THE GRADUATE SCHOOL OF NATURAL AND APPLIED
SCIENCES OF ÇANKAYA UNIVERSITY
DEPARTMENT OF INTERIOR ARCHITECTURE

EVALUATION ENERGY EFFICIENCY OF THE EXISTING BUILDING BY SIMULATION PROGRAM

AHMED IMAD ABDULWAHHAB

May 2019

EVALUATION ENERGY EFFICIENCY OF THE EXISTING BUILDING BY SIMULATION PROGRAM

A THESIS SUBMITTED TO
THE GRADUATE SCHOOL OF NATURAL AND APPLIED
SCIENCES OF
ÇANKAYA UNIVERSITY

BY
AHMED IMAD ABDULWAHHAB

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE
DEGREE OF
MASTER OF SCIENCE
IN
INTERIOR ARCHITECTURE
DEPARTMENT

May 2019

Title of the Thesis: **Evaluation energy efficiency of the existing building by simulation program**

Submitted by: **Ahmed Imad ABDULWAHHAB**

Approval of the Graduate School of Natural and Applied Sciences, Çankaya University.

Prof. Dr. Can ÇOĞUN
Director

I certify that this thesis satisfies all the requirements as a thesis for the degree of Master of Science.

Prof. Dr. Zuhal ÖZCAN
Head of Department

This is to certify that we have read this thesis and that in our opinion it is fully adequate, in scope and quality, as a thesis for the degree of Master of Science.

Prof. Dr. Gülser ÇELEBİ
Supervisor

Examination Date: 07/05/2019
Examining Committee Members

Prof. Dr. Gülser ÇELEBİ	(Çankaya Univ.)	
Assoc. Prof. Dr. İdil AYÇAM	(Gazi Univ.)	
Assoc. Prof. Dr. Gülsu U. HARPUTLUGİL	(Çankaya Univ.)	

STATEMENT OF NON-PLAGIARISM PAGE

I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

Name, Last Name : Ahmed Imad ABDULWAHHAB

Signature :

Date : 22.05.2018

ABSTRACT

EVALUATION ENERGY EFFICIENCY OF THE EXISTING BUILDING BY SIMULATION PROGRAM

AHMED IMAD ABDULWAHHAB
M.S. Interior Architecture Department
Supervisor: Prof. Dr. Gülser Çelebi

May 2019, 124 pages

The poor thermal insulation properties of the construction are responsible for high energy consumption of existing building. Passive solar gain, air ventilation and also the ability to view the outside are providing by the building's windows which are useful multifunctional devices. Among the elements of the typical building fabric, glazing is responsible for the greatest energy loss due to generally high heat transfer coefficients (U values). The glazing types are the main reason that cause 60% of heat losing through the outer shell of the existing building. However, they mainly controlled demand for heating and cooling in buildings in winter and summer, respectively. Traditional window techniques tend to have low U-values that cause significant heat losses during the winter and gain unwanted heat in the summer. An existing building was selected in (Çorum Ticaret ve Sanayi Odası -Turkey) aiming to improve its energy efficiency by changing its glazing with new different types (Multi layered and low- e coating) of glazing an with others direction instead of the currently type used (single-glazing). The simulation program (Revit- green building studio) was used to estimate primary energy consumption of that building. Also, the simulation program was used to calculate the energy consumption of the existing building after the changing of its glazing by new different types (Multi layered and low- e coating) and by different orientations. Comparison was made by SPSS statistical analysis program between the results obtained for the new glazing types (Multi layered and low- e coating) and different orientations aiming to choose the best type of glazing and best orientation, which performed the lowest energy consumption levels. The changing of the glazing type with different orientations approved that the (triple glazing with Low-e) and (South-West-North) were the best type and best orientation to be used instead of the existing glazing type (single-layer) and all direction. The suggested type (triple glazing with Low-e) with a U-value of 0.15 W/m2 K, solar heat gain coefficient of 0.24 and visible transmittance of 0.51, was the most energy efficient glazing type. The used type was declare decreasing the energy consumption of the existing building up to (78%) of the initial energy demand. The improvement of the visual and thermal comfort of the occupants could be required by using unique glazing technologies through the qualifying the energy consumption of existing building.

Keywords: Energy efficient, Energy efficient for an existing building, Building envelope components, Simulation programs, energy efficient indicators, Glazing types.

ÖZ

EVALUATION ENERGY EFFICIENCY OF THE EXISTING BUILDING BY SIMULATION PROGRAM

AHMED IMAD ABDULWAHHAB
Yüksek Lisans, İç Mimarlık Anabilim Dalı
TezYöneticisi: Prof. Dr. Gülser Çelebi

Mayıs 2019, 124 sayfa

Yapının, zayıf ısı yalıtım özellikleri, mevcut binanın yüksek enerji tüketiminden sorumludur. Pasif güneş enerjisi kazanımı, havalandırmanın yanı sıra dışarıyı görme yeteneği, binanın çok işlevli araçları olan pencereleri tarafından sağlanır. Tipik yapı dokusunun unsurları arasında camlar, genellikle yüksek ısı transfer katsayıları (U değerleri) nedeniyle en büyük enerji kaybını oluşturmaktadırlar. Cam tipleri, mevcut binanın dış kabuğundan %60 ısı kaybına neden olan ana sebeplerdir. Bununla birlikte, esasen sırasıyla kış ve yaz aylarında binalarda ısıtma ve soğutma talebini kontrol ettiler. Geleneksel pencere teknikleri, kış aylarında önemli ısı kayıplarına neden olan ve yaz aylarında istenmeyen sıcaklığa neden olan, düşük U değerlerine sahip olma eğilimindedir. Mevcut bir yapı yerine, şu anda kullanılmakta olan cam türü, farklı bir türde cam ile (Çorum Ticaret ve Sanayi Odası -Türkay) değiştirilerek, enerji verimliliğini artırmak amacıyla seçildi (tek cam). (Sanayi Odası-Türkiye ziyaretinde Çorum Ticaret) seçildi (tek cam), bu binanın birincil enerji tüketimini tahmin etmek için simülasyon programı (Revit- Green Biullding Studio) kullanılmıştır. Ayrıca, simülasyon programı mevcut binanın enerji tüketimini, yeni farklı tipler (Çorum Ticaret ve Sanayi Odası -Türkay) ve farklı oryantasyonlarla değiştirdikten sonra hesaplamak için de kullanılmıştır. Yeni cam türleri (Çorum Ticaret ve Sanayi Odası -Türkay) için elde edilen sonuçlar ile, en düşük enerji tüketim seviyesini, en iyi olan cam türünü ve en iyi yönelimi seçmeyi amaçlayan farklı yönelimler arasında SPSS istatistiksel analiz programı ile karşılaştırma

yapılmıştır. Cam tipinin farklı oryantasyonlarla değiştirilmesi, ((triple glazing with Low-e) ve (Güney-Batı-Kuzey) mevcut camlama tipi (tek katmanlı) yerine, her yöne kullanılacak en iyi tip ve en iyi yönelim olduğunu onaylamıştır. Önerilen değer (triple glazing with Low-e), U değeri 0.15 W / m2 K, güneş ısısı kazanç katsayısı 0.24 ve gözle görülebilir 0.51 geçirgenliği, enerji açısından en verimli cam tipi olmuştur. Kullanılan tür, mevcut binanın enerji tüketiminin başlangıçtaki enerji talebinin (% 78) altına düşürüldüğünü ilan etmekteydi. Mevcut binaların enerji tüketimini niteleyerek, eşsiz camlama teknolojilerini kullanarak, yolcuların görsel ve termal konforunun iyileştirilmesi gerekebilir.

Anahtar Kelimeler : Energy efficient, Energy efficient for an existing building, Building envelope components, Simulation programs, energy efficient indicators, Glazing types.

ACKNOWLEDGMENTS

I would like to express my sincere gratitude to Prof. Dr. Gülser ÇELEBİ for supervision, special guidance, suggestions, and encouragement through the development of this thesis.

It is a pleasure to express my special thanks to my family for their valuable support.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

INTRODUCTION

This part of the research aims to introduce the background of this study. In light of this, the relevant parts of the study area have defined, including the important features of energy efficient of an existing building. Moreover, in this section problem statement, research purpose, aims, objectives and research questions have been discussed. Furthermore, information regarding the chosen methodology and the thesis structure to provide a complete understanding of the entire research have presented in this section. Consequently, this chapter is a significant part of this thesis, which clarifies the entire research plan.

1.1. Background

Energy consumption is increasing rapidly around the world due to urbanization, population, and modern construction, so it has been quite interesting for everyone. Both developed and developing countries are facing problems with energy consumption; high cost is one of these problems (Yueer He et al. 2017). The main purposes of using energy are cooling and heating the building all over the world, so it is very important to save energy leading to lowering the costs (Raji, Tenpierik, and Van Den Dobbelsteen 2016). The potential performance of the energy consumption of any existing building should be its energy consumption evaluation efficiency (Tibi and Mokhtar 2015).

In recent years, the existing building had made the users and the designers to think that these buildings consume large amount of energy, where the idea of energy efficient has made the designer to developed the infrastructure of buildings such as (roof, wall, and windows), in order to reduce energy consumption. (Alrashed and Asif 2014).

The following statement describes the situation in Turkey (Tug 2003)

" Turkey in recent years has become one of the fastest and most important energy markets in the world. The annual growth rate of electricity demand was 6.6% between 1995 and 2004 and 8.5% between 2005 and 2015. Electricity consumption is estimated to have increased fourfold from 150 billion kilowatt-hours to 499 billion kWh in 2004. It was about 38,500 megawatts in 2005, and the installed capacity is required to triple about 96,000 megawatts by 2020"

The most important goal for Turkey is energy saving strategy. Climatic conditions in Turkey as in many European countries are inevitable using both heating and cooling systems in residential and commercial buildings. Reducing the cost of energy users in this country requires a high-performing insulation system (Ediger et al. 2018).

Saving energy in existing building is depending on the building typology orientation and it is insulation systems, e.g. it’s glazing types (Q. Wang et al. 2016)

The developing of existing buildings represents an opportunity to raise the energy performance of existing building assets for their continuous lives. The retrofitting of existing commercial buildings, shall be improve energy efficiency or reduce energy demand. In addition, retrofit adjustments are often used as an appropriate time to install the distributed generation of insulation systems for an existing building. Energy efficiency re-processes can reduce operating costs, especially in old buildings, as well as help attract tenants and rising the market gains (Elotefy et al. 2013).

Energy efficiency simulation tools for evaluating the energy efficiency of the existing building should be used, in order to reach the comfort zone of users and saving energy purposes. Many programs can be found for the simulation performance of the existing building (Lu et al. 2017).

The useful and suitable simulation program is Autodesk (green building studio) which is used for the creation of three-dimensional models, details, construction documents for architectural projects. By drawing and scheduling presentations, the green building studio collects information about the construction project and coordinates this information across all projects and other offers. (Finsterle 2007).

Therefore, it is the most common program can be used for building simulation and it can evaluate energy efficient building. This program features accurate calculations by PC, and this program with simulating activities normally takes a few minutes to simulate the data input for any building (Ilhan and Yaman 2016).

The objective of this research is to evaluate energy efficient building by simulation program, and developing the insulation systems in order to find suitable alternatives that would improve the energy performance of an existing building.

1.2. Research problem

Because of global movement for implementing energy efficiency in design and construction, Turkey is one of the most countries which interested in energy efficiency implementation. To achieve the best results in the field of energy efficiency development, the construction sector must be identified and understood the application strategies for energy efficiency techniques. The increasing consumption of natural resources directs the world towards the attitudes of depletion resources in the environment.

Consequently, Turkey also needs to implementing energy saving, with most of its resources being consumed in the construction sector. There is scarcity in resources in our environment nowadays and that is mainly due to the increment of natural resources consumption. Most of Turkey’s resources are consumed in the sector of construction, so Turkey must apply methods and strategies of evaluating energy efficiency for an existing building. Despite the extensive researches that have been conducted on the evaluation energy efficiency of an existing buildings, there has been minimal effort towards defining the energy consumption that should be considered for local requirements.

1.3. Purpose of the research

The purpose of the research is to develop energy efficiency for existing building in Turkey based on the best alternatives of efficient insulation systems that are used by the modern world. Consequently, the aim of this research is to reduce the energy consumption of an existing building, by presuming the best alternatives of efficient glazing types to be used for an existing building in Turkey, based on (Turkish Standard TS 825).

Evaluation energy efficiency concept implementation for an existing building has been proved the energy consumption reduction. This research offers wide concept of evaluate energy efficient for an existing building's envelope. Consequently, the purpose of the research is possible to change one of envelope components (glazing type) for an existing building and changing glazing type for each direction depending on its orientation to reduce its energy consumption, following the adopted in the developed countries, and find the best alternatives that should be used in Turkey depending on Turkish Standard TS 825.

1.4. Aim and Objective

This study aims examine and define a general outline methodology to be used for analyzing and comparing various glazing types for each orientation of building in order to define the advantages and disadvantages of each glazing type. In order to find the best alternatives for insulation system (glazing types) of an existing buildings in Turkey based on (Turkish Standard TS 825). The objectives of this research are:

- Finding out suitable building envelope component which could be change to reduce energy consumption.
- Finding out suitable orientation that can help to reduce energy consumption by changing glazing type for that orientation.
- Comparing several glazing types in terms of their U-value, solar heat gain coefficient, and visible transmittance, for the same reason.
- Finding out the best alternatives of efficient glazing type which improve the energy performance of that building depending on Turkish Standard TS 825.

1.5. Hypothesis and Research Questions

Q1: What is the best part of envelope components can be change for an existing building?

Q2: What is the best orientation can help to reduce energy consumption by changing its glazing?

Q3: which is the best alternative of glazing types can enhancing the energy performance of existing building?

Q4: What are the most important standards that shall be taken into consideration when retrofitting an existing building for Turkey?

1.6. Methodology

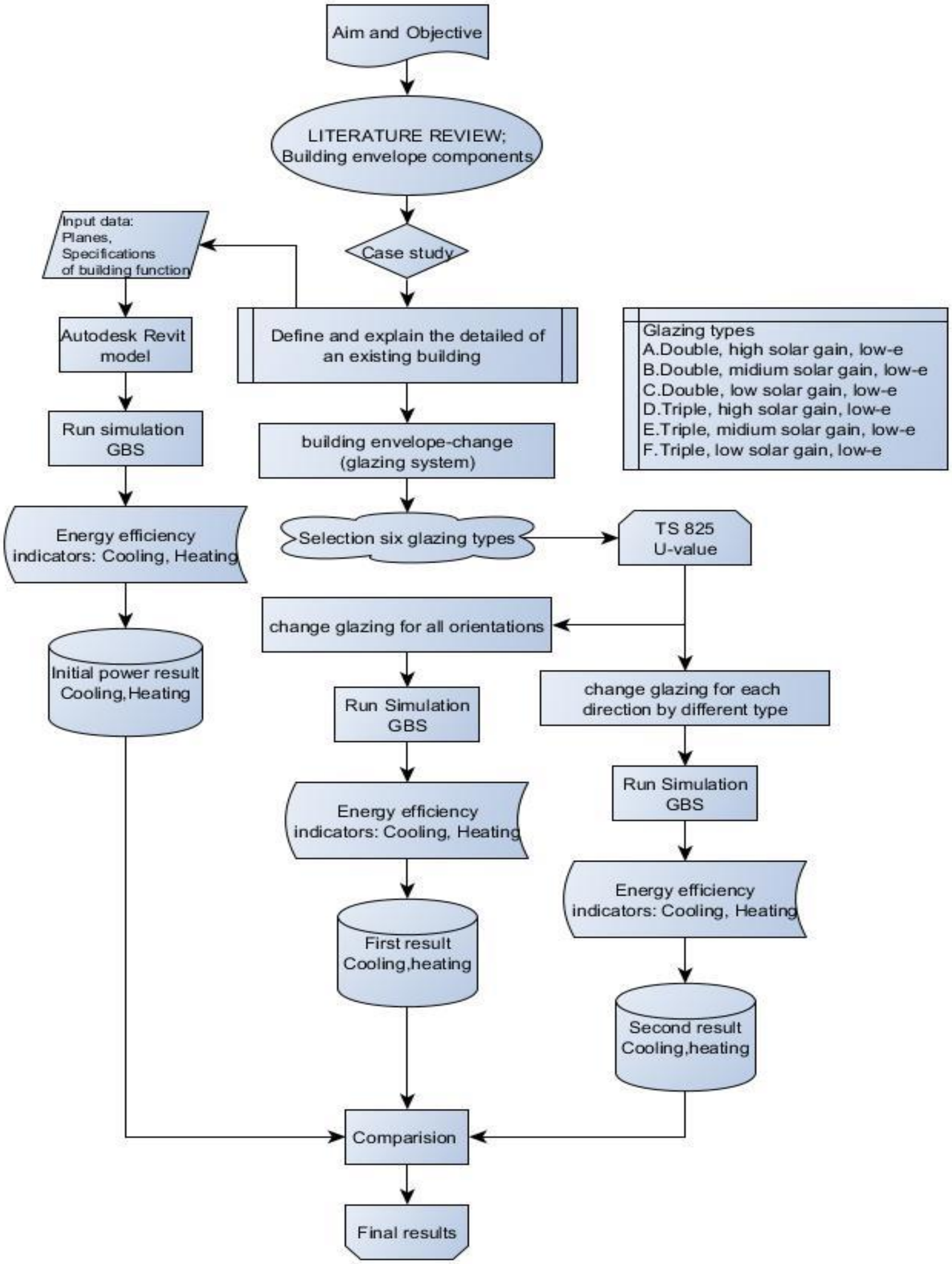
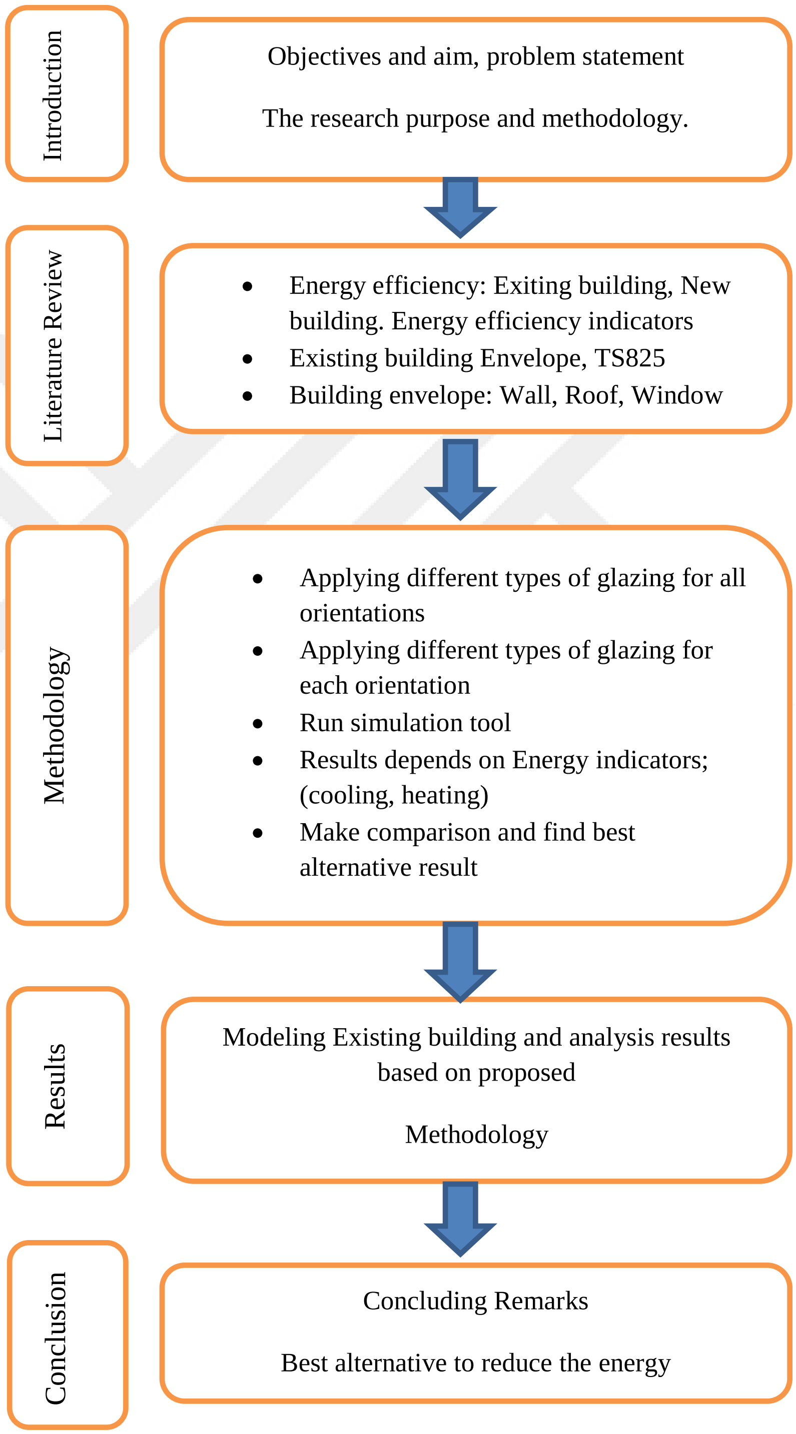


Figure 1.1 flow chart based methodology that will be used in this research.

1.7. Thesis Structure:

Figure 1.2: below illustrates the structure of this research.



CHAPTER 2

LITERATURE REVIEW

2.1. Introduction

This part discusses the related literature, which focuses on approach, concept and indicators of energy efficiency that apply to reduce energy consumption for an existing building. Furthermore, the new building and existing building envelope are also discussed. Moreover, this work strives to make an exhaustive technical study of the building envelope components and respective developments from an energy efficiency perspective. Different types of energy efficient exterior wall, window and roof are discussed. Performance of different glazing technologies including multilayer, Low-Ecoating glazing and frames depending on TS 825 are presented. Moreover, this part tries to finds alternatives glazing technologies to simplify the selection of the most suitable one for existing buildings in Turkey. Thus, this section is extremely important as it contains all the theories, related concepts, and other aspects relevant to the research objectives.

2.2. Energy efficiency

Energy efficiency or energy conservation have often been used in policy discussions but they do have very different meanings (Garcia Sanchez et al. 2014). It has become the ingredients of faith among environmental scientists to improve energy efficiency use, which will lead to reduce the energy consumption (Tian et al. 2014).

Enhancing energy efficiency will not necessarily lead to a reduction in energy use and thus reduce CO_2 emissions (Herring 2006). Energy efficiency improvement in new and existing buildings includes the most diverse, largest and most effective opportunities in buildings (Borgstein, Lamberts, and Hensen 2016).

Usually the final energy consumption appears divided into three main sectors: industry, transport and others, including another named residential and agricultural services sector, which makes it extremely difficult to gather information about building energy consumption (Klimczak et al. 2018). As the innovative technologies and energy efficiency recently are well known and spread widely. The key issue is to identify those that will prove to be more effective and reliable in the long term (Tian et al. 2016).

Energy is one of the most important resources used by modern society and it is at the heart of economic and social activities in industrialized countries (W. Tian 2014). A rise in energy consumption in a global scale is unavoidable (Keho 2016; Khatib 2012; Klimczak et al. 2018; Pérez-Lombard, Ortiz, and Pout 2008; Seddiki et al. 2016; Solangi et al. 2011; Yousefi, Gholipour, and Yan 2017).

The increase in energy consumption has been seriously considered due to industrial development and population growth rate. And the importance and necessity of reducing energy consumption became a vital global goal (Cascone et al. 2018; Garcia Sanchez et al. 2014; H. Wang and Zhai 2016; Yigit and Ozorhon 2018).

One major risk for cities in the future is climate change, and the buildings are largely responsible for the emission of greenhouse gases. Thus, researchers and designers committed to developed sustainable solutions to reduce energy and pollutant emissions for the consumption of buildings using environmentally friendly materials and innovative technological solutions (Klimczak et al. 2018).

“Various types of energy indicators are required to operate its departmental services. Different types of energy indicators are normally used in existing building. These are electricity, natural gas, diesel fuel, liquefied petroleum gas, coal, etc. Electricity is the primary form of energy indicator used within building facilities. Electricity is used generally for air-conditioning, vertical transportation lifts, heating, lighting, escalators and miscellaneous items including kitchen equipment, etc. The next most common energy type is liquefied petroleum gas, while the other sources, natural gas, diesel and coal, only play a minor role. These are generally used for cooking, water heating, etc”. (Önüt and Soner 2006)

2.2.1. Energy efficient of a new building

Energy efficient of a new building is regarded as a set of single actions that are expected to improve the sustainability of a building. Substituting a traditional oil heating system by a fuel-cell based combined heat and power system was a good example of a modern action hypothetically improving the sustainability of a building (Alanne 2004).

Costs of energy are continuously rising all over the world, so there is a raising awareness of the energy efficiency requirements. therefore, many countries created new building standards so to improve the fabric efficiency of their new buildings and in some cases improving the thermal performance of existing buildings through a process of retrofitting. As an example of renewing standards for the new building has to achieve an annual energy requirement (in terms of the energy required for heating) below a certain maximum level (Berry and Davidson 2015).

The modernization process of devastated glass façade of new building in Belgrade, Serbia was analyzed, bearing in mind positive examples of transformation and reskinning of buildings, where the aspect of modernization was an active part of urban renewal. Special attention was paid to the implementation of media technologies and final effects on energy balance of the newly designed façade (Tovarović, Ivanović-Šekularac, and Šekularac 2017).

Fully glazed front facades are highly preferred in the new constructions, since it is providing natural light, reducing the artificial light requirement and cooling load of the new building, which is so called glass curtain walls though using single- or double-glazing types. Windows areas need improvement in terms of thermal energy and the environment interior of the building consumption by studying different orientations (Ebrahimpour and Maerefat 2011; Frank 2005).

Field research was carried out over six heating seasons in sixteen multi-family system dedicated to four groups depending on the type of heating system modernization. Energy savings were calculated on the basis of average heat consumption before and after the update and ranged between 14.6% and 23.8%, depending on modification process (Cholewa, Balen, and Siuta-Olcha 2018).

The total energy required for heating during winter was reduced by 37% and 36% using energy strategies and negative energy efficiency to build standard homes of wood veneer and fiber, respectively. Thermal mass could be increased through the use of different wall and floor system through the replacement of fibro house with a house of brick crust and application of Passive Solar and Energy Efficiency Design Strategies, and total energy requirements could be reduced up to 58%. (Albayyaa, Hagare, and Saha 2019).

Four new buildings were studied in Aarhus, Denmark to analyze and evaluate energy conservation to improve energy performance. A systematic and energy-driven methodology for building energy modeling, simulation had been developed and implemented on the basis of a comprehensive technical, economic and environmental assessment. A deep strategies package along with a photovoltaic system saved up to 71% on primary energy use. (Jradi, Veje, and Jørgensen 2018).

The improved thermal comfort of new building, after replacing the glass façade of office building was investigated. Particular attention had been given to the implementation of media techniques and the final effects on the energy balance of the newly designed interface were recorded. The proposed solution was expected to evaluate the improved thermal comfort achieved through a radical system of the facade and the replacement of the new individual interface (double and triple glass units) with and without media elements (Tovarović, Ivanović-Šekularac, and Šekularac 2017).

Analysis of wood facades were studied and their impact on the thermal behavior of the entire building, taking into account the characteristics of materials and structural design, focusing on external cladding or protective layer. These structures had an improved assembly design with a protective treatment application, depending on their natural strength. whereas the results obtained were finally validated through an experimental facility. (Pelaz et al. 2017).

2.2.2. Energy Efficiency of An Existing Building

The building typology orientation and window to wall ratio are not the determining factors for identifying the best glass type which should be used for saving energy in existing building (Q. Wang et al. 2016) . The requirements concerning energy performance of existing buildings and their internal installations, particularly HVAC systems, have been growing continuously in all over the world (Albayyaa, Hagare, and Saha 2019).

Existing traditional calculation methods that follow a fixed heat exchange model are often insufficient to design a reasonable heating system for any building. Software methods are used over all the world, which allow detailed simulation of the heating and humidity conditions in the buildings, as well as an analysis of the performance of indoor conditioning systems. However, these systems are usually difficult to use and complex. In addition, the development of a simulation model that is sufficiently adequate to the existing building requires massive time involvement of a designer, (Klimczak et al. 2018). Introducing a number of different variants of the simulation model developed in any simulation programs effected the quality of final results obtained (Tian et al. 2014).

In order to satisfy the requirements of government regulations and green building accreditation programs, while improving energy consumption and maintaining thermal comfort. the test software package on a reference building represents a typical residential building in Turkey. The testing process conducted in the five-story building located in Istanbul and was used for construction information such as building size, location and schedule within the profession developer program (ASimulation-Based).

Noval and efficient approach for simulation based multi criteria optimization of the building energy performance was carried out, in order to obtain optimal solution leading to increase the building energy efficient. Simulation programs was used to investigate the building energy efficiency in four major calamitic regions in Iran. Aiming to explore the effect of some architectural parameters, and the final optimum configuration lead to 23.8 to 42.2% decrease annual total building energy consumption (Delgarm et al. 2016).

Existing Building energy efficiency circumstances based on data obtained from international energy reports were compared between the United states, China and the European union. Both similarities and differences were found in features of building energy (Cao, Dai, and Liu 2016). Zero energy building is the ultimate solution to mitigate the adverse effects of future energy consumption. In the European Union, the Directive on Energy Performance of Buildings has set zero energy building as the target for all new buildings (Y. Chen et al. 2019)

The basic step towards understanding energy use is comparability. The EnergyPlus simulation tool was used to assess energy performance in 400 residential buildings. Three types of buildings were classified. EnergyPlus models have been developed for the three types of building designs commonly found in the National Housing Scheme in Brunei Darussalam. EnergyPlus models produced energy intensity (EUI) per year for these buildings, with values ranging from 64.2 to 47.8 kWh / m2 (Shabunko, Lim, and Mathew 2018).

Low-cost building energy management system explanation uses a building simulation to predict optimal electrical start control points. Those who was using electricity for heating in Scotland, where this study existed, were often poor in fuel, so there was a strong case for improvement, especially when electricity was costing about three times as much as the equivalent of a gas equivalent of heating. The proposed system has shown a 50% energy saving at low heating time compared to the schedule when evaluated retroactively(Seeam, Laurenson, and Usmani 2018).

The thermal effect of Vertical Greenery Systems was simulated using a mathematical model based on the principle of heat balance from the leaf layer and subsequent layer, which was then integrated into the widely accepted construction simulation program, EnergyPlus. The integrated Vertical Greenery Systems model was valid against two pilot studies reported and showing good agreement. The Vertical Greenery Systems model was then used to evaluate the effect of Vertical

Greenery Systems on building energy performance in warm temperature climates (Dahanayake and Chow 2017).

The improvement analysis was useful in assessing both individual buildings and national building stock levels, and the possibility of applying measures and techniques currently installed to improve energy efficiency in the construction sector in Bahrain. Sequential search technology was used to improve the design of residential buildings in Manama to reduce the cost of life cycle energy using a wide range of energy efficiency measures. In the analysis, the design features of single-family homes were air-conditioned including orientation, location and size of the window, type of glazing, insulation levels of walls and ceilings, lighting fixtures, appliances, and heating and cooling systems efficiency.(Moncek Krarti and Dubey 2018)

Based on the multi-standard regression between energy bills in the entire building and external weather data, the proposed diagnostic method was used for regression coefficients to determine the energy use of the main systems. Building Offices in China was to be tested through this diagnostic method. All diagnosis results had been verified by the performance data from advanced energy consumption monitoring system together with field surveys and measurements (Ji et al. 2018)

Comprehensive and integrated energy analysis approach to improve the energy efficiency of commercial office buildings were considered. In particular, the interactions between various energy efficiency measures for existing and new office buildings were being investigated in Salamanca, Guanajuato using detailed simulation and optimization procedures (Elotefy et al. 2013). The optimization analysis indicated that the most cost-effective energy conservation capabilities in both new and existing offices were achieved by reducing office equipment loads and increasing the efficiency of lighting techniques and controls. More than 49% of annual energy savings could be achieved in a cost-effective manner for new office buildings(Griego, Krarti, and Hernandez-Guerrero 2015).

A comprehensive optimization analysis was carried out using total power simulation in construction to determine the best energy efficiency measures appropriate to improve power performance in buildings in Oman. Economic and environmental benefits were then assessed for a wide range of energy efficiency measurement techniques. The impacts of different levels of modernization of energy efficiency in existing buildings were estimated (Moncef Krarti and Dubey 2017)

The goal of zero energy building is an achievable goal, which is based on an accurate design that includes a combination of negative strategies and low energy consumption. However, taking into account the entire lifecycle of the buildings, nearly zero energy buildings reduces operational power near zero, increasing the embodied energy potential, which occurs during the construction phase. It is necessary to balance operational and physical energy values to reduce the environmental footprint of buildings (Brambilla et al. 2018).

Simulation framework systems were developed to analyze the use of life cycle energy in the building by integrating different dynamic events throughout the life cycle. The main contribution of this investigation was a way to test energy efficiency in Nearly zero energy building (Thomas, Menassa, and Kamat 2018).

The modernization of existing buildings represents an opportunity to raise the energy performance of commercial building assets for their continuous lives. The retrofit often involves modifications of existing commercial buildings that may improve energy efficiency or reduce energy demand. In addition, retrofit adjustments are often used as an appropriate time to install the distributed generation of insulation system for the existing building. Energy efficiency re-processes can reduce operating costs, especially in old buildings, as well as help attract tenants and rising the market gains. (Elotefy et al. 2013).

Green roof solutions had been evaluated and implemented. The analysis was conducted in the city of Catania on the Mediterranean Sea, and the results showed that the only green roof solutions with a load limit of 1.46 kN / m were suitable for the retrofit of existing buildings. In terms of energy saving the energy consumption of cooling decreased by 31-35%, and during the winter, heating energy consumption decreased by 2-10%.(Cascone et al. 2018).

Advanced Glass Effect and Solar overhangs and the energy transferred or lost from the room through the lighting areas of typical residential buildings in Tehran was evaluated using EnergyPlus ™. Suitable cavities or lateral fins in southern, western and eastern windows improve the annual energy transferred to buildings and could have an equivalent active behavior of high performance glass (Ebrahimpour and Maerefat 2011).

The internal environment and energy use of the reconstructed building were evaluated and compared with the non-retrofit building of the same area. The results showed that the building had access to 39% of the low demand for heating in space. The interior environment was improved compared with the renovated building. The addition of outdoor curtains from 15 May to 15 September between 10 am and 12 noon on the east side and from 12 noon to 3 pm on the west side seemed the best option to improve the indoor climate during the summer (Liu, Rohdin, and Moshfegh 2015).

Entire building categories were involved to evaluate energy retrofit programs. Simulation-based approach was used through combining detailed energy modeling and algorithmic optimization, the magnitude of energy savings that could be achieved for different retrofit levels along with optimal cost path towards achieving net zero energy conditions had been estimated (Luddeni et al. 2018).

Heating energy consumption in non-powered residential buildings in cities of northern China, which would be measured through heat exchange, secondary grid and construction during the heating season from 2015 to 2016 and from 2016 to 2017 (before and after retrofit), had been focused. The energy-saving rates of the heat supply for heat exchange stations and the heat consumption of buildings were 12.5% and 15.6%, respectively (Xin et al. 2018).

The improved design of the new buildings as well as the various energy retrofit programs for existing buildings were considered in pressure analysis using typical architectural power models in five locations representing a wide range of Saudi Arabia's climate. The analysis provided specific estimates of the extent of energy and demand savings that could be achieved in the construction sector even under high energy prices (Moncef Krarti, Dubey, and Howarth 2017).

Quantitative analysis of rigid energy codes for new facilities and three levels of energy update for existing buildings was considered. The new macroeconomic analysis using the concept of energy productivity to assess the cost-benefit of energy efficiency programs on a large scale in Qatar was investigated. It has been determined that the implementation of a large-scale energy retrofit program by the government on the current building stock is very cost effective in Qatar (Moncef Krarti et al. 2017).

Efficient energy saving technique that decreased the energy consumption and reduced HVAC system sizing in buildings was developed. The new system that was selected according to the new building cooling loads was compared against the existing building and significant energy saving (7,068,178 kW h/year) was found (Radwan et al. 2016).

2.3. Building Envelope

According to the International Energy Agency, the world energy consumption has increased by 48% in the last two decades. There is a growing concern over the exhaustion of resources and related heavy environmental impacts. The building sector is the largest contributor to energy use, accounting for more than one-third of all final energy and one-half of total electricity consumption worldwide (World Energy Outlook 2019).

The International Energy Agency identified energy efficiency as the “fuel” to make a difference to underpin a more sustainable energy system. In line with this opinion, the significant share of the potential to improve energy efficiency - more than 80% of building sector’s potential is untapped (E. S. Lee and DiBartolomeo 2002).

It is expected that growth in population, increasing demand for building services and comfort levels, together with the rise in time spent inside buildings will drive higher energy demand in the future. Therefore, designing buildings for energy efficiency becomes much more urgent. Building envelope is widely recognized as a key factor that influences building energy consumption (Yongqiang Luo, Ling Zhang, Michael Bozlar 2019).

The parameters affecting building envelope energy performances might be design variables (e.g., configuration of the exterior wall) or design had given inputs imposed by the context of the project (e.g., outdoor temperature of the site) (Aida Farzaneh, Danielle Monfet 2019). Growing body of knowledge of passive building envelope design in cold climates with a focus on superinsulation, extreme air tightness, high performance window, the feasibility of passive envelope design in hot humid climate had barely been studied (Carlos Ernesto Ochoa 2008).

Building envelope thermal conduction is dominant in the cold regions, the thermal performance of the building envelope plays a very important role in reducing building energy consumption. In cold areas, the annual air conditioning heating energy consumption of public buildings, there are about 50% consumed by the heat transfer of building envelope. Therefore, the study on energy saving building envelope is very important (Feng, Sha, and Xu 2016).

Generally, the U-values of roof, floor, external walls and windows in the typical building are between 0.16 and 2.00 W/m2K. (Jelle et al. 2012). Furthermore, Turkish Standard TS 825 had mentioned that U-values need to be further strengthened in average by 11% for new buildings and by 10% for existing buildings to be renovated. Moreover, the heat/cold bridge factors need be reduced from currently about 0.1 $W/(m^2.K)$ in new buildings and 0.15 $W/(m^2.K)$ in existing buildings to 0.05 $W/(m^2.K)$ and 0.1 $W/(m^2.K)$ respectively. In warm regions, this improvement of the heat bridge factor could already be sufficient for achieving the needed emission reduction without further improving the U-values (U-Value maps Turkey TS825 2016). It was predicted that the U-values of glazing would have to be in the region of or lower than (0.12–0.14) W/m2 Kin order to meet the fabric energy efficiency standard (Berry and Davidson 2015).

Table 2.1: U-value combination for new constructions in turkey in order to reach climate targets that the renovation rate can be increased to 2% until 2030 (U-Value maps Turkey TS825 2016).

Component	Unit	Heat bridge factor	Hot	Cooling-based	Moderate	Rather cold	Medium cold	Cold
Roof	W/(m²*K)	0.05	0.24	0.20	0.18	0.14	0.14	0.12
Façade	W/(m²*K)	0.05	0.32	0.26	0.25	0.18	0.20	0.16
Windows	W/(m²*K)	0.05	1.60	1.60	1.40	1.00	1.00	1.00
Ground	W/(m²*K)	0.05	0.52	0.41	0.39	0.28	0.30	0.26

Table 2.2: U-value combination for renovations building in turkey in order to reach climate targets that the renovation rate can be increased to 2% until 2030 (U-Value maps Turkey TS825 2016).

Component	Unit	Heat bridge factor	Hot	Cooling-based	Moderate	Rather cold	Medium cold	Cold
Roof	W/(m²*K)	0.1	0.25	0.20	0.20	0.15	0.16	0.13
Façade	W/(m²*K)	0.1	0.35	0.28	0.27	0.20	0.20	0.17
Windows	W/(m²*K)	0.1	1.80	1.45	1.10	1.00	1.00	1.00
Ground	W/(m²*K)	0.1	0.51	0.41	0.39	0.30	0.30	0.25

The principle method is built on balance that the heat is generated by the heating equipment equals the heat is lost to the outdoor environment through the building’s envelope. This heat generation vs. loss balancing process continues over time, being characterized by the heating equipment’s operating cycles. An actual home in the cold climate zone was used with outdoor temperature varying between 12.9 and 57.6, F. So that the given home’s heat loss was linearly correlated to the indoor–outdoor temperature difference (Shi and Shi 2017). Indicate measured data could be providing reliable information for assessing and benchmarking a building envelope’s energy performance (Cai et al. 2018).

Innovations in a systematic manner of energy-efficient building implementations, as well as sustainable decision-making was preferred to facilitate the conflicting nature of both energy efficiency and management performance indices.

Critical exposition in both energy efficiency and management within a viable framework for building envelope sustainability (Sayed et al. 2019).

Achieving with the use of energy simulation modelling to examine the energy-saving benefits of power consuming equipment's, power generation through renewable sources improving thermal comfort through Energy Conservation and Building Code India's compliance and motivating the buildings' occupants for energy-responsive behaviors. These strategies, when had been applied together, lead to an overall reduction of 40.4% in the total energy consumption (Sharma, Chani, and Kulkarni 2014).

An environmental impact comparison of four different building structural systems widely used in the construction of energy efficient houses in Central Europe: reinforced concrete, brick, cross-laminated timber, and timber-frame panel construction. The basic properties of wall and roof components had been determined according to the thermal transmittance equivalent, where their environmental performance using a lifecycle approach had assessed. An environmental impacts of individual structural systems and alternative thermal insulation materials, as well as their impact share on environmental performance of building envelopes (Kova 2018).

Evaluating and optimizing envelope retrofit strategies through a calibrated simulation approach. Based on an energy performance audit and monitoring, an existing building was evaluated on performance levels and improvement potentials with basic energy conservation measures (ECMs). The existing building was monitored for a full year and monitoring data was used in calibrating the simulation model (Campus 2014).

Architect's awareness and adoption of building envelope technologies (BET) for energy efficient housing in Lagos State, Nigeria were examined, based on seventy-four (74) returned questionnaires of both registered and non-registered Architects. A multistage sampling that involved cluster sampling and random sampling of architects in Lagos State had adopted. Descriptive statistical tools had been used to present the dataset. Intent of promoting energy sustainability by architect while designing their building envelopes, the awareness of the building envelope strategies to adopt, factors influencing their adoption of these strategies, which could be adopted to improve adoption of building envelope technologies for energy efficiency in housing units (Akinola and Adeboye 2018).

Investigating energy performance and potential energy savings associated with influencing envelope design parameters under hot-humid climatic conditions had discussed. Envelope parameters such as wall and roof thermal resistance, and air leakage rate are major determinants of mosque energy performance and subsequently, considerable savings can be achieved when properly considered. Envelope thermal design was presented to provide architects, engineers, planners, community developers and mosque operators with necessary guidelines for improving mosque energy performance (Budaiwi 2011).

Building envelope energy retrofit would be undertaking on an existing affordable multifamily building in Montcada i Reixac, Barcelona. With economic support from the Catalan Government together with the local Building Department, the Building Laboratory at Universitat Politècnica de Catalunya had been able to carry out the energy retrofit of the main façades and roof of the building. In addition, the Construction Technology Center iMat, together with the Building Department of this municipality, conducted the monitoring of the building before and after the energy retrofit effort (Casquero-modrego and Goñi-modrego 2019).

The building envelope is an indicator to detect the impact of energy consumption. Two major ways to assess the performance of the energy consumption in the buildings and they are statistical and simulation analysis (Huang, Niu, and Chung 2013). Thus, energy consumption of buildings can be measured to assess the effectiveness of energy management and consumption (W. S. Lee 2008)**.**

The flow of energy from the power plant to the building envelope with the temperature and humidity in the open air every hour as a reference rate was calculated. Chemical stress of room air was seen in cooling mode (Korjenic and Bednar 2012). Three instances of improvements were analyzed with a standard case using this method. The results showed that the building envelope was an essential insulator in the hot summer and the cold winter in China reducing external power consumption in the building (Zhou and Gong 2013).

The building envelope divided into four major systems, namely the roof system, wall system, fenestration system and underground system. Each of the four systems would contribute to the overall functional effectiveness in meeting performance requirements of thermal, acoustic, visual, aesthetic, and etc.(wbdg 2019). Roof systems are usually designed to weatherproof and improve buildings thermal resistance. Wall systems can be considered as either load bearing or non-load bearing and serve to prevent water or moisture penetration and improve thermal performance. Fenestration systems, which include all the windows, louvers and entrances, play a vital role in lighting, ventilation and thermal performance (Gil-Baez, Padura, and Huelva 2019). wall systems and fenestration systems have been prime targets of innovation since the early twentieth century due to material innovation. Therefore, in order to identify energy-efficient design measures, detail review of the two influential systems is essential (wbdg 2019).

2.3.1. Exterior Wall

Exterior wall consists of four elements, namely structural elements, exterior wall finish and exterior color, exterior and interior insulation. There are different types of exterior wall structures: mass walls, metal building walls, steel-framed walls, wood-framed and other walls. The majority envelope structures of any buildings are mass walls with 150mm thickness reinforced concrete and prefabricated façade (Guideline for Condition Assessment of the Building Envelope 2014).

Exterior wall finish is used to define the texture of the exterior wall surface, which influences the rate of heat loss/gain. Since the texture effect of exterior wall finish is minor, confirming this is not critical in the building energy performance simulation (Vilhena et al. 2017).Exterior wall color is used to set the exterior surface absorptivity which influences the rate of heat loss/gain as a function of solar incidence (Xie et al. 2018).

Exterior insulation retrofit strategies in subarctic climates to cause moisture accumulation in wood- framed structures, nine test wall sections had constructed using varying ratios of stud-fill and exterior insulation. The wall sections had tested in Fairbanks, Alaska, over two winters and had been monitored for temperature, humidity, and wood moisture content. Test walls with less than two-thirds of the nominal wall R-value exterior to the framing performed poorly in terms of wood moisture content and relative humidity at the sheathing interior surface whether or not the test walls were equipped with vapor retarders (Craven et al. 2014)

Thermal insulations are used to minimize heat loss while serving as a capillary break to block moisture infiltration. In cold climates, regulatory requirements on energy performance of building envelopes dictate the use of thermal insulation; however, applying thermal insulation to buildings in hot and humid climates remains rare. Special attention should also be given to thermal bridge issues which may significantly impair the overall thermal performance. The adverse impacts can be mitigated by using thermally broken materials, e.g. thermally broken aluminum and insulation (Villasmil, Fischer, and Worlitschek 2019).

Energy consumption could be increased globally by 40% following several attempts to improve energy efficiency in construction sector (Gounni and El Alami 2017). Studies focused on the isolation of the building envelope, which contributes to reducing the annual energy consumption and the size of the air conditioning system had been conducted (Gounni et al. 2018).

Thickness of optimum insulation materials for the building’s envelope (roof, facade and floor) are vital for energy saving of constructions, which is based on the Life Cycle Assessment and Life Cycle Costing methodologies to integrate both environmental and economic aspects, respectively (Braulio-Gonzalo and Bovea 2017).

Concrete is increasingly used today without the awareness of the amount of energy consumed in construction; it can cover different uses in the building: roof insulation, wall and ground floor insulating slabs. Through accurate and simple experiments dedicated the thermal characterization of materials with different sizes had great importance in the field of construction and energy saving (Elotefy et al. 2013). Hemp concrete is a porous heterogeneous material composed of millimeter-sized hemp shives mixed in a lime binder. It had been providing a customized thermal characterization of a simple method for samples with the size of a millimeter of low thermal conductivity (Pierre and Carin 2019).

Many of the thermal insulation and innovative materials had been developed. They meet the performance requirements of the thermal insulator building and had a low production cost and environmental impact of low. A study deal with the new thermal insulation materials that depend on textile waste (acrylic and wool) had been developed and characterized by thermal and physical characteristics. This model was developed and validated against experimental result by using the cavity at a low level of heat was controlled (Gounni et al. 2018). The thermal and energetic performances of the developed insulation materials were compared with some classical thermal insulation materials (i.e. Rock wool and Expanded polystyrene). The developed thermal insulation materials were a competitive solution in terms of annual loads compared with conventional thermal insulations (Khoukhi 2018).

Energy efficiency in the near-zero energy buildings, which will be built in the near future mandatory throughout the European Union offering an alternative solution given through the Nano insulating materials, such as aerogel and vacuum insulation panels (Moga and Bucur 2018).

2.3.2. Roof

Roof has been studied around the world about the thermal and energy saving performance, and its performance depends greatly on the local climate and the hygrothermal properties. Roof system had been studied around the world about the thermal and energy saving performance, and its earth-sheltered roof and green roof in Israel, that the cooling effect of earth-sheltered roof was performance depends greatly on the local climate and the hygrothermal properties, or the effect of soil layer, earth-sheltered roof and green roof in Israel (Yang He et al. 2018). Cooling effect of earth-sheltered roof was decrease in the number of heating hours of 22-139h during the heating season (depending on the combination of weather and the study showed that soil temperature of an intensive green roof remained rather stable at 10, 50 and 90cm significantly smaller than green roof, suggesting that plant layer plays an important role. For the effect of soil layer, renovation scenarios considered) (Jim and Tsang 2011). On the other hand, function intercept increased for 7.8-12.7% per decade (depending on the study showed that soil temperature of an intensive green roof remained rather stable at 10, 50 and 90cm coupled scenarios) (Sun, Bou-zeid, and Ni 2014). The values suggested could be used to modify the function parameters for the scenarios considered, and depth, which suggested that thermal performance of green roof could be obtained with only 10cm soil. With regard to the effect of evapotranspiration, moreover; noted that the contribution depended on local climate and was mainly controlled by energy availability and water availability. In addition, many researchers found that the increase of the thermal capacity of roofs compared to traditional roofs, if not controlled with insulation, may lead to higher cooling and heating loads (Berardi, GhaffarianHoseini, and GhaffarianHoseini 2014).

2.3.3. Windows

Windows are responsible for the biggest loss of energy due to the high heat transfer (U values). This can be attributed about 60% of the heat loss through the fabric of residential buildings to the glazed areas (Cuce 2014).

Windows are useful multifunctional devices for buildings which offering air ventilation, and passive solar gain also the ability to view the outside. Providing comprehensive Glazing innovative technologies were reviewed. Fenestration refers to openings in the building envelope that are primarily windows and doors. The word fenestration plays a vital role in providing thermal comfort and optimal lighting levels of building. It is also important from an architectural point of view to add aesthetics to the design of the building. (Sadineni, Madala, and Boehm 2011).

Glazing is the main component of buildings that provide visibility, ventilation, passive solar air, daytime lighting and the opportunity to leave the building in extreme cases. However, they have an important role in total building energy consumption for their remarkably higher U-values compared to other components of building envelope (Cuce and Riffat 2015). Glazing is responsible for about 60% of the total energy building consumption. Improving glazing performance had considerable attention at global scale, for their significance reducing of the energy demand of buildings (Jelle et al. 2012).

The ability to build high-efficiency buildings will only be achieved if measures are taken to reduce U-values of fabric and incorporate effective window performances. However, windows do not only have a glazing element but also a frame that has aspects of heat transfer and air tightness. In this regard, it is important to identify appropriate technologies for the manufacture of energy-saving windows, which will improve the visual and thermal comfort of residents (J. (Jialiang) Wang and Shi 2017).

There are three ways for heat exchange between windows and occupants:- long-wave heat exchange between window inside surface and building envelope, solar radiation (short wave) which penetrates through window glass and falls on the building envelope and breeze induced by cold air drainage off the window surface (Chaiyapinunt et al. 2005).

Even though windows are not the major element in determining human thermal comfort, their effect increased significantly when their inside surfaces are very hot or cold, the building occupant is very close to the window, or when very high solar radiation is passing through the windows (Parkinson, Parkinson, and de Dear 2019).

Glazing have significant role in determining the heating and cooling load of a building, chiefly when their overall area is large. Window energy balance considered through several parameters; thermal transmittance "(U-value, which determines the heat transfer between indoor and outdoor environment due to temperature difference)", air leakage and g-value. The g-value (The solar heat gain coefficient is ranging generally between 0 and 1 where 0 and 1 is referred to high shading and low shading, respectively) is an important parameter and is determined by the solar transmittance of the window and the solar energy absorbed by the window material and re produced indoors. The g-value is provided by Glazing manufacturers at normal incidence only, while its value at other oblique angles is important at most of the time (Van Nijnatten 1999; Pfrommer et al. 1995; Rubin, Powles, and Rottkay 2006; Rubin, Von Rottkay, and Powles 1998).

The demand for heating and cooling of the building depends on internal gains such as occupants and appliances, as well as external gains through the building's envelope. Solar energy (radiation) and thermal energy flowing through the glazed parts of the buildings are the most significant part of the external energy. The glazing energy performance is described in terms of thermal and optical parameters. Solar and lighting energy are determine by the Optical parameters like solar and visible transmittance (Burmeister and Keller 2002). Natural lighting source (Daylighting) is providing visual comfort and pleasant indoor environment for the occupants (Li and Lam 2000; Li, Lau, and Lam 2005). The cost of electrical energy consumption of the building could be reduced by the effectiveness of daylighting (Shaikh et al. 2017).

The estimation of daylight in the interior space requires precise determination of the availability of natural light source outside. This does not include the total amount of light coming from the sky but also it is a distribution method. Lighting at a point inside the room depends on the exact distribution of the sky lighting at that time. The standard sky range includes clear, cloudy and partly cloudy sky (Li et al. 2017).

There are many types of glazing that are commonly used in existing building (Fig. 1). Investigates an annual energy performance of different glazing types was carry out by using aluminum, wood or vinyl frame in existing building in two different climates. Investigated analysis utilized the visible transmittance (VT) and the solar heat gain coefficient including the frame effects (g_{tot}). “The VT is expressed as the amount of light in the visible portion of the spectrum that passes through a glazing material’’ (X. Chen, Zhang, and Du 2019).

The glazing type, the number of panes, and any glass coatings are affecting the visible transmittance. In table (1) the ranges of visible transmittance of glazing types were recorded. Uncoated clear glass had VT value more than 90%, while highly reflective coating on tinted glass had VT less than 10%. (Cuce and Riffat 2015).

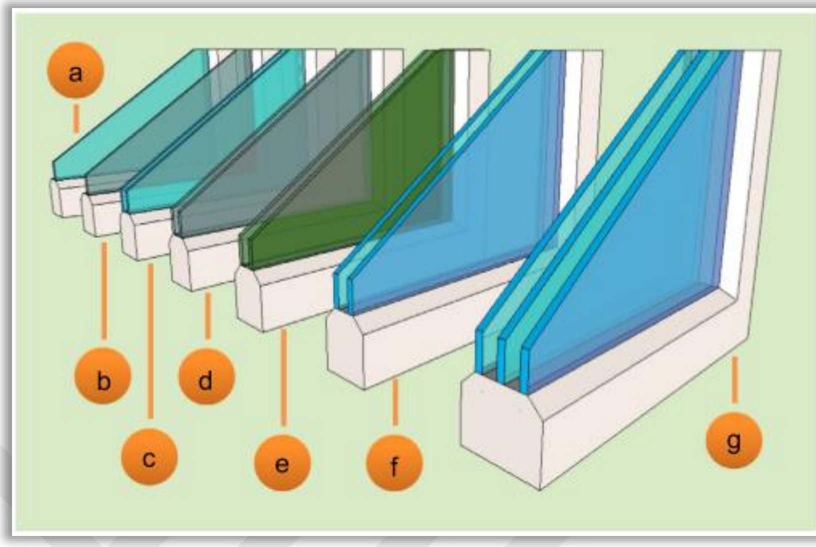


Fig. 2.1. Various glazing types for windows: (a) single clear glass, (b) single glazing with gray tint, (c) double clear glass, (d) double glazing with gray tint, (e) double glazing with selective tint, (f) double glazing with Low-Eand (g) triple glazing with low-e. (CSBR 2019)

Table 2.3 : Performance parameters of various glazing types for windows (CSBR 2019)

(where SHGC is solar heat gain coefficient, VT is visible transmittance)

Window	Glazing type	*U*-value (W/m^2 K)	SHGC	VT
A	Single, clear	0.84	0.64	0.65
B	Single, tint	0.84	0.54	0.49
C	Double, clear	0.49	0.56	0.59
D	Double, tint	0.49	0.47	0.44
E	Double, high performance tint	0.49	0.39	0.50
F	Double, high solar gain, low-e	0.37	0.53	0.54
G	Double, moderate solar gain, low-e	0.35	0.44	0.56
H	Double, low solar gain, low-e	0.34	0.30	0.51
I	Triple, moderate solar gain, low-e	0.29	0.38	0.47
J	Triple, low solar gain, low-e	0.28	0.25	0.40

The most energy efficient glazing system is Triple low-solar-gain low-e, with a U-value of 0.28 W/m2 K, solar heat gain coefficient of 0.25 and visible transmittance of 0.40 (CSBR 2019).

Glazing can be considered the most important part of fenestration products because it has a significant impact on the thermal properties of glazing. It is essentially constitutes the largest proportion of the glazing area and therefore the overall window's U-value is affected by glazing U-value significantly (Sadineni, Madala, and Boehm 2011).

- **Multilayer glazing**

This type of glazing can be described as the combination of glazing layers with air or a gas full of either Argon or Krypton. The thermal performance of the multilayer glazing is affected remarkably by the number of glazing and the inert gas type. By the way, Krypton has low thermal conductivity which make it producing lower U-values with smaller cavities compared to the other inert gases. However, the low cost of Argon gas makes it the most preferred inert gas to use in multilayer glazing. Some samples of the best low U-value multilayer glazing are given in Table 2 with glazing U-value, visible solar transmittance and the solar factor (Rezaei, Shannigrahi, and Ramakrishna 2017).

Table 2.4: Performance parameters of various multilayer glazing types for windows (Jelle et al. 2012). "The lowest U-value is found to be 0.49 W/m2 K with a 36 mm

Multilayer glazing type	*U*-value (W/m^2 K)	SHGC	VT
AGC GlassUK Top N$^+$	0.70	0.50	0.48
GURDIAN Flachglas Gmbh ClimaGuard N^3	0.72	0.49	0.54
GURDIAN Flachglas Gmbh ClimaGuard N	0.71	0.50	0.53
INTERPANE Glas Industrie AG Iplus 3CE	0.71	0.49	0.47
INTERPANE Glas Industrie AG Iplus 3CL	0.72	0.53	0.55

thick configuration (4 mm glass+12 mm Krypton+4 mm glass+12 mm Krypton+4 mm glass)."

There are many types of multilayer glazing technologies for example "Tinted glass is sometimes used as the outer pane of a double-glazed system. The tinting can produce various colors (e.g., green, grey, bronze). These glazing systems absorb solar radiation and reduce, both, the heat and light transmission" (Pfrommer et al. 1995).

Multilayer film structure consisting of high/low/high (TiO_2/SiO_2/TiO_2) refractive index materials were used in sol–gel synthesis and spin coating process (K. Han and Kim 2011).

- **Low-emittance coating**

Low-emission coatings are essentially metal or metal oxides, and are intended to allow the transfer of a large proportion of visible light in the solar spectrum while blocking many other wavelengths responsible for unwanted solar heat gain. Low-Ecoated products can be classified into two main types: soft and hard coatings (Chaiyapinunt et al. 2005; Chiba et al. 2005; Hammarberg and Roos 2003).

The Low-Ecoatings are capable of reducing heat gain through windows up to 48%. Therefore, they are widely preferred to use in modern architecture for thermal regulation of existing buildings. Retrofitting existing conventional windows with Low-Ecoatings is reducing a significant amount of heat transport through thermal radiation (J. Han, Lu, and Yang 2010).

A glazing design to increase energy efficiency during high-temperature periods would ideally allow the entire solar spectrum to pass, but would prevent heat radiation from re-entering space. The first Low-Ecoatings, are designed to contain a high solar thermal gain coefficient and visible permeability to allow a maximum of sunlight inside building environment with a greatly reduced U-value. The glaze, designed to minimize summer heat gains, will allow minimal daylight, but will allow most of the visible light to be illuminated, but will block all other solar spectrums, including nearby ultraviolet and ultraviolet radiation, Such building sounding environment. The second-generation of Low-Ecoatings types still maintain a low U-value, but are designed to reflect the solar near-infrared radiation, thus reducing the total solar heat gain coefficient (SHGC) while providing high levels of daylight transmission (figure: 2). (Efficient Window 2019)

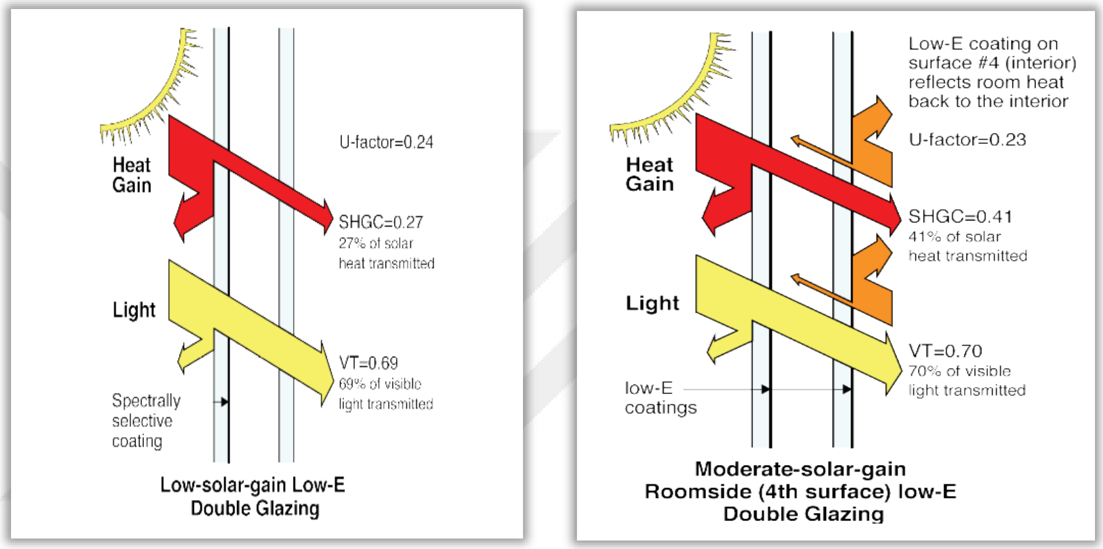


Figure 2.2: Double glazing design with Low-e. (Efficient Window 2019).

There are three types of triple glazing, solar gain, Low-e, and they are triple glazing with high solar gain and low-e. This product is suitable for buildings located in very cold climates. Both Low-Ecoatings in this product are characterized by high solar heat and visible light permeability, ideal for passive solar design. However, the use of three layers results in decreasing of solar heat compared to double glass with Low-Esolar energy. Triple glazing with medium solar gain with low-e, has the same characterization of high solar gain with Low-Ebut it differs in its U-value. The third type of triple glazing with low solar gain and Low-e, has both

Low-Ecoatings which are spectrally selective in order to minimize solar heat gain. This type is the best suited for both cold and hot climates (Figure-3, Table-3) (Efficient Window 2019).

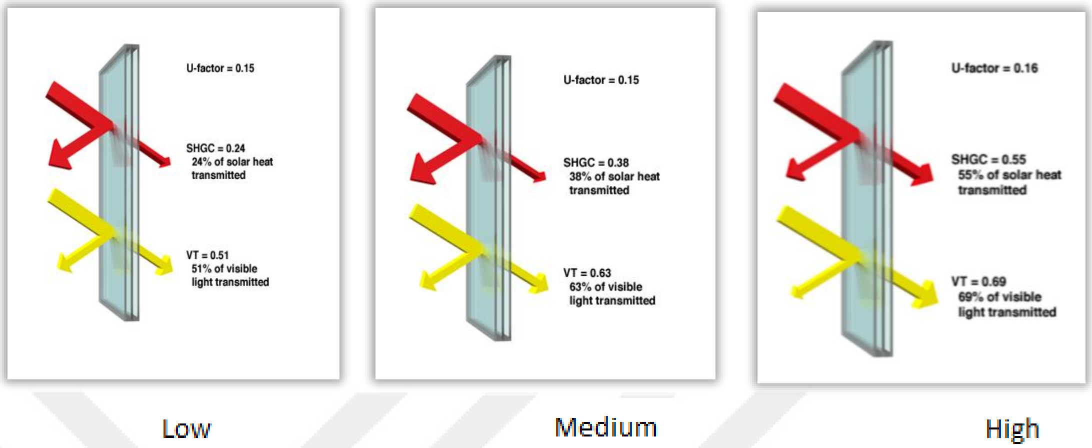


Figure 2.3: Triple glazing (Low, medium, high,) solar gain respectively, Low-Edesign. (Efficient Window 2019).

Table 2.5: Performance parameters of various triple glazing, Low-Etypes for windows (Efficient Window 2019). (where SHGC is solar heat gain coefficient, VT is visible transmittance) (Efficient Window 2019).

Glazing type	**U- value (W/m^2. k)**	**SHGC**	**VT**
Double glazing high solar gain, Low-Eglass	**0.24**	**0.38**	**0.70**
Double glazing, moderate solar gain, Low-Eglass	**0.23**	**0.41**	**0.70**
Double glazing, low solar gain, Low-Eglass	**0.20**	**0.27**	**0.69**
Triple-glazing, High-solar-gain, Low-Eglass	**0.16**	**0.55**	**0.69**
Triple-glazing, medium-solar-gain, Low-Eglass	**0.15**	**0.38**	**0.63**
Triple-glazing, medium-solar-gain, Low-Eglass	**0.15**	**0.24**	**0.51**

The most popular glazing types in Turkey are six types (Showed in table), and these types have the properties of Providing heat control and energy efficiency and reducing heating costs. Although, do not compromise on natural day lighting and transparency. These glazing types could unsure maximum solar heat for the existing building. In cold climate, the heat inside the room is radiated equally through the elimination of window’s cold spots. Provides extremely high levels of protection against UV radiation over 68%. Low-Ecoating is applying on laminated glass to provide safety and security (Table-4). (Sisecam Low-EGlass 2019).

Table 2.6: Performance parameters of various (Double-Triple) glazing, Low-Etypes for windows**, Product (only available in Turkish market)** (Sisecam Low-EGlass 2019)**.**

Product (only available in Turkish market)	**Daylight**		**Solar Energy**		**Thermal Conductivity (U-value) W/m^2. k**	
	Transmittance	**Reflectance Outdoor**	**Solar Factor**	**Shading Coefficient**	**Dry Air**	**Argon**
Double clear float glass	**0.8**	**0.14**	**0.75**	**0.86**	**2.7**	**2.6**
Low-e, clear float glass	**0.79**	**0.12**	**0.55**	**0.64**	**1.3**	**1.1**
Clear float glass, Low-E	**0.78**	**0.11**	**0.6**	**0.69**	**1.3**	**1.1**
Laminated Low-e, clear float glass	**0.74**	**0.14**	**0.49**	**0.56**	**1.3**	**2.6**
Clear float glass, Laminated Low-e	**0.77**	**0.14**	**0.71**	**0.82**	**2.7**	**2.6**
Triple glazing. Low-e, clear float glass, Low-e	**0.69**	**0.14**	**0.47**	**0.55**	**0.7**	**0.6**

The disadvantages of existing Low-Ecoating are the reduction of indoor lighting and their high cost of production (X. Chen, Zhang, and Du 2019).

2.4. Energy performance evaluation

The development and advancement of building simulation tools had influenced the building design profession to a high extent. Modelling tools were now used by different members of the design team at various stages of design and construction process. Progression and simplification of modelling tools from the original primitive script-based programming language to more user- friendly graphical interfaces allow more people within the design team to understand and benefit from the tools. Programmed capabilities had been localized to an acceptable level, and a substantial number of tools with a broad range of functions were available today (Mostafavi, Farzinmoghadam, and Hoque 2015).

The newly developed green heat and humidity transfer model had integrated into the TRNSYS program to verify its dynamic performance along with the multi-zone building code. (Djedjig, Bozonnet, and Belarbi 2014). Analysis of different conversion mechanisms showed that foliage shading reduced surface temperature variation while passive evaporation ensured negative cooling when water availability was sufficient (Djedjig et al. 2012; Djedjig, Bozonnet, and Belarbi 2015).

Comprehensive field measurements were carried out before and after the renovation to be used as input data in the IDA ICE and to validate the results of the model. The internal temperature was expected with the maximum standard deviation of 0.4 centigrade during winter and annual thermal demand was in good agreement with the measurement (La Fleur, Moshfegh, and Rohdin 2017).

Building shape coefficient and the heat transfer coefficient of the building envelope, using DEST energy simulation software had analyzed the office building energy consumption. Choosing the typical cold region Shenyang, establishing the

Office model, analysis the influence of office building envelops heat transfer coefficient to indoor equipment energy consumption. Pointing out that the architectural design and planning should try to select the building bottom shape close to a circle or a square, and try to select middle-high-rise buildings to reduce building shape coefficient. Generally, in cold region the heat transfer coefficient 0.5 W/m2. K, the windows and roofs try to select low heat transfer coefficient material, by reducing the heat transfer coefficient to achieve an insulating effect. (Feng, Sha, and Xu 2016).

Evaluated envelope retrofit as a tool to decrease reliance on air conditioning units in hot arid climates. Energyplus was used to model an apartment block in Cairo and analyze its energy performance. Retrofit through glazing improvement had evaluated in relation to cooling load and carbon emissions. Envelope retrofit as a part of a plan to empower energy efficiency in Egypt and hot arid countries.(Edeisy and Cecere 2017).

There are many simulation tools provided developing different models used to simulate and improve renewable energy project. Each model has different characteristics that make it unique, such as user input and the accuracy of the results. There are some tools designed to give the possibility of a quick test in advance. Some can give a model improved showing specifically the renewed resource that must be installed type. However, each common goal is to provide useful information for the work in the field of renewable energy (Tozzi and Jo 2017).

- Green Building studio

Autodesk GBS is a web-based building carbon and energy analysis service that performs hourly simulations on remote servers according to building geometry and exposure information imported from Autodesk Revit, location and type of use provided by the user, and additional external data such as weather data files. It provides estimations for annual/lifecycle energy cost/consumption, peak electric demand and CO_2 emissions based upon on-site fuel consumption and fuel source for electrical energy. Its projects water use/cost as well as estimated energy breakdowns for end use gas and electricity consumption by HVAC and lighting systems in a graphical format.

The design of the building begins with the start-up phase and follows the digital representation of the design program in order to obtain a real approach to the final construction product. Building Information Modeling (BIM) tools provide digital models closer to reality. During this digital process, information can be managed throughout the full life cycle of the project through a collaborative environment provided by BIM methodologies and tools. the reliability and flexibility of energy analysis using BIM-based simulations (with Revit® and Green Building Studio Autodesk®) (Nmr 2017).

Autodesk® Green Building Studio is a flexible cloud service that lets designer run building performance simulations to improve energy efficiency and work towards carbon neutrality early in the design process. it is a web-based energy analysis program that can help architects and designers to fully analyze the building, improve energy efficiency, and work on carbon neutrality early in the design process. This simulation tool can be used as a stand-alone Web service. It also operates full power analysis tools in Autodesk Revit. Rapid response surface creation method to optimize window geometry using dynamic daylighting simulation and energy simulation (Ward and Rubinstein 2013).

- Design builder

This tool offers advanced design and measure the performance of the building in an easy-to-use interface. This allows to use the same program to develop ergonomic and energy-saving buildings designs quickly from concept to finish up the construction process. Therefore, the Design-Builder integrated package provides a completely high-productivity tool to help in building design and analysis of sustainable performance. It provides many types of energy analysis procedures for the same model, allowing to meet more customer needs and to extract the maximum value from the time of the investigation (DesignBuilder 2019).

- Building Energy Asset

It provides an asset-point assessment of the target energy efficiency of the building envelope (roof, walls, and windows) and home power systems associated with it (such as lighting, hot water, and air conditioning systems). These physical and structural elements have a significant impact on how we use energy efficiency inside the building regardless of how to operate in the building or the behavior of its occupants. Make it easier for the original operating variables and the degree of occupancy, and do not require users to collect energy consumption data (Building Energy Asset Score 2019).

- ESP-r

ESP-r is an integrated program to simulate energy for integrated modeling of the performance of energy in buildings. The primary application of the program is to support researchers who do detailed studies, but it is also used in the teaching and practice of design, it has been included in a number of intensive design tools (such as inventory) modeling. You can simulate the flows of energy, air, humidity, light, and electric power when the spatial and temporal precision is specified by the user. ESP-r has a number of developers all over the world and is distributed under the management GitHub control in the source code. Moreover, the system is provided at no cost under an open source license. I have undergone many verifications of integrated environmental assessment and the European Commission projects (ESP-r 2019).

CHAPTER 3

METHODOLOGY

3.1. Introduction

This section describes the research methodology that will be used to achieve the objectives of this research by gathering the required energy efficiency data for the existing buildings to obtain the best results and reliable conclusion. It is well known that research methodology is an important part of the research.

All the activities related to the research could be effectively achieved, if the research methodology was established correctly, including data collection and evaluation and creating reliable results. Methodologies are considered to be scientific and ultimately help to develop the research and to accomplish the objectives of the research. It is worth mentioning that methodologies have more than one side. These include theoretical procedures, statistical approaches, numerical plans, experimental work, and other aspects. Therefore, the methodology of research allows the researcher to be productive without systematically satisfying the proposed aims of the research. Thus, this chapter presents the research methodology, the research design, the data gathering, the technique for the analysis, and the related issues of the sampling approach.

3.2. Building overview and energy efficiency measurements

The existing building (Çorum Ticaret ve Sanayi Odası) selected in this research is located in the Çorum city in Turkey. The Çorum state is located in northern Turkey near the black sea. It is bordered to the north by the provinces of Sinop and Kastamonu and to the east by Samsun and Amasya. While to the south is Yuzgat and in west Kirikale and Cankiri. The çorum city is the center of the province and it is associated with its historical character. Its continental climate is hot dry in summer and very cold in winter.

Table-3.1: Showing climate data for Çorum.

Climate data for Çorum [hide]

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Average high °C (°F)	4.2 (39.6)	6.2 (43.2)	11.6 (52.9)	17.4 (63.3)	22.0 (71.6)	25.9 (78.6)	29.0 (84.2)	29.3 (84.7)	25.6 (78.1)	19.7 (67.5)	12.6 (54.7)	6.4 (43.5)	17.5 (63.5)
Daily mean °C (°F)	−0.4 (31.3)	0.9 (33.6)	5.1 (41.2)	10.5 (50.9)	14.8 (58.6)	18.5 (65.3)	21.1 (70.0)	21.0 (69.8)	17.0 (62.6)	11.8 (53.2)	5.9 (42.6)	1.9 (35.4)	10.7 (51.2)
Average low °C (°F)	−4.3 (24.3)	−3.7 (25.3)	−0.6 (30.9)	3.8 (38.8)	7.3 (45.1)	10.2 (50.4)	12.4 (54.3)	12.3 (54.1)	9.0 (48.2)	5.2 (41.4)	0.7 (33.3)	−1.9 (28.6)	4.2 (39.6)
Average precipitation mm (inches)	38.4 (1.51)	30.4 (1.20)	37.8 (1.49)	52.6 (2.07)	60.2 (2.37)	54.3 (2.14)	20.3 (0.80)	14.4 (0.57)	22.7 (0.89)	29.9 (1.18)	36.6 (1.44)	47.2 (1.86)	444.8 (17.52)
Average rainy days	11.7	10.7	11.7	12.9	13.9	10.3	4.3	3.2	4.7	7.8	9.0	11.8	112
Mean monthly sunshine hours	77.5	98	151.9	186	238.7	273	316.2	313.1	252	176.7	111	65.1	2,259.2

Çorum has a warm with dry summers and cold, snowy winters, and mild to cool wet springs and autumns with light rain ((Çorum Weather) 2019).

Çorum's coordinates (40,34) and it is approximately 244 km (152 mi) from Ankara and 608 km (378 mi) from Istanbul. The city has an elevation of 801 m (2,628 ft) above sea level, a surface area of 12,820 km^2 (4950 mi^2), and as of the 2016 census, a population of 237,000.

The existing building (Çorum Ticaret ve Sanayi Odası) is the typical case to study because its windows are made of single glass type, so it is consuming a high level of energy. This building was built up at 2011, and it has been used since 2012. The land area is 3640 m^2, and the building has two floors and basement with total area of 9,692 m².

The basement of the building has floor thickness of 80 cm made of cast iron, ceramic adhesive, water isolation, protection concrete layer. Blinding layer, walls of this basement is 20 cm cast iron. The net height is 330 cm, and its roof is made of cast iron with thickness of 20 cm. (figure:3.1-A, B)

The ground floor of the building is made of furnished backing bricks ground with thickness of 50 cm and covered by granites layer. Outer glazing curtain walls are surrounding the ground floor and supported with reinforce concert columns. The net height of this floor is 376 cm. This floor has a secondary roof consisting with gab of 104 cm from ceiling. (figure:3.2-A, B)

The ground of the first floor is furnished with 12 cm of epoxy layer. The net height of this floor is 380 cm, and has secondary roof consisting of Epoxy partitions hung with gab of 104 cm from ceiling. Ceiling of this building is made three layers, the first layer is 20cm reinforce concrete, the second layer is consisted of standard checkered plate covered with thin layer of concert, the outer layer of the ceiling is made of carvel with suitable slopping. The first floor is surrounded with glazing curtain walls which is supported with reinforce concert columns. (figure:3.3-A, B)

A

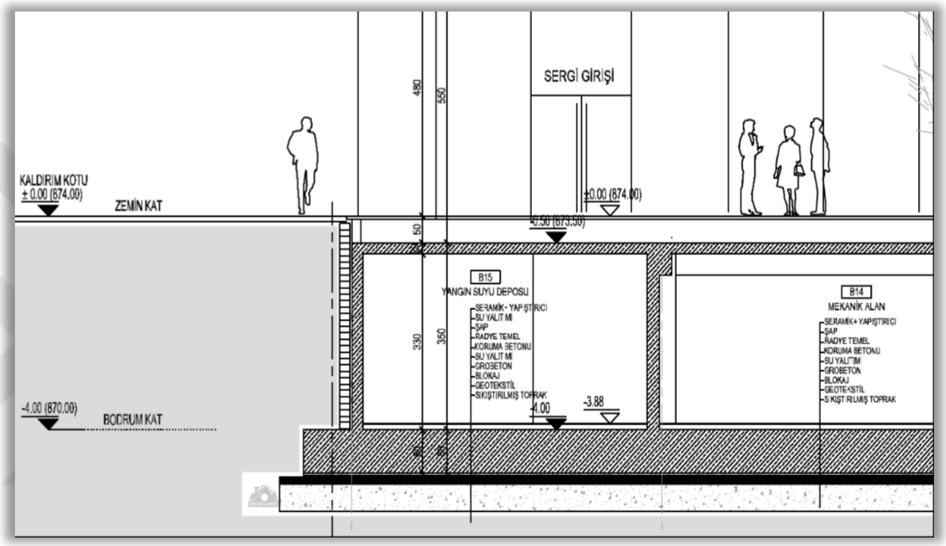


Figure:3.1-A, B: Basement side section.

Basement floor consisting of thickness of 80 cm made of cast iron, ceramic adhesive, water isolation, protection concrete layer. blinding layer, the walls of this basement is 20 cm cast iron. The net height is 330 cm, and its roof is made of cast iron with thickness of 20 cm.

B

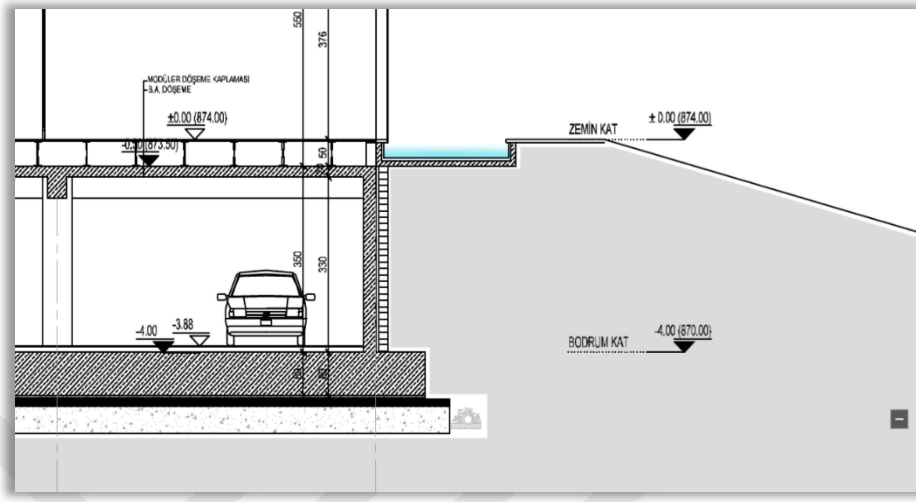


Figure:3.1-A, B: Basement another side section.

Basement floor consisting of thickness of 80 cm made of cast iron, ceramic adhesive, water isolation, protection concrete layer. blinding layer, the walls of this basement is 20 cm cast iron. The net height is 330 cm, and its roof is made of cast iron with thickness of 20 cm.

A

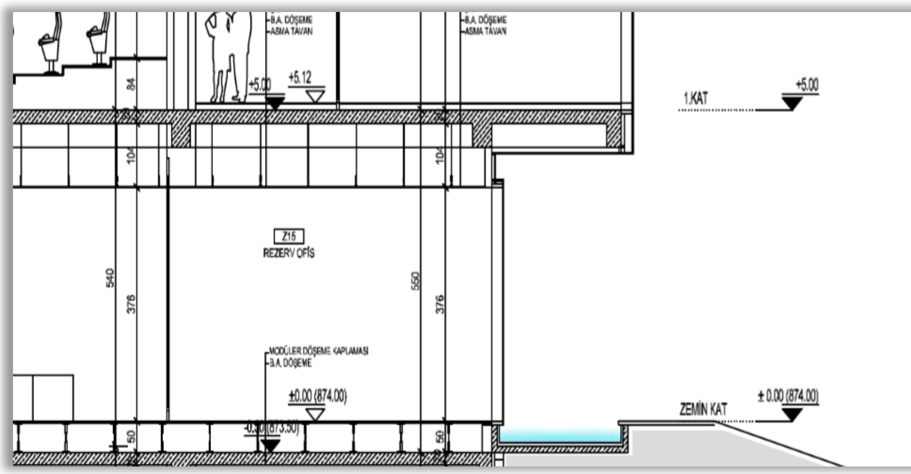


Figure:3.2-A, B: Ground floor side section

Ground floor consisting of furnished modular flooring ö backing bricks ground with thickness of 50 cm. Outer glazing curtain walls are surrounding the ground floor and supported with reinforce concert columns. The net height of this floor is 376 cm. This floor has a secondary roof with gab of 104 cm from ceiling.

B

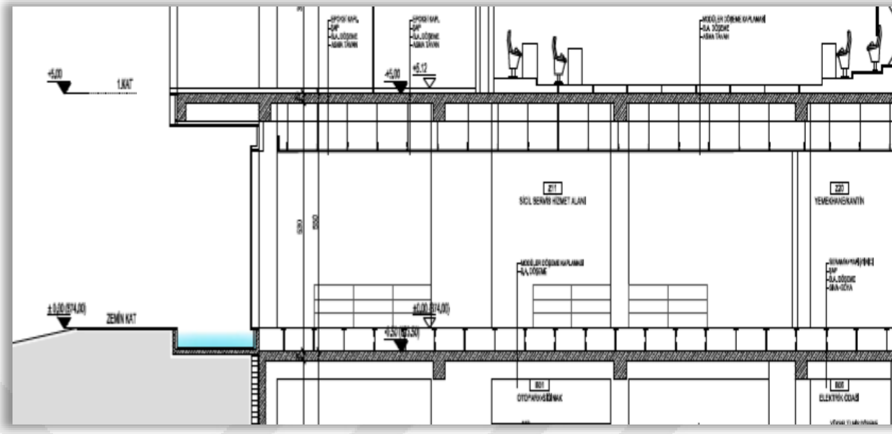


Figure:3.2-A, B: Ground floor another side section

Ground floor consisting of modular flooring, furnished backing bricks ground with thickness of 50 cm and covered by granites layer. Outer glazing curtain walls are surrounding the ground floor and supported with reinforce concert columns. The net height of this floor is 376 cm. This floor has a secondary with gab of 104 cm from ceiling.

A

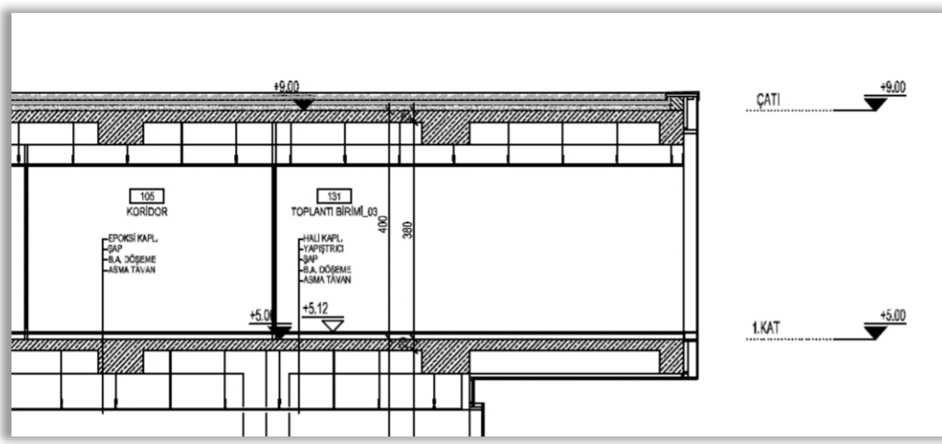


Figure:3.3-A, B: First floor side section

First floor furnished with 12 cm of epoxy layers. The net height of this floor is 380 cm, and has secondary roof with gab of 104 cm from ceiling. Ceiling of this building is made three layers, the first layer is 20cm reinforce concrete, the second layer is consisted of standard checkered plate covered with thin layer of concert, the outer layer of the ceiling is made of carvel with suitable slopping. The first floor is surrounded with glazing curtain walls which is supported with reinforce concert columns.

B

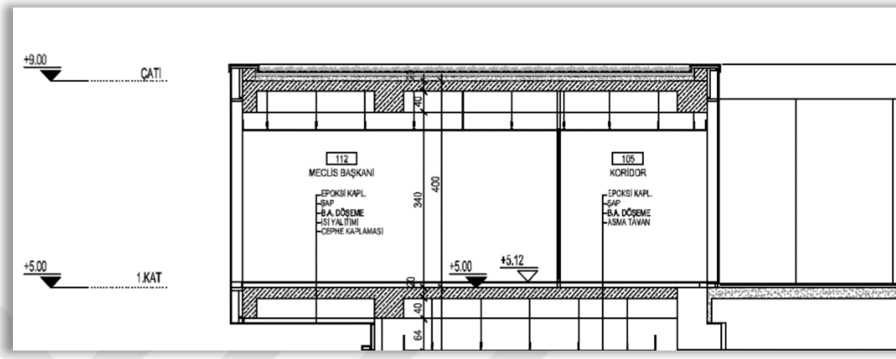


Figure:3.3-A, B: First floor another side section

First floor furnished with 12 cm of epoxy layer. The net height of this floor is 380 cm, and has secondary roof consisting of Epoxy partitions hung with gab of 104 cm from ceiling. Ceiling of this building is made three layers, the first layer is 20cm reinforce concrete, the second layer is consisted of standard checkered plate covered with thin layer of concert, the outer layer of the ceiling is made of carvel with suitable slopping. The first floor is surrounded with glazing curtain walls which is supported with reinforce concert columns.

Figure.3.4: Existing building is represented by render program.

Figure.3.5: Existing building is represented by render program, another outside direction.

Figure.3.6: Existing building is represented by render program, another outside direction.

3.2.1. Modelling the building for initial energy consumption

Based on the above description, the data was modeled by program (Autodesk-Revit), then Simulated by (Green building studio) to calculate the initial quantities of energy consumption of the existing building. The initial amounts of energy consumption of the existing building are explained with the following charts.

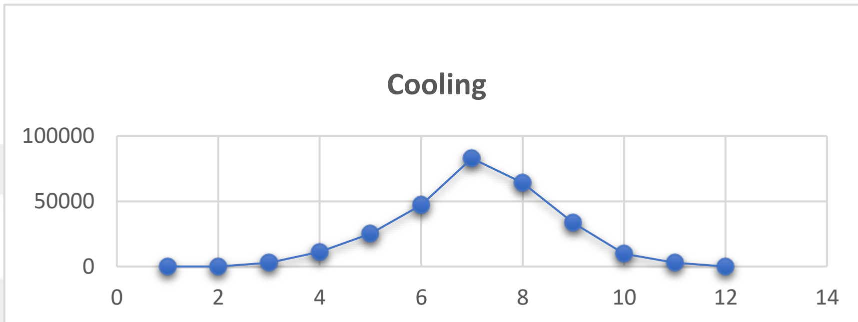


Figure 3.7: Annual initial electricity consumption for cooling. KWH.

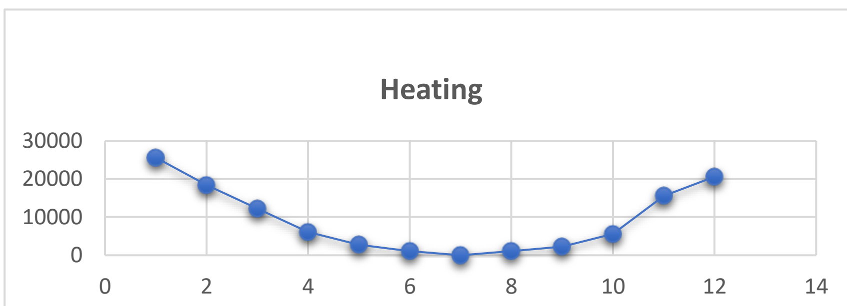


Figure 3.8: Annual initial electricity consumption for heating. KWH.

3.3.Energy-efficient envelope system

Different envelope measures had required for different climatic zones. Energy-efficient building envelope should be focusing on building's response to the exterior environment, i.e. Getting most maximum benefit from the local climatic conditions. In hot-humid climate, characteristics of high-performance envelopes include allowing daylight to enter the building, preventing unwanted solar heat, and improving thermal resistance (Sang, Pan, and Kumaraswamy 2014).

Efficient glazing types measures aim to enhance natural lighting, reduce heat gain and reduce energy consumption to improve indoor environment quality. Heat rejection measures including solar and thermal control through advanced glazing. advanced glazing is an effective measure to save energy consumed by existing building and to improve indoor environmental quality.

Decisions regarding the appropriate glazing types also play a vital role in determining energy performance. Therefore, energy-efficient building envelope can be approved by glass types. It is useful and easy to change the glazing type of the building with different type of glazing, because this building has some kind of difficulty to change insulation system for its roof or walls.

3.3.1. Glazing system of building envelope

From the results (Heating-Cooling) mentioned previously and through the using of single glazing type in the existing building. And depending on, the U-value of this type (4.8 $W/m^2.K$) (Pilkington 2016), the amount of energy consumption of the existing building was presumed with high level. In order to reduce energy consumption of this building, it is useful and easy to change the glazing type of it with different type of glazing, the thermal insulating of walls or ceilings, of that building, rather than changing infrastructure of the building.

3.4. Different glazing types Selection for all orientations following TS 825.

According to the information that had been mentioned in literature review, the different types of glazing to be used are, double glazing-high solar gain- Low-e, double glazing- medium solar gain- Low-e, double glazing- low solar gain- Low-e, Triple glazing- high solar gain- Low-e, Triple glazing- medium solar gain- Low-e, and Triple glazing-low solar gain- Low-e. depending on TS 825.

“Therefore, the different types of glazing had been chosen depending on TS 825, that has said U-values need to be further strengthened in average by 10% for existing buildings to be renovated. In addition, the heat/cold bridge factors need be reduced from currently about 0.15 $W/(m^2.K)$ in existing buildings to 0.05 $W/(m^2.K)$

and 0.1 W/(m².K)" (U-Value maps Turkey TS825 2016). Thus, U-value ranges of different glazing types will be show in (Table: 3.2)

Table 3.2 : Performance parameters of various triple glazing, Low-Etypes for windows (Efficient Window 2019). (where SHGC is solar heat gain coefficient, VT is visible transmittance).

Glazing type	U- value ($W/m^2.\ k$)	SHGC	VT
Double glazing high solar gain, Low-Eglass	**0.24**	**0.38**	**0.70**
Double glazing, moderate solar gain, Low-Eglass	**0.23**	**0.41**	**0.70**
Double glazing, low solar gain, Low-Eglass	**0.20**	**0.27**	**0.69**
Triple-glazing, High-solar-gain, Low-Eglass	**0.16**	**0.55**	**0.69**
Triple-glazing, medium-solar-gain, Low-Eglass	**0.15**	**0.38**	**0.63**
Triple-glazing, medium-solar-gain, Low-Eglass	**0.15**	**0.24**	**0.51**

3.5.Energy efficiency indicators

Various types of energy indicators are required to operate its departmental services. Different types of energy indicators are normally used in existing building. These are electricity, natural gas, diesel fuel, liquefied petroleum gas, coal, etc. Electricity is the primary form of energy indicator used within building facilities. Electricity is used generally for air-conditioning, vertical transportation lifts, heating, lighting, escalators and miscellaneous items including kitchen equipment, etc. (Önüt and Soner 2006). The most main form of energy indicator to be used within building facilities is electricity.

In order to obtain the estimated amount of energy consumption of this building after changing the glazing type and finding which orientation is better to change, the data was input in (Autodesk-Revit), and then the data was exported to (green building studio), for each suggested glazing types and different orientations. The best results for saving energy of this building as it will be found later by using of SPSS statistical program.

CHAPTER 4

RESULTS

There are several building envelope's components systems for an existing building, which differ in characteristic, strengths, and weakness. The building components can influence the identification of the best energy efficient for an existing building. Thus, this research aims to choose the most important component (glazing) that affect the high-quality of energy efficient for an existing building system for Turkey. Furthermore, six different glazing types shall be used for all orientations, and the results will be compared to determine the strengths and weakness of each of them. The six different glazing types that have been chosen are: double glazing-high solar gain- Low-e, double glazing- medium solar gain- Low-e, double glazing- low solar gain- Low-e, Triple glazing- high solar gain- Low-e, Triple glazing- medium solar gain- Low-e, and Triple glazing-low solar gain- Low-e. depending on TS 825. These six different glazing types were chosen due to the fact that they are the most common glazing, and most widely used around the world. In addition to providing a clarification of the most important glazing type for energy reduction, as well as creating a higher opportunity for energy efficient of an existing building in Turkey. Encouraging the adopting of suitable glazing type for future energy efficiency development in Turkey.

A comprehensive research was conducted on the most relevant case study in Turkey. The existing building (Çorum Ticaret ve Sanayi Odası) has been chosen, this is represented comprehensive views of the evaluation energy efficient of an existing building in Turkey.

3.6. Analysis the building physical for energy consumption

The building (Çorum Ticaret ve Sanayi Odası) is a typical three-storey office building with the land area of 3.640 m^2, consists of two floors and basement with total area 9,692 m². The building has HAVC system. The surface breakdown and geometric characteristics of the building are given in (Table-4.1).

Table-4.1: The building (Çorum Ticaret ve Sanayi Odası)'s surface breakdown and basic geometric characteristics.

Parameter	Value
Total area (m^2)	9692
Exterior surface (m^2)	6836
Total glazing area (m^2)	2532
Exterior area in contact to earth (m^2)	900
Exterior area in contact with ambient air (m^2)	
(a) Exterior wall	664
(b) Glazing area	2532
(c) Roof	3640
Building volume (m^3)	125996
Area to volume ratio (m^{-1})	0.077
Glazing to exterior surface ratio	0.37

3.7.Autodesk Revit model

The Autodesk Revit model of building (Çorum Ticaret ve Sanayi Odası) that is used for energy analysis is shown in (Figure 4.1). Three different plans are drawn for the basement, ground floor and first floor. The structure, interior walls (two type- reinforce concert, curtain glass wall), exterior walls (one type- reinforce concert), glazing and door types are inserted into the model based on the original drawings. Six different glazing types will be changing several times depends on them U-value, and in order to used six different glazing types for each orientation (Figure 4.3). Enabling connection between the Revit model and energy modelling tool (GBS), different zone are defined and spaces based on activity type. For every single zone construction and condition type, design heating and cooling loads, and electrical loads calculation work plane are entered using the software interface. Below the analyses process, in the energy setting section, the HVAC system are clarified. Later, the model is ready to be exported to Green Building (gbXML) file for energy analysis (Figure 4.2).

Figure 4.1. Model (Çorum Ticaret ve Sanayi Odası)'s geometry drawn by Autodesk Revit.

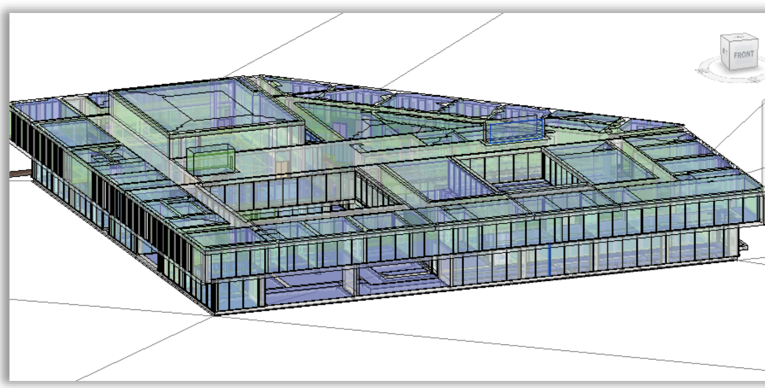


Figure 4.2. Energy modeling for gbXML format of the building (Çorum Ticaret ve Sanayi Odası).

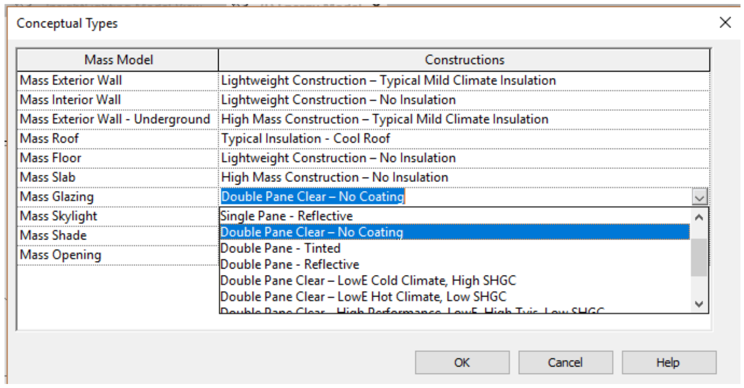


Figure 4.3. Format of the building (Çorum Ticaret ve Sanayi Odası) for selection glazing types.

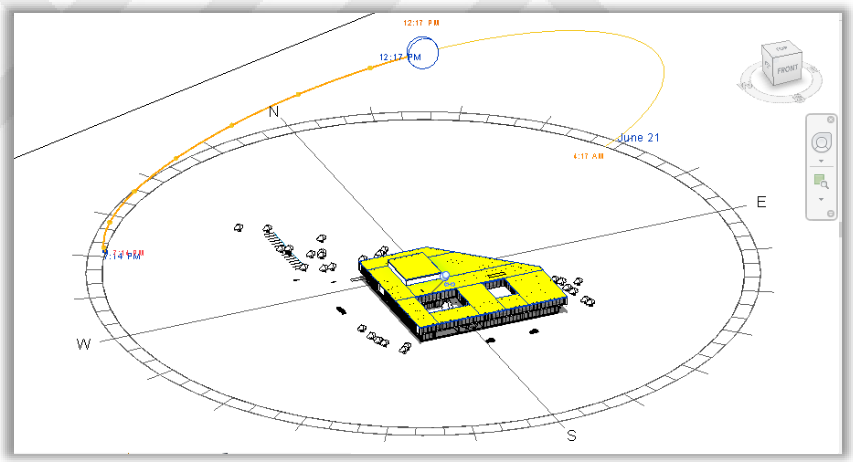


Figure 4.4. Sun path of the building of Çorum Ticaret ve Sanayi Odası.

In order to extract the multi (gbXML) file to GBS, sun path shell be set for several sun path in one day for results depending on the methods used in obtaining the reports data.

3.8.Green Building Studio (GBS) simulation

For the next step, the weather station and location for the analysis are set to be reliable with the weather data used in the Revit model. Other parameters such as construction details, zone groups, building system and heating and cooling were required to be entered as they already exist in the gbXML file. The results for initial energy consumption of baseline case simulation are shown in Figure 4.5-4.6. As there is no detailed scheduling option to define different seasons and occupancy changes to calibrate the baseline model for electricity, data for all months have been taken. The model accurately predicts the electricity consumption for the other 12 months.

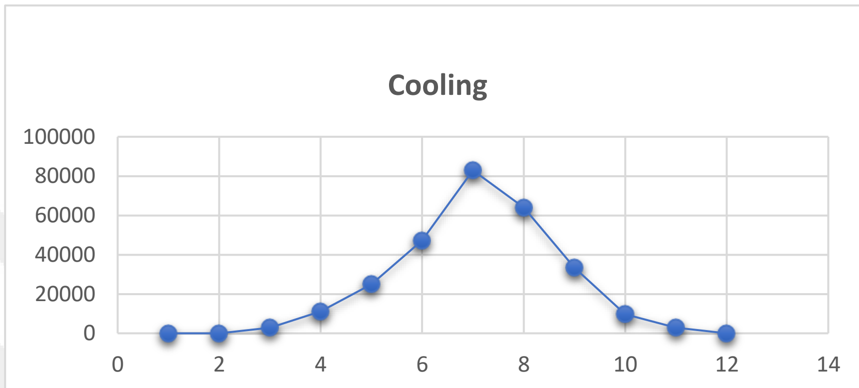


Figure 4.5: Initial electricity consumption for cooling annually (279110.5 KW).

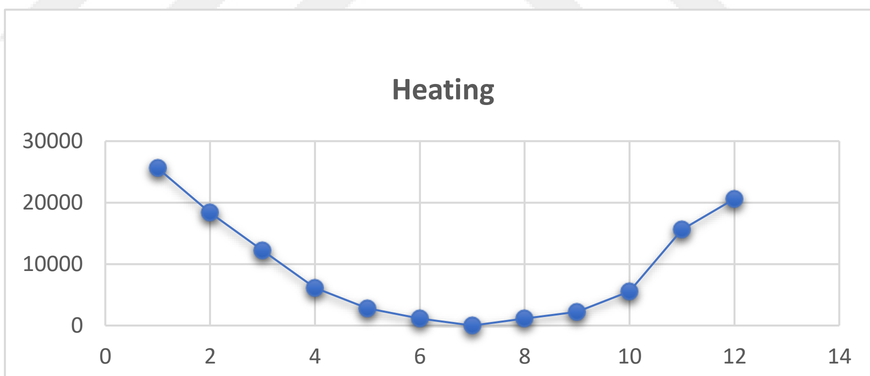


Figure 4.6: Initial electricity consumption for heating annually (111310.3 KW).

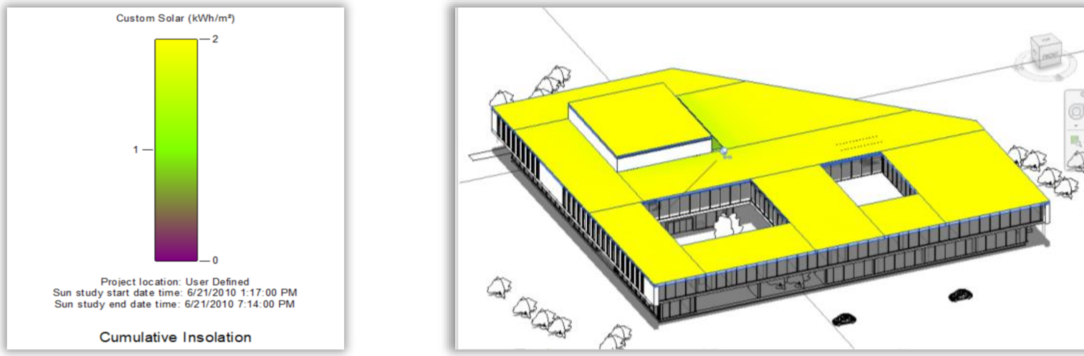


Figure 4.7: Radiation of Sun path exposure on the building (Çorum Ticaret ve Sanayi Odası).

3.9.Evaluation each different glazing types used for all orientations and each single orientation.

In order to obtain the final results of the energy consumption of existing building, a simulation program was used for this purpose, and the report obtained would provide estimated results of energy consumption monthly and annually. The report was depending on the changing of the glazing type in all orientation of the building and then compared with the multi-complex orientations. There are six types of glazing (Double glazing high solar gain, Low-e. Double glazing medium solar gain, Low-e. Double glazing low solar gain, Low-e. Triple glazing high solar gain, Low-e. Triple glazing medium solar gain, Low-e. Triple glazing low solar gain, Low-e), and these types were used for all orientations and also were used for each orientation. The estimated results were compared with initial energy consumption (Heating- cooling) of existing building. Aiming to find the most accurate results Statistical Package for the Social Sciences (SPSS) was used to analyze and compare the most suitable type of glazing and best orientation to reduce the amount of energy (Cooling-Heating).

Table (4.2): The arithmetic mean (Mean) value of energy consumption (KW/month).

Initial Power consumption KW/month Cooling 23259.2 Heating 9275.85	All directions	South	North	East	West
	Mean	Mean	Mean	Mean	Mean
Double, HSG, Low-e \Cooling	9768.867	16514.038	21572.915	20561.140	18874.847
Double, HSG, Low-E\Heating	3895.859	6585.857	8603.356	8199.856	1352.500
Double ,MSG, Low-e\Cooling	9303.683	16281.445	21514.767	20468.103	18723.662
Double, MSG, Low-e\Heating	3710.342	6493.099	8580.166	8162.753	1341.667
Double, LSG, Low-e\Cooling	8140.723	15699.965	21369.397	20235.511	18345.700
Double, LSG, Low-e\Heating	3246.549	6261.203	8522.192	8069.994	1314.583
Triple, HSG ,Low-e\Cooling	6512.578	14885.893	21165.879	19909.882	17816.553
Triple, HSG ,Low-e\Heating	2597.240	5936.548	8441.029	1426.667	1276.667
Triple, MSG, Low-e\Cooling	5814.802	14537.005	21078.657	19770.327	17589.776
Triple, MSG, Low-e\Heating	2318.964	5797.410	8406.244	1416.667	1260.417
Triple, LSG, Low-e\Cooling	4651.842	13955.525	20933.287	19537.735	17211.814
Triple, LSG, Low-e\Heating	2212.292	5565.513	8348.270	1400.000	1233.333

Where HSG=high solar gain, MSG=medium solar gain and LSG=low solar gain

Table (4.2) is clarifying compression of arithmetic mean of energy consumption related to initial power, glazing types and all orientation, and shows a comparison between the initial energy consumption (heating-cooling) and the results which calculated after the changing of glazing types in all orientation. The lowest amount of energy consumption appeared to be with the changing of glazing type using (Triple, LSG, Low-e) in all orientation. While the lowest energy consumption was obtained after the changing of glazing types in two orientations (south and west).

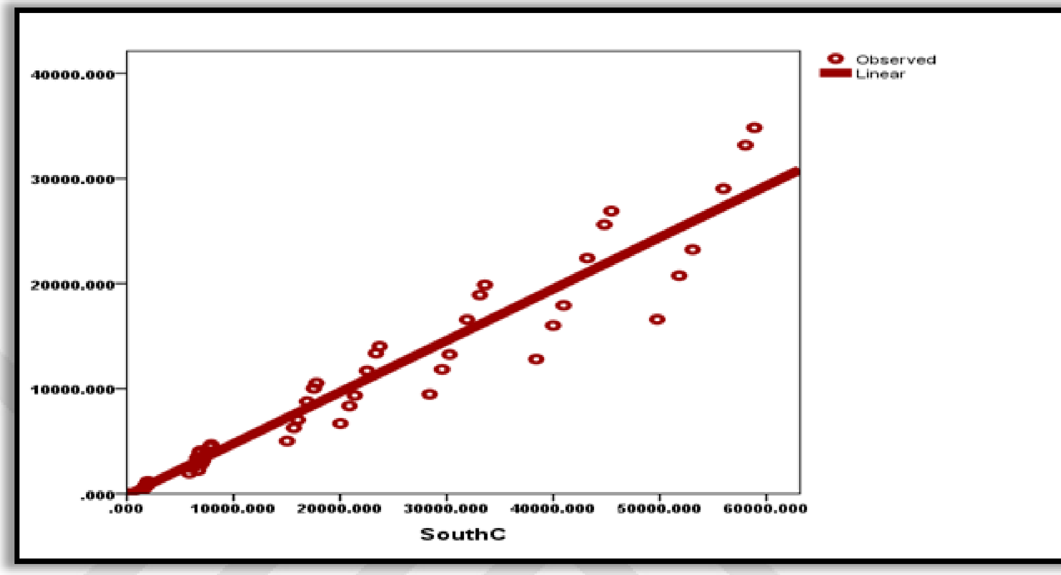


Figure 4.8: South orientation's equation for cooling (y = -147.981 + 0.491x)

Figure (4.8) is clarifying south orientation of energy consumption cooling, the X axis is represented imaginary energy consumption that got from simulation program, and Y axis shows the actual energy consumption (cooling).

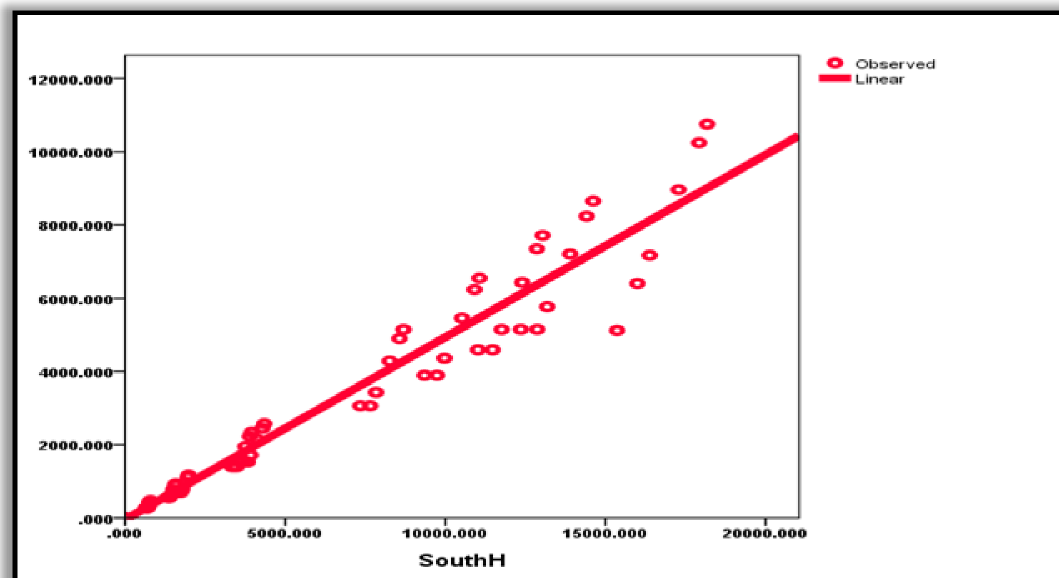


Figure 4.9: South orientation's equation for heating (y = - 44.355+ 0.498 x)

Figure (4.9) is clarifying south orientation of energy consumption for heating, the X axis is represented imaginary energy consumption that got from simulation program, and Y axis shows the actual energy consumption (heating).

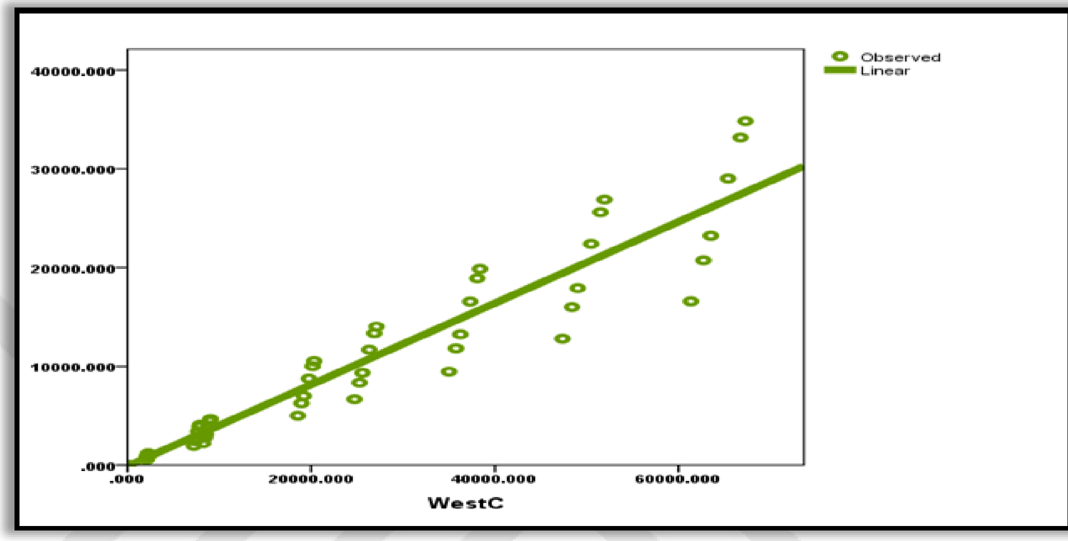


Figure 4.10: West orientation's equation for cooling (y = -93.414+ 0.412 x).

Figure (4.10) is clarifying west orientation of energy consumption for cooling, the X axis is represented imaginary energy consumption that got from simulation program, and Y axis shows the actual energy consumption (cooling).

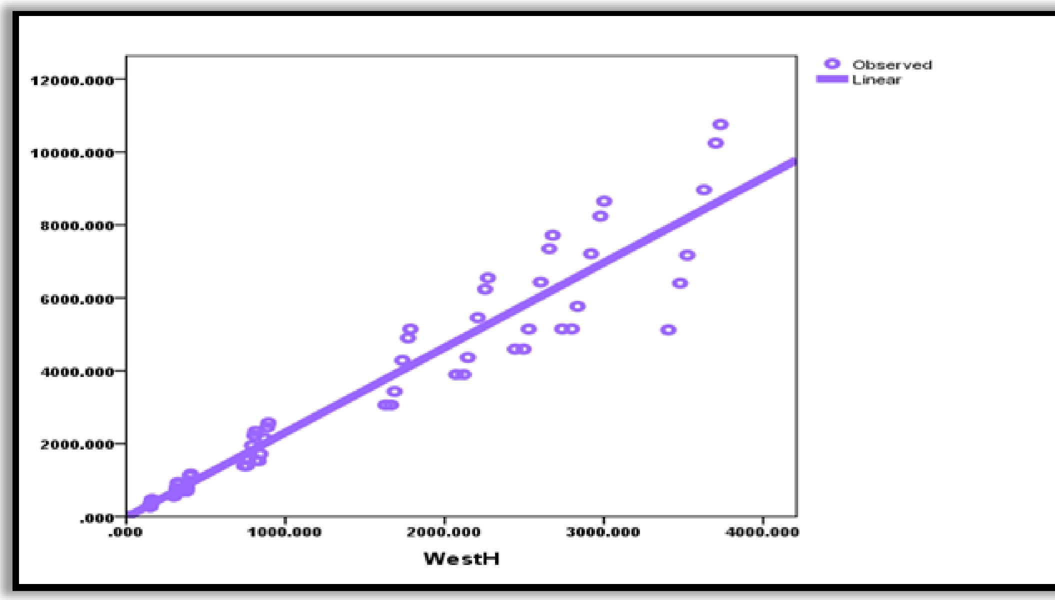


Figure 4.11: West orientation's equation for heating (y = - 21. 634 + 2.328 x)

Figure (4.11) is clarifying west orientation of energy consumption for cooling, the X axis is represented imaginary energy consumption that got from simulation program, and Y axis shows the actual energy consumption (heating).

Table (4.3): The arithmetic mean (Mean) value of energy consumption of multi orientations (KW/month).

Initial Power consumption KW/month Cooling 23259.2 Heating 9275.85	S.N	S.E	S.W	N.E	N.W	E.W
	Mean	Mean	Mean	Mean	Mean	Mean
Double, HSG, Low-e \Cooling	14827.745	13815.969	12129.677	18874.847	17188.555	16176.779
Double, HSG, Low-E\Heating	1062.500	990.000	869.167	1352.500	1231.667	1159.167
Double ,MSG, Low-e\Cooling	14537.005	13490.341	11745.900	18723.662	16979.222	15932.557
Double, MSG, Low-e\Heating	1041.667	966.667	841.667	1341.667	1216.667	1141.667
Double, LSG, Low-e\Cooling	13810.1546	12676.268	10786.458	18345.700	16455.890	15322.003
Double, LSG, Low-e\Heating	989.583	908.333	772.917	1314.583	1179.167	1097.916
Triple, HSG ,Low-e\Cooling	12792.564	11536.567	9443.238	17816.553	15723.224	14467.227
Triple, HSG ,Low-e\Heating	916.667	826.667	676.667	1276.667	1126.667	1036.666
Triple, MSG, Low-e\Cooling	12356.454	11048.124	8867.573	17589.776	15409.225	14100.895
Triple, MSG, Low-e\Heating	885.4167	791.667	635.417	1260.417	1104.167	1010.417
Triple, LSG, Low-e\Cooling	11629.604	10234.052	7908.131	17211.814	14885.893	13490.341
Triple, LSG, Low-e\Heating	833.333	733.333	566.667	1233.333	1066.667	966.667

Table (4.3) is clarifying compression of arithmetic mean of initial energy consumption (Heating -cooling) and its values after the changing of glazing types in multi orientation such as (south, North), (South, East) …. etc. The best results were obtained with the changing was in the (South-West) orientation. Triple, LSG, Low-Eglazing type exhibited the best reduction of energy consumption of existing building.

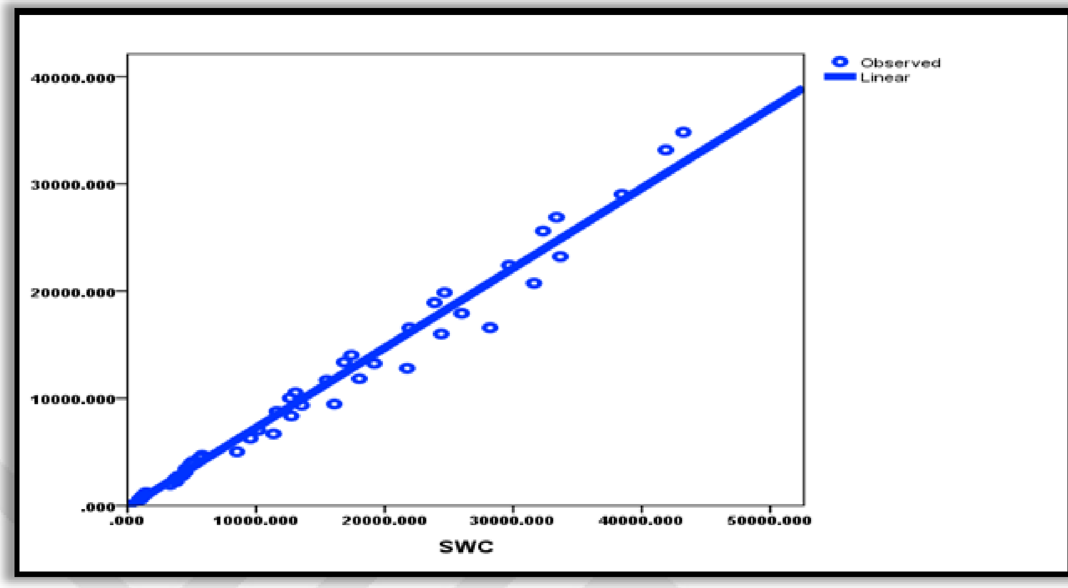


Figure 4.12: South-West orientation's equation for cooling (y = -188.384+ 0.744 x)

Figure (4.12) is clarifying (South-West) orientation of energy consumption for cooling, the X axis is represented imaginary energy consumption that got from simulation program, and Y axis shows the actual energy consumption (cooling).

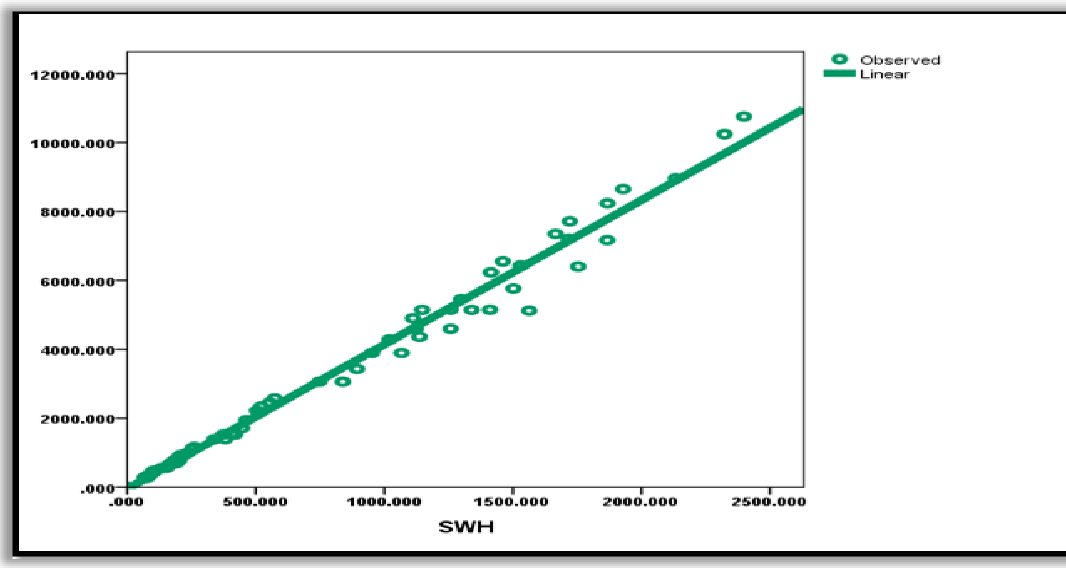


Figure 4.13: South-West orientation's equation for heating (y = - 48.679 + 4.189 x)

Figure (4.13) is clarifying (South-West) orientation of energy consumption for cooling, the X axis is represented imaginary energy consumption that got from simulation program, and Y axis shows the actual energy consumption (heating).

Table (4.4): The arithmetic mean (Mean) value of energy consumption of complex orientation (KW/month)

Initial Power consumption KW/month Cooling 23259.2 Heating 9275.85	E.S.W	E.S.W	E.N.W	S.E.N	S.W.N
	Mean	Mean	Mean	Mean	Mean
Double, HSG, Low-e \Cooling	10780.643	10780.643	14490.486	12129.677	10443.384
Double, HSG, Low-E\Heating	772.500	772.500	1038.333	869.167	748.333
Double ,MSG, Low-e\Cooling	10350.347	10350.347	14188.117	11745.900	10001.459
Double, MSG, Low-e\Heating	741.667	741.667	1016.667	841.667	716.667
Double, LSG, Low-e\Cooling	9274.609	9274.609	13432.195	10786.458	8896.647
Double, LSG, Low-e\Heating	664.583	664.583	962.500	772.917	637.500
Triple, HSG ,Low-e\Cooling	7768.575	7768.575	12373.899	9443.238	7349.910
Triple, HSG ,Low-e\Heating	556.667	556.667	886.667	676.667	526.667
Triple, MSG, Low-e\Cooling	7123.132	7123.132	11920.344	8867.573	6687.022
Triple, MSG, Low-e\Heating	510.417	510.417	854.167	635.417	479.167
Triple, LSG, Low-e\Cooling	6047.394	6047.394	11164.420	7908.131	5582.210
Triple, LSG, Low-e\Heating	433.333	433.333	800.000	566.667	400.000

Table (4.4) is clarifying compression of arithmetic mean of initial energy consumption (Heating -cooling) and its values after the changing of glazing types in complex orientation such as (East-South West), (East-North-West) …. etc. The best results were obtained with the changing occurred in the (South-West-North) orientation. Triple, LSG, Low-Eglazing type exhibited the best reduction of energy consumption of existing building.

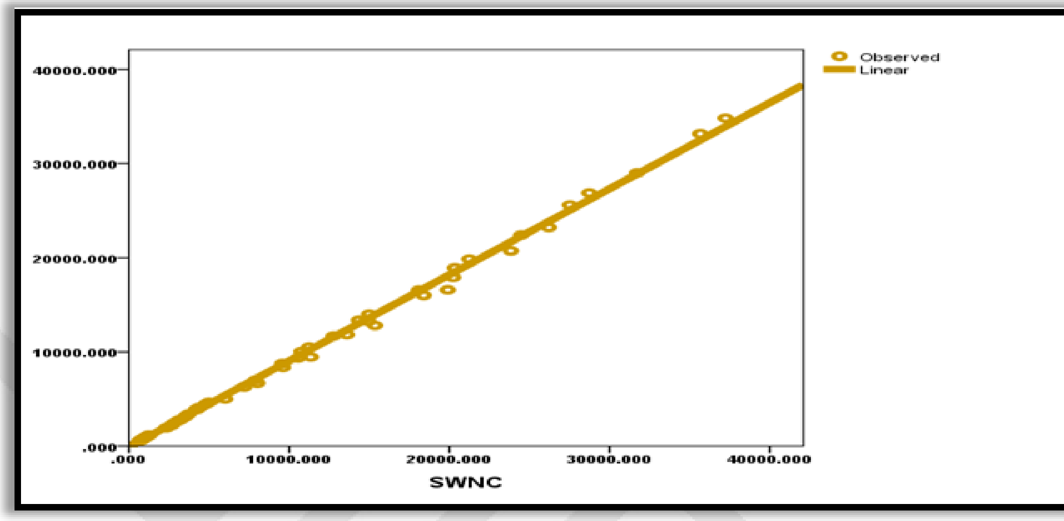


Figure 4.14: South-West-North orientation's equation for cooling (y = -92.138 + 0.914 x)

Figure (4.14) is clarifying (South-West-North) orientation of energy consumption for cooling, the X axis is represented imaginary energy consumption that got from simulation program, and Y axis shows the actual energy consumption (cooling).

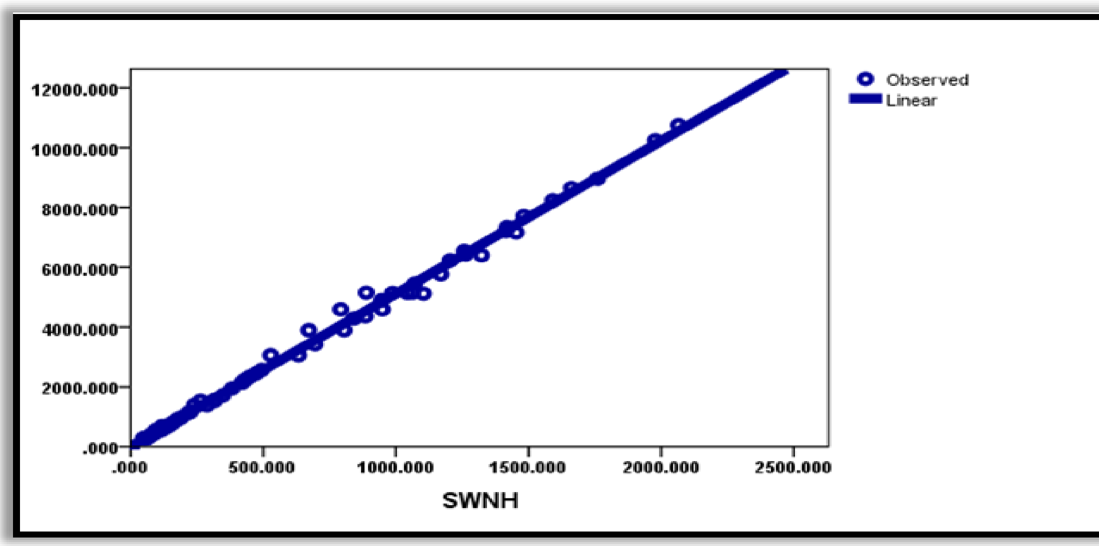


Figure 4.15: South-West-North orientation's equation for heating (y = 9.917 + 5.108 x)

Figure (4.15) is clarifying (South-West-North) orientation of energy consumption for cooling, the X axis is represented imaginary energy consumption that got from simulation program, and Y axis shows the actual energy consumption (heating).

Table (4.5): Mean Differences of energy consumption to all orientations (Cooling) and others orientation

Direction	Mean Differences	P-Value	**C.S**
All ***Ve*** South	-7946.896	.000	P<0.01 (HS)
All ***Ve*** North	-13907.068	.000	P<0.01 (HS)
All ***Ve*** East	-12715.034	.000	P<0.01 (HS)
All ***Ve*** West	-10728.310	.000	P<0.01 (HS)
All ***Ve*** SN	-5960.172	.000	P<0.01 (HS)
All ***Ve*** SE	-4768.136	.000	P<0.01 (HS)
All ***Ve*** SW	-2781.414	.000	P<0.01 (HS)
All ***Ve*** NE	-10728.310	.000	P<0.01 (HS)
All ***Ve*** NW	-8741.586	.000	P<0.01 (HS)
All ***Ve*** EW	-7549.551	.000	P<0.01 (HS)
All ***Ve*** ESW	-1192.034	.000	P<0.01 (HS)
All ***Ve*** ENW	-5562.827	.000	P<0.01 (HS)
All ***Ve*** SEN	-2781.413	.000	P<0.01 (HS)
All ***Ve*** SWN	-794.690	.000	P<0.01 (HS)

Table (4.5) is describing the compression of mean differences of energy consumption (cooling) after the changing of glazing types in all orientations with all different orientations. The best result was obtained with the changing occurred in the (South-West-North) orientation.

The results in table (4.5) declared that the mean difference of the results was highly significant for the changing of glazing types in all different orientations.

Table (4.6): Mean Differences of energy consumption to All direction (Heating)and others direction

Direction	Mean Differences	P-Value	C.S
All *Ve* South	-3109.731	.000	P<0.01 (HS)
All *Ve* North	-5486.669	.000	P<0.01 (HS)
All *Ve* East	-1782.449	.000	P<0.01 (HS)
All *Ve* West	1700.347	.000	P<0.01 (HS)
All *Ve* SN	2042.013	.000	P<0.01 (HS)
All *Ve* SE	2127.430	.000	P<0.01 (HS)
All *Ve* SW	2269.791	.000	P<0.01 (HS)
All *Ve* NE	1700.347	.000	P<0.01 (HS)
All *Ve* NW	1842.708	.000	P<0.01 (HS)
All *Ve* EW	1928.124	.000	P<0.01 (HS)
All *Ve* ESW	2383.680	.000	P<0.01 (HS)
All *Ve* ENW	2070.485	.000	P<0.01 (HS)
All *Ve* SEN	2269.791	.000	P<0.01 (HS)
All *Ve* SWN	-412.152	.000	P<0.01 (HS)

Table (4.6) is describing the compression of mean differences of energy consumption (heating) after the changing of glazing types in all orientations with all different orientations. The best result was obtained with the changing occurred in the (South-West-North) orientation.

The results in table (4.6) declared that the mean difference of the results were highly significant for the changing of glazing types in all different orientations.

Table (4.7): Limitation factor (R^2) of Direction (Cooling) All direction

Direction	R^2	P-Value	C.S
South	94.3	0.000	P<0.01 (HS)
North	90.9	0.000	P<0.01 (HS)
East	91.4	0.000	P<0.01 (HS)
West	92.5	0.000	P<0.01 (HS)
SN	95.8	0.000	P<0.01 (HS)
SE	96.8	0.000	P<0.01 (HS)
SW	98.5	0.000	P<0.01 (HS)
NE	92.5	0.000	P<0.01 (HS)
NW	93.7	0.000	P<0.01 (HS)
EW	94.6	0.000	P<0.01 (HS)
ESW	99.6	0.000	P<0.01 (HS)
ENW	96.1	0.000	P<0.01 (HS)
SEN	98.5	0.000	P<0.01 (HS)
SWN	99.8	0.000	P<0.01 (HS)

Table (4.7) is describing the compression of limitation factor (R^2) of energy consumption (cooling) after the changing of glazing types in all orientations with all different orientations. The best result was obtained with the changing occurred in the (South-West-North) orientation.

The results in table (4.7) declared that the mean difference of the results were highly significant for the changing of glazing types in all different orientations.

Table (4.8): Limitation factor (R^2) of Direction (Heating) All direction

Direction	R^2	P-Value	C.S
South	94.5	0.000	P<0.01 (HS)
North	90.7	0.000	P<0.01 (HS)
East	75.8	0.000	P<0.01 (HS)
West	92.8	0.000	P<0.01 (HS)
SN	96.0	0.000	P<0.01 (HS)
SE	97.0	0.000	P<0.01 (HS)
SW	98.7	0.000	P<0.01 (HS)
NE	92.5	0.000	P<0.01 (HS)
NW	93.9	0.000	P<0.01 (HS)
EW	94.8	0.000	P<0.01 (HS)
ESW	99.6	0.000	P<0.01 (HS)
ENW	96.4	0.000	P<0.01 (HS)
SEN	98.7	0.000	P<0.01 (HS)
SWN	99.9	0.000	P<0.01 (HS)

Table (4.8) is describing the compression of limitation factor (R^2) of energy consumption (heating) after the changing of glazing types in all orientations with all different orientations. The best result was obtained with the changing occurred in the (South-West-North) orientation.

The results in table (4.8) declared that the mean difference of the results was highly significant for the changing of glazing types in all different orientations.

Table (4.9): Mean Differences of energy consumption (Cooling)after changing Single glazing by others Glazing types

Glass	Mean Differences	P-Value	C.S
Single glazing *Ve* Double, HSG, Low-e	-3006.253	.000	P<0.01 (HS)
Single glazing *Ve* Double, MSG, Low-e	-2732.957	.000	P<0.01 (HS)
Single glazing *Ve* Double, LSG, Low-e	-2049.718	.000	P<0.01 (HS)
Single glazing *Ve* Triple, HSG ,Low-e	-1093.183	.000	P<0.01 (HS)
Single glazing *Ve* Triple, MSG, Low-e	-683.239	.000	P<0.01 (HS)
Single glazing *Ve* Triple, LSG, Low-e	-540.239	.000	P<0.01 (HS)

Table (4.9) is describing the compression of mean differences of energy consumption (cooling) after the changing of single glazing type by other glazing types. The best result was obtained with the changing of Single glazing *by* Triple, LSG, Low-e.

The results in table (4.9) declared that the mean difference of the results was highly significant for the changing of all glazing types.

Table (4.10): Mean Differences of single glazing (Heating) and others Glazing

Direction	R^2	P-Value	C.S
Double, HSG, Low-e	72.2	0.000	P<0.01 (HS)
Double, MSG, Low-e	72.2	0.000	P<0.01 (HS)
Double, LSG, Low-e	72.1	0.000	P<0.01 (HS)
Triple, HSG, Low-e	99.7	0.000	P<0.01 (HS)
Triple, MSG, Low-e	99.8	0.000	P<0.01 (HS)
Triple, LSG, Low-e	99.9	0.000	P<0.01 (HS)

Table (4.10) is describing the compression of mean differences of energy consumption (heating) after the changing of single glazing type by other glazing types. The best result was obtained with the changing of Single glazing *by* Triple, LSG, Low-e.

The results in table (4.10) declared that the mean difference of the results were highly significant for the changing of all glazing types.

Table (4.11): Limitation factor (R^2) of double glazing and triple glazing types (Cooling)

Direction	R^2	P-Value	C.S
Double, HSG, Low-e	96.6	0.000	P<0.01 (HS)
Double, MSG, Low-e	97.1	0.000	P<0.01 (HS)
Double, LSG, Low-e	98.3	0.000	P<0.01 (HS)
Triple, HSG, Low-e	99.5	0.000	P<0.01 (HS)
Triple, MSG, Low-e	99.8	0.000	P<0.01 (HS)
Triple, LSG, Low-e	99.9	0.000	P<0.01 (HS)

Triple, LSG, Low-e glazing type appeared to have the best limitation factor (R^2) (Table-4.11) among all others glazing types, for decreasing energy consumption (cooling)

Table (4.12): Limitation factor (R^2) of double glazing and triple glazing types (Heating)

Glass	Mean Differences	P-Value	C.S
Single glazing *Ve* Double, HSG, Low-e	-783.522	.000	P<0.01 (HS)
Single glazing *Ve* Double, MSG, Low-e	-746.580	.000	P<0.01 (HS)
Single glazing *Ve* Double, LSG, Low-e	-654.226	.000	P<0.01 (HS)
Single glazing *Ve* Triple, HSG ,Low-e	-117.838	.000	P<0.01 (HS)
Single glazing *Ve* Triple, MSG, Low-e	-65.279	.000	P<0.01 (HS)
Single glazing *Ve* Triple, LSG, Low-e	-40.374	.000	P<0.01 (HS)

(Table-4.12) Triple, LSG, Low-e glazing type appeared to have the best limitation factor (R^2) among all others glazing types, for decreasing energy consumption (cooling).

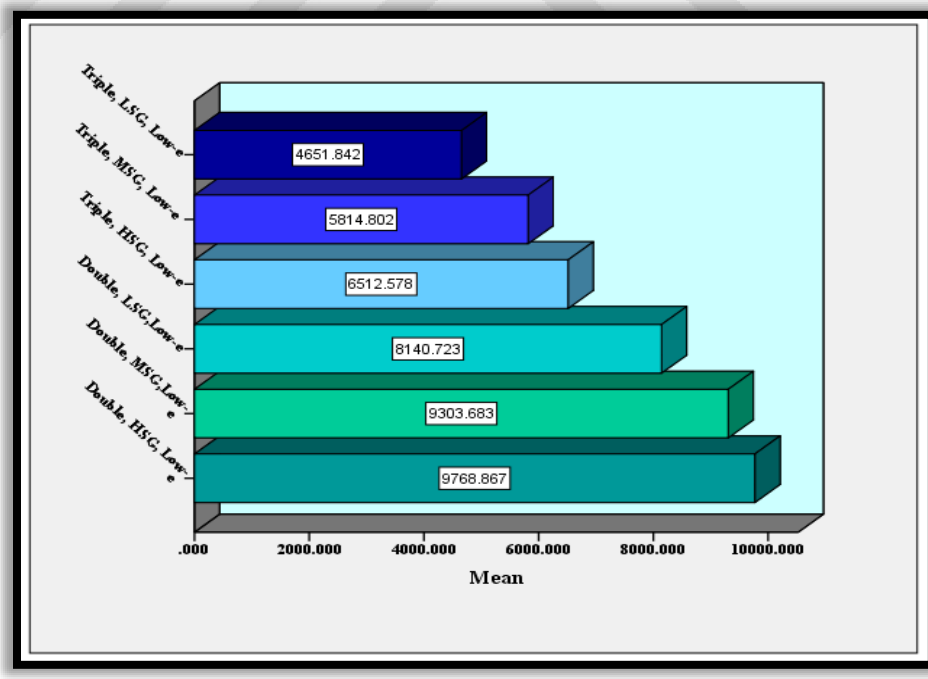


Fig. (4.16): Energy consumption comparison between all orientations with different glazing types (Cooling).

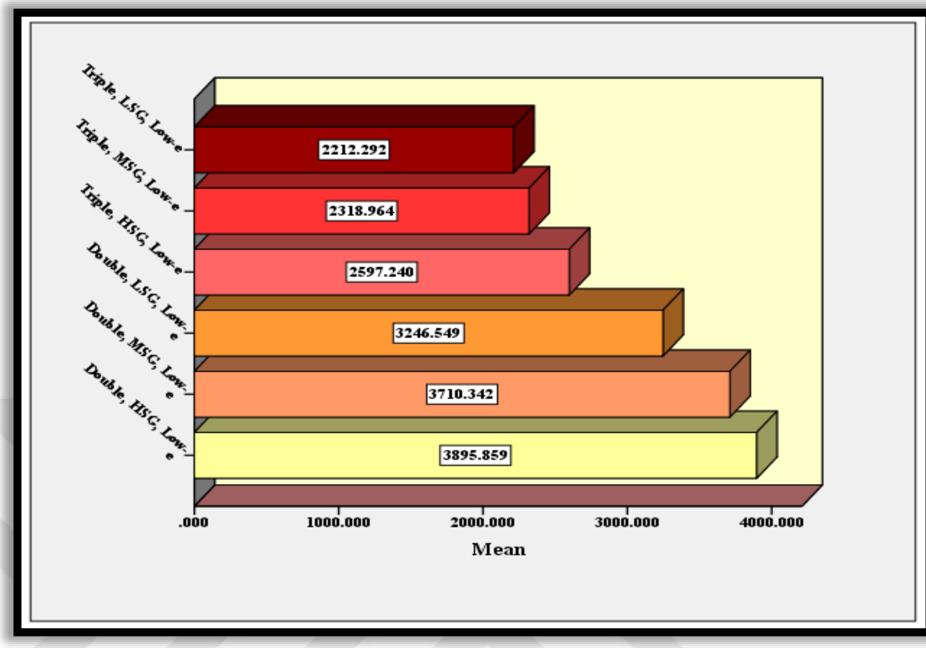


Fig. (4.17): Energy consumption comparison between all orientations with different types of glass (Heating)

CONCLUSION

Among the elements of the typical building fabric, glazing is responsible for the greatest energy loss due to generally high heat transfer coefficients (U values). However, they mainly controlled demand for heating and cooling in buildings in winter and summer, respectively. Aiming to examine and define a general outline methodology to be used for analyzing and comparing various glazing types for each orientation of existing building. In order to find the best alternatives for insulation system (glazing types) of an existing building in Turkey based on (TS 825).

Based on the description of existing building mentioned in chapter3, the data was modeled by program (Autodesk-Revit), then Simulated by (Green building studio) to calculate the initial quantities of energy consumption of the existing building. Energy-efficient building envelope should be focusing on building's response to the exterior environments.

Efficient glazing types measures aim to enhance natural lighting, reduce heat gain and reduce energy consumption to improve indoor environment quality. Heat rejection measures including solar and thermal control through advanced glazing. Advanced glazing is an effective measure to save energy consumed by existing building and to improve indoor environmental quality.

According to the information that had been mentioned in literature review, six different types of glazing had been used and they are:

A. Double glazing-high solar gain- Low-e.
B. Double glazing- medium solar gain- Low-e.
C. Double glazing- low solar gain- Low-e.
D. Triple glazing- high solar gain- Low-e.
E. Triple glazing- medium solar gain- Low-e.
F. Triple glazing-low solar gain- Low-e.

depending on TS 825. U-values need to be further strengthened in average by 10% for existing buildings to be renovated. In addition, the heat/cold bridge factors need be reduced from currently about 0.15 W/(m².K) in existing buildings to 0.05 W/(m².K) and 0.1 W/(m².K).

Various types of energy indicators are required to operate its departmental services. Different types of energy indicators are normally used in existing building. These are electricity, natural gas, diesel fuel, liquefied petroleum gas, coal, etc. Electricity is the primary form of energy indicator used within building facilities. Electricity is used generally for air-conditioning, vertical transportation lifts, heating, lighting, escalators and miscellaneous items including kitchen equipment, etc.

In order to obtain the final results of the energy consumption of existing building, a simulation program was used for this purpose, and the report obtained would provide estimated results of energy consumption monthly and annually.

The estimated results were compared with initial energy consumption (Heating- cooling) of existing building. Aiming to find the most accurate results Statistical Package for the Social Sciences (SPSS) was used to analyze and compare the most suitable type of glazing and best orientation to reduce the amount of energy (Cooling-Heating).

The best part of envelope components can be change for an existing building in order to reduce its energy consumption is the changing of the glazing types, In order to reduce energy consumption of this building, it is useful and easy to change the glazing type of it with different type of glazing, the thermal insulating of walls or ceilings, of that building, rather than changing infrastructure of the building.

The best orientations could help to reduce energy consumption by changing their glazing types were south, west, south-west and south-west-north orientations, because radiation of Sun path exposure on the building was starting south orientations moving towards west orientation.

The best alternative of glazing types could be enhanced the energy performance of existing building was Triple-LSG-Low-E glazing type, since its U-value of 0.15 W/m2 K, solar heat gain coefficient of 0.24 and visible transmittance of 0.51.

The most important standards that should be taken into consideration when retrofitting an existing building for Turkey were the U-values of roof, wall and glazing.

In order to reduce energy consumption of existing building it is worth to recommend the using of shading system consist of Low-E glazing type.

Table: Mean Differences of the best glazing Types (Triple glazing) and best orientations for (Cooling-Heating).

Initial Power consumption KW/month Cooling 23259.2 Heating 9275.85 Single Glazing type	All directions	South	West	S.W	S.W.N
	Mean	Mean	Mean	Mean	Mean
Triple, LSG, Low-e\Cooling	4651.842	13955.525	17211.814	7908.131	5582.210
Triple, LSG, Low-e\Heating	2212.292	5565.513	1233.333	566.667	400

Figure below is clarifying orientations of energy consumption for (Cooling-Heating), the X axis is represented imaginary energy consumption that got from simulation program, and Y axis shows the actual energy consumption (Cooling-Heating) for an existing building, and also can be applied by equations showed under figures. Charts and equation below are standard for energy consumption for an existing building.

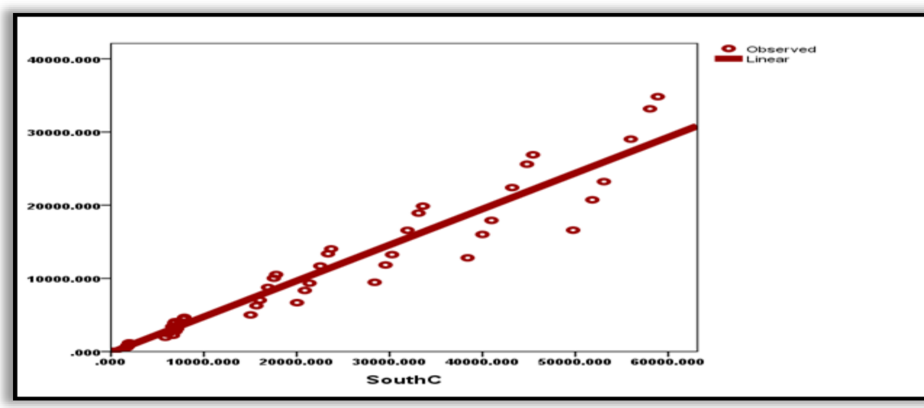


Figure: South orientation's equation for cooling (y = -147.981 + 0.491x)

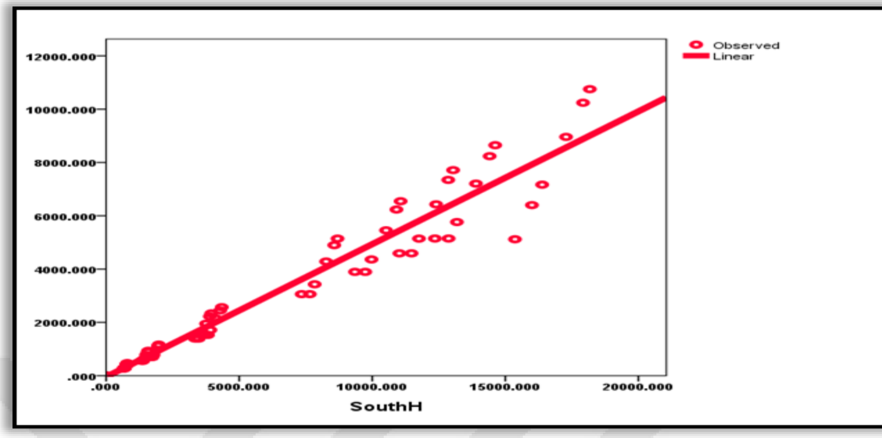


Figure: South orientation's equation for heating (y = - 44.355+ 0.498 x)

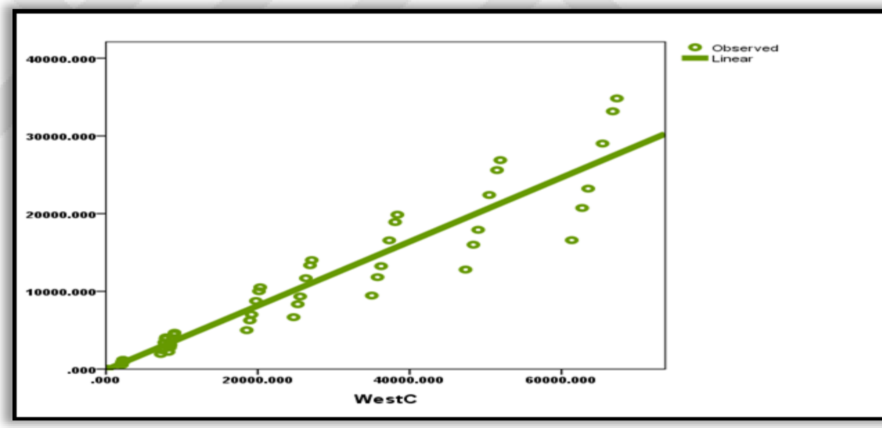


Figure: West orientation's equation for cooling (y = -93.414+ 0.412 x).

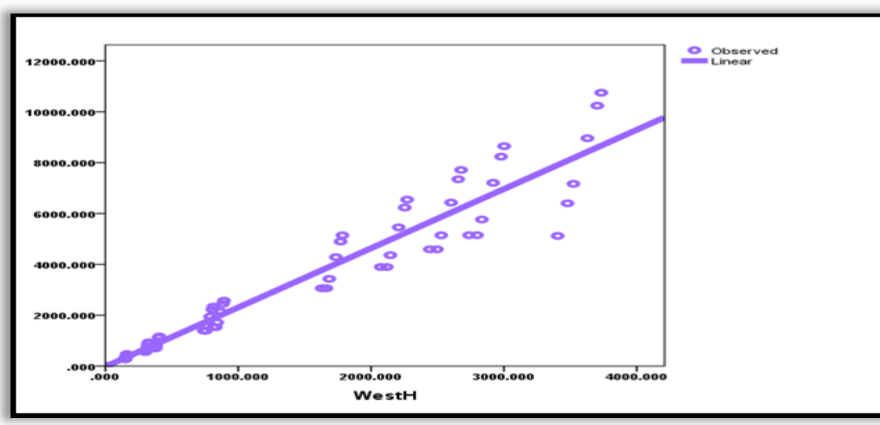


Figure: West orientation's equation for heating (y = - 21. 634 + 2.328 x)

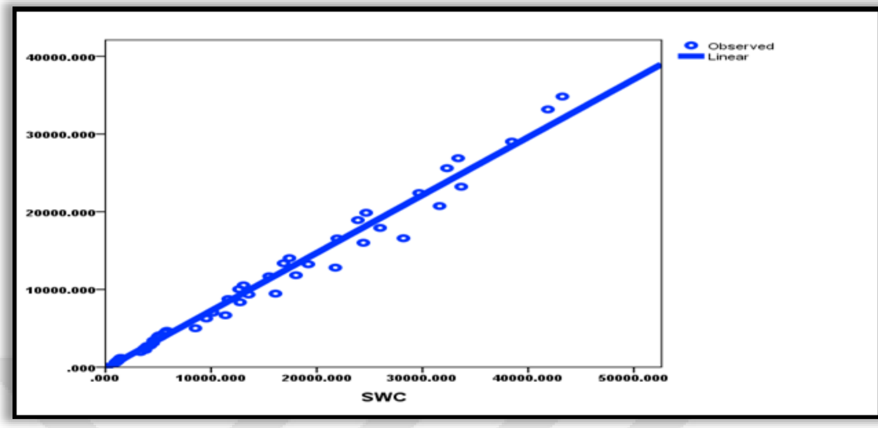


Figure: South-West orientation's equation for cooling (y = -188.384+ 0.744 x)

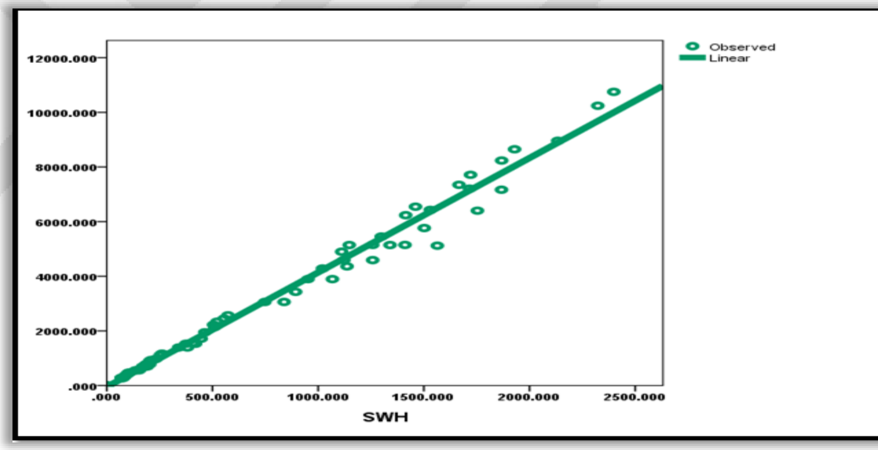


Figure: South-West orientation's equation for heating (y = - 48.679 + 4.189 x)

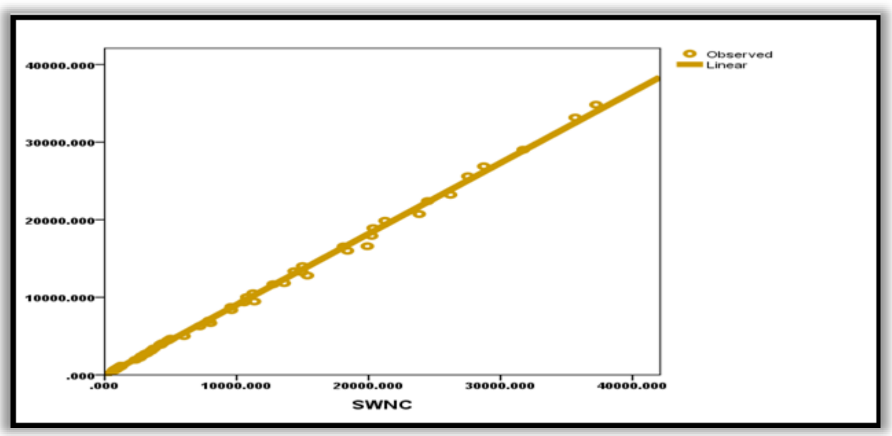


Figure: South-West-North orientation's equation for cooling (y = -92.138 + 0.914 x)

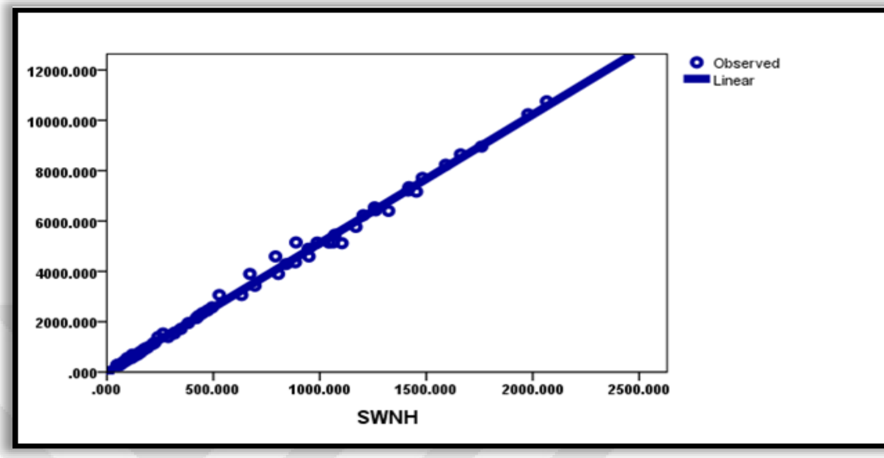


Figure: South-West-North orientation's equation for heating (y = 9.917 + 5.108 x)

For farther academic study, another part of building envelope component can be use in order to reduce building energy consumption, that components will be thermal of insulation materials in walls or roof, in order to reduce energy consumption of this building.

REFERENCES

(Çorum Weather). 2019. “(Çorum) Weather.” *(Çorum)*. https://web.archive.org/web/20110430154329/http://dmi.gov.tr/veridegerlendirme/il-ve-ilceler-istatistik.aspx?m=CORUM (March 28, 2019).

Aida Farzaneh, Danielle Monfet, Daniel Forgues. 2019. *Energy Simulation Supporting the Building Design Process*. http://021092rt2.y.https.www.sciencedirect.com.proxy.cankaya-elibrary.com:9797/science/article/pii/S235271021831012X/pdfft?md5=58c1795277aaedf9adfdd858efd80e25&pid=1-s2.0-S235271021831012X-main.pdf (April 5, 2019).

Akinola, Adedotun O, and Albert B Adeboye. 2018. “Data in Brief Survey Dataset on Architect ’ s Awareness and Adoption of Building Envelope Technologies for Energy Ef Fi Cient Housing in Lagos State.” *Data in Brief* 19: 1894–1901. http://dx.doi.org/10.1016/j.dib.2018.06.093.

Al-Hamdani, N. I., and A. I. Ahmad. 1987. “Effect of Window Parameters on Indoor Thermal Environment of Buildings.” *Solar and Wind Technology* 4(1): 71–75.

Alanne, Kari. 2004. “Selection of Renovation Actions Using Multi-Criteria ‘Knapsack’ Model.” *Automation in Construction* 13(3): 377–91.

Albayyaa, Haider, Dharmappa Hagare, and Swapan Saha. 2019. “Energy Conservation in Residential Buildings by Incorporating Passive Solar and Energy Efficiency Design Strategies and Higher Thermal Mass.” *Energy and Buildings* 182: 205–13. https://doi.org/10.1016/j.enbuild.2018.09.036.

Alrashed, Farajallah, and Muhammad Asif. 2014. “Saudi Building Industry’s Views on Sustainability in Buildings: Questionnaire Survey.” *Energy Procedia* 62: 382–90. http://dx.doi.org/10.1016/j.egypro.2014.12.400.

Berardi, Umberto, Amir Hosein GhaffarianHoseini, and Ali GhaffarianHoseini. 2014. “State-of-the-Art Analysis of the Environmental Benefits of Green Roofs.” *Applied Energy* 115: 411–28. http://dx.doi.org/10.1016/j.apenergy.2013.10.047.

Berry, Stephen, and Kathryn Davidson. 2015. “Zero Energy Homes - Are They Economically Viable?” *Energy Policy* 85: 12–21. http://dx.doi.org/10.1016/j.enpol.2015.05.009.

Borgstein, E. H., R. Lamberts, and J. L.M. Hensen. 2016. “Evaluating Energy Performance in Non-Domestic Buildings: A Review.” *Energy and Buildings* 128: 734–55. http://dx.doi.org/10.1016/j.enbuild.2016.07.018.

Brambilla, Arianna, Graziano Salvalai, Marco Imperadori, and Marta Maria Sesana. 2018. “Nearly Zero Energy Building Renovation: From Energy Efficiency to Environmental Efficiency, a Pilot Case Study.” *Energy and Buildings* 166: 271–83. https://doi.org/10.1016/j.enbuild.2018.02.002.

Braulio-Gonzalo, Marta, and María D. Bovea. 2017. “Environmental and Cost Performance of Building’s Envelope Insulation Materials to Reduce Energy Demand: Thickness Optimisation.” *Energy and Buildings* 150: 527–45. http://dx.doi.org/10.1016/j.enbuild.2017.06.005.

Budaiwi, I M. 2011. “Envelope Thermal Design for Energy Savings in Mosques in Hot-Humid Climate.” 1493.

Building Energy Asset Score. 2019. “Building Energy Asset Score | Home.” *2019*. https://buildingenergyscore.energy.gov/ (April 6, 2019).

Burmeister, Harald, and Bruno Keller. 2002. “Climate Surfaces: A Quantitative Building-Specific Representation of Climates.” *Energy and Buildings* 28(2):

167–77.

Cai, Wei et al. 2018. “Energy Benchmarking Rules in Machining Systems.” *Energy* 142: 258–63. https://doi.org/10.1016/j.energy.2017.10.030.

Campus, Bademlik. 2014. “Optimization of an Envelope Retrofit Strategy for an Existing Office Building.” 55(2012): 647–59.

Cao, Xiaodong, Xilei Dai, and Junjie Liu. 2016. “Building Energy-Consumption Status Worldwide and the State-of-the-Art Technologies for Zero-Energy Buildings during the Past Decade.” *Energy and Buildings* 128: 198–213. http://dx.doi.org/10.1016/j.enbuild.2016.06.089.

Carlos Ernesto Ochoa, Isaac Guedi Capeluto. 2008. *Strategic Decision-Making for Intelligent Buildings: Comparative Impact of Passive Design Strategies and Active Features in a Hot Climate. Building and Environment*. http://021092rt2.y.https.www.sciencedirect.com.proxy.cankaya-elibrary.com:9797/science/article/pii/S0360132307002090/pdfft?md5=3bceb61b3dbbdcbd5b8895a5c197839e&pid=1-s2.0-S0360132307002090-main.pdf (April 5, 2019).

Cascone, Stefano, Federico Catania, Antonio Gagliano, and Gaetano Sciuto. 2018. “A Comprehensive Study on Green Roof Performance for Retrofitting Existing Buildings.” *Building and Environment* 136(February): 227–39. https://doi.org/10.1016/j.buildenv.2018.03.052.

Casquero-modrego, Núria, and Marta Goñi-modrego. 2019. “Energy Retrofit of an Existing Aff Ordable Building Envelope in Spain , Case Study.” 44(August 2018): 395–405.

Chaiyapinunt, Somsak, Bunyarit Phueakphongsuriya, Khemmachart Mongkornsaksit, and Nopparat Khomporn. 2005. “Performance Rating of Glass Windows and Glass Windows with Films in Aspect of Thermal Comfort and Heat Transmission.” *Energy and Buildings* 37(7): 725–38.

Chen, Xiaodong, Xin Zhang, and Jiangtao Du. 2019. “Glazing Type (Colour and Transmittance), Daylighting , and Human Performances at a Workspace : A Full-Scale Experiment in Beijing.” *Building and Environment* 153(February): 168–85. https://doi.org/10.1016/j.buildenv.2019.02.034.

Chen, Yixing, Tianzhen Hong, Xuan Luo, and Barry Hooper. 2019. “Development of City Buildings Dataset for Urban Building Energy Modeling.” *Energy and Buildings* 183: 252–65. https://doi.org/10.1016/j.enbuild.2018.11.008.

Chiba, Kiyoshi, Toshiyuki Takahashi, Takashi Kageyama, and Hironori Oda. 2005. “Low-Emissivity Coating of Amorphous Diamond-like Carbon/Ag-Alloy Multilayer on Glass.” *Applied Surface Science* 246(1–3): 48–51.

Cholewa, Tomasz, Igor Balen, and Alicja Siuta-Olcha. 2018. “On the Influence of Local and Zonal Hydraulic Balancing of Heating System on Energy Savings in Existing Buildings – Long Term Experimental Research.” *Energy and Buildings* 179: 156–64. https://doi.org/10.1016/j.enbuild.2018.09.009.

Craven, Colin, Robbin Garber-slaght, Colin Craven, and Robbin Garber-slaght. 2014. “Exterior Insulation Envelope Retrofits in Cold Climates : Implications for Moisture Control Exterior Insulation Envelope Retrofits in Cold Climates : Implications for Moisture Control.” 9669(May).

CSBR. 2019. “Center for Sustainable Building Research: CSBR | University of Minnesota College of Design.” *Efficient glazing*. http://www.csbr.umn.edu/ (March 27, 2019).

Cuce, Erdem, and Saffa B. Riffat. 2015. “A State-of-the-Art Review on Innovative Glazing Technologies.” *Renewable and Sustainable Energy Reviews* 41: 695–714. http://dx.doi.org/10.1016/j.rser.2014.08.084.

Dahanayake, K. W.D.Kalani C., and Cheuk Lun Chow. 2017. “Studying the Potential of Energy Saving through Vertical Greenery Systems: Using EnergyPlus Simulation Program.” *Energy and Buildings* 138: 47–59.

http://dx.doi.org/10.1016/j.enbuild.2016.12.002.

Delgarm, Navid, Behrang Sajadi, Saeed Delgarm, and Farshad Kowsary. 2016. “A Novel Approach for the Simulation-Based Optimization of the Buildings Energy Consumption Using NSGA-II: Case Study in Iran.” *Energy and Buildings* 127: 552–60. http://dx.doi.org/10.1016/j.enbuild.2016.05.052.

DesignBuilder. 2019. “DesignBuilder Software Ltd - Home.” *2019*. https://designbuilder.co.uk// (April 6, 2019).

Djedjig, Rabah, Emmanuel Bozonnet, and Rafik Belarbi. 2014. “Analysis of Thermal Effects of Vegetated Envelopes: Integration of a Validated Model in a Building Energy Simulation Program.” *Energy and Buildings* 86: 93–103. http://dx.doi.org/10.1016/j.enbuild.2014.09.057.

———. 2015. “Experimental Study of the Urban Microclimate Mitigation Potential of Green Roofs and Green Walls in Street Canyons.” *International Journal of Low-Carbon Technologies* 10(1): 34–44.

Djedjig, Rabah, Salah Eddine Ouldboukhitine, Rafik Belarbi, and Emmanuel Bozonnet. 2012. “Development and Validation of a Coupled Heat and Mass Transfer Model for Green Roofs.” *International Communications in Heat and Mass Transfer* 39(6): 752–61.

Ebrahimpour, Abdulsalam, and Mehdi Maerefat. 2011. “Application of Advanced Glazing and Overhangs in Residential Buildings.” *Energy Conversion and Management* 52(1): 212–19. http://dx.doi.org/10.1016/j.enconman.2010.06.061.

Edeisy, Mohamed, and Carlo Cecere. 2017. “Envelope Retrofit in Hot Arid Climates.” *Procedia Environmental Sciences* 38: 264–73. http://dx.doi.org/10.1016/j.proenv.2017.03.075.

Ediger, Volkan et al. 2018. “Turkish Public Preferences for Energy.” *Energy Policy* 120(March): 492–502.

Efficient Window. 2019. “Window Glazing Types | Efficient Windows Collaborative.” *Efficient Windows*. https://www.efficientwindows.org/gtypes_3lowe.php (March 26, 2019).

Elotefy, Hazem et al. 2013. “Energy Regenerative Tuned Mass Dampers in High-Rise Buildings.” *Energy and Buildings* 361–363(2): e2072. http://dx.doi.org/10.1016/j.enbuild.2017.05.057.

ESP-r. 2019. “ESP-R.” *2019*. http://www.esru.strath.ac.uk/Programs/ESP-r.htm (April 6, 2019).

Feng, Guohui, Shuai Sha, and Xiaolong Xu. 2016. “Analysis of the Building Envelope Influence to Building Energy Consumption in the Cold Regions.” *Procedia Engineering* 146: 244–50. http://dx.doi.org/10.1016/j.proeng.2016.06.382.

Finsterle, S. 2007. “User ’ S Guide.” (April 2010).

La Fleur, Lina, Bahram Moshfegh, and Patrik Rohdin. 2017. “Measured and Predicted Energy Use and Indoor Climate before and after a Major Renovation of an Apartment Building in Sweden.” *Energy and Buildings* 146: 98–110. http://dx.doi.org/10.1016/j.enbuild.2017.04.042.

Frank, Th. 2005. “Climate Change Impacts on Building Heating and Cooling Energy Demand in Switzerland.” *Energy and Buildings* 37(11 SPEC. ISS.): 1175–85.

Garcia Sanchez, D., B. Lacarrière, M. Musy, and B. Bourges. 2014. “Application of Sensitivity Analysis in Building Energy Simulations: Combining First- and Second-Order Elementary Effects Methods.” *Energy and Buildings* 68(PART C): 741–50. http://dx.doi.org/10.1016/j.enbuild.2012.08.048.

Garg, S N, N Lugani, M S Bhandari, and Hauz Khas. 1994. “DETERMINATION OF GLAZING AREA IN DIRECT GAIN Qn.” 53(I).

Gil-Baez, Maite, Ángela Barrios Padura, and Marta Molina Huelva. 2019. “Passive

Actions in the Building Envelope to Enhance Sustainability of Schools in a Mediterranean Climate.” *Energy* 167: 144–58.

Gounni, Ayoub et al. 2018. “Thermal and Economic Evaluation of New Insulation Materials for Building Envelope Based on Textile Waste.” *Applied Thermal Engineering* 149(December 2018): 475–83. https://linkinghub.elsevier.com/retrieve/pii/S1359431118350002.

Gounni, Ayoub, and Mustapha El Alami. 2017. “The Optimal Allocation of the PCM within a Composite Wall for Surface Temperature and Heat Flux Reduction: An Experimental Approach.” *Applied Thermal Engineering* 127: 1488–94. https://doi.org/10.1016/j.applthermaleng.2017.08.168.

Griego, Danielle, Moncef Krarti, and Abel Hernandez-Guerrero. 2015. “Energy Efficiency Optimization of New and Existing Office Buildings in Guanajuato, Mexico.” *Sustainable Cities and Society* 17: 132–40. http://dx.doi.org/10.1016/j.scs.2015.04.008.

Guideline for Condition Assessment of the Building Envelope. 2014. Reston, VA: American Society of Civil Engineers. http://ascelibrary.org/doi/book/10.1061/9780784413258 (April 5, 2019).

Hammarberg, Elin, and Arne Roos. 2003. “Antireflection Treatment of Low-Emitting Glazings for Energy Efficient Windows with High Visible Transmittance.” *Thin Solid Films* 442(1–2): 222–26.

Han, Jun, Lin Lu, and Hongxing Yang. 2010. “Numerical Evaluation of the Mixed Convective Heat Transfer in a Double-Pane Window Integrated with See-through a-Si PV Cells with Low-ECoatings.” *Applied Energy* 87(11): 3431–37. http://dx.doi.org/10.1016/j.apenergy.2010.05.025.

Han, Koohee, and Jung Hyeun Kim. 2011. “Reflectance Modulation of Transparent Multilayer Thin Films for Energy Efficient Window Applications.” *Materials Letters* 65(15–16): 2466–69.

He, Yang et al. 2018. “Thermal Performance Evaluation of a New Type of Green Roof System Thermal Performance Evaluation of a New Type of Green Roof System Pengda the the Feasibility Heat Temperature for a Long-Term District Demand Forecast.” *Energy Procedia* 152: 384–89. https://doi.org/10.1016/j.egypro.2018.09.161.

He, Yueer, Meng Liu, Thomas Kvan, and Shini Peng. 2017. “An Enthalpy-Based Energy Savings Estimation Method Targeting Thermal Comfort Level in Naturally Ventilated Buildings in Hot-Humid Summer Zones.” *Applied Energy* 187: 717–31. http://dx.doi.org/10.1016/j.apenergy.2016.11.098.

Herring, Horace. 2006. “Energy Efficiency—a Critical View.” *Energy* 31(1 SPEC. ISS.): 10–20.

Huang, Yu, Jian Lei Niu, and Tse Ming Chung. 2013. “Study on Performance of Energy-Efficient Retrofitting Measures on Commercial Building External Walls in Cooling-Dominant Cities.” *Applied Energy* 103: 97–108. http://dx.doi.org/10.1016/j.apenergy.2012.09.003.

Ilhan, Bahriye, and Hakan Yaman. 2016. “Green Building Assessment Tool (GBAT) for Integrated BIM-Based Design Decisions.” *Automation in Construction* 70: 26–37. http://dx.doi.org/10.1016/j.autcon.2016.05.001.

Jelle, Bjørn Petter et al. 2012. “Fenestration of Today and Tomorrow: A State-of-the-Art Review and Future Research Opportunities.” *Solar Energy Materials and Solar Cells* 96(1): 1–28. http://dx.doi.org/10.1016/j.solmat.2011.08.010.

Ji, Wenjie et al. 2018. “Building Energy Performance Diagnosis Using Energy Bills and Weather Data.” *Energy and Buildings* 172: 181–91. https://doi.org/10.1016/j.enbuild.2018.04.047.

Jim, C Y, and S W Tsang. 2011. “Biophysical Properties and Thermal Performance of an Intensive Green Roof.” *Building and Environment* 46(6): 1263–74. http://dx.doi.org/10.1016/j.buildenv.2010.12.013.

Jradi, M., C. T. Veje, and B. N. Jørgensen. 2018. “A Dynamic Energy Performance-Driven Approach for Assessment of Buildings Energy Renovation—Danish Case Studies.” *Energy and Buildings* 158: 62–76. http://dx.doi.org/10.1016/j.enbuild.2017.09.094.

Keho, Yaya. 2016. “What Drives Energy Consumption in Developing Countries? The Experience of Selected African Countries.” *Energy Policy* 91(December 2015): 233–46.

Khatib, Hisham. 2012. “IEA World Energy Outlook 2011-A Comment.” *Energy Policy* 48: 737–43. http://dx.doi.org/10.1016/j.enpol.2012.06.007.

Khoukhi, Maatouk. 2018. “The Combined Effect of Heat and Moisture Transfer Dependent Thermal Conductivity of Polystyrene Insulation Material: Impact on Building Energy Performance.” *Energy and Buildings* 169: 228–35. https://doi.org/10.1016/j.enbuild.2018.03.055.

Klimczak, Marcin, Jacek Bojarski, Piotr Ziembicki, and Piotr Kęskiewicz. 2018. “Analysis of the Impact of Simulation Model Simplifications on the Quality of Low-Energy Buildings Simulation Results.” *Energy and Buildings* 169: 141–47.

Korjenic, Azra, and Thomas Bednar. 2012. “Validation and Evaluation of Total Energy Use in Office Buildings: A Case Study.” *Automation in Construction* 23: 64–70. http://dx.doi.org/10.1016/j.autcon.2012.01.001.

Kova, Rebeka. 2018. “Environmental Impact Assessment of Building Envelope Components for Low-Rise Buildings.” 163: 501–12.

Krarti, Moncef, Fedaa Ali, Alaa Alaidroos, and Mahdi Houchati. 2017. “Macro-Economic Benefit Analysis of Large Scale Building Energy Efficiency Programs in Qatar.” *International Journal of Sustainable Built Environment* 6(2): 597–609. https://doi.org/10.1016/j.ijsbe.2017.12.006.

Krarti, Moncef, and Kankana Dubey. 2017. “Energy Productivity Evaluation of

Large Scale Building Energy Efficiency Programs for Oman." *Sustainable Cities and Society* 29: 12–22. http://dx.doi.org/10.1016/j.scs.2016.11.009.

Krarti, Moncef, Kankana Dubey, and Nicholas Howarth. 2017. "Evaluation of Building Energy Efficiency Investment Options for the Kingdom of Saudi Arabia." *Energy* 134: 595–610.

Krarti, Moncek, and Kankana Dubey. 2018. "Benefits of Energy Efficiency Programs for Residential Buildings in Bahrain." *Journal of Building Engineering* 18: 40–50. https://doi.org/10.1016/j.jobe.2018.02.018.

Lee, E. S., and D. L. DiBartolomeo. 2002. "Application Issues for Large-Area Electrochromic Windows in Commercial Buildings." *Solar Energy Materials and Solar Cells* 71(4): 465–91.

Lee, Wen Shing. 2008. "Benchmarking the Energy Efficiency of Government Buildings with Data Envelopment Analysis." *Energy and Buildings* 40(5): 891–95.

Li, Danny H.W. et al. 2017. "A Review of Calculating Procedures on Daylight Factor Based Metrics under Various CIE Standard Skies and Obstructed Environments." *Building and Environment* 112: 29–44. http://dx.doi.org/10.1016/j.buildenv.2016.11.019.

Li, Danny H.W., and Joseph C. Lam. 2000. "Measurements of Solar Radiation and Illuminance on Vertical Surfaces and Daylighting Implications." *Renewable Energy* 20(4): 389–404.

Li, Danny H.W., Chris C.S. Lau, and Joseph C. Lam. 2005. "Predicting Daylight Illuminance on Inclined Surfaces Using Sky Luminance Data." *Energy* 30(9 SPEC. ISS.): 1649–65.

Liu, Linn, Patrik Rohdin, and Bahram Moshfegh. 2015. "Evaluating Indoor Environment of a Retrofitted Multi-Family Building with Improved Energy Performance in Sweden." *Energy and Buildings* 102: 32–44.

Lu, Shilei et al. 2017. “Establishment and Experimental Verification of TRNSYS Model for PCM Floor Coupled with Solar Water Heating System.” *Energy and Buildings* 140: 245–60. http://dx.doi.org/10.1016/j.enbuild.2017.02.018.

Luddeni, Giacomo, Moncef Krarti, Giovanni Pernigotto, and Andrea Gasparella. 2018. “An Analysis Methodology for Large-Scale Deep Energy Retrofits of Existing Building Stocks: Case Study of the Italian Office Building.” *Sustainable Cities and Society* 41: 296–311. https://doi.org/10.1016/j.scs.2018.05.038.

Moga, Ligia, and Adrian Bucur. 2018. “Nano Insulation Materials for Application in NZEB.” *Procedia Manufacturing* 22: 309–16. https://doi.org/10.1016/j.promfg.2018.03.047.

Mostafavi, Nariman, Mohamad Farzinmoghadam, and Simi Hoque. 2015. “Envelope Retrofit Analysis Using EQUEST , IESVE Revit Plug-in and Green Building Studio : A University Dormitory Case Study.” 6451. https://doi.org/10.1080/14786451.2013.848207.

Van Nijnatten, Peter A. 1999. “Predictive Algorithms for Directional Optical Properties of Coated Glazing for Building and Automotive Applications.” *Thin Solid Films* 351(1–2): 295–300.

Nmr, C. 2017. “Abstracts.” *Fuel and Energy Abstracts* 58(2): 94–175.

Önüt, Semih, and Selin Soner. 2006. “Energy Efficiency Assessment for the Antalya Region in Turkey.” *Energy and Buildings* 38(8): 964–71.

Parkinson, Thomas, Alex Parkinson, and Richard de Dear. 2019. “Continuous IEQ Monitoring System: Performance Specifications and Thermal Comfort Classification.” *Building and Environment* 149(October 2018): 241–52.

Pelaz, Belinda et al. 2017. “Analysis of the Influence of Wood Cladding on the Thermal Behavior of Building Façades; Characterization through Simulation by Using Different Tools and Comparative Testing Validation.” *Energy and*

Buildings 141: 349–60. http://dx.doi.org/10.1016/j.enbuild.2017.02.054.

Pérez-Lombard, Luis, José Ortiz, and Christine Pout. 2008. "A Review on Buildings Energy Consumption Information." *Energy and Buildings* 40(3): 394–98.

Pfrommer, P., K. J. Lomas, C. Seale, and Chr Kupke. 1995. "The Radiation Transfer through Coated and Tinted Glazing." *Solar Energy* 54(5): 287–99.

Pierre, Thomas, and Muriel Carin. 2019. "Characterization of the Thermal Properties of Millimeter-Sized Insulating Materials." *International Journal of Thermal Sciences* 135(September 2018): 247–55. https://doi.org/10.1016/j.ijthermalsci.2018.09.009.

Pilkington. 2016. "Table of Default U Values." *Helping you meet part L of Government Building Regulations*.

Radwan, Ahmed F., Ahmed A. Hanafy, Mohamed Elhelw, and Abd El Hamid A. El-Sayed. 2016. "Retrofitting of Existing Buildings to Achieve Better Energy-Efficiency in Commercial Building Case Study: Hospital in Egypt." *Alexandria Engineering Journal* 55(4): 3061–71. http://dx.doi.org/10.1016/j.aej.2016.08.005.

Raji, Babak, Martin J. Tenpierik, and Andy Van Den Dobbelsteen. 2016. "An Assessment of Energy-Saving Solutions for the Envelope Design of High-Rise Buildings in Temperate Climates: A Case Study in the Netherlands." *Energy and Buildings* 124: 210–21. http://dx.doi.org/10.1016/j.enbuild.2015.10.049.

Rezaei, Soroosh Daqiqeh, Santiranjan Shannigrahi, and Seeram Ramakrishna. 2017. "A Review of Conventional, Advanced, and Smart Glazing Technologies and Materials for Improving Indoor Environment." *Solar Energy Materials and Solar Cells* 159: 26–51. http://dx.doi.org/10.1016/j.solmat.2016.08.026.

Rubin, M., K. Von Rottkay, and R. Powles. 1998. "Window Optics." *Solar Energy* 62(3): 149–61.

Rubin, M, R Powles, and K Von Rottkay. 2006. “Models for the Angle-Dependent Optical Properties of Coated Glazing Materials Models for the Angle-Dependent Optical Properties of Coated Glazing Materials.” *Contract* 66(March 1998): 267–76.

Sadineni, Suresh B., Srikanth Madala, and Robert F. Boehm. 2011. “Passive Building Energy Savings: A Review of Building Envelope Components.” *Renewable and Sustainable Energy Reviews* 15(8): 3617–31. http://dx.doi.org/10.1016/j.rser.2011.07.014.

Sang, Xiaoxia, Wei Pan, and M. M. Kumaraswamy. 2014. “Informing Energy-Efficient Building Envelope Design Decisions for Hong Kong.” *Energy Procedia* 62: 123–31. http://dx.doi.org/10.1016/j.egypro.2014.12.373.

Sayed, Mir et al. 2019. “A Managed Framework for Energy-Efficient Building.” *Journal of Building Engineering* 21(June 2018): 120–28. https://doi.org/10.1016/j.jobe.2018.10.013.

Seddiki, Mohammed, Karima Anouche, Amar Bennadji, and Prince Boateng. 2016. “A Multi-Criteria Group Decision-Making Method for the Thermal Renovation of Masonry Buildings: The Case of Algeria.” *Energy and Buildings* 129: 471–83. http://dx.doi.org/10.1016/j.enbuild.2016.08.023.

Seeam, Amar, David Laurenson, and Asif Usmani. 2018. “Evaluating the Potential of Simulation Assisted Energy Management Systems: A Case for Electrical Heating Optimisation.” *Energy and Buildings* 174: 579–86. https://doi.org/10.1016/j.enbuild.2018.06.063.

Shabunko, V., C. M. Lim, and S. Mathew. 2018. “EnergyPlus Models for the Benchmarking of Residential Buildings in Brunei Darussalam.” *Energy and Buildings* 169: 507–16. http://dx.doi.org/10.1016/j.enbuild.2016.03.039.

Shaikh, Pervez Hameed et al. 2017. “Simulation Tools Application for Artificial Lighting in Buildings.” *Renewable and Sustainable Energy Reviews* 82(March

2017): 3007–26. https://doi.org/10.1016/j.rser.2017.10.035.

Sharma, Aanchal, P S Chani, and S Y Kulkarni. 2014. "Energy-Efficient Retrofit of an Unconditioned Institute Building." 8628.

Shi, Jonathan, and Jonathan Shi. 2017. "A Quantitative Method for Assessing Home Envelope ' s Energy Performance Using Measured Data Measured Data." 3599. https://doi.org/10.1080/15623599.2016.1207367.

Sisecam Low-EGlass. 2019. "Sisecam Low-EGlass | Sisecam Flat Glass." *Sisecam Low-EGlass*. http://www.sisecamduzcam.com/en/business-segments/architectural-glass/professional-product-catalog/sisecam-low-e-glass (March 27, 2019).

Solangi, K. H. et al. 2011. "A Review on Global Solar Energy Policy." *Renewable and Sustainable Energy Reviews* 15(4): 2149–63. http://dx.doi.org/10.1016/j.rser.2011.01.007.

Sun, Ting, Elie Bou-zeid, and Guang-heng Ni. 2014. "To Irrigate or Not to Irrigate : Analysis of Green Roof Performance via a Vertically-Resolved Hygrothermal Model." *Building and Environment* 73: 127–37. http://dx.doi.org/10.1016/j.buildenv.2013.12.004.

Thomas, Albert, Carol C. Menassa, and Vineet R. Kamat. 2018. "A Systems Simulation Framework to Realize Net-Zero Building Energy Retrofits." *Sustainable Cities and Society* 41: 405–20. https://doi.org/10.1016/j.scs.2018.05.045.

Tian, Wei, Jitian Song, Zhanyong Li, and Pieter de Wilde. 2014. "Bootstrap Techniques for Sensitivity Analysis and Model Selection in Building Thermal Performance Analysis." *Applied Energy* 135: 320–28. http://dx.doi.org/10.1016/j.apenergy.2014.08.110.

Tibi, Ghaith, and Ahmed Mokhtar. 2015. "Glass Selection for High-Rise Buildings in the United Arab Emirates Considering Orientation and Window-to-Wall

Ratio." *Energy Procedia* 83: 197–206.
http://dx.doi.org/10.1016/j.egypro.2015.12.210.

Tovarović, Jasna Čikić, Jelena Ivanović-Šekularac, and Nenad Šekularac. 2017. "Renovation of Existing Glass Facade in Order to Implement Energy Efficiency and Media Facade." *Energy and Buildings* 152: 653–66. http://dx.doi.org/10.1016/j.enbuild.2017.07.049.

Tozzi, Peter, and Jin Ho Jo. 2017. "A Comparative Analysis of Renewable Energy Simulation Tools: Performance Simulation Model vs. System Optimization." *Renewable and Sustainable Energy Reviews* 80(May): 390–98. http://dx.doi.org/10.1016/j.rser.2017.05.153.

Tug, R. 2003. "Energy Sector and Wind Energy Potential in Turkey." 7: 469–84.

"U-Value Maps Turkey TS825." 2016.

Vilhena, António, Carla Silva, Paulo Fonseca, and Sandra Couto. 2017. "Exterior Walls Covering System to Improve Thermal Performance and Increase Service Life of Walls in Rehabilitation Interventions." *Construction and Building Materials* 142: 354–62.

Villasmil, Willy, Ludger J. Fischer, and Jörg Worlitschek. 2019. "A Review and Evaluation of Thermal Insulation Materials and Methods for Thermal Energy Storage Systems." *Renewable and Sustainable Energy Reviews* 103(July 2018): 71–84. https://doi.org/10.1016/j.rser.2018.12.040.

Wang, Haidong, and Zhiqiang (John) Zhai. 2016. "Advances in Building Simulation and Computational Techniques: A Review between 1987 and 2014." *Energy and Buildings* 128: 319–35. http://dx.doi.org/10.1016/j.enbuild.2016.06.080.

Wang, Julian (Jialiang), and Donglu Shi. 2017. "Spectral Selective and Photothermal Nano Structured Thin Films for Energy Efficient Windows." *Applied Energy* 208(August): 83–96.

Wang, Qian, Adnan Ploskić, Xingqiang Song, and Sture Holmberg. 2016. “Ventilation Heat Recovery Jointed Low-Temperature Heating in Retrofitting - An Investigation of Energy Conservation, Environmental Impacts and Indoor Air Quality in Swedish Multifamily Houses.” *Energy and Buildings* 121: 250–64.

Ward, Gregory J., and Francis M. Rubinstein. 1988. “A New Technique for Computer Simulation of Illuminated Spaces.” *Journal of the Illuminating Engineering Society* 17(1): 80–91.

wbdg. 2019. “Building Envelope Design Guide - Introduction | WBDG - Whole Building Design Guide.” *2019*. http://www.wbdg.org/guides-specifications/building-envelope-design-guide/building-envelope-design-guide-introduction (April 5, 2019).

World Energy Outlook 2019. 2019. *World Energy Outlook 2019*. World Energy Outlook 2019. https://www.iea.org/newsroom/news/2012/november/world-energy-outlook-2012.html (April 5, 2019).

Xie, Shuai et al. 2018. “Design and Manufacture of a Dual-Functional Exterior Wall Structure for 1.1–5 GHz Electromagnetic Radiation Absorption.” *Composite Structures* 201(December 2017): 608–15. https://doi.org/10.1016/j.compstruct.2018.06.079.

Xin, Liu et al. 2018. “Effect of the Energy-Saving Retrofit on the Existing Residential Buildings in the Typical City in Northern China.” *Energy and Buildings* 177: 154–72. https://doi.org/10.1016/j.enbuild.2018.07.004.

Yigit, Sadik, and Beliz Ozorhon. 2018. “A Simulation-Based Optimization Method for Designing Energy Efficient Buildings.” *Energy and Buildings* 178: 216–27. https://doi.org/10.1016/j.enbuild.2018.08.045.

Yongqiang Luo, Ling Zhang, Michael Bozlar, Zhongbing Liu. 2019. “Sustainable Facades: Design Methods for High-Performance Building Envelopes.” *2019*.

http://021092rt2.y.https.www.sciencedirect.com.proxy.cankaya-elibrary.com:9797/science/article/pii/S1364032119300061/pdfft?md5=6c6ee0171375051ed84ed0305fd039f8&pid=1-s2.0-S1364032119300061-main.pdf (April 5, 2019).

Yousefi, Fatemeh, Yaghob Gholipour, and Wei Yan. 2017. “A Study of the Impact of Occupant Behaviors on Energy Performance of Building Envelopes Using Occupants’ Data.” *Energy and Buildings* 148: 182–98. http://dx.doi.org/10.1016/j.enbuild.2017.04.085.

Zhou, Yan, and Guangcai Gong. 2013. “Exergy Analysis of the Building Heating and Cooling System from the Power Plant to the Building Envelop with Hourly Variable Reference State.” *Energy and Buildings* 56: 94–99. http://dx.doi.org/10.1016/j.enbuild.2012.09.041.

Appendix

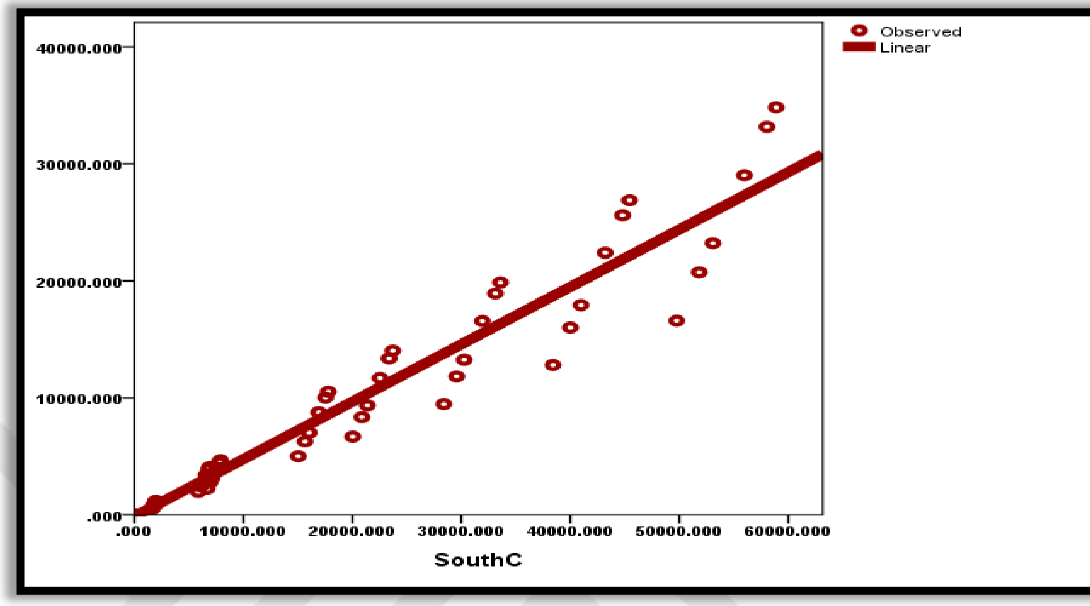


Fig.(1): South Cooling (y = -147.981 + 0.491x)

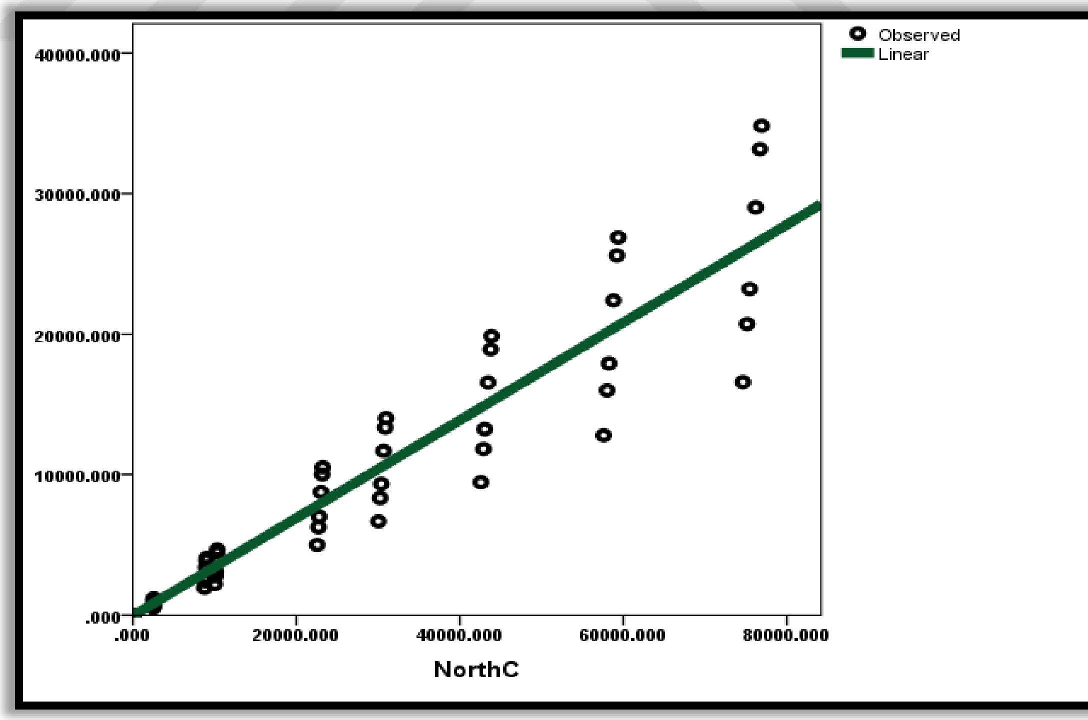


Fig.(2): North Cooling (y = -33.753 + 0.348x)

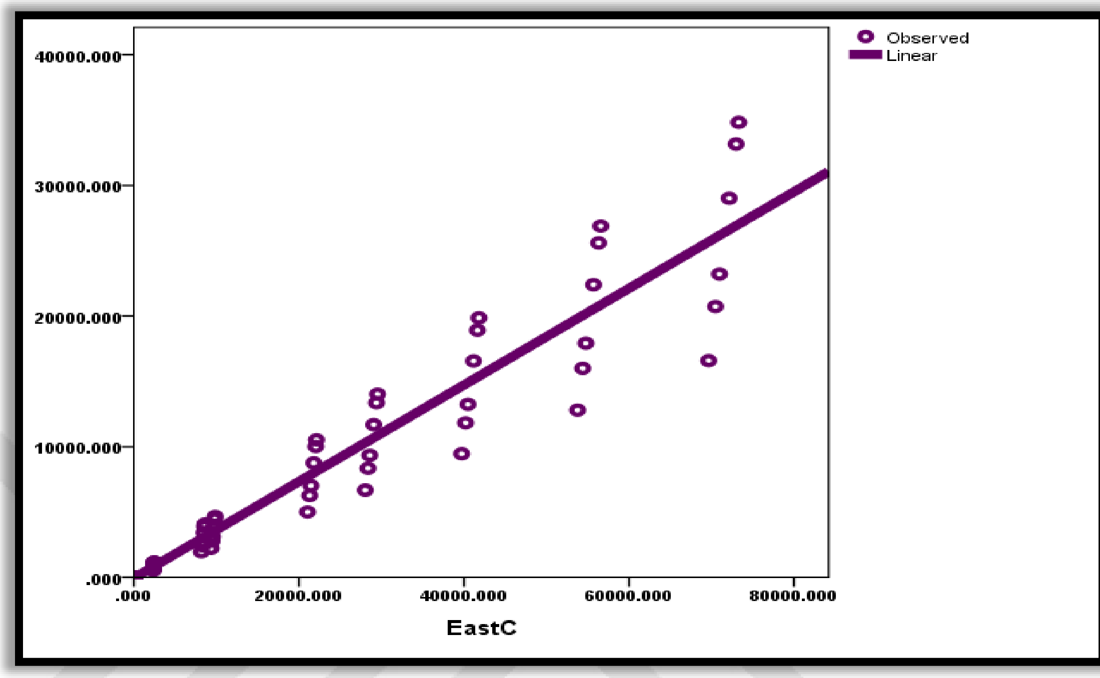


Fig.(3): East Cooling (y = -55.390 + 0.370x)

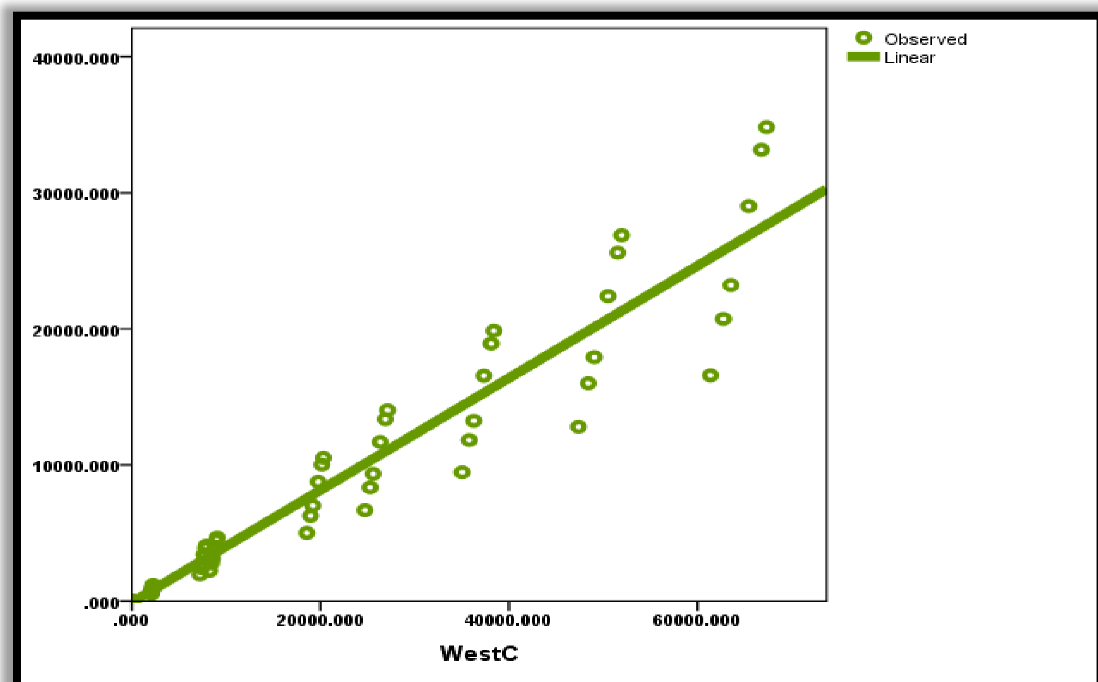


Fig.(4): West Cooling (y = -93.414+ 0.412 x)

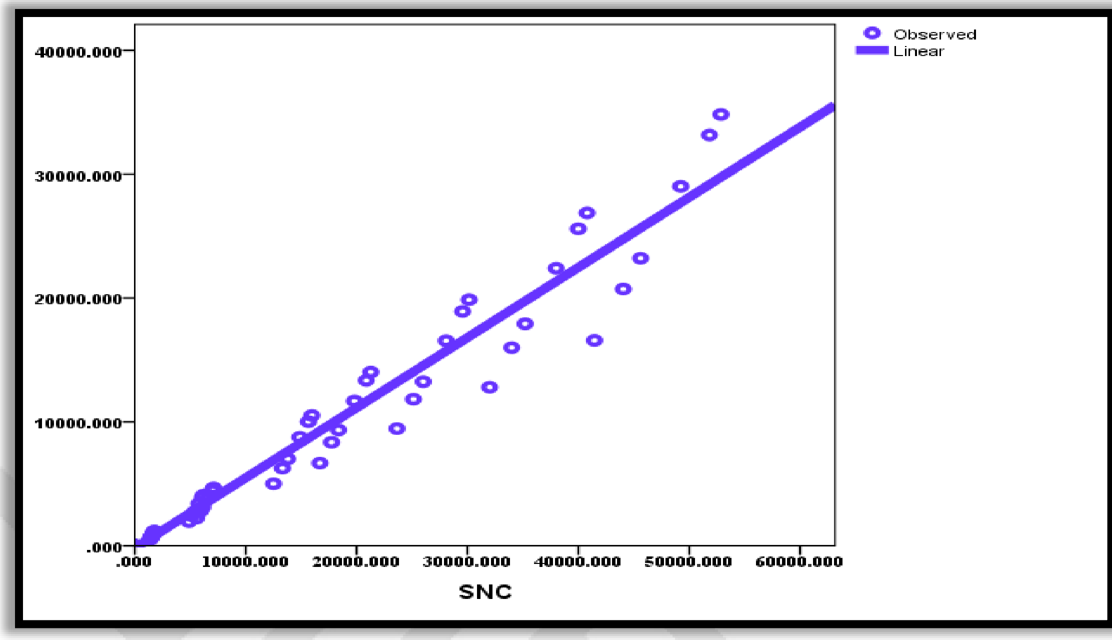


Fig.(5): South-North Cooling (y = -181.953+ 0.566 x)

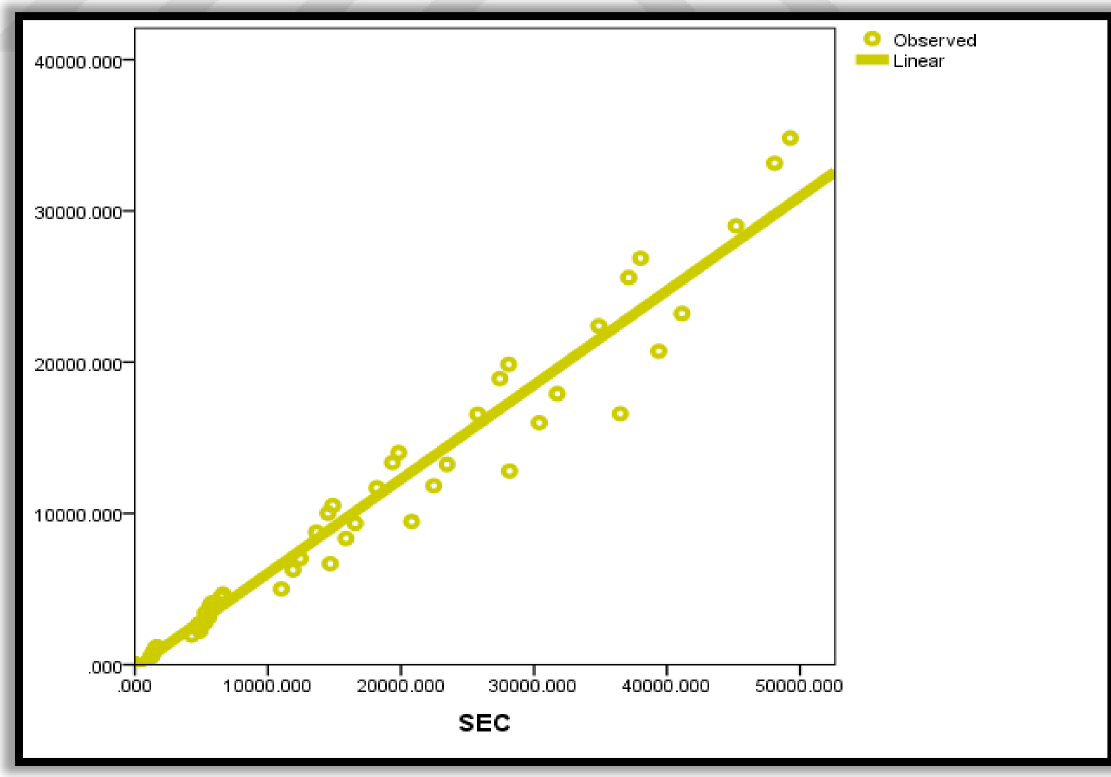


Fig.(6): south-East Cooling (y = -195.330+ 0.623 x)

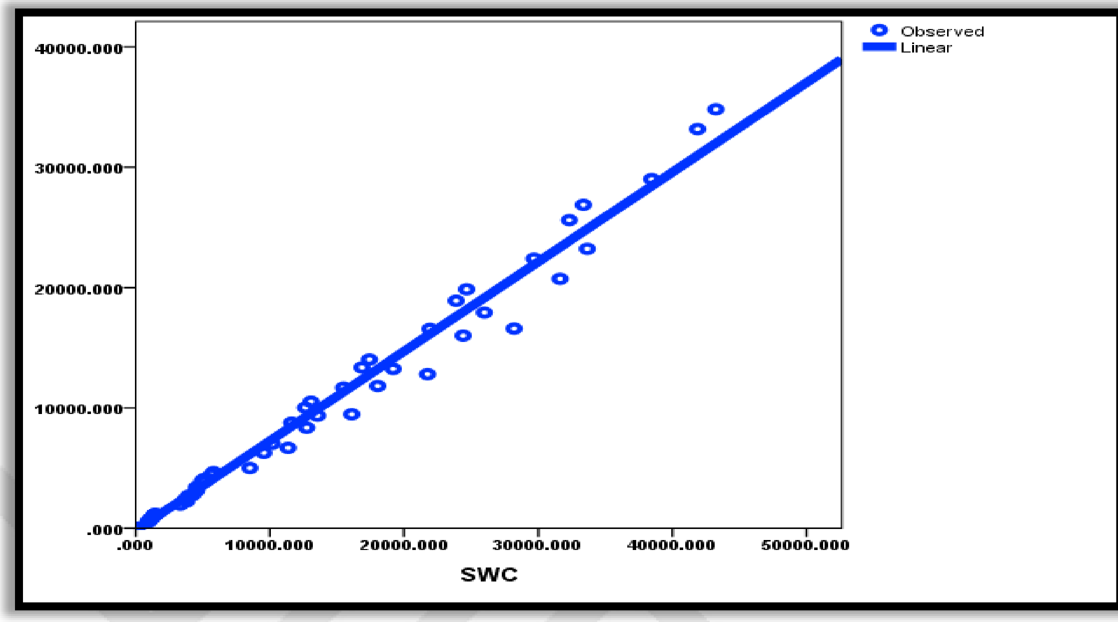


Fig.(7): South-East Cooling (y = -188.384+ 0.744 x)

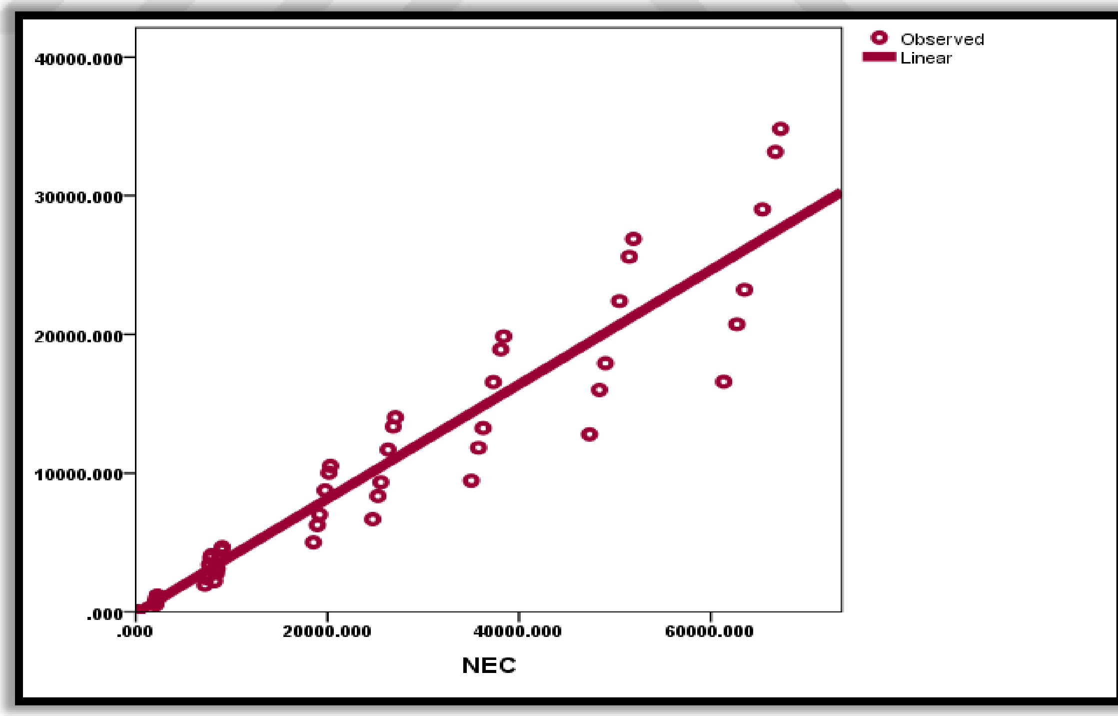


Fig.(8): North-East Cooling (y = -93.414+ 0.412 x)

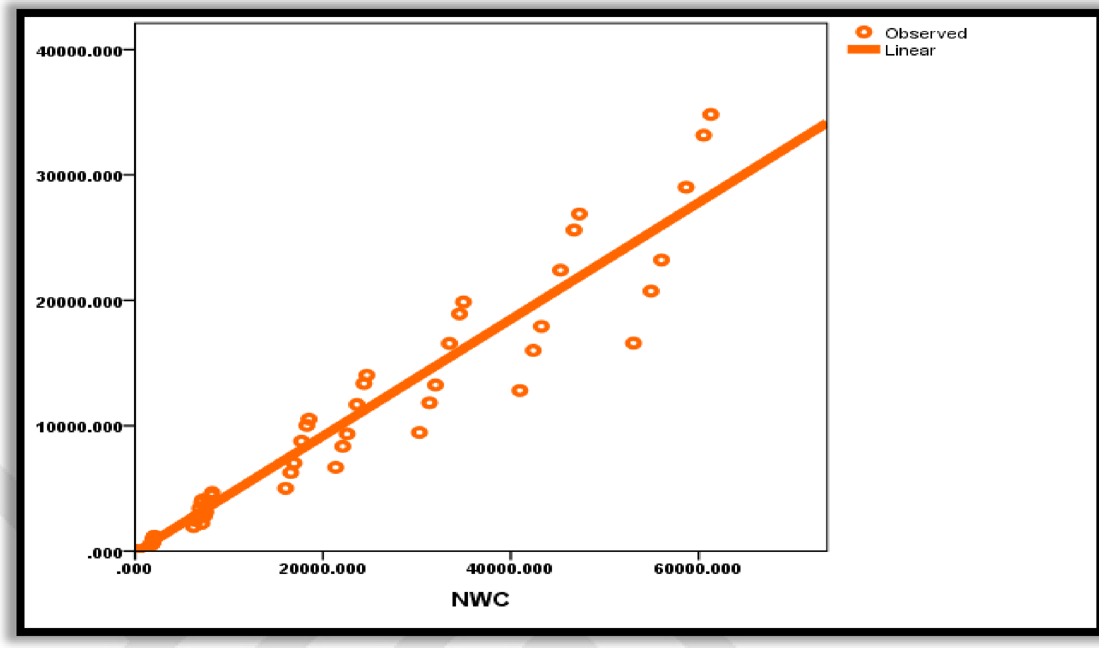


Fig.(9): North-West Cooling (y = -93.414+ 0.412 x)

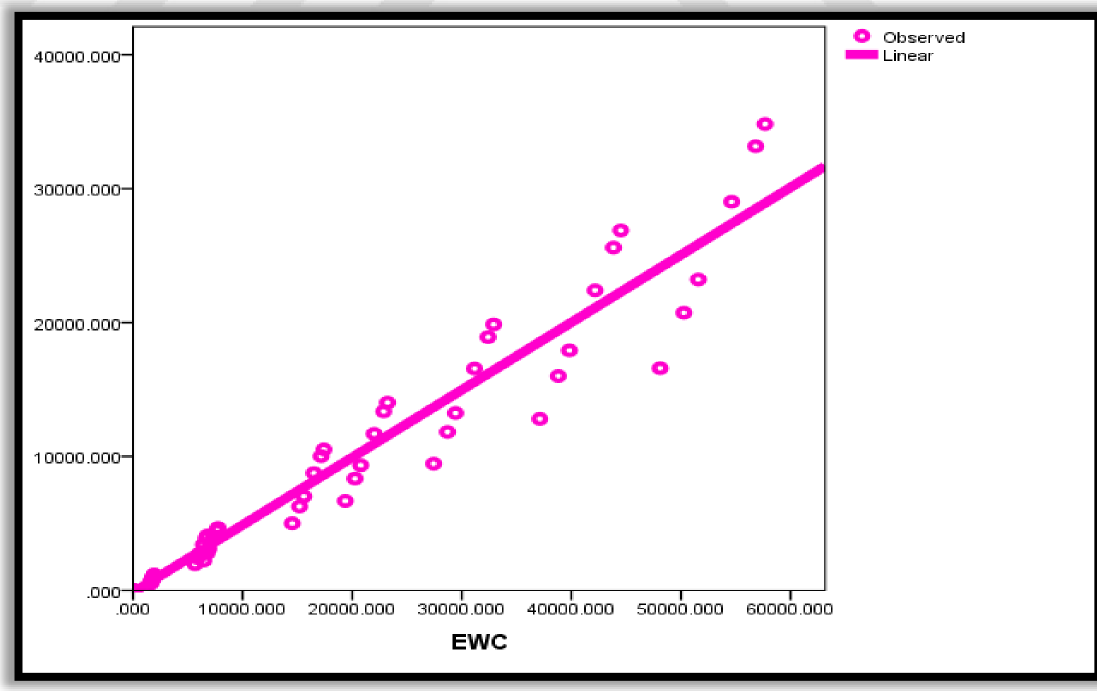


Fig.(10): East-West Cooling (y = -155.421+ 0.504 x)

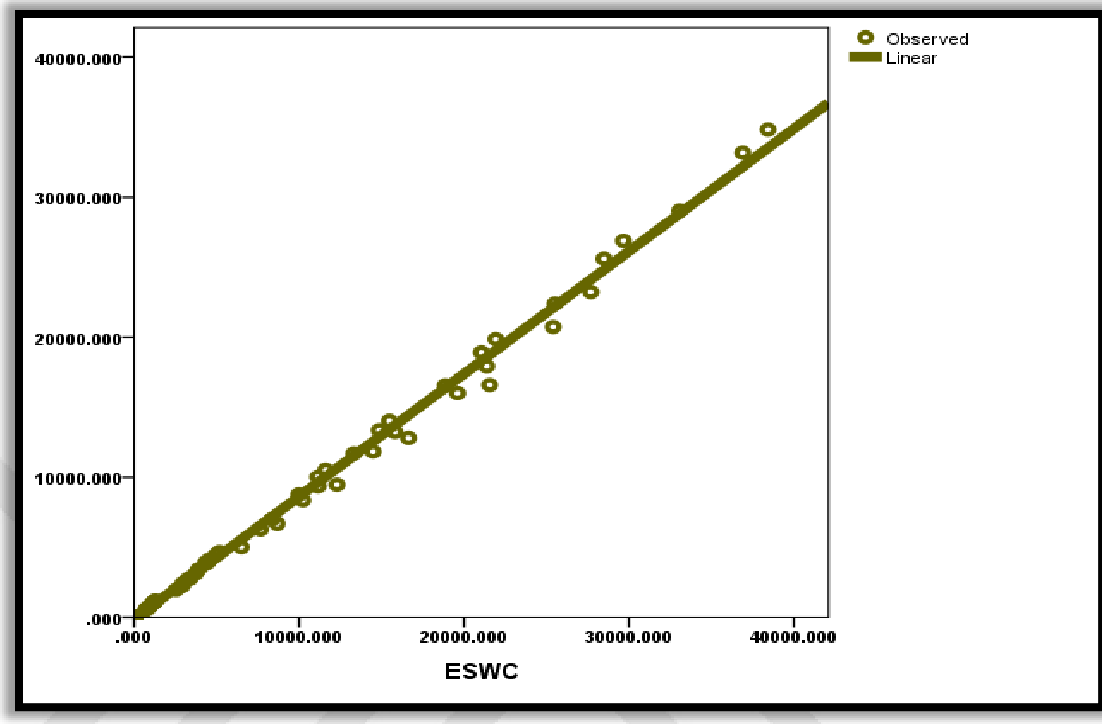


Fig.(11): East- South-West Cooling (y = -123.647+ 0.875 x)

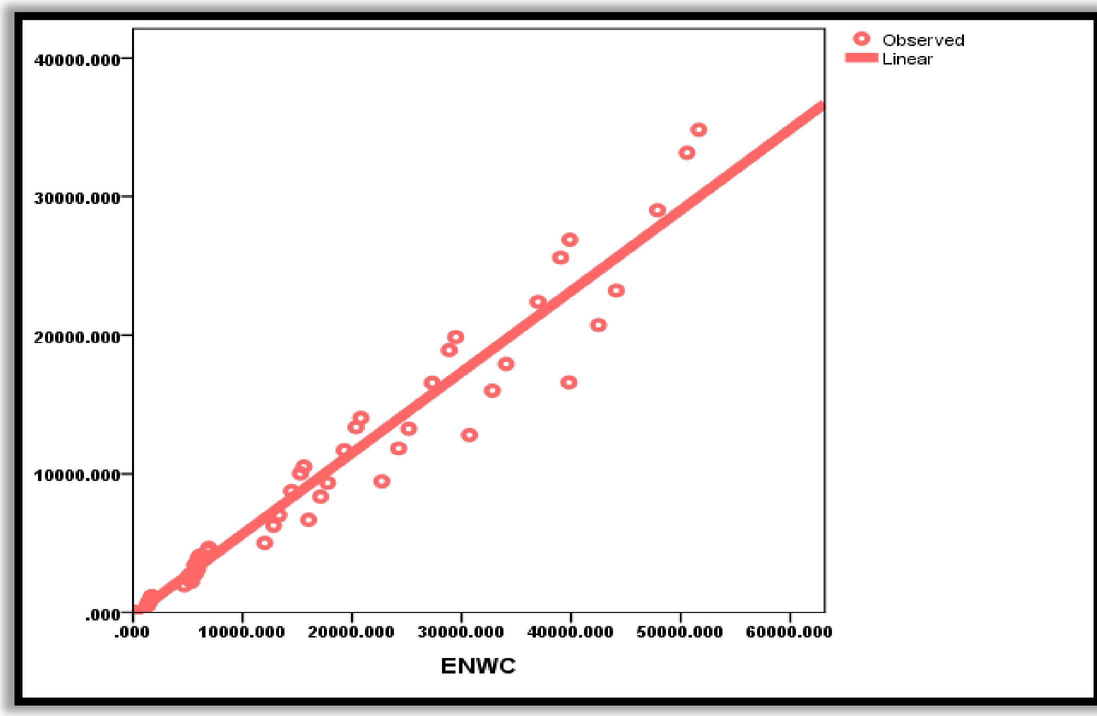


Fig.(12): East-North-West Cooling (y = -187.275 + 0.584 x)

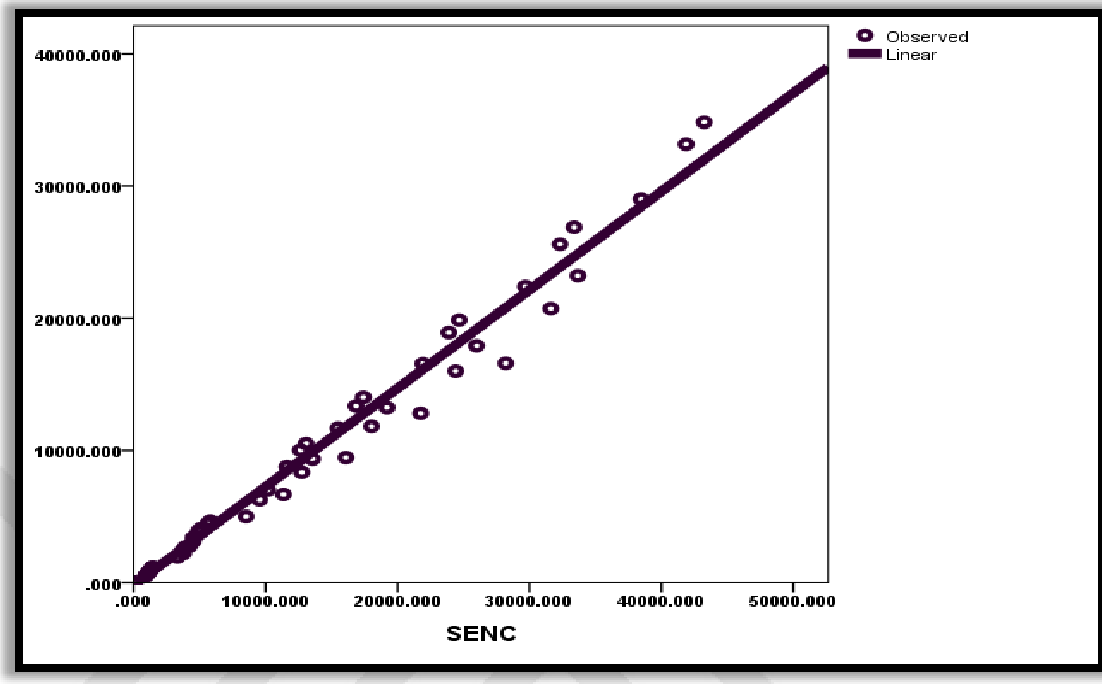


Fig.(13): South-East-North cooling   (y = -188.384 + 0.744 x)

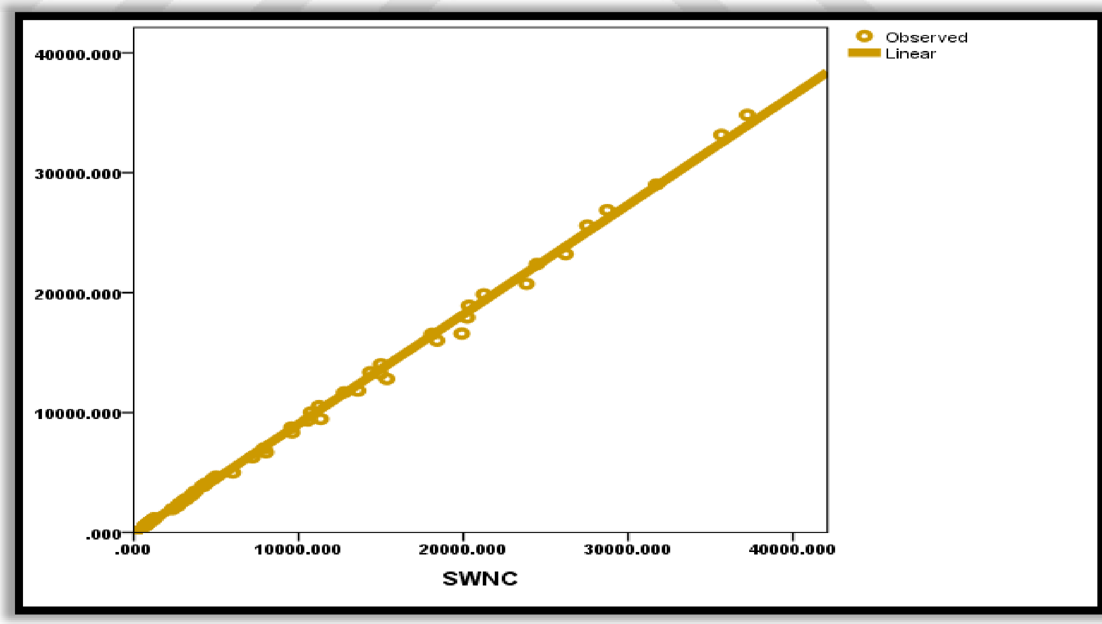


Fig.(14): South-West -North Cooling (y = -92.138 + 0.914 x)

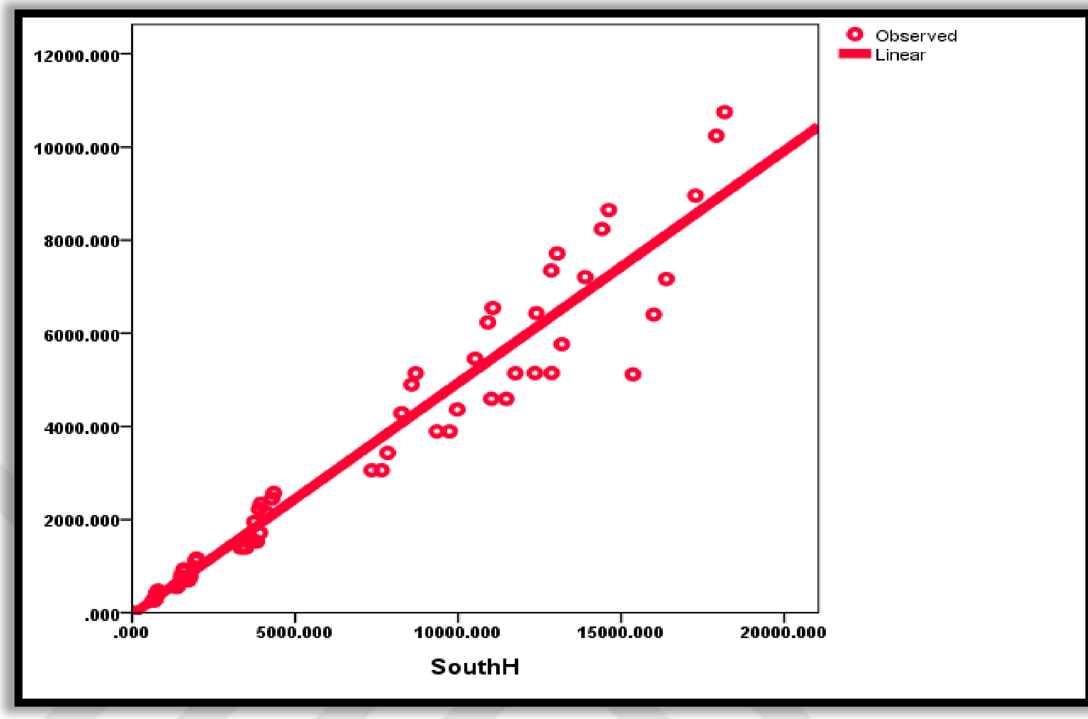


Fig.(15): South Heating (y = - 44.355+ 0.498 x)

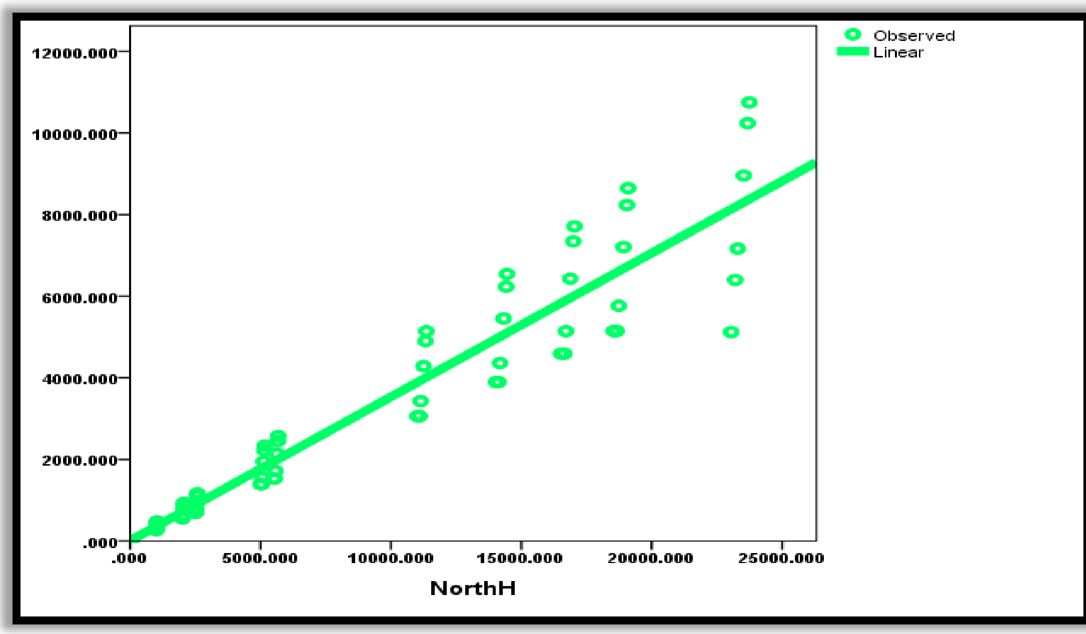


Fig.(16): North Heating (y = 4. 589 + 0.353 x)

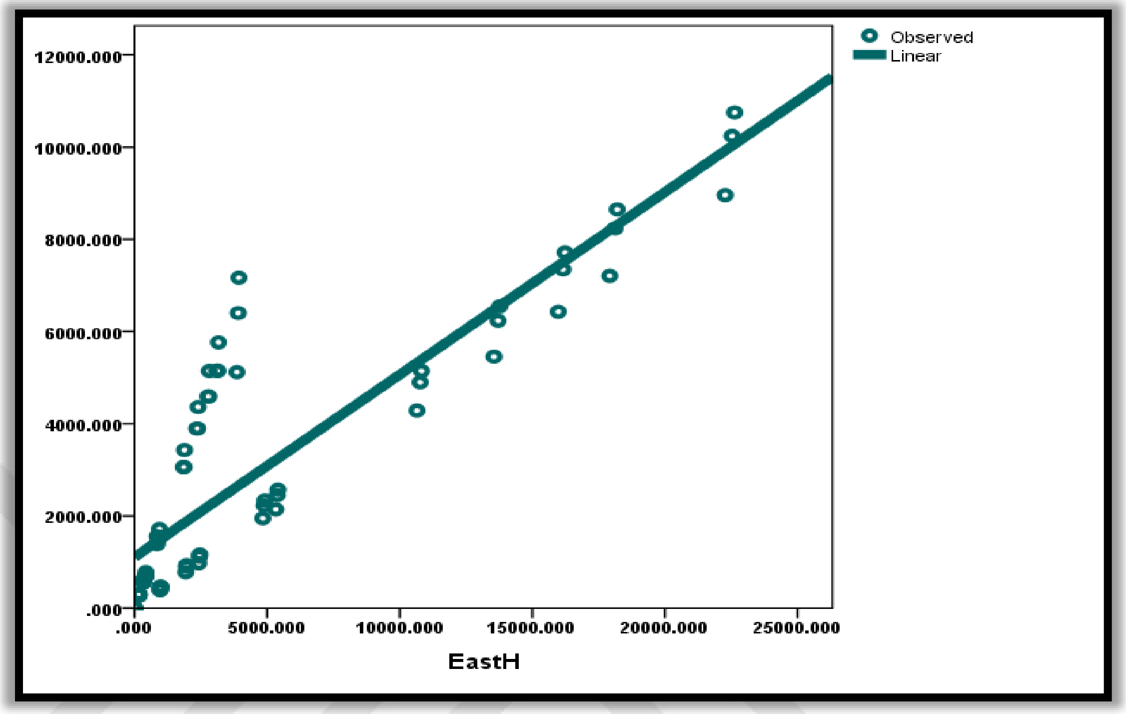


Fig.(17): East Heating (y = 1104. 401 + 0.396 x)

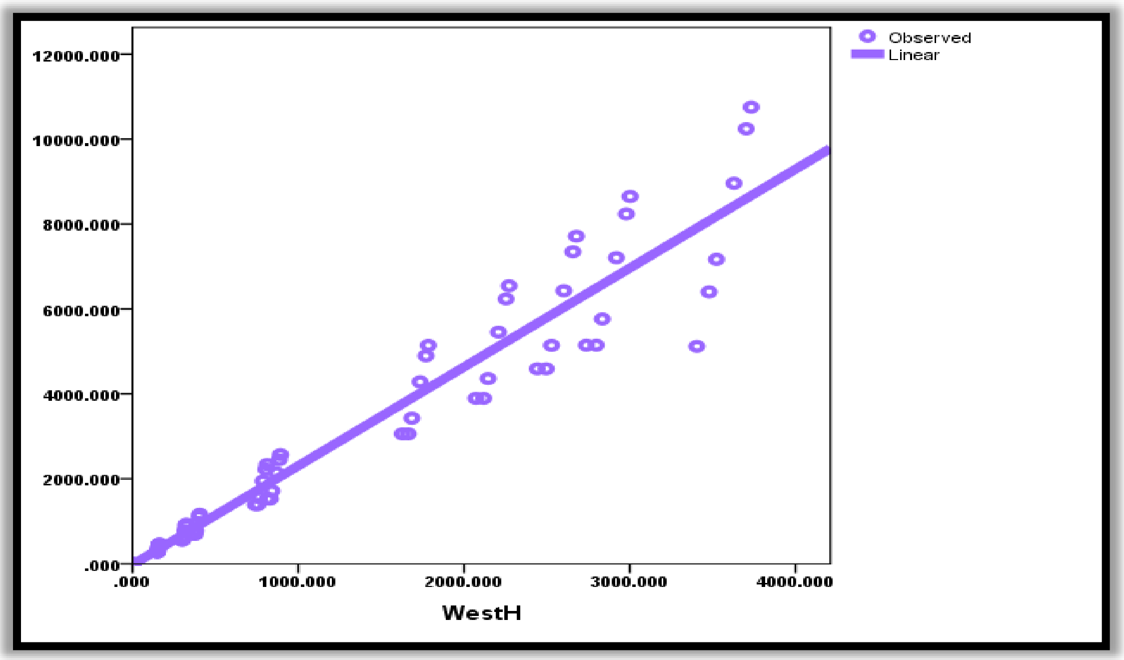


Fig.(18): West Heating (y = - 21. 634 + 2.328 x)

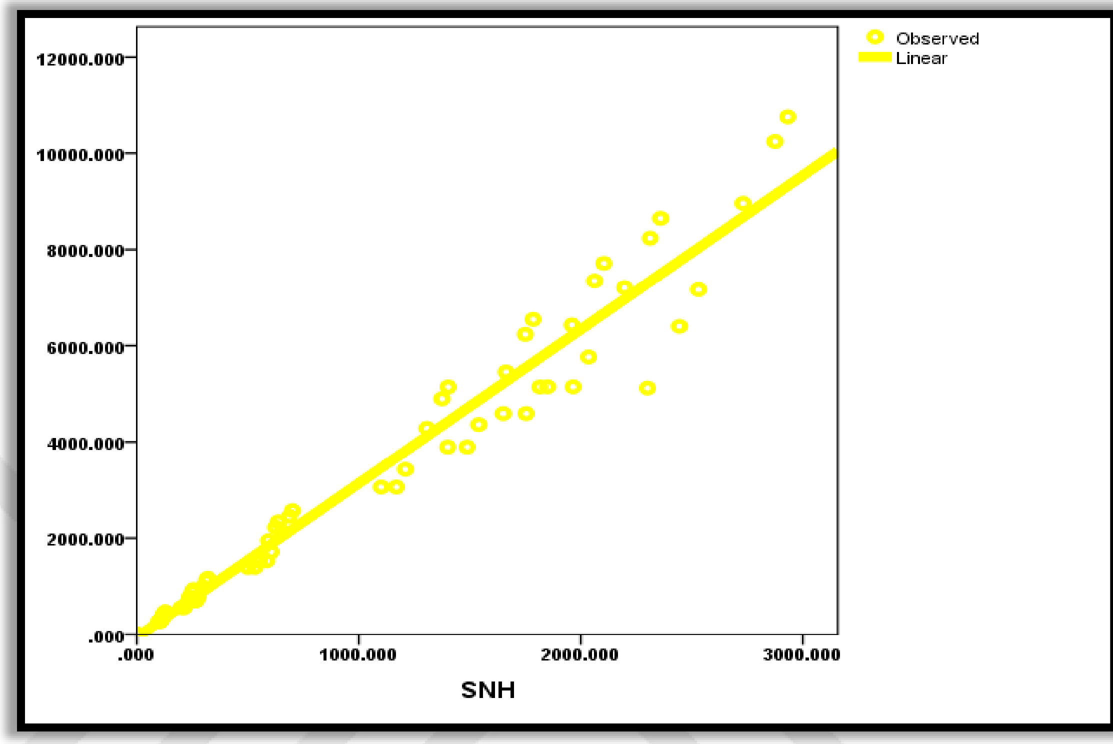


Fig.(19): South-North Heating (y = - 56. 754 + 3.198 x)

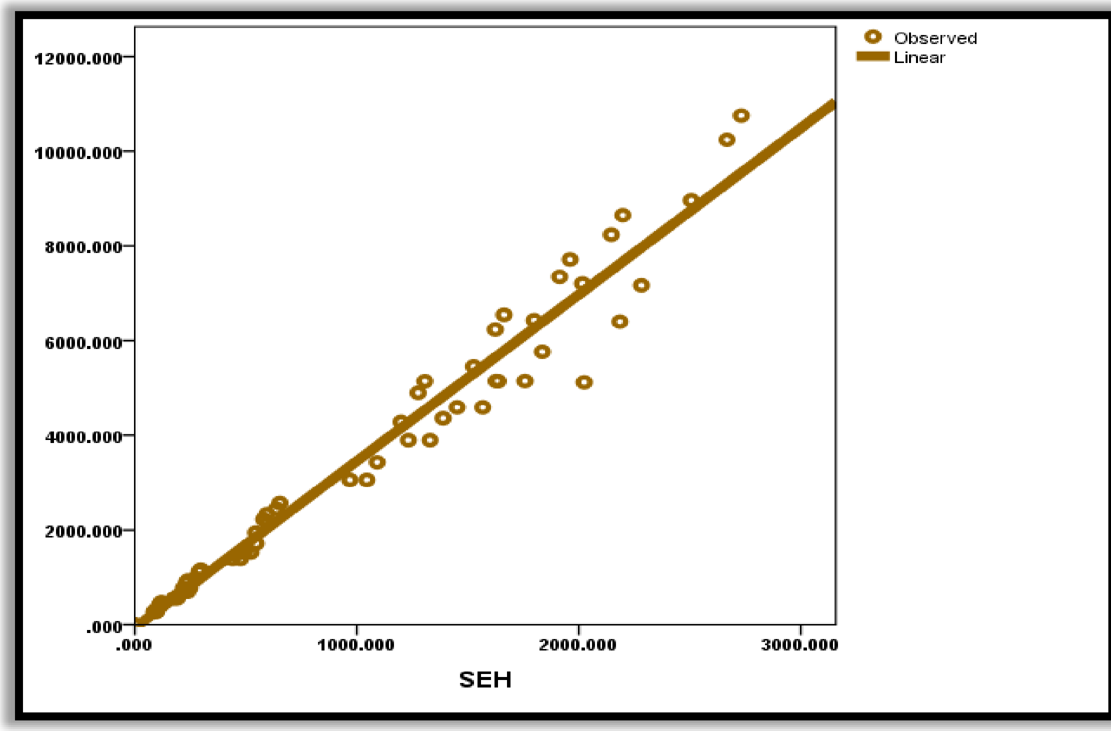


Fig.(20): South-East heating (y = - 59.900 + 3.516 x)

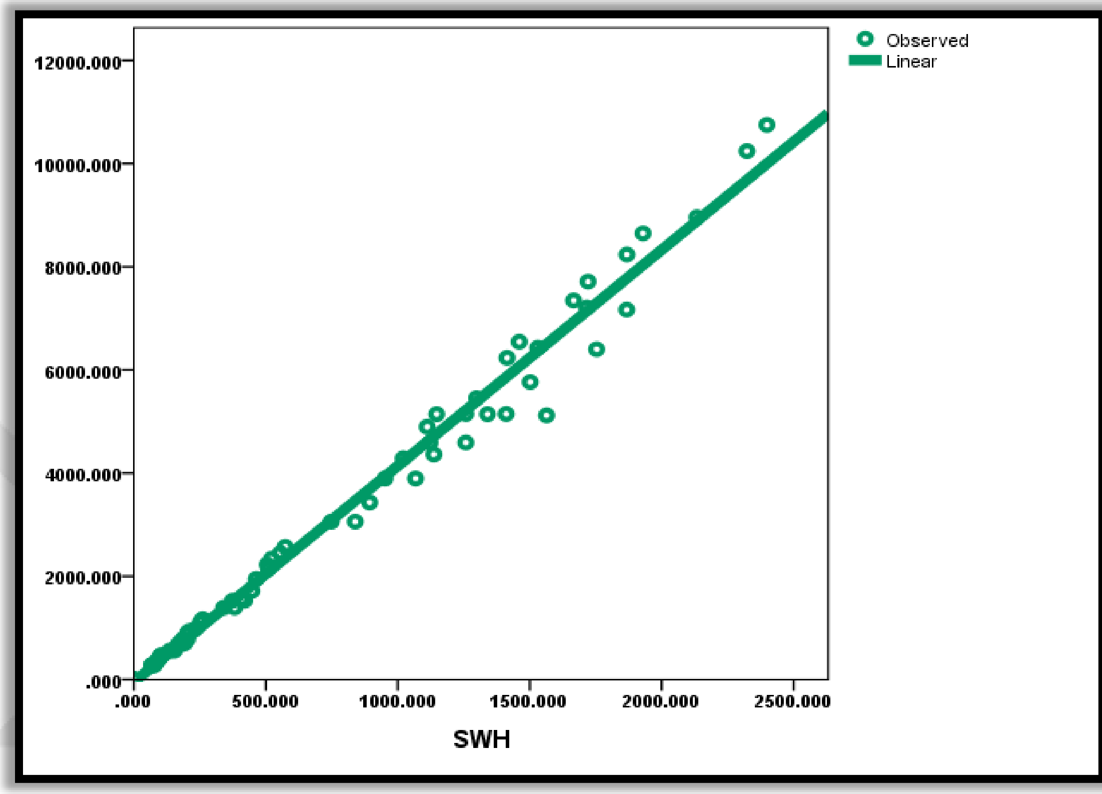


Fig.(21): South West heating (y = - 48.679 + 4.189 x)

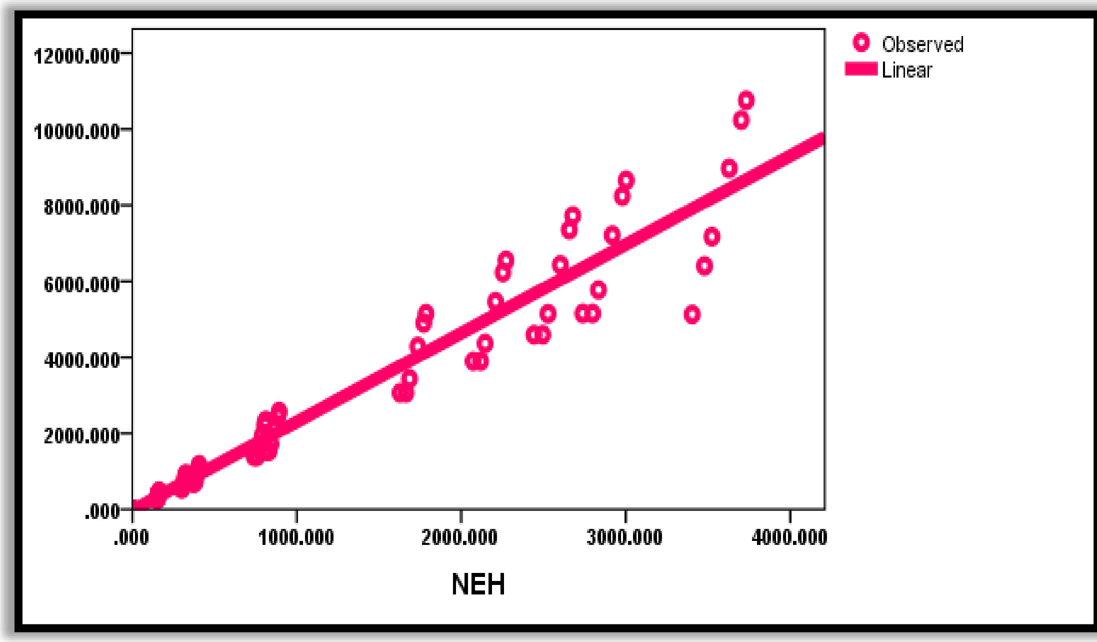


Fig.(22): North-East Heating (y = - 21.634 + 2.329 x)

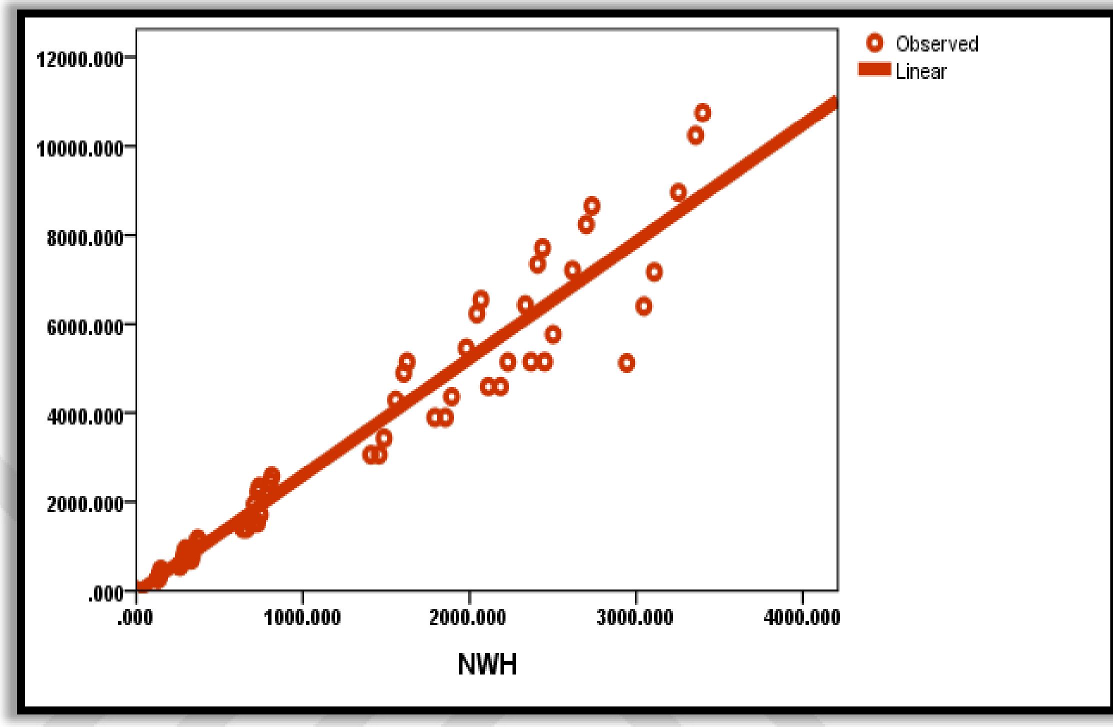


Fig.(23): North-West heating (y = - 38.163 + 2.630 x)

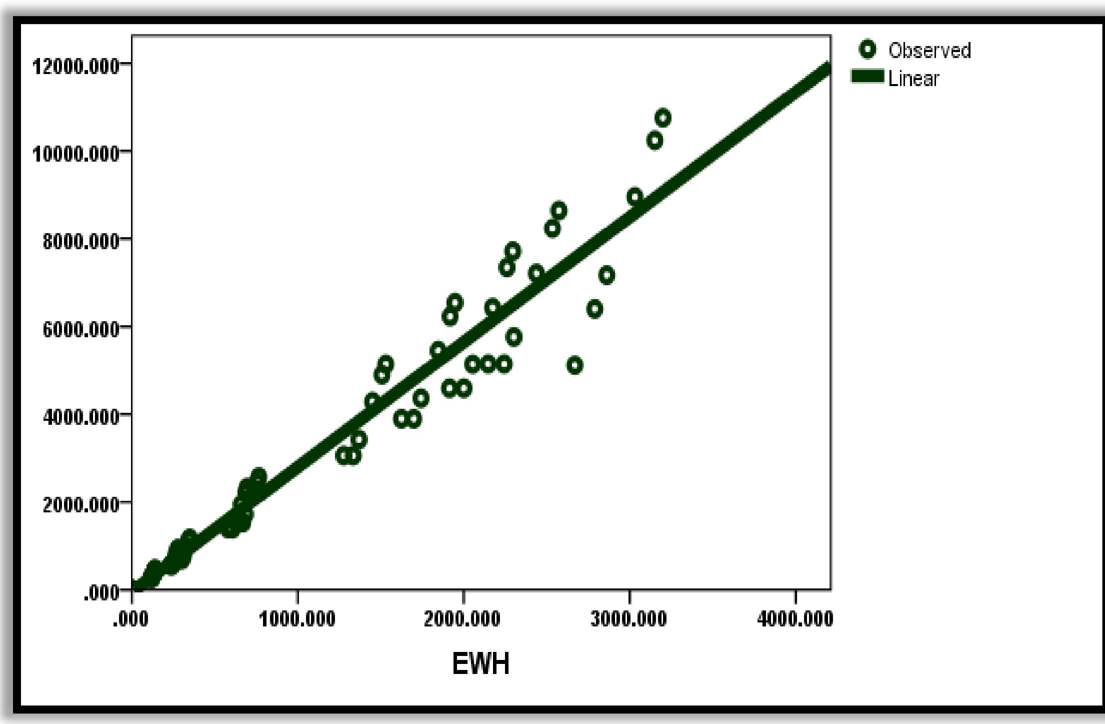


Fig.(24): East-West heating (y = - 47.265 + 2.848 x)

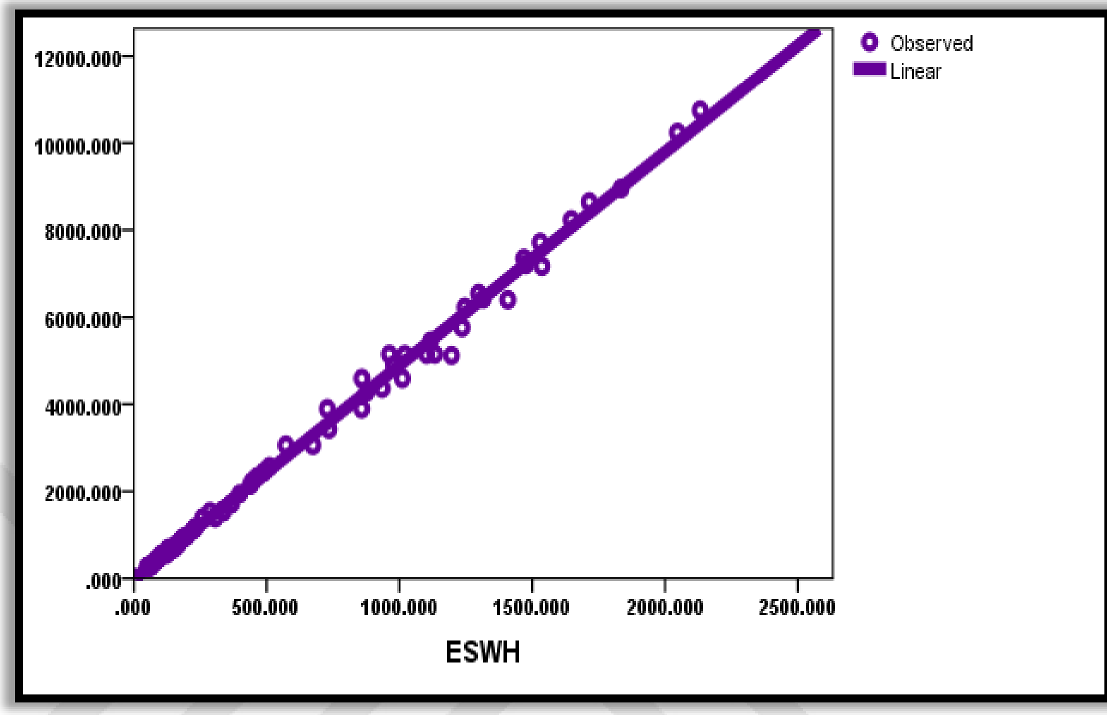


Fig.(25): East-South-West heating (y = - 8.119 + 4.901 x)

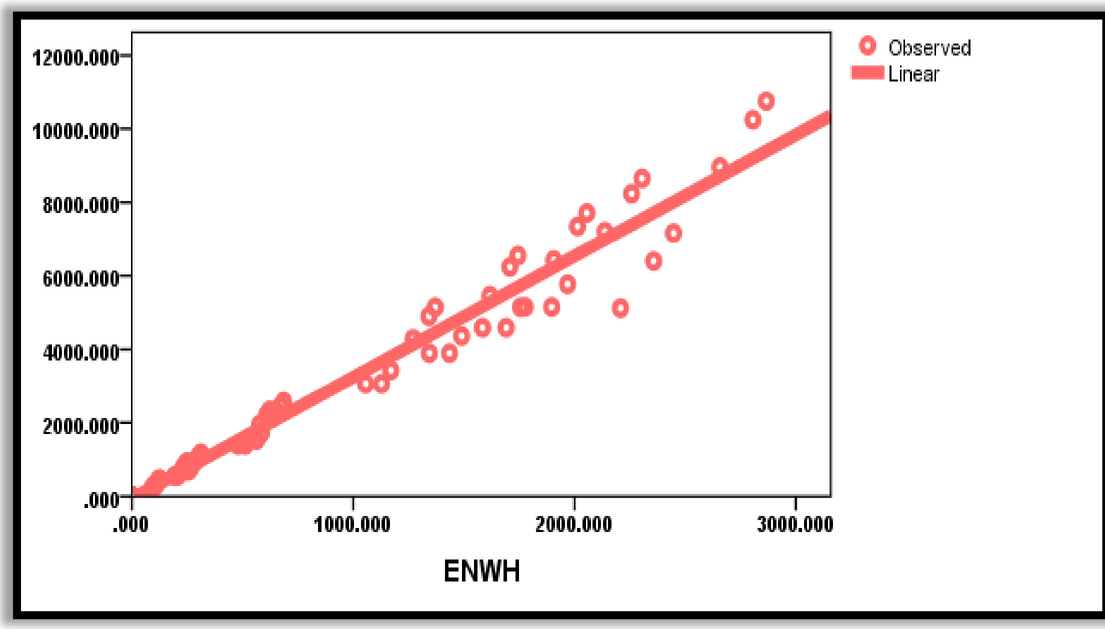


Fig.(26): East-North-West heating (y = - 58.311 + 3.298 x)

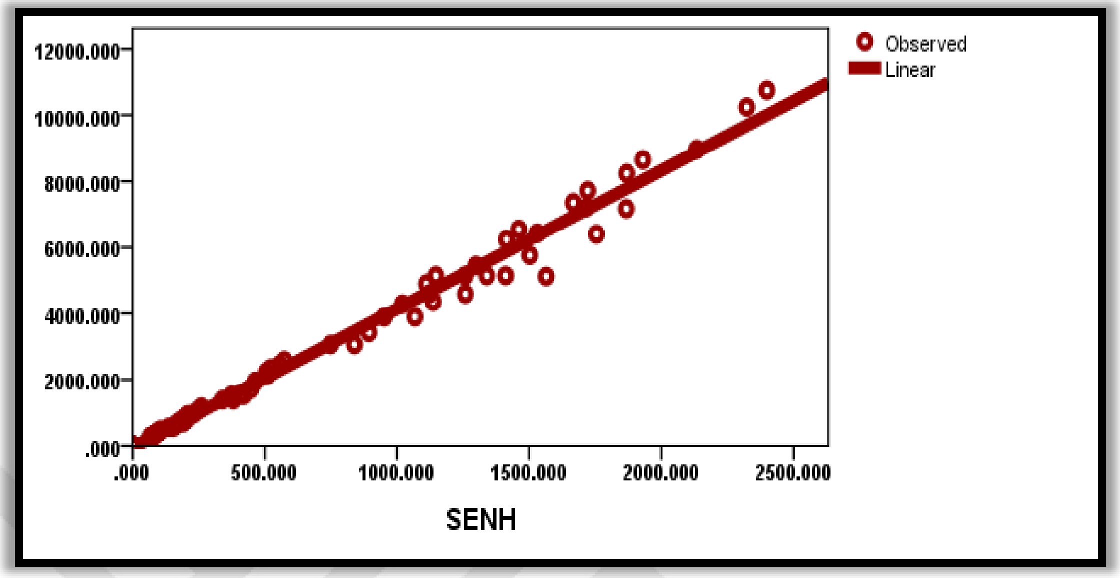


Fig.(27): South-East-North heating (y = - 48.679 + 4.189 x)

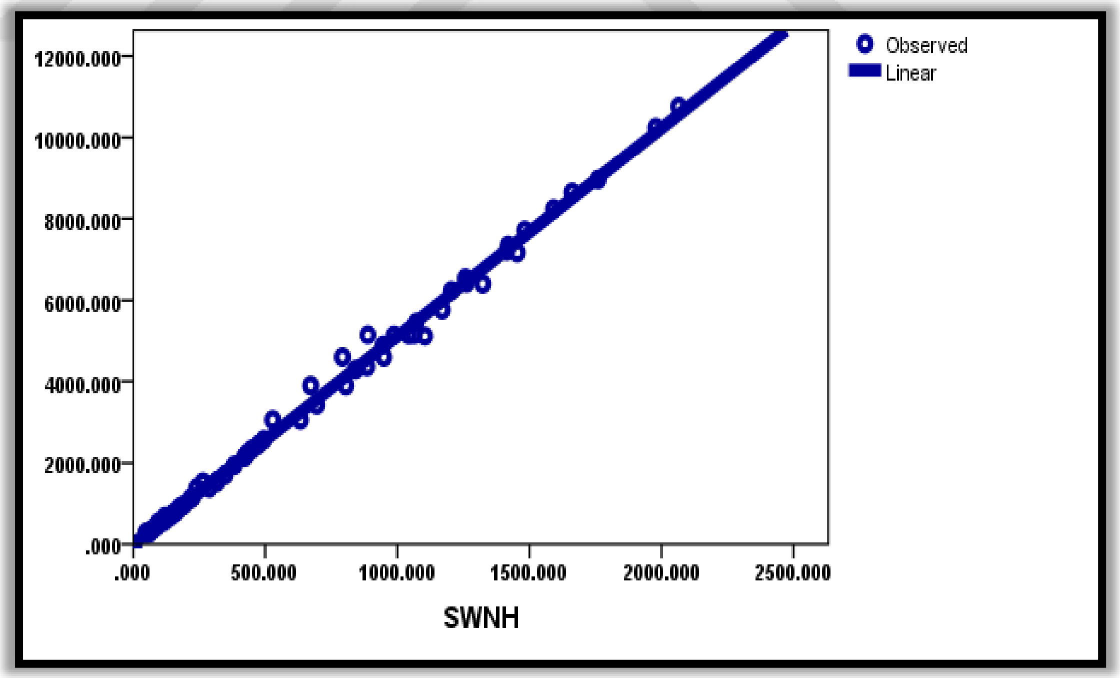


Fig.(28): South-West-North Heating (y = 9.917 + 5.108 x)

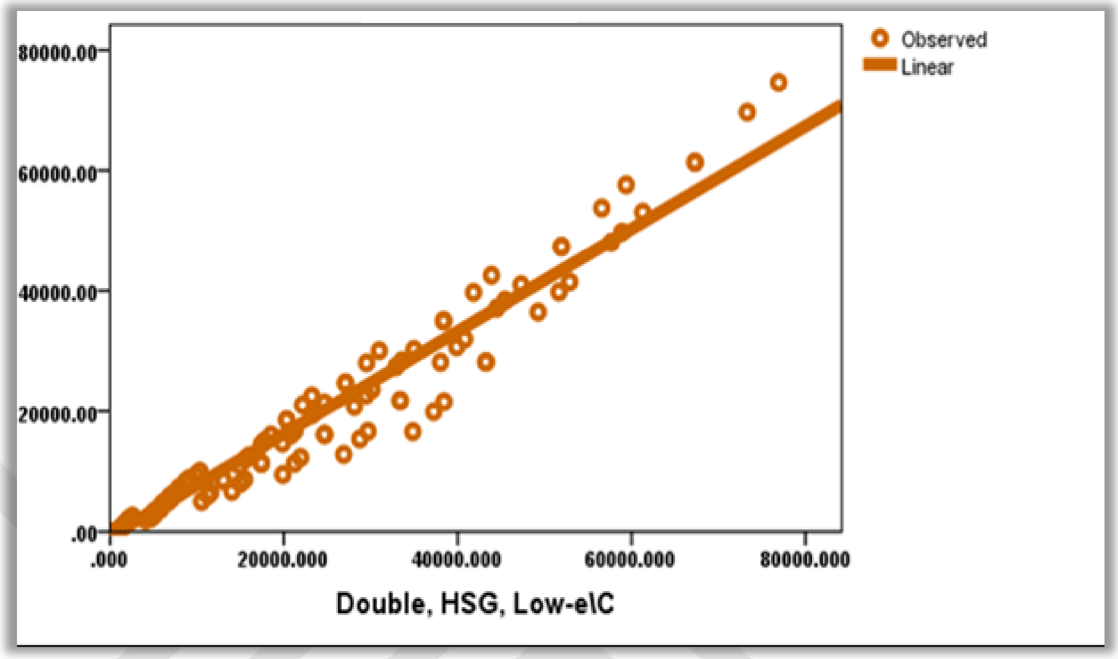


Fig.(29): Double, HSG,Low-e\Cooling (y = - 792.406 + 0.851 x)

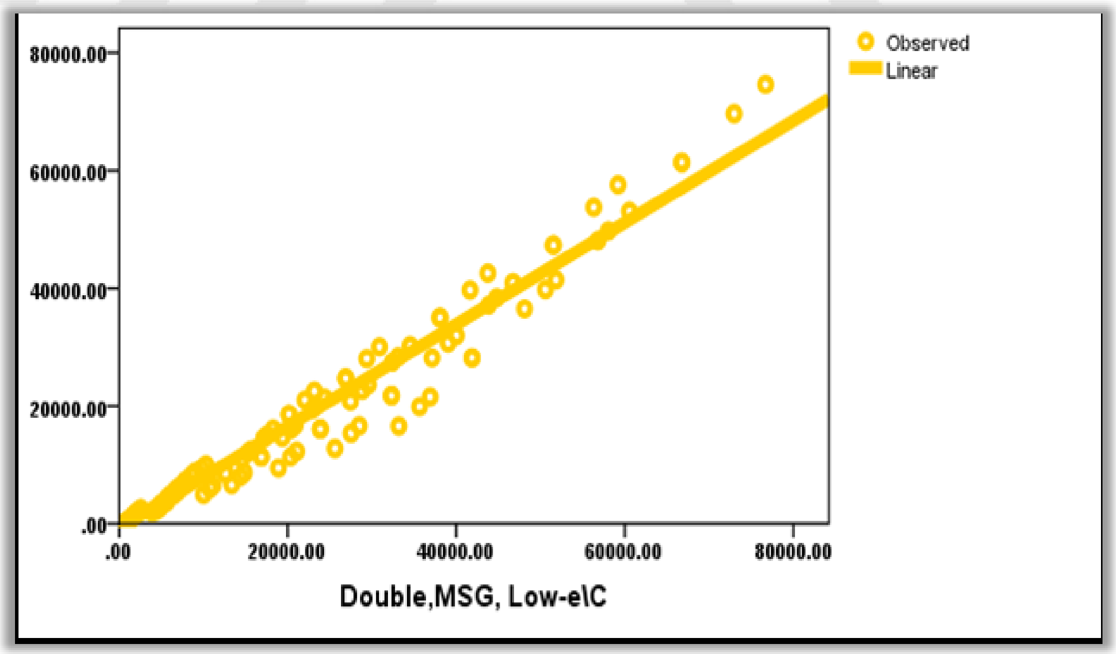


Fig.(29): Double, MSG,Low-e\Cooling (y = - 765.586 + 0.865 x)

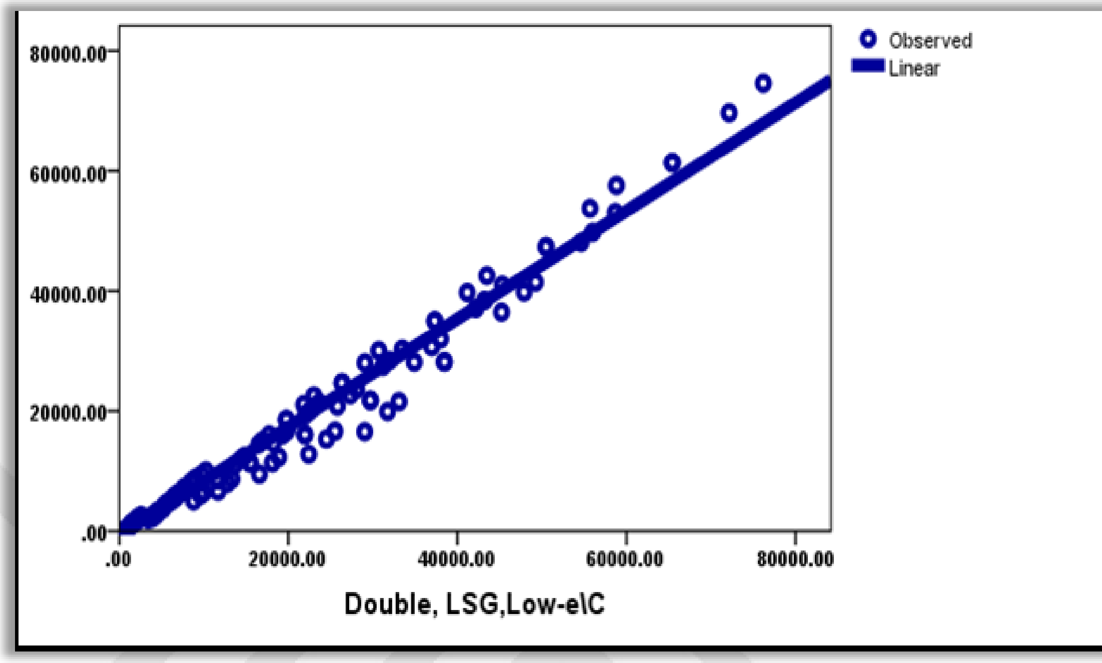


Fig.(29): Double, LSG,Low-e\Cooling (y = - 665.048+ 0.901 x)

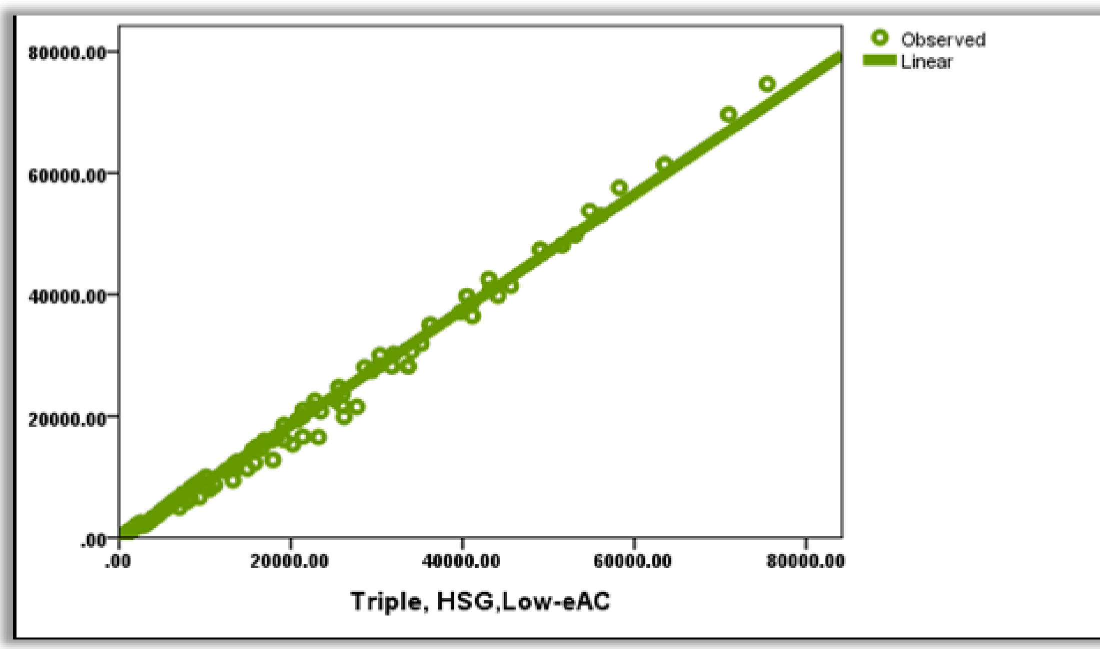


Fig.(30): Triple, HSG,Low-e\Cooling (y = - 430.492+ 0.949 x)

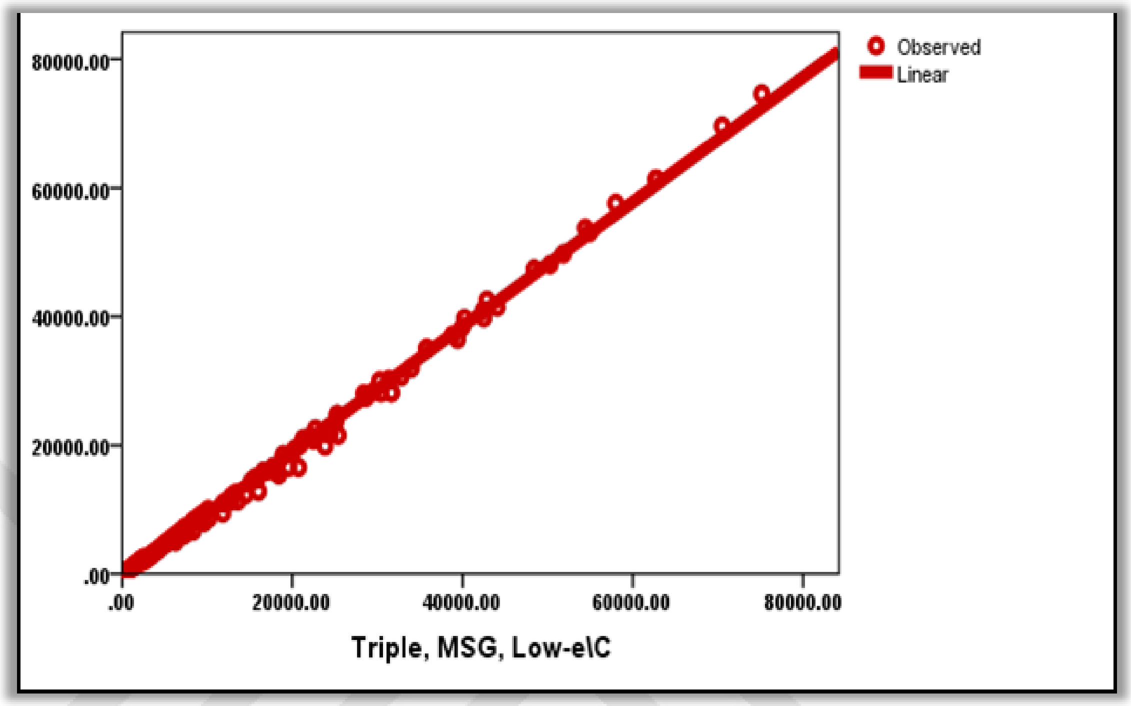


Fig.(31): Triple, MSG,Low-e\Cooling (y = - 291.132+ 0.969 x)

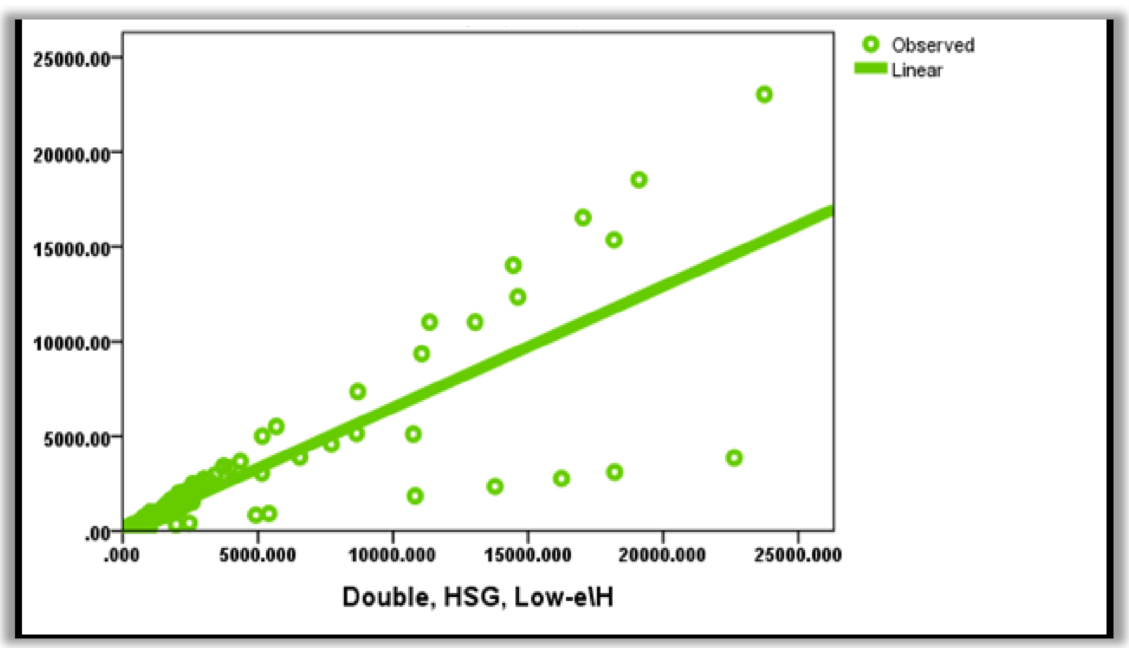


Fig.(32): Double, HSG,Low-e\Heating (y = 101.698+ 0.641 x)

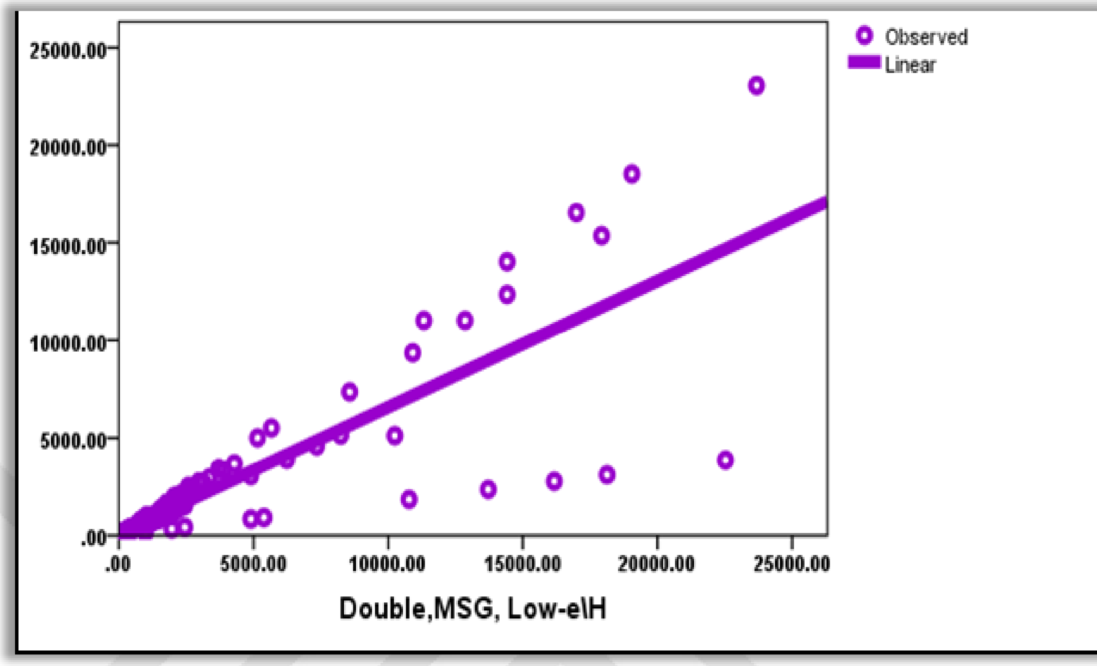


Fig.(33): Double, MSG,Low-e\Heating (y = 113.062+ 0.646 x)

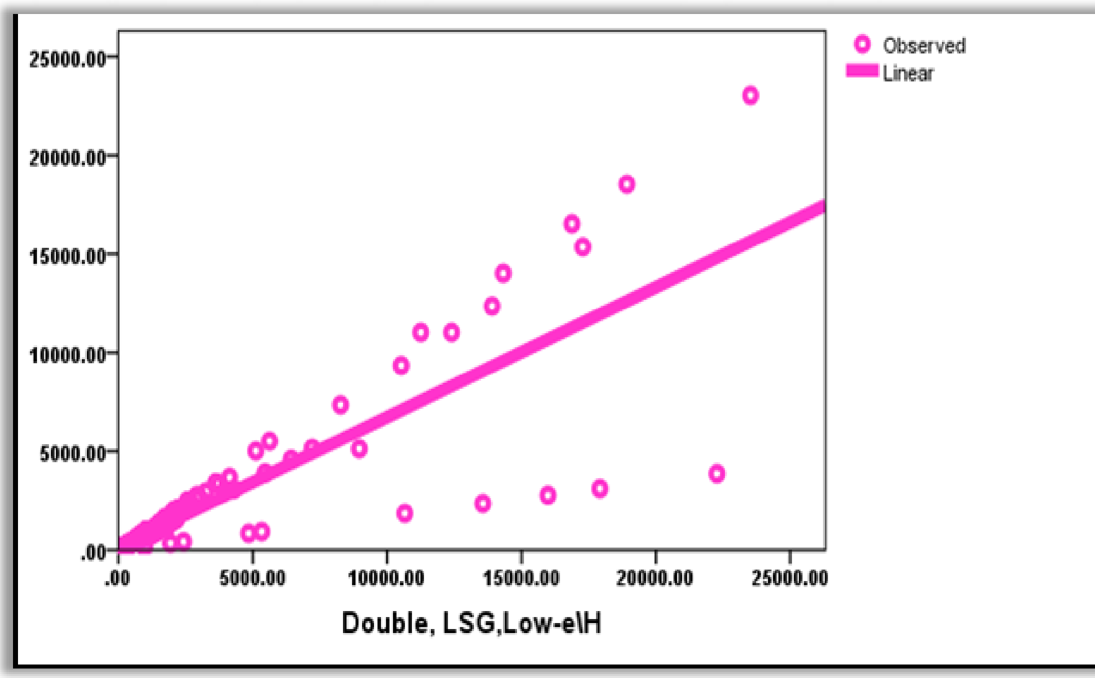


Fig.(34): Double, LSG,Low-e\Heating (y = 145.021+ 0.659 x)

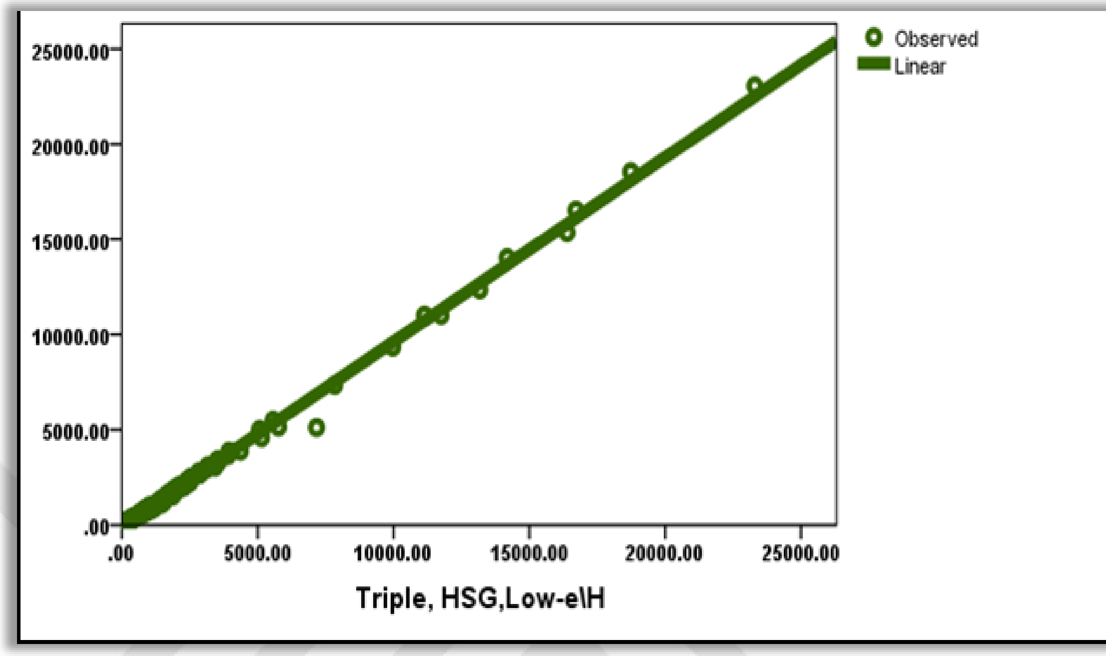


Fig.(35): Triple, HSG,Low-e\Heating (y = - 61.715+ 0.968 x)

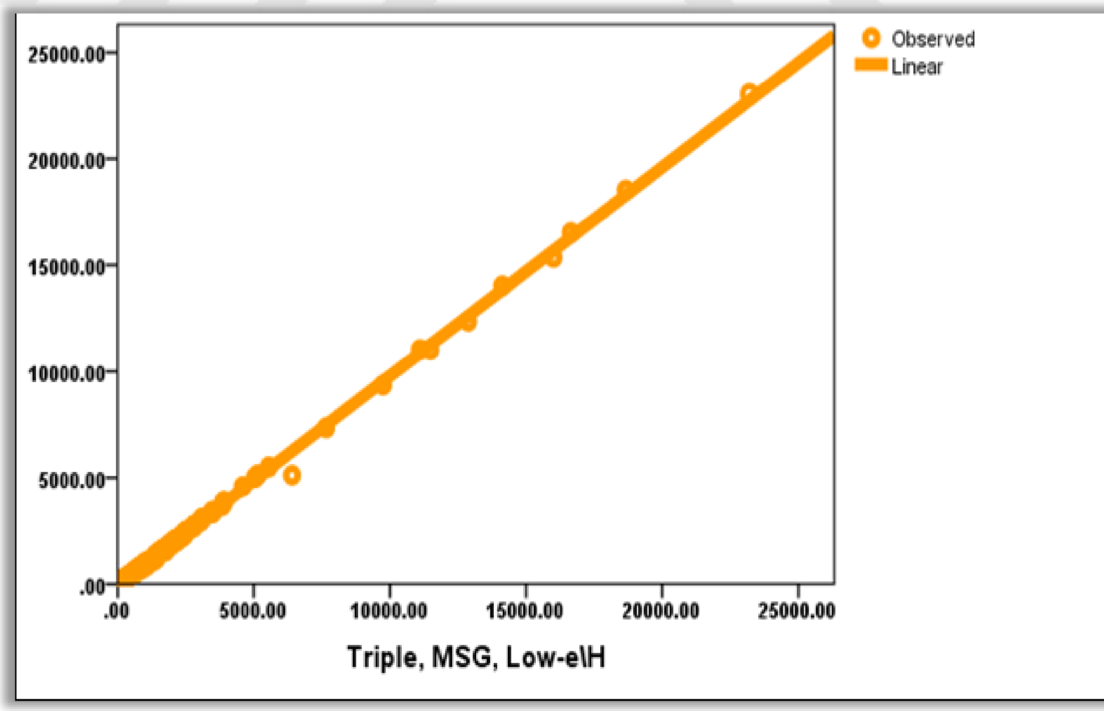


Fig.(35): Triple, MSG,Low-e\Heating (y = - 34.218+ 0.982 x)