A COMPARATIVE STUDY ON CONVENTIONAL AND SUSTAINABLE CONSTRUCTION WITH SPECIAL REFERENCE TO TOKI BUILDINGS

by

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ABSTRACT

A COMPARATIVE STUDY ON CONVENTIONAL AND SUSTAINABLE CONSTRUCTION WITH SPECIAL REFERENCE TO TOKI BUILDINGS

In this thesis, conventional and sustainable construction methods and materials are investigated and discussed in detail to gain insight of the relations between the effects of construction industry and sustainability through literature review. The environmental issues are addressed and introduced in order to explain and enhance understanding the need for alternative energy resources.

The common methods of construction in Turkey are also investigated in order to comprehend the sustainability potential of the industry. Considering that the TOKI is one of the most important financers and promoters of the construction industry, two TOKI buildings were selected carefully to be used as a representative building type in the thesis. Since the weather conditions would also make a significant effect on the sustainability potential, two extreme locations were also determined and used in the analytical study. In order to understand the climate conditions, selected weather regions are also investigated and explained.

Carefully selected Cases are analyzed in terms of sustainability potentials such as orientation, wall and roof assemblies, window sizes, water consumption and carbon emissions with the “green building studio”. All the parameters have significant effects on the sustainability potential and that the effect of each parameter is explained and necessary suggestions are made to the construction industry. Different combinations of these parameters are also compared and results are explained in detail to obtain further understanding of sustainability potential of selected buildings. It must be noted that the suggestions provided in this thesis are potentially important for the construction industry in Turkey.

ÖZET

KONVANSIYONEL VE SÜRDÜRÜLEBİLİR YAPI METODLARININ TOKİ BİNALARI REFERANS ALINARAK DEĞERLENDİRİLMESİ ÜZERİNE BİR ÇALIŞMA

Yapı sektörünün sürdürülebilirlikle olan ilişkisini detaylı olarak anlamak için geleneksel yapı teknikleri ve malzemeleri literatür taraması ile araştırılmış ve kapsamlı olarak tartışılmıstır. Çevresel problemler belirtilmiş ,alternatif enerji kaynaklarına duyulan ihtiyacın nedenleri detaylarıyla anlatılmıştır.

Yapı endüstirisinin sürdürülebilirlik potansiyelinin anlaşılabilmesi bakımından Türkiye'de kullanılan temel yapı teknikleride incelenmiştir.
TOKI nin Türkiyede yapı sektörünün en önemli finansörü ve destekleyicisi olması dolayısı ile iki farklı TOKI binası, tez kapsamında kullanılmak üzere örnek olarak seçilmistir. İklim koşullarının sürdürülebilirlik potensiyeli üzerindeki etkisi göze alındığında, iki farklı iklim bölgesi bu çalışmanın analitik kısmında kullanılmak üzere belirlenmiştir.

Tezin son bölümü için ,dikkatle secilen örneklemler, oryantasyon, duvar ve çatı bileşenleri, pencere boyları ve su tüketimi gibi sürdürülebilirlik potansiyelleri bakımından, "green building studio" programı kullanılarak analiz edilmiştir. Binaların karbon emisyonlarıda yine "green building studio" programi kullanılarak en iyi sonucu elde edebilmek üzere analiz edilmiştir. Belirtilmelidir ki bu çalışma kapsamında değerlendirilen tüm parametreler, sürdürülebilirlik potansiyeline doğrudan etki etmektedir. Bu parametreler tek tek açıklanmış ve elde edilen neticeler sonucunda yapı endüstirisine gerekli görülen tavsiyelerde bulunulmuştur. Bu parametrelerden oluşan çesitli kombinasyonları ayrica karşılaştırılmış ve seçilmiş olan binalar için oluşturulabilecek en yüksek sürdürülebilirlik potansiyeli detayları ile açıklanmıştır.Bu tez kapsamında sunulmuş olan önerilerin Türk inşaat sektörünün gelişimi için önemli olacağı öngörülmektedir.

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LIST OF ABBREVIATIONS

2D	Two Dimensional
3D	Three Dimensional
AP	Accredited Professional
BIM	Building Information Modeling
CAD	Computer Aided Design
^0C	Celsius
CFC	Chlorofluorocarbon
CIB	International Council of Building
GBS	Green Building Studio
GBXML	Green Building Extensible Markup Language
IEQ	Indoor Environmental Quality
IPCC	Intergovernmental Panel on Climate Change
KG	Kilogram
LEED	Leadership in Energy and Environmental Design
m	Meter square
MMT	Million Metric Tons
O_3	Ozone
TOKI	Prime Ministry Housing Development Administration of Turkey
TUKDER	Tuğla ve Kiremit Üreticileri Derneği
UN	United Nations
USGBC	United States Green Building Council
US	United States
VE	Virtual Environment

1. INTRODUCTION

1.1 . INTRODUCTION TO THE SUBJECT AREA

The need for sheltering started with the first human being existed on Earth, at first, people started to use any enclosed spaces as a protection from the natural disasters, wild animals, environmental conditions or any potential harms. The caves were the first shelters for the humankind, later people started to use materials provided by nature. Earth products like adobe, wood and animal skin were the first building materials and used safely for centuries. Materials and construction methods are improved and industrialized in order to catch up with the growing demand for buildings.

World War II not only affected the world's economy, industrial production and agriculture but also stopped the development of construction industry. After the end of the World War II, most nations of the world started to rebuild their environments in order to provide necessary accommodation to the people. The construction industry also played a key role for developing the economy of the involved nations. Even though Turkey has never been a part of the World War II, the development of the construction industry also started in Turkey around the same time as the other nations.

In early years of Turkish Republic, Turkey had gone through different phases as a nation in order to build and accommodate the needs of the public. The development of new housing and governmental buildings followed a stable increase since 1980's. According to the TOKI's data, growth in the construction industry during most of the 1990s remained below its potential because of the rising interest rates and increasing costs of the construction [1].

In the last 10 years, Turkey started to invest more into the construction industry. Republic of Turkey Prime Ministry Housing Development Administration of Turkey (TOKI), financing and promoting mass housing projects under the name of urban regeneration.

After the industrial revolution, there was a huge competition between the developed and developing countries to increase the production of the goods in massive quantities. As a result almost all nations began manufacturing more products based on natural resources of the planet. This resulted in using more fossil fuels and natural resources such as iron ores, coal and minerals. Combustion of fossil fuels and deforestation has resulted in a26 per cent of increase in carbon dioxide concentrations in the atmosphere [2].

It is observed that more natural resources are spent than earth can produce that negatively affects our planets' natural balance. The energy usage and carbon dioxide ($CO_{2)}$ emissions reached highest level at the begging of this century due to the rapid growth of construction industry [3].

The developed countries across the world are aware of this problem and taking into considerations to limit the energy consumption and CO_2 emissions by signing protocols like "Kyoto Protocol" which is signed by 39 industrialized countries. They are also enforcing rules and regulations on the related industries. However, underdeveloped and developing countries are still ignoring this problem and the potential harm of excessive usage of natural resources [3].

If the extreme consumption of natural resources cannot be avoided, current and future human race will use great amounts of time and money to stop the negative effects of unconscious consumption of natural resources.

The construction industry is the leading part of this consumption, USA and European countries are bringing these issues into the consideration and began to invest on alternative energy resources and materials for the construction industry and they are enforcing new rules and energy regulations by developing green building assessment methods [4].

Even though the Turkish government forcing the industry to prevent excessive energy consumptions in the buildings as stated in the energy performance of buildings directive, it is unfortunate that in the Turkish construction industry professionals still do not appreciate the importance and the potential destructive effects of the growing construction industry in Turkey [5].

1.2 . OBJECTIVES

The main objective of this thesis is to understand and explore the sustainability potential and possible carbon dioxide emissions of buildings by implementing software packages during the design phase. It is also aimed to see the thermal behavior and the capabilities of conventional and sustainable construction methods and material due to the different climate regions of the construction site. It is targeted to understand and measure the energy efficiency and carbon dioxide emissions of the buildings with different heights, by changing the variables, like exterior wall assemblies, roof assemblies and materials.

Distinguishing the effects of building orientation, window sizes, glazing types and lighting power density to the cost of energy and possible natural resource savings are also objected in this thesis.

1.3. POTENTIAL USERS OF THE STUDY

The main target of this thesis is to provide guidance in order to show the benefits of sustainable construction and materials, to the construction professionals such as architects, interior designers, contractors, civil engineers, manufacturers and most importantly to the end users.

This thesis can be used to acknowledge the benefits of designing a building using the principles of sustainable design and alternative energy resources and recycled materials. It can also be beneficial to the contractors and manufacturers to eliminate the high cost of non-recycled materials, the transportation expenses of nonnative materials and labor.

This study can also be used by any professional in order to gain a deeper understanding of the possible potentials of designing a building according to the regional climate. The thesis also incorporates in choosing the suitable alternative construction materials and using rainwater harvesting, which reflects to the consumers, as savings on the utility bills and maintenance costs.

1.4. THE METHODOLOGY

The first stage of this thesis is the literature review, focusing on construction industry and its environmental effects in Turkey and in the world. The global climate change and the necessity of the new and alternative energy resources and CO_2 emission issues addressed as background information.

Environmental effects of the construction industry investigated and explained deeply in order to gain a better understanding of the subject in the second stage of this thesis. The growing need for alternative energy resources are also investigated, therefore, global climate change, greenhouse gases, ozone hole and population growth are explained in detail.

The conventional and sustainable construction methods and materials are described and identified in the third stage. Energy usage and CO_2 emissions and harmful effects of the construction materials are examined and explained through examples and charts.

At the fourth stage, Housing Development Administration of Turkey is researched and explained in detail. Buildings chosen as case studies according to the regions of Turkey are introduced in this stage. It was important to choose the buildings by the regional climates and square footage of the building for properly and accurately compare the results from the current design and the alternative design. The drawings and required information about the buildings are obtained from both the construction companies of the buildings and TOKI's Istanbul headquarters. Computer modeling with "Autodesk Revit Architecture" and the energy efficiency simulation software "Green Building Studio" are introduced for deeper understanding of the capabilities of the software's used for this study. The buildings are modeled in Revit Architecture and are exported to Green Building Studio for energy analysis.

In the last stage alternative energy analyses based on the sustainable design principles, alternative materials and water saving system's integration, are conducted by using the software and are compared with original analyses. Conclusions and suggestions depending on the software analysis and literature reviews are made on this final stage.

1.5. PROBLEM DEFINITION

Considering the energy consumption and the carbon emissions in Turkey caused by the construction industry, the necessity of investing the sustainability potential of both conventional and sustainable construction methods and materials has needed in this thesis.

It has been aimed to address the following research questions:

- What are the common construction methods and materials in Turkey?
- Is it possible to reduce CO_2 emissions and provide a better quality of living to the next generations by using sustainable construction methods and materials?
- How to reduce CO_2 emissions, save energy and natural resources in Turkish construction industry? Can sustainable construction techniques and materials be the solution?

Aims to solve the problem of:
“Mass housing development in Turkey is not optimized in terms of energy use, carbon emissions and water management.”

1.6. CONSTRAINS AND LIMITATIONS

Due to the nature of construction industry, there are endless phases of building construction from design process to the end result.

There are also many different possibilities of conventional and sustainable construction methods and materials. It requires a great potential of workforce and finance to accurately measure the energy efficiency and CO_2 emissions of a building in real time environment, therefore this thesis is limited by capabilities of the software packages chosen.

However, researchers in the field, industry professionals and research laboratories suggest that, the “Autodesk Green Building Studio” provides very accurate results for the energy and CO_2 analysis of a building.

2. LITERATURE REVIEW

2.1. INTRODUCTION

In this chapter brief background information is provided about the construction industry and the negative environmental effects of conventional construction. The greenhouse effect and causes of global climate change are also addressed in this chapter.

2.1.1. Environmental Effects of Construction Industry

Construction industries such as material production and transportation industries, together with the related industries, are the biggest energy consumers around the world. It is very unfortunate that most of the carbon emissions and the greenhouse effects are largely caused by the construction industry [6]. However, it must be emphasized that the consumption of natural resources and fossil fuels have an enormous effects on the climate change that lowers the quality of living.

The U.S. Green Building Council (USGBC) states that, “the building industry is one of the most energy and water intensive industries on the planet” [6].

According to authors of Energy manual, the construction industry consumes approximately 50 per cent of all the materials extracted from the Earth and about 60 per cent of all the waste produced comes from building and civil engineering work [7]. Nearly 136 million tons of waste is produced yearly from buildings and their construction in U.S. [8]. Buildings are not only responsible for 73.1 per cent of electricity consumption but also liable for 30 per cent of greenhouse emissions in the United States [9].

Recent studies about the energy consumption and carbon emissions of the construction industry as stated at Green Building Summit 2012 that 40 to 50 percent of all energy usage and carbon emissions are caused by the construction industry in Turkey [10].

Norbert Lechner also states that air conditioning and lighting of the buildings are consuming nearly 40 per cent of the energy [11].

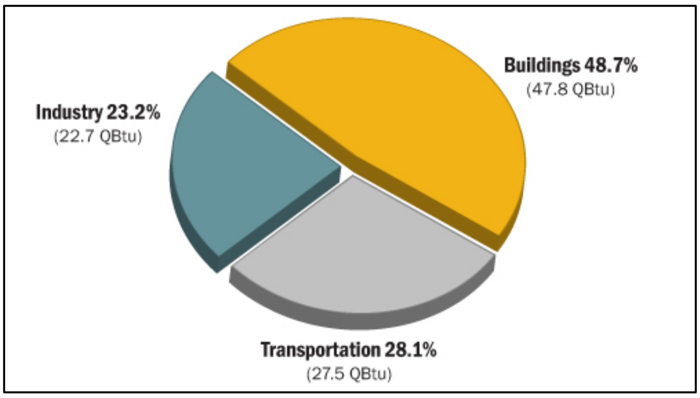


Figure 2.1. U.S. Energy Consumption by Sector[12]

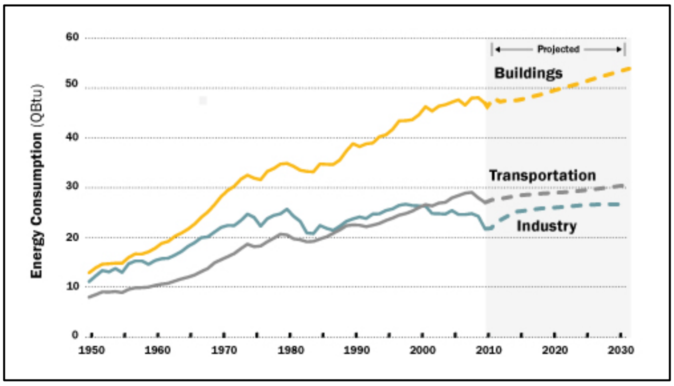


Figure 2.2. U.S. Energy Consumption by Sector in Historic and Projected Frame [12]

U.S. Energy consumption by sector in percentage and in historic frame, are given in Figures 2.1 and 2.2 respectively. It can be seen in Figure 2.1 that the buildings occupy the most of energy consumption in the U.S. Although there seem to be a slight increase in the fields of transportation and related industries between 1950s to 2010, there is a dramatic increase in building's energy consumption in the same time period.

2.1.2. Construction Industry in Turkey.

The Minister of Environment and Urbanism of Turkey, Erdoğan Bayraktar delivered a speech on the construction industry in Turkey at the International Green Building Summit, 2012.Bayraktar stated that 78 per cent of the Turkish population lives in the cities and the buildings in Turkey are consuming 40 per cent of total energy consumed in Turkey and that construction industry accounted for more than 30 per cent of Turkish economy. 51 per cent of energy used in Turkey comes from imported natural gas. According to Bayraktar, “We are spending 55 Billion dollars on energy which is more than 40 per cent of our annual export and 60 per cent of current account deficit is from energy import.” [13].

In his speech Bayraktar, also addressed the current building stock of Turkey and the near future plans for the urbanization around Turkey. According to the data Bayraktar provided, Turkey has 18 million building stock that does not satisfy the demand and hence 2, 5 million more are needed. It must also be noted that 8 to 9 million out of the current building stock needs to be renewed in order to bring them up to the current earthquake codes in Turkey [13].

According to the information obtained from the Minister, it is easy to estimate that between 10 to 12 million new buildings will be constructed in the near future all around Turkey which means another 30 to 35 per cent more energy will be needed just to operate these buildings alone [13].

2.2. NEED FOR ALTERNATIVE ENERGY

As discussed in the above section it is clear that energy consumption on buildings is dramatically too high and that there is an emerging need to review the alternative energy resources for possible energy savings of the buildings and to lower the environmental impacts of intense fossil fuel consumption.

2.2.1. Global Climate Change

Excessive use of fossil fuels, deforestation and high rates of population growth not only changes the natural balances of Earth but also negatively affects our quality of life

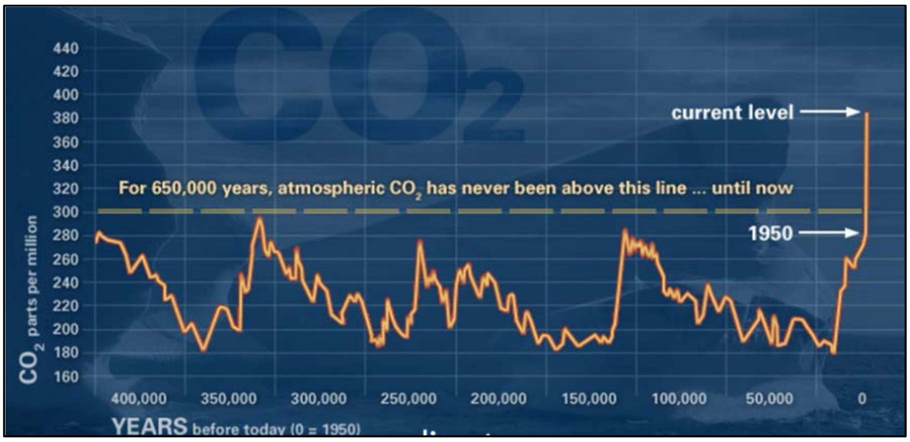


Figure 2.3. CO_2 emissions [14]

Carbon dioxide variations over the last 400,000 years are shown in Figure 2.3. Beginning in the 1850s and accelerating ever since, the consumption of fossil fuels has elevated CO_2 levels from a concentration of 280 parts per million (ppm) to more than 380 ppm today. These increases have been projected to reach more than 560 ppm before the end of the this century. It is a fact that CO_2 levels are considerably higher now than at any other time in the past 800,000 years [15].

The 2007 report of the Intergovernmental Panel on Climate Change (IPCC) states that the global warming is undeniable and greenhouse gasses and carbon emission are responsible for most of it. Report also indicates that before the end of this century the Earth's temperature will rise between 1,1 ^{0}C and 6,4^{0}C, and that there will greater and denser droughts, heat waves, cyclones, and heavy rainfall. The sea levels will rise between 18 to 59 cm unless there are rapid dynamic changes in ice flow, in which case the increase could be much greater [16].

2.2.2. Greenhouse Effect

It has been stated by Yeang that there is a trapped and built up heat in the lower levels of the atmosphere. Even though some of the heat escapes from the Earth’s atmosphere, the remaining parts is absorbed by water vapor, carbon dioxide, ozone and several other gases in the atmosphere. The reflected heat emitted by these gases is known as the greenhouse effect [17].

A schematic explanation of greenhouse effect is shown at Figure 2.4.

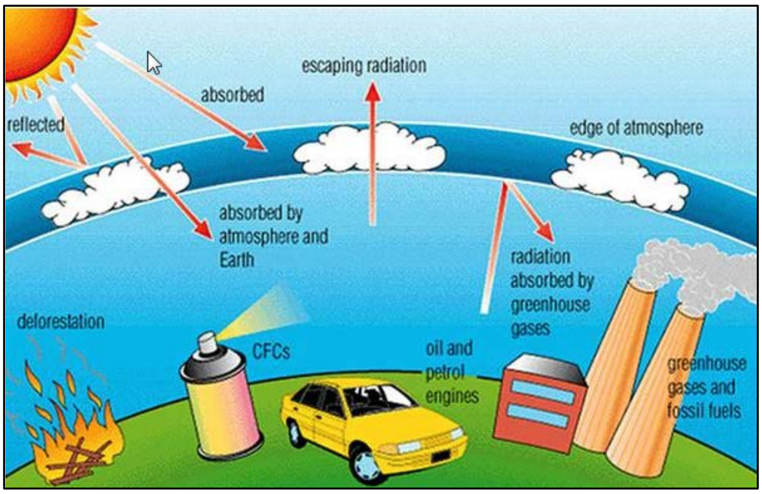


Figure 2.4.: Greenhouse Effect [18]

The greenhouse gases are summarized in Table 2.1. It is very unfortunate to observe that the cement production results the highest level of carbon emissions compared to the other sources. When cement considered as the main ingredient of concrete which is one of most commonly used conventional construction material, it can be identified as one of the main causes of greenhouse effect.

Table 2.1. Greenhouse Gases [15]

Greenhouse Gases	Chemical Formula	Preindustrial concentration	Concentration in 1994	Atmospheric lifetime (years)	Anthropogenic Sources	Global Warming Potential (GWP)
Carbon dioxide	CO_2	278.00 PPBV	358.00 PPBV	Variable	Fossil Fuel combustion Land use combustion Cement production	1
Methane	CH_2	700 PPBV	1721 PPBV	12.2	Fossil Fuel combustion Rice Paddles Waste dumps Livestock	21
Nitrous Oxide	N_2O	275 PPBV	311 PPBV	120	Fertilizer Industrial processes combustion	310
CFC-12	CCL_2FF	0	0.503 PPBV	102	Liquid coolants Foams	6200-7100
HCFC-22	$CHCIF_2$	0	0.105 PPBV	12.1	Liquid coolants	1300-1400
PerFluoromethane	CF_4	0	0.070 PPBV	50,000	Production of aluminum	6500
Sulphur Hexa-fluoride	SF_4	0	0.032 PPBV	3200	Dielectric fluid	23900

2.2.3 The Ozone Layer Depletion

The hole in the Ozone layer is one of the well-known issues in our atmosphere. It is probably the first globally recognized problem about the environment.

The air conditioning of buildings has influenced indirectly to a hole in the ozone layer which protects the Earth from the sun’s harmful ultraviolet waves. The chlorofluorocarbon (CFC) molecules that were to providing a safe, passive refrigerant for air conditioners have turned out to have a dramatic weakness, unresponsiveness, which ironically was considered their major advantage. When these molecules escape from air conditioner units or are released as propellants in spray cans, they rises to the upper atmosphere, which contains ozone [11].The ozone layer depletion is one of most important causes of the global warming. In order to prevent further problems, this issue has to be considered and necessary cautions needs to be taken.

Ozone layer is schematically shown in Figure 2.5 where the ozone layer and ultraviolet and chlorofluorocarbon (CFC) molecules are pointed.

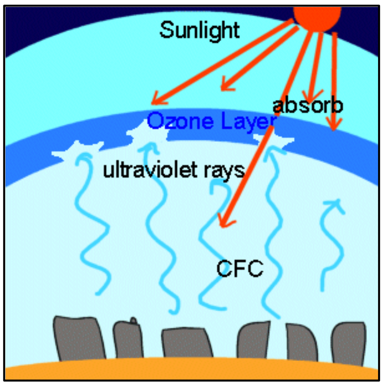


Figure 2.5. Ozone Layer [19]

2.2.4 Population Growth

World population which is currently 6.5 billion showing and increase of 76 million people per year. According to the United Nations 2.6 billion people will be added to world's population by 2050. Earth's resources are also deeply affected by this rapid population growth. Global demand for water has almost tripled since the 1950s; however, the supply of fresh drinking water has been declining because of contamination and excessive consumption. Half a billion people having trouble to reach drinkable water, and by 2025 that number will increase to three billion. In the last 50 years, cropland has been reduced by 13 per cent and grassland by 4 per cent [20]. The dramatic increase and assumptions in world's population are shown in Figure 2.6.

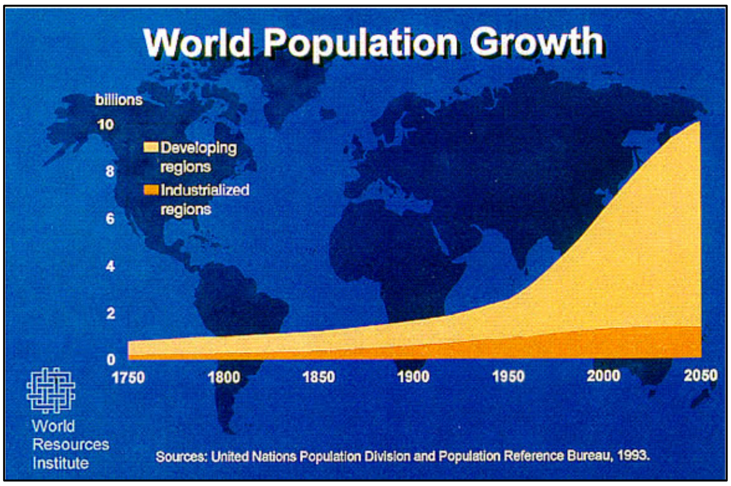


Figure 2.6. World Population Growth [21]

2.2.5. Fossil Fuels

World's population growth resulted more demand on almost any kind of product from computers to plastic water bottles .In order to provide enough energy to support the production facilities, we started to use more fossil fuels. The use of fossil fuels can be looked in two perspectives. Firstly, the amount of energy and resources used towards the excavation of the fossil fuels such as coal and petroleum. Secondly, the environmental effects of burning fossil fuels for energy production [15].

As Peter Gevorkian states that,

> "Dependency on fossil fuels over the last century has shaped our way of life, customs, moral standards, population distribution, demographics, hygiene, life expectancy, standard of living, global economies, security, and international politics. Control of global fossil fuel resources has caused political upheavals and international strife, defined international geographic boundaries, displaced multitudes of populations, caused wars, and resulted in the destruction of property and human life. However, the most significant effect has been the deterioration of the global habitat for all living species." [15].

Figure 2.7 indicates that, there had been a dramatic increase in fossil fuel consumption since early 1800s. Types of energy sources are also identified in Figure 2.8, it can be observed from Figure 2.8 that, there is a dramatic increase on oil and coal consumption in recent years.

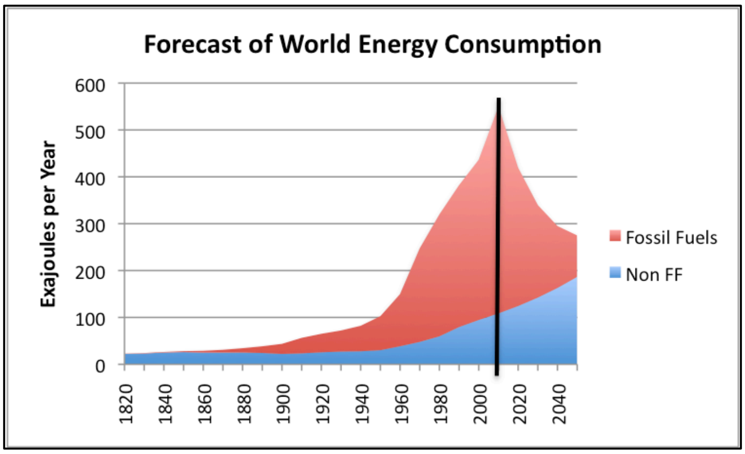


Figure 2.7. World Energy Consumption [22]

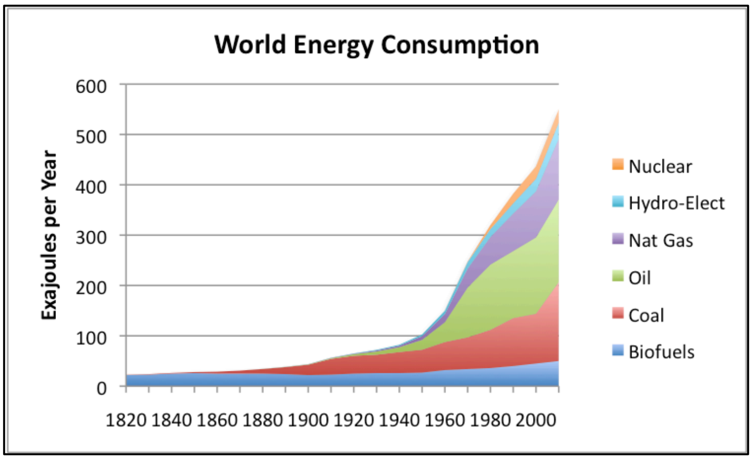


Figure 2.8. World Energy Consumption by Fuel Types[22]

2.3 CHAPTER RESULTS

The brief background information on the construction industry and sustainability aspects are discussed in chapter 2 in general. The chapter began with describing and discussing the environmental effects of construction industry, it has reviewed the data related to the construction industry then it carried on discussing the construction industry in Turkey. One of the most important conclusions came from Bayraktar where he stated that although there are 18 million building stocks in Turkey, this does not satisfied the demand and at least 2.5 million more are also needed. [13].

From there the chapter carries on reviewing the need for alternative energy sources considering that the energy consumptions on building were two high so there was an emerging need to review the alternative energy sources so from this point It has been focused on reviewing the main causes of the energy consumption.

Global climate change, greenhouse effect, the ozone hole, population growth and consumption of fossil fuels are identified and discussed as main causes for the need of alternative energy resources in this chapter.

3. COMMONLY USED CONSTRUCTION METHODS AND MATERIALS

3.1 INTRODUCTION

In Europe, construction industry, with a share of 28.1 per cent, is the biggest and most active sector. It is the driving force of the European economy with the employment rate of 7.5 per cent. It not only represents 25 per cent of European industrial production which has 750 million euros annually but also the largest exporter with 52 per cent of the market share. Globally, it is accepted that construction industry considered as the fastest growing industry. It is expected that in the next 20 years China alone, will need total 40 billion square meters of residential and commercial floor space which equals to the area of Switzerland in every two years [23].

Construction industry is also responsible for the 30 per cent of carbon emissions and the buildings are consuming 42 per cent of all energy produced in Europe. Since it was using nearly 3000Mt/yr, it is called to be the largest raw material consuming sector [24].

In Turkey, there is a dramatic growth in construction sector in the last quarters of 2010 when compared with the same time period of 2009. There is a 24.1 per cent growth in construction sector in 2010 and 18.4 per cent of this accomplished in the first nine months of the fiscal year as shown in Figure 3.1.[25].

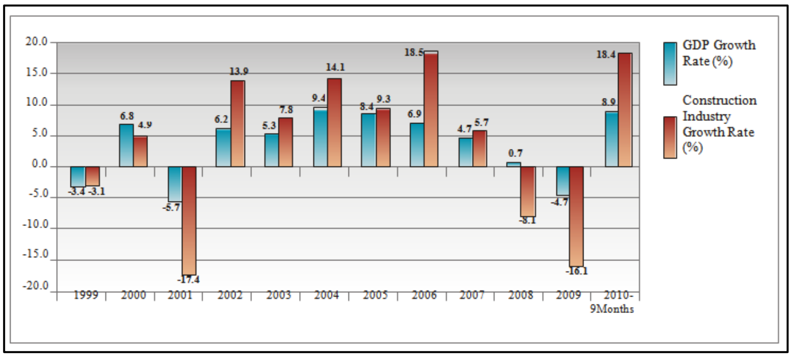


Figure 3.1. Growth rate of Construction Industry in Turkey (1999-2010) [25]

This dramatic increase in construction industry played a significant role in the economy of Turkey. There had been an escalation of 8.9 per cent in gross domestic product (GDP) in 2010 as shown in Figure 3.1. When compared to the data of 2009, in the first nine months of 2010, there was an increase of 30 per cent in the gross construction area and 34.1 per cent in the number of building units obtained from the building permits provided by the municipalities [25].

Given that the construction industry is the most active and largest industry both in Europe and in Turkey. It should be noted that it is the largest industry that consumes energy and is also largely responsible from the carbon emissions.

3.2. CONVENTIONAL CONSTRUCTION METHODS IN TURKEY

For centuries, several construction methods and materials have been used and investigated in Turkey. According to the availability of materials, methods like stone masonry or timber frame construction are used in different regions. In some regions people also developed their own construction methods due to their needs, life styles and cultures such as “Göz Dolma” and “Muskali” methods. These two techniques, as a vernacular architecture, mostly preferred in Eastern Black Sea region of Turkey while the common natural materials used, like stone and timber. Even though, the applications of these methods are not commonly seen today. They in fact are much environmentally friendly than recent methods [26]. Examples of these construction methods are presented in Figures 3.2. and 3.3.

Figure 3.2. Example of a Goz Dolma Construction Method [2]

Figure 3.3. Example of a Muskali Dolma Construction Method [27]

In recent years, reinforced concrete frame construction replaced almost all other types of traditional construction methods. In this construction method, reinforced concrete frames filled with bricks, which are later plastered and texturized or painted with different finishes, are used to construct facades and architectural partitions. Extruded polystyrene foam boards are also added as an insulation material in recent years for this type of construction [28].

It is now the most preferred method of construction in Turkey, due to its mass production capacity, earthquake resistance of reinforced concrete, design flexibility and lower costs of construction.
According to the TUIK's building permit statistics, there exist of 132 589 buildings that are only constructed in 2010. It can be seen in Table 3.1 that the building types are categorized in 7 different groups [29].

It can be seen that 85per cent of these types are one dwelling buildings and two or more dwelling buildings. This is why it has been focused on these two kinds of building types in the case study of this thesis.
Last of all a comparison can be made between 2009 and 2010. Although there is such a small time frame in between 2009 and 2010, there is a tremendous increase in the total number of buildings as shown in Table 3.1.

Table 3.1. Statistical Data of Construction in Turkey [29]

Year		Total	One Dwelling Buildings	More Dwelling Buildings	For Communities	And Retail Trade Buildings	Buildings And Warehouses	Entertainment Education,	Other Non-Residential Buildings
2010									
	Number of buildings	132 589	24 819	88 590	691	5328	4400	1460	3663
	Floor area m^2	166 999 697	4 647 348	127 041 400	2 544 698	6 812 618	7 273 526	6 646 006	3 282 847
	Value (TL)	96 438 036 831	2 477 060 213	74 179 489 114	1 470 811 711	3 873 282 950	3 942 473 805	3 763 495 939	1 720 217 034
	Number of dwelling Units	858 143	24 942	828 761	11	3444	271	68	299
2009									
	Number of buildings	92 342	19 736	59 285	346	4 094	2756	1330	1948
	Floor area m^2	100 726 544	3 753 485	74 158 683	980 781	5 180 246	4 418 828	5 132 042	1 480 729
	Value (TL)	54 367 862 313	1 879 484 673	40 437 696 623	510 313 307	2 796 465 024	2 280 266 045	2 709 637 553	742 512 388
	Number of dwelling Units	518 475	19 733	496 496	5	1 602	187	47	82

Construction methods of buildings constructed in 2009 and 2010 are summarized in Table 3.2. It can be seen that 88 per cent of the preferred construction method is, unfortunately, reinforced concrete frame.As opposed to this high percentage, the wood frame construction has only about 0.3 per cent of all construction methods used in Turkey in 2010 [29].

Table 3.2. Statistical Data According to the Construction Methods [29]

Year		Total	Bearing wall construction	Steel Frame	Wood Frame	Reinforced Concrete Frame	Composite	Prefabricated
2010								
	Number of buildings	132 589	9 621	2 337	365	117 536	585	2 145
	Floor area m^2	166 999 697	2 265 843	2 910 130	71 901	157260 345	1 600 454	2 891 024
	Value (TL)	96 438 036 831	788 096 791	1 577 545 248	26 094 967	91 654 158 825	848 116 280	1 544 024 720
	Number of dwelling Units	858 143	13 927	479	395	841 810	1 065	467
2009								
	Number of buildings	92 342	7 334	1 622	310	80 375	1 536	1 165
	Floor area m^2	100 726 544	1 676 740	1 460 416	64 892	94 816 239	1 284 181	1 424 076
	Value (TL)	54 367 862 313	555 146 738	768 857 981	23 679 102	51 718 682 543	576 381 012	725 114 937
	Number of dwelling Units	518 475	11 639	279	340	503 158	2 445	614

Besides the advantages of reinforced concrete frames, this type of construction considered as non-sustainable method due to the use of excessive amounts of natural materials, higher consumption of energy and vast amounts of toxic gas releases during production.

Typical reinforced concrete frame construction for residences is shown in Figure 3.4.

Figure 3.4. Typical Reinforced Concrete Construction for Residences [30]

3.3. SUSTAINABLE CONSTRUCTION

The definition of Sustainable Development was first published in 1987 at the report of "Our Common Future" which is also known as the Bruntland Report. It is worth mentioning that the report discussed the sustainable development with the following phrase ''Sustainable development is a development that meets the needs of the present without compromising the ability of future generations to meet theirs''[31].

The main principle of Sustainable construction derived from the idea of using less energy and natural sources to get the same quality of life. This idea presented to the world of building industry under many different names. These names are Green Architecture, Sustainable Architecture and Development, Eco-Efficient buildings or Eco-design. Sustainable construction is not always used for its right. Unfortunately, this type of construction is used as an advertisement for marketing and not for its huge advantage of sustainability purposes.
It is believed that sustainability is usually addressed to the construction industry in order to sell high numbers of developments rather than informing public for its advantages. Considering the rising population especially in recent years, the advantage of sustainability should be understood and appreciated in order to use the energy resources effectively.

Author has highly influenced by the definition of sustainability given by Yeang, which states that

> " It is not just about proscribing one material or system in favor of another from a technical standpoint, but rather about the overall perception of how our human communities and built environment can become an integral and benign part of life on the planet. As Yeang continues, Ecodesign must be applied to all aspects of our built environment (such as land use, building design, product design, energy systems, transportation , materials, waste, agriculture, forestry, urban planning, etc.) Ecodesign calls for a revisioning of both architecture and our built Environment as we understand them' [32].

3.3.1. Principles of Sustainable Construction

The concept of sustainable construction is defined by the International Council of Building (CIB) in 1994 as “responsible for creating and maintaining’’ a healthy built environment based on the efficient use of resources and in the project based on ecological principles [33].

Sustainability principles are well understood and published quite often in recent years and therefore it is not aimed to re-view the whole sustainability overall but to focus rather on the key elements of sustainable construction [33].

Following list is summarizing the key elements of sustainable construction:

- Reduce resource consumption (resources)
- Reuse resources (reuse)
- Use of recycle resources (recycle)
- Protection of nature (Nature)
- Elimination of toxics (toxics)
- Application of life cycle costing (economics)
- Focus on quality (quality) [33].

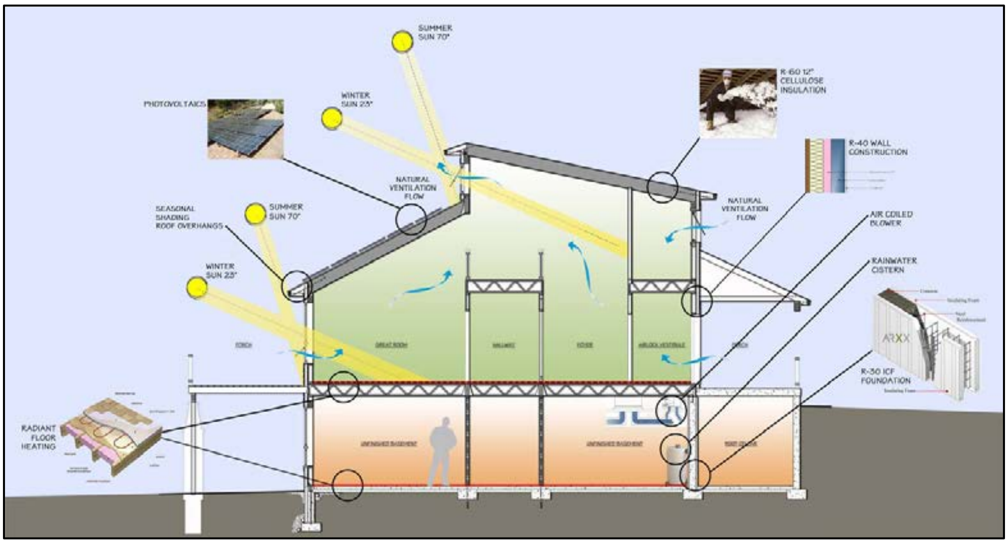


Figure 3.5. Depiction of Energy Efficiency Measures [34]

Sustainable construction principles shown in Figure 3.5.For instance, the orientation of the building, window directions and sizes, glazing types, type of insulation materials, roof and wall assemblies are displayed in the figure. These parameters are the bases of the analyses that are presented in the following chapters.

3.4. BUILDING MATERIALS IN TURKISH CONSTRUCTION INDUSTRY

3.4.1. Commonly Used Building Materials in Conventional Construction

The most commonly used construction materials in Turkish construction industry are concrete and construction steel due to the preferred conventional construction method.

Turkey is one of the biggest producers of commonly used construction materials such as cement, construction steel, bricks and glass etc. Especially cement, ceramic construction steel and glass production industries in Turkey can compete in exports with other countries. The exported construction materials data are shown in Table 3.3. [35].

Table 3.3. Table: Turkey's Export Data of Major Building Materials [35]

Materials	**2010**	**2011**
Brick	6,791,000	6,767,000
Cement	1,131,081,000	914,441,000
Gypsum	68,707,000	72,117,000
Plastic Based Building Materials	971,145,000	1,154,004,000
Iron and Steel Bars	4,533,026,000	6,239,125,000

3.4.1.1 Concrete

Concrete is the most common and widely used construction material around the world. It is one of the most preferred and versatile construction materials in Turkey. Considering the increasing demand for public housing and office buildings and rapid growth of construction industry, cement manufacturing and concrete production industries are major parts of the Turkish economy [36].

The main components of concrete are aggregate, cement, water and special additives as strengthening. 60 per cent of concrete is aggregate, 30 per cent is cement and 10 per cent are other additives are used in concrete as ingredients [37].

In 2010 Turkey was the biggest cement exporter in the world with an annual production of 62.7 million tons. Cement production industry also employs more than 15 thousand people in Turkey [35].

Table 3.4 shows that over 15 million tons of cement exported to different countries in 2011[38].

Table 3.4. Turkey's Cement Export Data of 2011[38]

COUNTRIES	**TONS**
Iraq	3,087,913
Syria	2,558,726
Italy	683,895
Libya	1,771,278
Egypt	1,870,278
Nigeria	354,929
Russia	468,128
Israel	596,841
Other Countries	3,671,012
TOTAL	15,063,000

Portland cement is widely used as an ingredient in concrete and also as a binding material for the aggregates. However, it has been believed that it is the ingredient in concrete which produces the greatest environmental burden.

3.4.1.2 Brick

There are 498 brick manufacturing plants which are spread all through Turkey depending on the availability of raw materials. [39].

The statistical data provided by Tuğla ve Kiremit Sanayicileri Derneği (TUKDER) indicates the annual production of brick and clay roofing tile that are summarized in Table 3.5.

Table 3.5. Clay Brick and Roofing Tile Production Capacity [40]

Clay Brick	5.327.000.000 pc/yr
Clay Roofing Tile	609.000.000 pc/yr

Production of a single brick uses 3 kilograms of raw materials while 2.5 kilograms of raw materials are needed for clay roofing tile production. This adds up to millions of kilograms of raw material consumption as shown in Table 3.6. [40].

Table 3.6. Clay Brick and Roofing Tile Production Kilograms per year [40]

Clay Brick	15.981.100.000 kg/yr
Clay Roofing Tile	1.522.500.00 kg/yr

3.4.1.3 Construction Steel

There are 29 irons and steel manufactures existing in Turkey according to the data of the Ministry of Economy. In the year of 2011, 34.1 million tons of steel is produced for the construction industry. It is dramatic to report that 6.2 billion tons of long products exported in 2011. Different types of iron and steel pipes and pipe fittings are produced and exported 1.8 billion U.S dollars’ worth of product in 2011. [35].

3.4.2 Commonly used Building Materials in Sustainable Construction

Natural building materials are considered as sustainable or green products which are environmental friendly and nontoxic. Productions of these materials are taking limitations of nonrenewable resources like coal and metal ores into consideration. These types of materials are not only energy and water efficient but also recyclable or recycled materials. These materials are respecting the resource management; they have lower impact on indoor environmental quality and have better energy saving performances [41].

In recent years considering the construction industry, it is obvious that there is a growing demand for the environmental friendly construction materials. Many construction companies choose to use recycled or certified materials for marketing purposes. Transportation of heavier and larger building materials not only requires excessive amount of fossil fuel consumption, but also toxic gas releases which pollutes the air and the water. Selecting locally produced and manufactured construction materials not only lowers the harmful environmental impacts of transportation but also reduces the cost of transportation [42].

3.4.2.1 Thermal Insulation Materials

One of the main goals of sustainable construction and sustainable design is to lower the energy consumption of the buildings. The most energy is consumed by the air conditioning of the building. It is very essential for a sustainable design to keep the temperature levels inside the building constant and balanced in order to save energy, therefore thermal insulation materials are the first to consider for the sustainable construction [43].

The most effective sustainable insulation materials are the natural products such as wool, recycled cellulose, straw boards (produced from waste of agricultural products), wood wool and cork. These natural products have similar or in some cases lower U-values than conventional insulation materials. Slag wool which is produced from the slag wastes, and sheep’s wool, can also be recommended as alternatives [43].

Examples of commonly used recycled or natural insulation materials are:

- **Recycled Denim:** It is made by shredding and compressing used denim, it is a naturel fabric and a waste material.
- **Recycled Cellulose:** Manufactured from recycled paper.

Figure3.6.Recycled Denim Insulation [44]

Figure 3.7. Recycled Newspaper-Cellulose Insulation [45]

Thermal conductivity, known as the K-value, is a measurement of heat transferred through a certain thickness of a material. K-values of common insulation products are summarized in Table 3.7.

Table 3.7. K -Values of Basic Insulation Materials [46]

Material	**K Value (W/mK)**
Polyurethane Foam	0.024–0.039
Rock Wool	0.03–0.04
Glass Wool	0.032–0.04
Polystyrene Foam	0.033–0.035
Phenolic Foam	0.036
Wood-Wool Slabs	0.093
Compressed Straw Slabs	0.101

3.4.2.2 Timber

Wood is another commonly used versatile and early material in construction industry. Wood is very valuable and useful natural resource due to its relative characteristics. There are several applications of wood in the building construction. There are several types of wood depending on the geographical location, species and growth conditions of trees, and are used for different purposes. Planting new trees in the harvested area and sustainable forest management, provides endless wood supplies for the construction industry, therefore it is considered as a continuous product unlike other industrial construction materials. [47].

Table 3.8. Energy and Environmental Performances of Common Construction Materials [47]

Material	Embodied Energy	Envronmental Impacts		
	(GJ/m^3)	GWP (kg/ m^3)	AP (kg/ m^3)	POCP (kg/ m^3)
Aluminium	497	29 975.4	162	321.3
Bricks	5.4	342	3.6	30.6
Ceramic Tiles	16	1142	8	102
Concrete	4.8	156	2.4	0.72
Glass	19.2	1365.6	96	4.8
Plaster Board	4.5	238.5	2.7	1.8
Roof Tiles	2.2	288.2	2.2	2.2
PVC	116	1932	17.9	0.69
Steel	200	17 840	80	6720
Wood	1.65	63.8	0.55	0.55

As it can be seen in Table 3.8, the embodied energy spent on wood is much less than other non-sustainable materials such as aluminum, brick, concrete and steel.

3.4.2.3 Earth Based Building Materials

Earth is one of the most important natural building material. It is also widely available all around the world. This natural construction material not only has superiority to most of the industrial materials by energy efficiency but also a healthy material. Recent developments in earth building techniques, makes it preferable not only by inexperienced home builders but also by professional contractors [48].

There are many different names for earth based construction materials. Depending on the content and production technique, it is referred as, “adobe”, “mud bricks” or “rammed earth” [48].

Examples of early buildings constructed with mud based products are shown in Figures 3.8 and 3.9. [48].

Figure 3.8. Reconstruction of mud-brick wall, Heuneburg, Germany, 6th century BC [48]

Figure 3.9. Rammed earth house, Weilburg, Germany, 1828[48]

3.4.2.4 Straw Bale

Nature provides not only food and water but also gives possibilities of sheltering or materials for buildings. There are several natural materials that have been used for centuries and one of the most commonly used one is straw bales.

Straw bales are made by compressed cereal grain stalks and can be used as building blocks. During the harvest of wheat, barley, or rice, the heads of the grain are collected, and the stalks are left in the field to dry. The straw is a waste product. When it dried, the stalks are harvested and made into compressed bales [49].

Figure 3.10.Straw Bale House Construction [50]

Simple construction, using straw bales are shown in Figure 3.10.

The heat transition value for a straw bale is relatively low; it is one of the best insulation materials nature provided. Preferring straw bale to a manufactured products can both save money and energy consumption. It is also lighter and bigger than most wall materials which can dramatically reduce the man power needed for the construction of a building. Commonly used straw bale sizes are 40 cm X 60 Cm x 120cm and it weighs about 18-36 kg. The condense structure of straw bale also provides the necessary fire proofing for the buildings [49].

The cross section and hence the details of the straw bale wall assembly is shown in Figure 3.11

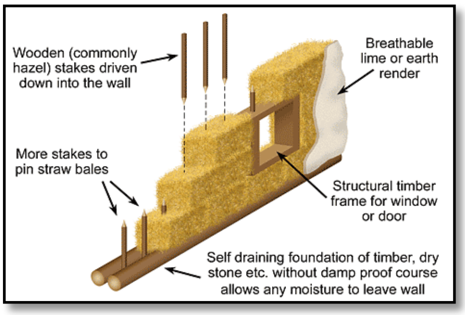


Figure 3.11.Straw Bale Wall Assembly [51]

3.2.2.5 Low E Glass

Window glazing is another important part of the sustainable construction due to its advanced thermal conductivity properties. Specifying the correct type of windows for a building, plays crucial role for the heat loss and ambient lighting levels.

The low E glasses are glazed with special coatings which reflect up to 90 per cent of heat and admit most of the lighting into the building. This coating is applied due to the climate conditions of the region. It can be applied to the outer layer of the windows in hot climates in order prevent heat gain or it can be applied to the inside layers for protecting the building from heat losses. The type of low E glass is determined by application side and the color of the coating. Mostly, for the residential buildings, the coatings applied inside of the layers are preferred [52].

Low E glass assembly is shown in Figure 3.12.

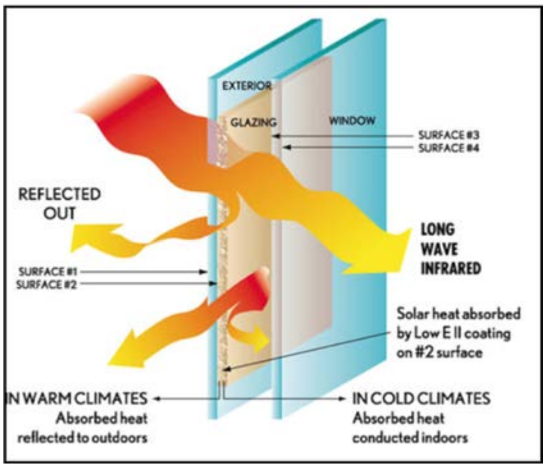


Figure3.12. Low E Glass Assembly [53]

3.5 CHAPTER RESULTS

Chapter 3 discusses both construction methods and materials. For example conventional construction methods and sustainable construction methods are covered in detail in order to make a better comparison between two, authors stated all the details. The statistical data provided by TUIK has been discussed according to the number of building permits issued in 2010 and 2009 briefly .It has been observed that most preferred construction method was reinforced concrete frame construction in the year 2010 with a growing rate.

Construction material are also discussed in chapter 3 and relevant distinguishes had been done between the commonly used materials, between the conventional and sustainable construction methods.

4. CASE STUDY: HOUSING DEVELOPMENT ADMINISTRATION OF TURKEY (TOKI)

4.1 INTRODUCTION

The foundations of modern Turkey established after the announcement of the Turkish Republic in 1923 after 600 years of ruling of Ottoman Empire. The country and the nation had several wars and had economic dilemma.

The redevelopment of the country was the main interest of the government; they started to invest on public transportation infrastructure such as airports, seaports and railroads which helps the development of the cities and resulted in immigrating to more developed regions.

However, the economic problems were always the biggest concern for the development of the new republic. In early 1980's, housing development taking place slowly, individual construction companies started changing the face of modern cities. These companies normally were building five to ten story mid-size buildings. Although the development of construction industry progressed until about 1988 due to the increase in interest rates and the rise of construction cost, the progress has gone down thereafter. This was the general situation until 90's, however following earthquakes in Kocaeli and Düzce in1996 and 1999, the development of the construction industry has almost vanished [1].

4.2 HOUSING DEVELOPMENT ADMINISTRATION OF TURKEY

The Housing Development Administration of Turkey established in 1984 as to promote the construction industry and to build modern and economical accommodation for the nation. It is a nonprofit government organization which its revenue comes from the proceeds of the sales [1].

According to the TOKI's corporate profile catalog, between 1984 and 2001, dramatic number of 43145 housing units has been built only in 17 years. From 2001, TOKI demonstrated dramatic increase for promoting construction sector and began growing more and more each year and became the leading financer and promoter of the construction industry [1].

By 2011 TOKI, was able to provide jobs to 600 contractors and 30 sectors in the field of construction industry. Over 800.000 people are benefited in many different fields from TOKI developments [1].

4.3 STATISTICAL DATA OF TOKI

Even though it established as a promoter for the housing needs of the country TOKI, successfully finance and construct government buildings and structures for different social needs. There are many building types from schools to hospitals, disaster shelters to multi-purpose sports complexes, have been built under the management and the administration of TOKI.

Successfully built or still under construction projects by TOKI by 2011 are listed below:

- 500 000 Housing Units by 2011
- 18 000 Disaster Housing Units
- 23495 Migrant Dwellings
- 4000 Housing Units for Agricultural Village Projects.
- 686 Schools with 20000 Classes, started in 2007,total investment of 1.6 Billion TL.
- 138 Hospitals started 2006. Total investment of 2.1 Billion TL
- 88 Local Healthcare Centers
- 2 Stadiums and 1 Multi-purpose sport complex in Istanbul
- 715 Gymnasiums
- 319 Mosques
- 38 Libraries
- 67 Dormitories
- 27 Orphanages
- 21 Non handicapped Life Centers
- 7 Rehabilitation Centers
- 2 Daycare Centers

- 5 Nursing Homes
- 2 Stream İmprovement Junctions
- 8 Operation Alarm Settlements
- 4286 Facilities
- 37 Shift Dormitories
- 1 Ministry Service Building
- 250 Police Stations
- 407 Trade Centers
- 17 Million m^2 of Landscaping [1].

Construction cost of 35 billion TL allowed 382.000 housing units to be sold by 2011. TOKI is also the master planer of the urban regeneration projects of Turkey. TOKI has both completed and still developing projects in all regions of Turkey. Further data can be obtained from TOKI’s official web site [54].

4.4 CASE STUDIES: TOKI PROJECTS

In this thesis, two TOKI projects are investigated and the impact of their geographical location, building design and the area of the units are studied to assess the sustainability criteria. They are both social housing projects for the lower-middle income families.

Table 4.1 Decisive Factors of Both Case Studies

	CASE A	**CASE B**
Location	Izmit Kocaeli-Arızlı	Sanlıurfa-Halfeti
Climate	Marmara Region Climate	Southeast Anatolia Region
Number of Flats	8 Story Building	Single Story Building
Type of Building	Residential Unit	Residential Unit
Units	20 Blocks-36 Units/Block	140 Single Units
Total Area	337.6 m^2	121.88 m^2

One of the projects is selected from the Marmara region of Turkey and the other is selected from the Southeast region of Turkey and these are shown at Figure 4.1 and Figure 4.2. These locations are intentionally chosen in order to assess differences of parameters such as energy efficiency potential, rainwater collection potential and carbon emissions potential of the case studies. It is worth noting that these two locations also have very different population density. Marmara region and Southwestern region of Turkey have got very different weather patterns and hence are carefully selected for this study.

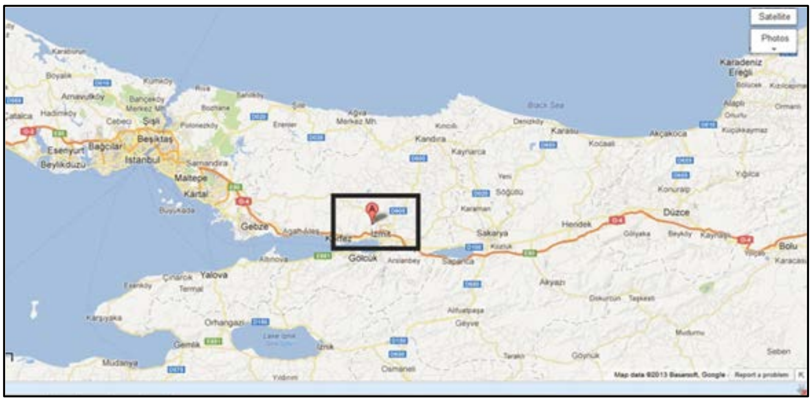


Figure 4.1. Geographical Location of Case A [55]

The first selected project is TOKI Kocaeli, Arızlı, social housing complex, located on the Marmara region which is Northwest part of Turkey. However this project has been referred as "Case A" from here throughout the thesis.

The construction consists of 706 housing units, one elementary school, one mosque and a commercial unit. The building blocks are group according to the number of stories. There are total of 20 building blocks and are as B-1 Blocks but separated as B+Z+8, 2B+Z+7, 3B+Z+6 types and shown in Table 4.1.

The project is located in Kocaeli and the general contractor for this project was Özülke Ins.Müh.Mim.San.Tic.Ltd.Sti and Maksem Yapı Ins.San.Tic.Ltd.Sti.

Table 4.2. Block Types and Number of Units for Case A

 B1 (84,43 m2)	B+Z+8	14 BLOCKS	504 UNITS
 B1 (84,43 m2)	2B+Z+7	5 BLOCKS	170 UNITS
 B1 (84,43 m2)	3B+Z+6	1 BLOCKS	32 UNITS
TOTAL		20 BLOCKS	706 UNITS

The gross area of the project is 49555.70 m^2 and divided into 8 sections. Total area of each section is summarized in Table 4.2.

Table 4.3. Area of Sections of Case A

SECTION #	AREA OF THE SECTION
Section 1	5161.30 m^2
Section 2	1403.70 m^2
Section 3	6659.40 m^2
Section 4	13704.20 m^2
Section 5	2699.80 m^2
Section 6	12383.00 m^2
Section 7	4365.70 m^2
Section 8	3178.60 m^2
TOTAL	49555.70 m^2

The second project is located in Sanlıurfa Halfeti. The project designed as “Tarım köy” project which is a social housing project mostly for the agricultural workers and local villagers around the area. This project has been referred as “Case B” for the rest of the thesis. The geographical location of case B is shown at Figure 4.2.

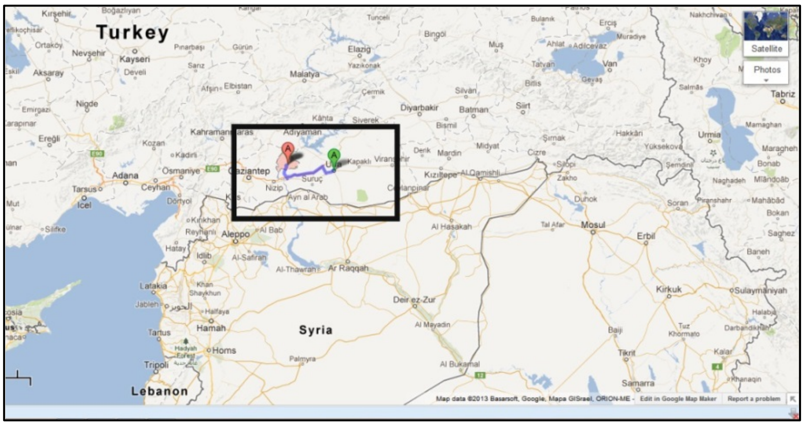


Figure 4.2. Geographical Location of Case B [55]

The general contractor of this project was Sagır Ins.Gıda.Tek.Turz.San. Tic. Ltd.Sti. The gross total area of construction is 18038.24 m^2 and has 148 single story units which is shown in Figure 4.3.

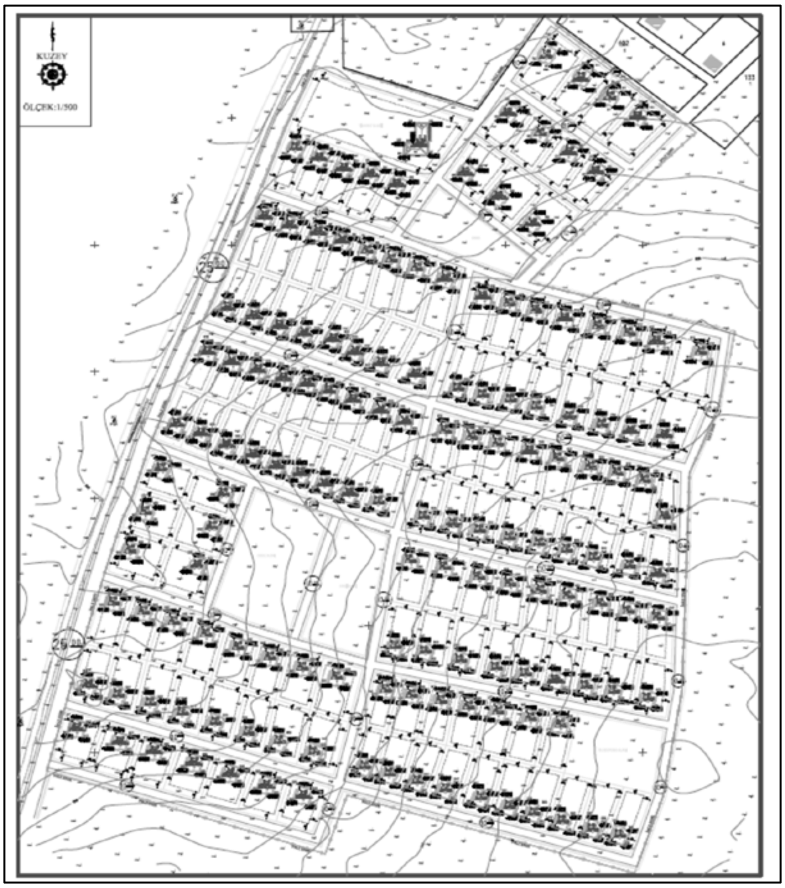


Figure 4.3. Site Plan of Case B

All the units have exactly the same size and design and they are 121.88 m^2 each, placed on approximately 430 m^2 of land shown in Figure 4.4. It has been observed that there is no special orientation chosen for the buildings when the site plan considered. It can be seen that although some buildings are facing north, some of them are facing south as shown in Figure 4.3.

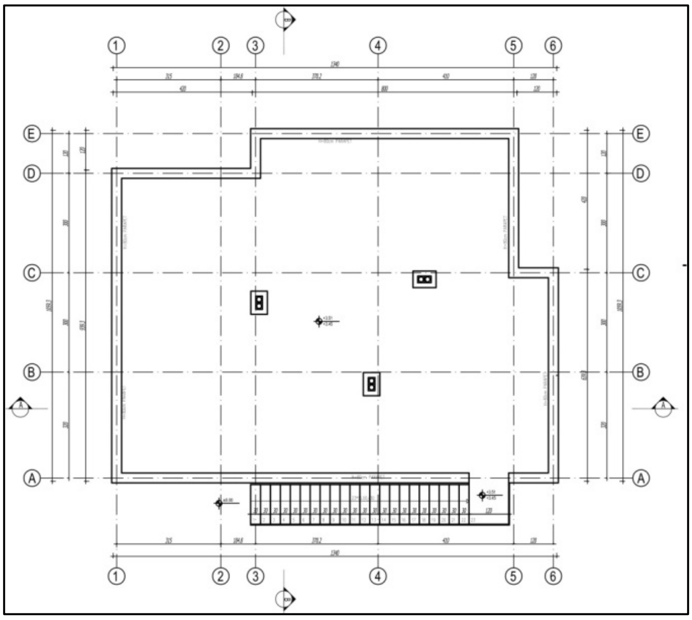


Figure 4.4. Representative Layout Plan of Case B.

4.5 WEATHER DATA USED FOR THE ANALYSES

The weather data is one of the key elements of sustainable design and construction. As discussed in the above section, Case A and B have been selected from different locations intentionally (Marmara reg. and Southeast Anatolia reg. respectively) in order to investigate the influence of different weather conditions to examine the energy efficiency and sustainable criteria. However, it must be noted that the weather data plays a significant role in design process of buildings such as orientation of the building is influenced by the temperature difference, amount of sunlight and the amount of rain fall.

In order to understand the energy efficiency and sustainability of the existing construction, the regional weather data should be investigated deeply. The weather data provided by the

Turkish State Meteorological Service's analyses had been used to study the potential of the projects chosen as case studies in this thesis.

4.5.1 Weather Conditions of Marmara Region

For the year of 2012 the average temperature is above the normal temperatures in the Marmara region. The minimum mean temperature in Marmara Region is 5,0 ^{0}C recorded in Kırklareli and Edirne and the maximum mean temperature is 9,4 ^{0}C in Sakarya (Kocaeli) [56].

The monthly temperature data, minimum and maximum data, of Kocaeli is provided by the Turkish State Meteorological Services are summarized in Tables 4.3,4.4,4.5 and 4.6 that are used in the analysis discussed in chapter 5.

Table 4.4. Monthly Average Temperatures of Kocaeli (1960-2012) [56]

KOCAELİ	**January**	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**	**October**	**November**	**December**
Average Temperature(^{0}C)	6,1	6,6	8,5	13,0	17,5	21,8	23,7	23,6	20,3	16,0	11,8	8,4
Maximum Average Temperature(^{0}C)	9,6	10,5	13,1	18,4	23,2	27,6	29,5	29,4	26,0	20,8	16,1	11,8
Minimum Average Temperature(^{0}C)	3.2	3.4	4.9	8.8	12.9	16.9	19.1	19.2	16.0	12.6	8.5	5.5

Table 4.5. Maximum and Minimum Temperatures of Kocaeli (1960-2012) [56]

KOCAELİ	**January**	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**	**October**	**November**	**December**
Maximum Temperature(^{0}C)	24.9	26.0	30.2	34.7	36.6	38.7	44.1	41.6	37.8	36.2	29.1	27.4
Minimum Temperature(^{0}C)	-9.7	-8.3	-5.7	-0.9	2.8	8.5	11.3	12.4	6.0	2.4	-0.7	-5.7

Table 4.6. Monthly Average Sunshine of Kocaeli (1960-2012) [56]

KOCAELİ	**January**	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**	**October**	**November**	**December**
Average Daily Sunshine (Hours)	2.3	2.6	4.6	5.3	7.1	9.6	9.2	8.5	7.1	4.5	3.3	2.3

Table 4.7. Monthly Rainfall Data of Kocaeli (1960-2012) [56]

KOCAELİ	**January**	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**	**October**	**November**	**December**
Average Number of Rainfall (Days)	17.4	15.6	13.8	12.1	9.8	8.2	5.8	5.4	7.3	12.0	13.8	16.8
Monthly Total Rainfall (Kgm2)	91.8	73.0	72.8	54.8	45.0	50.4	36.7	48.4	54.3	89.2	84.9	112.4

4.5.2 Weather Conditions of Southeastern Anatolia Region

The average temperature of Southeastern Anatolia region was about annual standards for the year 2012. The minimum average temperature was recorded at Gaziantep as 9.4 ^{0}C and the maximum average temperature was recorded at Cizre as 12, 9 ^{0}C.

The monthly temperature data, minimum and maximum data, of Sanlıurfa is provided by the Turkish State Meteorological Services are summarized in Tables 4.7,4.8,4.9 and 4.10 that are used in the analysis discussed in chapter 5.

Table 4.8. Monthly Average Temperatures of Sanlıurfa (1960-2012) [56]

SANLIURFA	January	February	March	April	May	June	July	August	September	October	November	December
Average Temperature(^{0}C)	5.6	6.9	10.9	16.1	22.2	28.2	31.9	31.2	26.8	20.2	12.7	7.5
Maximum Average Temperature(^{0}C)	10.0	11.8	16.5	22.2	28.6	34.6	38.7	38.2	33.8	26.9	18.5	12.0
Minimum Average Temperature(^{0}C)	2.3	2.9	6.2	10.5	15.6	20.8	24.4	24.0	20.1	14.8	8.4	4.1

Table 4.9. Maximum and Minimum Temperatures of Sanlıurfa (1960-2012) [56]

SANLIURFA	January	February	March	April	May	June	July	August	September	October	November	December
Maximum Temperature(^{0}C)	21.6	22.7	29.5	36.4	40.0	44.0	46.8	44.8	42.0	37.0	29.4	26.0
Minimum Temperature(^{0}C)	-8.0	-9.6	-7.3	-3.2	6.0	10.0	16.0	16.0	11.2	2.5	-2.7	-6.4

Table 4.10. Monthly Average Sunshine of Sanlıurfa (1960-2012) [56]

SANLIURFA	January	February	March	April	May	June	July	August	September	October	November	December
Average Daily Sunshine (Hours)	4.0	5.6	6.2	7.4	10.1	12.2	12.3	11.3	10.1	7.5	5.5	4.0

Table 4.11. Monthly Rainfall Data of Sanlıurfa (1960-2012) [56]

SANLIURFA	**January**	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**	**October**	**November**	**December**
Average Number of Rainfall (Days)	12.4	11.3	10.9	9.8	6.5	1.5	0.3	0.2	0.9	5.3	8.1	11.2
Monthly Total Rainfall (Kgm2)	86.5	71.2	64.3	48.0	28.3	4.1	2.4	3.8	4.8	27.9	47.5	78.8

It can be observed from the Table 4.3 to 4.10 that the weather data of these two various regions have both significant temperature differences in general and temperature differences of summer and winter months. Also the rainwater harvesting potential of these regions, are very different from each other.

There is 0,5^{0}C to 3,1^{0}C degrees of temperature difference, during the winter months in between these two cities, during the summer months the temperature gap reaches to 8,2 ^{0}C degrees. The Southeaster Anatolian region is significantly hotter at the months of June, July, August and September which shows that it has much more potential of photovoltaic panel usages in order to produce electricity and hot water. December is the only month that Kocaeli is hotter than Sanlıurfa with a difference of 0, 9 degrees Celsius.

The average daily sunshine between these cities also shows substantial differences during the year. In the winter months, the daily average sunshine is 2,3 to 5,3 hours a day in Kocaeli while it is 4,0 to 7,4 hours in Sanlıurfa, with an average difference of 2,1 hours in total. This difference goes up to 3 hours during the summer months.

On the other hand Kocaeli has a greater rainwater harvesting potential than Sanlıurfa, there is 5,1kg/m^2 to 6, 8 kg/m^2 rain fall difference between the months of January and April; however it dramatically increases up to 61, 3 kg/m^2 between June and September.

4.6 SOFTWARE PACKAGES USED FOR THE ANALYSES

There are two different software packages for the analyses that have been used in this thesis. The first is Autodesk Revit Architecture which is building information modeling (BIM) software, used for the 3D modeling and the calculation of the square meters of the rooms, facades and openings. The second software is Green Building Studio (GBS), a web based program, used for the calculation and comparison for the potential sustainability of the existing buildings.

The AutoCAD drawings of Case A and B obtained from TOKI headquarters are used to model the representative buildings in Autodesk Revit Architecture in order to obtain the 3D model of the existing buildings. The model created in Autodesk Revit Architecture is then exported to “Green Building Studio” in order to introduce the necessary data to the software for all analyses. The 3D Model is then converted to the gbXML (Green Building Extensible Markup Language) format for exporting the data to the green building studio. As it is discussed by Stumpf et.al , gbXML format is specially designed layout in order to obtain the energy related information from the software which is Autodesk Revit Architecture in this case. This format automatically controlled by the green building studio for the accuracy of the 3D model [57].

The imported gbXML data is then analyzed on the green building studio to obtain the energy efficiency related data. The first analysis conducted based on the data provided in original AutoCAD drawings that reflects the existing condition of the buildings. Further analyses are conducted by changing the variables in order to make comparisons between the results and existing conditions of the buildings.

The details of the results are discussed in chapter 5.

4.6.1 Autodesk Revit Architecture

Building information modeling is the new choice for the architects, designers, engineers and anyone related with the design and construction industry, using computer aided design (CAD) software. It is not only able to create detailed 2D drawings but also provides 3D models with all the necessary information related to the building such as material quantity take offs, sun and shadow analysis, building area information etc.

According to Azhar, building information modeling exemplifies the process of progress and use of a computer generated model to mimic the planning, design, construction and operation of a building. Azhar also explains the finished model as is an information full, object oriented, intelligent and parametric representation of the building [58].

Autodesk Revit Architecture is one of the most commonly used BIM program between the architects and construction related professionals. It provides the user flexible design options and provides both 2D and 3D drawings. It also is able to analyze and provide sun exposure of the building according to the actual location of the construction site. It has a user friendly interface and considerably easier learning curve. It has a free student version with the subscription of Autodesk student center which was one of the main considerations while selection process of the suitable software. Autodesk Revit Architecture has also the ability to export the finish model in gbXML format which is the necessary format for the sustainability analyses for most green building analyzing software.

4.6.2 Green building Studio (GBS)

Autodesk describes the “Green Building Studio” as web based service which works with the gbXML file format which can be introduced from different modeling software’s like Revit Arhitecture, ArchiCAD and Triforma. The software has the ability to analyze different alternatives in order to compare different variables such as the orientation, glazing types, roof and wall assemblies and lighting power density [57].

Green Building Studio is the most preferred and used BIM based building energy consumption and carbon emission analysis software. It has been preferred and used by 59 per cent of industry related professionals. There are also many other software packages like Autodesk Ecotect and Integrated Environmental Solutions Virtual Environment, for the energy analysis of buildings[59]. However, green building studio is preferred by the author for the analytical study of this thesis.

4.7. CHAPTER RESULTS

In this Chapter TOKI’s profile carefully investigated in order to gain deeper understanding of TOKI’s position in Turkish construction industry. It has been observed that TOKI is the largest and most active promoter of the construction industry. The geographical regions and their weather conditions are investigated and explained. It has been observed that Marmara region and Southeaster Anatolia regions of Turkey have very different climate conditions. The data from the National Weather Services proved that there are significant differences on the average weather temperatures, hours of daily sunshine and rainfall amounts. Therefore two TOKI projects, each from one of these regions were selected and investigated deeply. The software packages are also identified and selected for the analytical part of this thesis. It has been observed that Autodesk Green Building Studio would be the best option for the purpose of this study.

5 ANALYSES OF THE SELECTED CASES

5.1 INTRODUCTION

In this chapter selected TOKI buildings from two different regions, are analyzed and compared with the sustainability potentials in terms of energy efficiency, carbon emissions and water usage.

Selected TOKI buildings are modeled and analyzed using computer programs mentioned in the previous chapters.

5.2 CASE A BUILDING ANALYSES

First project investigated in this thesis for the energy analysis is TOKI Case A building complex. The whole complex is consists of 20 buildings and have the exact same construction plan. However their orientations are a variable which is already taken into account in the analyses. Hence one of the buildings could be selected as a representative for this analysis. The selected building has a total of eight floors and each floor has four same size units, located on the four corners of the building. Test analyses are made for the whole building without taking the location of the units in consideration. The staircases, elevator shafts and main hall connecting each unit, has no windows or any other openings therefore were not included in the energy analysis in order to get accurate measurements for the energy consumption of the actual living areas.

Final energy analysis was calculated based on the location of units in the building to compare the energy consumption and carbon emissions of different units in different corners of the building.

5.2.1 Orientation Analysis

Orientation analysis shown in Figure 5.1 indicates that the rotation of the building does not have a significant impact on the energy use intensity therefore, it has almost no effect on the carbon emissions of the building.

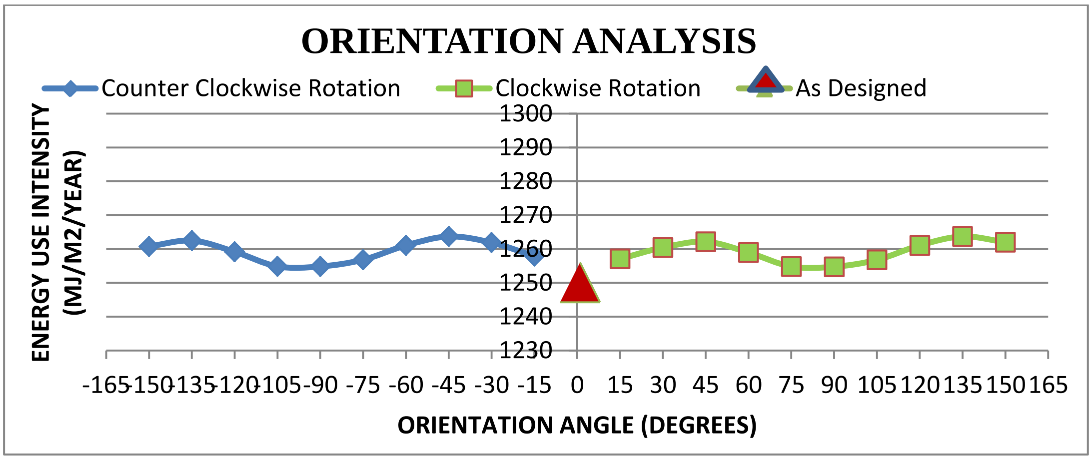


Figure 5.1.Energy Use Intensity Results for orientation analysis of Case A

The building was rotated by 15 degrees on both clockwise and counter clockwise direction on the north-south axis. The final analysis showed that the minimum energy use intensity can be achieved by rotating the building 105 degrees of angle to counterclockwise direction, which resulted in only 0.04 per cent decrease of energy use intensity. The maximum increase of energy usage intensity observed at the 135 degree angle to clockwise direction with an increase of 1039 Mj/ m^2/year which is 0.89 per cent more of the original design.

From this analysis, it can be concluded that, the rotation of the building does not provide significant energy savings or carbon emission savings. The reason for this can be attributed to the fact that, as clearly seen from the site plan and the construction plans provided in Appendix A, the design of the building is almost a square and each unit located on the corners of this square design with the exact amount of total window area and the unit area. The amount of lighting and sun exposure of the facades of the building does not change in any direction because of its shape and exposure to the light.

However, it has been believed that the orientation analysis should be investigated prior to the planning stage for the natural ventilation potential and wind effects to reflect optimum design principles.

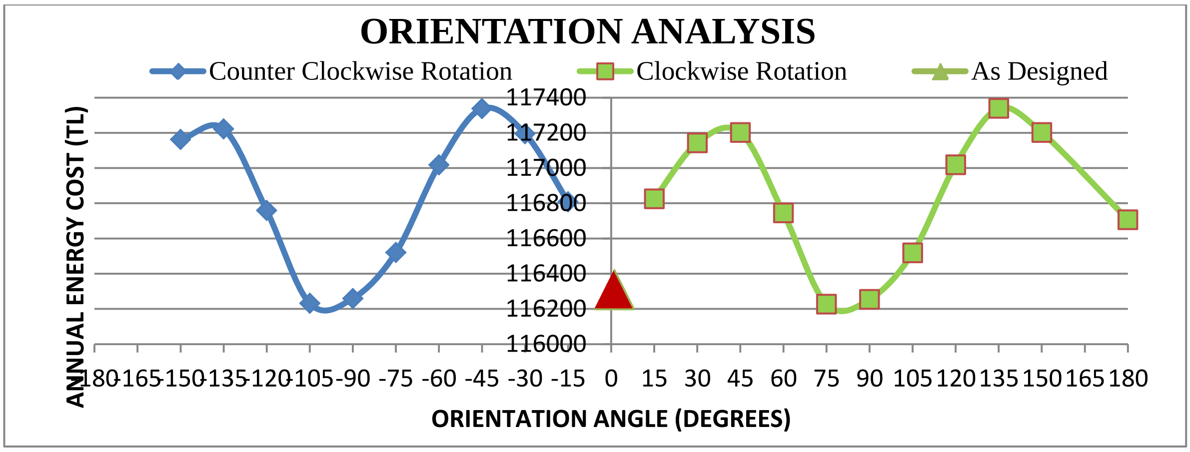


Figure 5.2. Orientation Analysis for Annual Energy Cost of Case A

5.2.2 Exterior Wall Assembly Analysis

Exterior wall assembly is an important part of energy consumption analysis for this building. Proposed changes in both insulation and wall materials have direct effects on the energy use intensity and the annual energy costs. Various types of wall assemblies are investigated and analyzed in this section. The exterior wall assembly analysis that consist of different types of wall assemblies are shown in Figure 5.3.

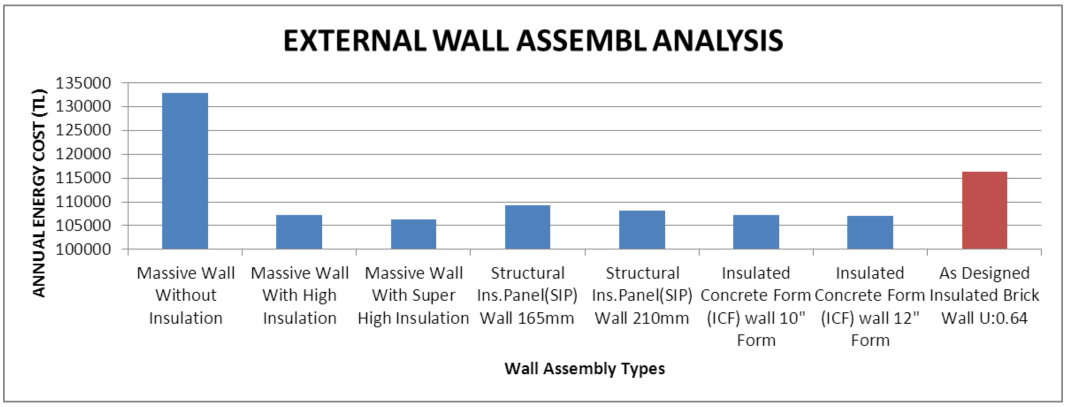


Figure 5.3. Exterior Wall Assembly Analysis for Annual Energy Cost of Case A

The original design consists of four centimeter foam insulation over brick to be used for external walls. This type of wall assembly has a heat transition value (U) of 0.84. The recommended external wall U Value by the Turkish Energy Standards for this region is 0.70. The heat transition values of the current building below the recommended value.

Massive walls with super high insulation (U Value of 0.17) provided the most energy saving potential in this analysis as shown in Figure 5.3. There are three layers of expanded polystyrene (EPS) insulation over 19 cm thick concrete wall in this type of wall assembly. The insulation material used in this assembly, expanded polystyrene (EPS) foam is not a sustainable material and can be very labor intensive and costly to recommend for this building. Also it is almost impossible to build this type of wall without interfering with the structural design.

It is highly possible to achieve the same U Value results, using recycled insulation materials like recycled denim or cellulose insulation supplies. These types of materials have better U values and they are environmentally friendly. Using recycled denim insulation over brick wall has a U value of 0, 36. In this case it is recommended to use recycled or natural insulation materials with same or better heat transition values.

5.2.3 Roof Assembly Analysis

The current building has wood frame pitched roof however, other types and materials are considered in the analyses in order to assess the annual energy cost as shown in Figure 5.4

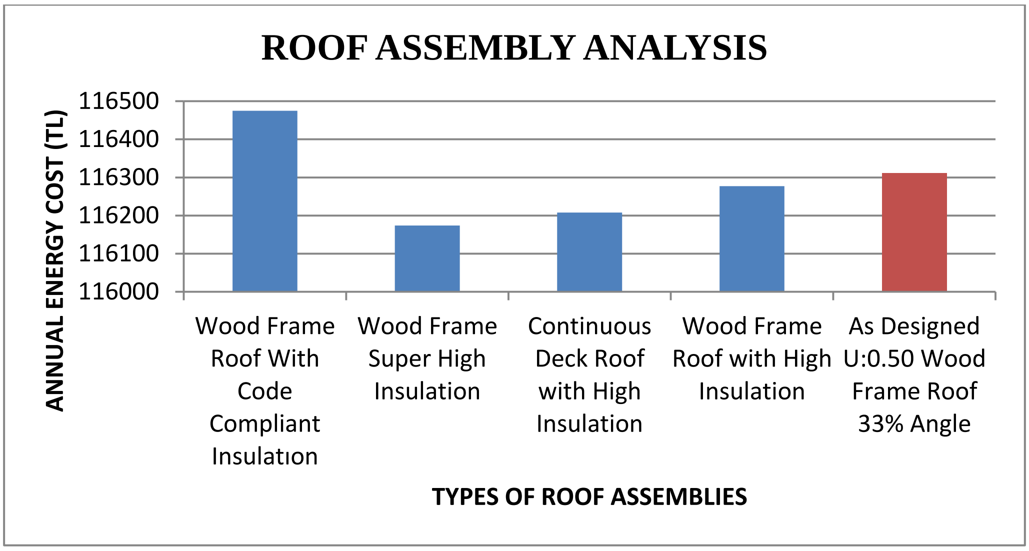


Figure 5.4. Roof Assembly Analysis of Case A

It can be seen in Figure 5.4 that the roof does not have a significant effect on the annual energy cost. The analysis with different types of insulations and structures suggested very little improvement for the overall energy consumption. The specified roof construction has a low U Value of 0.50, even though other analyzed roof assemblies have lower values. In the author's opinion; the construction and the insulation materials of the roof might probably only affect the story, just underneath. Other stories located in the lower levels might not benefit from roofs energy savings potential.

According to the author's opinion in most European countries, flat roofs with vegetation providing similar U Values, are recommended for this type of buildings since pitched roof does not make a tremendous difference with multiple stories.

5.2.4 Analysis of Window Glazing Types

In this section the effects of window glazing types are investigated. Five different window types are analyzed in this section. Polyvinyl chloride (PVC) frame windows with double layer of glazing specified in this building have a U Value of 2.61.

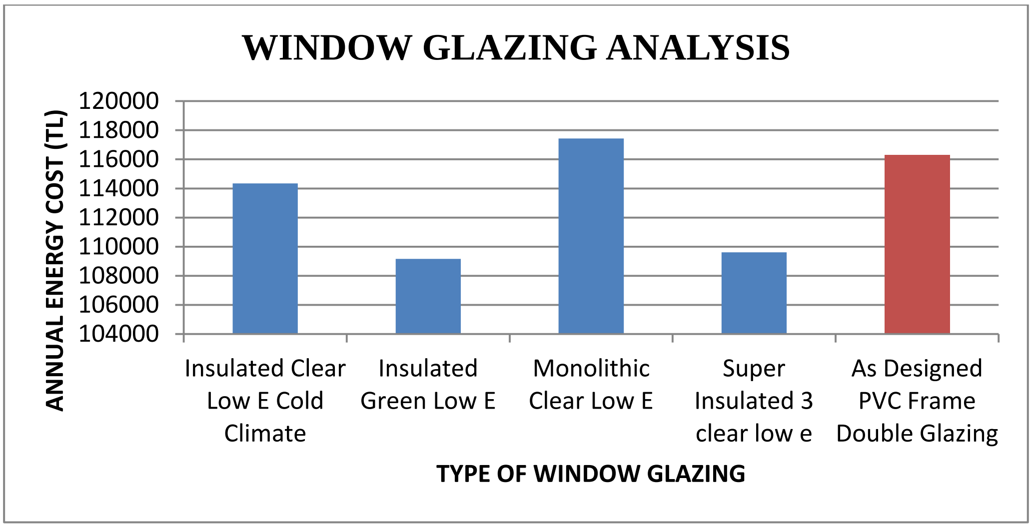


Figure 5.5. Window Glazing Analysis for Annual Energy Cost of Case A

As shown in Figure 5.5, the best type of window for the most energy savings is the insulated green low e type of windows. Replacing the existing windows of the building with green low e types provides 6.1 per cent in energy savings with an annual energy cost savings of 7156TL.

It is also observed that if monolithic clear low e windows would have been used for this building, the annual energy cost would increase by 0.9 per cent.

5.2.5 Analysis of Window Sizes

The window sizes on four sides of the building are both decreased and increased for this analysis by percentages shown in Figure 5.6. It has been observed that increasing or decreasing the exact same percentages of window sizes on all facades would not improve the energy savings of the building significantly except reducing the window sizes by 50 per cent.

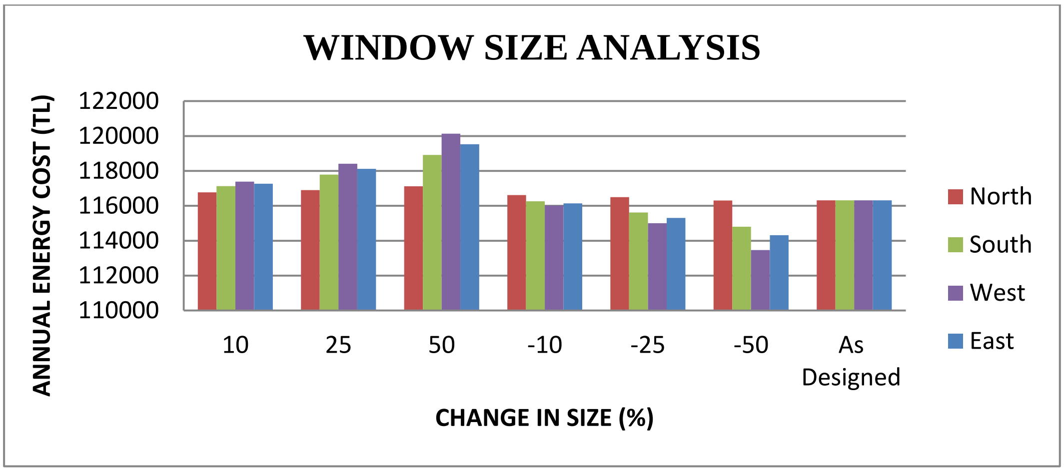


Figure 5.6. Window Sizes Analysis for Annual Energy Cost of Case A

Decreasing the window sizes by 50 per cent shows an improvement on the energy savings, but the changes on north facing windows are decreasing the energy costs while west facing windows are reducing it. It is also not suitable for residential units to decrease the size of the windows. Almost all other analysis pointed an increase in annual energy costs.

It might be possible to save energy by changing window sizes on different facades; on the other hand, this might also affect the equality between different units which can directly affect the end user. It is the author's opinion that the owner of the project would not approve this type of change for marketing purposes. Further analyses need to be conducted with the combination of both changes of the window sizes, window glazing types and orientation of building for advanced improvements on the energy savings.

5.2.6 Lighting Power Density Analysis

Improvements on the lighting design and mechanical design for this building can results in total savings of 7 per cent in the annual cost of energy.

Adopting better lighting sources for the entire building has a significant effect to the lighting power density. It is shown in Figure 5.7 that reducing the lighting power density of the building helps to improve the energy usage and annual energy costs.

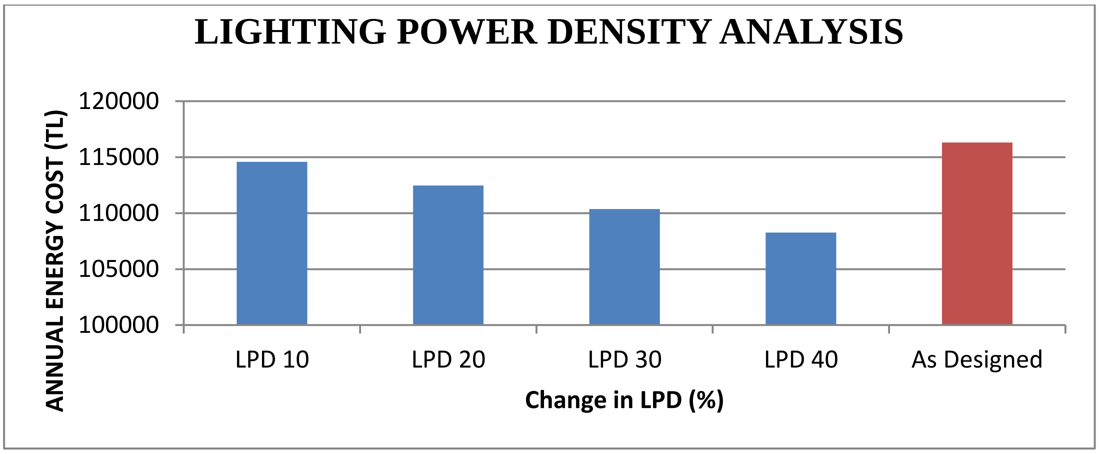


Figure 5.7. Lighting Power Density Analysis for Annual Energy Cost of Case A

An example of simple calculation for the reduction of energy consumption and lighting cost are summarized in Table 5.1 for better understanding of the importance when determining the optimized type of lighting source.

Table 5.1. Comparison of Cost of Lighting sources [4]

	Incandescent Bulbs	Compact Florescent Lights (CFL)
	75 Watts	15 Watts
Purchase Price	0.40 £	1.50 £
Lifetime	1000 hours	7000 hours
Cost of Bulbs for 7000 hours of Use	2.80 £	1.50 £
Cost of Electricity for 7000 hours of use	36.75 £	7.35 £
Total Cost for 7000 hours	39.55 £	8.85 £
Total Saving Using CFL =30.70 £ at 0.07 £ per kWh		

5.2.7 Water Consumption Analysis

The water consumption and annual cost of water are calculated by the green building studio with the provided information, shown in Table 5.2.

Table 5.2.Current Situation of Water Usage and Cost, of Case A

Water Usage & Cost						
Water Usage & Cost			Indoor Water Factors		Unit Water Prices	
Total	4920,783L/yr	TL7,514 / yr	Number Of People	77	Water	0.69 TL/ m^3
Indoor	4476,727L/yr	TL7,208 / yr	(Typical People for this Building type/size :79		Sewer	0.92 TL/ m^3
Outdoor	444,056 L / yr	TL306 / yr				
Net Utility	4920,783L / yr	TL7,514 / yr				

There are total of 36 units in this building. Total number of toilets, sinks, showers and clothes washers, are determined from the provided construction drawings. Each unit of the building has one bathroom and one kitchen with sinks. It is also assumed that every unit has a clothes washer. There are also two additional toilets and a single unit for the janitor in the ground floor.

Table 5.3.Water Savings Potential of Case A

	Total	Male	Female	Employee Only	Efficiency	Percent of Indoor Usage	Liters Per Year	Annual Cost Savings
Toilets	39	20	19	0	Low Flow	17.4	776,755	1,251
Urinals	0			0		0	0	0
Sinks	76	38	38	0	Low Flow	1.9	86,796	140
Showers	39	20	19	0	Low Flow	7.2	320,618	516
Clothes Washers	38			0	Horizontal Axis	9.6	428,470	690
Dishwashers	38			0	Efficient	0.1	5,019	8
Cooling Towers	0			0		0	0	0
Total Efficiency Savings						**36.1%**	**1,617,657**	TL**2,604**

As summarized in Table 5.3 using low flow faucets for the sinks and low flow shower heads for the showers in addition to energy efficient appliances makes a total of 36.1 per cent savings on indoor water usage. The data indicates that 1617.657 tons of water equivalents of 2604TL can be saved annually.

According to the data provided from the weather station, the annual rainfall of this region is 796 mm/m^2 and total catchment area of rainfall for this building is calculated as 350 m^2. By integration of a water harvesting system, 22.2 tons of water can be collected and used for irrigation annually. Grey water reclamation and site portable water sources also save up to 12.9 tons of water annually. Adopting native vegetation has a potential of 15.1 tons of water savings on the annual water consumption as shown in Figure 5.4.

Table 5.4. Rainwater Harvesting and Potential Water Savings of Case A

Rainwater Harvesting and Potential Water Savings					
	Annual Rainfall (mm)	Catchment Area (m²)	Surface Type	Net Zero Savings	
	796	350	Gravel/Tar		
				Liters per Year	Annual Cost Savings (TL)
Rainwater Harvesting:				222,880	154
Native Vegetation Landscaping:				151,024	104
Greywater Reclamation:				111,014	179
Site Potable Water Sources:				18,250	13
			Total Net-Zero Savings:	503,168	TL449

5.2.8 Carbon Emission Analysis

Results presented in Figure 5.8 indicates that when all potential energy savings are combined, the carbon emission savings for this building calculated as 39.4 Mg per year which means 28.3 per cent less amount of harmful gasses released to the atmosphere we breathe.

A 28.3 per cent reduction in carbon emissions cannot be underestimated and cannot be compared with the potential cost of sustainability especially when the whole number of buildings are considered in the complex.

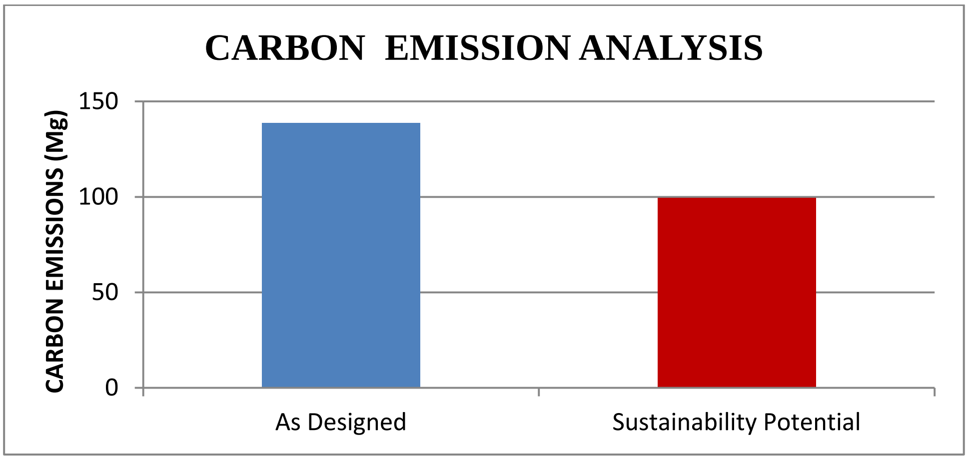


Figure 5.8. Carbon Emission Analysis of Case A

The results summarized in Table 5.5 also showed that with the potential savings of carbon emissions in this building, it is possible to take 3.9 SUVs, off the roads every year.

Table 5.5. Carbon Emissions Saving Potential of Case A in Large SUV equivalency.

ANNUAL CO_2 EMISSIONS		
	As Designed	Sustainability Potential
Electric	72.3Mg	54.8 Mg
Onsite Fuel	66.6Mg	44.6 Mg
Large SUV Equivalent	13.9SUVs/year	10.0 SUVs / Year

5.2.9 Final Energy Analysis

All optimum parameters from the previous analyses are used in the program and a final analysis was conducted. The Figure 5.9 indicates that there is a potential of 23 per cent savings in annual energy costs.

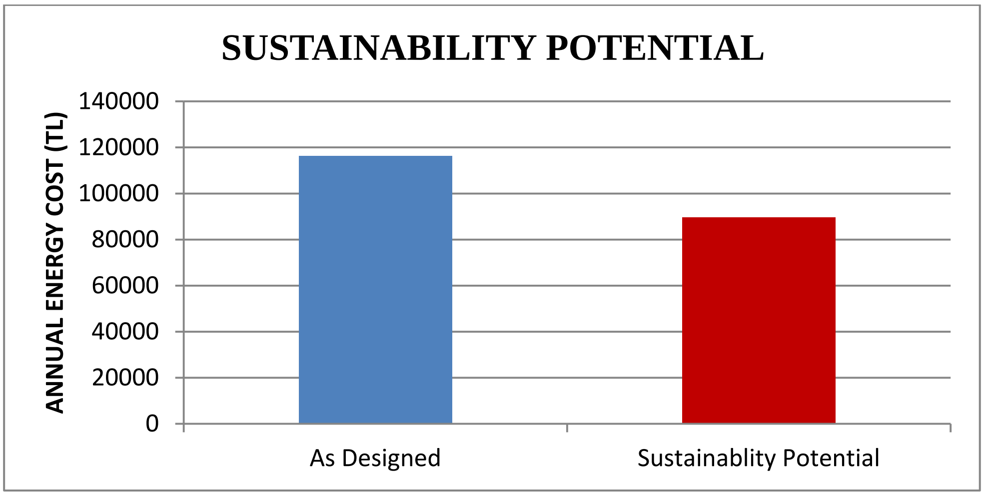


Figure 5.9. Sustainability Potential Analysis of Case A

The annual energy costs can be reduced to 26.771TL in total by adopting the most optimum parameters such as sustainable type wall materials, insulation, change in window sizes and glazing.

5.2.10 Analysis with Respect to the Location of Units

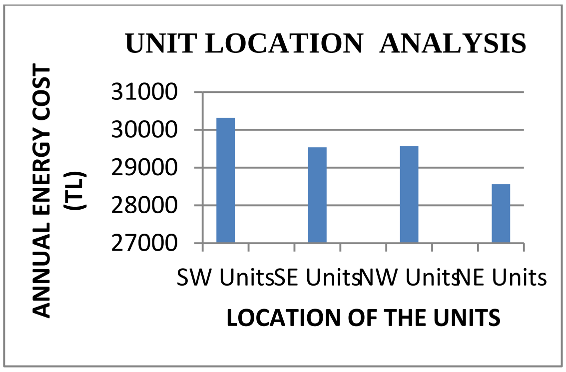


Figure 5.10.Annual Energy Cost Analysis According to the Location of the Units.

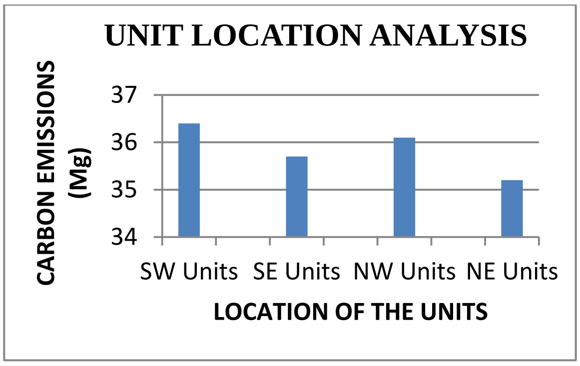


Figure 5.11. Carbon Emission Analysis According to the Location of the Units

When the varied locations of units in the building are considered, there is a need for further analyses in order to examine the total energy consumption. In this section an analysis was carried out without making any changes to the current project in order to compare the actual annual energy cost and carbon emissions of the units.

Figures 5.10 and 5.11 show that while the southwest and northwest units are consuming more energy that causes more carbon emissions, the southeast and northeast units are using less energy and therefore are more environmentally friendly.

Locations of the southwest and northwest units and southeast and northeast units are shown in Figure 5.12 and Figure 5.13 respectively.

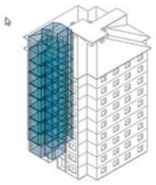
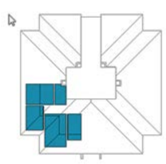
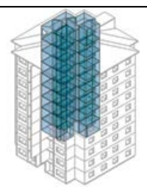
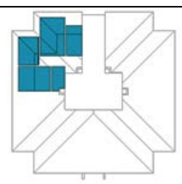
<table>
<tr><th colspan="2">Southwest Units</th></tr>
<tr><td></td><td></td></tr>
<tr><th colspan="2">Northwest Units</th></tr>
<tr><td></td><td></td></tr>
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Figure 5.12. Southwest and Northwest Unit’s Location in the Building

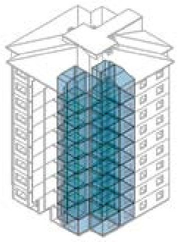
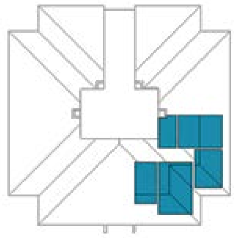
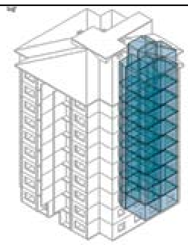
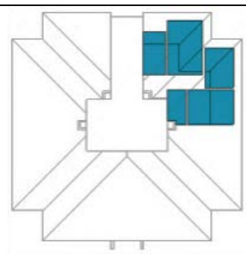
Southeast Units	
	
Northeast Units	
	

Figure 5.13. Southeast and Northeast Unit’s Location in the Building

It has been observed that there is a 1760 TL annual energy cost difference between the southwest units and northeast units. There is a potential of 6 per cent annual energy cost difference for the end user depending on the units considered.

5.3 CASE B BUILDING ANALYSES

5.3.1 Orientation Analysis

The orientation of the subject building according to the weather conditions of the selected area, plays a significant role on the sustainable design approach. There is no doubt that the correct orientation of a building can improve the amount of sunlight taken into the building. Direct sunlight coming through the northern windows not only improves the lighting conditions inside the building but also helps to the heat gain during the winter months.

The size of the windows on both northern and southern facades, the construction type including the insulation for the external walls, and the placement of sun screens can be determined from the results of the orientation simulations accordingly.

In this section changes of the orientation of the building with respect to its original position is addressed and hence several analyses are conducted.

15 degree angle increments in clockwise and counter clockwise directions are used to get as many data as possible in order to compare the results. The software makes the necessary calculations according to the orientation of the building and provides the annual energy consumption and energy use intensity of the building.

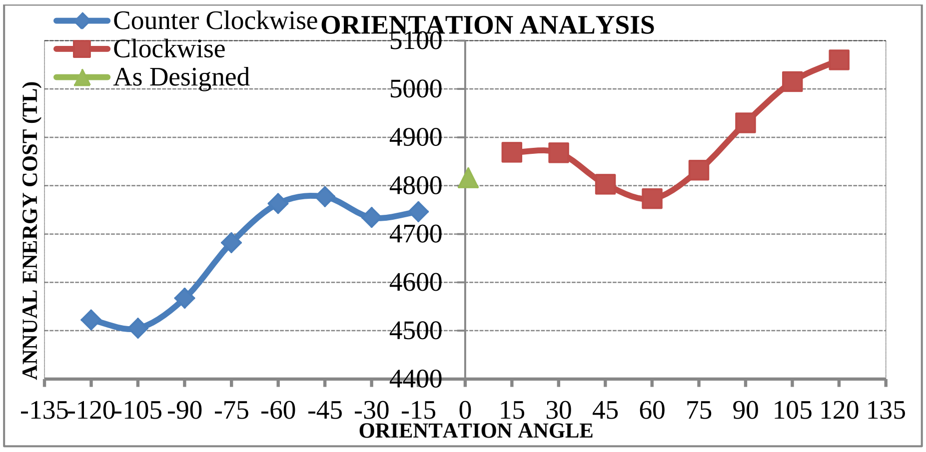


Figure 5.14. Parametric Orientation Analysis of Case B

According to the parameters used on the energy analyses program results presented in Figure 5.14, are obtained. The results show that the least energy consumed orientation of this building is observed when the building is rotated 105 degrees counterclockwise from its current position

By rotating the building 105 degrees, the longer façade of the building with higher ratio of windows are getting more sun exposure. This does not only improve the heat gain and lower the fuel consumption of the building as shown in Figure 5.15; but also improves the amount of daylight taken into the building which lowers the electric energy usage as demonstrated in Figure 5.16

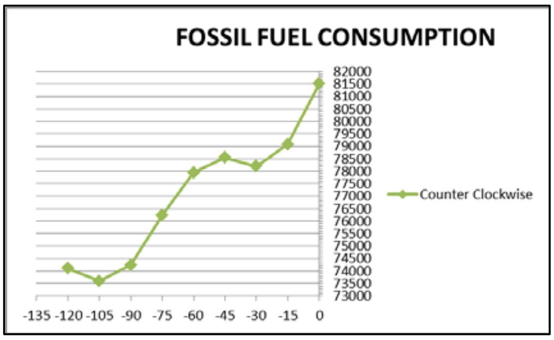


Figure 5.15. Fossil Fuel Energy Consumptions for Counter clockwise Orientations

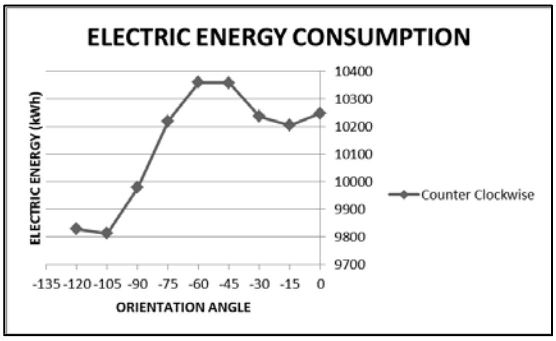


Figure 5.16 Electric Energy Consumptions for Counter clockwise Orientations

It can be easily seen in Figures 5.15 and Figure 5.16, 105 degrees of counter clockwise rotation provides less fossil fuel and electric energy usage. However, it is also observed that the 15 degree increments of the orientation angle can result in higher usage of electric energy compared to the original position of the building between 45 and 60 degrees due to the decrease of day lighting taken inside the building.

5.3.2 Exterior Wall Assembly Analysis

The construction plans of the building, presented in Appendix A, indicate the structure and the external wall assembly as reinforced concrete and conventional brick wall.

This type of construction has a high U-value of 1.18 which is above the suggested energy codes for the Southeast Anatolian region of Turkey.

Figure 5.17 and Figure 5.18 show the parametric analysis of different wall assemblies and the annual cost of energy consumption for the building. However, it is important to note that different wall types have different U-Values that directly affect the energy consumption.

As many different types of wall assemblies delivered by the program, straw bale, a sustainable material, previously discussed in this thesis, gives the best result because of its low U-Value of 0.30. Straw bale is not only a suitable construction material for this type of building but also acts as a natural insulation material. Because of its high insulation capacity, no extra cost for another layer of insulation will be needed.

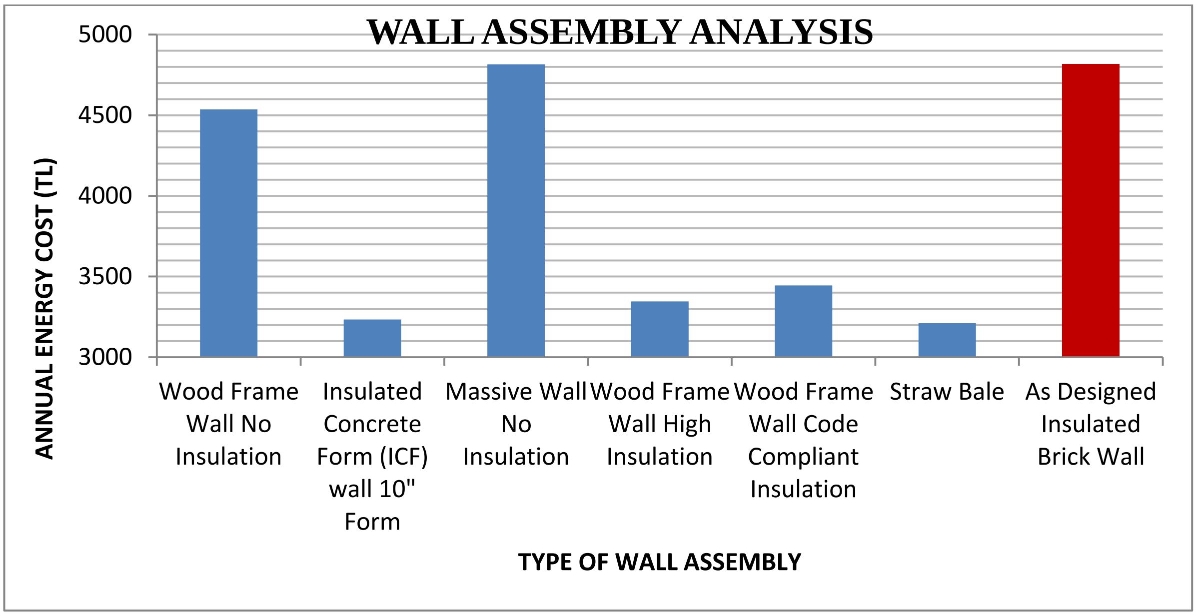


Figure 5.17. Exterior Wall Assembly Analysis for Annual Energy Cost of Case B

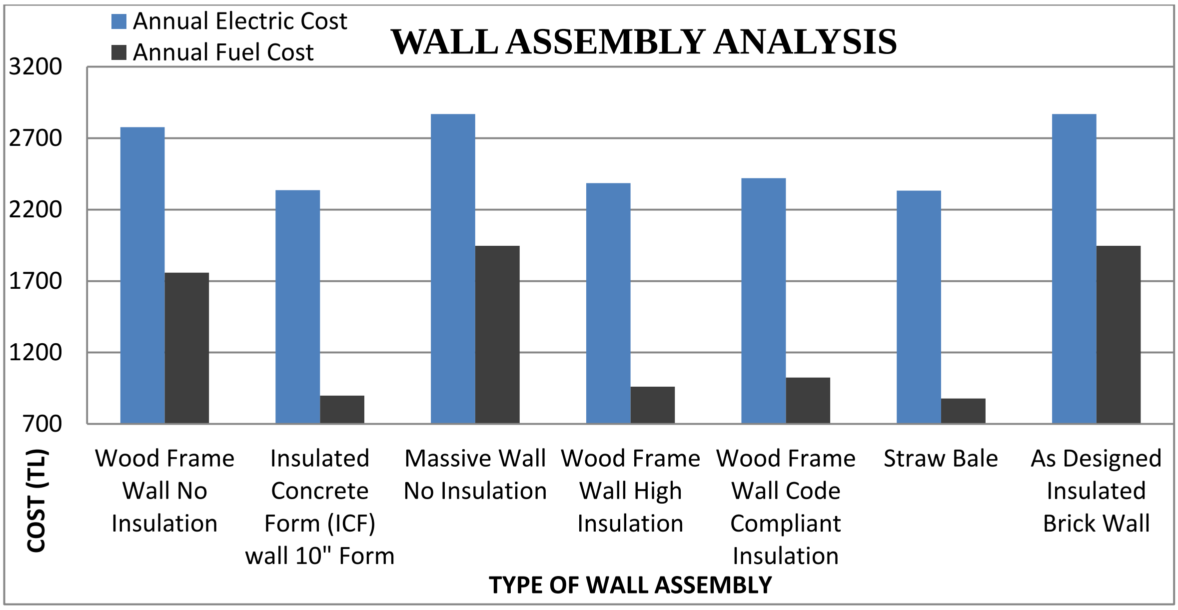


Figure 5.18. Wall Assembly Analysis for Annual Electric and Fossil Fuel Costs of Case B

The Annual electric and fuel cost presented in Figure 5.18 implements that straw bale wall construction and the provided conventional wall construction has significant cost differences on both electric and fossil fuel consumption.

Code compliant insulation also gives lower values but in this choosing, natural waste materials over industrial insulation materials could provide a better alternative. As explained in previous chapters, when production costs and CO_2 emissions of industrial insulation materials are taken into consideration, they have unacceptable environmental affects, on the other hand straw bale or recycled denim insulations has very low or no negative effects to the environment.

5.3.3 Roof Assembly Analysis

The specified roof construction is 4 centimeters foam insulation over 12 cm reinforced concrete slab. This type of roof provides heat transition value (U) of 0.56. The recommended U value for the region is 0.40 which is below the specified assembly.

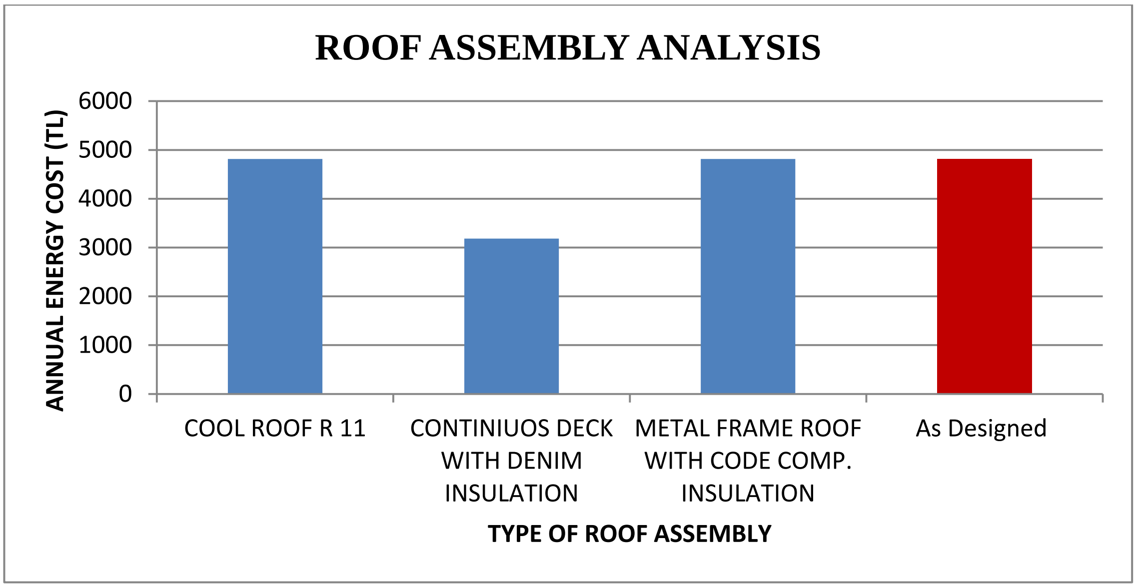


Figure 5.19. Roof Assembly Analysis of Case B

The various roof assembly types tested by the program suggested that using the existing roof assembly and metal frame roof with code compliant industrial insulation as an alternative provided comparative results for the annual energy costs. However using recycled denim or sheep's wool insulation with lower U-values creates almost 29per cent less energy consumption which dramatically reduce the annual cost of energy.

In this analysis cool roof with R 11 heat transitions ratio is used instead of provided roof construction assembly because of the limitations within the program. The R- 11 value is equivalent to the U value of 0.56.

Annual cost for electric and fossil fuel costs are shown in Figure 5.20., provide a clear understanding of the effects of roof construction assemblies to the energy consumption.

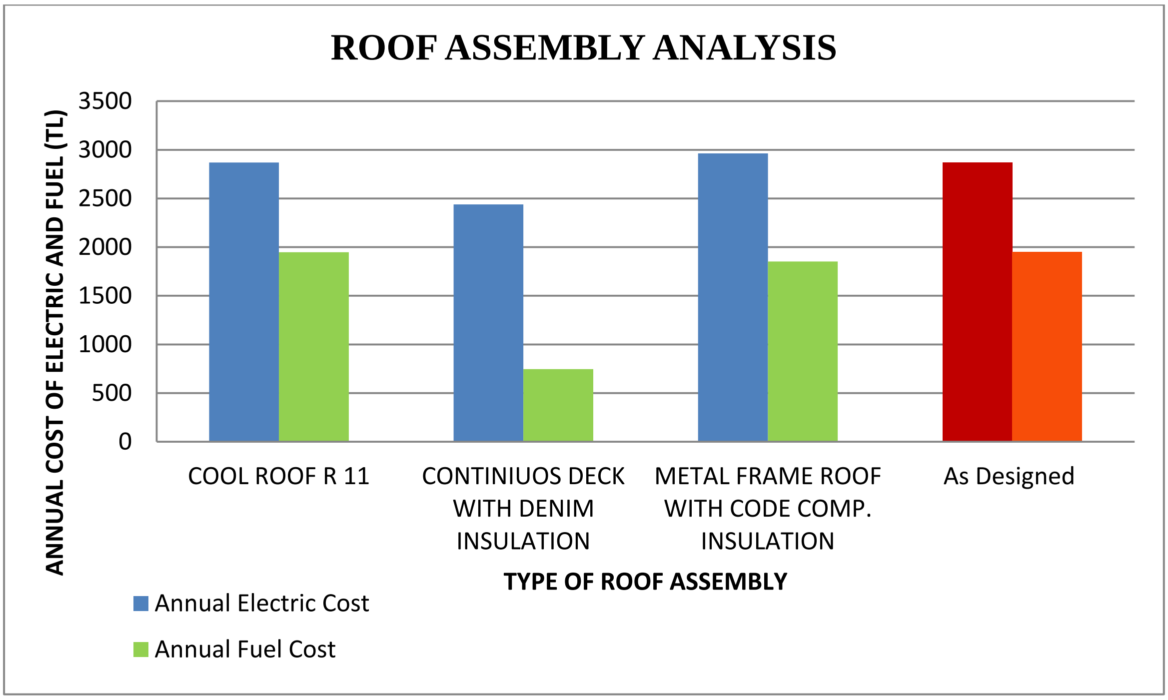


Figure 5.20. Roof Assembly Analysis for Annual Electric and Fossil Fuel Costs of Case B

5.3.4 Analysis of Window Glazing Types

Choosing the window glazing according to the weather conditions also plays an important role on the energy savings. Correct type of window framing with the better quality window glazing can save both energy and money. In order to complete the exterior envelope of the building, right size and types of windows should be taken into consideration as a part of sustainability and energy savings.

This section addressed different types of window glazing that have different U values and number of layering for the windows for comparison reason.

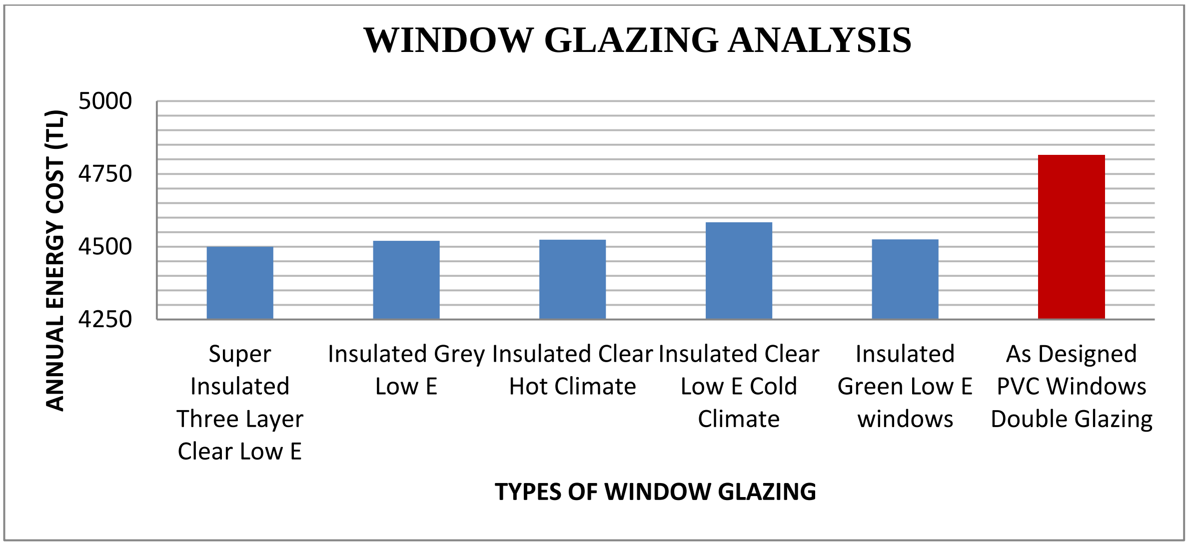


Figure 5.21. Window Glazing Analysis for Annual Energy Cost of Case B

As the Figure 5.21 indicates that Polyvinyl chloride (PVC) frame with double layer (4mm +16mm+4mm) type of window can be replaced with any other type of windows shown, to save energy. In this chart super insulated 3 layers clear low-e glazing provides the best results however replacing PVC windows with any other type of window provided in Figure 5.21 results in improved efficiency and cost.

5.3.5 Analysis of Window Sizes

Window sizing is considered as another important aspect of sustainable design principles. The amount of lighting allowed inside the building through the windows can directly affect the ambient lighting levels which is a critical energy saving factor.

North and south facing window sizes are changed when sizes of the windows of west and east facades kept constant and annual energy costs are calculated as shown in Figure 5.22

Similarly, sizes of windows of west and east facing are changed when north and south facings are kept constant and annual energy costs are calculated as show in Figure 5.23

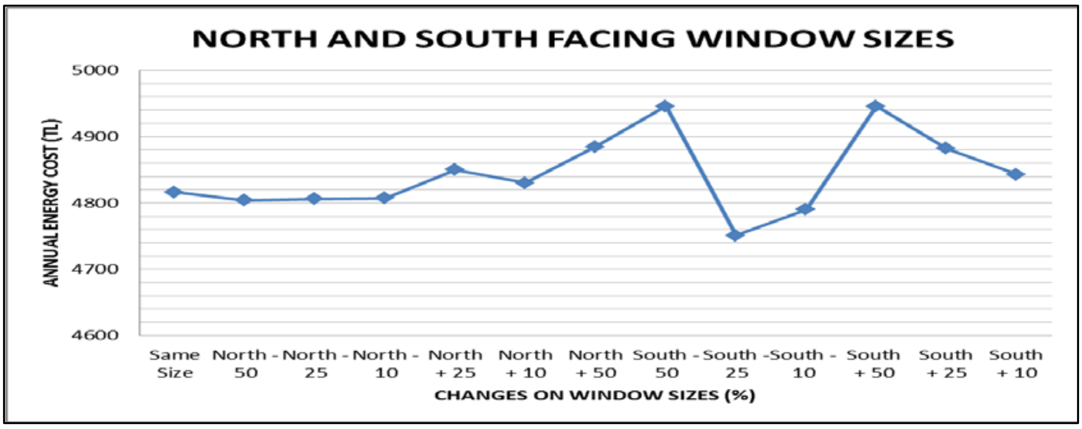


Figure 5.22. Changes in Size of North and South Facing Windows by Percentage

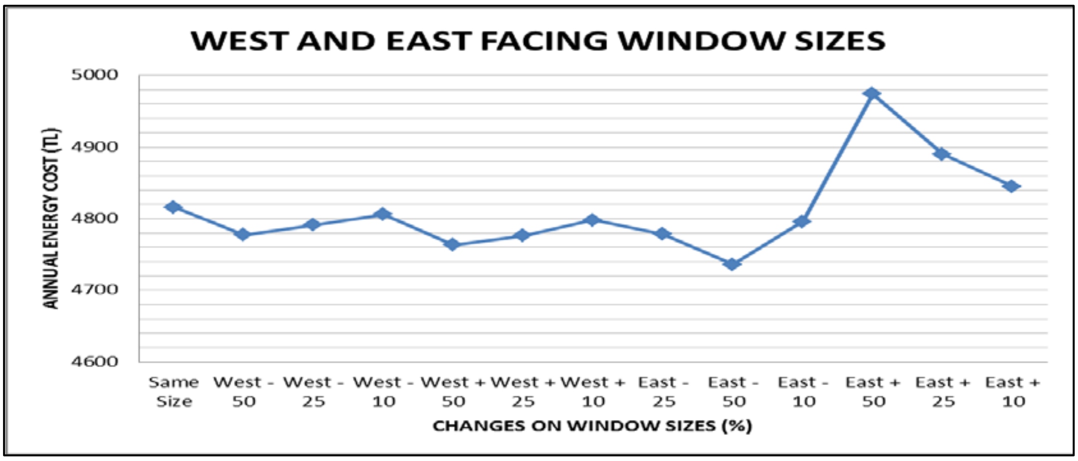


Figure 5.23. Changes in Size of West and East Facing Windows by Percentage.

5.3.6 Lighting Power Density (LPD) Analysis

Lighting power density (LPD) is the measurement of lighting energy per area; in this case Watts per m^2.Reduction of LPD can be easily accomplished by just using power saving light bulbs or LED lights for residential buildings.

It is possible to design an office building with 0.9 W/ m^2 or even less. There are several examples of 0.6 W/ m^2 of power density buildings.
For this analysis, Figure 5.24 shows lighting power density (LPD) values changed by 10 per cent decreases energy usage up to 40 per cent energy savings and cost reduction.

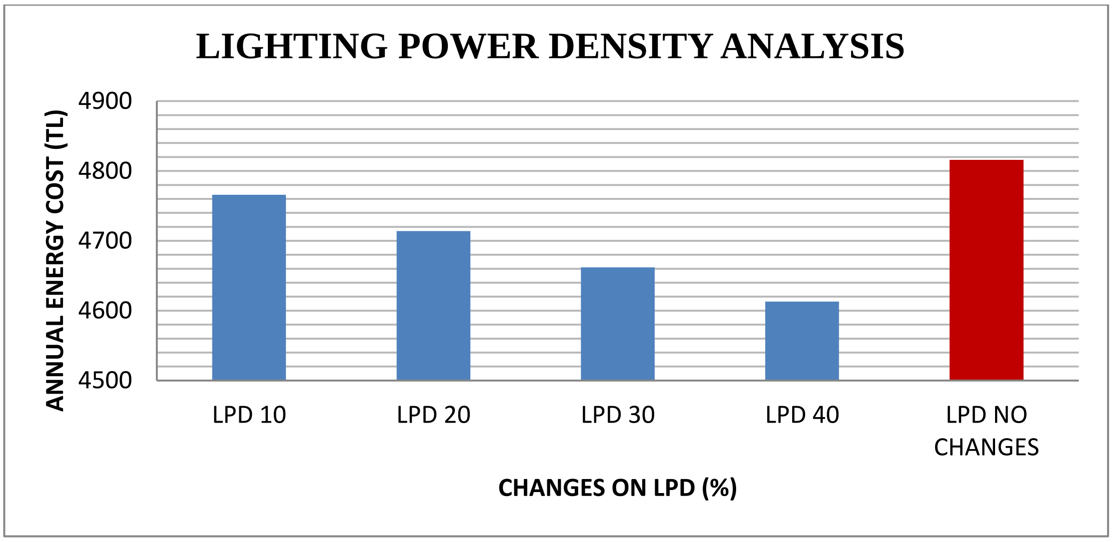


Figure 5.24. Lighting Power Density Analysis of Case B

It is observed that reducing the lighting power density by 40 per cent can save up to 23 per cent in electricity consumption which lowers the annual cost of electric energy used in this type of residential buildings.

5.3.7 Water Consumption Analysis

Table 5.6 demonstrate the water usage and costs according to the project specifications of the original building.

Table 5.6. Current Situation of Water Usage and Cost of Case B

Water Usage & Cost						
Water Usage & Cost			Indoor Water Factors		Unit Water Prices	
Total	556,648 L / yr	488 TL / yr	Number Of People	2	Water	0.69 TL/ m^3
Indoor	112,592 L / yr	181 TL / yr	Typical People for this Building type/size :4		Sewer	0.92 TL/ m^3
Outdoor	444,056 L / yr	306 TL / yr				
Net Utility	556,648 L / yr	488 TL / yr				

While all the parameters were kept constant, the efficiency of plumbing fixtures and energy efficient appliances are changed and demonstrated in Table 5.7

The results shown in Table 5.7 indicate that using more effective plumbing fixtures and energy efficient appliances resulted in 30.8 per cent savings in water consumption. The data explains that 34.6 tons of water can be saved by choosing the correct type of fixtures and appliances.

Table 5.7. Water Savings Potential of Case B

	Total	Male	Female	Employee Only	Efficiency	Percent of Indoor Usage	Liters Per Year	Annual Cost Savings
Toilets	2	1	1	0	Low Flow	14.8	16,632	27
Urinals	0			0		0	0	0
Sinks	3	1	2	0	Low Flow	1.7	1,859	3
Showers	1	1	1	0	Low Flow	6.1	6,865	11
Clothes Washers	1			0	Horizontal Axis	8.1	9,175	15
Dishwashers	1			0	Efficient	0.1	107	0
Cooling Towers	0			0		0	0	0
					Total Efficiency Savings	**30.8**%	**34,639**	**56** TL

Since the green building studio does not take rainwater harvesting, native vegetation landscaping, grey-water reclamation and site potable water source parameters into account, it has been decided to investigate the influence of such parameters by including them into the analyses.

Table 5.8 Rainwater Harvesting and Potential Water Savings of Case B

Rainwater Harvesting and Potential Water Savings					
	Annual Rainfall (mm)	Catchment Area (m²)	Surface Type	Net Zero Savings	
	542	117	Gravel/Tar		
				Liters per Year	Annual Cost Savings (TL)
Rainwater Harvesting:				50,731	35
Native Vegetation Landscaping:				151,024	104
Greywater Reclamation:				111,014	179
Site Potable Water Sources:				18,250	13
			Total Net-Zero Savings:	331,019	TL331

Table 5.8 shows that when all the aforementioned parameters are considered, the rainwater harvesting potential for one building is 50 tons per year alone, with the combination of native vegetation landscaping, grey-water reclamation and site potable water sources, 331 tons of water per building can be saved. The potential savings for this building reduces the annual cost of water by 83 per cent compared to the current situation of the building.

5.3.8 Carbon Emission Analysis

In this analysis, the optimum values obtained from the previous analyses when all parameters are studied, are adopted for the analysis of Case B building in order to minimize the carbon emission for sustainability purposes.

Figure 5.25 shows that 3.6 Mg reduction in carbon emission which is 55 per cent lower than the specified building.

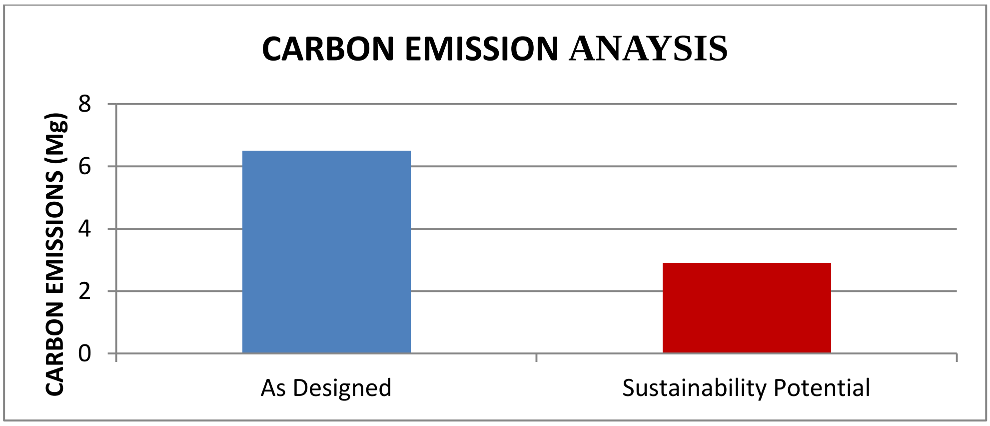


Figure 5.25 CO_2 Emissions Analysis of Case B

In order to make a better comparison, the results shown in Table 5.9 are presented in sports utility vehicle (SUV) equivalent.

Table 5.9. Carbon Emissions Saving Potential of Case B in Large SUV equivalency

ANNUAL CO_2 EMISSIONS		
	As Designed	Sustainability Potential
Electric	2.5 Mg	1.5 Mg
Onsite Fuel	4.1 Mg	1.4 Mg
Large SUV Equivalent	0.7 SUVs / Year	0.3 SUVs / Year

Results in Table 5.9 shows that an equivalent carbon emission of 0.4 SUVs per year can be achieved by the application of sustainable principles and materials to the building.

5.3.9. Final Energy Analysis

For the final analysis, the optimum parameters obtained in the previous analyses are used and the influence of parameters such as orientation, wall and roof assemblies, window sizes and glazing types are investigated. Results shown in Figure 5.26 suggest that there is a dramatic change in the annual energy cost of the building.

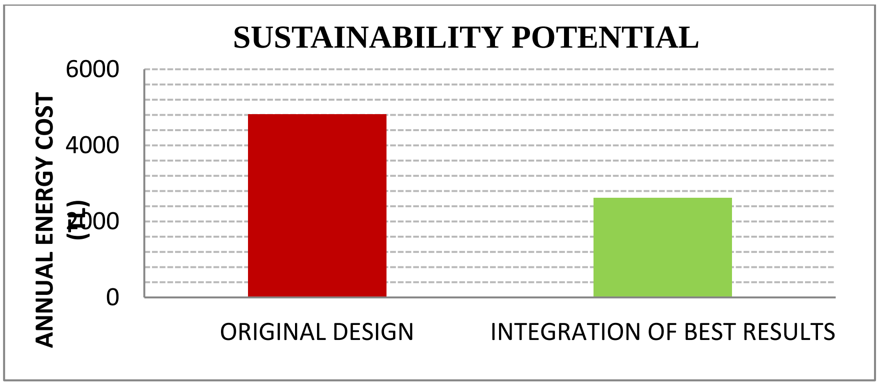


Figure 5.26. Sustainability Potential Analysis for Case B.

The records provided by the program clearly indicate that when all the sustainability principles and criteria are taken into consideration, it is possible to save up to 45 per cent which is 2201TL in annual energy cost.

Possible savings for both selected cases according to the parameters of the study are summarized and shown in figure 5.27 and 5.28 accordingly.

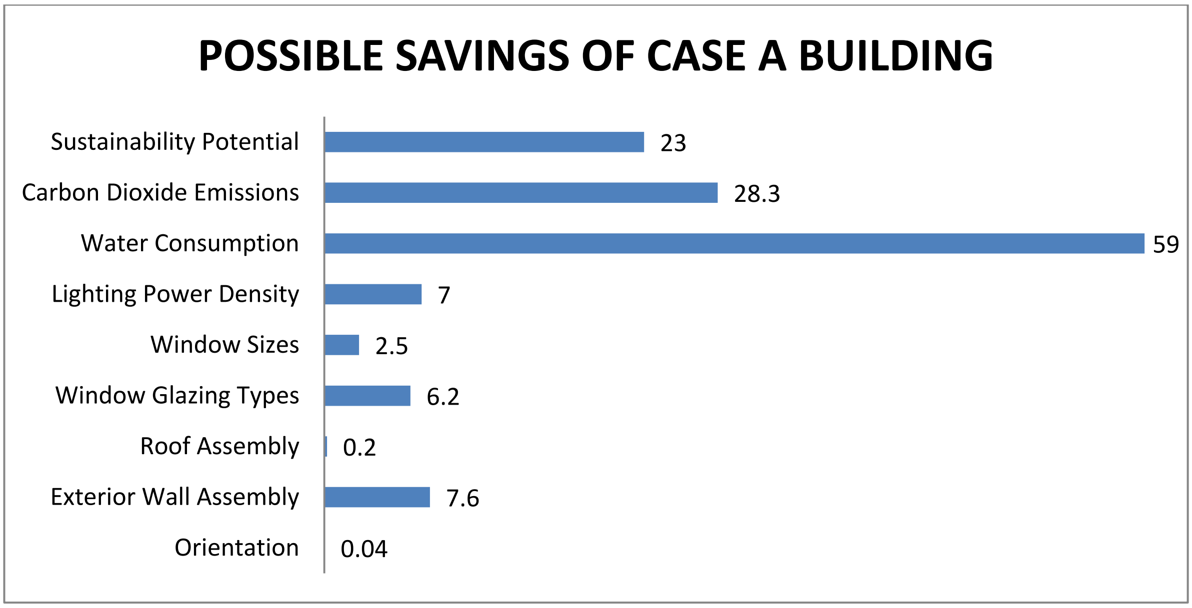


Figure 5.27. Impact of Energy Efficiency to Case A Building

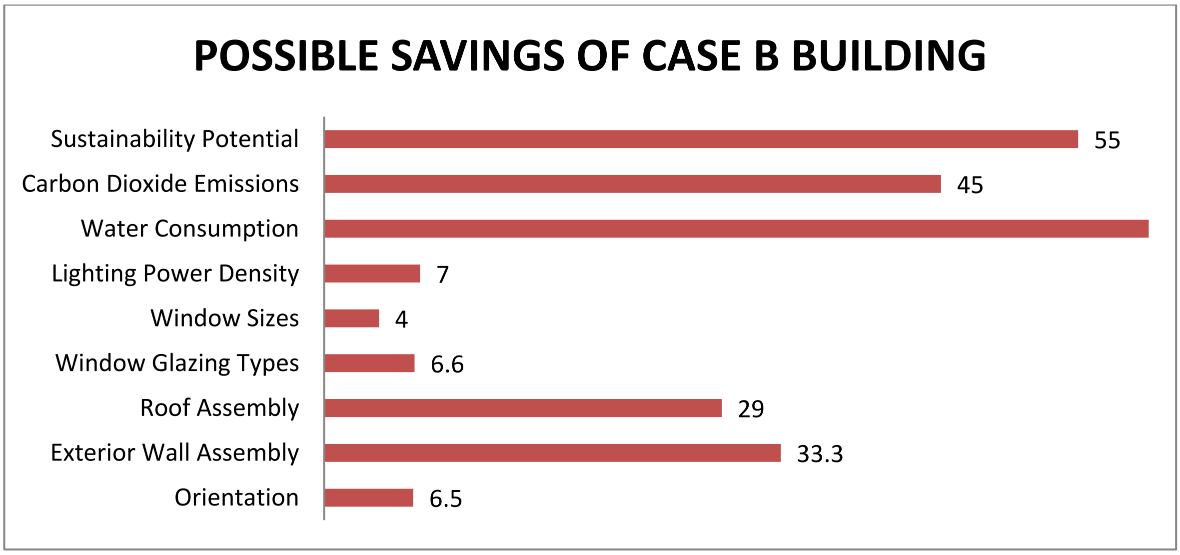


Figure 5.28. Impact of Energy Efficiency to Case B Building

6 CONCLUSIONS

6.1 ANALYSIS OF THE SELECTED BUILDINGS

- The analyses carried out for both Kocaeli (Case A) and Sanlıurfa (Case B) buildings have shown that the orientation does not significantly affected the energy consumption of Case A, due to its square plan design. However the orientation analysis for Case B showed that there is a significant reduction on the annual energy costs when the building rotated to 105 degrees counter clockwise from its current position.
- The exterior wall assembly analyses suggested that for Case A building, massive walls with super high insulation showed a better energy saving results when compared to the other wall assembly types. The exterior wall assembly analysis in Case B building, shown that straw bale exterior wall assembly could reduce the annual cost of energy by 33.3 per cent.
- Roof assembly analyses for Case A building indicated that the construction method and the insulation materials have almost no effect on the energy consumption when it is applied to this building type. The analysis of Case B building for different roof assembly types showed that continuous deck with denim insulation provides the optimum annual energy cost. The annual cost of energy was reduced by 29 per cent and resulted in 1631 TL of savings by this type of roof assembly.
- The optimum results are obtained with the insulated green Low E type glazing for Case A. While for Case B building, the application of insulated clear glazing, specified for hot climates, dramatically lowers the annual cost of energy.
- Window size analyses indicated that when both window sizes on all façades are changed proportionally, the energy consumption of the building does not significantly affected for Case A building. Analyses of the Case B building showed that changing the window sizes on the northern facades does not improve the energy consumption; while there was a significant difference in the energy consumption when southern facing window sizes were changed. It is also observed that increasing the window sizes on the eastern facades by 50 per cent also increase the annual cost of energy dramatically.

- It was observed that the reduction in the energy consumption of the building is proportional to the reduced percentages of lighting power density for both cases.
- A total of 1617.6 tons in annual water saving was achieved when the water savings criteria applied to the Case A building which resulted in 59 per cent of reduction in the annual cost of water. It was also concluded that by integrating the water harvesting system in addition to energy efficient appliances and low flow plumbing fixtures, a total of 83 per cent saving in annual cost of water for Case B building can achieved.
- When the optimum parameters were applied, it was shown that the Case A building can save up to 23 per cent in annual energy cost and 28.3per cent of reduction on the carbon emission. However, reduction of 45 per cent of energy saving and 55 per cent of carbon emission reduction was obtained for Case B building.

6.2 RECOMMENDATIONS FOR IMPROVEMENT OF TOKI BUILDINGS

It has been observed that majority of the TOKI buildings do not consider orientation, wall and roof assemblies, window sizing and glazing types or the construction methods and materials during the design process. It was also shown that site planning, regional weather conditions or urban planning are unfortunately not taken into consideration while they are designed. Therefore TOKI buildings can be categorized as not environmental friendly and energy efficient buildings. Considering TOKI, as the highest promoter and the largest contractor of construction industry in Turkey, it seems that TOKI does not have any intent to protect the natural resources or prevent global climate change. Therefore, the author suggests that TOKI, as a pioneer in construction industry, should take all the sustainable principles and sustainable construction methods and materials in to the consideration in order to save the natural resources. The work in this thesis showed that it is possible to lower the energy consumption and reduce carbon dioxide emissions by minor changes during design stage. Therefore it has strongly been suggested to consider the application of sustainable design in new projects of TOKI.

6.3 FUTURE WORK

It is essential to have a detail investigation on sustainable materials and methods considering the availability of the materials in Turkey in order to provide precise suggestions to the construction industry. Moreover, renewable energy resources and integration of sustainability parameters, such as photovoltaic panels and wind and wave turbines, vertical gardens and natural ventilation potentials, are also required to be carefully investigated and added for better understandings of the sustainability potentials and energy consumptions of the buildings in order to make suggestions to the construction industry in Turkey. It is also essential to make further investigations on the possible energy savings and carbon emissions according to the architectural designs of the buildings.

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APPENDIX A: CASE A AND CASE B ARCHITECTURAL CONFIGURATIONS

Architectural drawings of Case A and Case B are shown from Figure A.1. to Figure A.21.

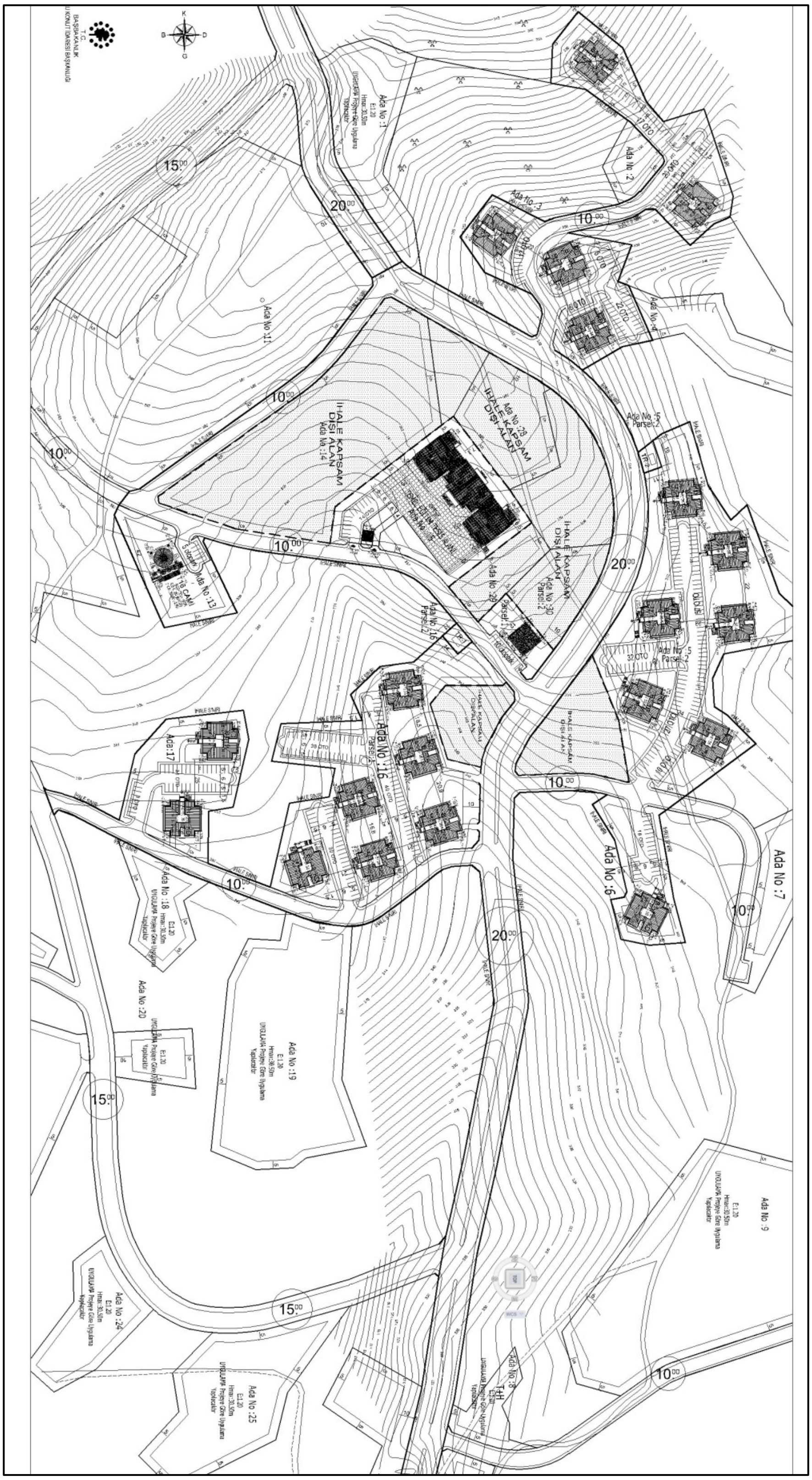


Figure A.1. Case A Site Plan

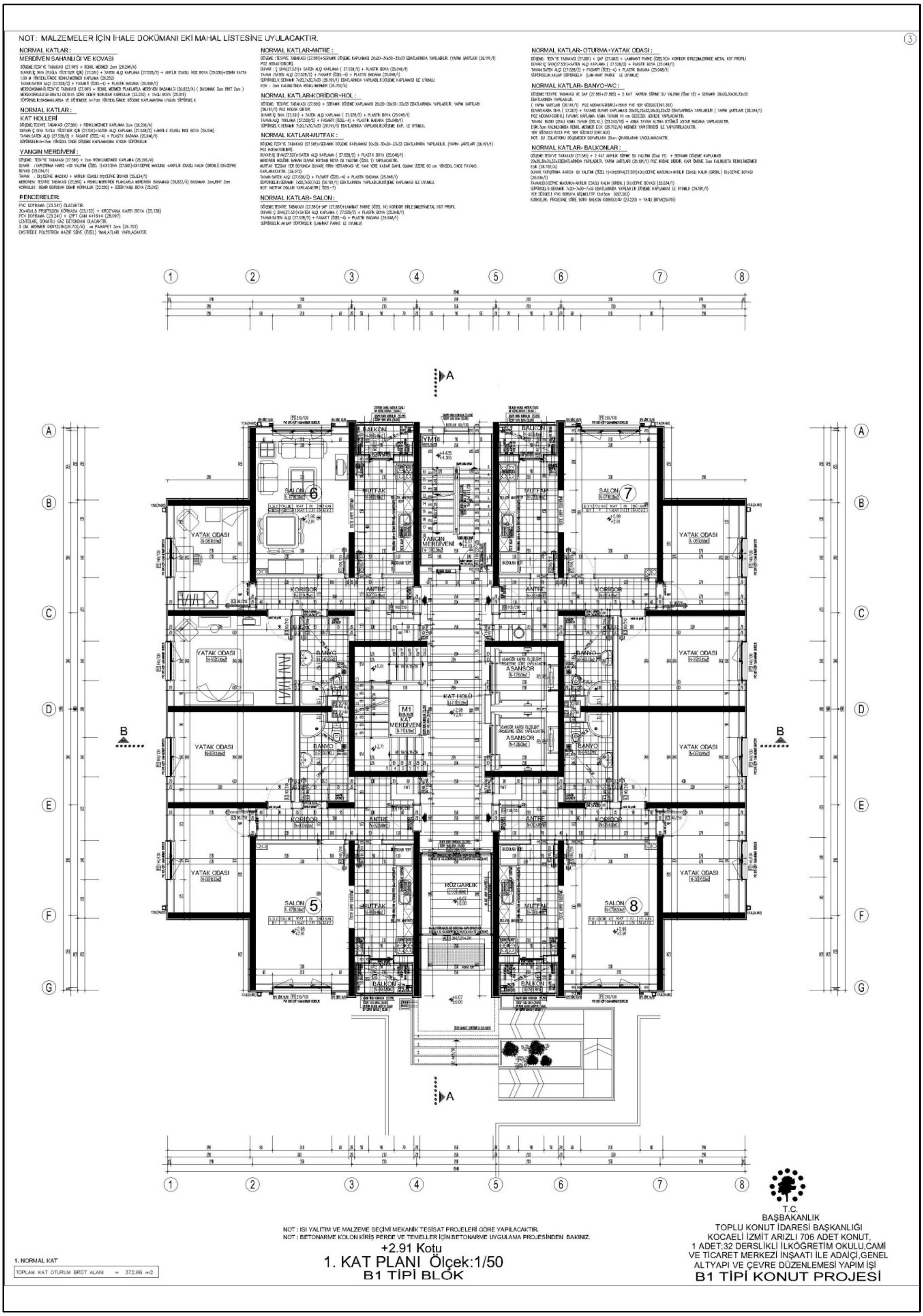


Figure A.2. Case A, 1st Floor Plan

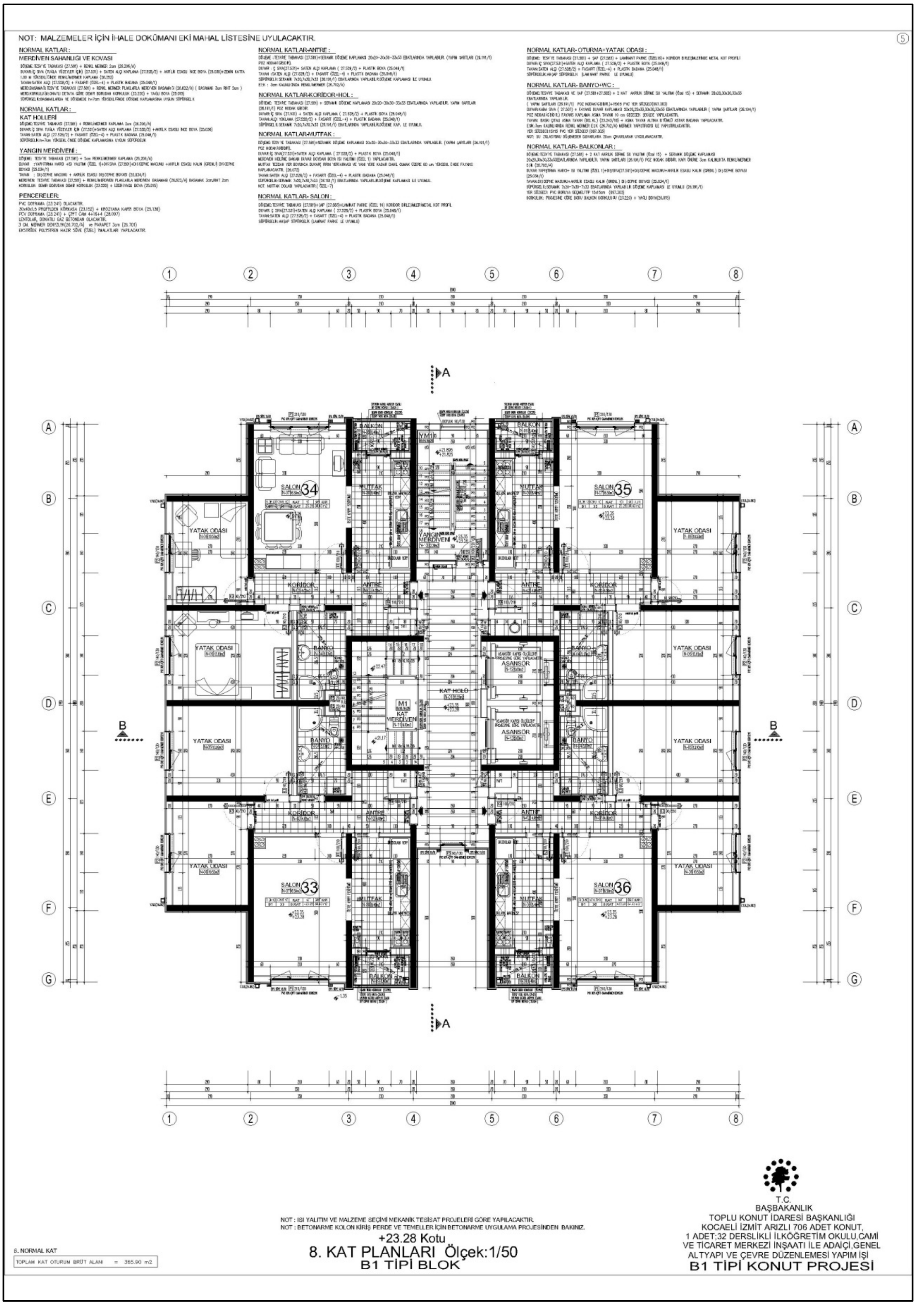


Figure A.3. Case A 8th Floor Plan

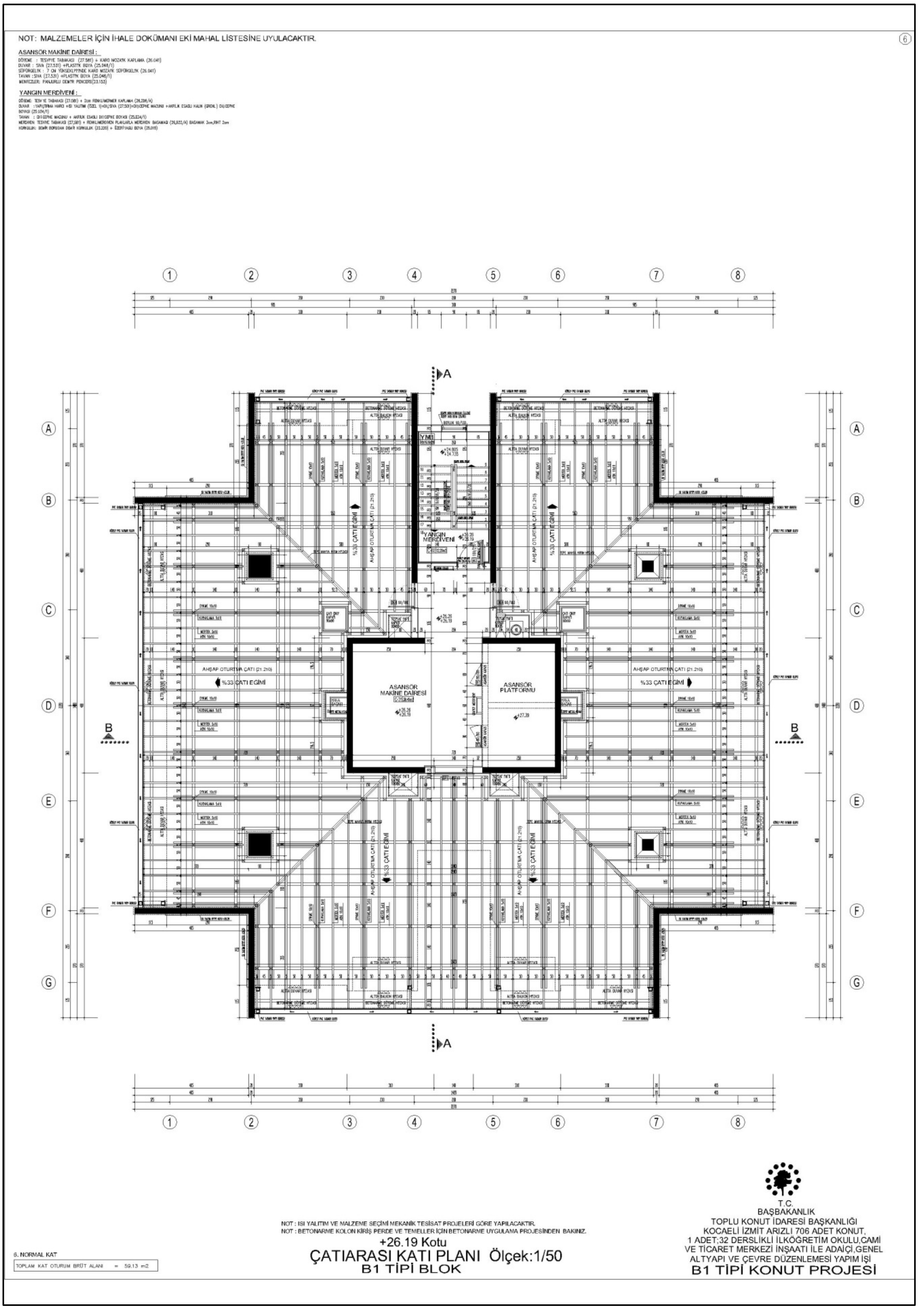


Figure A.4. Case A Roof Plan

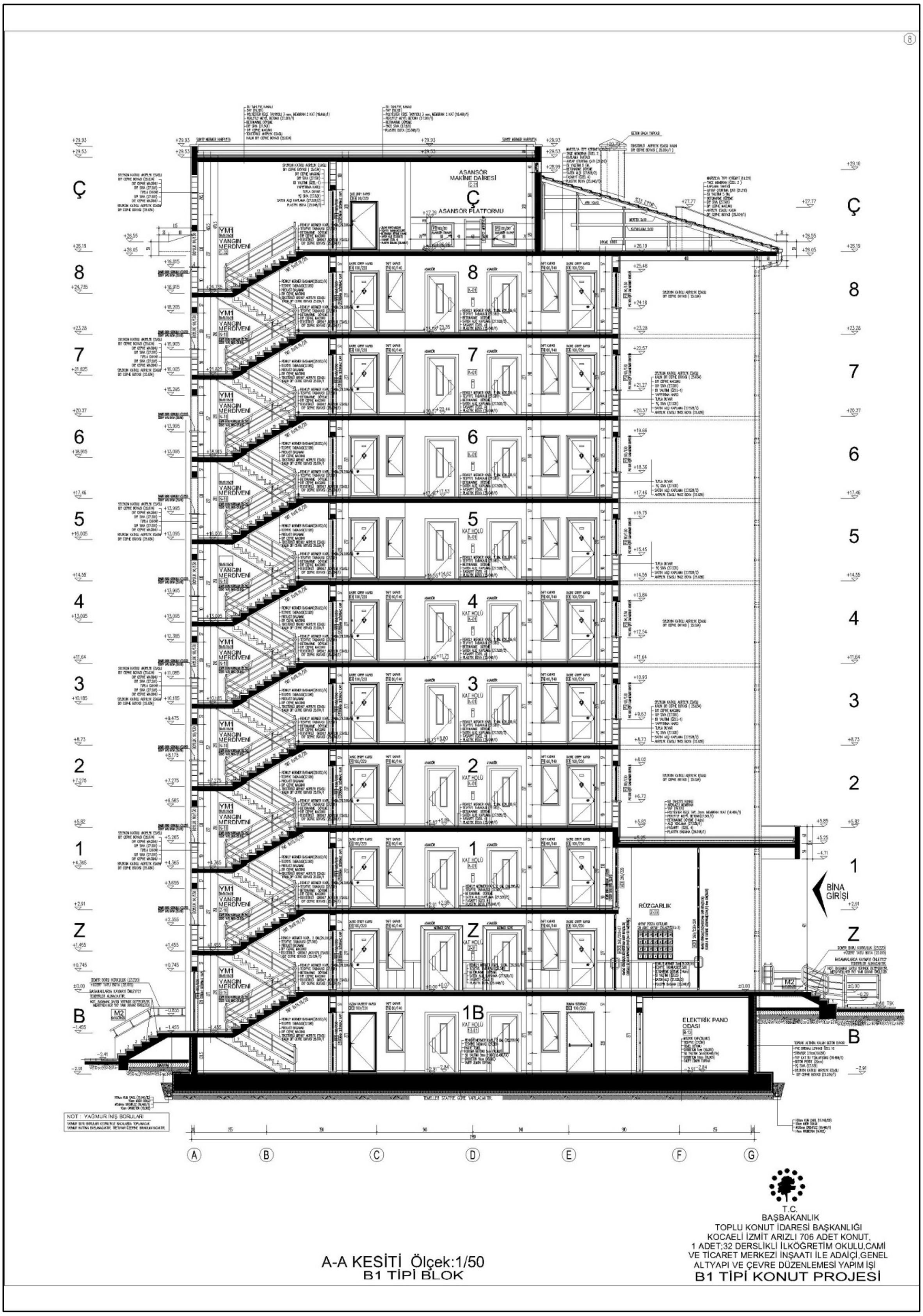


Figure A.5. Case A Section A-A

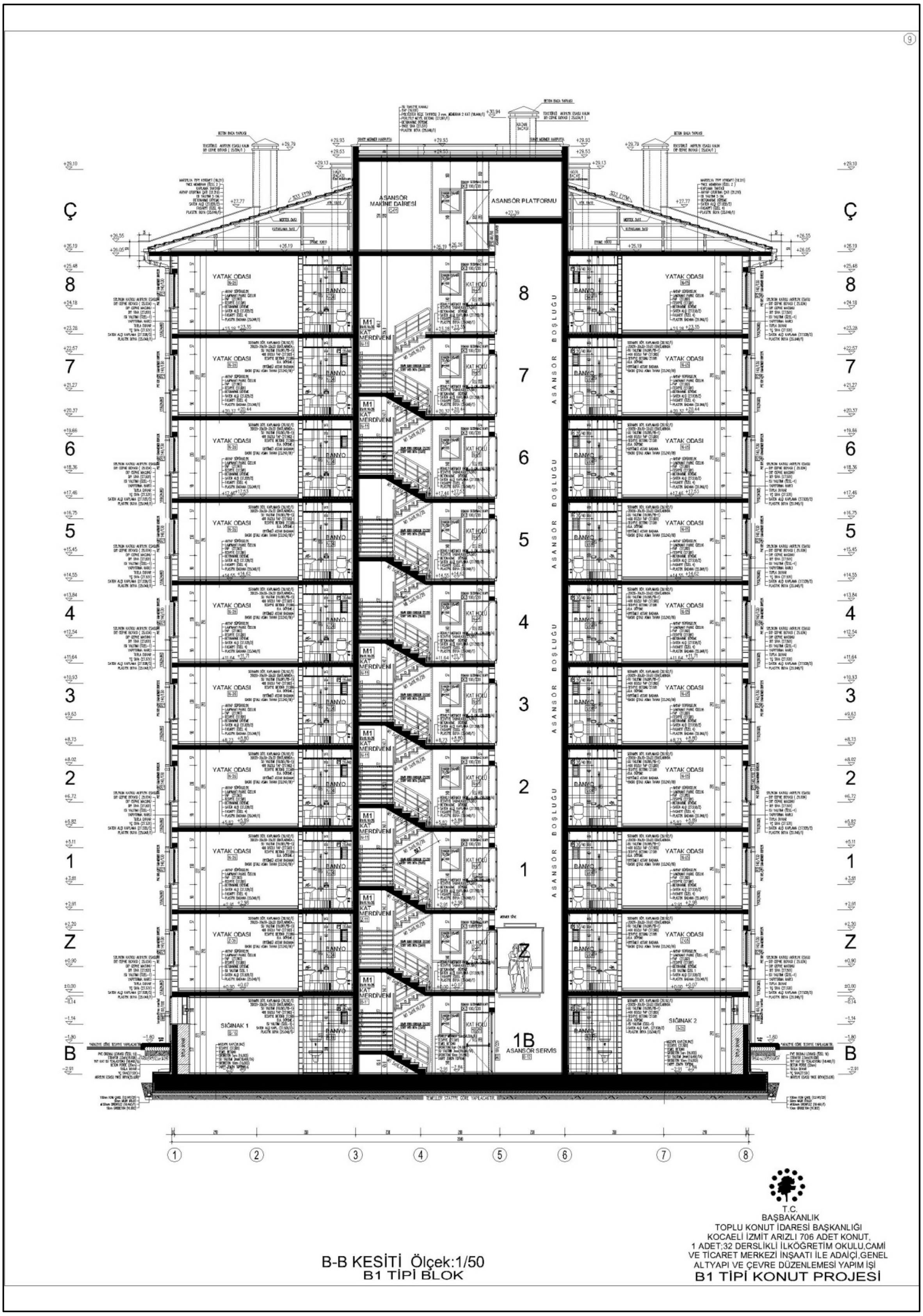


Figure A.6. Case A Section B-B

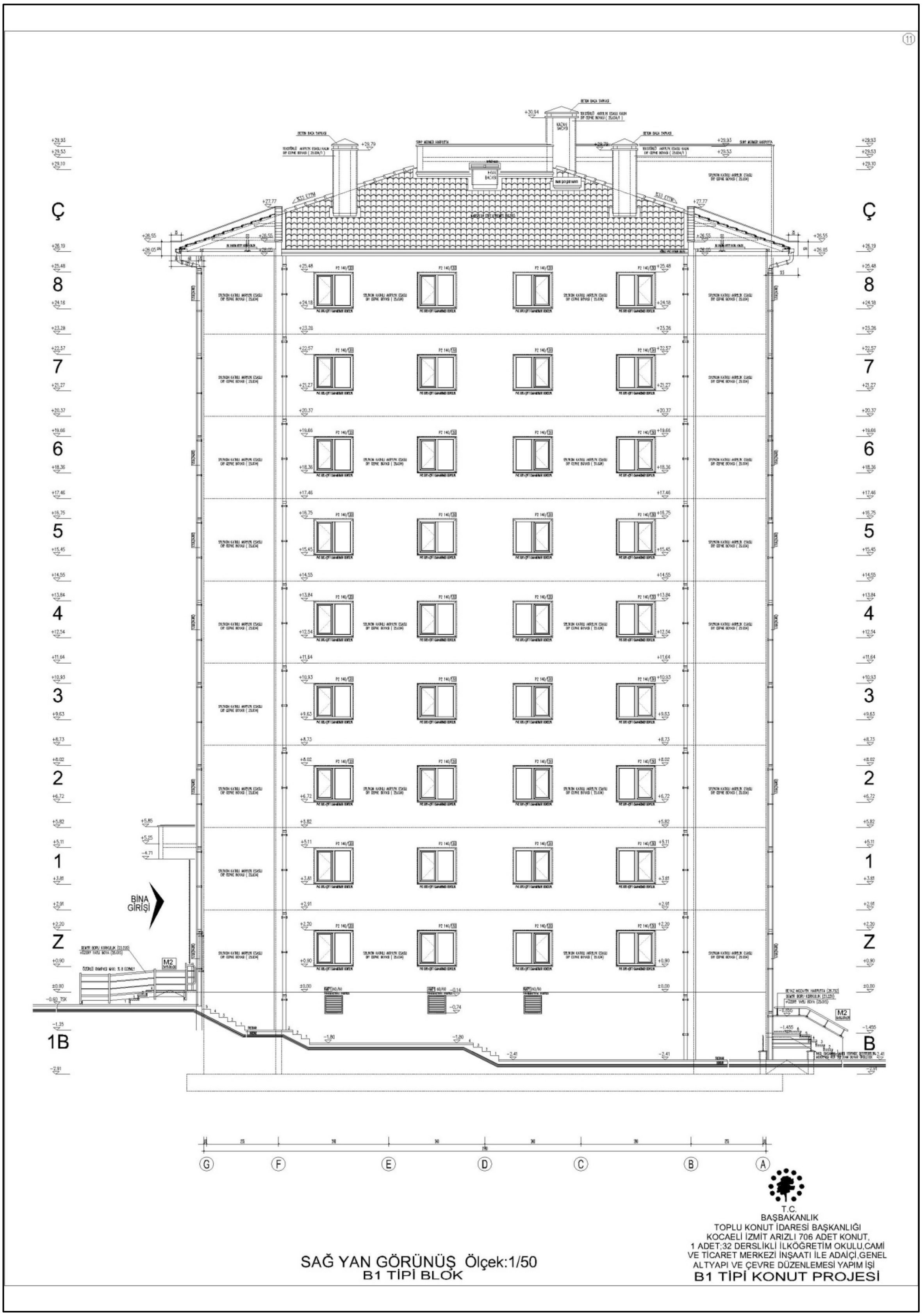


Figure A.7. Case A Right Elevation

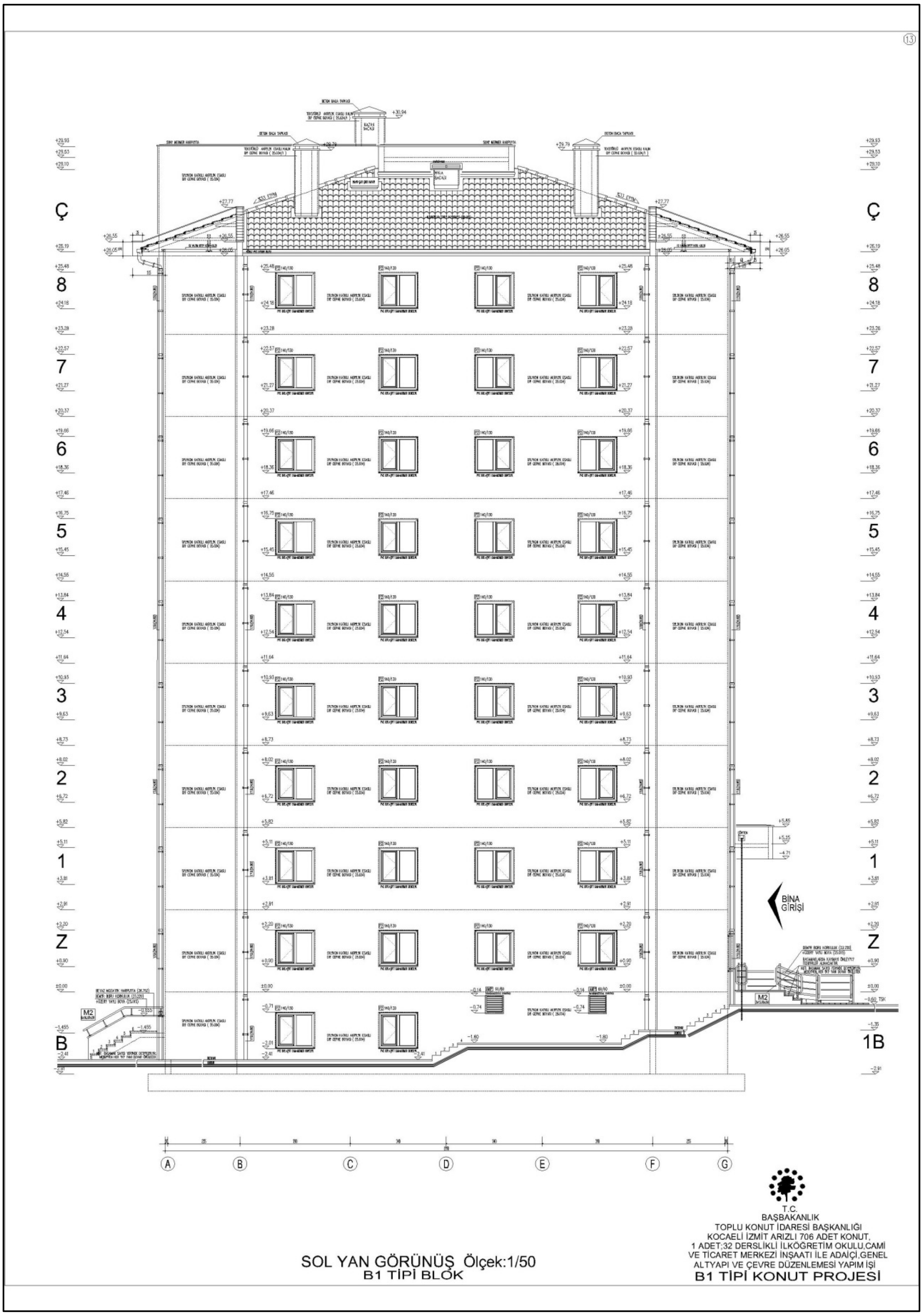


Figure A.8. Case A Left Elevation

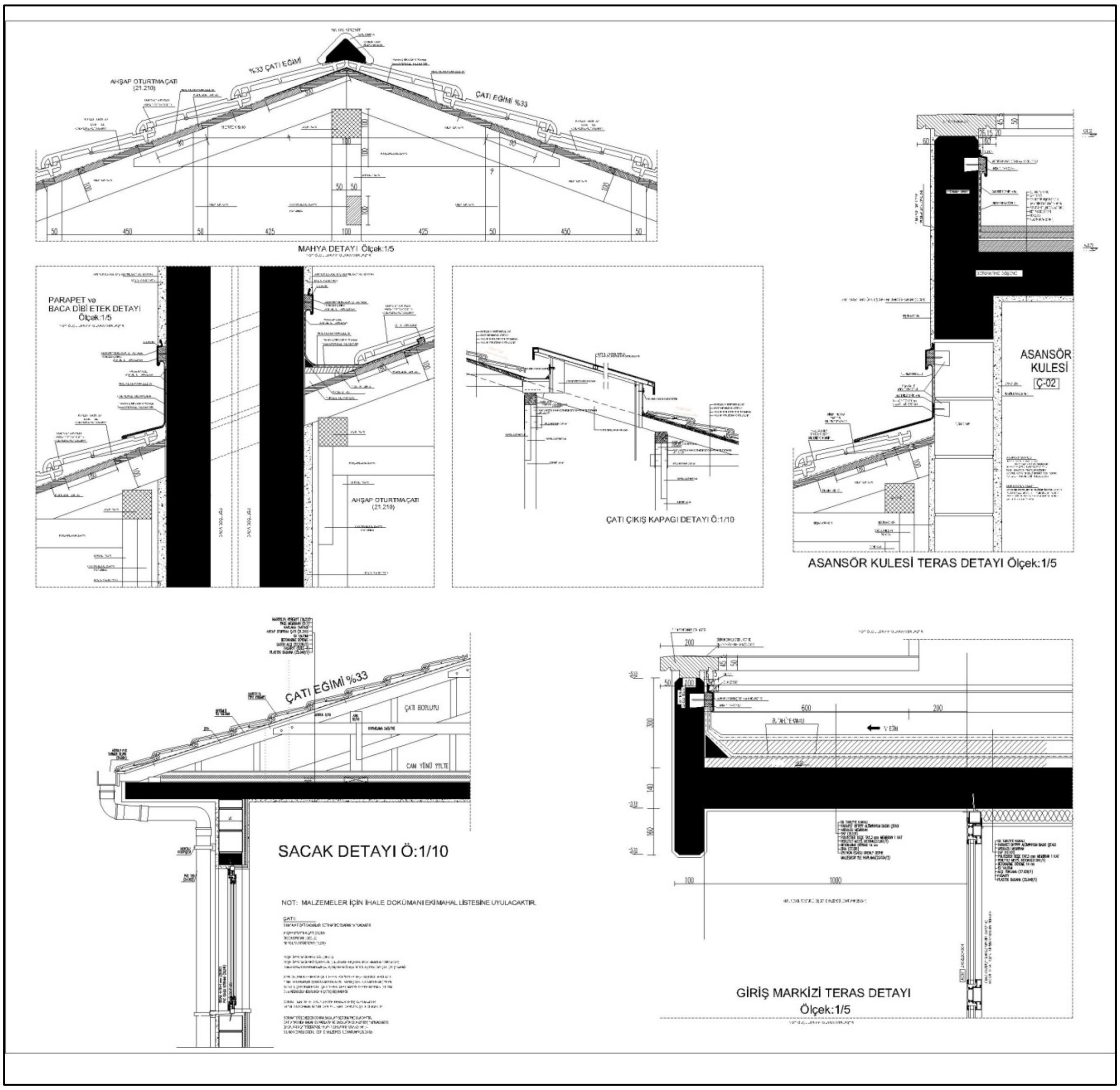


Figure A.9. Case A Roof Details

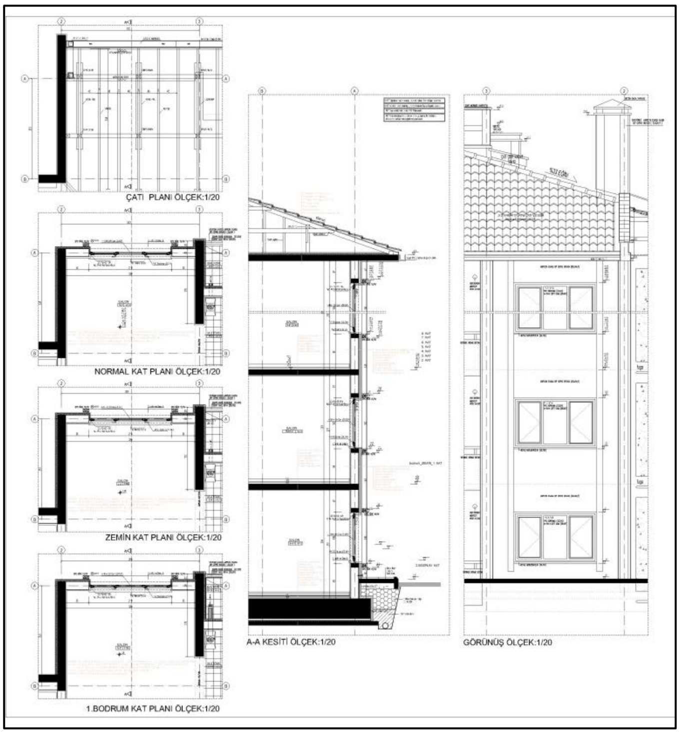


Figure A.10. Case A Detail I

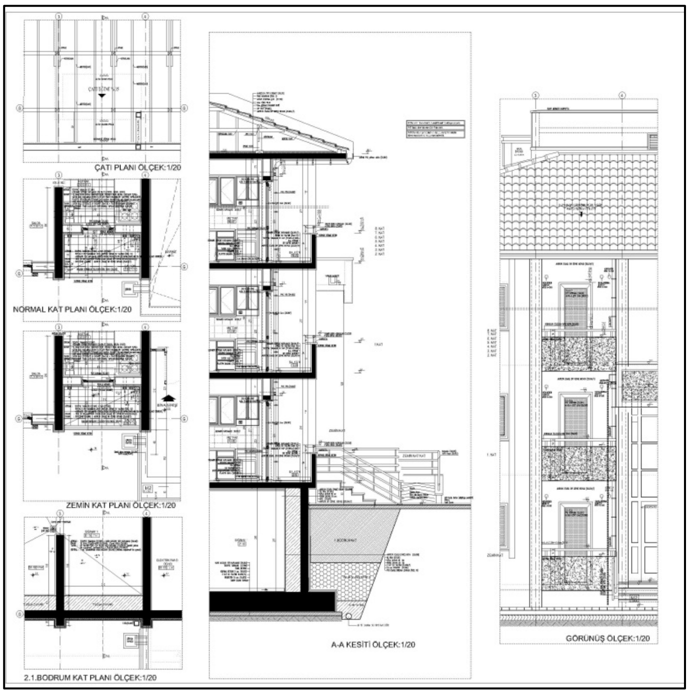


Figure A.11. Case A Detail 2

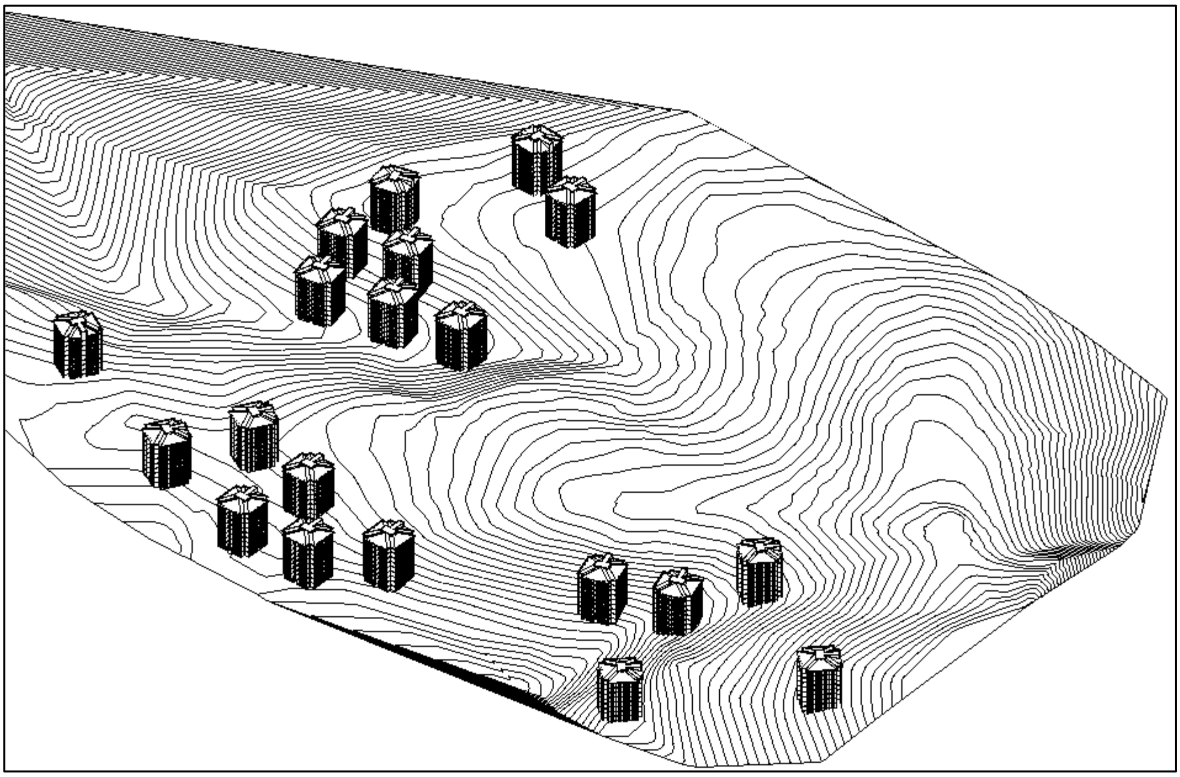


Figure A.12. Case A 3D Site Model

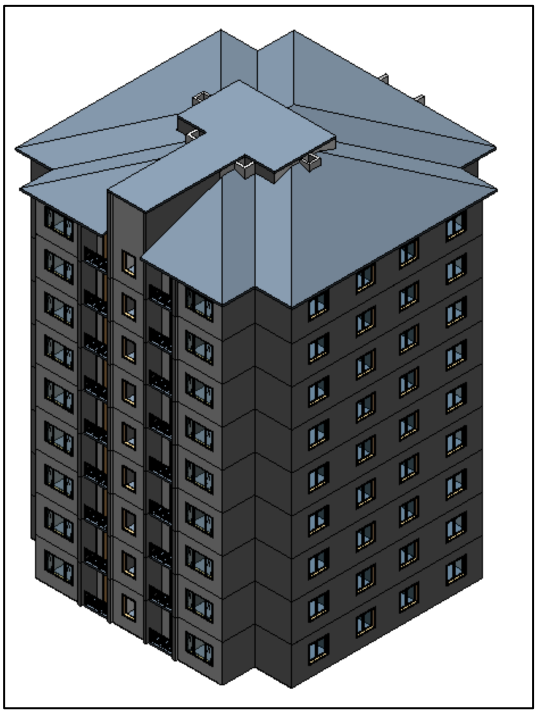


Figure A.13. Case A 3D Building Model

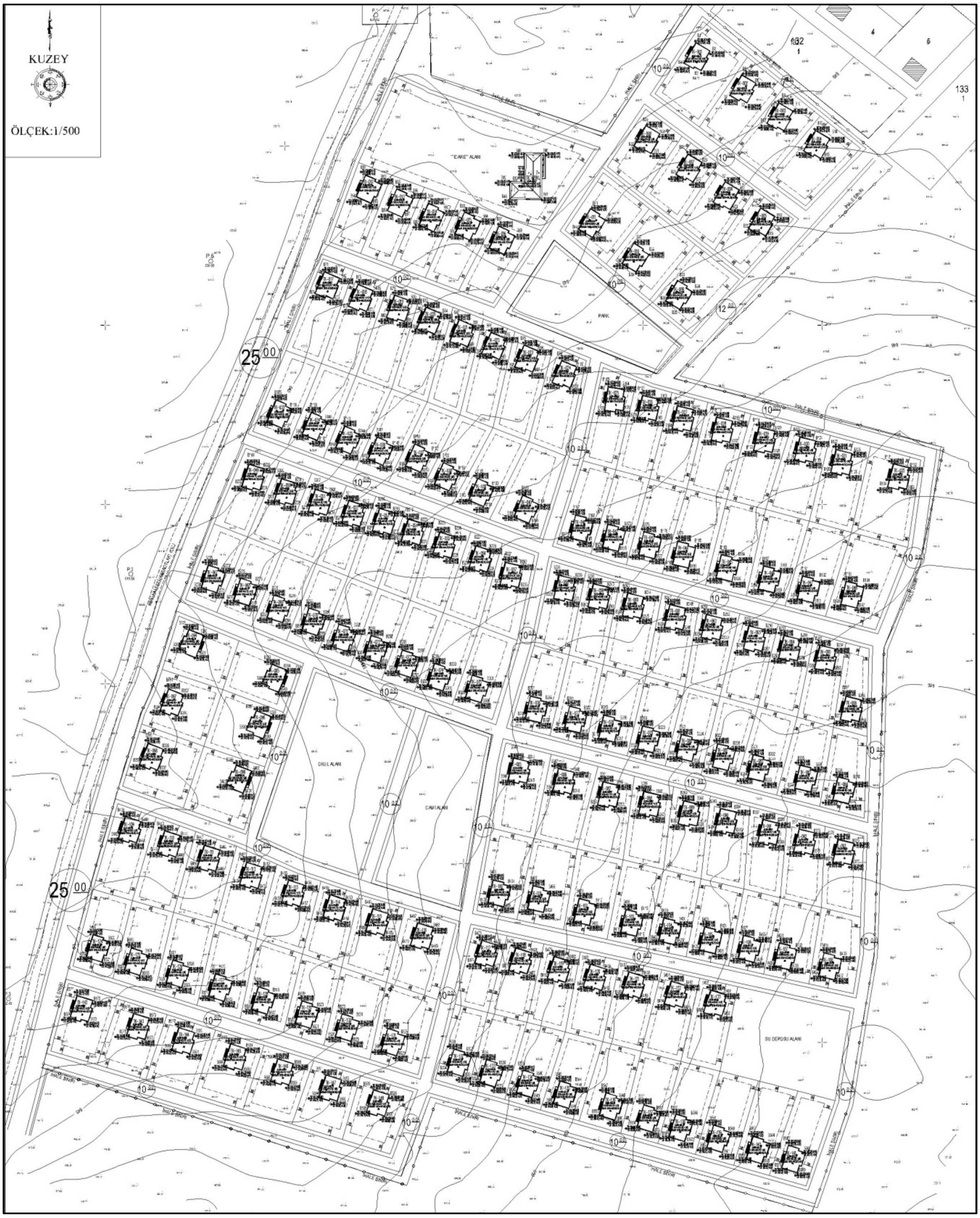


Figure A.14. Case B Site Plan

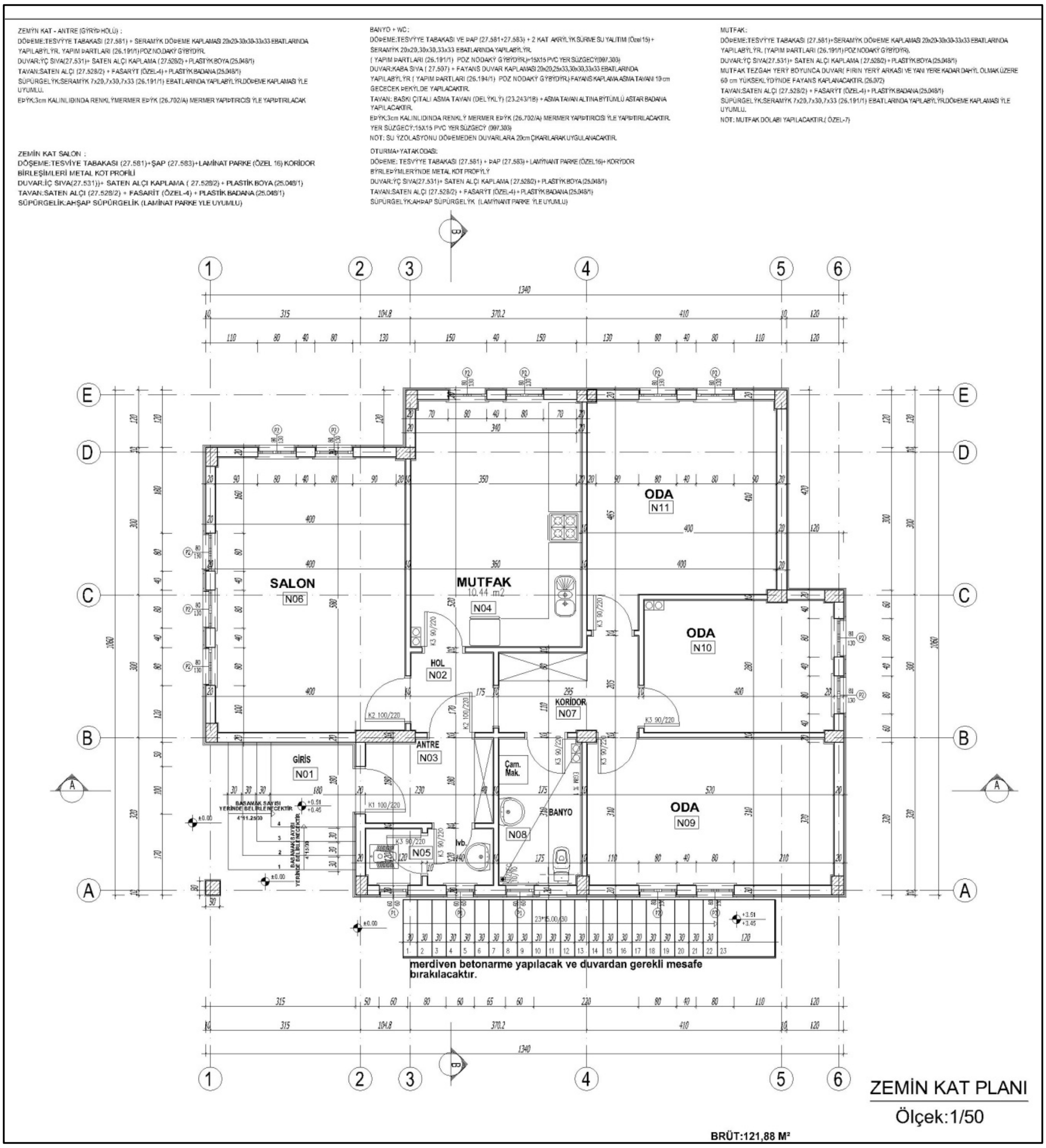


Figure A.15. Case B Floor Plan

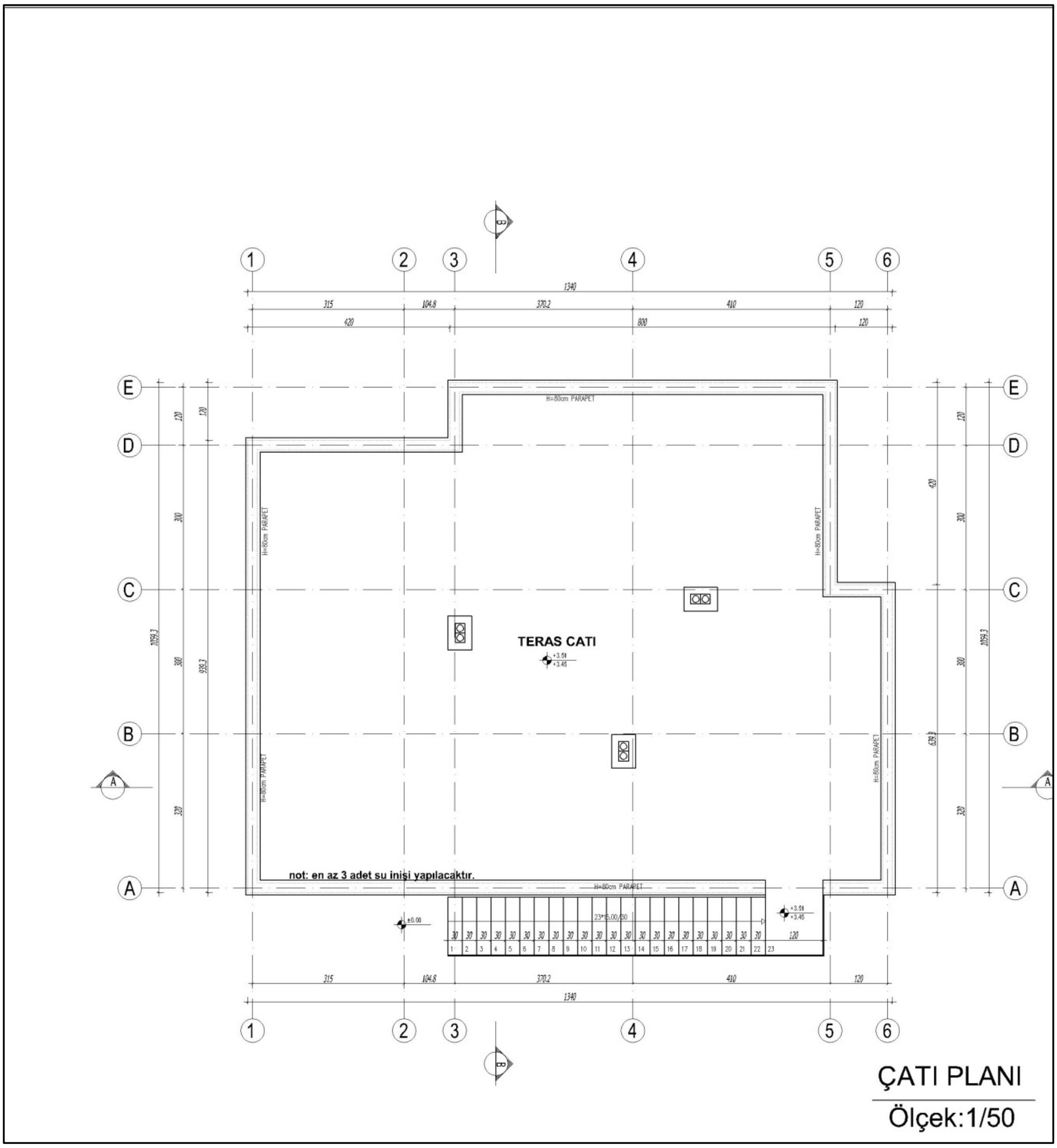
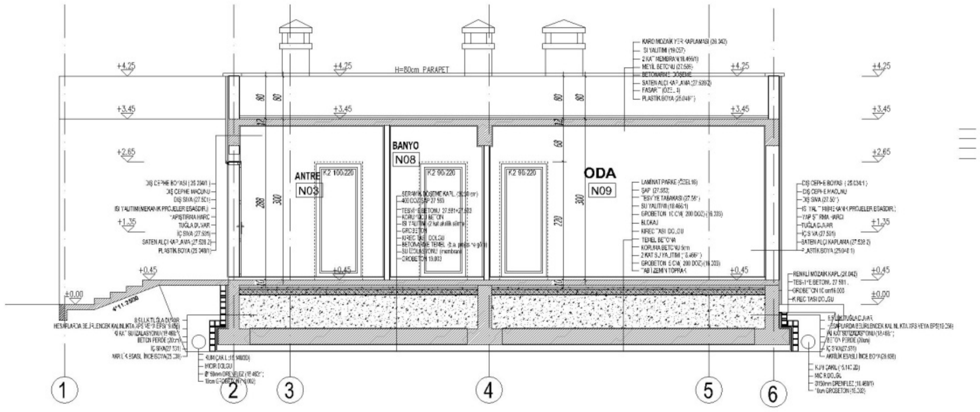
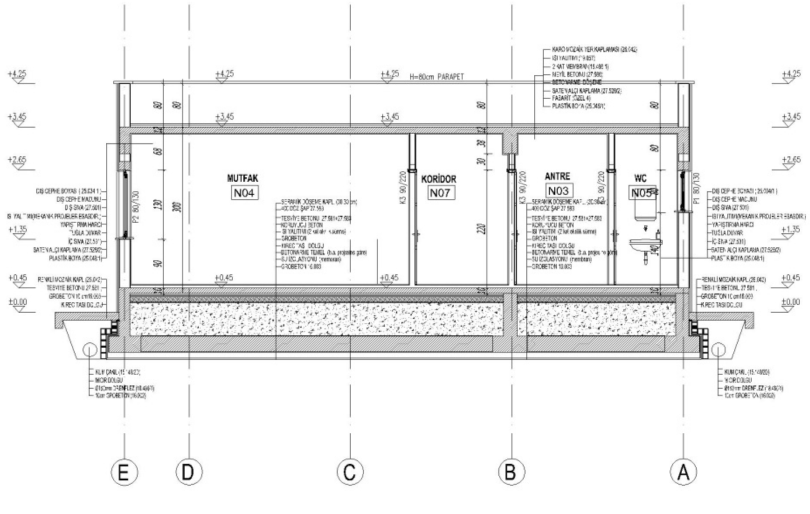


Figure A.16. Case B Roof Plan



A-A KESİTİ
Ölçek:1/50



B-B KESİTİ
Ölçek:1/50

Figure A.17 Case B. Elevation A-A and B-B

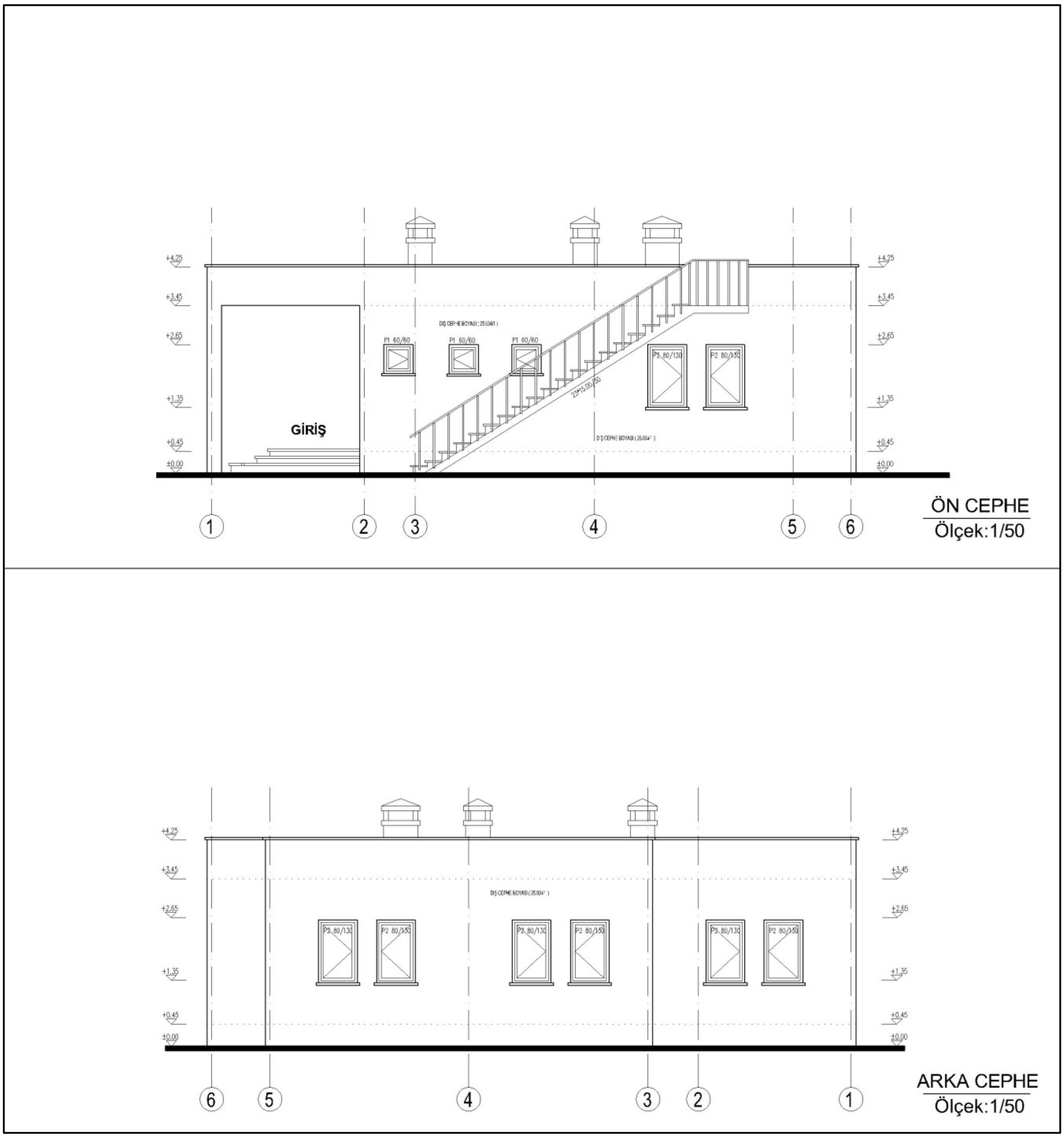


Figure A.18 Case B. Front and Back Elevations

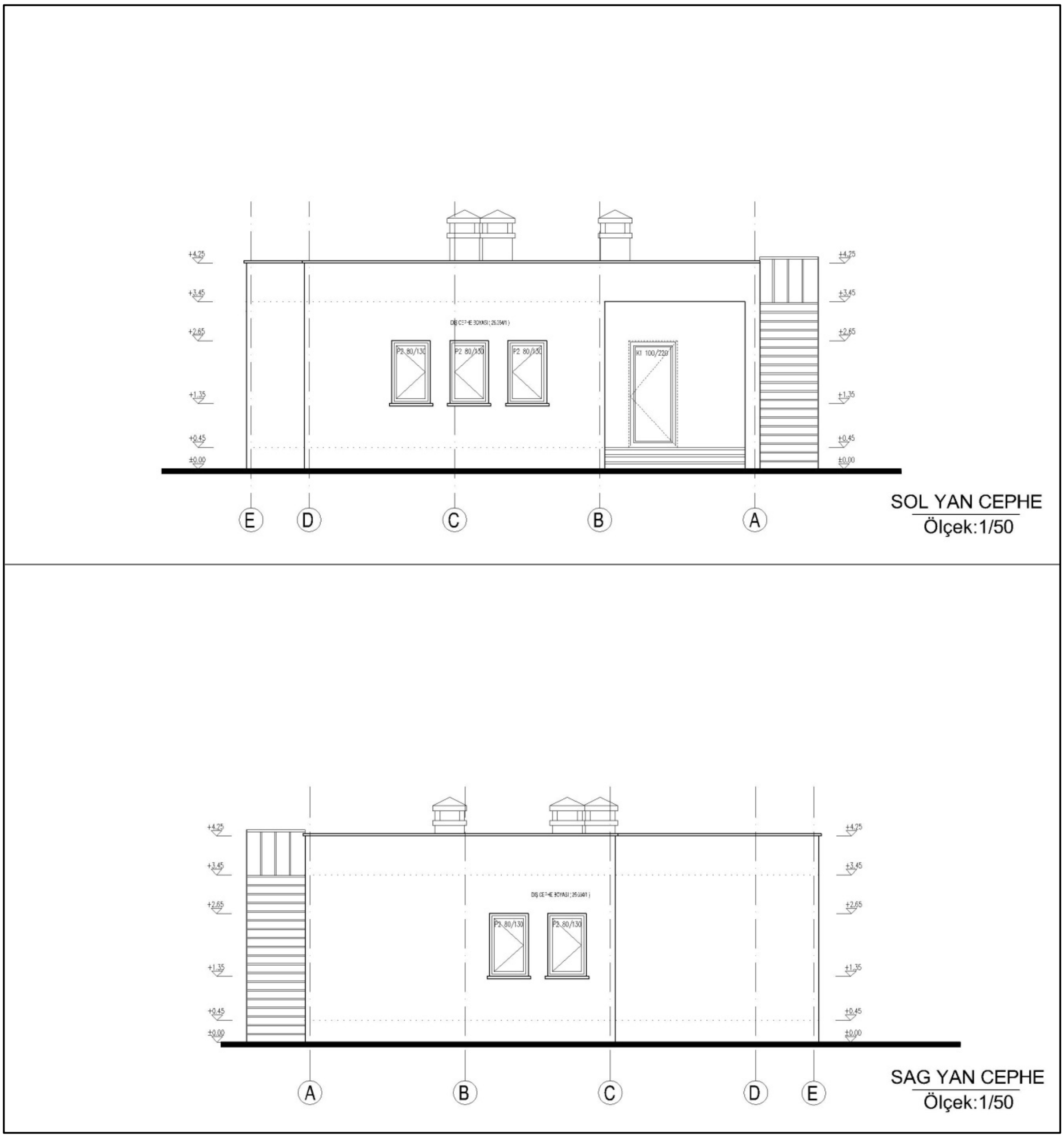


Figure A.19. Case B Left and Right Elevations

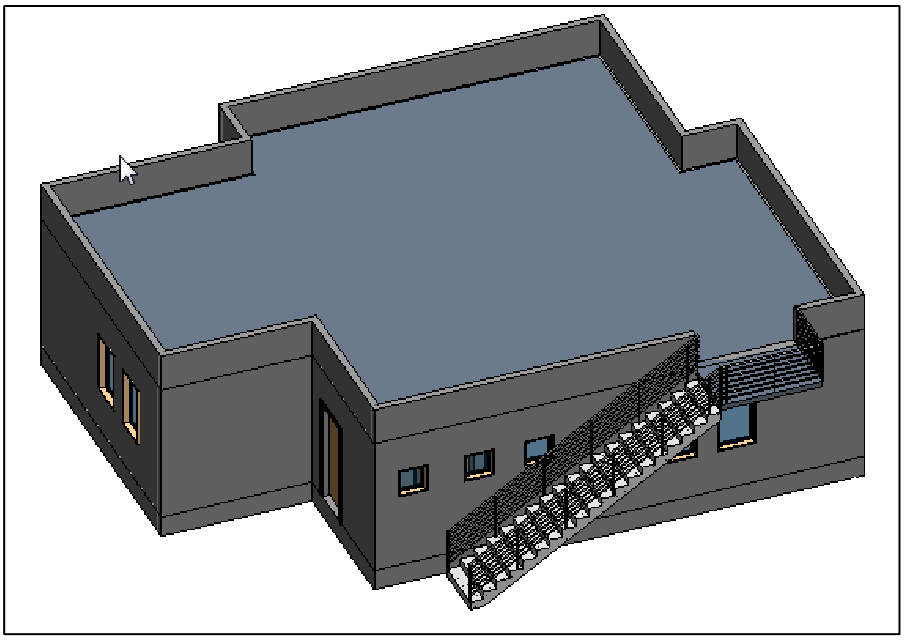


Figure A.20. Case B 3D Model 1

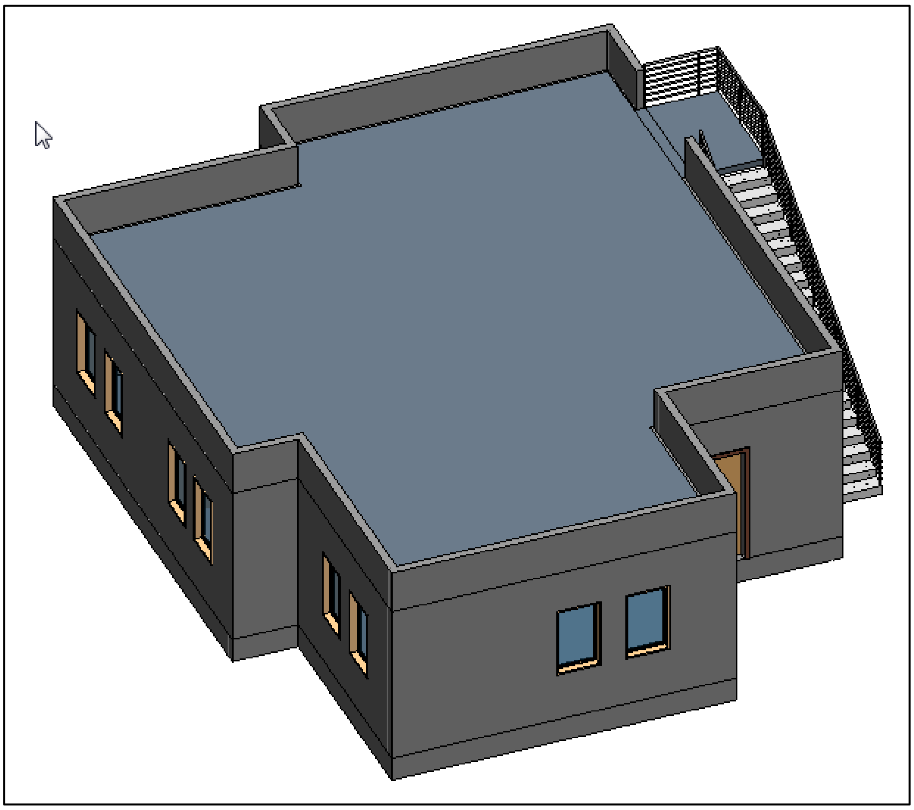


Figure A.21. Case B 3D Model 2

APPENDIX B: GREEN BUILDING STUDIO ANALYSES

Alternative energy and carbon emissions analysis by green building studio for Case A and Case B are shown in Figure B.1 and Figure B.2.

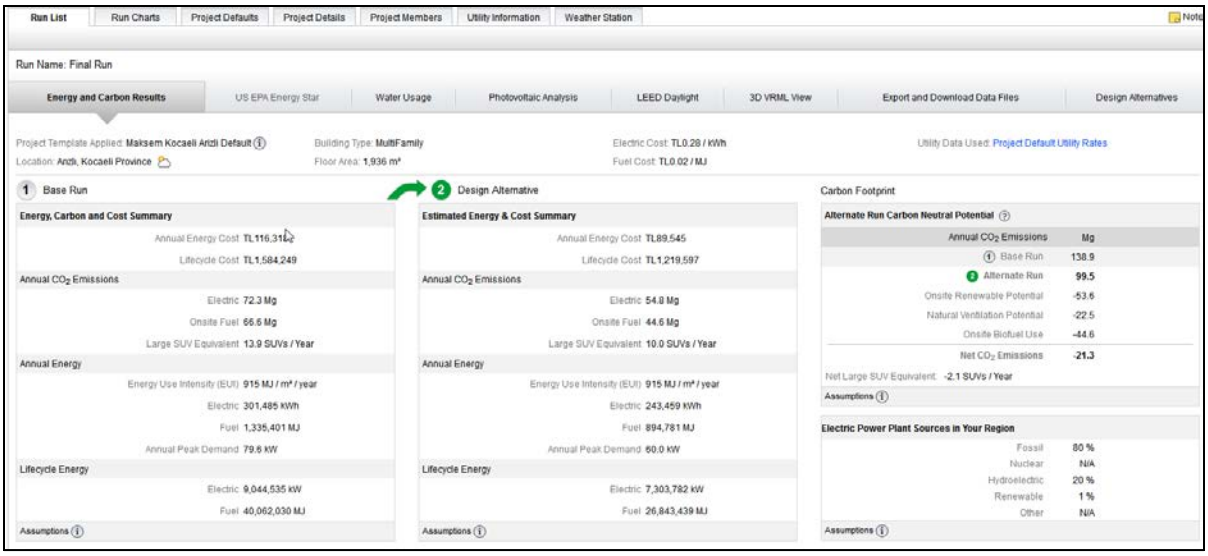


Figure B.1. Alternative Energy and Carbon Emission Analysis for Case A

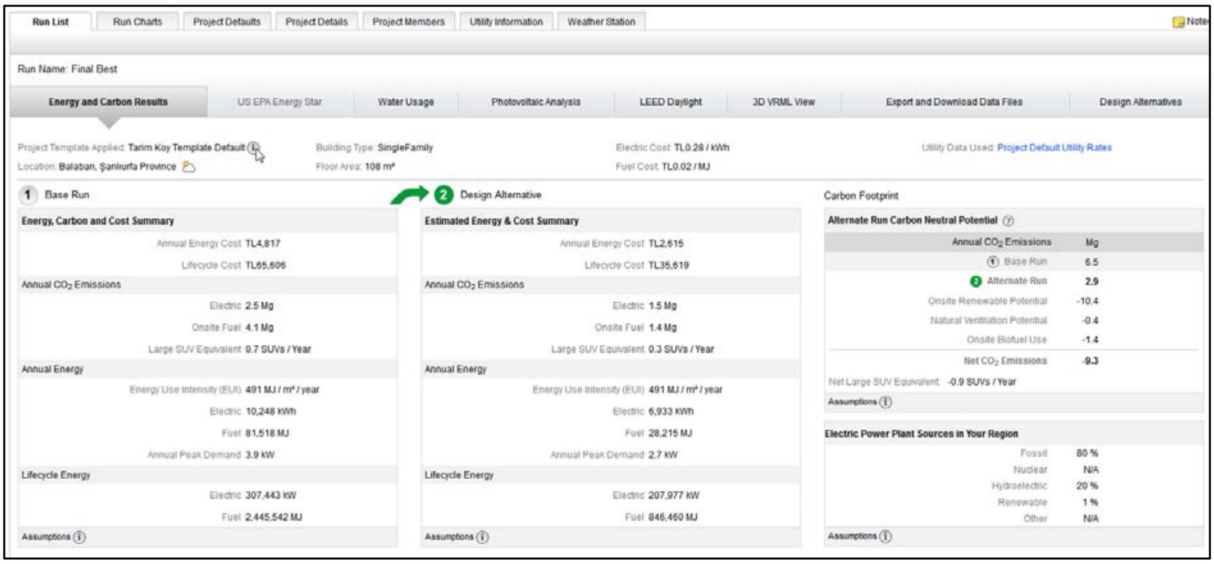


Figure B.2. Alternative Energy and Carbon Emissions Analysis for Case B