional buildings use less energy and cost less across a range of criteria than contemporary buildings. Hence, the ideal technologies for residential buildings are determined and a guide is reached on the design of environmentally friendly residential buildings in the city of Mosul.

Keywords: Energy efficiency, environmental sustainability, traditional vs. contemporary buildings, thermal comfort, energy consumption, building energy modeling, computer simulation programs, Mosul.

ENERJİ VERİMLİLİĞİNİN ANALİZİ: MUSUL ÖRNEĞİ ÇALIŞMASI - GELENEKSEL VE ÇAĞDAŞ MİMARİ TARZLARIN KARŞILAŞTIRMALI İNCELENMESİ

ÖZ

Son yıllarda enerji ve çevre konuları dünya genelinde büyük bir ilgi odağı haline gelmiştir. Enerji kaynaklarının kontrolsüz kullanımı ve çevresel kirlilik, geri dönüşü olmayan doğal afetlerin meydana gelmesine yol açabilmektedir. Enerji tasarrufu uygulamaları, bina tasarımı ve iskân planlarının yanı sıra genel stratejilerin önemli bir parçası olarak öne çıkmaktadır. Araştırmalar, insanların tükettiği enerjinin yaklaşık yarısının binalarda harcandığını göstermektedir.

Konut binaları, enerji tüketiminde önemli bir paya sahiptir ve bu tüketimin büyük bir kısmı ısıtma ve soğutma cihazları aracılığıyla termal konfor sağlamaya yöneliktir. Bu yüksek enerji tüketimi, araştırmanın temel sorusunu oluşturmuştur: *Musul'daki binaların enerji tüketimi nasıl azaltılabilir?* İnşaat öncesinde enerji tüketiminin doğru bir şekilde hesaplanması ve modellenmesi için bilgisayar simülasyon programlarının kullanımı, dünya genelinde yaygın ve etkili bir yöntemdir. Bu çalışmanın amacı, Musul'daki geleneksel evlerin temel özelliklerini detaylı bir şekilde incelemek ve bina planlarını, dış kabuk özelliklerini, kullanılan malzemeleri ve yapım tekniklerini analiz etmektir. Aynı zamanda, geleneksel ve çağdaş bina stratejilerinin enerji verimliliğini karşılaştırmak için Autodesk Revit ve Green Building Studio programları kullanılmıştır. Araştırma, enerji tüketimi, maliyet, aydınlatma, havalandırma ve yıllık CO_2 emisyonları açısından geleneksel ve çağdaş binaları karşılaştırarak, inşaat sürecine başlamadan önce bina enerji modellemesinin önemine vurgu yapmaktadır.

Modelleme sonuçları, geleneksel binaların birçok kriter açısından çağdaş binalara göre daha az enerji tükettiğini ve daha düşük maliyetli olduğunu göstermiştir. Bu bulgular doğrultusunda, konut binaları için en uygun teknolojiler belirlenmiş ve Musul şehrinde çevre dostu konut binalarının tasarımı için bir rehber geliştirilmiştir.

Anahtar Kelimeler: Enerji verimliliği, çevresel sürdürülebilirlik, geleneksel ve çağdaş binalar, termal konfor, enerji tüketimi, bina enerji modellemesi, bilgisayar simülasyon programları, Musul.

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NOMENCLATURE

CO_2	Carbon dioxide
BIM	Building Information Modelling
KW/h	kilowatt-hour
UN	United Nations
BEM	Building Energy Modelling
GBS	Green Building Studio
gbXML	Green Building Extensible Mark-up Language
PV panels	Photovoltaic panels
IFC	Industry Foundation Classes
DOE	Department of Energy simulation engine
TRNSYS	Transient Systems Simulation
IES-VE	Integrated Environmental Solutions - Virtual Environment
QUEST	Quick Energy Simulation Tool
Bep-Tr	Building Energy Performance - Turkey
m^2	Square meters
cm^2	Square centimetres
3D	3 Dimension
HVAC	Heat Ventilation and Air-Conditioning
GUI	Graphical user interface
2D	2 Dimension
CAD	Computer Aided Design
DWG/DXF	Drawing /Drawing Exchange Format
ASHRAE	American Society of Heating, Refrigerating and Air Conditioning Engineer
CBECS	Commercial Buildings Energy Consumption Survey
TRACE	Trane Air Conditioning Economy
MWh	Megawatt hours
USD	United States Dollar
MJ	Megajoule
L	Liter

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Technological developments after the industrial revolution have led to an increase in the production speed in all areas of life. With these developments, our living conditions have completely changed. The most important factor in the change in our living conditions is due to the fact that our consumption habits are increasing more and more every day with the increase in the production rate. With this increase and the increasing population over the years, energy demand has reached higher levels than ever before today. In the International Energy Outlook report published by the International Energy Agency, it is estimated that the current amount of energy consumption will be 28% higher by 2040 due to the increasing need for energy [1]. In an environment where energy consumption is so high, natural life becomes endangered. The irreversible damage caused to the environment during the consumption process and the fact that limited resources are increasingly being depleted have led to the need for every individual to do his/her part in the field of energy. For this reason, people are searching for sustainable solutions in all areas of life [2]. The constructed environment is an important component of climate change. One of the most critical issues discussed recently is sustainable construction. The main goal of sustainable energy is to decrease the environmental effect of buildings and increase their efficiency to provide better living conditions for future generations. So, it is necessary to conserve energy in a more appropriate way, use natural resources and manage waste, particularly after changes in temperature, increase in carbon dioxide in the environment and variation in rainfall cause a lot of changes in natural woodlands, thus, it results in many Irreversible harm to human health [3]. Also, buildings are a major source of global warming gas emissions, buildings have received a lot of local and state regulatory concentrate. This concentrate on buildings is the result of statistics which show, for example, that buildings use 39% of the total amount of energy in the United States [4] [5]. Also, 72% of the country's electricity, while it produces 39% of global warming

gas emissions in numbers and buildings are responsible for more greenhouse gas emissions compared to transportation or industry [6]. Also, the growing shortage of oil in the world has made the world move towards sustainable development and the use of renewable energies [7]. Energy efficiency is significant for the energy use in the residential sector [8].

Due to this energy consumption in the construction sector, studies are being carried out to use energy more efficiently and avoid unnecessary energy consumption. The common goal of the approaches in these concepts is to employ energy in the most effective manner, with the least harm to the environment, at all stages of the building, starting from the design process and including the period during its use. Energy consumption in buildings occurs mostly to provide comfort conditions that affect the interior such as lighting, heating, cooling and ventilation. Energy consumption is also very important in issues such as construction, maintenance and raw material supply in the life cycle of the building [2]. One of the factors that increase the energy consumption of buildings is the design of the building envelope. The building envelope is the element of the building that may experience the most energy loss.

Buildings consume energy in five phases: production of materials used in buildings; transportation of materials to building sites; construction of buildings; construction procedure; and finally, the demolition of buildings [9]. [10] confirms that for energy-producing buildings to be successful, they must reflect local conditions that they are rooted. Such design strategies used in traditional architecture reduce energy needs [11]. A lot of studies have shown that energy efficiency is achieved much simpler and more cost-effectively if buildings are taken into account at the planning and design stage rather than retrofitting buildings later [9]. Therefore, analysis programs can view the energy performance of buildings before they begin construction or existing buildings, and from here engineer or the architect can choose the most appropriate for the project. Hence the importance of modeling and these programs to detect errors from the beginning [12].

This research aims to compare traditional and contemporary buildings in Mosul city in terms of building strategies, energy consumption, cost, annual carbon dioxide emissions, lighting and ventilation using computer programs to finding a clear

mechanism for constructing residential buildings in a manner that ensures energy saving, user comfort, and applying the principles of environmentally friendly architecture.

1.2 The Research Goals

1. Study and knowing which of the traditional or contemporary building strategies is more energy efficient.
2. An indication of the importance of building energy modeling before starting the construction process to know the amount of energy needed in the building.
3. Finding a clear mechanism for constructing residential buildings in a manner that ensures energy saving, user comfort, and applying the principles of environmentally friendly architecture.
4. Determine the ideal technologies for residential buildings and come up with a guide about designing environmentally friendly residential buildings in Mosul city.
5. Through the comprehensive overview provided by the researcher, the research hopes to expand the understanding and awareness of the scientific community about the impact of design and construction choices on energy consumption in residential buildings. The research is also expected to make a valuable contribution to the field of architecture and environmental sustainability, enhancing ongoing efforts to develop more energy-efficient building methods and less environmental impact in Mosul.

1.3 The Importance

The importance of the study is the real need to model the structural energy of buildings in the initial construction stages and determine strategies for the effective use of energy based on which residential buildings are built to achieve the principles of environmentally friendly green architecture in Mosul city.

If the results are accepted, this research is expected to have a Significant effect on Mosul's residential developments as it provides an understanding of the impact of present building practices on home energy consumption in Mosul city. Further, it highlights the significance of effectively reducing occupants' residential energy

consumption. The research could help urban civil engineers make smarter design choices and develop housing projects that use less energy. The findings of this research may also help people become more aware of the employ of energy-efficient devices.as well as it can be used as the basis for building and land growth codes, to ensure energy conservation in future housing units and therefore sustainable development.

1.4 Research Questions

1. What is the goal of a study that aims to learn more about energy management in buildings, and how were the specific tasks scheduled to achieve this goal?
2. What is the difference between traditional and contemporary construction strategies and what are the advantages of each?
3. How can we evaluate the energy performance of traditional buildings compared to contemporary buildings, and does one emerge as the better choice from an environmental and economic standpoint?
4. What are the tools and programs used to evaluate the energy performance of buildings, especially with a focus on those programs that contribute to determining environmental efficiency and analyzing energy consumption in urban structures?
5. What are the optimal techniques and strategies for designing energy-efficient, environmentally and user-friendly buildings?

Why was the current housing structure chosen for the thesis work?

The residential structure was chosen for the thesis study because the number of users of residential buildings significantly exceeds other buildings, and this is accompanied by a greater amount of energy consumed during the day and higher waste formation. Ensuring users' comfort requires thinking about improving energy efficiency.

In order to improve energy efficiency, it becomes necessary to perform energy performance modeling to understand which building strategies consume less energy. This analysis is essential to comply with energy conservation standards and regulations.

Overall, this selection provides an opportunity to examine the methods and technologies used in construction and determine how best to achieve a balance between human comfort and energy efficiency. The findings from this study are encouraged to be used to guide future designs towards sustainability and reducing energy consumption in the housing sector.

1.5 Problems

1. Global warming and climate change, which are important threats today. In the 1990s in particular, people's environmental awareness began to increase around the world and studies on energy efficiency increased [13]. Energy loss and thus energy consumption increase in buildings built in periods when energy awareness is not developed. One reason for this energy loss is that building techniques in years past were not as advanced as they are today. Making energy efficient improvements to these buildings that are still in use is just as important as building new energy efficient buildings.
2. As a result of the modern society of the age turning in the direction of global and present trends, the designs and principles of vernacular design has been negatively affected. New building environments are being developed through the use of new materials. Architectural images lack the existence or transformation of ancient pearls of contextual and wisdom approaches [14]. Also, modern luxury and personalization are gaining more importance currently [15,16] despite of energy menaces. However, today there are many exemplary local dwellings all over the world to learn from. Modern buildings have extremely high energy request. Buildings require not just the materials (embodied energy) however also large amounts of electrical energy to get thermal comfort inside. These modern structures use environmental energy sources without slowing down to improve indoor comfort and living conditions. These are used to meet construction, cooling, heating, water needs, lighting and do not include emission shares. Emissions should be reduced in environmentally friendly methods. Therefore, there is a significant relationship among the rise use of energy in contemporary buildings and the damage caused to the environment.

3. Lack of use building performance simulation applications in initial design stages results in decreased energy performance of the building. This leads energy simulation specialists to study the energy use of construction elements in later design phases after major modifications are difficult to make. This is why residential units should receive a lot of interest to be buildings with excellent performance because they are used most of the time [17].
4. Despite the existence of these studies, there are engineers and architects in Mosul who find that the problem with the buildings in the city of Mosul not approaching the limits of thermal comfort is due to a gap in the availability of special data and information to help the designer make his buildings responsive to the climate to improve the efficiency of thermal performance and reduce energy consumption.

The research tries to find a solution to these problems by using the energy element as one of the important elements in the study environmentally sustainable design by using the Revit program.

1.6 Limitations

1. This work is limited to energy modeling in residential buildings in the city of Mosul, focusing on both traditional and contemporary buildings. This work includes analyzing the consumption and utilization of energy in these buildings, with a focus on comparing traditional and modern methods of construction and building design.
2. The researcher relies mainly on data derived from the use of advanced computer programs, including the Revit program, which contributes to modeling buildings in three dimensions, and the Green Building Studio program, which allows analyzing the impact of buildings on the environment and estimating energy consumption. These computer tools are essential tools for analyzing and evaluating the environmental impact and sustainability of the buildings studied in Mosul.

CHAPTER 2

LITERATURE REVIEW

2.1. Literature Review

2.1.1 Energy Based Studying in Iraq-Mosul

Definition of Energy In general terms is a tool that ensures the continuation of life in the comfort conditions we are accustomed to and responds to people's daily activities and needs such as heating, shelter and transportation. Basic energy resources are divided into two main headings: limited resources such as coal, oil, and natural gas, and unlimited resources such as water, wind, and sun [18]. While energy efficiency is the reduction of energy consumption per unit amount of service or product without causing a decrease in the standard of living and service quality in buildings or in the quality and quantity of production in industrial enterprises [18]. As for energy performance in buildings is the amount of energy envisaged in new buildings and measured in existing buildings to meet standard needs such as heating, cooling, ventilation and lighting, depending on the function of the building [19].

Many researchers have begun to focus on practices and operating models to reduce the energy consumption of buildings. According to [20], it is important to estimate the energy consumption of a building in order to plan, manage and conserve energy. Estimating energy consumption based on the physical attributes of the building, outdoor weather conditions, installed equipment and the energy use attitude of Residents of the building [20]. The use of electricity and petroleum products in residences has increased recently in Iraq. Additionally, the building strip, especially the residential strip, accounts for a significant portion of total energy use. As residential buildings account for 78% of energy consumption in Iraq [21].

Increasing global warming along with the depletion of clean water resources and natural resources has also affected the construction sector. The construction sector started to build more environmentally friendly, sustainable structures and ecological

buildings due to these passive elements. According to the World Energy Council, the energy efficiency means lowering the energy consumption amount in any living activity [22]. The advancement of technology, better management and structuring, and greater public awareness can help reduce the amount of energy [23]. Energy efficiency means using less energy for a business or the same amount of production, or theoretically increasing production by using the same level of energy without sacrificing the quantity and quality of production [24].

Due to the greater heating needs brought on by the present weather in northern Iraq, especially Mosul, the simulated model in Mosul indicated a higher primary energy use of 104.49 kWh/m²/year [25].

According to the finding of BIM Application, a typical residential unit consumes a rate of 2500-3000 KW/h of energy per month for overall applications like cooling, heating and lighting. Traditional Iraqi planning strategies do not include practical measures that can respond to the needs of sustainable construction solutions [26]. As a result, the use of BEM provides a decision-making evaluation tool that can help choose more sustainable long-term options when making plans.

Iraq is among the countries that enjoy huge wealth of types of renewable energies, as it does not exploit any of them despite their availability, as it relies heavily on oil and natural gas [27]. In Iraq, there are many stations that produce energy, for example in Mosul, there is the main Mosul Dam station, which is considered the largest dam in Iraq and is located on the Tigris River in northern Iraq, and the fourth largest dam in the Middle East, as its production before 2016 reached (1,875,713) megawatt/hour, likewise, the Mosul Regulatory Dam station reached its production capacity (311,038) megawatt/hours in 2017 [27]. Iraq's electricity consumption has more than doubled since 1990, reaching nearly fifty terawatt-hours by 2018 [28].

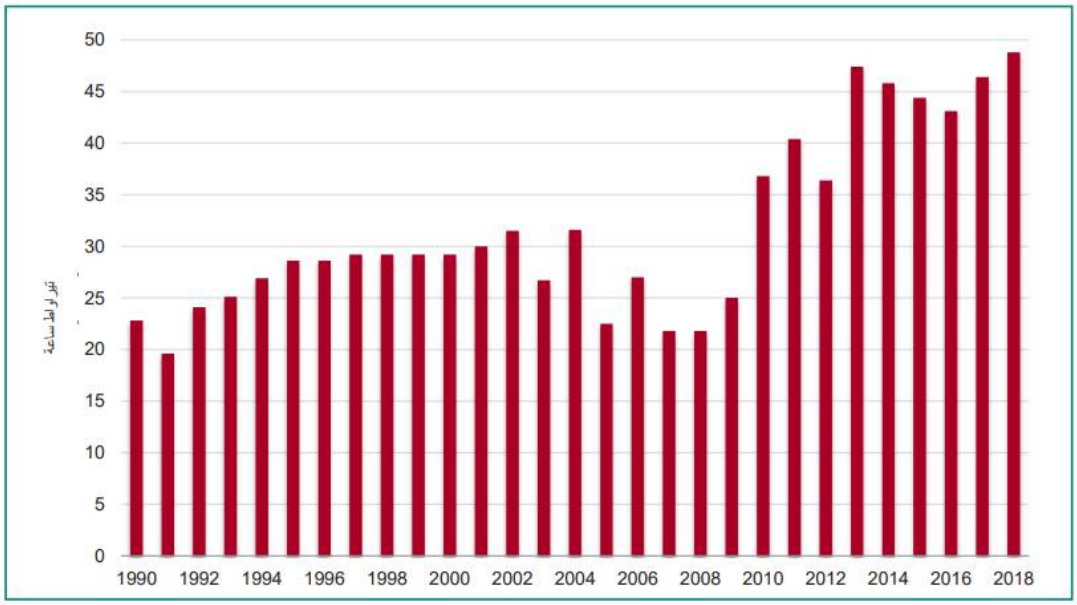


Figure 2.1 Electricity consumption in Iraq during the period 1990-2018 [28]

Iraq is considered a developing country dealing with international problems and where pollution increases due to misuse of energy. Due to Iraq's high oil income as other Gulf nations and the fact that the structure was not built in line with the environment or the traditional Arabian architectural legacy, which features effective design and construction techniques. The problem of energy shortage, known as power outages in Iraq in recent years due to increasing consumption rates, makes it necessary to emphasize the importance of green design practices and the role they play in the development plan [29].

The energy performance of buildings is affected by a number of factors such as structure, weather conditions and physical characteristics (orientation, shape, occupancy, building envelope, etc.) [17]. As a result, estimating energy consume in buildings is critical for assessing energy performance to save energy and decrease environmental effects for sustainable architecture goals. Additionally, energy efficiency can be defined as “using less energy to complete the same mission” or “Elimination of energy waste” [30]. These terms "energy efficiency”, "energy efficiency modelling" or "energy efficient building" are largely related to the concepts and goals of sustainable and bioclimatic architecture by reducing the need for energy

imports, reducing emissions of greenhouse gases and reducing the costs at the household and economic levels [30].

2.1.2 Comparison Between Traditional and Contemporary Building in Iraq

Buildings is considered one of the three largest uses of energy in addition to industry and transportation, are crucial to reducing greenhouse gas emissions in the sector [31].

Buildings consume a lot of primary energy once built. A building built without thinking energy efficiency wastes energy for several decades [31,32].

In a report by UN-Habitat, it was stated that in Iraq, the current building laws lack sufficient environmental and sustainable standards that save energy use in buildings, as this phenomenon is common and most countries in the Middle East suffer from it [33]. Insulation and Thermal mass are important problems to consider in traditional dwelling in Iraq in terms of climatic conditions [17].

The ascertaining factors in traditional house construction are both the explicit and implicit socio-religious also socio-cultural rituals and beliefs that specify what is not okay socially and what is really [34]. In traditional houses in Iraq, true privacy can be implemented in cantilevered sections (shanashil), that represent physical parts which help ensure the privacy of their users [35]. It is intended for women in particular in order to ensure the idea of separation between the gender and visual communication with everyone outside the house or guests inside the house without anyone seeing them except those from the same family. Additionally, the elements of "shanashil" provide unlimited interaction between women living in neighboring dwellings [36]. Every house demonstrates the private realm on different levels in terms of social groupings, privacy dynamics, and used techniques.

The appearance of this relationship and its various transition places tend to change more over time [37]. The house has many private and public spaces that show various activities that take place over time. There are multiple physical boundaries that form the thresholds between the outer alley and the public domain associated; it also includes the semi-public space of the house shown at the entrance [38]. The political and economic changes that have occurred since the early 20th century and specifically

after the oil economic growth in Iraq in the 1970s have influenced social and cultural patterns and patterns of behavior within the home. New principles and values, controlled by political and economic forces, have emerged as key determinants of domestic life due to the travel of the people from rural regions to urban regions and the resulting high level of need for new settlements in many Iraqi cities. and influenced the hidden aspects of society respectively [39,40]. The lack of cultural and social elements is a significant weakness in domestic architecture [41]. The new method creates an outward-facing house pattern, like a villa pattern, in the center of the individual plot. Opening private spaces to the outside facilitates unrestricted access and reduces the cultural and social function of privacy. The concept of social space in contemporary units is vague and unclear. The perception of the family social area as the main combined activity area is limited by the division of the internal space of the house into different enclosed areas that perform specific tasks. (e.g., kitchen, bedrooms and dining rooms, etc.). A few architectural methods have a traditional and old look like the terrace on the first floor is closed with light-weight cover materials to prevent visual interference from adjacent or opposite houses and to obtain additional space. These architectural approaches reflect the idea of "shanashil" [36].

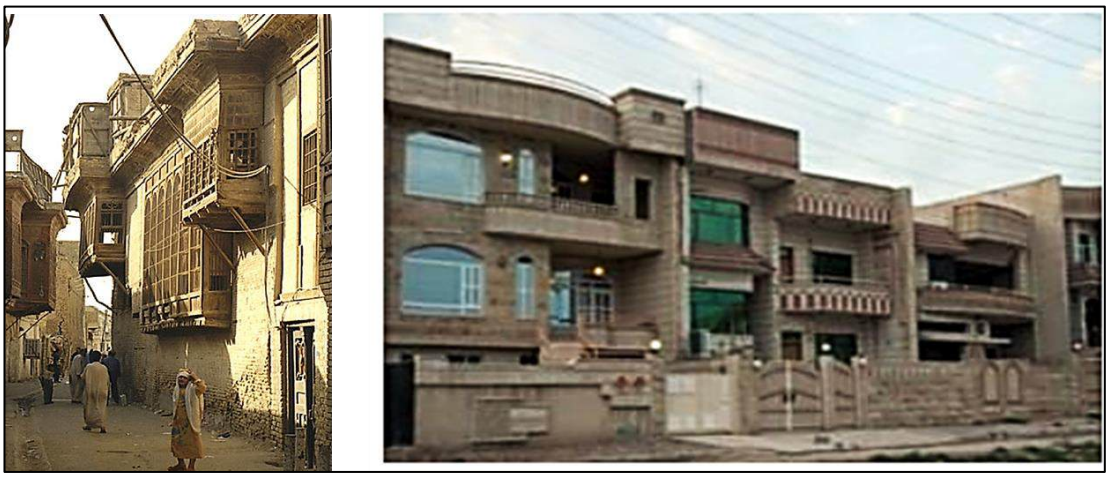


Figure 2.2 Traditional and contemporary buildings in Iraq

2.1.3 Vernacular Architecture in Mosul

Climate was treated as the beginning point for local building design; this led architects to take into account not only construction practices and forms, but also cultural values.

A process of trial and error over centuries has succeeded in developing “vernacular” design solves which are aesthetically, culturally and climatically appropriate [42].

Our ancestors were adept at manage climatic conditions in buildings at a time when a mechanical system had not yet been invented. Vernacular architecture is a designing architecture depend on interrelationships between economic, material, ecological, social and political factors [43] and supplies a good solve to climatic restrictions.

The Old City of Mosul has a famous and rich architectural heritage in terms of architectural, technical features and decorative and has gone through various urban phases throughout various historical periods [44]. In Mosul Old City, the concept of grouping units and thick fabric at the urban level is used in vernacular housing architecture. It is embodied by the traditional unit, which described by its rich ingredients and numerous aesthetics, architectural elements and showing the supreme fabric of the Town [45].

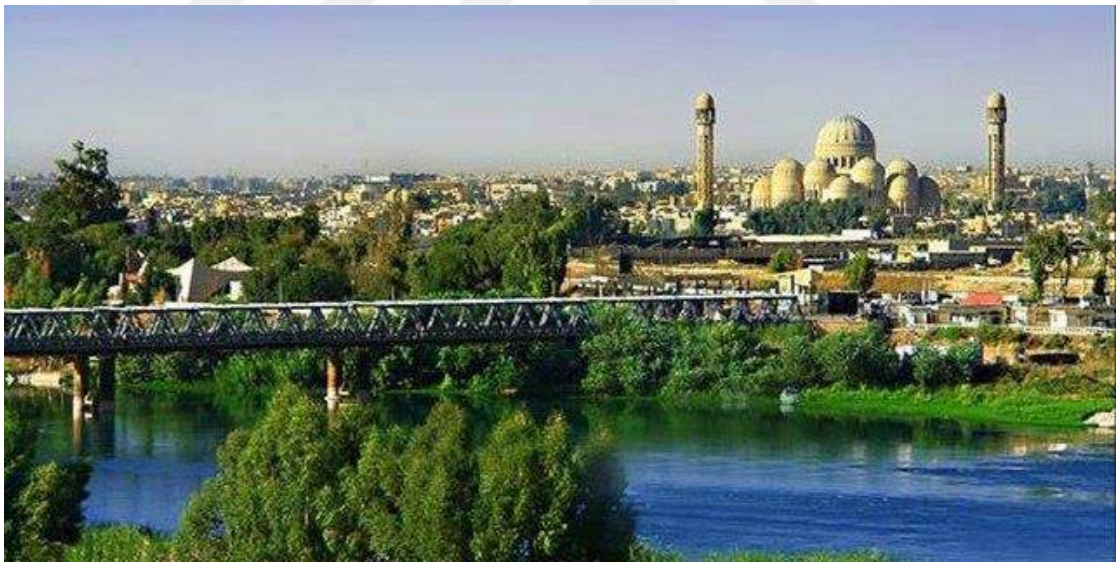


Figure 2.3 Mosul city

The basic characteristics of the Mosul house over the past centuries and before the process of modernization that took place in traditional housing in the past century share the characteristics of the prevailing houses within the regional scope, which are characterized by the stability of natural and climatic characteristics, as well as the similarity of cultural, economic, religious and social factors etc. [46]. The old city of

Mosul has a group of monuments and buildings distinguished historical architectural value, which represents a part whatever the identity of the city and its culture [47]. The urban fabric of the traditional Mosul city consists of 38 residential quarters, with an area of 300 hectares, the ancient city preserved various urban land uses, including residential, commercial, recreational, educational, public services, religious, baths and khans [48].

The residential shops in the old city were characterized by narrow and winding alleys surmounted by many arches (Qantara) opening into the old houses, and these traditional architectural styles were inspired by the ancient Iraqi architecture [49]. The use of the basement, galleries, iwan, and shanshool in the urban design of the Mosuli house reflects the geographical importance of the environment in mitigating climatic effects such as solar radiation and temperatures, in order to adapt the environment of the Mosuli house to it according to the seasons of the year [48].

Regarding the building materials for the dwelling, plaster, alabaster, and stone are among the basic materials in building the general structure of the Mosul house. The walls are built with cement and plaster, and the foundations are made with the same material, with (alnuwruh) added to it. Likewise, (the arch), white is added to the plaster along with the kharshan, which is also the old building plaster. It is kept after demolition (as it is lighter than stone). As for alabaster, entrances, columns, arches, stairs, paving, and walkways are made from it, and it is usually in places that are not exposed to weather factors, especially rain, in contrast to Al-Halan stone, which is used instead of alabaster in open places, such as paving the courtyard of a house, or materials that are exposed to water, such as (the courtyard floor) [46].

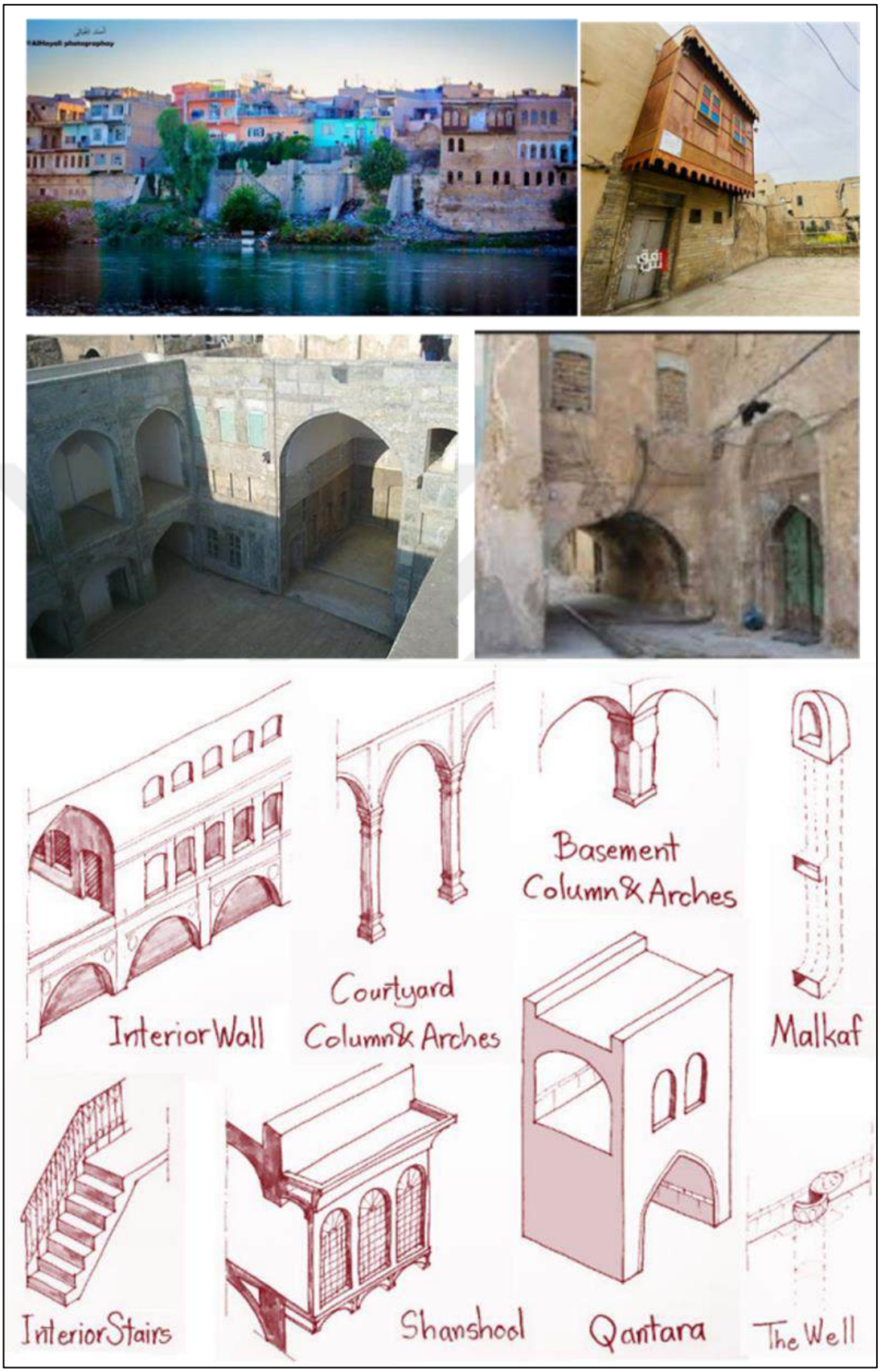


Figure 2.4 Examples of the physical architectural elements of the traditional house in Mosul city [50]

Currently, houses are being built in the city of Mosul influenced by the Western style characterized by surrounding residential homes with external gardens, which was encouraged by social and economic change, the improvement of modern construction techniques (concrete), and the growth of their area, which caused the dispensation of traditional building methods and materials and the disappearance of some architectural components such as the courtyard and the iwan, and the adding of new architectural components such as car garages and balconies, which caused a change in the relationships between the architectural elements in the Mosul house [51].



Figure 2.5 Example of modern house in Mosul city

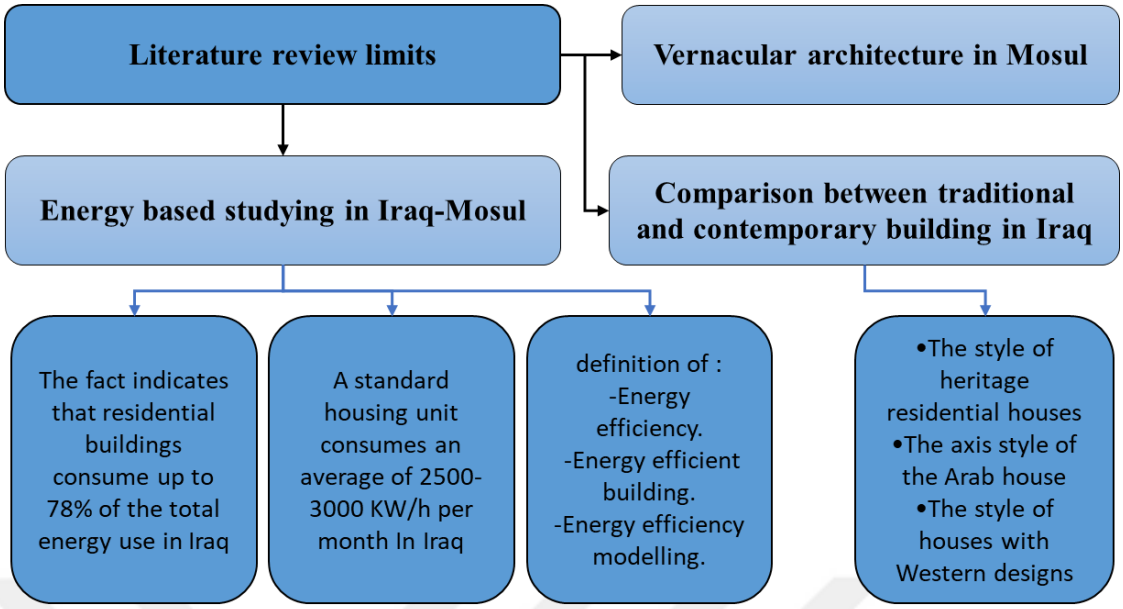


Figure 2.6 Literature review limits (Source: Author)

2.2 Related Research

[52] after conducted a comparative study between traditional and modern construction methods for housing in Siwa Oasis, Egypt, with the advantages and disadvantages of both, he proposed a building technique that combines the advantages of modern and traditional construction in a way that respects the environment, at a lower cost, and is more durable. The study by [53] focuses on identifying local architectural features that contribute to energy saving and improving thermal comfort to adapt these local features to modern features. The study concerns architectural features and the use of vernacular materials to improve thermal comfort in modern units around the world. [54], “Energy Efficient Design Strategies in the Hot Dry Area of Turkey.” In their study titled, they compared 100 traditional and modern houses in Mardin. As a result of the study, they emphasized that the performance of traditional houses is better in terms of thermal and spatial comfort than today's houses.

[55] pointed out that the environmental impact, economic dimension and user comfort of residences, which constitute approximately 50% of the energy consumption, must be taken into consideration before they are built. With the advancement of technology, BIM software is developing rapidly, providing more accurate results, and the number

of individuals using these programs is increasing. His study was prepared by integrating GBS with Autodesk Revit 2017 software. The effects of the parameters affecting building energy performance such as orientation of building, transparency ratio also thermal insulation materials of the external wall on a currently used pattern were checked with BIM and design of alternative was created by taking into account the analysis outcomes. It has been shown that it is possible to perform energy analyzes with building information modeling applications for a structure that is at the design stage or has been implemented, and that the validity of these analyzes can be ensured.

Using the Design Builder program, [56] examined the performance of energy in contemporary and traditional buildings in Iran. Since the walls of contemporary buildings are uninsulated and not thick as looked at traditional buildings, their yearly energy performance drops significantly. Additionally, although the physical thermal characteristics of window glass are the same in two buildings, heat move via the window varies between buildings according to ratios of window-to-wall. As a result, more energy is used for heating, ventilation and cooling as modern units in Tabriz, Iran are being structure without studying conditions of the climatic. This causes greenhouse gas emissions to rise and pollutes the environment. While the result of the analysis of the energy efficiency of the traditional building was less compared to the modern building, because the traditional methods, including thick walls and the small size of the windows, all constitute thermal insulation and thus consume less energy than modern methods.

[57] research addressed one of the aspects related to the concept of sustainable architecture, which is the issue of energy. The study addressed the hypotheses of the traditional residential system as a good model for achieving sustainability characteristics, and energy consumption within the residential system affects the characteristics of the spatial organization of this system. The important sustainability impact appears to be related to energy consumption and hence this limit has been used in possible forms. The thesis includes a widespread reference to achieving sustainability in relation to energy and multiple forms of consumption and their relationship to the characteristics of spatial organization. As a result, the research problem was represented by (weakness of modern functional solutions to control for

energy uses at border of sustainability). Final conclusions are discussed the importance of energy topic in sustainable architecture and the necessity of dealing with traditional forms – despite many problems it suffers from – it is the real representation of the reality of the society and the nature of its individuals.

The study by [58] analyzed the effects of parameters of historical houses on people's thermal comfort and energy use compared to new houses in Umm Qais. This analysis examined a variety of factors, from construction materials, window size to wall area, wall thickness. It was concluded that the passive design approaches in vernacular buildings is considered more efficient than the approaches used in modern buildings. It was also found with regard to the heating load that the modern dwellings had the highest load, amounting to 9,571 (Watts), that is considered 50% higher from the vernacular three-space dwellings, even the dwellings have the same interior space. Also, the cooling load of a modern building is thrice higher than a vernacular three-space building. The monthly electricity and fuel use for all kinds of building was also examined. The results found that modern residences use more electricity and fuel than vernacular residences. The main responsible for cooling and heating loads are the walls. In vernacular housing the walls are made of natural stone and clay as the coefficient of heat loss is very low and thus leads to reduced cooling and heating loads in building.

[59] conducted an energy analysis of the building under continental climate conditions and studied ways to transform it into a green building. The existing building project was designed with the help of architecture simulation software Autodesk Revit 2021. Building energy modeling was created for 162 alternative building scenarios by incorporating common and alternative building insulation materials with different thermal and physical properties into the model building. These alternative scenarios were saved in gbXML file format and analyzed in terms of energy performance according to the scenarios designed with the help of Autodesk Green Building Studio software. For each alternative scenario, outputs parameters such as total annual energy consumption, energy consumption amounts according to places of use, CO2 emissions emitted by the building, energy use intensity etc. It was received. In addition, the energy required for the alternative scenarios is supported by solar energy. In order to

meet this, the annual energy production and payback period of the system that could be achieved if mono-crystalline, polycrystalline and thin-film PV panels were used were analyzed. Finally, among the alternative scenarios, the exterior wall was decomposed into the “most positive” and “most negative” alternatives for each wall type according to the electrical energy consumption of the building to be transformed into a “green wall” form. By mutually evaluating the results through design criteria, an attempt was made to identify the most viable design in terms of energy efficiency.

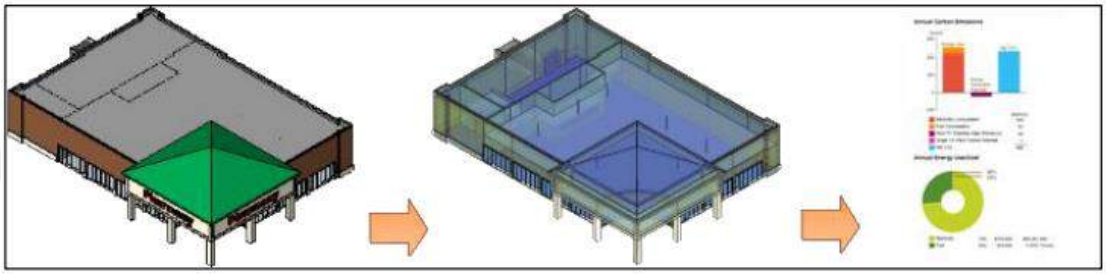


Figure 2.7 Stages for energy analysis of a building [59]

[22] energy efficiency has become an important issue as a result of the decline in resources of energy and the negative impact of basic energy resources to the surrounding environment. Improving the energy efficiency of buildings is becoming more popular around the world. Countries are constantly using new technological advances in their energy systems to decrease environmental harm like global warming and decrease costs. This study discusses energy modeling of buildings. The study found that Green Building XML (gbXML), Industry Foundation Classes (IFC), BEM and BIM building modeling methods form the basic standards of data formats. Computer Helped Building Information Modeling (BIM) methods have become more efficient for constructing and designing buildings. BEM can provide more trusted results during the design operation and best energy efficiency effects than manual calculations by designers. In conclusion, this study revealed how important BEM founded on Building Information Modeling is for energy efficient design of building and enhancement of existing buildings and proposed BIM/BEM, which is the most common and recognized option. Building energy simulation can be done using a variety of tools such as DOE-2, Energy Plus, TRNSYS, Revit, Archibald, Green

Building Studio, IES-VE and e-QUEST. From now on, numerous parameters will be determined to create a model and calculate the cost of yearly energy of the building.

[18] investigated the necessity of developing the Energy Performance Calculation Method in buildings. For the study, he created 8 scenarios according to 5 variables (transparency ratio, ambient temperature setting, south-facing edge, single or 4 zone criteria, calculation method) using the Building Energy Performance Calculation Method - Turkey (Bep-Tr). He continued the study by comparing the heating and cooling needs of these industries. As a result, he has shown that the distribution of solar gain should be provided according to the shape and dimensions of the building, and the results found in 4 zones of the floor according to the directions and surface lengths with Bep-Tr are close to the results calculated by Energy Plus software.

In his research, [60] has prepared the integration with a comparative study of Autodesk GBS to investigate the effects of building information modeling on energy use, carbon emissions and life cycle energy cost of an elementary school. For this purpose, reviews have been conducted to disclose the sustainable benefits and lifetime cost of buildings through BIM. He concluded from his studies and emphasized that the analyzes of energy modeling should be incorporated into the conceptual design of building projects at an early point. He reported that the early analyzes of energy modeling will give an opportunity to make cost decisions at the beginning of the building's life cycle, to model building information and to achieve energy savings through the use of GBS.

In 2014, [61] presented Autodesk Green Building Studio, which is a building analysis program. Based on an actual model, weather data and local energy sources, this software provides information on energy use, including carbon emissions, natural ventilation possibilities, costs and water usage. He carried out his work on a 279 m^2 villa simulated in Revit program. Thus, the best energy efficient, sustainable design is recommended for future projects. Among the results of his study, he stated that GBS is a very useful and powerful tool that works under true criteria also provides very reliable results.

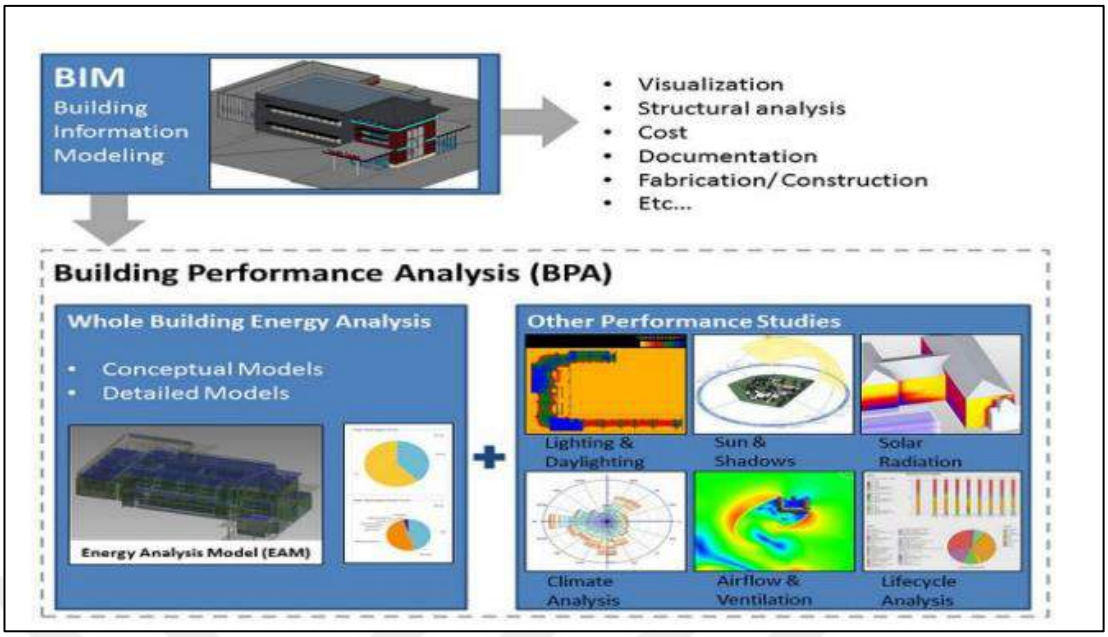


Figure 2.8 Main structure of building performance analysis [61]

Although these programs cause the design phase of the building to be prolonged, they provide a significant advantage in terms of foreseeing difficulties that may arise later. For this purpose, with building energy modeling applications, a comparison was made between traditional and modern houses located in Mosul according to the construction strategies, the variables of orientation, glazing ratio, wall materials used, their thickness, and CO_2 emission values to study the amount of energy consumed in houses. In this study, 3D models were made using Autodesk Revit and energy analyzes were obtained using Green Building Studio (GBS).

2.3 Energy Efficient Building

2.3.1 Energy Efficiency and Sustainability

While energy is an indicator of social development on a state scale, it is also the most important tool that enables people to meet their basic needs as individuals. Energy, which is an important economic power element in today's conditions, directly affects the communication between countries. Economic development depends on the sustainable use of energy. For this reason, sustainable approaches are being considered in order to meet the increasing energy demand from limited resources [62].

During the energy crisis that manifested itself all over the world in 1973, the concept of "less is more", which emerged with Modernism, became dominant as an architectural style. In this understanding, it is generally seen that the interior comfort of the building is ensured with the help of mechanical and electrical systems by using all the possibilities of technology, building envelope designs are made in the form of curtain walls without relying on climatic data, and energy consumption increases. During the Post Modernism period, which took effect in the 1980s, it was opposed that decisions that would ensure the energy efficiency of buildings would determine the shell or form of the building. However, in these years, practices such as the use of thermal insulation and the reduction of the proportion of transparent surfaces have been observed to ensure energy conservation [63].

In the 1980s, the concept of "sustainable development" came to the fore with the report titled "Our Common Future" (1987), which was produced as a result of the appointment of the Norwegian President Bruntland by the United Nations. Bruntland defined this at the United Nations General Assembly on Environment and Development as development that does not reduce today's needs from those of future generations [64]. Accordingly, it has been stated that for a sustainable future goal, it is primarily necessary to have ecological approaches that produce solutions in accordance with ecological sensitivity with all inputs and outputs of the building, are economical, pay attention to reuse and do not harm the environment. An energy-efficient building design approach that pays attention to reducing energy consumption at all stages of building design, construction, operation, maintenance and repair is stated. According to this approach, it is stated that eco-technology systems that will provide optimum comfort conditions for building users by using climate data should be used in areas such as air conditioning and lighting [65].

2.3.2 Energy Efficient Building Design

In order to be compatible with the ecological environment in buildings, methods such as choosing materials that will consume minimum energy in the use, maintenance, operation and disposal processes of the materials to be used for the construction of the building, and using passive air conditioning methods that will keep the indoor comfort

conditions at an optimum level during the use of the building, make a design that can use energy effectively is one of the main goals of the approach.

According to this approach, energy awareness emphasizes the trend towards renewable energy sources due to increasing energy needs and decreasing oil resources. Climatic compatibility aims to take climatic conditions into account in building design and increase energy efficiency. The recycling of materials encourages economical use and recycling. It emphasizes respect for human factors and culture, the inclusion of local elements in designs, and aims to create sustainable cities. It aims to design without causing harm and to choose solutions that will cause the least harm to nature. Holistic evaluation, on the other hand, takes into account the ecological and sustainable aspects of design in collaboration with different disciplines [65,66].

The difference of the energy efficient design approach from other approaches is that it aims to keep energy inputs in the life cycle of all components that make up the building at the lowest level without reducing the quality standard of the building. In this targeted approach, although a general method that will increase energy efficiency for all buildings cannot be determined, only common basic principles can be determined. The design approach should be considered separately for each building, taking into account the function of each building, its climatic conditions, its cultural environment, and the material and design decisions taken according to its architectural and engineering systems. In order to achieve the targeted energy performance in energy efficient building design, a conscious approach should be followed from the first stage of the design to the last stage of the life cycle [2].

Three basic stages complement each other in energy efficient building design:

1. In the first stage, the conservation of existing energy is aimed. A building should be designed to use sunlight at the most appropriate level, with a heating load in the winter and a minimum cooling load in the summer. In addition to heating and cooling loads, the interior of the building should be illuminated as naturally as possible and artificial lighting should be avoided. The design decisions taken at this stage determine the amount of energy load of the building. Design decisions taken without considering this approach not only

increase the energy consumption of the building, but may also cause the electrical and mechanical systems used to grow.

2. In the second stage, the most appropriate passive air conditioning methods are applied according to the type and environmental conditions of the building and priority is given to the use of natural energy resources such as sun, wind, etc.
3. Although the design decisions in the first two stages provide energy efficiency, energy still needs to be consumed. This consumption arises from the mechanical and electrical systems used in the active air conditioning process. Comfort conditions are provided with these active systems depending on the requirements in terms of indoor comfort conditions or variable user preferences [63].

2.3.3 Energy Efficient Building Design Parameters

The parameters to be used for energy efficient building design can be examined under two headings: active and passive systems. Passive systems are systems developed to preserve energy and reduce energy requirements in the designed structure. Active systems are defined as systems applied to increase energy efficiency in the building. Accordingly, design decisions that will increase energy efficiency in newly designed buildings need to be taken. In addition, it is important to make improvements to existing buildings that will reduce energy consumption [67].

A building's energy consumption is influenced by many of building factors. [68] stated that these fall into three different varieties: building forms, building facades and fabric. The shape, size, width and depth of the building and its surface/volume ratio create the form. Building windows are included in the facade, as are glass ratio, shading and distribution techniques. Fabric involves materials used for roof, walls, floor, doors, windows and other building parts. Additionally, the planning of spaces, techniques of natural ventilation, air filtration or air sealing of a building are factors that can specifically affect energy use [69,70].

Exterior walls, floors, roofs, ceilings, window s and doors are parts of the building envelope. The most important limit in determining the energy use of a facility is this limit between the indoor and outdoor area of the facility [69]. Each part of the building

cover can greatly affect the level of comfort indoors and subsequently the request for cooling and heating energy [69].

Additionally, the dimensions and proportion of vitreous areas affect the amount of natural light transmit in, which in turn affects a building's use of artificial lighting during the day. However, glass allows greater heat loss or get, that impact inside comfort. To maximize the energy consumption of the building, it is necessary to strike a balance, taking into account both artificial lighting and thermal comfort. However, the building envelope plays a very important role in limitation the cooling and heating load of a constructing and must be efficient to achieve effective energy efficiency.

CHAPTER 3

METHODOLOGY

3.1 Building Energy Modelling (BEM)

3.1.1 Design Process in Building Energy Modeling

The rapid depletion of energy resources in the world as a result of technological developments after the industrial revolution has made it necessary for construction technologies to focus on sustainability and producing energy-efficient structures. For this reason, the "Building Information Modelling" method has begun to be used to simulate the construction and operation processes of buildings by developing computer software models. Based on this method, in recent years, an approach called "Building Energy Modelling" has been adopted to achieve building energy efficiency targets [2]. Thus, BEM becomes a time-saving, low-cost, easy-to-use, more practical and compatible process. Designers can evaluate design options and make design decisions by using the BIM-based BEM approach during the building design process. In this way, the building energy efficiency target can be achieved more easily [71].

Building Energy Modeling (BEM) is a strong computer framework dedicated to estimate the performance of structural and mechanistic design of buildings [72]. Using the Autodesk Revit-2021 Architecture Simulation program, the energy analysis of a building can be started after all the building components such as windows, walls, floors, roofs, etc. Specified on the project, gaps, other components of the building surrounding the gaps and the limitations of the rooms are created. From a general perspective, the main purpose of an energy modeling done on Revit is to optimize the energy used for the building [59]. The most well-known BEM equipment have an Interface user which includes building envelope, regional loads, sunlight, airflow and ventilation, renewable energy systems, climate data, environmental emissions and electrical systems, additionally economic estimate of HVAC systems and share the findings [73]. In the first stages of the design process of a project, conceptual masses can be used and energy analysis of the building can be performed. However, as the

design develops, technical information about the building-insulation materials and components to be used in the building is added to the simulation as input [59]. In order to show the results of the operation in a graphical manner, the graphical user interface (GUI) typically processes the final files [74]. In this way, detailed information about the energy performance of the building can be obtained. It is possible for building modeling to reach the optimum level in terms of sustainability by performing energy analyzes at regular intervals with the material details planned to be applied throughout the design [75]. Researchers have developed dynamical patterns to solve construction issues in BEM predictions for energy modeling. These models can be used to predict the energy performance of the building [76,77]. In the last design stage, the construction information needed for BEM is made more comprehensive. In specifically, it is possible to create a more comprehensive energy model to evaluate a variety of building design ideas, including heating, ventilation, and air conditioning (HVAC) systems.

The team of design can optimize the design to get together final budget criteria via comparing the performance of energy for different designs [78]. Examples of usual BEM instruments are Energy Plus, Design Builder, eQUEST, Autodesk Green of Building Studio (GBS), Trace 700 and IES Virtual Environmental [79].

3.1.2 Building Energy Simulation Software

Autodesk Revit Architecture Simulation Program

Revit was created in 2000 as the software of Charles River Software Cambridge. It is a nickname, derived from English words meaning Revision and Speed (overhaul and speed). It was acquired by Autodesk in 2006. It is currently the most widely used building information modeling program in the world [80]. With this software, different building components such as windows, walls and roofs are used to create a 3D model. It enables quick and easy geometry creation from free forms with building modeling and conceptual design support. It includes built-in tools to create complex models and convert them into a building information model. It has high control possibilities with functions such as limitation and parameter assignment. It has many tools for analyzing

both the design phase and the final product. In the Autodesk Revit program, 2D and 3D views and bill of quantities consist of the same building database.

While users work in any view, the Revit program collects the data required for the building and stores it in the building information system and reflects it on the entire project. Any changes made in one phase or part of the project can be directly reflected in all lists and sheets [59]. Plugins known as Green Building Studio, Etect and Project Vasari are integrated with Revit [81].

eQUEST

It is a sophisticated simulation tool widely used for energy performance examination. Building design with high performance of energy also obvious -to-use interfaces, parametric analyzes and constantly updated library throughout the construct procedure from the initial steps of the design to final steps. The wizard of development Design, detailed interface (DOE-2), and wizard of schematic design use input data at various levels. In these interfaces, input data is transferred from the program's library to the model. Natural ventilation, ground connection and infiltration models are limited and simple [82]. eQUEST allows importing data from two-dimensional computer-aided drawing files, multi-zone modeling and inclined surface or pitched roof models, but no three-dimensional CAD, BIM, gbXML, etc. cannot share data with the model [83]. The weakness of the eQUEST analysis and simulation program is that the infiltration (air leakage) factor is limited and simplified in the program. However, the infiltration value has an important place in energy consumption calculations and affects the result [82]. It is weak in determining whether the air in the spaces in the selected building is suitable or not and is weak in creating the building envelope of the selected building [84].

Design Builder

It is considered one of the most prominent simulation programs which used in energy simulation. The "Energy Plus" program is for simulation, that is continuously renewed by the US Department of Energy, supports this program. Design Builder is distinguished by its easy-to-use and understand interface and the system flexibility.

Also, this program, used in order to energy developed, lighting, carbon emissions and comfort management in the constructing, DWG files included in Energy Plus axillary weather software [85]. However, despite its innovations, Design Builder is limited to the ability to import CAD/BIM files created in other applications – currently it is only possible to import 2D DWG/DXF files [86].

Energy Plus

Energy Plus program is simulation tools. Basically, this just works as a simulation tool, providing input and output to easy text files. There is no user interface, however trade companies have developed interfaces. The program can do accurate mathematical calculations even on dense structures in lower from a one hour. circumstances like air flow, electrical energy simulation, fuel cells, water use, distributed energy framework and building energy profiles can be designed for multi-space conditions with newly extra characteristics. Compared to many software with an interface of graphical, the reality is the input information is in text form So this makes it hard to use [85].

Green Building Studio (GBS)

Green Building Studio is a static modeling-based energy analysis program that provides independent cloud-based services and works in conjunction with the DOE-2 energy simulation engine. Models created in programs such as Autodesk Revit, Autodesk Vasari and ArchiCAD can be transferred to the GBS program in gbXML format and energy analysis can be performed [81]. GBS calculates the energy consumption values required for lighting and heating-cooling functions, taking into account the building envelope, climatic data and the residential ventilation, cooling and heating (HVAC) system.

It was Designed by Autodesk and it delivers design buildings with superior performance in a less time and at a cheaper cost from traditional approaches [22].

GBS also provides information about the building's water use, costs of materials, carbon footprint and more. It offers the opportunity to make quick design decisions by comparing design alternatives side by side. It has a simpler interface than other building energy simulation programs. Building parameters can be easily changed in

this web-based interface. Examples of applications include changing the orientation of a material or building with a different thermal value or making changes to the HVAC system. The gbXML format is used as the bridge that allows information to pass between GBS and the Revit application as in the Figure 3.1. If there is no parameter definition in the model to be analyzed, GBS uses a default value to create an energy model containing the minimum information required for simulation. These smart values are appropriate to building size, type and location. These defaults are based primarily on ASHRAE 90.1, ASHRAE 90.2, ASHRAE 62.1 and CBECS data. These vary with building location, building type and number of floors. GBS automatically tests different building features to create a potential energy savings chart. In this way, it provides guidance on which alternatives will have the best impact on energy use. Thanks to the integration between GBS and Revit, it has made the analysis used to design buildings easier for most architects, designers and engineers [87]. The software is based on the DOE-2 simulation engine. Since the software is cloud-based, it does not require installation on a computer and can be used at any time with internet access [83].

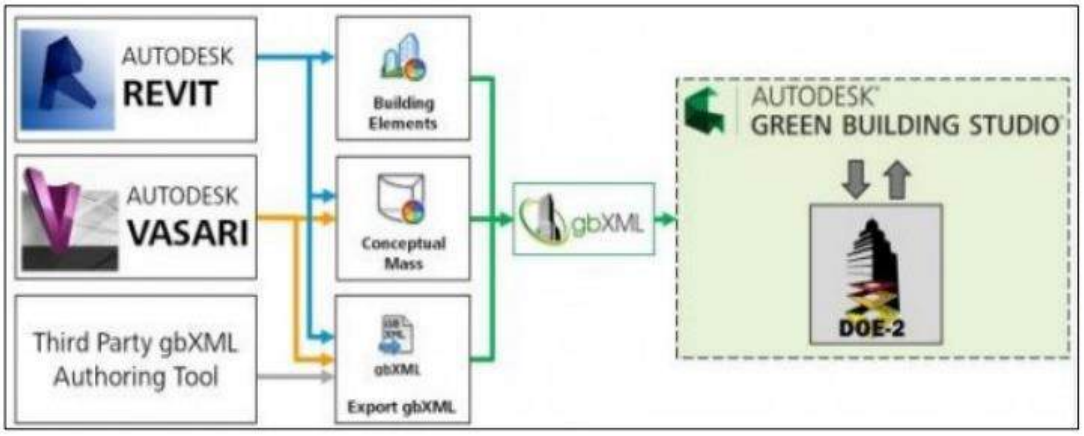


Figure 3.1 Autodesk whole building energy analysis [88]

IES-VE

Integrated Environmental Solutions Ltd (IES) has produced a suite of building BIM simulation and assessment tools including VE-Ware, VE-Toolkits, VE/Energy, VE/Lighting & Daylighting, and VE/Solar [83]. It is a program to simulation that is

used to design buildings that are environmentally friendly and also energy efficient. It performs analyzes such as calculating the amount of energy consumption and evaluating the indoor climate in order to design ventilation, cooling and heating systems. Climate data is entered every hour, material data, building elements, building usage chart, service systems information and component fees into the program as input data. Users can view energy use information studied each hour, each week, each month or periodically as a graph or table. This program is constantly being improved, but this program is most efficient in small-sized buildings [82]. One of the disadvantages is that it currently only works on models exported from Revit or Google Sketch Up TM. IES plans to extend it to work with other BIM applications in a future release [86].

TRACE 700

TRACE 700 Abbreviation for Trane Air Conditioning Economy. It is a program that runs on the Windows operating system that produces virtual buildings and estimates air conditioning loads. Also, it is able to life cycle cost evaluation. TRACE 700 helps buildings optimize the energy use of ventilation, heating and air conditioning devices. Although the TRACE 700's interface is straightforward, its capabilities are limited [89].

Green Building Studio was used because it provides flexibility to the design process in the simulation tools used to improve energy efficiency. It also helps develop high-performance building design skills in a shorter time and at a lower cost than traditional methods.

3.1.3 Advantages of Energy Analysis Software

Energy analysis software can provide information about the energy to be consumed through high estimation processes during building design. It can provide the selection of mechanical and electrical power parameters to be designed. Thanks to building energy analysis software, the costs of components with high energy consumption, such as lighting and HVAC, can be planned in advance and alternative solutions can be evaluated. There is a high probability of prediction with a margin of error of 3%. Thanks to analysis software, the energy performance of new buildings in the design

phase or existing buildings that are planned to be rehabilitated can be viewed before construction, and thus the architect or engineer can test all possible scenarios and choose the most suitable one for the project. One of the biggest benefits of energy analysis software is detecting possible errors at the beginning [90].

3.1.4 Disadvantages of Energy Analysis Software

Since building and environmental values are transferred to the computer environment through mathematical modeling in energy analysis software, there are margins of error in the calculations. Since real-life data cannot be digitized with 100% accuracy. That's why there are erroneous data in the energy analysis software results. In November 2014, 21,010,069 MWh (megawatt hours) of electrical energy was consumed in Turkey for example [91]. An average of 5,462,617 MWh was used in building and residential energy consumption. According to [90], 2,185,047 MWh of energy was used in HVAC systems within buildings and residences only in November 2014 to ensure good air and air conditioning conditions in buildings. The 3% margin of error, which is considered ideal in energy analysis software, corresponds to 65,551 MWh of energy per month. Since it is not possible to compensate for errors in energy analysis software after the project is commissioned, disadvantages arising from calculation errors must be eliminated. Methods that analyze analysis software have been developed to detect errors and eliminate disadvantages. However, today there is no database that instantly collects these errors in a common pool. Since there is no correction mechanism that can be measured with real values in the field, even the errors of energy analysis software cannot be clearly proven. Since the errors cannot be revealed, solution suggestions cannot be created. For this reason, the biggest slogan of energy analysis software includes the word prediction, and the rate of capturing real data is not given [90].

3.2The Methodology

The research methodology is generally based on procedure a large amount of literature reviews on energy performance of buildings. After that, an in-depth study of the literature collected in traditional areas was conducted in order to see the impact

traditional strategies on energy performance and to identify problems that affect energy consumption.

This stage helped generate scenarios for comparison between vernacular and contemporary architecture in terms of energy performance in the next stage, which represents energy modeling buildings (BEM) and then learning about energy analysis tools.

This framework depended on comparing the buildings in Mosul as a case study. For this purpose, a model of traditional and contemporary buildings in the city was chosen to be created in 3D models were created with Revit Architecture application. The models contained the information necessary to perform the simulation.

Thermal characteristics of the building materials, opening-to-wall ratios and wall thicknesses, rooms and spaces tables, building type, weather data by Mosul city location, and the occupancy level has been set in the Revit energy setups and it is ready to be transferred to Green Building Studio (GBS), where the program gives all data regarding the building's energy performance. The scenario and the base model for energy analytical were created in Revit and then transferred to Green Building Studio. After that, it was concluded which strategy consumes less energy and environmentally friendly. Also, optimal technologies for dwelling units were identified and a guide was developed on the design of environmentally friendly dwelling units in Mosul.

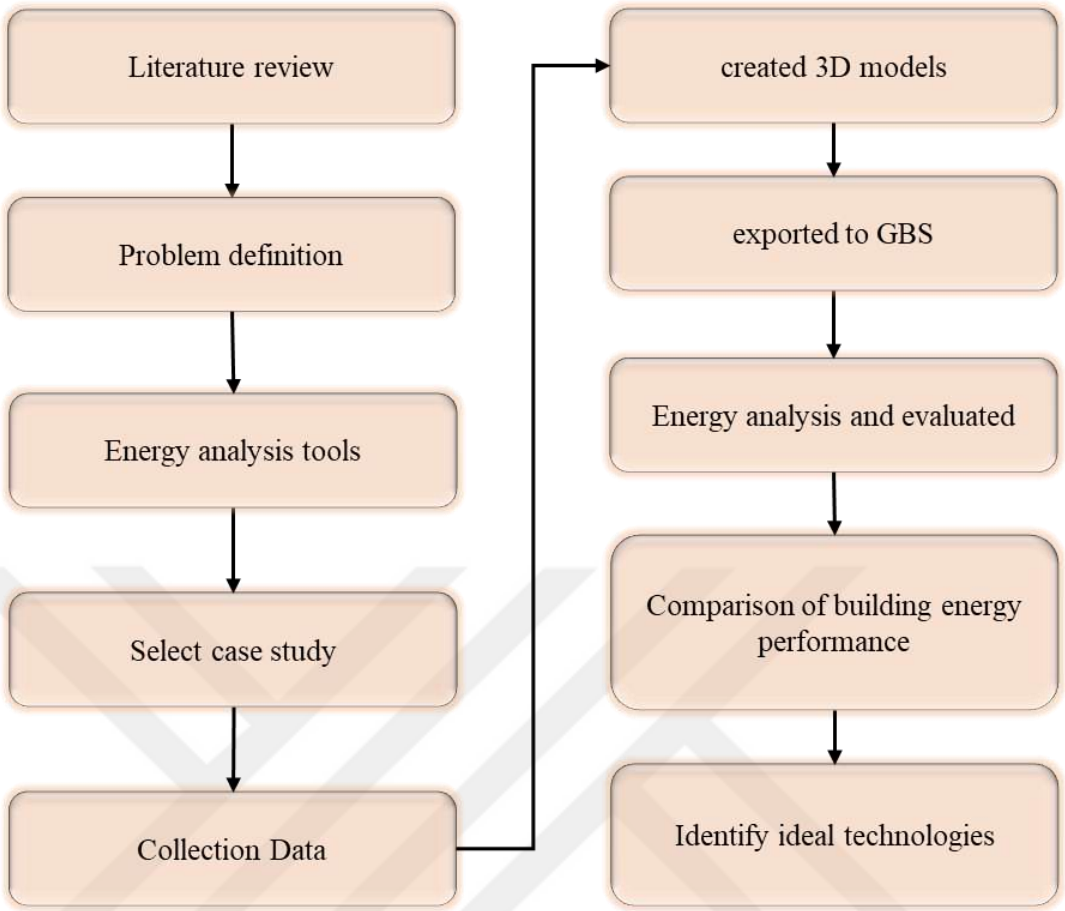


Figure 3.2 Research methodology framework (Source: Author)

CHAPTER 4

CASE STUDY

4.1 Historical Background of Mosul

The city of Mosul is one of Iraq's oldest cities, as it was established in the year 1080 BC. The Mosul city is the center of the Nineveh Governorate, located in the north of the Republic of Iraq. The Tigris River in the city of Mosul divided the city into two parts, the right side, which includes the old and historical city, and the left side, which is the new city [92]. The old city in Mosul is the urban center of the Greater Mosul city and its beating heart with urban, historical and heritage buildings inherited [48].

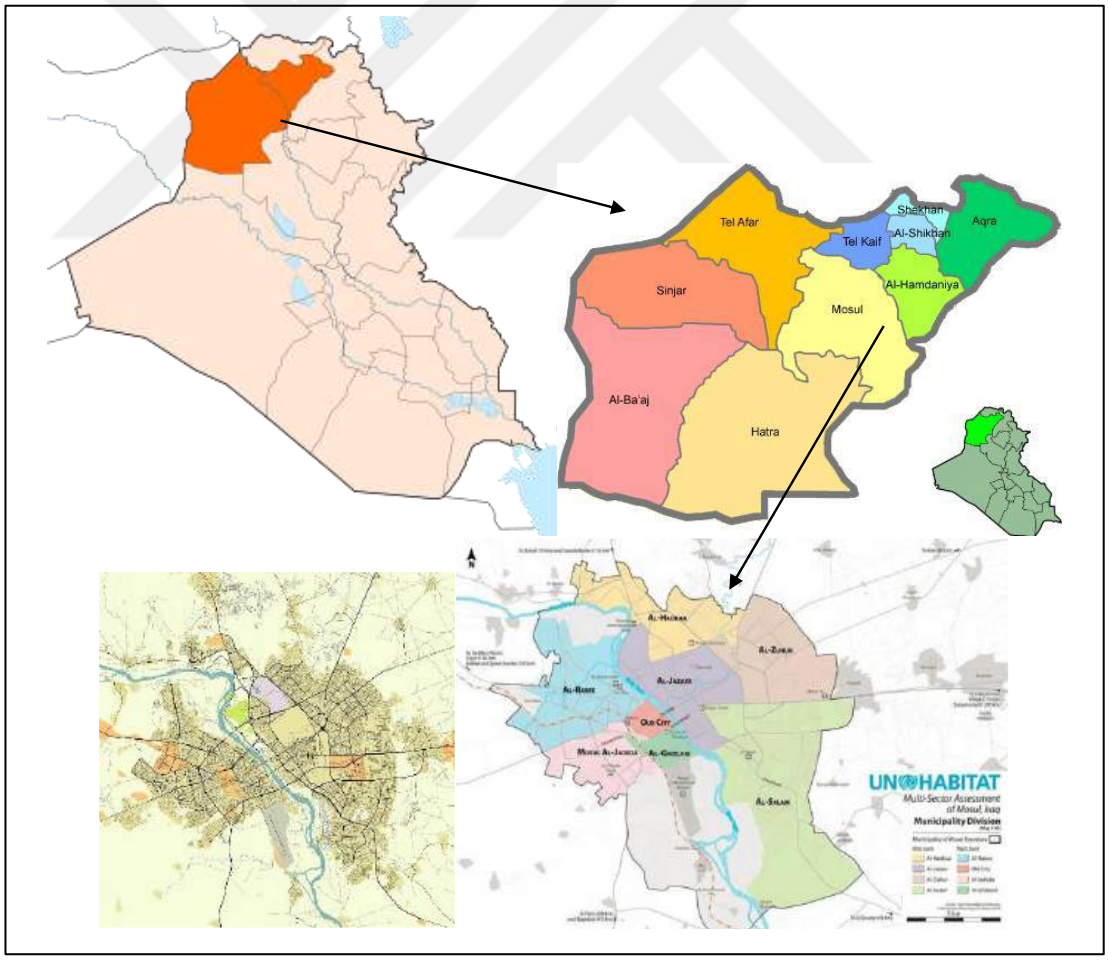


Figure 4.1 Location of Mosul city

From 1914 to 2000, the plans of contemporary's city of Mosul changed. The city went through a series of morphological urban development stages that constituted planned landmarks as in Figure 4.2. New residential suburbs were built according to basic architectural standards in spaces between principal avenue corridors. When the master plan was implemented, the spatial pattern called "planned pattern". The new suburbs are separated of the principal avenues as a result of highly vehicle motions in every direction and unrestricted Spatial enlargement on major axes [93].

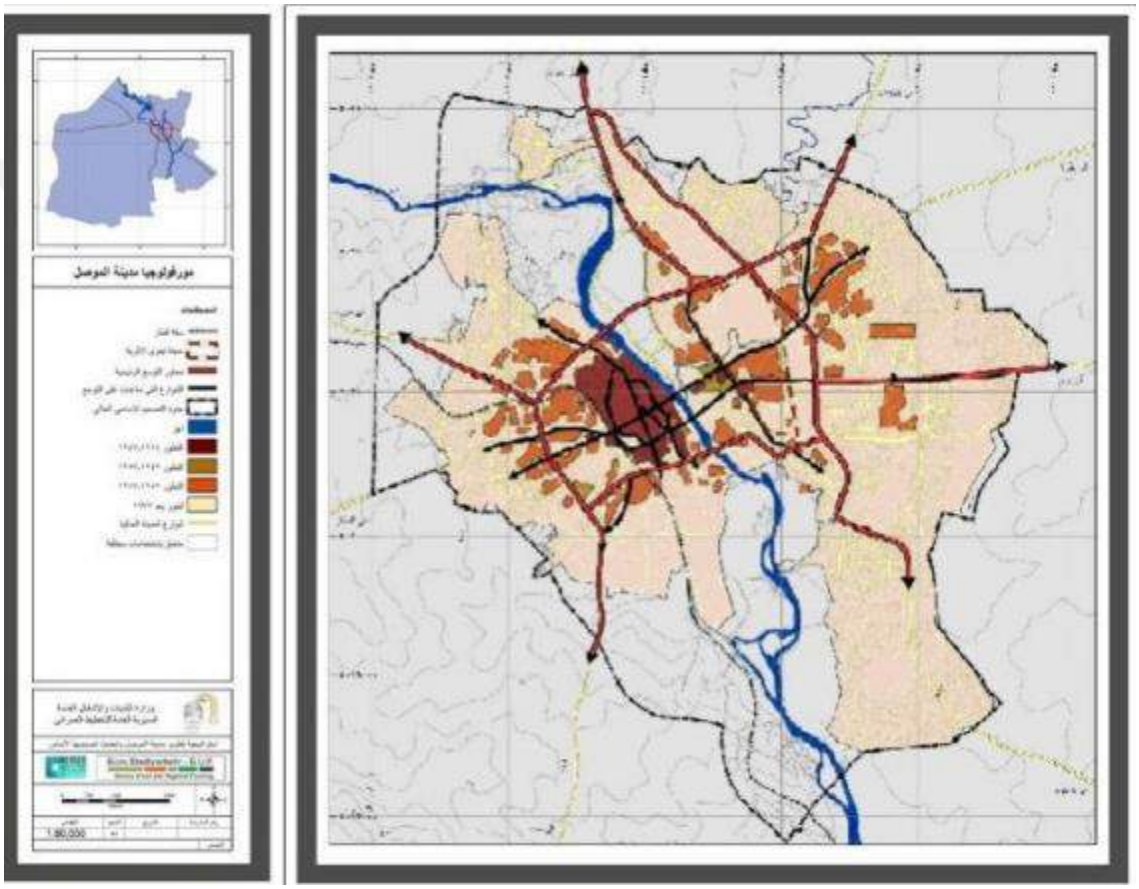


Figure 4.2 Expansion and morphological changes of Mosul since 1914 [93]

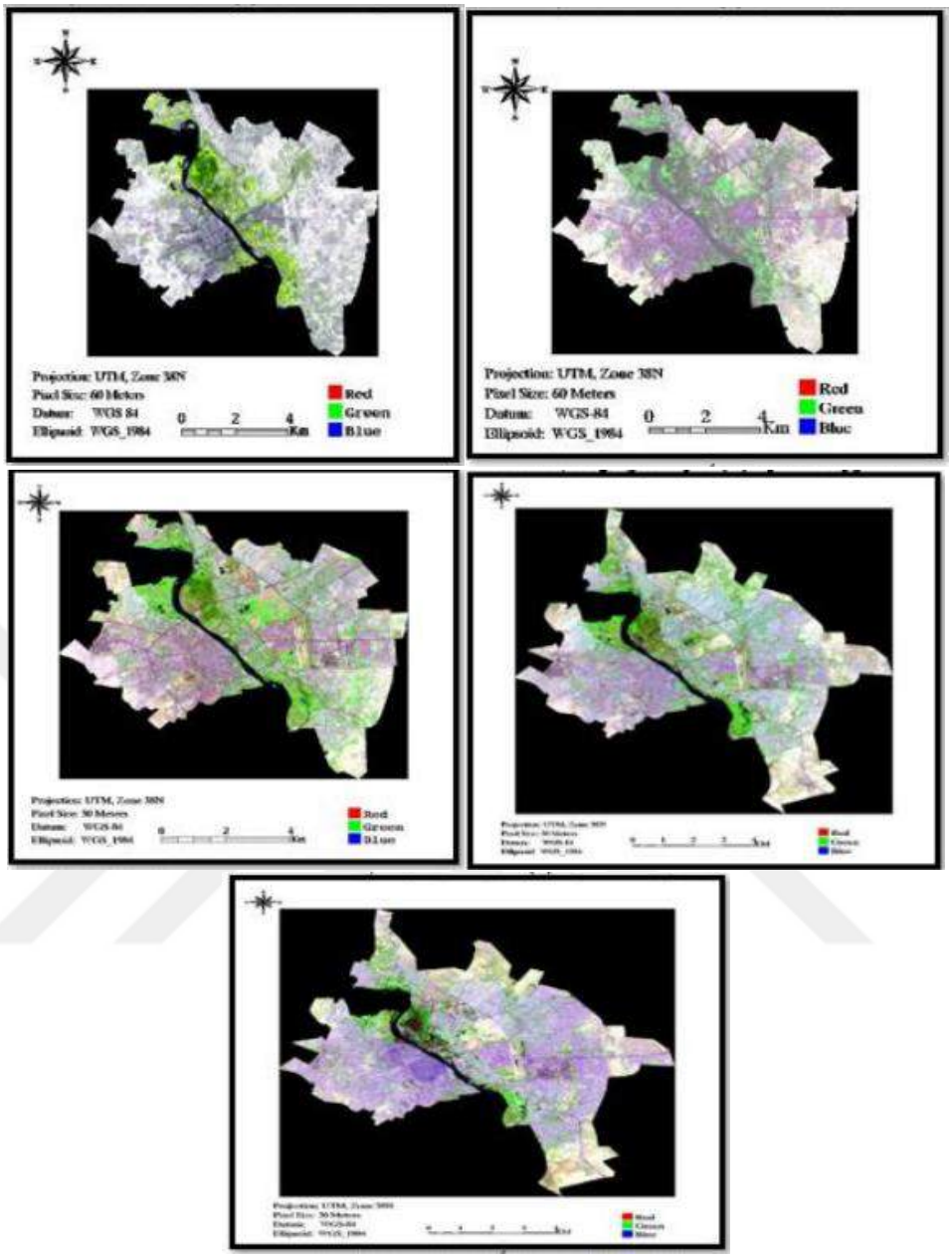


Figure 4.3 Expansion and morphological changes of Mosul city (1977-2017) [94]

The city includes of two parts, the right and the left bank, and the two banks are separated from each other through the Tigris River. Mosul city's 251 regions are spread on two banks of river, and five primary bridges connecting the two banks. The Right Bank consists of 91 neighborhoods and the other Bank consists of 160 neighborhoods. In general, the left bank of the city is characterized by more services, security and modern buildings from the right bank [95].

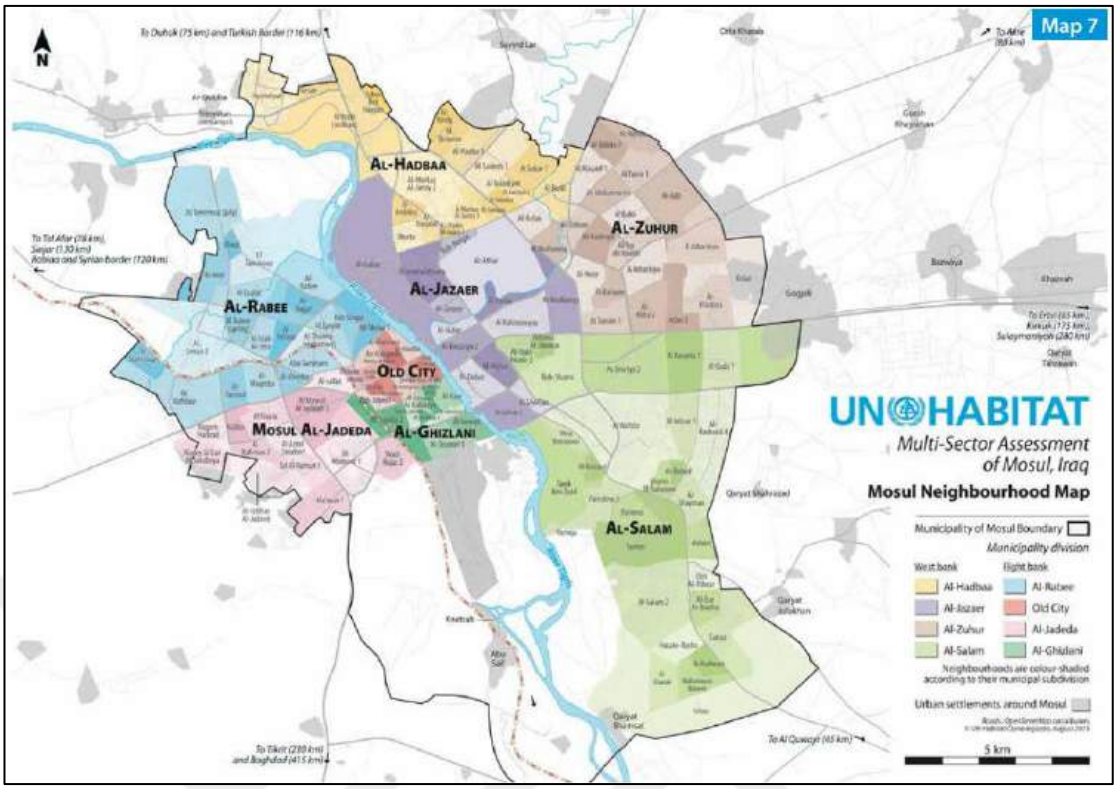


Figure 4.4 Mosul neighborhood map [95]

4.1.1 Popular Uses of Land in the City of Mosul

1. Residential: The residential sector constitutes a large portion of land use in Mosul. There are a variety of residential areas, ranging from older, historic neighborhoods to modern areas.
2. Commercial and Business: Mosul contains active commercial areas that include markets, malls, and stores. Trade plays an important role in the local economy.
3. Industrial: There is an industrial sector concerned with the production and manufacture of a variety of products. This includes factories and workshops that specialize in different industries.
4. Educational: Mosul contains important educational institutions, including universities and public and private schools. The educational sector occupies a large area of land.
5. Cultural and entertainment: The city contains cultural and entertainment areas such as theatres, museums, parks and green areas.

6. Religious: Land uses also include religious buildings such as mosques, churches, and holy sites.
7. Governmental and service: There are government and service buildings, such as government administration buildings, hospitals, and public service centers.

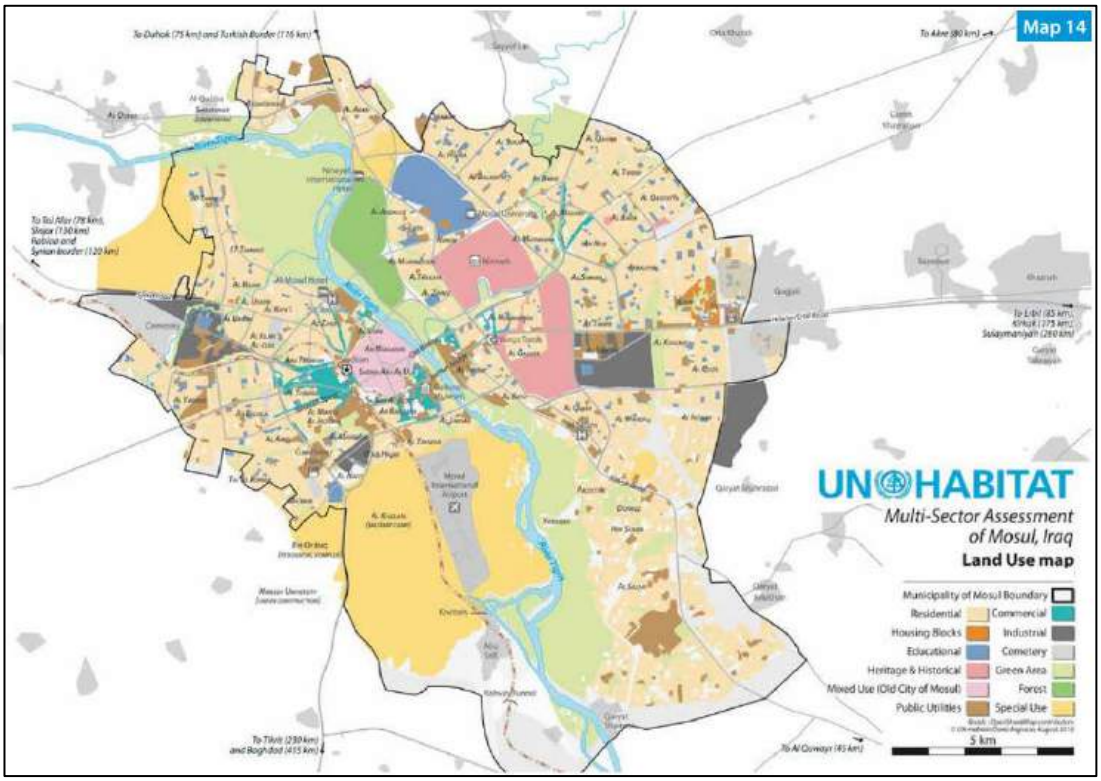


Figure 4.5 Land use map of Mosul city [95]

4.1.2 Evaluation of Mosul Climate Values

The city of Mosul, which relied on the open grid system in planning its new residential areas, which existed side by side with its compact traditional fabric, affected the geometric and physical characteristics of the urban space and its local climate [96].

The city of Mosul is located in northern Iraq at latitude (36.35) degrees north and longitude (43.10) degrees east. This location makes the angle of incidence of solar rays very close to the vertical projection, reaching in January (34.24), while the angle of incidence reaches in the month of June (77.14), which makes the amount of solar radiation high, especially in the long summer months, as the daylight hours in January reach (9.67) hours and reach their peak in June (14.93) hours. The rate of solar

radiation also reaches its peak in the month of June and reached (636,44 ml/watts/cm²) while it reaches (181,96 ml/watts/cm²) in December, where the annual average is (9.5) hours per day, and it differs in the months of December and January is only (5) hours, while it reaches (12.4) hours in July [97].

The Autodesk Revit Architecture Simulation Program with Green Building Studio use the default city graph of the building for building design. while the World Meteorological Organization compares latitude coordinates and the longitude of the selected location with a database of more than 4,400 available weather stations derivative from the ASHRAE 2005 Fundamentals Manual. The nearest meteorological station with weather data from the World Meteorological Organization is chosen and the values are shown in the climate part. That is, it uses climate parameters such as wet and dry bulb temperatures, prevailing winds, relative humidity and diffuse and direct sun to evaluate data of weather.

One of the most effective and important determinants in the energy performance analysis of a building is the cooling and heating degree days. In Figure 4.6, heating and cooling degree day values and annual design conditions according to the analyzed building location are shown using the Autodesk Green Building Studio program. The degree-day index is the most simple and practical indexes, is used to ensure building comfort conditions. It is the parametric value used to determine the energy needed for measurement of cooling and heating degree-day values can provide a clear and accurate calculation of the thermal needs of the building and city. It also plays a useful role in improving and preserving thermal comfort energy consumption patterns [98]. The reading and estimation of the average degree-day requirement for cooling and heating as the fundamental data that calculating energy amount required to heat and cool the building in summer and winter is a task of energy consumption planning [99].

Weather Station: GBS_06M12_18_183231
Distance to your project 5.0 mi (8.0 km)
Latitude = 36.3500 , Longitude = 43.1000

Cooling Degree Day		Heating Degree Day	
Threshold	Value	Threshold	Value
18.3 °C	2269	18.3 °C	1220
21.1 °C	1729	15.6 °C	802
23.9 °C	1247	12.8 °C	451
26.7 °C	838	10 °C	186

○ IP ◉ SI

Annual Design Conditions				
Threshold	Cooling		Heating	
	Dry Bulb(°C)	MCWB(°C)	Dry Bulb(°C)	MCWB(°C)
0.1 %	47.9	21.2	-1.7	-3.1
0.2 %	47.5	21.3	-1.3	-2.8
0.4 %	46.7	20.6	-0.8	-2.3
0.5 %	46.3	20.6	-0.5	-2.0
1 %	45.6	20.5	0.4	-1.6
2 %	44.2	19.9	1.4	-0.9
2.5 %	43.8	19.8	1.8	-0.3
5 %	42.2	19.7	3.3	0.8

Figure 4.6 Daily values of heating and cooling degree and annual design conditions according to the location of the analyzed buildings

Threshold plots represent a class of versatile motivated charts. Determining threshold temperatures suitable for ensuring climatic and thermal comfort is necessary and vital for the well-being of people in the building. The most common type of degree day measurement is based on thresholds for indoor cooling and heating. The threshold level's daily temperature is the maximum average temperature deviation from the norm for human comfort. At temperatures above the minimum temperature, the general atmosphere must be cooled, and at temperatures below the minimum, the air must be heated. These are referred to as heating and cooling requirements [99]. The data of Monthly design (2% threshold) is shown in Figure 4.7, taken from the Autodesk Green Building Studio program.

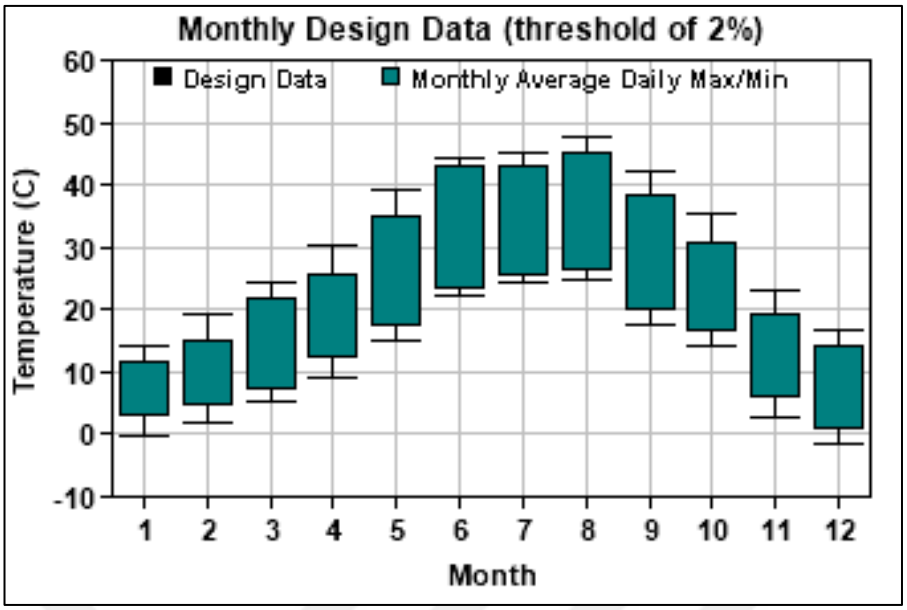


Figure 4.7 Monthly design data by buildings location in the analysis (2% threshold)

For Mosul province, the dry bulb temperature frequency distribution and the effect of the dry bulb temperature cumulative distribution, which are the basis for the building performance analysis, are taken from the Autodesk Green Building Studio program and given in Figure 4.8

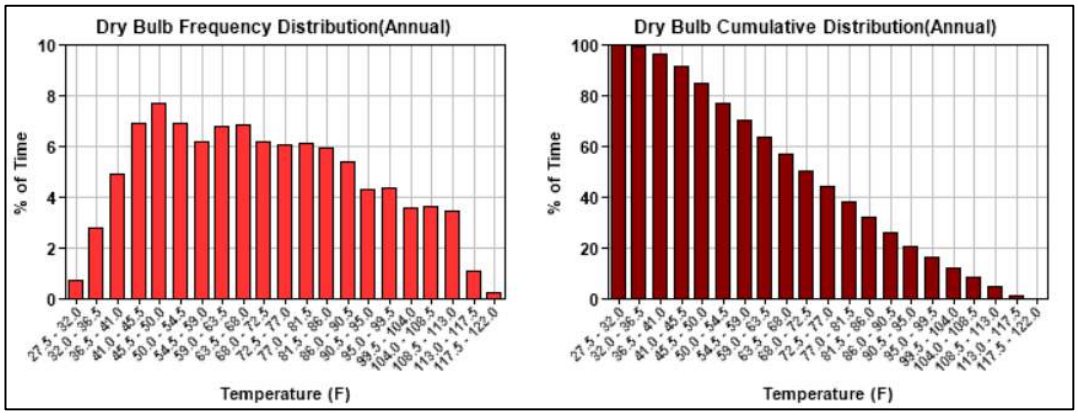


Figure 4.8 In the analysis, the impact of dry bulb temperature frequency distribution also dry bulb temperature cumulative distribution according to buildings location.

Wind promotes natural ventilation which is a passive way of cooling the buildings in summer. For Mosul province, the wind impact in the analysis is taken from the Autodesk Green Building Studio program and is given in Figure 4.9. Winds blow in

the city of Mosul in different directions depending on the differences in global or local pressure systems, but the prevailing winds of the city and the most continuous throughout the year are the northwestern winds [97].

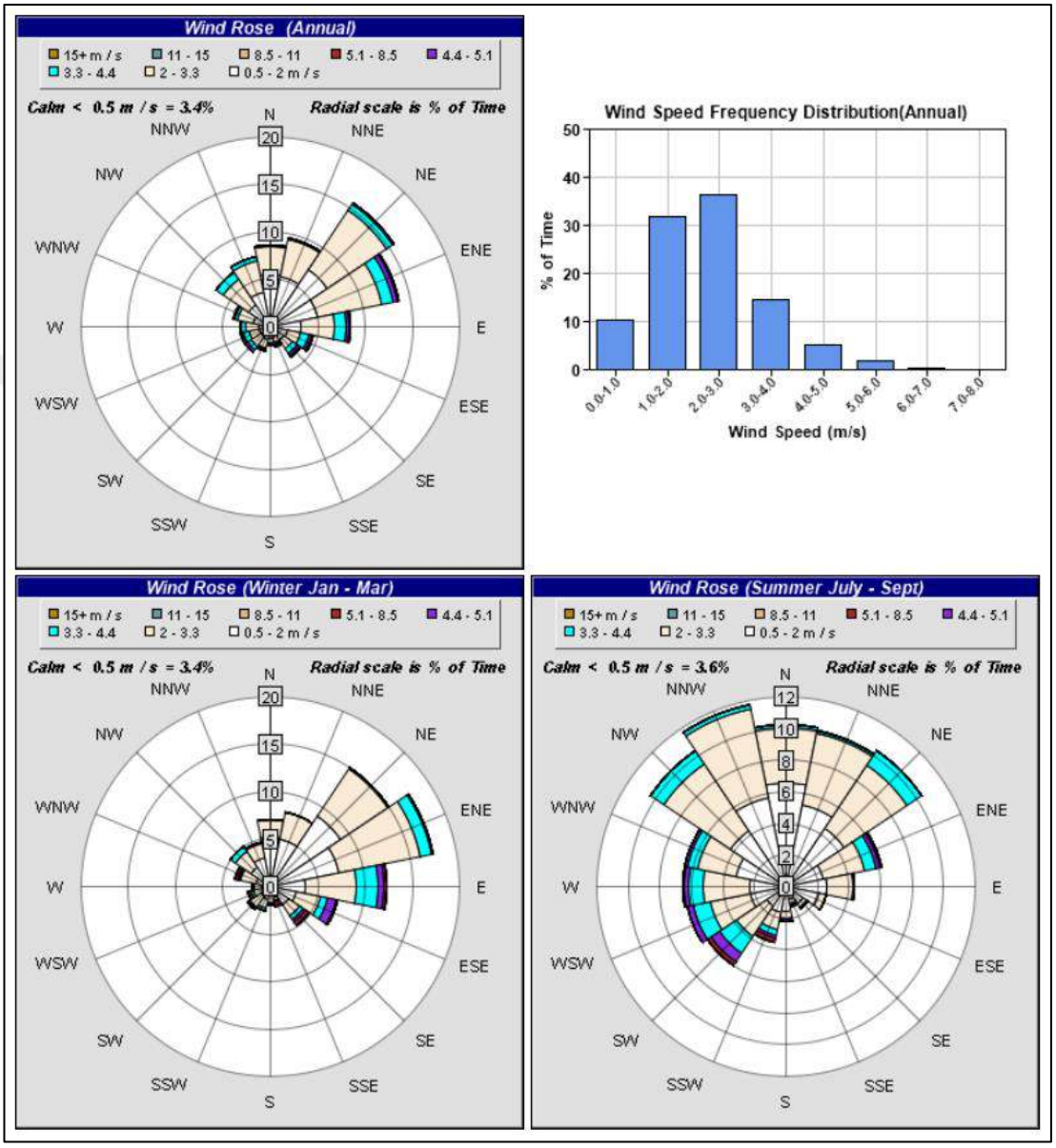


Figure 4.9 Wind effect according to buildings location in the analysis

The distribution effect of both dew point frequency and annual humidity in the analysis are shown in Figure 4.10, taken from the Autodesk GBS program. The selection of bioclimatic enhancements is depended on analysis of Mosul's climate and sensitivity study. This sensitivity is determined according to the dew point frequency distribution

and relative humidity frequency distribution. These simulation results are important to properly control the distribution of conditioned air into the building by monitoring the dew point and humidity level, providing greater comfort for building occupants while optimizing cooling demand and minimizing the building's HVAC cost.

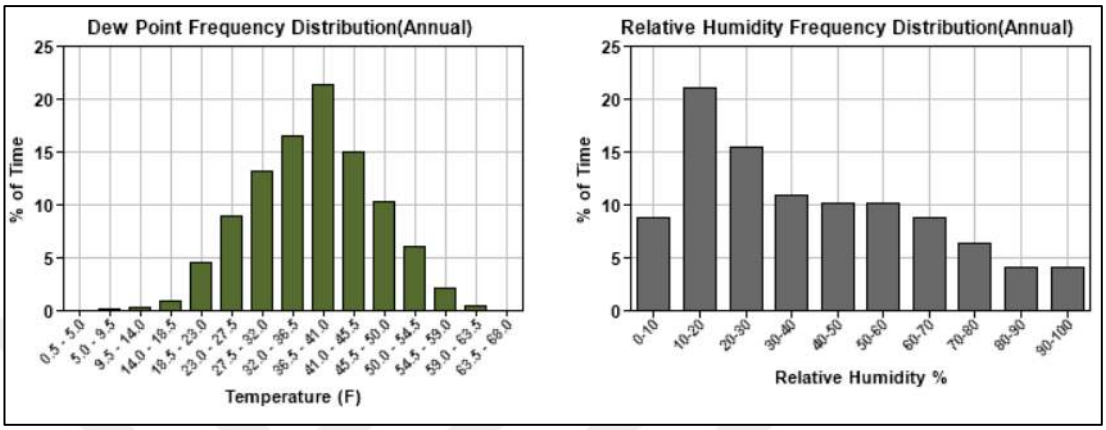


Figure 4.10 Frequency distribution of dew point & humidity according to buildings location in the analysis

The term "sky cover" refers to the area of the sky covered by the clouds. This calculation requires measuring the percentage of sky which covered by clouds. The calculation also includes the area of the clouds which did not totally cover the sky at the time of observation. According to climatological observations, total sky area is assumed 10/10. As a result, a scale from 0 until 10 is used. And on this scale, a 0 value is indicating a sky with no clouds, and a 10 value indicates a sky totally filled with clouds [59]. While to evaluate the energy consumption, the values of the yearly frequency distribution of total sky cover are taken into account within the Revit framework are very important for an accurate evaluation.

In the analysis, the values of the yearly frequency distribution of total sky cover and the yearly frequency distribution of direct natural radiation effect are taken GBS program and presented in Figure 4.11

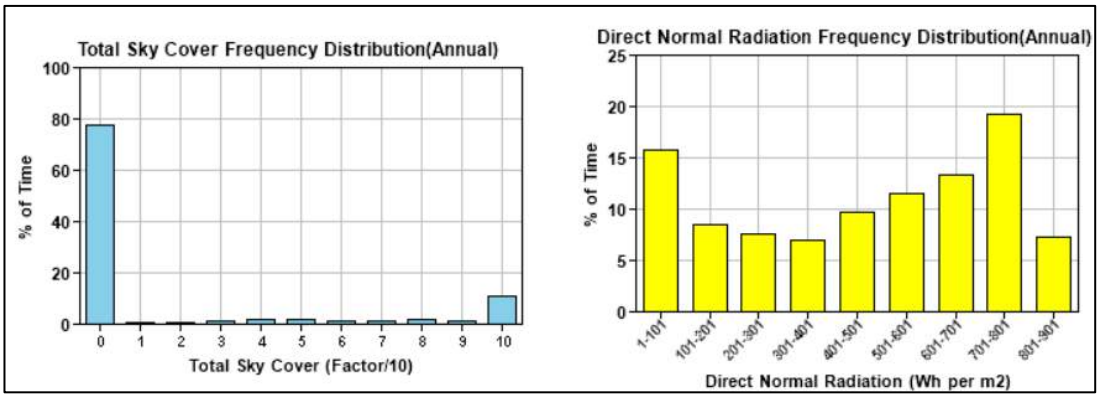


Figure 4.11 The total frequency of sky cover & frequency of natural radiation

The solar radiation received per unit area by rays coming directly from the sun is known as direct natural radiation. It is always received by a surface held upright or normal. As the most important component of simulation of energy efficiency, reliable provision of solar radiation data is required. Diffused horizontal irradiance or direct normal irradiance are also important, but global horizontal irradiance is the most useful solar irradiance data. For example, radiation at the solar collector or at the surface of a solar cell is characterized by either direct natural radiation or horizontal diffuse radiation is provided moreover to radiation of global horizontal [100]. The simulation software of this study uses the values of these three radiations. The frequency distribution of natural radiation table is directly used to calculate the analysis results. This chart shows the amount of available direct sunlight more than a twelve-month period.

The impact of frequency distributions of global and diffuse horizontal radiation (annual) in the analyses are shown in Figure 4.12. Radiation of global horizontal is the sum of emitted shortwave radiation from a surface horizontal from above to the surface of the earth. This is very important for photovoltaic systems as it includes natural direct radiation and horizontally emitted radiation.

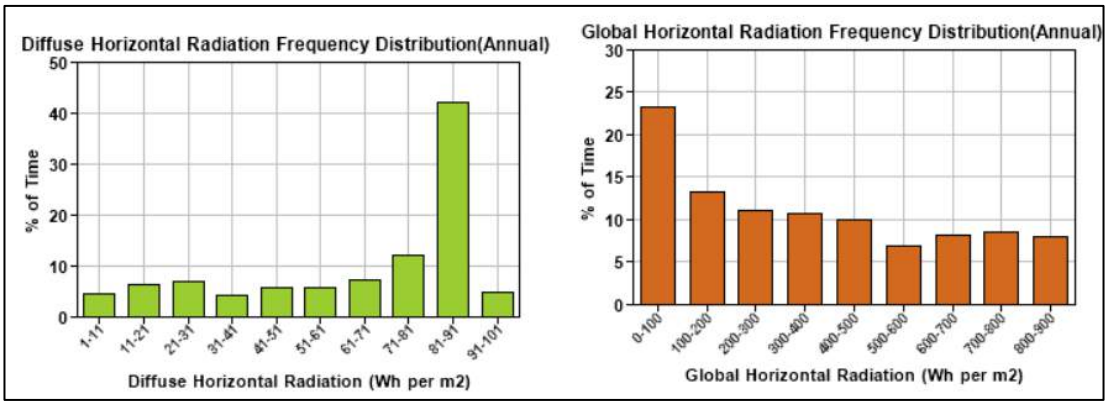


Figure 4.12 Frequency distributions of global and diffuse horizontal radiation affecting the building location in the analysis

Diffused horizontal radiation is solar radiation which does not originate in a direct path from the sun, but spreads through particles and molecules in the atmosphere and arrives equally from all directions. In essence, it is light reaching the blue sky and clouds [100].

Selecting suitable weather data for analysis of energy allows for better energy estimation.

4.1.3 Development of Mass Housing Type Buildings in Mosul

Residential use makes up a very large percentage of the city, often accounting for 80% until 88% of Mosul's traditional urban area.

Residential use occupies a very elevated ratio of the Mosul city’s area, often reaching 80% - 88% of the city’s area [101].

In urban planning, housing patterns housing appear in the Arab city, where the traditional model of residential units (with a central courtyard) was observed since the period of the Abbasid Caliphate, and its continuation in the Ottoman period until the beginning of the twentieth century, and then foreign models began to appear in the twenties and thirties of this century, during which Iraq was subjected to colonialism. Then the emergence and spread of the modern residential neighborhood in the suburban areas extending outside the old wall of the city [102].

In his study, researcher Hafez Abd Yahya Al-Hayali distinguished three kinds of dwellings in the Mosul city, and mentioned them and their characteristics when four stages of change that architecture went through in this city were identified, which were as follows [51]:

1. The style of heritage residential houses that represent the traditional Arab house, which represents a continuation of the periods that preceded it regarding characteristics and the use of building materials, architectural elements and details. It is considered the only residential style in the first phase (the phase of traditional heritage architecture), which extends from the second half of the eighteenth century and the nineteenth century. Until the outbreak of World War I and the end of Ottoman rule with the British occupying the city of Mosul in 1917.

2. The axis style of the Arab house, in which the building faces outward instead of shutting inward and closing the courtyard, preserving some of the architectural elements, modifying some of these elements, and changing some of the relationships between the elements. This style appeared in the second phase (the transitional phase) ending with the establishment of the Iraqi Republic in 1958.

3. The style of houses with Western designs, where they were surrounded by external gardens, the disappearance of the courtyard and the iwan, and adding of new architectural components such as porches, balconies, garages, etc. This style appeared in the third phase (the international style phase).

Al-Hayali pointed out the characteristics of a fourth stage (the stage of counter-change), which continues to this day, and is influenced by calls for inspiration from local heritage as a reaction against modernity and the growth of symbolic architectural values and concepts, which post-modern architecture called for. However, no distinctive residential style was announced in this period.

4.1.4 Definition of the Housing Unit

It is the main component of any residential complex and the main signal of a lot of Planning parameters also embodies a group of areas with constant urban characteristics [103].

According to Al-Hakim, most of the uses of land in Mosul city are residential. The fact that a person can live in a certain area, be a portion of an area where able to work, and be a productive individual in a certain way (trade, manufacturing, farming, etc.) makes this residence important [104].

Therefore, a dwelling unit is a place that can provide for the needs and activities of people life, while also protecting the property and the requirements of the occupant. These requirements change over time as lifestyles change from age to age. Let's present an example to verify this: In ancient times, there had to be a place in residences because animals were the only method for transportation, while in modern residences there must be a parking lot as it is a contemporary method for transportation.

4.2 Design Characteristics of Mosul Housing to Preserve the Climate

The site of Mosul city is based on a plateau, and the one who enters it sees it while it is built on a high place in the middle, taking the form of domes. The old city is integrated in the environment and does not harm other elements of the ecosystem [105]. Characteristics of its climate is moderate, hot summers and cold, rainy winters. If the basic design characteristics are taken, then there are many things that were taken into account when building the house, changing climatic conditions imposed consideration of the thickness of the building, so the walls are built with cement, plaster, and foundations with the same material, to which (alnuwruh) is added, and the rooms are also roofed with a knot system and add to it the old building plaster (Al-Kharshan) because they are light in weight and all these materials are local, which contributes to benefiting from natural resources .

The climatic effects were also taken into account in terms of weather fluctuations and winds, and these conditions imposed taking into account the entry of the sun and light into the rooms in winter and blocking them in summer through the hallway that precede the rooms. It is necessary to build basements to prevent the summer heat, high iwan for dense shade, and to create air currents that soften the atmosphere, similar to the air passages that connect the basement to the roof and high-ceilinged rooms with few openings or narrow to provide a suitable atmosphere in winter and summer, as well as the wide courtyard, and take the building towards the south and blocking the

western front in shielding the influential afternoon sun [105]. As well as the presence of malqaf in some buildings, which receives moist air from its northwest source into the building, which contributes to natural ventilation and the shanshool from other elements that serve the conditions climate works on natural ventilation and lighting and that contribute to healthy quality. There is also another element called the qantara, which connects two houses to each other and gives strength and cohesion to the two houses in addition to shading the alley. Thus, all contribute to heat control, comfort devices, thermal insulation, natural lighting, natural ventilation and buffer spaces.

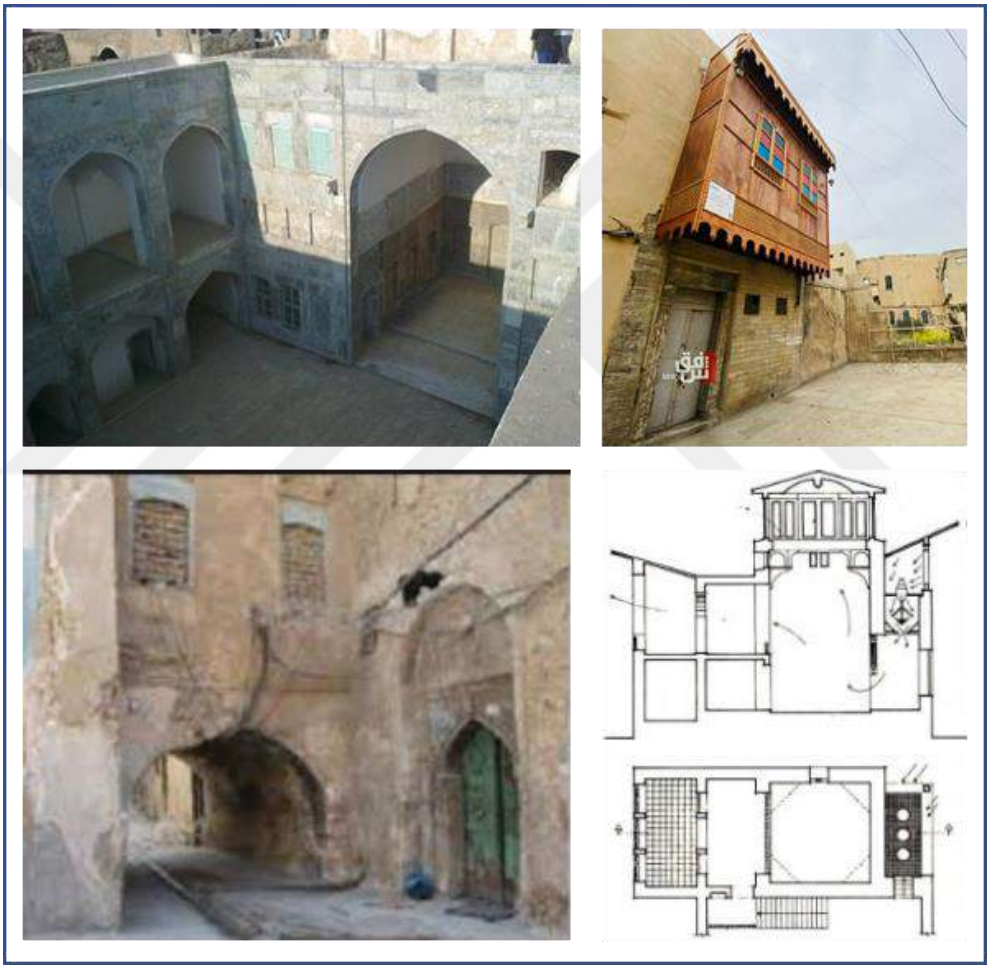


Figure 4.13 Environmental designs

4.2.1 Components of the Housing Unit

Heritage houses in Mosul old city date back to the half of the 18th and 19th centuries, as some of them are still standing. These houses reflect local architectural styles that

reflect Arab-Islamic architecture. On the one hand, these houses respond to climatic conditions, and on the other hand, they show a continuation of the previous periods in terms of social traditions, conditions of economic, religious convictions, and the application of construction materials and architectural elements [106].

As seen in Figure 4.14, the aim of the research includes comparing the plans of contemporary houses and traditional houses in Mosul city.

1- Entrances: The look of the home and the initial perception of the building come from the entrance [107].



Figure 4.14 Comparison between the entrance plan in both houses (Source: Author)

In terms of Islamic architecture, in plan of the traditional house, the entrance is indirect in order to ensure privacy [108]. And entrances in contemporary house plans are classified into two types. First, it is done without an entrance area designed to directly enter the space. These types of entrances have failed over time as if the main entrance door is remains open, this will reveal what is in the interior of the house. Since the spaces are with eye level, they can be easily seen by people on the street, while the

second type is indirect entrance. The entrance area is the best place to manage thermal comfort and the privacy of the building.

2. Living Hall: the living room where the family members gather throughout the day. This room's furniture was chosen based on the needs and preferences of the family. The living space is usually employed to receive visitors, particularly in relatively small residential buildings which have just bedrooms adjacent to the living hall [107].

In the traditional house plan, the living zone consists of an iwan opening onto the main courtyard and on either side of it are two rooms connected to it. In cold weather, the rooms are used like rooms of living [108]. But the living room in contemporary house plan is located at the starting of the dwelling building also it is the first place which the guest walks in following the entrance, as shown in Figure 4.15



Figure 4.15 Comparison of the living room plan in both houses (Source: Author)

3. The bedroom: It includes high privacy, as the room of parents in the house should be away from the living zone. There is an area in the bedroom which able to

accommodate the bed size. Also, it is better to gather it with double or plain wardrobes [107].

In traditional house plan, it has small windows and door openings on the central courtyard and iwan side [108]. In contemporary house plans, it is the last place in the residential unit, as shown in Figure 4.16

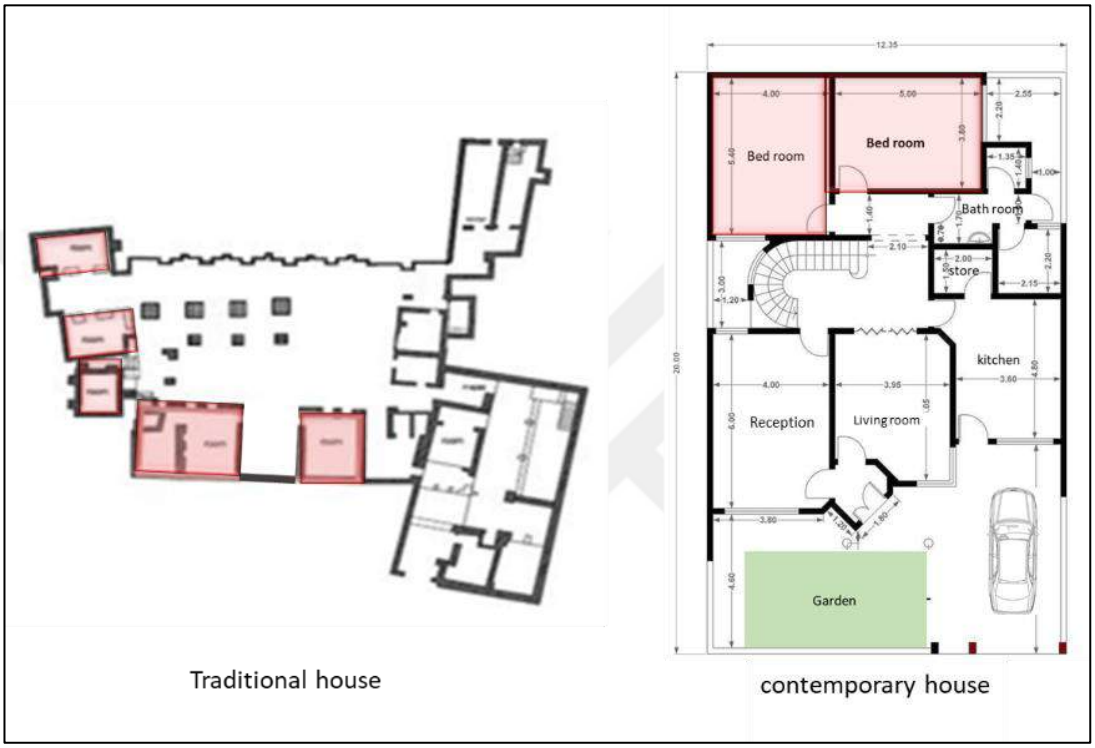


Figure 4.16 Comparison of the bedroom plan in both houses (Source: Author)

4.The kitchen: is the place used for cooking, as it necessarily has a garden view, the entrance door, children's playground and perfect air flow and orient the space in order to remove unacceptable smells. The distance of kitchen must not be lower from 5 square meters, also it must be closely connected to the room of dining and service spaces such as the bathroom, laundry room, toilet, and the other spaces equipped by water and gas [107].

In traditional house plan, the kitchen has a higher ceiling and is located at the housing unit end. It contains one small opening for ventilation at the upper part of wall in the rear alley [108]. The kitchen location in the contemporary house plan is in the front

part of the house for the purpose of good air flow and also to control the entrance, children's playground, and the front garden, as shown in the Figure 4.17



Figure 4.17 Comparison of the kitchen plan in both houses (Source: Author)

5. The dining room: is directly related to the kitchen. It can be shortened just enough to do its function. It also can be used as the corner of a room or connected to the living room or entrance hall [107]. The iwan is known as the dining room in a traditional house, which opens to the central courtyard that family members get together to eat [108]. In contemporary house, the house often does not have a dining room, it is in a part of living room or the kitchen, as seen in Figure 4.18



Figure 4.18 Comparison of the dining room plan in both houses (Source: Author)

7. Bathrooms and toilets: In residential houses, sanitary fixtures are usually located in its own rooms. It should be one window or more than one in the outside walls in order to have natural lighting and these windows should not be lower from half a square meter. Covering materials at least 1.5 meters high will cover the bathroom walls and will prevent them from absorbing moisture [107]. In traditional houses, bathrooms and toilets are placed in the central courtyard. While in contemporary houses the toilet and bathroom can be participate in a single open zone, that is considered negatively as it is participate with the bedroom and thus bad smells in the house are unwanted, as seen in Figure 4.19

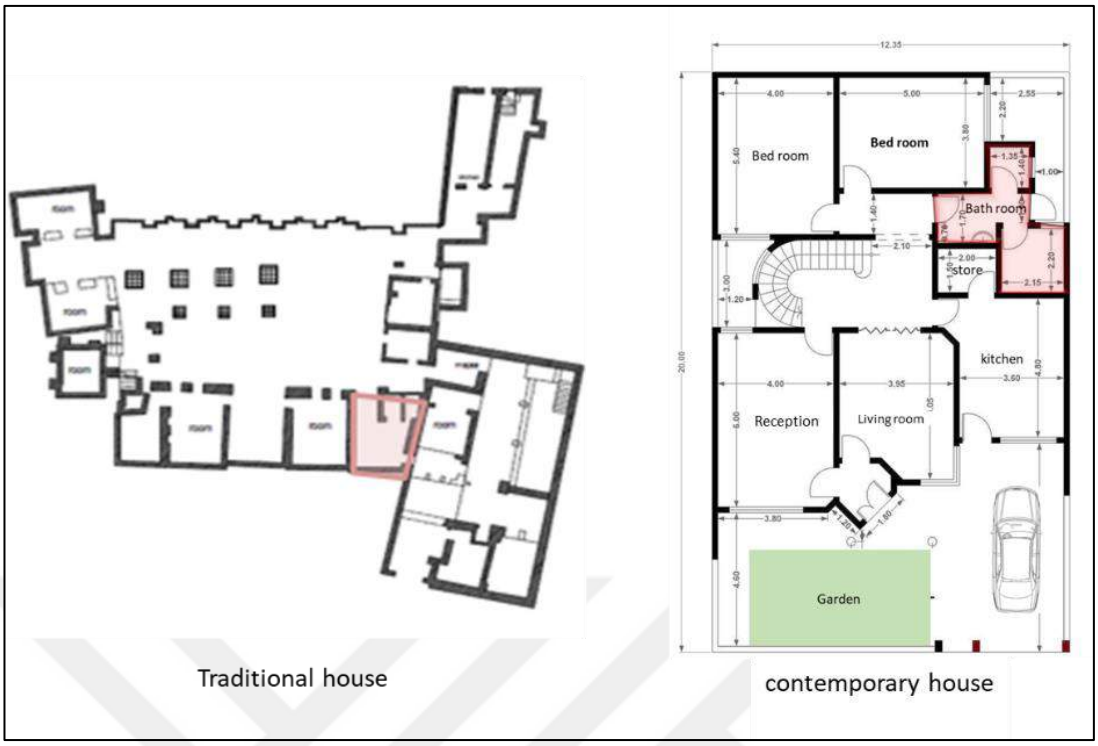


Figure 4.19 Comparison of the bathroom plan in both houses (Source: Author)

8. Parking Garage: are covered or open spaces and its location should be lot is close to the residence entrance. Traditional houses do not have parking garages because there were no cars at that time, as shown in Figure 4.20. If residences consist of more than one floor, they must be located under or within parking areas. Sliding doors are mounted on interior walls if the area is narrow [107].



Figure 4.20 Comparison of the garage plan in both houses (Source: Author)

9. Store: Every house must have 8.0 square meters area of food storage space. Hermetic locking is used to protect stores from mice [107].

In traditional houses there is a store near to the kitchen. However, it is not directly connected but looks out the central courtyard. Since the weather is rather cold throughout the summer months, food storage in traditional houses is usually located in the basement. The basement was previously storage dried food as there was no refrigerator. While contemporary houses usually have a store directly attached to the kitchen, as seen in Figure 4.21



Figure 4.21 Comparison of the store plan in both houses (Source: Author)

10. Location of open spaces in regarding to blocks, such as the central courtyard, gardens in the front or the back. [109] defines the ratio of open space between the volume of open space and solid block volume. The central courtyard was served like an open space in traditional houses of Mosul, and distributed of the rooms on four or three sides depending on the design [110]. But in contemporary houses, the open space is served like a back or front gardens and the solid mass representing the building which containing small ventilation gaps where not exceeding three square meters, as seen in the Figure 4.22

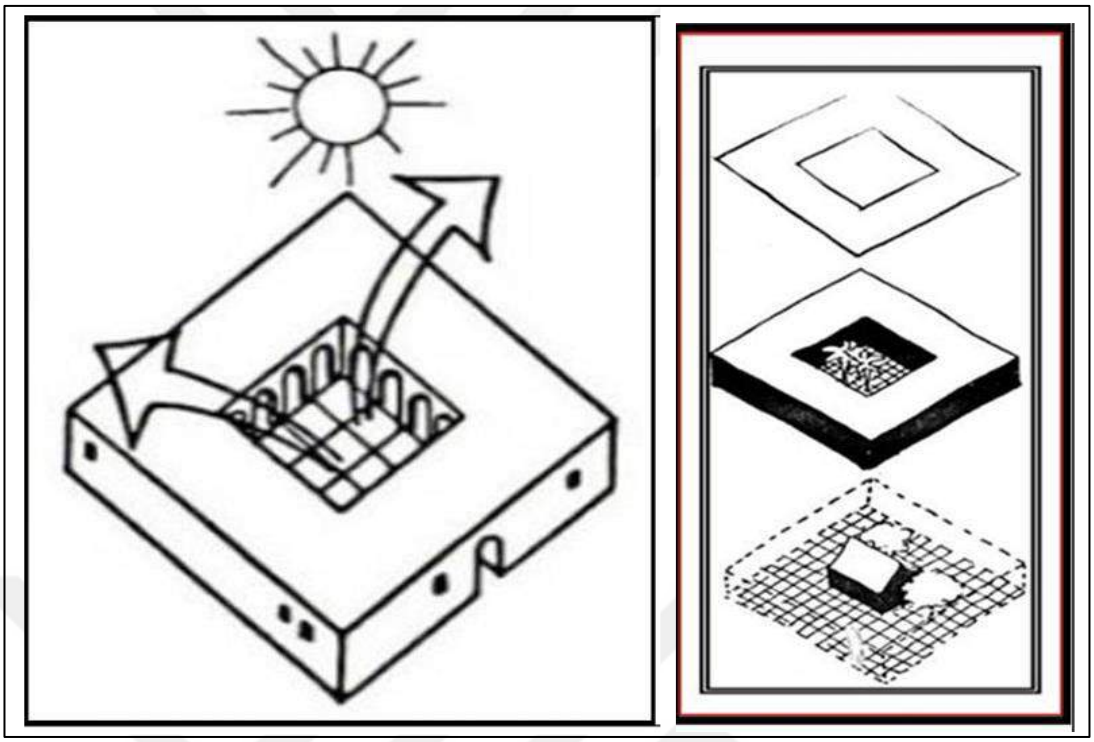


Figure 4.22 Comparison of the open spaces in both houses [109]

11. The basement: It is usually located under the courtyard of the traditional house or on its sides. If it is under the courtyard of the house, the lighting and ventilation are above the roof of the courtyard and are formed by up to four or two windows, depending on the area of the courtyard. There is lighting and side ventilation, which is on one side of the house, overlooking a little higher than the courtyard. It is either rectangular or semi-circular, and has iron engravings for protection. The basement is usually deep, and part of the basements has its walls and floors lined with alabaster, and the other section is plastered, and it can be entered via its own staircase. The basement is used. Usually for several purposes, including storing grains and foodstuffs. There are some basements used for raising animals or practicing some crafts. They are warm in winter, mild in summer, and adapted to climate conditions [105]. As for contemporary houses, they are devoid of basements.

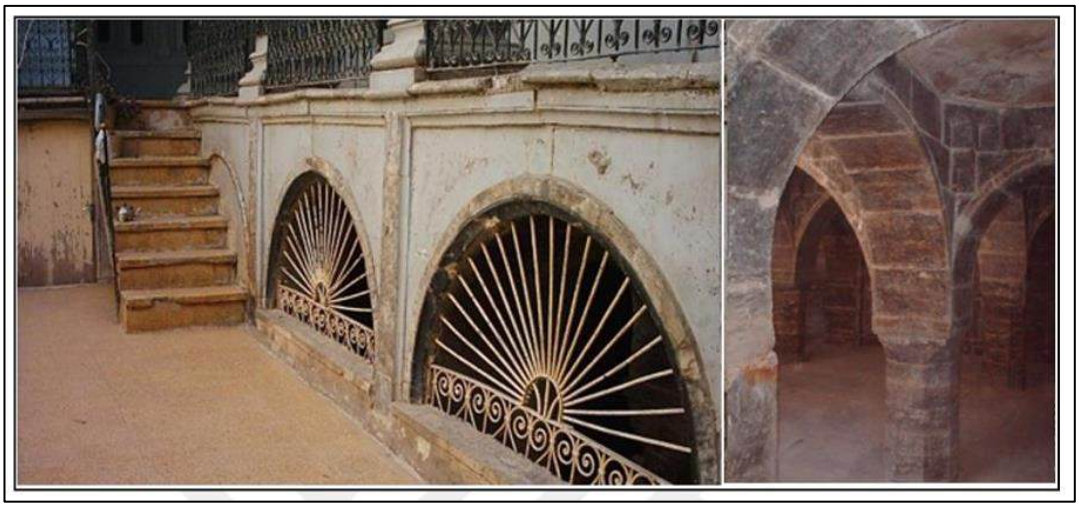


Figure 4.23 The form of the basement out and inside [109]

12. Building area: Researchers distinguished old Mosul houses into three categories according to their areas, including private houses (for rich families), which are large in size, houses with occupations, and houses for the poor [105], while contemporary houses are often small in size because families are independent.

13. Building materials: Mosul's traditional buildings used brown and white marble, also known as Al-Halan. Those materials were used as to their proximity to the city and the abundance of stone quarries placed outside Mosul city. The stone that surround the city is after cut using specific large-sized cutters upon request. Pebble (al-Samman) is used in construction in irregular forms and gives well-known and a special shape to Mosul buildings. Reinforced concrete, brick and iron are used in contemporary Mosul houses. Furthermore, lime, domestic finishing materials, marble and Plaster [109].

Table 4.1 The difference between traditional and contemporary buildings (Source: Author)

	Traditional houses	Contemporary houses
The design	The design is often inspired by traditional Eastern architecture, with traditional cultural themes.	The design may be more contemporary and integrated with modern architecture trends.
Materials	Traditional local materials such as clay, mud and wood are used.	It uses modern materials such as reinforced concrete, glass and steel.

Table 4.1 (continued): The difference between traditional and contemporary buildings (Source: Author)

Technology	It is based on traditional building techniques and uses traditional cooling and heating systems.	It relies on modern technology in design and construction, which includes modern cooling and heating systems also renewable energy systems.
The structure	It is characterized by thick walls and intersecting internal partitions.	They may have more complex and varied structures with the use of open spaces.
Integration with the environment	Its integration with the natural environment and local culture may be more pronounced.	They may be designed to better integrate with modern urban city structures and provide modern amenities.
Entrance	Indirect entrance	Direct entrance
Building area	Building area wide	Building area narrow
Open area	Open area courtyard	Open area front garden
The basement	The basement	No basement
roof	Dome roof	Flat roof
The Garage	No garage	The Garage
Window	Window small	Window wide open out door
Historical period	18-19 centuries	After first world war

4.2.2 Selecting the Sample Building

Model selection method: Since traditional architecture is the true expression of local architecture, it is important to deal with traditional models in a way that serves the direction of the research. Through this, traditional architectural models contained within this model will be dealt with and adopted as case studies for the purpose of analysis. Since contemporary local architecture has been greatly influenced by the prevailing trends in the architectural arena, it is important to deal with contemporary models in order to compare them with traditional models in a way that serves the direction of the research. The study chose various models of individual dwellings in the Mosul city because they represent the largest category of local dwellings compared

to multi-storey residential buildings on the one hand, and due to the diversity of their building materials and construction methods on the other hand. The samples selected for research took into account the different kinds of individual residential units in the Mosul city. Which included traditional heritage-style residential units built using local on-site methods, and contemporary-style residential units built using semi-fabricated on-site methods. These residences were chosen because they achieve different strategies and construction methods for the residential unit. As well as limiting it to accurately documented models for heritage housing, and models executed by engineering personnel for contemporary housing as much as possible. Through this, contemporary architectural models contained within this model will be dealt with and adopted as case studies for the purpose of analysis.

a. The traditional model:

With regard to the traditional model represented by the area (the Great Mosque, this area is one of the distinctive features of the old city of Mosul as it is centered around the Grand Mosque of Al-Nuri) known for its humpbacked minaret, which represents an important historical landmark within the city. It represents an appropriate model for application because today there is a need for plans (Development and rehabilitation) within various sustainability trends, including the energy issue. Figure 4.24 shows the location of the traditional urban model in relation to the city of Mosul. Regarding traditional architectural models, two models of residential homes defined as heritage models and documented in the Cultural Museum in Mosul will be approved.

b. Contemporary model

Regarding the contemporary model, represented by the (Al-Millions District) area and the (Arian District) area, these two areas are considered relatively modern residential neighborhoods within the Mosul city, and Figure 4.24 shows the location of the contemporary urban model in relation to the city of Mosul. Two models of residential homes will be approved, defined as designed by architects - with experience in the field of architectural work within specialized engineering offices - and documented in the Mosul Municipality with this classification, and these models will be divided according to the available spaces within the site.



Figure 4.24 The location of both traditional and contemporary urban models in relation to the city of Mosul (Source: Author from google earth)

4.3 3D Modeling of Building Geometry

After determining the locations of the selected models, the traditional buildings will be compared against the residential buildings in two groups, each group contains two residential houses, the first group is the traditional buildings (A1, A2) and the second group is the contemporary buildings (B1, B2). In groups (A) and (B), the units are of equal or similar area, which achieves a fair and accurate comparison between the buildings.

All building details are entered into the Autodesk Revit 2023 program for building information modeling and forming the 3D of the building in terms of construction materials, wall components, ceilings, floors, and wall height. Traditional buildings are characterized by their high and thick walls, with a height of about 4 meters and a thickness of about 40 cm. These buildings are based on traditional building materials such as clay brick or local stone, which makes them highly durable and stable.

As for contemporary buildings, they are characterized by lower and thinner walls, with a height of about 3 meters and a wall thickness of about 20 cm. These buildings use modern building materials such as reinforced concrete and cement bricks, making them lighter in use and maintenance.

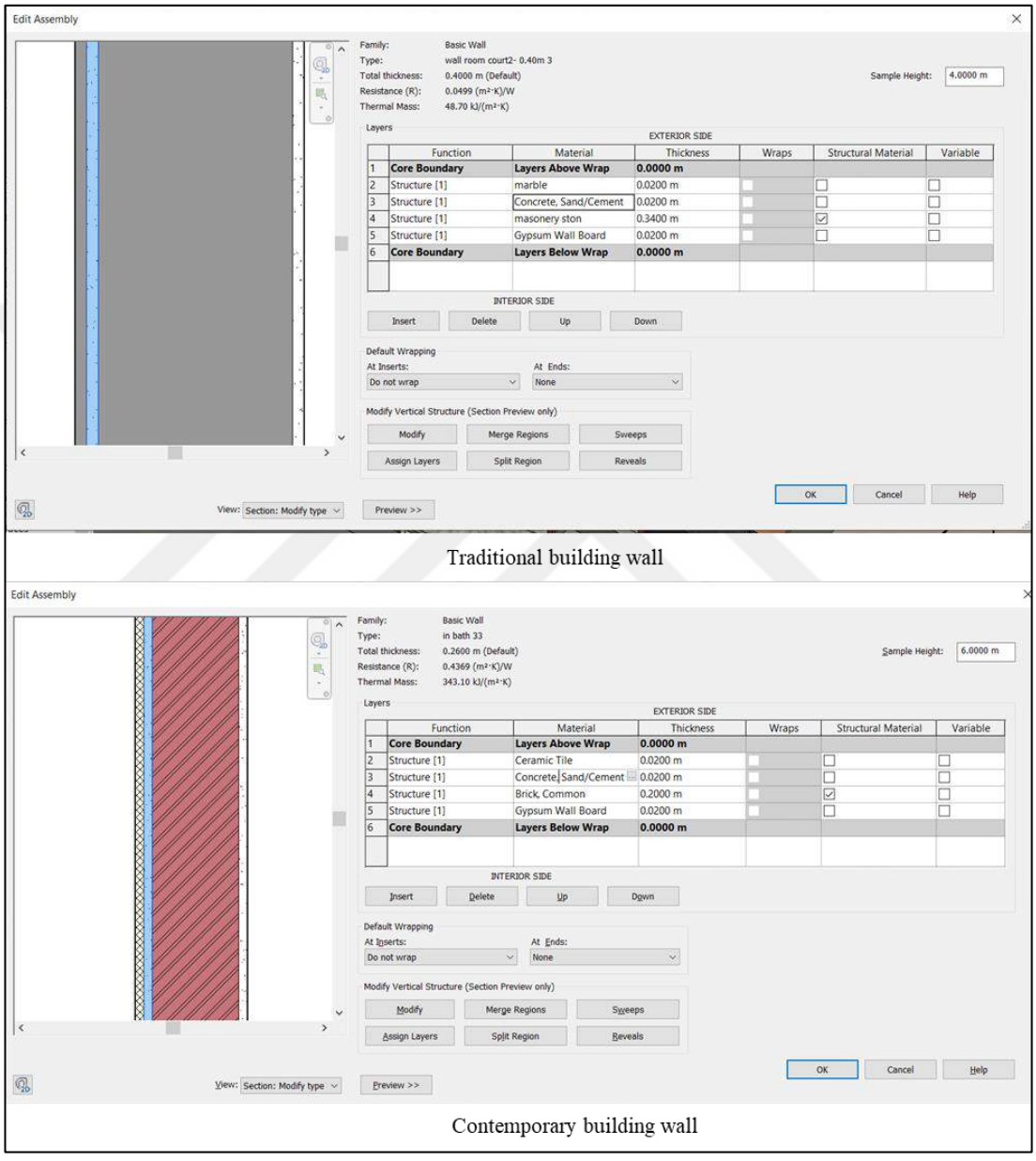


Figure 4.25 Wall components in both buildings

As for ceilings, their components vary according to the type of construction, as the ceilings for traditional buildings may be made of local stone or traditional tiles, while

contemporary buildings use reinforced concrete ceilings or light panels such as gypsum.

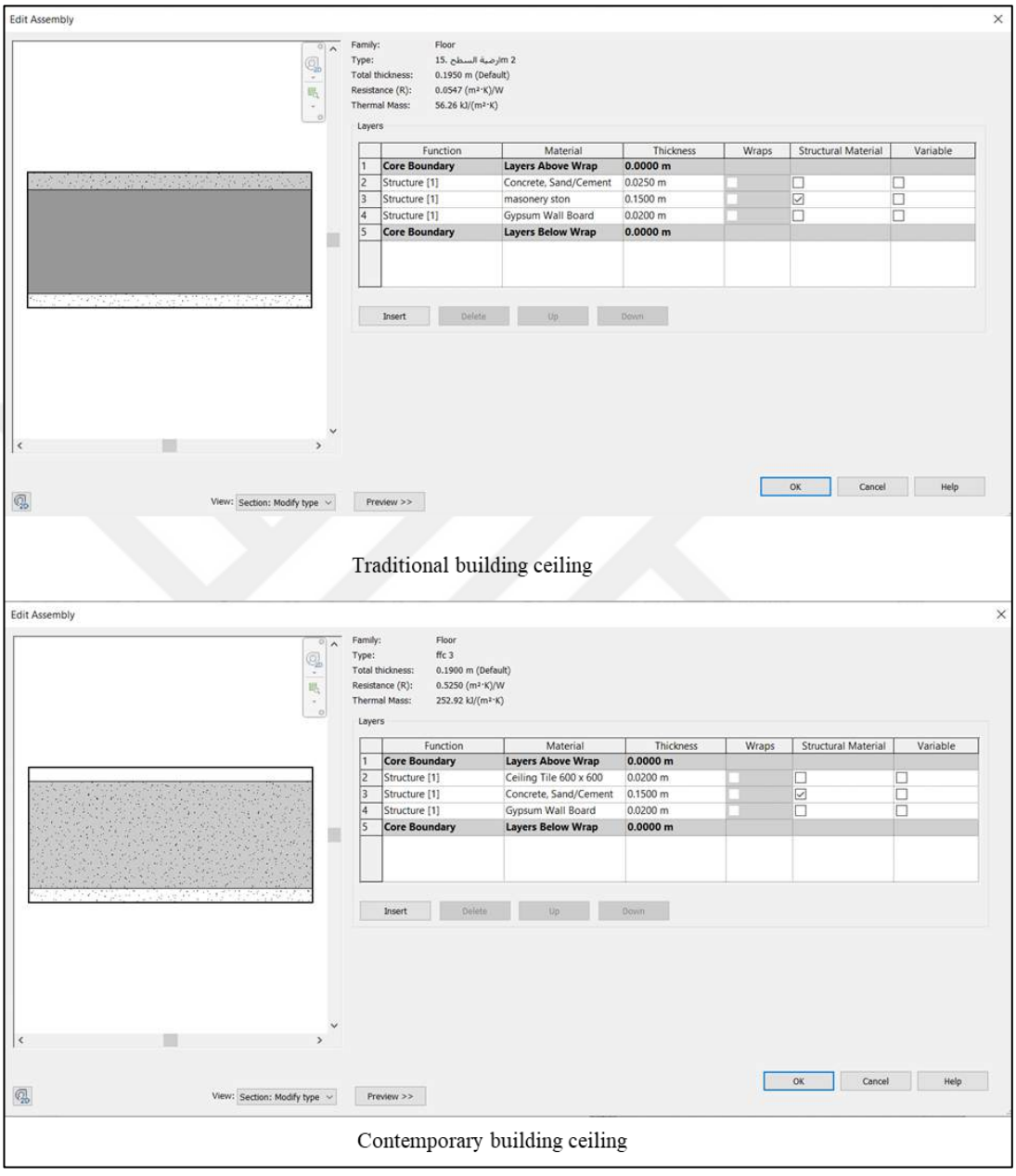


Figure 4.26 Ceiling components in both buildings

As for floors, traditional buildings often use alabaster, while contemporary buildings prefer to use ceramic or artificial porcelain.

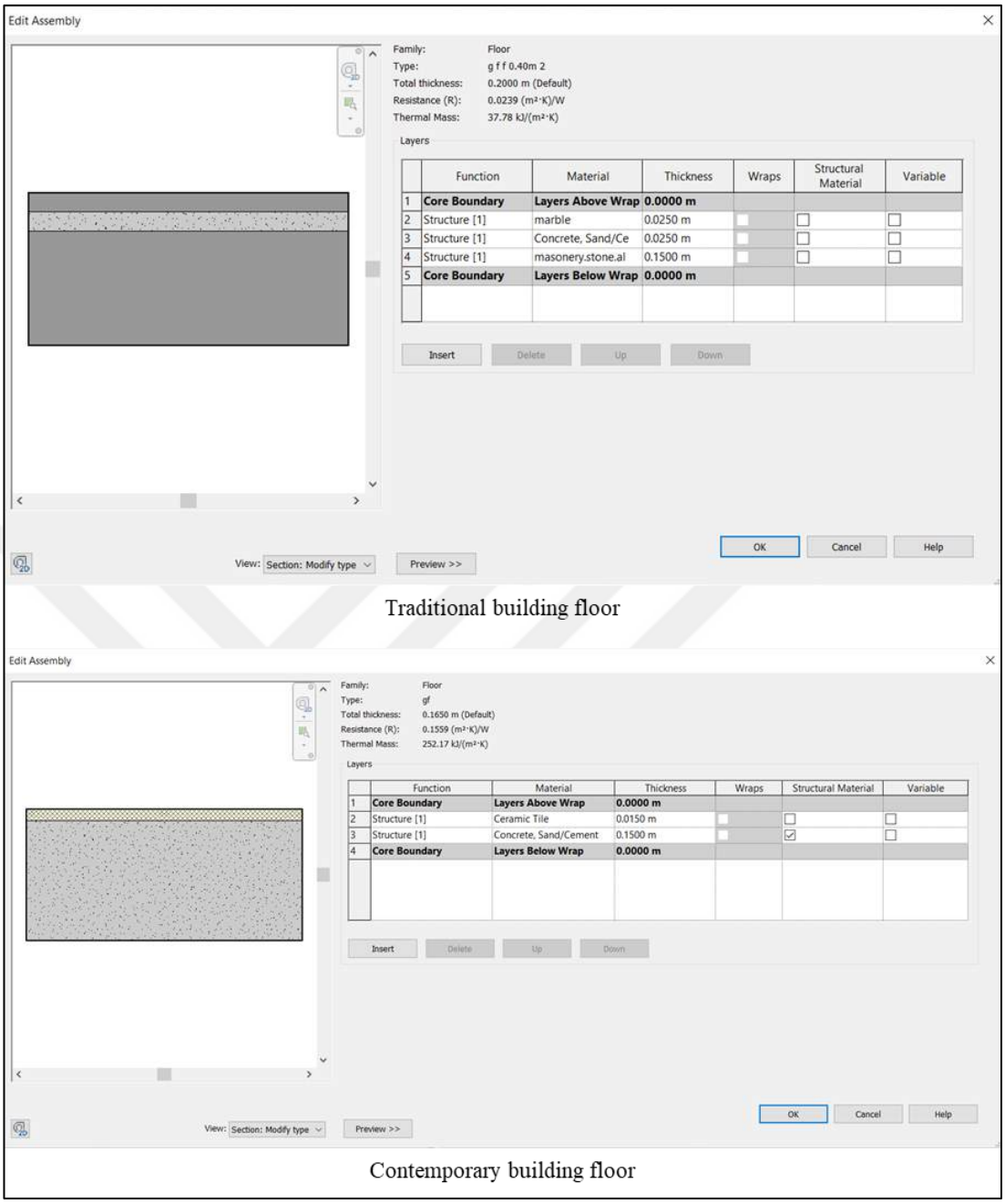


Figure 4.27 Floor components in both buildings

In this way, the difference between traditional and contemporary buildings appears with regard to their components, building materials and dimensions, as shown in Table 4.2, where traditional construction is distinguished by strength and stability, while contemporary buildings are characterized by lightness.

Table 4.2 Information and structural components of buildings (Source: author)

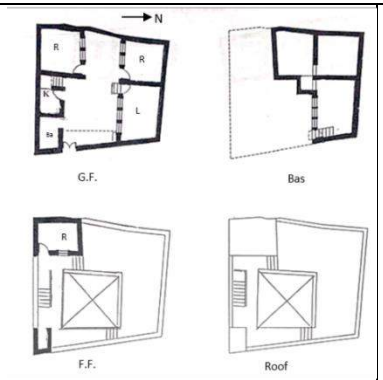
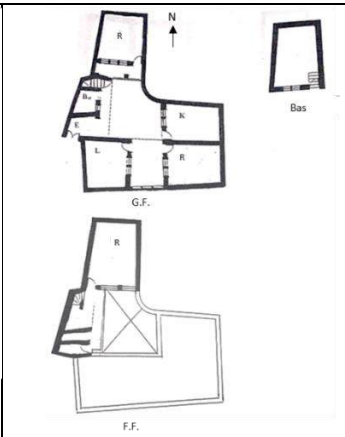
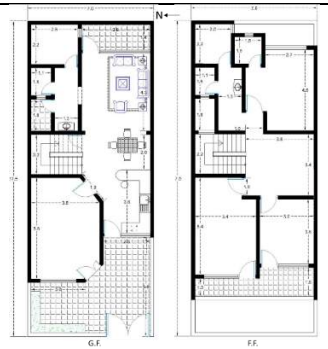
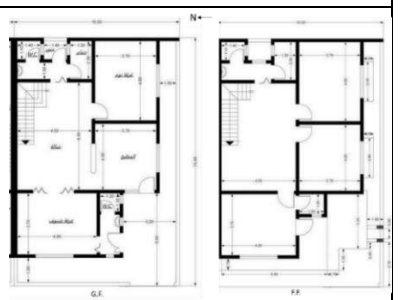
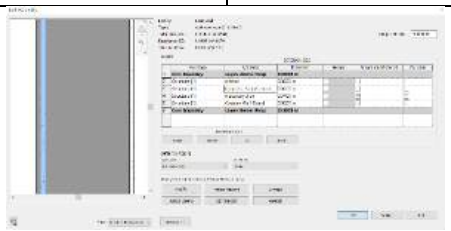
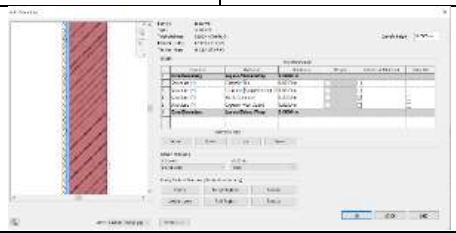
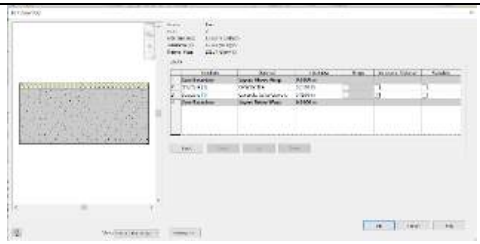
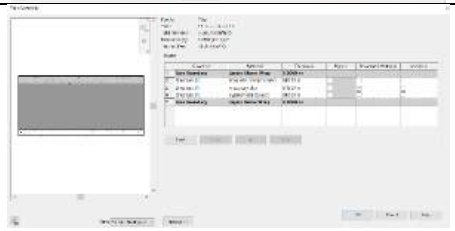
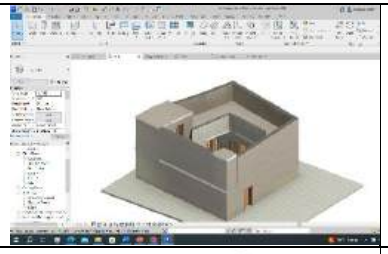
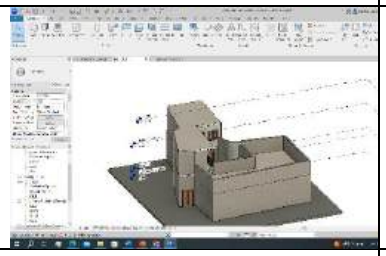
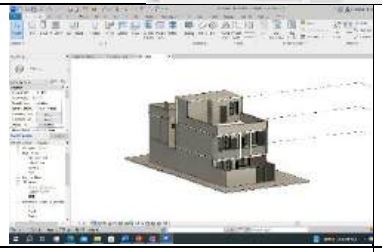
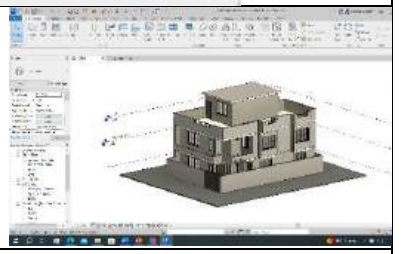
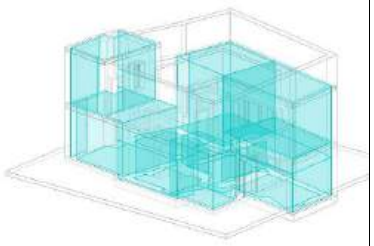
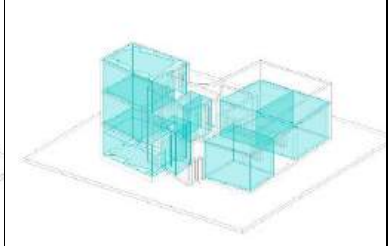
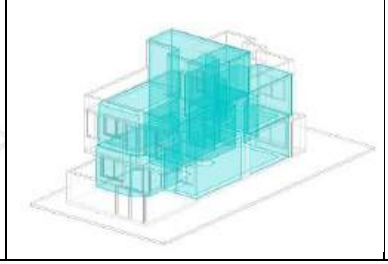
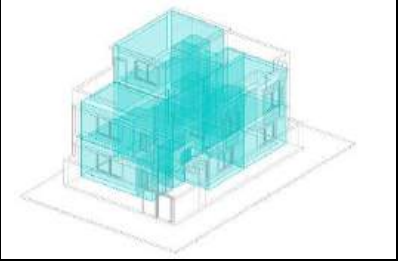
Building type	Traditional units		Contemporary units	
Building code	A1	A2	B1	B2
Building area	110 m²	150 m²	122.5 m²	150 m²
Location	Old city of Mosul / the right side		Mosul / the left side	
Basic building material	Stone and plaster mortar		Concrete block	
Style and method of construction	Site construction using traditional methods		Site construction using guided methods	
Plans				
wall				

Table 4.2 (continued): Information and structural components of buildings (Source: author)

Floor				
Ceiling				
3D model				
The energy model				

4.4 Defining Energy Parameters in 3D Model

After completing entering and modeling the building information, some settings are adjusted for energy modeling, which include the following:

1. From the analyze menu, the Create Energy Model icon is selected where the energy model will be created as shown in the Figure 4.25

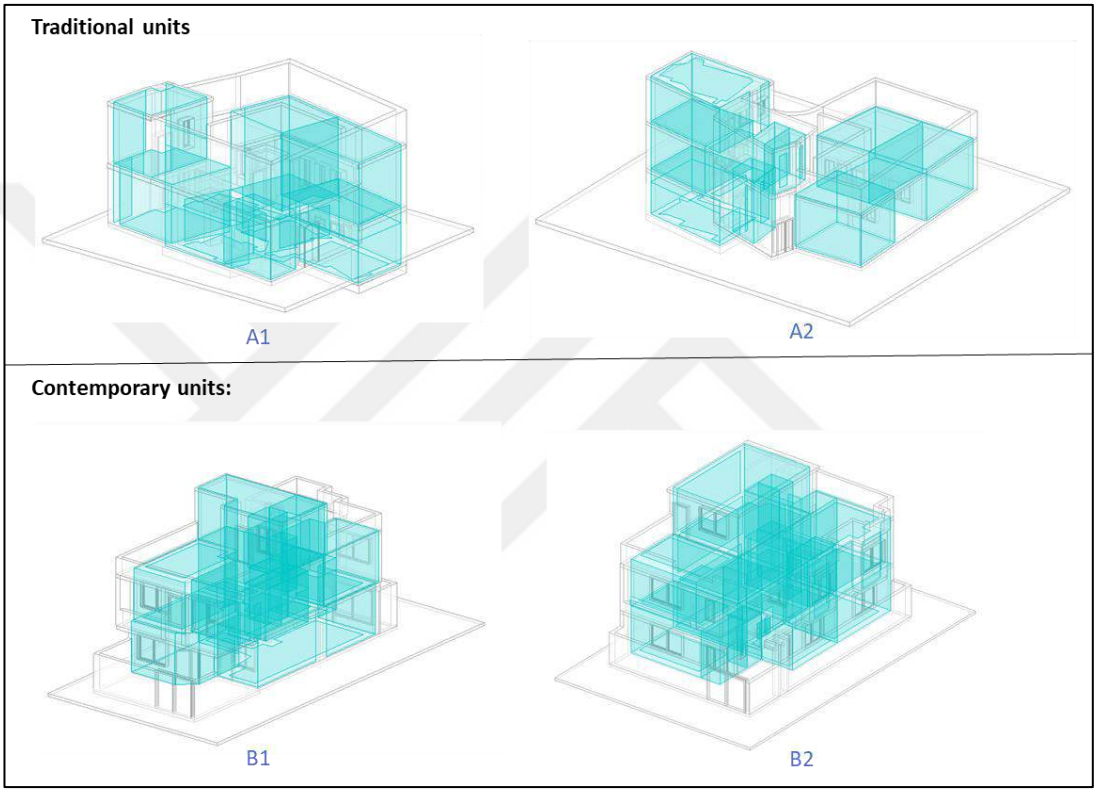


Figure 4.28 The Energy modeling for each building (Source: Author)

2. Also from the analysis menu, the location icon is selected, then the city of Mosul is selected as the location as shown in the Figure 4.26

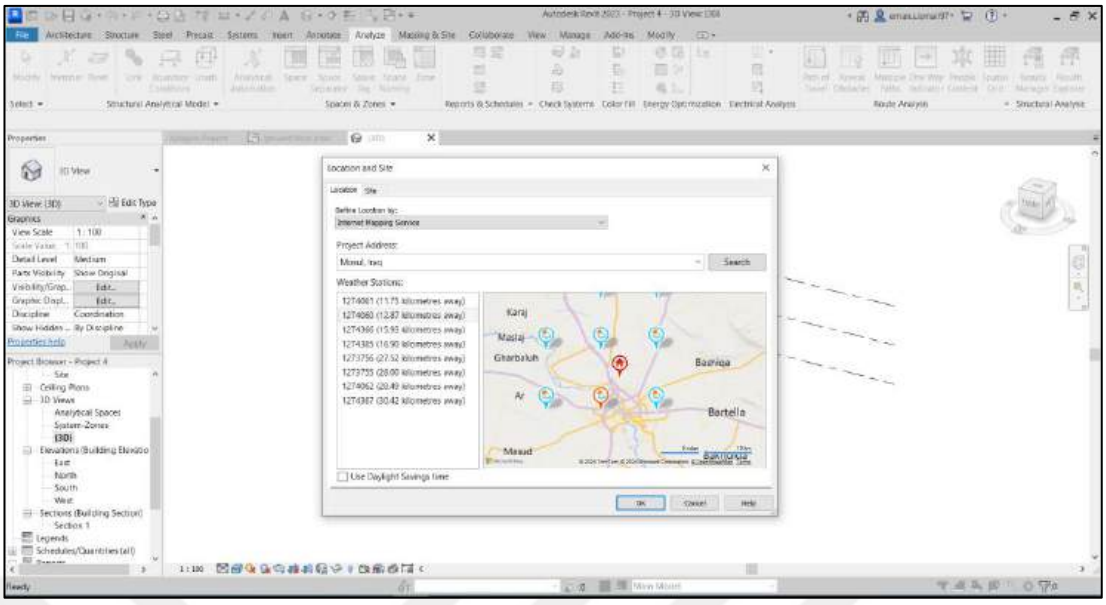


Figure 4.29 Determine the location of the building in Revit (Source: Author)

3. From the same analysis menu, the energy settings icon will be selected, and then some settings will be modified as shown in the Figure 4.27

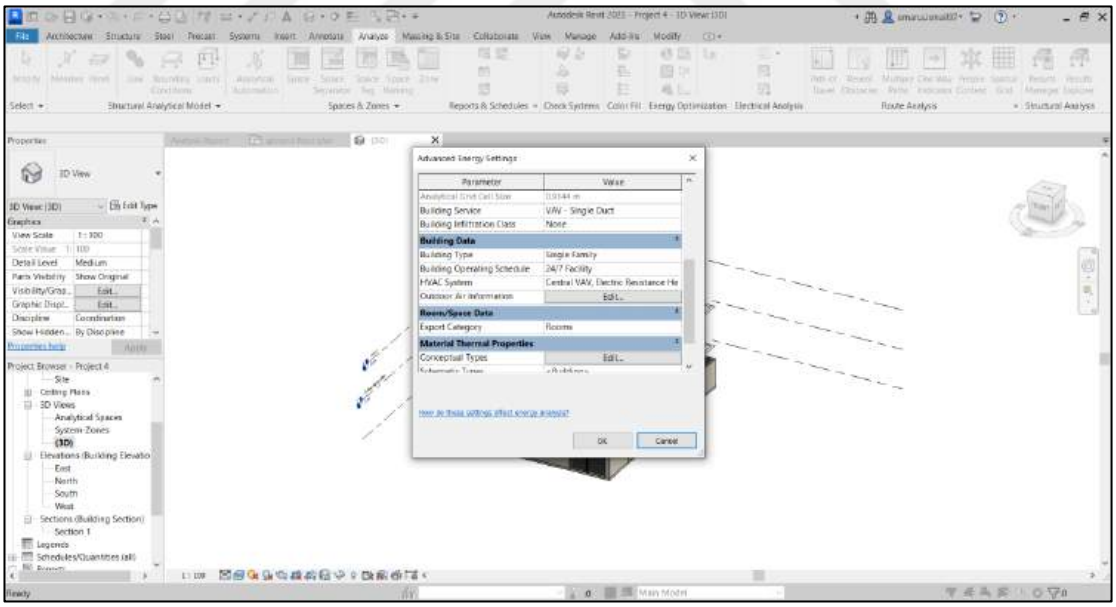


Figure 4.30 Specifying some energy settings in the program (Source: Author)

4. In the analysis menu, the Generate icon will be selected to create an energy analytical model and determine the building cost range using Insight, which is linked

to the Revit program, then from the same menu, the Insight platform will be navigated to as shown in the Figure 4.28

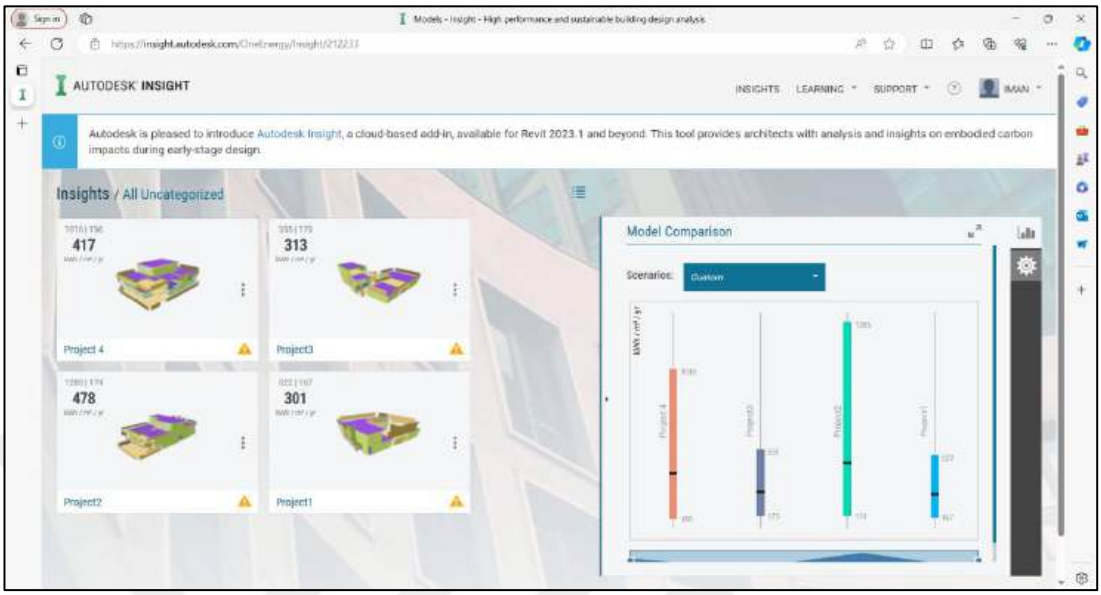


Figure 4.31 Shows the insight interface that is linked to the Revit program (Source: Author)

5. In the final stage, some settings will be adjusted to enter the cost of the electricity and gas rate in Iraq, where the electricity rate is (0.015$) per KWh [111], and gas (0.31$) per Cubic Meters [112], as shown in the Figure 4.29

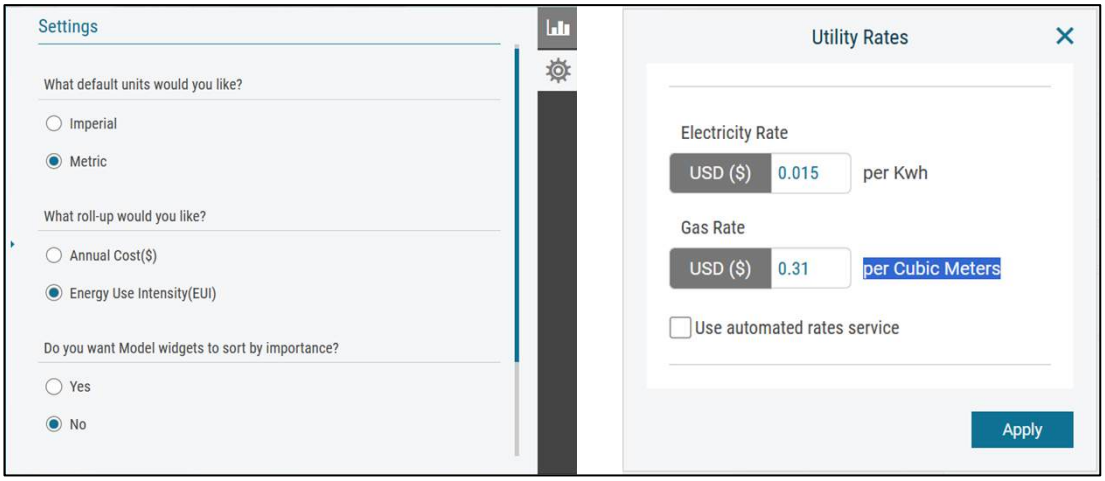


Figure 4.32 Shows some settings and the cost of electricity and gas rates (Source: Author)

6. After performing these steps, all the information will be automatically saved in the Green Building Studio program, and it can also be opened via the Google browser, through which the results of the building analysis in terms of energy and cost are compared, as in the Figure 4.30

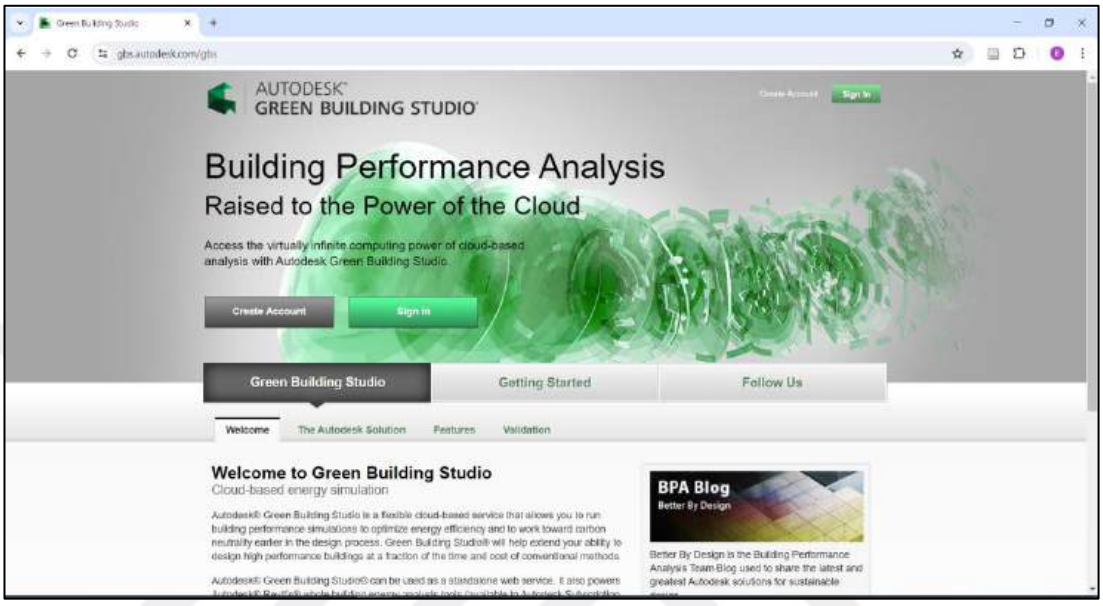


Figure 4.33 Shows the green building studio interface (Source: Author)

CHAPTER 5

FINDINGS

5.1 Findings

After completing the building modeling and adjusting the settings in the Autodesk Revit program to simulate the four selected buildings, the results of the analysis of the buildings in terms of energy consumption and cost are shown by choosing the optimize command. A comparison of the four buildings in terms of energy consumption is also seen, as in the Figure 5.1

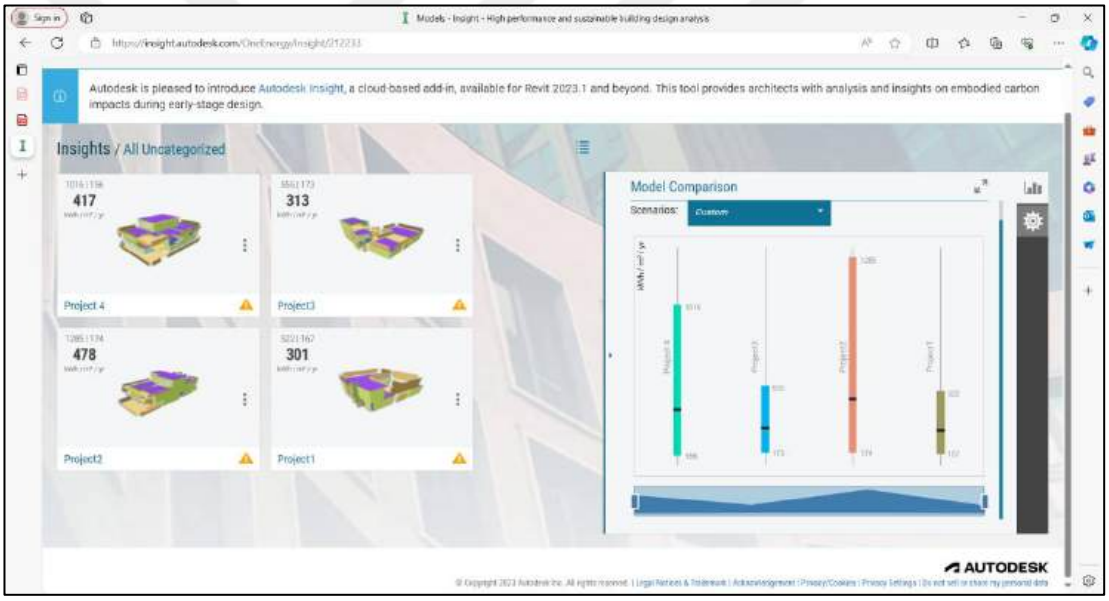


Figure 5.1 The results of the analysis for the four buildings in terms of energy consumption (Source: Author)

The results appeared the amount of energy consumption in both of two groups as shown in Figure 5.2 and the cost as shown in the images in the Figure 5.3

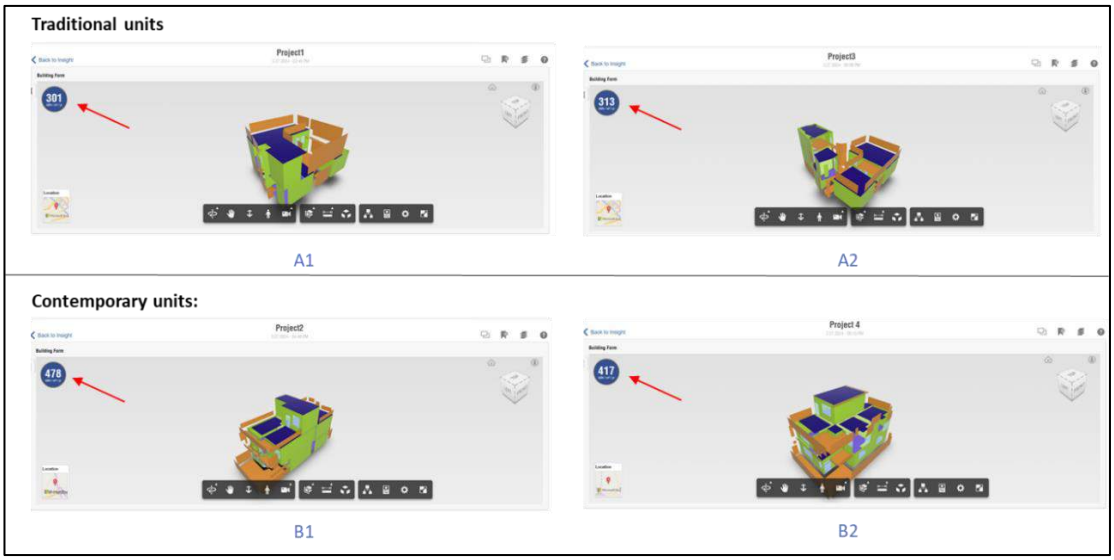


Figure 5.2 Energy consumption in four buildings (Source: Author)



Figure 5.3 Cost amount in the buildings (Source: Author)

5.2 Green Building Studio Findings

From the green building studio program, more data is obtained regarding energy, carbon, and costs, which were obtained based on the Revit program, where the results are as follows:

1. The first group: The results of the traditional houses (A1, A2) are as shown in the Figure 5.4 and Figure 5.5

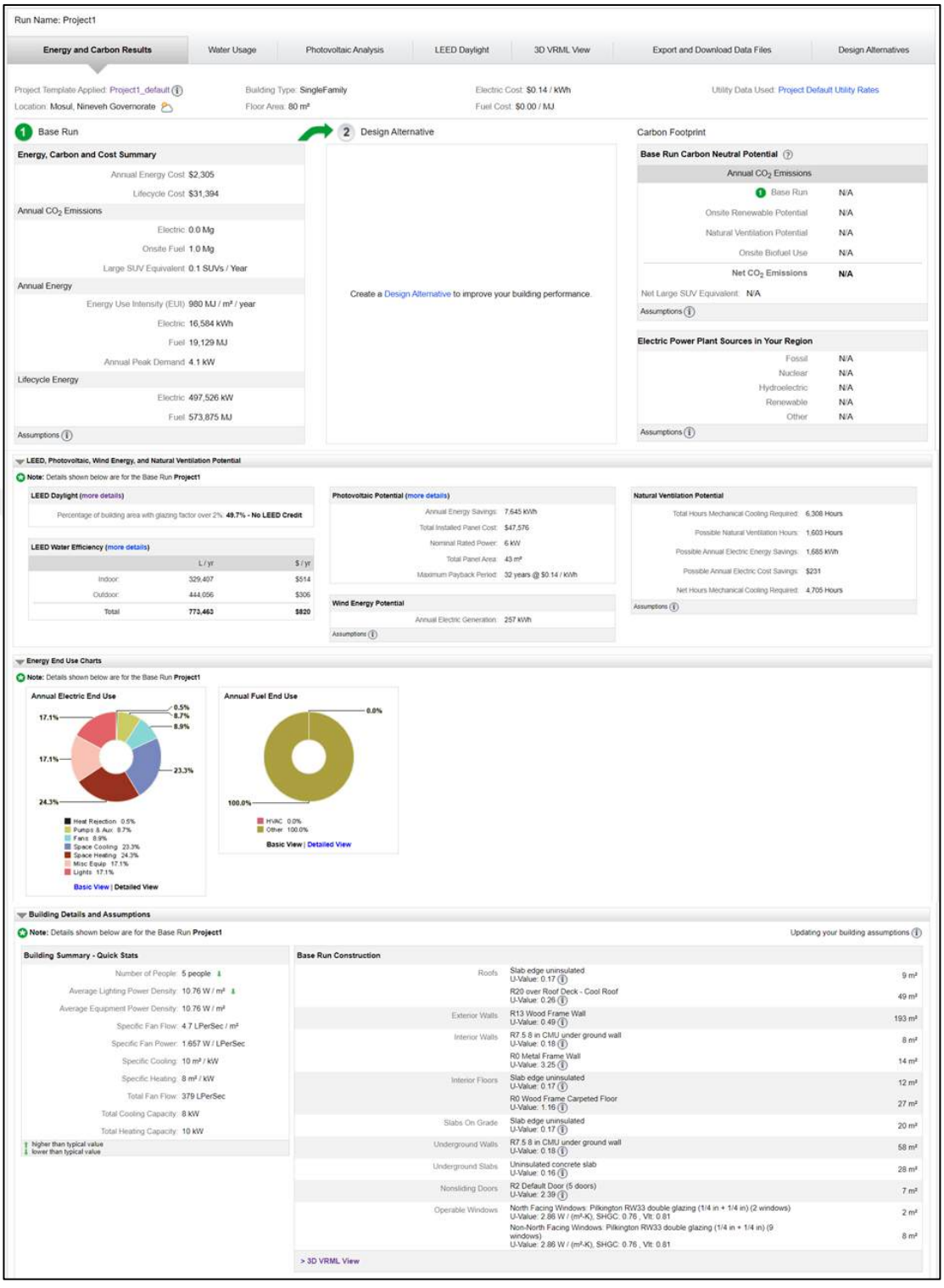


Figure 5.4 Traditional house results (A1)

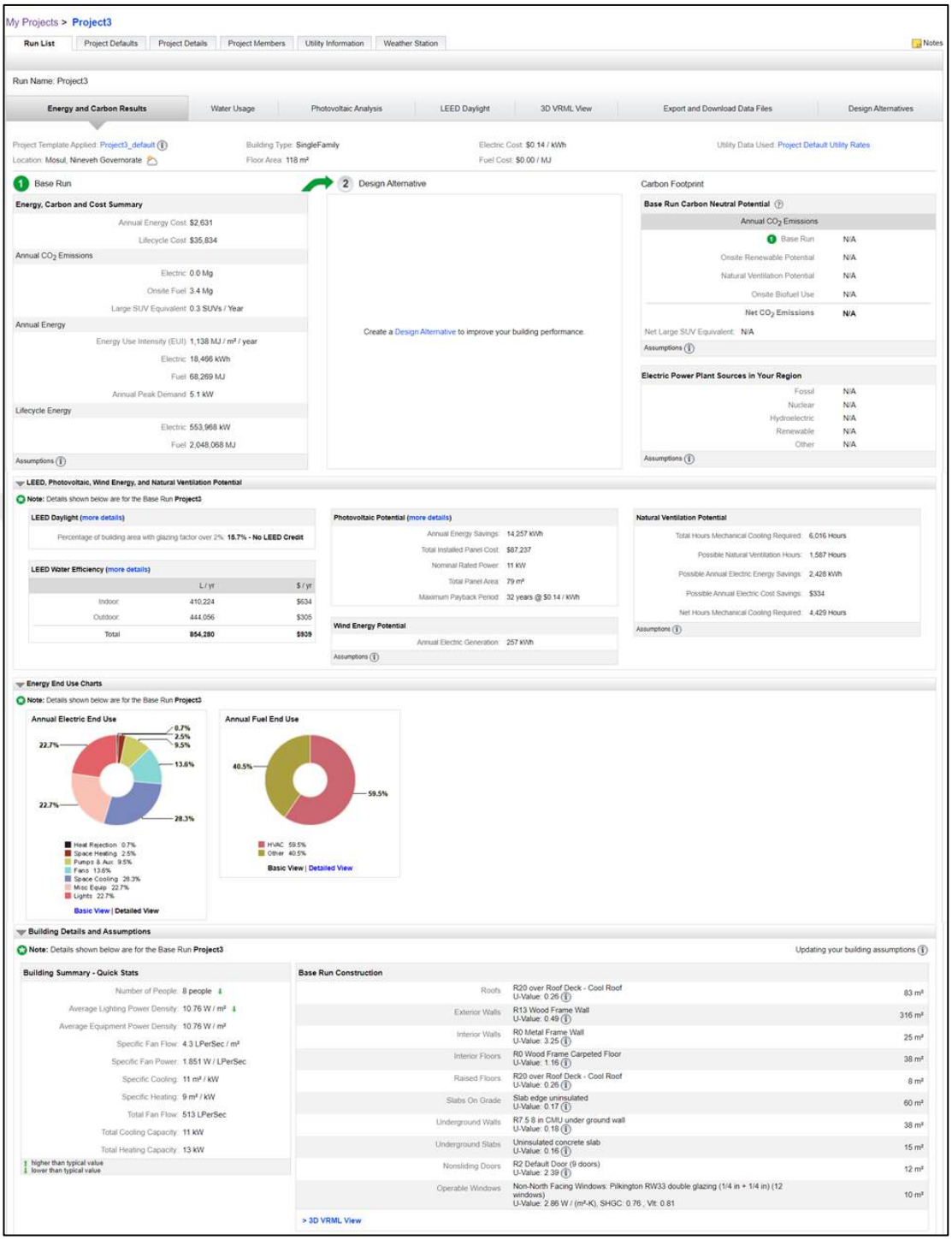


Figure 5.5 Traditional house results (A2)

2. The second group: The contemporary houses results (B1, B2) are as shown in the Figure 5.6 and Figure 5.7

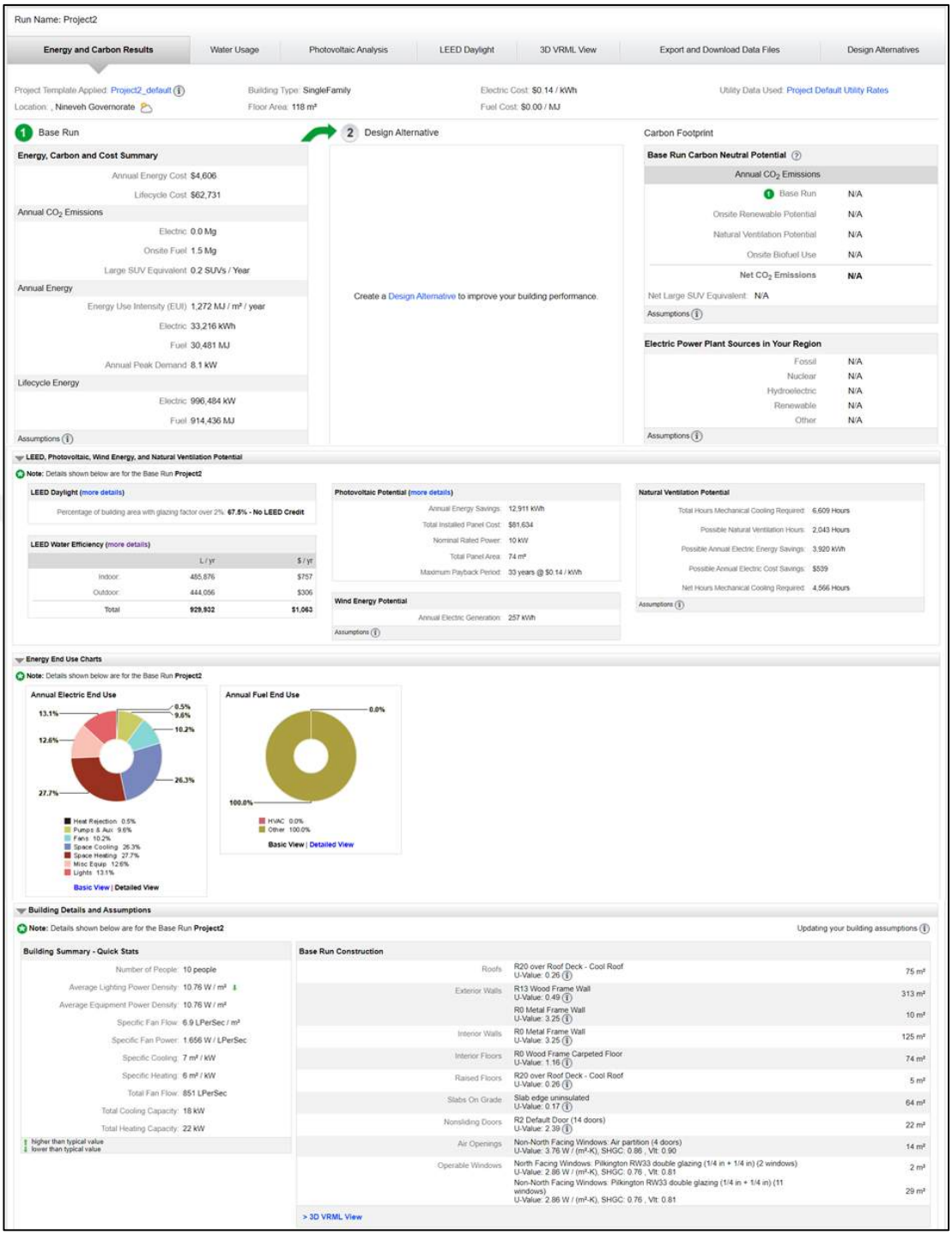


Figure 5.6 Contemporary house results (B1)

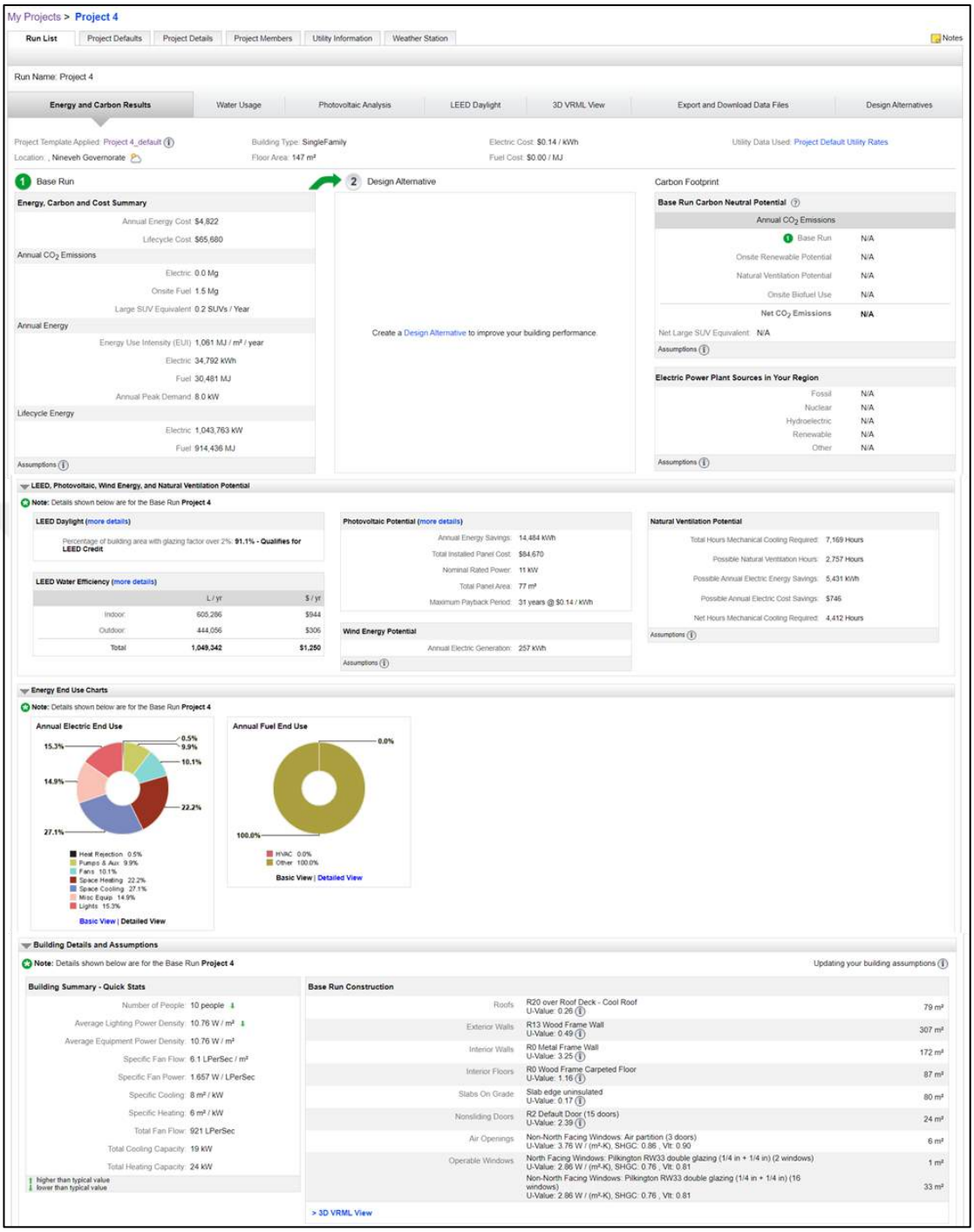


Figure 5.7 Contemporary house results (B2)

CHAPTER 6

DISCUSSION

After reviewing the results obtained from previous tests using the computer simulation program (Autodesk Revit), the following results were reached:

The results of the energy comparison in the Revit program for both groups showed that traditional buildings consume less energy than contemporary buildings, as the energy consumption in the first group in the traditional building(A1) reached (301 kwh/m²/yr) while in the A2, the amount of it was (313 kwh/m²/yr). For the second group, it was in B1 (478 kwh/m²/yr) and it was (417 kwh/m²/yr) in B2. Regarding the cost, in the first group the amount of cost in A1 was (3.31 USD/m²/yr), while in A2 (3.72 USD/m²/yr). For the second group, it was in B1 (5.43 USD/m²/yr) and it was (4.96 USD/m²/yr) in B2 as shown in the images in the Figure 6.1

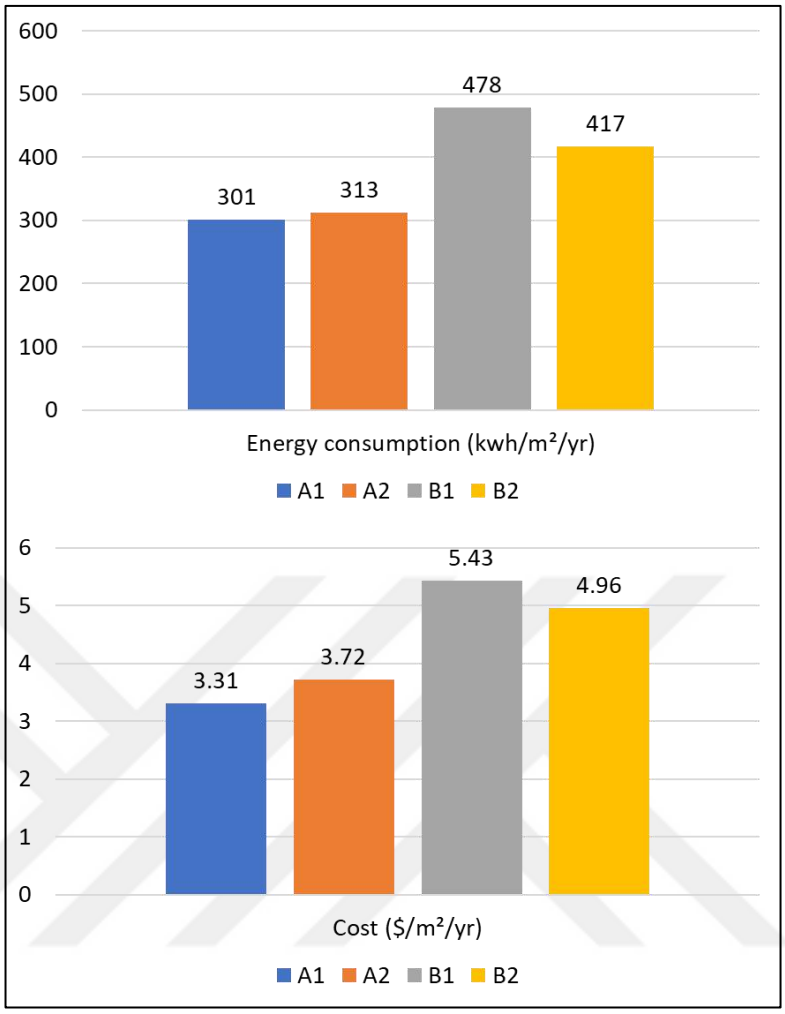


Figure 6.1 Energy consumption and costs in four buildings

As for the results of the green building studio, they were as follows:

1. Energy, Carbon and Cost Summary

a. Annual energy cost for both groups were that traditional buildings had a lower cost than contemporary buildings, as annual energy cost in the first group in A1 reached (2,305 $) while in A2, the amount of it was (2,631 $). For the second group, it was in B1 (4,606 $) and it was (4,822 $) in B2. Therefore, Annual energy cost of contemporary buildings is twice that of traditional buildings.

b. Lifecycle Cost for both groups were that traditional buildings were less expensive than contemporary buildings by half, as Lifecycle Cost in A1

reached (31,394 $) while in A2, the amount of it was (35,834 $). For the second group, it was in B1 (62,731 $) and it was (65,680 $) in B2.

c. Annual CO_2 Emissions (Onsite Fuel) in A1 were lower than the carbon dioxide emissions in B1, while in B2 they were lower than in A2, as Annual CO_2 Emissions (Onsite Fuel) in the first group in A1 reached (1.0 Mg) while in A2, the amount of it was (3.4 Mg). For the second group, it was in B1 (1.5 Mg) and it was (1.5 Mg) in B2.
d. Annual CO_2 Emissions (Large SUV Equivalent) were slightly similar as in A1 were lower than the emissions in B1, while in B2 they were lower than in A2, as Annual CO_2 Emissions (Large SUV Equivalent) in the first group in A1 reached (0.1 SUVs / Year) while in A2, the amount of it was (0.3 SUVs / Year). For the second group, it was in B1 (0.2 SUVs / Year) and it was (0.2 SUVs / Year) in B2.
e. Energy Use Intensity (EUI) varied slightly, as in A1 it was much lower than the intensity in B1, while in B2 it was close and slightly lower than in A2, as Energy Use Intensity (EUI) in the first group in A1 reached (980 MJ / m^2 / year) while in A2, the amount of it was (1,138 MJ / m^2 / year). For the second group, it was in B1 (1,272 MJ / m^2 / year) and it was (1,061 MJ / m^2 / year) in B2.
f. Electric for both groups, as electricity consumption in traditional buildings was much lower than contemporary buildings, as Electric in the first group in A1 reached (16,584 kWh) while in A2, the amount of it was (18,466 kWh). For the second group, it was in B1 (33,216 kWh) and it was (34,792 kWh) in B2.
g. Fuel differs slightly, as the need for fuel in A1 was less than in B1, while in B2 it was less than in A2, as it was a fixed amount in the second group, as Fuel in the first group in A1 reached (19,129 MJ) while in A2, the amount of it was (68,269 MJ). For the second group, it was in B1 (30,481 MJ) and it was (30,481 MJ) in B2.
h. Annual Peak Demand for both groups were such that traditional buildings had less demand than contemporary buildings, as Annual Peak energy Demand in the first group in A1 reached (4.1 kW) while in A2, the amount of it was (5.1 kW). For the second group, it was in B1 (8.1 kW) and it was (8.0 kW) in B2.

i. Lifecycle Energy (Electric) for both groups were that the traditional buildings were much lower than in contemporary buildings, as Lifecycle Energy (Electric) in the first group in A1 reached (497,526 kW) while in A2, the amount of it was (553,968 kW). For the second group, it was in B1 (996,484 kW) and it was (1,043,763 kW) in B2.

j. Lifecycle Energy (Fuel) differs slightly, as it was lower in A1 than in B1, while in B2 it was lower than in A2, and Lifecycle Energy (Fuel) in the first group in A1 reached (573,875 MJ) while in A2, the amount of it was (2,048,068 MJ). For the second group, it was in B1 (914,436 MJ) and it was (914,436 MJ) in B2.



Figure 6.2 Energy and cost summary

2. LEED Daylight

   a. Percentage of building area with glazing factor over 2%: for both groups were that traditional buildings had a much lower glazing factor than contemporary buildings, since traditional buildings have small windows, unlike contemporary buildings with large windows, as it reached (49.7%) in the first group in A1. While in A2 the percentage reached (15.7%). %). The second group was in B1 (67.5%) and (91.1%) in B2 as shown in the Figure 6.3

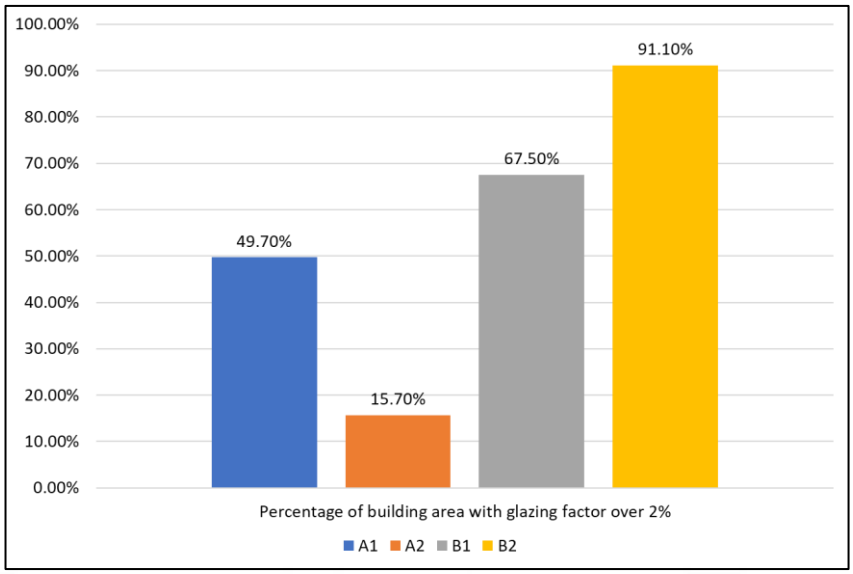


Figure 6.3 Percentage of building area with glazing factor

b. LEED Water Efficiency (Indoor) for both groups were that traditional buildings had a lower LEED Water Efficiency (Indoor) than contemporary buildings, as in the first group in A1 reached (329,407L / yr) (514$ / yr) while in A2, the amount of it was (410,224 L/yr) (634 $/yr). For the second group, it was in B1 (485,876 L/yr) (757 $/yr) and it was (605,286 L/yr) (944 $/yr) in B2.

c. LEED Water Efficiency (Outdoor) for both groups were that constant for each group (traditional & contemporary), as in the first group in A1 reached (444,056L / yr) (306$ / yr) while in A2, the amount of it was (444,056 L/yr) (305 $/yr). For the second group, it was in B1 (444,056 L/yr) (306 $/yr) and it was (444,056 L/yr) (306 $/yr) in B2.

d. Total LEED Water Efficiency for both groups were that traditional buildings had a much lower total than contemporary buildings, as in the first group in A1 reached (773,463 L / yr) (820$ / yr) while in A2, the amount of it was (854,280 L/yr) (939 $/yr). For the second group, it was in B1 (929,932 L/yr) (1,063 $/yr) and it was (1,049,342 L/yr) (1,250 $/yr) in B2, as shown in the Figure 6.4



Figure 6.4 LEED water efficiency

3. Photovoltaic Potential
    a. Annual Energy Savings for both groups were that traditional buildings had a lower Annual Energy Savings than contemporary buildings, as in the first group in A1 reached (7,645 kWh) while in A2, the amount of it was (14,257 kWh). For the second group, it was in B1 (12,911 kWh) and it was (14,484 kWh) in B2. This means that contemporary buildings have the ability to generate higher light energy than traditional buildings. This may be because contemporary buildings are designed to support the installation of solar panels, and due to the increased roof area in contemporary buildings, they may provide larger spaces for the installation of solar panels.
    b. Total Installed Panel Cost varied slightly, as in A1 it was much lower than the cost in B1, while in B2 it was close and slightly lower than in A2, as in the first group in A1 reached (47,576 $) while in A2, the amount of it was

(87,237 $). For the second group, it was in B1 (81,634 $) and it was (84,670 $) in B2.

c. Nominal Rated Power for both groups were that traditional buildings had a lower Nominal Rated Power than contemporary buildings, as in the first group in A1 reached (6 kW) while in A2, the amount of it was (11 kW). For the second group, it was in B1 (10 kW) and it was (11 kW) in B2.

d. Total Panel Area varied slightly, as it was much less in A1 than in B1, while in B2 it was close and slightly lower than in A2, as in the first group in A1 reached (43 m^2) while in A2, the amount of it was (79 m^2). For the second group, it was in B1 (74 m^2) and it was (77 m^2) in B2.

e. Maximum Payback Period varied slightly, as it was less in A1 than in B1, while in B2 it was close and slightly lower than in A2, as in the first group in A1 reached (32 years @ $0.14 / kWh) while in A2, the amount of it was (32 years @ $0.14 / kWh). For the second group, it was in B1 (33 years @ $0.14 / kWh) and it was (31 years @ $0.14 / kWh) in B2.

4. Wind Energy Potential: Annual Electric Generation for both groups were that constant for each group (traditional & contemporary), as in the first group in A1 reached (257 kWh) while in A2, the amount of it was (257 kWh). For the second group, it was in B1 (257 kWh) and it was (257 kWh) in B2.

5. Natural Ventilation Potential

a. Total Hours Mechanical Cooling Required for both groups were that traditional buildings had a lower Total Hours Mechanical Cooling Required than contemporary buildings, as in the first group in A1 reached (6,308 Hours) while in A2, the amount of it was (6,016 Hours). For the second group, it was in B1 (6,609 Hours) and it was (7,169 Hours) in B2.

b. Possible Natural Ventilation Hours for both groups were that traditional buildings had a lower Possible Natural Ventilation Hours than contemporary buildings, as in the first group in A1 reached (1,603 Hours) while in A2, the amount of it was (1,587 Hours). For the second group, it was in B1 (2,043 Hours) and it was (2,757 Hours) in B2. This is due to the thermal design of traditional buildings, as traditional buildings are often designed using thick natural and local building materials that act as a

natural thermal insulator, which helps to significantly reduce the need for heating and cooling as the thick walls and roofs built of clay or stone maintain moderate temperatures for longer periods.

c. Possible Annual Electric Energy Savings for both groups were that traditional buildings had a lower Possible Annual Electric Energy Savings than contemporary buildings, as in the first group in A1 reached (1,685 kWh) while in A2, the amount of it was (2,428 kWh). For the second group, it was in B1 (3,920 kWh) and it was (5,431 kWh) in B2.

d. Possible Annual Electric Cost Savings for both groups were that traditional buildings had a lower Possible Annual Electric Cost Savings than contemporary buildings, as in the first group in A1 reached (231 $) while in A2, the amount of it was (334 $). For the second group, it was in B1 (539 $) and it was (746 $) in B2.

e. Net Hours Mechanical Cooling Required for both groups were very close, as the traditional buildings had more net mechanical cooling hours required by a very slight difference than the contemporary buildings, as in the first group in A1 reached (4,705 Hours) while in A2, the amount of it was (4,429 Hours). For the second group, it was in B1 (4,566 Hours) and it was (4,412 Hours) in B2.

6. Energy End Use Charts

In these charts, varying percentages appeared for each of (Heat Rejection, Pumps & Aux, Fans, Space Cooling, Space Heating, Misc Equip and Lights) as in the Figure 6.5

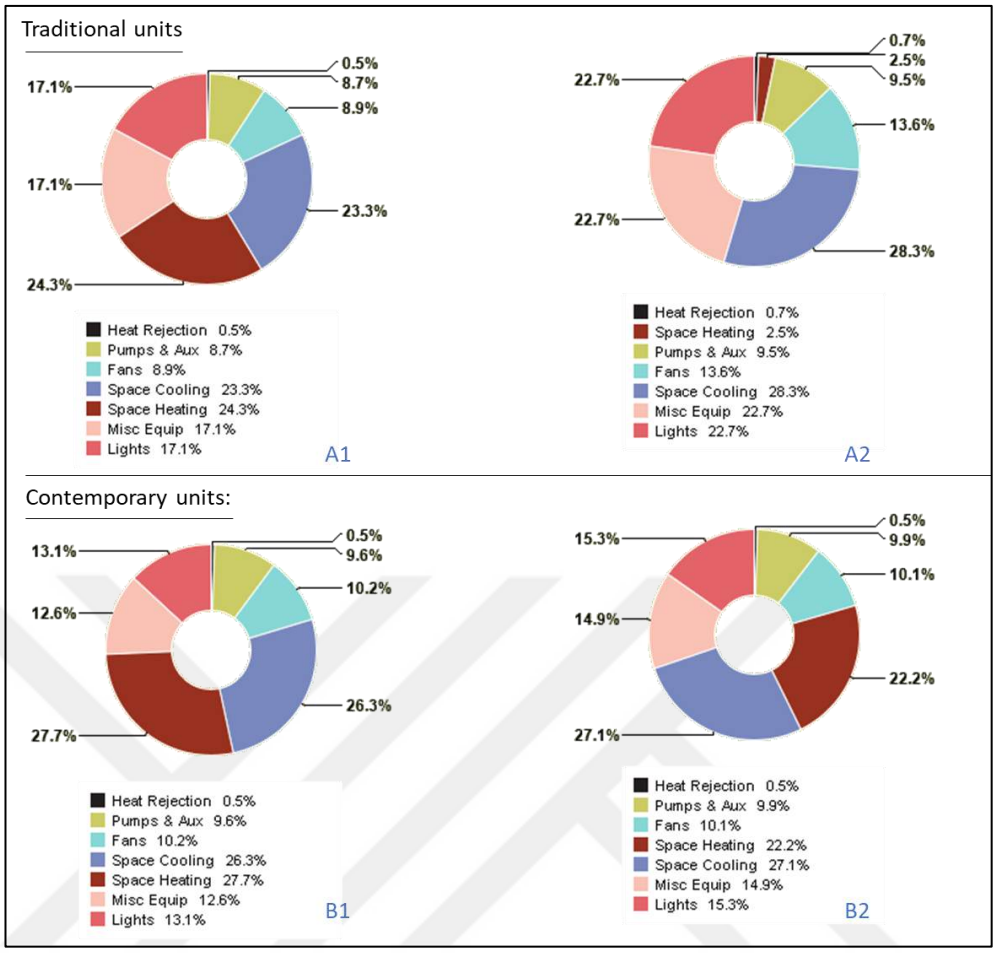


Figure 6.5 Energy end use charts

Table 6.1 The results from the green building studio

The description	A1	A2	B1	B2
1. Energy, Carbon and Cost Summary				
The annual energy cost	2,305 $	2,631 $	4,606 $	4,822 $
Lifecycle Cost	31,394 $	35,834 $	62,731 $	65,680 $
Annual CO_2 Emissions (Onsite Fuel)	1.0 Mg	3.4 Mg	1.5 Mg	1.5 Mg
Annual CO_2 Emissions (Large SUV Equivalent)	0.1 SUVs / Year	0.3 SUVs / Year	0.2 SUVs / Year	0.2 SUVs / Year
Energy Use Intensity (EUI)	980 MJ / m^2 / year	1,138 MJ / m^2 / year	1,272 MJ / m^2 / year	1,061 MJ / m^2 / year
Electric	16,584 kWh	18,466 kWh	33,216 kWh	34,792 kWh
Fuel	19,129 MJ	68,269 MJ	30,481 MJ	30,481 MJ
Annual Peak Demand	4.1 kW	5.1 kW	8.1 kW	8.0 kW
Lifecycle Energy (Electric)	497,526 kW	553,968 kW	996,484 kW	1,043,763 kW

Table 6.1 (continued): The results from the green building studio

Lifecycle Energy (Fuel)	573,875 MJ	2,048,068 MJ	914,436 MJ	914,436 MJ
2. LEED Daylight				
Percentage of building area with glazing factor over 2%	49.7% - No LEED Credit	15.7%	67.5%	91.1%
LEED Water Efficiency (Indoor)	(329,407 L/yr) (514 $/yr)	(410,224 L/yr) (634 $/yr)	(485,876 L/yr) (757 $/yr)	(605,286 L/yr) (944 $/yr)
LEED Water Efficiency (Outdoor)	(444,056 L/yr) (306 $/yr)	(444,056 L/yr) (305 $/yr)	(444,056 L/yr) (306 $/yr)	(444,056 L/yr) (306 $/yr)
Total LEED Water Efficiency	(773,463 L/yr) (820 $/yr)	(854,280 L/yr) (939 $/yr)	(929,932 L/yr) (1,063 $/yr)	(1,049,342 L/yr) (1,250 $/yr)
3. Photovoltaic Potential				
Annual Energy Savings	7,645 kWh	14,257 kWh	12,911 kWh	14,484 kWh
Total Installed Panel Cost	47,576 $	87,237 $	81,634 $	84,670 $
Nominal Rated Power	6 kW	11 kW	10 kW	11 kW
Total Panel Area	43 m²	79 m²	74 m²	77 m²
Maximum Payback Period	32 years @ $0.14 / kWh	32 years @ $0.14 / kWh	33 years @ $0.14 / kWh	31 years @ $0.14 / kWh
4. Wind Energy Potential				
Annual Electric Generation	257 kWh	257 kWh	257 kWh	257 kWh
5. Natural Ventilation Potential				
Total Hours Mechanical Cooling Required	6,308 Hours	6,016 Hours	6,609 Hours	7,169 Hours
Possible Natural Ventilation Hours	1,603 Hours	1,587 Hours	2,043 Hours	2,757 Hours
Possible Annual Electric Energy Savings	1,685 kWh	2,428 kWh	3,920 kWh	5,431 kWh
Possible Annual Electric Cost Savings	231 $	334 $	539 $	746 $
Net Hours Mechanical Cooling Required	4,705 Hours	4,429 Hours	4,566 Hours	4,412 Hours

The conclusion was that all the results showed that traditional buildings consume fewer resources in many aspects compared to contemporary buildings, except for the fuel consumption was less in building A1 than B1. Except for A2, it was slightly more and

close to B2. As for the other criteria evaluated, they all clearly indicated the superiority of traditional buildings given that the spaces of the traditional local dwelling - despite their differences and multiple energy consumptions - are more interconnected as a spatial system than the spaces of the contemporary local dwelling.

It has emerged through this research that the idea of dealing with the environment in buildings is not something new (emerging) in architecture, but what is new is the adoption of this idea within sustainability trends and linking it to many aspects that contribute to consolidating the foundations and principles of architecture desired for the future, as many traditional buildings It carried specifications with environmental considerations at a high level of application and proved its success over time. From the research point of view, environmental considerations are linked to the building through two aspects.

The first aspect: dealing with the building as a system within the level of the comprehensive surrounding environment through which the building integrates with everything that surrounds it and is connected with it in terms of physical systems related to humans, society, the ocean, and all other basic considerations that make up the comprehensive general structure that is governed by climate conditions and fluctuations in weather factors.

The second aspect: It deals with the independent, private and internal system of the building, and here the formation of the internal environment of the buildings is an important and fundamental factor that includes a number of considerations and concepts according to which the general structure of this environment is determined.

CHAPTER 7

CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusions

The use of computer simulation programs used globally is the most successful and accurate means of calculating energy in buildings and modeling it virtually before commencing construction to determine the best solutions for preparing building designs that take into account the architectural form and economic operation of buildings and reducing the waste of electrical energy, which is what developed countries are working on for the purpose of protecting the environment and preserving energy sources. Which threatens life on Earth if it is consumed at rates that nature cannot sustain. Through the use of the programs (Autodesk Revit) and (Green Building Studio) it was proven that there is a difference in energy consumption in buildings in Mosul city.

Energy and the environment are among the issues that have attracted the most attention globally in recent years. Unless the necessary precautions are taken, uncontrolled consumption of energy resources and environmental pollution will lead to irreversible natural disasters. The environmental impact, economic dimension and user comfort of dwellings, which constitute about 50% of energy consumption, must be taken into account before they are built. As technology advances, BIM software is developing rapidly, providing more accurate results, and the number of people using these programs is increasing. Efforts to deploy BIM applications are an important factor in reducing the energy consumption consumed by buildings. While the use of computer software offers advantages in designing energy-efficient buildings, knowledge and experience in using the software are very important to avoid false results. This study was prepared by integrating GBS with Autodesk Revit 2023 software after entering all the data of the homes that were studied. The modeling results, based on several criteria, showed that traditional buildings use less energy and cost less, in addition to achieving other criteria compared to contemporary buildings, as they were designed taking into

account the local environment, as is the case in the city of Tabriz in Iran, where traditional building techniques and strategies are superior to contemporary techniques. Therefore, the ideal techniques for residential buildings were identified, which represent the traditional techniques for designing environmentally friendly residential buildings in the city of Mosul.

7.2 Recommendations

The study's recommendations can be addressed to those who are interested in issues of construction, energy, and urban design in general, and to those interested in these issues in Mosul city in particular, in order to realize urban and architectural projects suitable for the environment needs in general and the country's climate in particular, as these recommendations are represented in the following:

1. Awareness of engineers and architects in general and in the city of Mosul in particular, as they cannot create the best design if it does not react with the local environment, climatic conditions, local materials, and other factors. Therefore, the thorough performance of the building will be indirectly or directly affected by these factors and thus will affect the user experience.
2. The use of parametric and BEM software in energy-efficient design makes it easy to determine the energy consumption of a building in advance, take precautions against it and speed up the design process. The calculation methods of the tools used in these programs and the data used are very important.
3. Increase awareness and spread a culture of construction that will takes pride in Mosul’s local architecture in every region and not be deceived by materials and Emergency roads, which were exported as a result of the exceptional situation the country is experiencing and its openness to global markets.
4. Focusing on the energy axis in building construction due to its importance and its connection to the overall construction processes, attention to the building’s life cycle, and the economy in all stages of construction, especially the (operation and maintenance) stage, as it consumes a greater amount of energy.
5. The costs and benefits in the field of constructing residential buildings must be looked at from a sustainability perspective, not looking at a specific stage, but

rather looking at all stages in a balanced manner and according to their importance.

6. When developing retrofit strategies in dry and hot climates, glazing ratio is an important issue to consider. During the preliminary design phase, this parameter should be examined along with the building orientation through a multi-objective improvement process. This ensures that daylight performance and ventilation are maintained as much as possible.

Future Works

1. The impact of technology on energy consumption: Research can be done into how the technology used in contemporary buildings affects energy consumption compared to traditional buildings. Do contemporary buildings use advanced technology to better save energy?
2. Government policies and legislation: Consider how government policies and legislation affect energy consumption in buildings. Are there policies that encourage the use of energy-efficient technologies in construction?
3. Establishing a center for educational research in order to give lectures and courses in using computer programs and numerical modeling in several fields, including environmental and climate analysis.
4. Studying the phenomenon of sustainable construction in the vertical housing pattern (multi-family housing).

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APPENDICES

Appendix A: Additional Results for Model A1

Appendix B: Additional Results for Model A2

Appendix C: Additional Results for Model B1

Appendix D: Additional Results for Model B2

Appendix A: Additional Results for Model A1

Base Run Hydronic Equipment		Note: this information should not be used for sizing purposes.
Primary Chilled Water	Electric Chiller Capacity	27,875
	Pump Flow	0 LPerSec
Condenser Water	Pump Flow	0 LPerSec
	Cooling Tower Capacity (Approach:2.8)	32,025
Domestic Hot Water	Average Demand	2,892

Base Run Air Equipment		Note: this information should not be used for sizing purposes.
Variable Air Volume	Supply Fan Flow	58 LPerSec
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	1
	Heating Capacity	2
Variable Air Volume	Supply Fan Flow	111 LPerSec
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	2
	Heating Capacity	3
Variable Air Volume	Supply Fan Flow	171 LPerSec
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	4
	Heating Capacity	4
Variable Air Volume	Supply Fan Flow	38 LPerSec
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	1
	Heating Capacity	1

Figure A.1 Additional results for model A1

Appendix B: Additional Results for Model A2

Base Run Hydronic Equipment		Note: this information should not be used for sizing purposes.
Hot Water	Boiler Capacity	45,528
	Pump Flow	0 LPerSec
Secondary Chilled Water	Pump Flow	0 LPerSec
Primary Chilled Water	Electric Chiller Capacity	38,799
	Pump Flow	0 LPerSec
Condenser Water	Pump Flow	1 LPerSec
	Cooling Tower Capacity (Approach:2.8)	44,576
Domestic Hot Water	Average Demand	4,628

Base Run Air Equipment		Note: this information should not be used for sizing purposes.
Variable Air Volume	Supply Fan Flow	94 LPerSec
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	2
	Heating Capacity	2
Variable Air Volume	Supply Fan Flow	60 LPerSec
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	1
	Heating Capacity	2
Variable Air Volume	Supply Fan Flow	80 LPerSec
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	2
	Heating Capacity	2
Variable Air Volume	Supply Fan Flow	107 LPerSec
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	2
	Heating Capacity	3
Variable Air Volume	Supply Fan Flow	88 LPerSec
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	2
	Heating Capacity	2
Variable Air Volume	Supply Fan Flow	84 LPerSec
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	2
	Heating Capacity	2

Figure B.1 Additional results for model A2

Appendix C: Additional Results for Model B1

Base Run Hydronic Equipment		Note: this information should not be used for sizing purposes.
Primary Chilled Water	Electric Chiller Capacity	61,720
	Pump Flow	1 LPerSec
Condenser Water	Pump Flow	1 LPerSec
	Cooling Tower Capacity (Approach:2.8)	70,909
Domestic Hot Water	Average Demand	5,206

Base Run Air Equipment		Note: this information should not be used for sizing purposes.
Variable Air Volume	Supply Fan Flow	114 LPerSec
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	2
	Heating Capacity	3
Variable Air Volume	Supply Fan Flow	20 LPerSec
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	0
	Heating Capacity	1
Variable Air Volume	Supply Fan Flow	183 LPerSec
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	4
	Heating Capacity	5
Variable Air Volume	Supply Fan Flow	135 LPerSec
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	3
	Heating Capacity	4
Variable Air Volume	Supply Fan Flow	141 LPerSec
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	3
	Heating Capacity	4
Variable Air Volume	Supply Fan Flow	146 LPerSec
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	3
	Heating Capacity	4
Variable Air Volume	Supply Fan Flow	111 LPerSec
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	2
	Heating Capacity	3

Figure C.1 Additional results for model B1

Appendix D: Additional Results for Model B2

Base Run Hydronic Equipment		Note: this information should not be used for sizing purposes.
Primary Chilled Water	Electric Chiller Capacity	66,770
	Pump Flow	1 LPerSec
Condenser Water	Pump Flow	1 LPerSec
	Cooling Tower Capacity (Approach:2.8)	76,712
Domestic Hot Water	Average Demand	5,206

Base Run Air Equipment		Note: this information should not be used for sizing purposes.
Variable Air Volume	Supply Fan Flow	15 LPerSec
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	0
	Heating Capacity	0
Variable Air Volume	Supply Fan Flow	186 LPerSec
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	4
	Heating Capacity	5
Variable Air Volume	Supply Fan Flow	269 LPerSec
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	6
	Heating Capacity	7
Variable Air Volume	Supply Fan Flow	129 LPerSec
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	3
	Heating Capacity	3
Variable Air Volume	Supply Fan Flow	173 LPerSec
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	4
	Heating Capacity	4
Variable Air Volume	Supply Fan Flow	149 LPerSec
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	3
	Heating Capacity	4

Figure D.1 Additional results for model B2

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