YAŞAR UNIVERSITY
GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

MASTER THESIS

THE ENERGY PERFORMANCE EVALUATION OF ETFE (ETHYLENE TETRAFLUOROETHYLENE) CUSION SYSTEMS INTEGRATED ON THE SOUTH FAÇADE OF A HYPOTHETICAL TEST ROOM AND COMPARISON OF IT WITH GLASS FAÇADE SYSTEMS

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PRESENTATION DATE: 10.06.2019

BORNOVA / İZMİR
JUNE 2019

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ABSTRACT

THE ENERGY PERFORMANCE EVALUATION OF ETFE (ETHYLENE TETRAFLUOROETHYLENE) CUSION SYSTEMS INTEGRATED ON THE SOUTH FAÇADE OF A HYPOTHETICAL TEST ROOM AND COMPARISON OF IT WITH GLASS FAÇADE SYSTEMS

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May 2019

The outer shell of the structure, which stands as a separator between the exterior and the interior, is a system that needs to be considered in terms of energy efficiency. The components of these facade elements and the importance of the system they assemble have increased. Efficiency for building envelope is thought to be the control of indoor comfort and climatic factors. Considering today's architectural construction methods and techniques, glass material is preferred by many designers as building cover. Besides, ETFE (Ethylene tetrafluoroethylene) systems are present as an alternative with their thermal and optical properties. This study investigates the thermal and optical performances of different types of glass currently used in ETFE, which has high chemical resistance over a wide temperature range, and shows the differences between them. In this study, thermal - optical performances of İzmir - Erzurum cities having hot and cold climatic types were investigated by simulation method. In the study conducted in the computer environment, it was emphasized that the right materials should be selected and the carbon footprint should be reduced with performance-based concerns in the early design-editing processes of the buildings. In this study, it was shown that ETFE system performs better in cold region and it was observed to be at a negative point in daylight performance maintenance.

Key Words: ETFE, ETFE Facade Systems, Sustainable Architecture, Energy, Performance Based Design, Computational Design, Glass, Glass Façade Systems

ÖZ

HİPOTETİK VE GÜNEYE BAKAN BİR TEST ODASININ, ETFE (ETHYLENE TETRAFLUOROETHYLENE) SİSTEMLERİ İLE CAM DIŞ CEPHE SİSTEMLERİNİN KARŞILAŞTIRILIP, ENERJİ PERFORMANSLARININ DEĞERLENDİRİLMESİ

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Mayıs 2019

Dış mekan ve iç mekan arasında bir ayrıcı olarak duran yapı dış kabuğu, enerji verimliliği açısından üzerine düşünülmesi gereken bir sistem bütünüdür. Bu cephe elemanlarının bileşenleri ve bir araya getirdikleri sistemin önemi günümüzde iyice artmıştır. Yapı kabuğu için verimlilik, iç mekan konforu ve iklimsel faktörlerinin kontrol altına alınması olarak düşünülmektedir. Günümüz mimarlık yapım yöntemleri ve teknikleri göz önüne alınınca cam malzemesi birçok tasarımcının yapı örtüsü olarak tercih ettiği bir malzemedir. Bunun yanı sıra ETFE (Etilen tetrafloroetilen) şişme sistemleri ise termal ve optik özellikleri ile bir alternatif olarak günümüzde kendisini göstermektedir. Bu çalışma, çok geniş ısı aralığında yüksek kimyasal direnci barındıran ETFE malzemesinin, hali hazırda kullanılan farklı cam tipleri ile termal ve optik performanslarını inceleyerek aralarındaki farkları ortaya koymuştur. Yapılan çalışmada, sıcak ve soğuk iklim tiplerine sahip İzmir – Erzurum kentlerindeki termal – optik performansları simülasyon yöntemi ile incelenmiştir. Bilgisayar ortamında yapılmış olan çalışmada, yapıların erken tasarım-kurgu süreçlerinde performansa dayalı kaygılar ile doğru malzemenin seçilmesi ve karbon ayak izinin küçültülmesi gerektiği vurgulanmıştır. Çalışmada ETFE şişme sisteminin soğuk bölgede daha iyi performans verdiği ortaya koyulmuş ve gün ışığı performansı bakımında olumsuz bir noktada olduğu gözlemlenmiştir.

Anahtar Kelimeler: ETFE, ETFE Cephe Sistemleri, Sürdürülebilir Mimari, Enerji, Performans Tabanlı Tasarım, Bilişimsel Tasarım, Cam, Cam Cephe Sistemleri

To my Family. .

ACKNOWLEDGEMENTS

Since I have graduated in 2013 and got my bachelors degree I have been working as a professional architect and it has taken a turn since 2016 by my application to Yaşar University's Architecture program. When this decision is made now, it is seen from my standpoint this decision is exactly as it should be. In this process, I have experienced another campus life, acquired different learning methods, had vast information about the area and met with new friends. I cannot express my gratefulness for all of these and the teachers that I had opportunity to meet with. This process has shown that continuous - lifelong learning, our personal development and ethical rules, and the future or tomorrow will be more beneficial to us on the road of becoming a citizen of the world. For this reason, I would like to thank Yaşar University for its open/closed spaces, people and its habitat.

I would like to thank my supervisor Assoc.Prof.Dr. Başak KUNDAKCI KOYUNBABA for her guidance and patience during this study. In the accomplishment of this study she has given her valuable knowledge and time with great patience and interest. She offered me the help that I needed and has given more than I wanted. Whenever I had a problem, without hesitation I asked her help and with her smiling face and sincerity she has given me all the information and knowledge which will be a great use in my future life in the profession. I would like to express my gratitude as a duty for her.

Also I would like to tell my best regards to the jury members Prof.Dr Tuğçe KAZANASMAZ and Assist.Prof. (PhD) İlker KAHRAMAN. They have given me their time, listened to me and given their precious comments and contributions.

I would like to thank Ali Akgün, the design and intellectual partner of Zero Architecture which we found together, my colleague and professional partner, who have always supported me in this process and who has spent extra effort in the day of this work for me to finish this process.

I thank Ayça Kırımtat and Oben Akmaz for guiding me with their knowledge and supporting me and I wish success in their lives. I would like to thank my friends Cenan Kızılay, Can Durmuşoğlu and Emre Sancak for their friendship and being in my life since my undergraduate.

It's really hard for me to write this part, but I know she is still there watching and feeling proud of me. I've led you to eternity on 26.04.2018, but you will be in my heart forever. My grandmother Gülizar Kurtul, thank you endlessly for what you have given us and thank you for your great heart. With this loss I devote this thesis to all my close family members.

In the last part, I would like to leave my thanks to my nuclear family. To my father Ahmet Karaman, who has never deprived his support and gave trust his trust my entire life. I would like to thank my mother Zengül Karaman who has given all her support and her life, and shaped my life with her heart. Ever since coming to our family, becoming my best friend and my brother Alp Karaman, I thank him for his presence and being a great brother. I would like to thank the entire Karaman family for their gratitude, eternal love, patience and deep faith. I know that being at this point is the end of their existence.

With Respect and Love,

Selim KARAMAN
İzmir, 2019

TEXT OF OATH

I declare and honestly confirm that my study, titled "THE ENERGY PERFORMANCE EVALUATION OF ETFE (ETHYLENE TETRAFLUOROETHYLENE) CUSION SYSTEMS INTEGRATED ON THE SOUTH FAÇADE OF A HYPOTHETICAL TEST ROOM AND COMPARISON OF IT WITH GLASS FAÇADE SYSTEMS" and presented as a Master's Thesis, has been written without applying to any assistance inconsistent with scientific ethics and traditions. I declare, to the best of my knowledge and belief, that all content and ideas drawn directly or indirectly from external sources are indicated in the text and listed in the list of references.

Selim KARAMAN

Signature

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TABLE OF CONTENTS

ABSTRACT v

ÖZ v

ACKNOWLEDGEMENTS vii

TEXT OF OATH x

TABLE OF CONTENTS xi

LIST OF FIGURES xv

LIST OF TABLES xix

SYMBOLS AND ABBREVIATIONS 21

CHAPTER 1 INTRODUCTION 22
1.1. CONTEXT 22
1.2. STATEMENT OF THE PROBLEM 23
1.3. RESEARCH QUESTIONS 24
1.4. RESEARCH OBJECTIVES 24
1.5. DATA GATHERING TECHNIQUE 25

CHAPTER 2 LITERATURE REVIEW 26
2.1. EXAMPLE STUDIES ON ENERGY EFFICIENCY OF ETFE AND GLASS 33

CHAPTER 3 DEFINITION OF ENERGY 42
3.1. WHAT IS ENERGY? 42
3.2. ENERGY RESOURCES 43
3.2.1. Nonrenewable Energy Resources 43
3.2.2. Renewable Energy Sources 44
3.3. WORLD ENERGY DEMAND 45
3.4. ENERGY PERFORMANCE AND SUSTAINABLE ARCHITECTURE 46

CHAPTER 4 CLIMATE DIFFERENCES 49
4.1. WHAT IS CLIMATE? 49
4.2. DIFFERENT CLIMATES IN THE WORLD 49
4.3. CLIMATES IN TURKEY 50
4.3.3. Climate Of İzmir 53
4.3.4. Climate Of Erzurum 54

CHAPTER 5 GLASS 55
5.1. WHAT IS GLASS? 55
5.2. MECHANICAL AND PHYSICAL PROPERTIES 59
5.3. OPTICAL PROPERTIES 60
5.4. DURABILITY TO FIRE 60
5.5. GLASS TYPES...61
5.6. EXTERIOR SYSTEMS OF GLASS 62
5.6.1. SILICONE EXTERIOR SYSTEM...62
5.6.2. STICK CURTAIN WALLING SYSTEM...62
5.6.3. PANEL GLASS FAÇADE SYSTEM 63
5.6.4. PLANER GLASS FAÇADE SYSTEM 64
5.7. PHOTOVOLTAIC SYSTEM 64
5.8. EXAMPLES OF STRUCTURES WITH GLASS...65
CHAPTER 6 ETFE (ETHYLENE/TETRAFLUOROETHYLENE COPOLYMER)...........68
6.1. WHAT IS ETFE?...68
6.1.1. CHEMICAL AND MECHANICAL PROPERTIES OF ETFE 68
6.1.2. INSULATION 72
6.1.3. PATTERNS OF ETFE 74
6.1.4. DURABILITY TO FIRE...75
6.1.5. ETFE LOAD BEARING...75
6.1.6. INSTALLATION OF PHOTOVOLTAIC COMPONENT ON ETFE 76
6.1.7. ENVIROMENTAL BENEFITS OF ETFE 78
6.1.8. COMPARISON OF ETFE WITH OTHER MATERIALS 78
6.2. EXAMPLES OF STRUCTURES WITH ETFE...80
CHAPTER 7 METHODOLOGY...85
7.1. TOTAL ENERGY CONSUMPTION AND ENERGY PLUS....................................88
7.2. USEFUL DAYLIGHT ILLUMINANCE (UDI) AND RADIANCE 89
7.3. CASE STUDY..90
7.3.1. SITE LOCATION 91
7.3.2. PARAMETRIC MODEL 91
CHAPTER 8...99

RESULTS AND DISCUSSION 99
8.1. RESULTS FOR İZMIR REGION 99
8.2. RESULTS FOR ERZURUM REGION 120

CHAPTER 9 CONCLUSION 142

REFERENCES 146

APPENDIX 1 – 158

LIST OF FIGURES

Figure 1: Method of the Research 25

Figure 2: Thermal Tempreatures 32

Figure 6: Pie Chart of Resource Consumption Rates 43

Figure 7: Sustainable Building Criteria 47

Figure 8: Meteorology Stations in Turkey 51

Figure 9: Turkey's Climate Regions according to Köppen 52

Figure 10: Average Temperature of İzmir 53

Figure 11: Average Temperatures in Erzurum 54

Figure 12: A Glass Facade 56

Figure 13: Glass Energy Transfer 57

Figure 14: Solar Heat Gain Coefficient 57

Figure 15: VT Rate in Double Glaze Glass 58

Figure 16: U Factor 58

Figure 17: Glass Types 61

Figure 18: Silicone Exterior 62

Figure 19: Curtain Wall System 63

Figure 20: Panel Glass System 63

Figure 21: Planer Glass System 64

Figure 22: Photovoltaic Glass 64

Figure 23: 30 ST MaryAxe 65

Figure 24: Basque Health Department Headquarters 66

Figure 25: Louvre Museum 67

Figure 26: Molecuar Structure of ETFE 68

Figure 27: Blown ETFE Film Schematic 69

Figure 28: Extruded ETFE Film Schematic 70

Figure 29: Slipped and Clamped Frames 71

Figure 30: ETFE Cushion Air Valve 71

Figure 31: ETFE Insulation Sketch 72

Figure 32: Single layered ETFE 72

Figure 33: Double layered ETFE 73

Figure 34: Triple layered ETFE 73

Figure 35: Printable ETFE patterns 74

Figure 36: Photovaltaic Aparatus 77

Figure 37: Photovoltaic Apparatuss on ETFE 78

Figure 38: National Aquatic Sturcture 81

Figure 39: National Aquatic Structure 81

Figure 40: Allianz Arena 82

Figure 41: Eden Project 83

Figure 42:Kingsdale School Design Sketch 84

Figure 43: Khan Shatyry Entertainment Center 85

Figure 44: Parametric Model Simulation Progress 87

Figure 45: Energy Consumption Calculation Progress 89

Figure 46: Daylight Illumination Calculation Progress 90

Figure 47: Method of the Research''Parametric Model'' - as schematic flowchart 93

Figure 48: 3D Test Room - 17 January 2019 at 11:00 ''By Autodesk Revit'' 93

Figure 49: 3D Test Room - 21 June 2019 at 11:00 ''By Autodesk Revit'' 94

Figure 50:Test Room's Plan – For Measurement Points 94

Figure 51: Collated ETFE and Glass Material's Values 96

Figure 52: Complete Grasshoper Model of Case Study 98

Figure 53: 17 January – Indoor Air Temperature 99

Figure 54: 17-19 January – Indoor Air Temperature 100

Figure 55: 17 January – Indoor P1 Illumination 101

Figure 56: 17 January – Indoor P2 Illumination 101

Figure 57: 17 January – Indoor P3 Illumination 102
Figure 58: 17 January – Indoor P4 Illumination 103
Figure 59: 17 January – Indoor P5 Illumination 103
Figure 60: 17 January - Indoor P6 Illumination... 104
Figure 61: 17-19 January - Surface Energy Losses&Gain 105
Figure 62: 17-19 January - Surface Energy Losses&Gains 106
Figure 63: 21 June – Indoor Air Temperature 107
Figure 64: 20-22 June – Indoor Air Temperature 108
Figure 65: 21 June – Indoor P1 Illumination 109
Figure 66: 21 June – Indoor P2 Illumination 109
Figure 67: 21 June – Indoor P3 Illumination 110
Figure 68: 21 June – Indoor P4 Illumination 111
Figure 69: 21 June – Indoor P5 Illumination 111
Figure 70: 21 June – Indoor P6 Illumination 112
Figure 71: 21 June - Surface Energy Losses&Gains 113
Figure 72: 20-22 June - Surface Energy Losses&Gains 114
Figure 73: Annual Total Heat Gains and UDI Values for Each Material 115
Figure 74:Annual Total Heat Gains for each Material 117
Figure 75: UDI values and annual total heat gain for each material................................... 119
Figure 76: 17 January – Indoor Air Temperature 120
Figure 77: 16-18 January – Indoor Air Temperature 121
Figure 78: 17 January – Indoor P1 Illumination 122
Figure 79: 17 January – Indoor P2 Illumination 122
Figure 80: 17 January – Indoor P3 Illumination 123
Figure 81: 17 January – Indoor P4 Illumination 124
Figure 82: 17 January – Indoor P5 Illumination 124
Figure 83: 17 January - Indoor P6 Illumination... 125

Figure 84: 17 January - Surface Energy Losses&Gains..126
Figure 85: 17-19 January - Surface Energy Losses&Gains..127
Figure 86: 21 June – Indoor Air Temperature..128
Figure 87: 20-22 June – Indoor Air Temperature...129
Figure 88: 21 June – Indoor P1 Illumination...130
Figure 89: 21 June – Indoor P2 Illumination...130
Figure 90: 21 June – Indoor P3 Illumination...131
Figure 91: 21 June – Indoor P4 Illumination...132
Figure 92: 21 June – Indoor P5 Illumination...132
Figure 93: 21 June – Indoor P6 Illumination...133
Figure 94: 21 June - Surface Energy Losses&Gains...134
Figure 95: 20-22 June - Surface Energy Losses&Gains..135
Figure 96: Annual total heat gains and UDI values for each material....................................136
Figure 97: Annual total heat gains for each material...138
Figure 98: Annual total heat gains for each material...140
Figure 99: Annual total heat gains for each material...141

LIST OF TABLES

Table 1: Literature review previous studies 40

Table 2: Literature review previous studies2 41

Table 4: Types and Source of Renewable Energy 44

Table 5: World Energy Demand 45

Table 6: Physical properties of ETFE and Glass 79

Table 7: UDI values and annual total heat gain for each metarial 140

SYMBOLS AND ABBREVIATIONS

ABBREVIATIONS:

AIA	Association of International Architects
BREEAM	Building Research Establishment Environmental Assessment Method
CASBEE	Comprehensive Assessment System for Building Environmental Efficiency
UNEP	The United Environment Program Nations
UNFCCC	The United Nations Framework Convention on Climate Change
EU	European Union
ETFE	Ethylene Tetrafluoroethylene
GEA	Gesellschaft für Entstaubungsanlagen
IPCC	Intergovernmental Panel on Climate Change
LEED	Leadership in Energy and Environmental Design
MARPOL	Maritime pollution
TFE	Tetrafluoroethylene
UDI	Useful Daylight Illumination
PV	Photovoltaic
WGSC	Working Group on Sustainable Construction Methods and Techniques

SYMBOLS:

CO_2	Carbon dioxide
dp	Desipol
O_2	Oxygen
SiO_2	Silicon dioxide

CHAPTER 1
INTRODUCTION

Since ancient times in history, humankind has provided all kinds of benefits necessary for its life from the nature and the sources it contains and they tried to build buildings that were safe and comfortable to adapt to the environment. The mechanical improvements that began with industrial revolution empowered people to have control on their environment in easy ways and brought advanced life standards all together. The main aim of all these mechanical advance efforts is to maximize the level of life standards of humans. Diversely, the rapid population growth, the depletion of existing raw materials, and the increase in energy costs have brought new dimensions to buildings and building design approaches. With the increasing importance of energy efficiency and saving issues, efforts to increase the quality of energy are increasing day by day.

Energy efficiency is the most important aim of sustainable architecture because of buildings entire life span and its cycle. There are different passive and active types of energy efficient solutions that create the needs of a building to increase its ability or capture and generate energy. In the light of these variants ETFE (EthylenTetraFluoroEthylen); as an envelope type and sustainable architecture material will be thoroughly studied, compared and analyzed.

The key point of having a building made by the idea of sustainability is crucial for the countries and the world's resources in the long run. To accomplish that, the architects must face and analyze many variants such as site constraints, climate, building forms and also environmental differentiations. However, these are not the only factors that are taken into consideration. The aim of this chapter is to make an introduction to the framework of the problem, to define the main premises of the research, express the research questions and recognize the outline of the research.

1.1. Context

Humankind for years without thinking consumed energy resources and natural resources and damaged them. However, winning back the lost nature and the energy is either impossible or it requires intensive work and expenditure. Due to the conscious or unconscious, and also inefficient and unnecessary consumption of energy, results in fossil resources rapidly running out. Energy prices rise, environment and nature are being polluted, and all these factors lead to climate change.

One of the main elements in the lives of people is energy and it is inevitable for people to create, produce or design buildings without it. In this perspective, the energy usage must be done in the most efficient way as possible. Energy as a concept; requires that the parameters of "Production, Transportation, and Consumption" should be taken into account as a whole. As energy is used for the services to provide comfort conditions such as heating, cooling and ventilating the buildings, energy consumption at various levels throughout the whole construction life expectancy is at the stages of the raw material acquisition until the demolition and destruction of the structure.

As long as the characteristics of a structure are important, the features around the structure are also important. Nevertheless, it is not possible to control air temperature, wind and other air factors. A well-designed landscape arrangement and energy efficient materials help protect the building from the wind in winter and sun in summer. It helps to reduce water and fuel consumption and contributes to the green environment and also reduces the budget allocated to energy.

1.2. Statement of the Problem

Buildings and development as a group record nearly 36% worldwide last energy usage also 39% of energy related carbon dioxide (CO_2) emanations after upstream power reproduction is added. (Global Status Report, 2018) Therefore, to reduce the carbon footprint of the building construction there should be more energy efficient buildings. By developing and enhancing the energy performance of constructions and also buildings, energy efficiency can be increased and significant energy savings can be achieved. For this reason, studies on energy performance of buildings continue to increase all over the world. In this thesis implementation of ETFE (Ethylen TetraFluoroEthylen) in comparison to glass is stressed out to create an efficient environmental and mental change for building the constructions in an energy efficient way.

1.3. Research Questions

The facade, which is one of the leading constraints for its efficiency and its exposure to climatic conditions, is a well-known trait. With this method, energy efficiency and efficient daylight comfort are made in the use of the building. With the help of computational material analyzes, the factors of thermal and visual comfort of the structure will be discussed in accordance with climate and standards. In addition to the building orientation in the early design steps, the annual energy usage of our structure changes in the selection of materials in the building shell. In this context, the following questions are asked in regards with computational simulation model.

- Can loss of energy be reduced or recovered by using ETFE in buiding façade designs?
- Within comparison to glass, is ETFE more efficient?
- Is it suitable to use ETFE for a place with a warm climate like İzmir?

1.4. Research Objectives

Research objective consists of (1) addressing ETFE in the literature, (2) pointing out the researches that are offered in the previous studies, (3) discussing potential solutions that can be offered, (4) contributing to the current literature by researching and combining the data and analyzing a computer modelling.

1.5. Data Gathering Technique

Research process includes empirical work that is completed with the gathering of information which can happen, disprove or challenge speculations which thus takes into consideration comprehension and elucidation for various perceptions (May, 1997). Books and articles related to the subject as data and resources published by governmental or independent organizations journals, publications and research related subject surveys and interviews. By using Rhino software and with the aid of Grasshopper plug-in simulations will be produced to figure out the possible outcomes (thermal comfort and distribution and usage of daylight) of the integration of ETFE to an office in Turkey, İzmir.

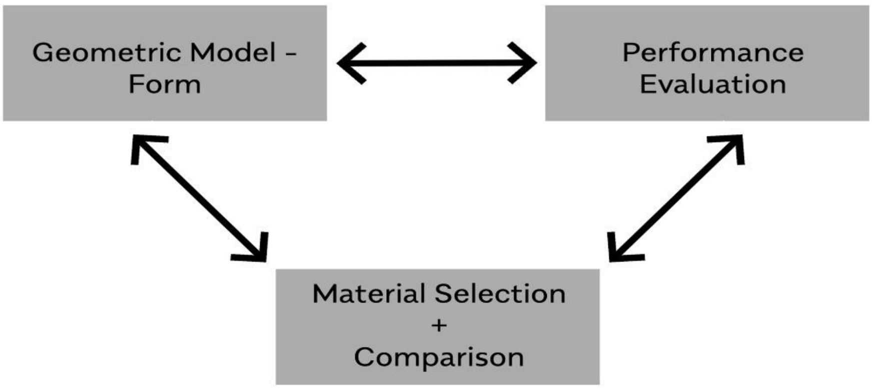

Figure 1: Method of the Research

The computerized simulation work as a test model is done with repeating the same process by obtaining the performance based outputs of the materials after the model is created as a parametric and returning the model with the results.

CHAPTER 2
LITERATURE REVIEW

The section reviews the past investigations directed about energy utilization in structures and improvement strategies from architectural perspective just as, centers around the deficiency of the structures as far as concealing and energy productivity. In the first place, connection among structures and energy with respect to productivity is discussed to give primer data why sun oriented energy ought to be considered while planning structures. Motivations to develop structures with ETFE were examined with compositional angles. Energy use and daylight usage for lighting, warming and cooling, and so forth was considered. Contextual investigations were inspected to comprehend answer for the energy utilization issues better. Additionally glass facades and its impact on energy were examined and strategies utilized for sparing energy in glass exteriors were researched. The glass facades are commonly preffered, however apart from style it is kept in the closer view during the design stage and the energy loss at the front are disregarded. The worldwide energy emergency, the consumption of petroleum products sooner rather than later, and the natural contamination brought about by them have driven individuals to utilize sustainable power source assets and use energy more viably. Designers have quite recently started to consider energy proficiency in their structures. The significance and effect of the concealing components in the architecture field and in the energy field are referenced. ETFE can avoid the sun's overabundance radiation and permit the measure of light required to be moved to the interiors. Various kinds of ETFE can be separated into unique sorts as per their use and places of utilization. The fundamental motivation behind the ETFE is to make a warm environment in the winter while making a cool environment in summer. At the point when ETFE is planned and designed productively, they give the ideal warm parity in the interiors. While structuring the exterior of a building, the position of area, the situating of the structure, the facade plan of the structure and properties of the materials utilized in the structure and the light properties are thought about during the design stage. So as to control the calculation strategy utilized in mathematical figurings and simulations, it will be suitable to gather field information. When planning a structure its encompassing condition ought to be considered. Design of a structure requires mathematical count and overlooking numerous significant elements to streamline the figuring. These days, PC projects have made it conceivable to simplify the production of such complex recreations and to think about more factors. Today, utilizing PC programming is the main alternative to evaluate the energy requests, warm and visual solace quick and precisely. Some of ordinarily utilized programs are Radiance, EnergyPlus, Therm, Rhinoceros. EnergyPlus has no easy to understand interface and utilizations content records to produce energy examination and thermal load recreations. Typically it is utilized related to visual plan programs. Radiance makes simulations and envisions results with the goal that structures can be effectively deciphered. Term is utilized widely to recreate heat transfer examination and energy efficiency of structure segments, for example, entryways, windows, dividers, rooftops. It utilizes the limited component strategy for two dimensional heat transfer investigation.

Today, building stocks and buildings to be built; There are some standards related to thermal comfort and UDI comfort. The importance of thermal and UDI comfort in the early design stages of these new buildings is becoming increasingly important. The energy use and lifelong costs of a structure not considered at these stages may be far from sustainable. (Chi et al.,2018) Diverse control techniques for wise exteriors have been assessed searching for the improvement of thermal comfort execution and the minimization energy interest for a place of business. Long haul thermal comfort has been evaluated through the time recurrence of the solar classes proposed. (Liu et al., 2015)

The target of the Bodart et al. work was to assess the effect of lighting energy reserve funds on worldwide energy utilization in places of business. This assessment originates from a coordinated methodology consolidating the daylighting and the warm perspectives. The examination displayed here depends on recreation results. A few façade setups have been demonstrated, for the four principle directions and three blends of inside divider reflection coefficients. These reenactments were performed by coupling a daylighting reproduction apparatus (ADELINE) and a dynamic warm recreation programming (TRNSYS). These reproductions enabled us to decide the fundamental parameters playing a standard on lighting utilization. They discovered that daylighting can decrease lighting utilization from 50 to 80%. The worldwide essential vitality sparing coming not just from the decrease of the lighting utilization yet in addition from the decrease of lighting interior burdens could then achieve 40%, for a sort of coating normally utilized in places of business. (Bodart and Herde, 2002)

Today, people spend a significant portion of their time spend work places. In the first decades of the 20th century, less than 15% of the total number of people living in the world populated in urban areas. At present, over 50% of urban areas will represent 80% of the world population. Therefore, thermal comfort and air quality in office buildings; It affects the work efficiency of the employees and brings some physical and psychological disturbances on the user. Thermal comfort is also about feelings and emotions. Therefore, heat balance and comfort conditions are different concepts. (Özdamar, 2017) The inspiration is to have the option to perform nitty gritty examinations of complex fenestration frameworks (CFS) from the lively and daylighting perspectives in a computationally effective way, so the advantages of creative items can be effectively evaluated. (Bueno et al., 2015) The conditions under which daylighting decreases net anual energy use just as those conditions under which energy use may increment. Mixes of divider and fenestration properties that limit net vitality necessities as a component of atmosphere and direction are portrayed. (Johnson et al, 1984)

Another study utilized measurements for daylighting and energy performance were (SDA300/half) and EUI individually. There were numerous parameters to find the ideal structure, for example, WWR, a glass material, development material and concealing gadgets. Almost 300 arrangements were delivered in 6 phases. Every phase is considered as more upgraded from the past ones. These arrangements have shaped the Pareto front which contained the ideal Pareto bend that ideal arrangement situates on it. The majority of the arrangements which are laying on this bend were analysed to find the ideal arrangement for energy effciency. (Toutou et al. 2018)

The quality desired for individuals in structures have additionally expanded and advantages like warm sunlight, lighting, and cooling have gone to the front line. This is the situation concerning the structures having enormous coating territories making high cooling burdens because of radiation originating from sun. Places with hot and parched atmosphere qualities have all the more cooling energy utilization as they are increasingly presented to sun based radiation. What is significant is that the structure makes comfort conditions as far as the ideal energy. (Korpela et al., 1982) By observing of heating, cooling, ventilation, heat recuperation frameworks and so on., improving structures energy productivity and diminishing in structure energy utilization are getting to be huge progressively on account of worldwide energy emergency and carbon discharge. Thus, assessment on structure energy effectiveness and energy protection are important. (Kralj et al., 2018) The indoor temperature should be at a level where people feel comfortable in winter and summer. The temperature should be neither too low nor too high. Although the indoor temperature in summer conditions is mostly chosen according to the outdoor temperature, the indoor design temperature in winter is determined according to the purpose and type of use of the environment. The ambient temperature in which most people work comfortably is 20-26 degrees. (Özdamar, 2017) Another study examined U-Values of residential buildings that are in hot humid, mildly hot and humid summers. And it figured out during hot months a low U-Value window prevents conduction. (Frost and Selkowitz, 1993) Furthermore, study of Bektaş Ekici, (2005) showed that windows are places where heat losses occur intensively in buildings. However, it is possible to benefit between 20% and 30% without the need for heating facilities and the appropriate cost for what needs to be done as a result of proper orientation and suitable glass units.

Another study showed that base single-and twofold sheet precise specific windows did not fundamentally lessen the yearly energy utilization and pinnacle electric interest when contrasted with their regular window partners. Nonetheless, we characterized a hypothetical sun powered optical dissemination of a tuned rakish particular coating, which brought about a decreased yearly cooling vitality utilization of 18%, a diminished all out yearly power utilization of 15%, and a diminished pinnacle electric interest of 11%, when contrasted with a traditional frightfully specific window with the equivalent sunlight based optical properties at typical rate.(Wang et al, 2015)

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Another study indicates that distinctive lighting and shading control systems were tried for an office simulation. The consequences of the examination showed that improving daylight can prompt a decrease of up to 30% in the worldwide energy demand for a structure. (Cammarano et al., 2015) Yet studying glass in office buildings Manuel et al. (2019) states that in all cases the expansion of the window-to-divider proportion produces a huge increment of yearly energy request, however there are coating proportions for every direction in which the sunlight accessibility is balanced out. As an outcome, the decrease of window-to-divider proportion down to these qualities can give satisfactory sunshine, with a noteworthy reduction in HVAC vitality utilization which means lower CO2 outflows. (Manuel et al., 2019)

Office with exceedingly straightforward coating requests essentially high vitality. Also, vitality request increments with diminishing shade transmittance and of suitable optical properties. Besides, varieties in the discoveries are normal with various the bigger coated zone. (Singh and Lazarus, 2015) Another investigation maps the impact of various different window size and essential coating and edge properties on performance, daylighting and warm places in almost zero-usage. The point was to distinguish choices that can bolster the simple and vigorous plan of future homes with commonplace utilization of rooftop and façade windows. Hourly light levels were determined in DAYSIM, while space warming interest and usable temperatures were determined in EnergyPlus. (Skarning, Hviid and Svendsen, 2016)

Moisture content is another factor that determines thermal comfort. Above normal, humid and hot air is the distressing air. At low humidity, there is dryness in the nose, eyes and mouth, and the body is rapidly losing water, so it is often necessary to drink water. It is recommended that the indoor relative humidity value is in the range of 30-70%. In fact, the temperature and relative humidity of the indoor environment should be considered together. Therefore, comfort zones are determined for summer and winter conditions according to temperature and relative humidity. (Özdamar, 2017)

Manz et al. (2018) thermal comfort investigation shows that in a well-structured office and by methods for average protection (Uwall =0.54 W/(m2· K)), twofold coating, variable shading and inactive cooling, and ventilation an abnormal state of warm solace is feasible in the Mediterranean atmosphere of the Maltese archipelago utilizing truth be told, minor measures of energy for heating and cooling or conceivably even none by any means. Additionally thermal performance of the buildings is studied by and the importance of heat gains for buildings expressed. (Coşkun et al., 2017)

According to a study conducted in China, it is found that the office temperature should be at least 26 ° C for thermal comfort. In another study, it was determined that in an environment where low energy cooling system works, the average office temperature should be 23 ° C and the humidity should be 55%. According to US ASHRAE standards, the ideal conditions should be between 20-25.5 ^{0}C and humidity between 30-60%. Body surface area and the clothes we wear are also factors affecting thermal comfort in the working environment. Daily activities also affect thermal comfort. While sitting and standing, body temperature changes. For example, body temperature increases to 0.85 ^{0}C when standing up, and 3.4 ^{0}C increases if you move around the room calmly. (Bulut, 2002) Other results demonstrated that solitary clear coating (g-factor: 0.9 and U-esteem: 6.38 W/m 2 k) is more viable than low-e twofold coating (g-factor: 0.4 and U-esteem: 3.35 W/m 2 k) regarding yearly cooling energy. Essentially, supplanting tinted glazing with clear glazing for concealed façades obviously improves sunlight accessibility in tropical places. (Yaikwah et al., 2012) The outcomes demonstrated that the RBE permitted yearly essential vitality exhibitions fundamentally lower contrasted with a customary straightforward façade with a twofold board Low-E coating. The enactment profile of the 2 dynamic layers during a time uncovered that they are utilized with a recurrence similar, despite the fact that to an alternate degree in various periods. (Iennarella, Serra and Valerio, 2015)

In an efficient and healthy workplace, the ideal air flow should be around 150 mm / sec. When this current increases to 510 mm / s, the environment is described as “breezy” and when it drops to 100 mm / s, the environment is called “airless ”. (Mergen and Öngel, 2009)

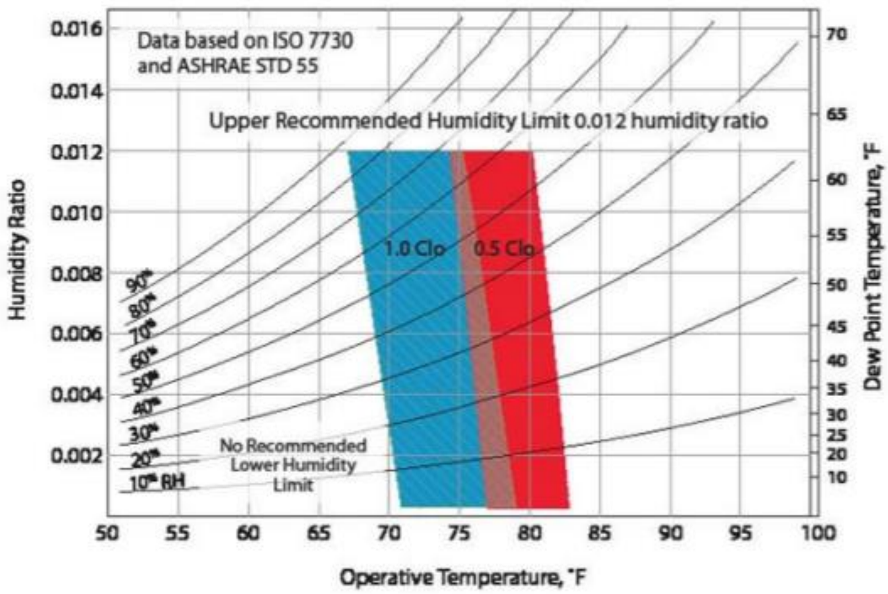


Figure 2: *Thermal Tempreatures*

Source: (Pivac and Nizeti, 2017)

Heat disappointment may likewise happen because of local causes of undesirable warming, cooling or air development for a specific piece of the body. As indicated by the ASHRAE 55-2010 standard, there are four fundamental driver of neighborhood thermal discomfort. First, air development in the manner in which that is undesirable and causes inconvenience as the warm sensation is cool. Individuals are destined to feel a draft on revealed body (head, neck, shoulders, lower legs, feet or legs) and may make inhabitants stop ventilation frameworks, which prompts diminished apparent indoor air quality, wellbeing impacts and lessening the exhibition of tenants. Second, Radiant temperature asymmetry: enormous contrasts in the thermal radiation of the surfaces encompassing an individual that may cause local uneasiness. Thirdly, floor temperature inconvenience because of direct contact between the feet and floor in light of excessively high or too low surface temperature. It is significant when individuals are exposed feet. To dispense with the craving for higher encompassing temperatures, floor materials with a low contact coefficient or floor warming frameworks can be utilized. Lastly, vertical temperature differentiations may cause heat inconvenience at the head and cold distress at the feet. ASHRAE Standard 55 suggests that the distinction ought not be more than 3 °C for situated inhabitants or for standing tenants 4 °C. (Pivac and Nizeti, 2017)

High structures and expanded energy utilization contrasted with low-ascent structures have uncovered the need of estimating the energy utilization in these structures. At this stage, it is imperative to analyze three essential criteria: the components close to the structure and the direction of the structure; the structure of the environment is exceptionally compelling in keeping up the heat balance among inward and outer climatic conditions. The essential materials utilized in the development of the structure additionally assume a significant job in giving the inside comfort.

The UDI paradigm safeguards a great part of the interpretive effortlessness of the customary sunlight factor approach. Rather than sunshine factors nonetheless, UDI is established on a yearly time-arrangement of total qualities for illuminance anticipated under sensible skies created from standard meteorological datasets. Accomplished UDI is characterized as the yearly illuminances over the work plane where every one of the illuminances are inside the range 100 lux to 2000 lux. These breaking points depend on reports of inhabitant inclinations and conduct in daylight workplaces with client worked concealing gadgets. How much UDI isn't accomplished in light of the fact that illuminances surpass as far as possible is characteristic of the potential for tenant inconvenience. The connection between accomplished UDI and yearly vitality utilization for lighting is analyzed.

2.1. Example Studies on Energy Efficiency of ETFE and Glass

It is found in the literature that a large portion of the investigations about ETFE and glass facades have been picking up a pace that is directed in the energy efficiency phase step by step while diverse simulation tools are being used in the simulations of the given materials. ETFE film is transparent to long-wave radiation to a limited degree, as opposed to glass, which is opaque to it (Poirazis et al., 2010). Studies that are done in particular, several articles stress out that the environmental issues regarding ETFE is less than that of glass (Lamnatou et al. 2018, And Maywald C. Et al. 2016)
There are various researches academically done about ETFE in the literature. Wolfgang Rudorf-Witrin and Edward M. P. et al. presented structures, fundamental mechanical properties and utilizations of ETFE foil in detail (Wolfgang Rudorf-Witrin, 2005). Christan H., Annette B. et al. proposed the air unit, demonstrated the air for burden conveying of ETFE cushion. Galliot and R.H. Luchsinger of the Center for Synergetic Structures at the Swiss Federal Laboratories for Materials Science and

Technology displayed results on mechanical trial of ETFE films. (Galliot, C. & Luchsinger, R.H., 2010) Moritz K. et al. explored efficiently plan and designing use of ETFE cushion, brought up the marvel of time-temperature-shift (TTS) (Moritz K., 2009). Borgart, A. examined mechanical conduct of multilayered air expanded cushions through the numerical examination and analysis (Borgart, 2007). Lei Gu and Peng Wang et al. led examination and model trial of ETFE pad, proposed a coarse approach to quantify stress (Lei Gu, Peng Wang and Chen Shiping, 2012). Another result showed that the alloted daylighting criteria were met in the two cases while, the outside sun powered screen was increasingly viable in diminishing energy loads which came to about 85% not exactly the inward. (Fatma et al, 2017)

There is also an investigation that plans to address radiotinal rates by playing out a test and computational examination on the warm reaction of an ETFE cladding unit, close by a glass cladding, presented to a similar outer conditions and upheld by the equivalent inner condition managing instrument. (Dimitriadou, 2015)

Max et al. (2012) analyzed ETFE layers as a major aspect of a novel greenhouse glazing system. Their work utilized three hot boxes that were secured then again with a solitary coated unit, in blend with a solitary ETFE film and the course of action of ETFE filmglass-ETFE film.

Ansell led uniaxial creep tests on ETFE foil at temperatures of 40, 60 and 100 °C. The 60 and 100° tests were done under dry conditions yet the 40° tests were done under states of roughly 100% relative dampness. A worry of 5 MPa was connected to the examples and held for the whole testing time frame. The tests done at 40 °C went on for 46 days (1104 hours), the tests done at 60 °C endured 19 days (456 hours), and the tests done at 100 °C went on for just four hours because of over the top stream in the material. The film tests were 100 and 300 μm thick and had a measure length of 250 mm. Two examples were examined toward every path at every temperature (Ansell, 1985).

In the outcomes from the 40° tests, the 48-hour strain is more prominent than the resulting values. Ansell ascribed this to exploratory blunders or something to that affect, and left the 48-hour values off. Likewise, since the 100° tests were just estimated at one point in time, they were additionally excluded on the diagram as no strain-time relationship could be resolved. Ansell demonstrates the strain versus time plots for the rest of the strain, showed on a log time scale (Ansell, 1985).

Also in hot and cold atmospheres, for example, Houston and Chicago, EC windows with shades can fundamentally decrease the normal yearly sunshine glare file (DGI) and convey noteworthy yearly vitality use reserve funds if the window region is huge. Absolute essential yearly vitality use was expanded by 2–5% for moderate-zone windows in either atmosphere yet diminished by 10% in Chicago and 5% in Houston for enormous territory windows. Pinnacle electric interest can be decreased by 7–8% for moderate-region windows and by 14–16% for huge region windows in either atmosphere. Energy and pinnacle request decreases can be fundamentally more noteworthy if the reference case does not have outside shading or best in class static glass. (Lee and Tavil, 2007) Concealing of windows can lessen these heaps. In contrast to the woven sun oriented screens, wooden sun based screens have a thickness that gives particular concealing properties. Punctured wooden sunlight based screens were customarily utilized for windows concealing. Creating present day kinds of these concealing frameworks can prompt huge energy investment. (A. Sherif et al. 2012) Furthermore, according to research of Gene Harn , glazing transmittance and blind transmittance show lighting savings. (Gene Harn et al., 2017)

The creep tests done by Liu et al. were established on tests with same measurements from those utilized in the cyclic loading tests. Tests were uniaxial, done at stress scale of 3, 6 and 9 MPa and temperatures of 25, 40 and 60°C. The examples were again stacked at a rate of 3 mm/minute, until the ideal stress was accomplished, and afterward the pressure was kept up for 24 hours (Liu et al., 2008).
Figure below demonstrates the strains for the distinctive stress at three in time and for three temperatures. Time 0 alludes to when the ideal burden was first occurred.

In 24 hours period low stress and normal temperature, creep level is also low. The full creep of the example examined at 3MPa and 25^0C is 0.49%. When the stress levels get higher and the hours get longer, also the rates of creep get bigger. The full creep of the example tried at 9MPa and 60°C is 13.21%.

Gomez et al. outlines the most important patterns, as per the investigation of a substantial amount of global propositions, and generally recent decade, which have been dissected through a wide scope of qualitative parameters. Along with these lines, inflatable proposition quantity has expanded extensively, identified with rooftop covering and less to façade frameworks. In addition, improvement of layer materials and the impact of certain media-mass undertakings have likewise served to this advancement. The higher solidness supports the application on changeless structures and the nascent mix in retrofitting forms, exploiting the maintenance and simple upkeep of this innovation. Enthusiastic retrofitting represents a standout amongst the most fascinating zones of progress.

Findings of the forms of ETFE was analyzed in the study. In spite of the fact that, by definition the pneumatic frameworks morphology depends straightforwardly from the weight impacts over the membrane, the inflatable typologies are often structured under different parameters. Along these lines, the frameworks dependent on the ideal membrane conduct or minimal surface, that are a minority (2%); like the ones anticipated with predefined geometrical structures are much of the time utilized (95%). In connection with the most widely recognized geometries, the cushion typology presents to 70% of the all out geometric proposition that have been analyzed. Rectangular edge shapes represented to the most widely recognized cushion geometries (54%), which support the way that numerous designs utilize this innovation as a substitution for glass, yet proceeding with its development designs without exploiting maximal properties of adaptable layers. (Gomez et al., 2011)

Façade frameworks are, in charge of both the energy execution and aesthetic characteristics of a structure. The investigation introduced in the study investigates the structural combination of a conveyed computer arrange and the façade of a skyscraper tower using ETFE cushions. Taking the delicate idea of this material to implant a sensor system which gives contact responsive changes of murkiness in the façade, possibly improving the energy efficiency of structure, and advancing a novel sort of exchange between a space and its occupants.

According to Sherif et al., In desert bright clear-sky areas sunlight based entrance can wind up inordinate. This can cause non-uniform sunshine appropriation, glare and high sunlight based warmth increase, influencing both visual and warm solace. Concealing gadgets, for example, sunlight based screens, were generally used to diffuse and counteract direct sun based infiltration into spaces. Their paper examines the effect of changing sun oriented screen hub pivot edge and screen opening perspective proportion on daylighting execution in a normal private lounge room space under the desert bright clear-sky. The bigger point is to land at productive sun based screen plans that suit the various directions.

They suggest that the consideration of Computer organizes and shows in the condition prompt new structure rationalities. Those unravel structurally the exchange between customary materials and mechanical gadgets, and they set forward the principal after-effects of an examination into electrochromic "smart cushion" that takes into consideration changing opacities of the façade components of a structure with human touch (Cardoso, Michaud, Dennis and Sass, 2019).

Within the parameters of research; Smart windows, pressure sensors, touch responsive electrochromic ETFE foil cushions are questioned, the problems are stated and further research should be done to question the prototype that is presented.

Antretter et al. (2008) examined the uneven conveyance of heat in the interior of film pads. Their work concerned the utilization of a full scale model of a structure secured by an ETFE pad to confirm the outcomes that happen when Computational Fluid Dynamics (CFD) is utilized to foresee heat appropriation under a few tendencies.

In the last years, there are some articles reports on ETFE foils combined with thin Photo Voltaic modules, that are generally produced with amorphous silicon. Hu et al. (2015) understood that under standard working conditions electrical properties are moderately not initiated by thermal and mechanical changes. Be that as it may, an immediate connection among mechanical and warm properties (stress bends at different temperatures) is watched. It ought to be noticed that examples investigated are precisely fixed onto ETFE and not printed. Menéndez et al. (2018) structured, created, and tried a novel planar multifunctional ETFE module including LEDs, OPVs, and flexible hardware.

Zhao et al. (2015) built up a thermal model for the amorphous silicon photovoltaic modules coordinated into an ETFE pad rooftop. They anticipated the PV module temperature under radiant and shady conditions. Their model was approved with the study and demonstrated a sensible accuracy. In any case, their model couldn't anticipate the air temperature inside the pad, the ETFE layer temperatures just as the pneumatic force.

Bhangdia (2017) considered ETFE cushions in the quest for a substitution to coating, as an answer for the disservices related with utilization of glass, for example, its delicacy, weight and conduct towards warmth transmission. According to the research glass introduces high transmission of close Infra-Red radiation, causing an expansion in cooling prerequisites during warm climate, and ordinary cooling because of tropical climatic conditions. The extreme utilization of coating additionally expands the encapsulated vitality and along these lines lift the structure support cost and influence worldwide condition. This can be limited by supplanting glass board by ETFE. Moreover, the geometry of the structure is regularly a deterrent to the utilization of glass which isn't case with ETFE, accordingly creator have opportunity to ETFE pads have been considered in the quest for a substitution to coating, as an answer for the disservices related with utilization of glass, for example, its delicacy, weight and conduct towards warmth transmission. Glass introduces high transmission of close Infra-Red radiation, causing an expansion in cooling prerequisites during warm climate, and ordinary cooling because of tropical climatic conditions. The extreme utilization of coating additionally expands the encapsulated vitality and along these lines lift the structure support cost and influence worldwide condition. This can be limited by supplanting glass board by ETFE.

Monticelli, Zanelli, & Centrulli,(2017) has demonstrated the approval of the referenced a methodology through five diverse contextual analyses of ETFE constructed structures, both contrasted and an) other customary straightforward innovation, b) different plans and geometries of ETFE cushions. The developed outcomes, comprehensively, are the initial moves towards the foundation of criteria for use of the LCA to assess film structures in the structure life cycle.

Hertz et al. (2010) Melbourne, Australia utilized ETFE pads and an elective plan for a similar rooftop utilizing a conventional glass structure. They discovered that the ETFE option brought about a 42 percent decrease in life cycle energy necessities. The paper shows the advantages and difficulties related with the utilization of materials in structures.

De Lima and Caram (2014), in their study The sunshine investigation demonstrated that is conceivable to accomplish illuminances somewhere in the range of 500 and 2000lx in the room up to 70% of yearly involved hours, time when the utilization of electric lighting might be administered. This presentation marker was the one having most scattering because of the diverse window situations.

Looking at the proportion EUI/AVA and its equal among the eight window arrangements, the corner window has the least EUI/AVA apportion. Moreover, using either the tinted or twofold sheet covered glass in level, inlet and corner windows lessens vitality utilization by 18.3-22.4% contrasted with the reasonable glass windows. (Sudprasert and Tipa, 2014)

Lamnatou et al (2018) says that ETFE offers numerous favorable circumstances, in correlation with glass, from various perspectives. Its natural profile (which incorporate LCA (life cycle appraisal)/ecological issues about ETFE) assess epitomized energy (the discoveries show esteems from 26.5 to 210 MJ/kg). They also show applications (rooftops, veneers, atria, in mix with PV (photovoltaic) innovation, and so forth.).

Aleš et al. (2019) investigated 6-sheet protecting glass (IG) unit was designed and analysed. A general portrayal of the creation of the 6-sheet coating unit has been given. Significant qualities, for example, U-esteem, variable sun based energy transmittance, noticeable transmittance, thermal gain coefficient, glass sheet temperatures, water vapour penetrability, conservative viewpoints including comfort of living, among others, were researched.

Year	Author(s)	Paper Name	Studied Location	Simulation Type	Simulation Tool	Glazing Type	Climate Type	Building Type	Study Type
1982	Korpela, Seppo & Lee, Yee & D. Drummond, Jerry	Heat Transfer Through a Double Pane Window	USA	Thermal performance	no	Double pane glazing	Continental	Residential	Theoretical
1984	Johnson, R & Sullivan, R & Selkowitz, Stephen & Nozaki, S & Conner, C & Arasteh, D.	Glazing energy performance and design optimization with daylighting	USA	Energy performance	DOE-2.1B	Different types of glazings	Mediterranean climate	office	Simulation
1985	Ansell	Acceptability of ETFE Film for Use in Buildings	United Kingdom	Thermal Performance - Creep test	no standardized testing methods were available	No glazing type is mentioned.	Maritime temperate	Office	Experimental
1993	Sullivan, R & Frost, Karl & Arasteh, D & Selkowitz, Stephen	Window U-value effects on residential cooling load	USA	U-value	DOE-2.1D	No input data is given.	Hot humid - mildly hot - humid summer	Residential	Simulation
2002	M.Bodart, A.De Herde	Global energy saving in offices buildings by the use of daylighting	Belgium	Thermal Performance - Daylight performance	TRNSYS ADELINE	Glazing : 9 Different varies	Maritime temperate	Office	Theoretical
2005	Wolfgang Rudorf-Witrin	Tropical Islands-Implementation of the new ETFE film cushion roofing	Germany	Energy Comfort Performance	no	Double pane glazing	Tropical and sub-tropical climates	Tropical island	Theoretical
2005	Bektaş Ekici, Betül.	Soğuk İklimlerdeki Binalarda Pencere Sistemlerinin Enerji Performansı	Türkiye	Daylight and thermal Performance	no	single and double plane glazing	dry summer-subtropical	Residential	Theoretical
2007	Borgart	Mechanical Behaviour of Multi Layered Air Inflated Cushions. In *International Conference on Textile Composites and Inflatable Structures: Structural Membranes*	Spain	Energy Comfort Performance	no	No glazing type is mentioned.	Temperate	No input data is given.	Experimental
2007	E.S. Lee, A.Tavil	Energy and visual comfort performance of electrochromic windows with overhangs	Houston - Chicago	Energy Efficiency - Visual Comfort	DOE-2	Double pane glazing	Humid subtropical (Houston) - Humid continental (Chicago)	Office	Theorical
2008	Liu et al.	Cycle Loading and Creep Tests of ETFE Foil	Taiwan	Creep test	no	No glazing type is mentioned.	temperatures are used(25, 40 and 60 °C)		Experimental
2008	Antretter et al.	Thermal Transfer through Membrane Cushions Analyzed by Computational Fluid Dynamics	Germany	Membrane Fluid Dynamics	CFD	No glazing type is mentioned.	different temperatures are used	pentagonal tower	Simulation
2009	Moritz K.	A multifunctional ETFE module for sustainable façade lighting: Design, manufacturing and monitoring. Energy Build	Barselona and Paris	Thermal Performance	SketchUp - Trnsys - LBL	No glazing type is mentioned.	Mediterranean climate	Office	Simulation
2010	Poirazis et al.	Energy Modelling of ETFE Membranes in Building Applications	United Kingdom	Energy Efficiency - Visual Comfort	no	Triple glazing unit.			Simulation
2010	Galliot, C. & Luchsinger	Biaxial testing of architectural membranes and foils	Switzerland	biaxial mechanical properties	no	No input data is given.	No input data is given.		Experimental
2010	Hertz et al.	A life cycle energy comparison of textile and glass materials for building envelopes	Australia	Life cycle energy materials	no	toughned laminated glass	Humid subtropical climate	outdoor plaza	Experimental
2011	Gomez et al.	Pneumatic Skins in Architecture. Sustainable Trends in Low Positive Pressure Inflatable Systems	Spain	Qualitative data gathering	No input data is given.	No input data is given.		No input data is given.	Theorotical
2012	Ahmed H. Sherif Hanan M. Sabry Mahmoud I. Gadelhak	The impact of changing solar screen rotation angle and its opening aspect ratios on Daylight Availability in Residental Desert building	Jeddah - Saudi Arabia	Daylight Simulation	Diva for Rhino	No glazing type is mentioned.	Hot Arid	Residential	Theoretical
2012	A. Sherif A. El-Zafarany R. Arafa	External perforated window Solar Screens: The effect of screen depth and perforation ratio on energy performance in extreme desert environments	Kharga Oasis - Egypt	Thermal Performance	Energy Plus	No glazing type is mentioned.	Hot Arid	No input data is given.	Simulation
2012	Lei Gu, Peng Wang and Chen Shiping	Experimental study and FEA of ETFE cushion	Brazil	Creep test	Photomodeler software	No glazing type is mentioned.			Experimental
2012	Max et al.	Glass–film-combination: Opto-physical properties and energy saving potential of a novel greenhouse glazing system	Germany	Energy Efficiency - Visual Comfort	no	Coated glass	No input data is given	Hot box	Experimental
2012	Yaik-Wah Lim, Mohd Zin Kandar, Mohd Hamdan Ahmad, Dilshan Remaz Ossen, Aminatuzuhariah Megat Abdullah	Building façade design for daylighting quality in typical government office building	Johor Bahru, Maleysia	Daylight analysis - Visual comfort	Radiance	Tinted glazing	tropical and sub-tropical climates	Office	Experimental - Theorical
2014	De Lima, Kamila & Caram, Rosana	THE INFLUENCE OF WINDOW-RELATED DESIGN VARIABLES ON THERMAL, DAYLIGHT AND ENERGY PERFORMANCE OF OFFICES	Brazil	Daylight and energy performance	DAYSIM	Reflective, Grey, Clear	Hot humid	office	Simulation
2014	Sudprasert, Sudaporn & Norkaewmool, Tipa	The Effect of Window Configurations on Visible Area and Energy Consumption	Thailand	Daylight and energy performance	Ecotect - eQuest	Double pane glazing	Tropical Savanna Climate	building	Simulation
2015	Mingzhe Liu, Kim bjarne wittchen, Per Kvols Heiselberg	Control strategies for intelligent glazed façade and their influence on energy and comfort performance of office buildings in Denmark	Denmark	Energy Comfort Performance	Bsim "Danish dynamic building tool"	Double pane glazing	Temperate	Office	Experimental - Theoretical

Table 1: Literature review previous studies

Year	Author(s)	Paper Name	Studied Location	Simulation Type	Simulation Tool	Glazing Type	Climate Type	Building Type	Study Type
2015	Bruno Bueno, Jan Wienold, Angelina Katsifaraki, Tilmann E.Kuhn	Fener: A Radiance-based modelling approach to assess the thermal and daylighting performance of complex fenestration systems in office spaces	Germany	Indoor Illuminance - Cooling/Heating	Radiance - Energy Plus - Fener	Double pane glazing	Continental	Office	Theoretical
2015	Dimitriadou	Experimental Assesment and Thermal Characterisation of Lightweight Co-Polymer	United Kingdom	Energy Use - Thermal Comfort	Autodesk EcoTect - ESP-r	Double pane glazing	Temperate	notional building	Simulation
2015	Hu et al.	Thermal performances of ETFE cushion roof integrated amorphous silicon photovoltaic.	Taiwan	Thermal comfort	Radiance	No glazing type is mentioned.	Hot Arid	Office	Simulation
2015	Zhao et al.	A thermal model for amorphous silicon photovoltaic integrated in ETFE cushion roofs	China	Thermal comfort	no	No glazing type is mentioned.	Humid Subtropical Climate	Hot box	Simulation
2015	Cammarano, Silvia & Pellegrino, Anna & Lo Verso, Valerio Roberto Maria & Aghemo, Chiara.	Daylighting Design for Energy Saving in a Building Global Energy Simulation Context	Italy	Daylight and thermal Performance	Daysim and EnergyPlus	Different types of glazings	Marine west coast	Office	Simulation
2015	Singh, Ramkishore & Lazarus, Ian.	Energy and daylighting performance of highly glazed buildings	India	Daylight and thermal Performance	EnergyPlus	DG I and DG II	Hot dry	office	Simulation
2015	Iennarella, Simone & Serra, Valentina & Lo Verso, Valerio Roberto Maria	A Novel Concept of a Responsive Transparent Façade Module	Italy	Energy performance	DIVA-for Rhino	low-E selective glass PCM filled double-pane glazing	Marine west coast	office	Simulation
2015	Wang, Huan & Wu, Huijun & Ding, Yunfei & Feng, Jingchen & Wang, Shengwei	Feasibility and optimization of aerogel glazing system for building energy efficiency in different climates	China	Daylight and energy performance	no	aerogel glazing - one/two/three pane glazing	different climates	building	Experimental
2016	Maywald C. et al	Sustainability-The Art of Modern Architecture	Germany -France	Thermal comfort - Acoustic comfort	no	Double pane glazing	Temperate - continental	building	Theoretical
2016	Skarning, Gunnlaug Cecilie & Hviid, Christian & Svendsen, Svend	Roadmap for improving roof and façade windows in nearly zero-energy houses in Europe.	Denmark	Daylight and thermal Performance	DAYSIM-EnergyPlus	Triple glazing unit.	different climates	office	Simulation
2017	Gene-Ham Lim Michael Barry Hirning Nila Keumala Norafida Ab. Ghafar	Daylight performance and users' visual appraisal for green building office in Malaysia	Putrajaya, Kuala Lumpur -Malaysia	No	No	Glazing Transmittence: %53, %54 Blind Transmittence : %8, %30	tropical and sub-tropical climates	Green Office Buildings	Experimental
2017	Bhangdia	An Alternative Material for Tall Building's Glass Façade in Tropical Countries	India	Energy performance	no	no	tropical climates	tall buildings	Theoretical
2017	Monticelli, Zanelli and Centrulli	Sustainability – the art of modern architecture	Germany -France	Energy Comfort Performance		Double pane glazing	Temperate - continental	Residential	Simulation
2017	Coşkun, Turgay & Turhan, Cihan & Arsan, Zeynep & Gökçen Akkurt, Gülden	The Importance of Internal Heat Gains for Building Cooling Design	Turkey	Thermal performance	DesignBuilder	Double pane glazing	Mediterranean climate	Office	Simulation
2017	Fathy, Fatma & Sabry, Hanan & Faggal, Ahmed	External Versus Internal Solar Screen: Simulation Analysis for Optimal Daylighting and Energy Savings in an Office Space	Egypt	Daylight and energy performance	DIVA-for Rhino - Grasshoper	Double pane glazing	Hot arid	office	Simulation
2018	Chi Doris David Moreno Jaime Navaro	Lighting, heating and cooling energy consumption	Seville	Daylight Simulation Thermal Performance	Diva for Rhino	U-Value : 2.785 W/m2K Visible Transmittance : %78.1 Solar Trnsmittance : %60.4 SHGC : 0.703	Warm and Temperate	Open Office	Simulation
2018	Lamnatou et al.	Ethylene tetrafluoroethylene (ETFE) material: Critical issues and applications with emphasis on buildings	Spain	Daylight Simulation Thermal Performance	no	No input data is given.	Warm and Temperate	Open Office	Simulation
2018	Menendez et al.	A multifunctional ETFE module for sustainable façade lighting: Design, manufacturing and monitoring	Spain	Thermal Performance - Energy Comfort	no	No input data is given.	Warm and Temperate	Hot box	Experimental
2018	Toutou, Ahmed & Fikry, Mohamed & Mohamed, Waleed	Parametric based optimization framework daylighting and energy performance in residential buildings	Egypt	Daylight and Energy Performance	Grasshopper	Double pane glazing	Hot arid	Residential	Simulation
2018	Manz, Heinrich & Micallef, Daniel & Borg, Simon Paul & Buhagiar, Vincent.	A parametric building energy simulation case study on the potential and limitations of passive design in the Mediterranean climate of Malta	Malta	Thermal insulation and thermal comfort	WUFI Plus	Double pane glazing	Mediterranean climate	office	Simulation
2018	Kralj, Aleš & Žnidaršič, Matjaž & Drev, Marija	Multipane glazing Werge 7 Case study	Norway	Energy performance	no	6 pane glazing	Warm Summer Continental Climate	office	Experimental
2019	Cardoso, Michaud, Dennis and Sass	Soft Façade: Steps into the definition of a Responsive ETFE Façade for High-rise Buildings Work in Progress	United States	Energy performance	no	No input data is given.	No input data is given.	no	Theoretical
2019	Aleš Kralj, Marija Drev, Matjaž Žnidaršič, Boštjan Černe, Jože Hafner, Bjørn Petter Jelle,	Investigations of 6-pane glazing: Properties and possibilities	Slovenia	Daylight and thermal Performance	LBNL Window 7.4	6 pane glazing	Marine west coast	building	Simulation
2019	Manuel, Jose & Melendo, Almodóvar & La roche, Pablo	Effects of window size in daylighting and energy performance in buildings	USA	Daylight and thermal Performance	Energy Plus - Wis - ESP-r	Different types of glazings	Mediterranean climate	office	Simulation
2019	Sullivan, R & , Beltran & Lee, Eleanor & Rubin, Mario & Selkowitz, Stephen	Energy and daylight performance of angular selective glazings	USA	Daylight and energy performance	DOE-2.1E - Radiance	single- and double-pane angular selective windows	Mediterranean climate	office	Simulation

Table 2: Literature review previous studies2

CHAPTER 3
DEFINITION OF ENERGY

3.1. What is Energy?

Energy, in the simplest way is a condition function that determines how much work a physical system can do or how much heat it can exchange. The basic rule to know about energy is: "Energy is present in nature; it cannot be destroyed, it cannot be produced from nothing and existing energy cannot be destroyed. However, it can be transformed from one form to another. This is the principle of conservation of energy"(Britannica, 2019) and this is the main principle of all systems that use energy. "In physics energy, is the capacity or limit for doing work. It might prevail in potential, dynamic, electrical, thermal, atomic, chemical, or within different structures." (Britannica, 2019) Transfer from one body to another is the crucial point of energy and in the process; it is designated according to its nature. Also energy in the heat from when transferred becomes thermal energy and when a work is done energy manifest itself as mechanical energy.

Energy is one of the basic requirements for modern people to continue their daily lives. Energy needs before the industrial era was different and after the discovery of basic steam engines, materials that are used for energy completely changed. Coal and other fossil fuels, mineral oil and natural gas propellants are the most used resources. They were the basic example of raw materials that are used in transport and also heating. Most of the modern society is based on; finite resources like fossil fuel and also for nature to produce coal or mineral oil take millions of years. Some of the brutal exploitation of nearby deposits will create shortages. "Coal is thought to be last a couple of centuries more however; mineral oil is going to run dry sooner" (Maggio and Cacciola, 2012).

Nowadays, diversification of the energy resources and making these resources available through rational methods constitute the basis of energy policies. The fact that usual ways of energy production and expenditure have negative impacts over the environment in local, regional also global scales, has started to be as important as the minimum accessibility of the selected resources.

3.2. Energy Resources

Energy sources are to provide energy in any way. In fact, energy sources as a result of the laws that are pro conservation of energy; is a state of energy stored in nature. There are many known energy sources in the world. It is possible to classify these energy sources in different ways according to their characteristics:

- According to matter
- Based on solar basis
- According to warehouse availability
- According to renewability
- According to convertibility
- According to availability

In the classification of energy sources, the classification according to the renewability criteria should be the basis of the energy policies based on sustainability. In this context, it would be more accurate to examine the classification of energy resources according to the criteria of renewability and non-renewability.

3.2.1. Nonrenewable Energy Resources

Some energy resources cannot be replenished that is why they are called non-renewable energy. These include nuclear energy, coal, oil and natural gas, and also hydraulic power plants cannot be renewed. Fossil resources, as it is today, are expected to maintain drastic ratios in world and be the primary energy production in the upcoming years.

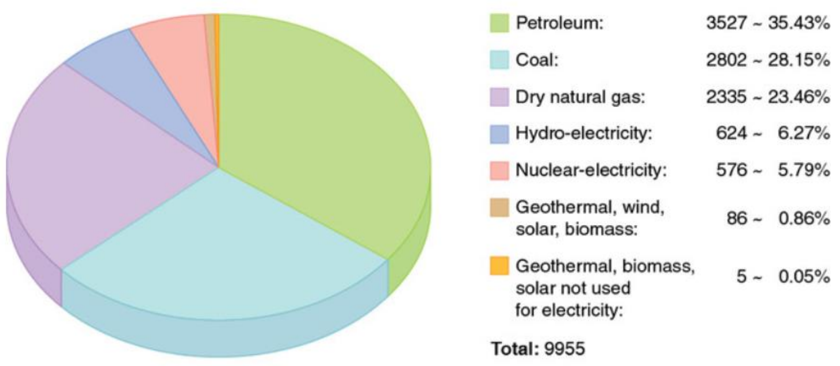


Figure 3: Pie Chart of Resource Consumption Rates

Source: Adapted from Boundless (Boundless Physics, 2016)

Pie chart shows the consumption of non-renewable energy resources is around %85 of the total consumption rate. It is estimated that the total share of these resources in 2020 will be 88.5% in world primary energy production. The largest share in this ratio belongs to petroleum and it has the capacity to reach over 35% from the final consumption rate. Coal is the second leading resource that is consumed and has a rate of more than 28%. Third major resource is the dry natural gas and more than 20% percent of the resource consumption is seen in that category. This category is also important for the residential heating purposes.

3.2.2. Renewable Energy Sources

Renewable energy can be identified as the energy source which can be present on the next day in nature's own evolution. The most significant element that recognizes sustainable power source from different kinds of energy is that it can normally restore itself and not vanish. After the major oil crisis in 1973, the significance of energy has begun to be seen well by the nations of the world. Starting from that day on, nations have found a way to differentiate their energy assets and to utilize different energy sources. In 2000s, issue of alternative energy gained strength and renewable energy studies began to grow in different fields. Source of energies that are renewable have an important place for the world and our country. With their renewable characteristics, minimum environmental impact, low operation and maintenance costs that are reliable for national energy supply characteristics are gathered. There are different types of renewable energies.

RENEWABLE ENERGY TYPES	SOURCE OF ENERGY
Solar energy	Sun
Wind power	Wind
Geothermal energy	Groundwater
Hydraulic Energy	Rivers
Biomass Energy	Biological wastes
Wave Energy	Oceans and seas
Hydrogen Energy	Water and Hydroxides

Table 3: Types and Source of Renewable Energy

Source: Adapted from BBC (BBC)

Renewable and sustainable energy sources are grouped as sunlight based, wind, geothermal, hydraulic, biomass, and wave, and hydrogen energies. It can be said that the sun is the main source of a large part of energy categories that are listed and that it has direct or indirect power on them. Even coal, oil and natural gas, which are even known as fossil fuels, are the transformations of solar energy. Consequently it is conceivable to characterize the sun as the most significant wellspring of energy on the planet.

3.3. World Energy Demand

Sources/Years	1971	2002	2010	2020	2030	2002-2030
Coal	1407	2389	2763	3193	3601	1.5%
Oil	2413	3676	4308	5074	5766	1.6%
Gas	892	2190	2703	3451	4130	2.3%
Nuclear	29	692	778	776	764	0.4%
Hydro	104	224	276	321	365	1.8%
Biomass	687	1119	1264	1428	1605	1.3%
Other Renewables	4	55	101	162	256	5.7%
Total	***5536***	***10345***	***12194***	***14404***	***16487***	***1.7%***

Table 4: World Energy Demand

Source: (GEA, 2012)

Over the last 50 years, energy demand in the global scale has had an upwards tendency as a result of the number of countries that are developed and also technological advancements have other big impact on the issue. Additionally, for the next 30 years this trend is expected to be higher and higher. Essential energy expenditure develops by and large at 2% every year, its greater part (80%) is non-renewable energy sources (GEA, 2012). In many developing regions recognize the need for renewable energy sources. Countries around the world are to understand non-renewable energy cannot be maintained indefinitely. It is estimated that fossil fuels will cover 85% of the energy consumed in 2030 and 55% of the energy that is consumed. If the ongoing demand would proceed as the way it is, the need for it will be 16.5 billion tons of oil equivalent, and as it is indicated in 2002 demand was 10.3 billion tons. The chart shows that crucial measures should be considered and immediate solutions must be established. The need for shifting to renewable energy also reducing the consumption of non-renewable energy seems to have an enormous roll for our feature.

3.4. Energy Performance and Sustainable Architecture

Effective use of energy is specified as diminishing the energy amount that is required to obtain a service, without compromising on the desired level of performance, quality and comfort. In energy performance-based design, the determination of parameters that may be effective in making decisions necessary especially for the early stages of design plays an important role in facilitating designer's decisions. Among many parameters that multiply the design options and make the decision difficult, the determination of parameters that directly and significantly affect the performance of the whole building can be achieved by a series of precision measurements.

The principles listed below through energy efficient building design it is intended:

- Combining passive and active air conditioning,
- Preventing atmospheric contamination, climate imbalances and ecological distortion,
- Instead of using expensive and scarce fossil-based resources, using efficient and environmentally friendly renewable energy sources (Sev, 2009)

As it can be deduced sustainable architectural design is a highly complex process with many requirements in it. The energy crisis that has been experienced for many years has increased the importance of building design approach aiming to minimize energy expenditure and usage of sustainable energy sources. This is one of the important features that distinguish this design approach from others. In the design of the constructions, it is aimed for adapting to the changing seasonal circumstances and to obtain the appropriate comfort conditions by spending minimum energy. In this process, also the designer has to use the support systems to help solve the complex interactions.

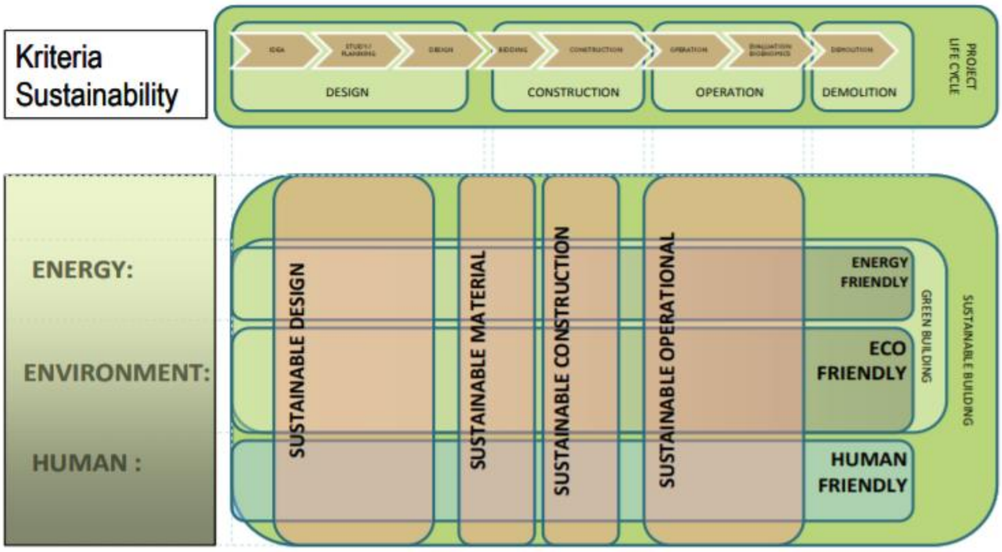


Figure 4: Sustainable Building Criteria

Source: (Klotz, 2007)

"The parameters that are effective in the energy efficient building design process are classified as building location, building ranges, building orientation, building form, building shell, natural ventilation layout." The area where the building will be constructed is a design parameter that is crucial in controlling the climate and preventing air pollution. This parameter includes elements such as direction, slope, where the building is positioned. Also these design systems can be conducted by a few simple calculations, and in parallel to today's technical and technological development, there are many different options that can help the designer for solving any problem creatively (three-dimensional modelling, virtual real environment, etc.).

Buildings can function as solar radiation and wind barriers for each other, depending on their distance, height and location relative to each other. Therefore, the use or protection of the heating effect of solar radiation is a function of the dimensions of the openings between the buildings. The building form is also a factor that can be defined by building geometric variables, such as height of building, roof type, roof slope and facade slope. Depending on the form of the building shell that covers any living space and separates it from the outside environment, the total external surface area of the building varies between the facade and roof surfaces areas facing different directions. One other factor is "the optical and thermo physical speciality of the building shell which are important for energy efficient building design." (Klotz, 2007) Optical and thermo physical properties are determinants that amount of heat lost and lost by the effects of outside temperature and solar radiation from the unit area of the building shell. The internal environmental climatic condition and the making heating and air conditioning loads vary depending on the total heat amount gained and lost from the building shell. There are also things like; energy and environmental factors in building design that are limited to questioning whether the requirements set by the regulations are fulfilled.

CHAPTER 4
CLIMATE DIFFERENCES

4.1. What is Climate?

The general character of the weather behavior of a given region over the years is called climate. Normally measured as the weather, these values are averaged when we hit a mean of 30 to 40 years and how a region generally behaves. The information we obtained is the climate.

For example, if summer rainfall has been low on average in the last 30 years, we would refer to the climate of this region as arid summers. The main difference between climate and weather is that the weather includes short-term information and the climate includes long-term information. Long-term weather conditions of a place are expressed as characteristic climatic characteristics.

4.2. Different Climates in the World

There are various climate types on earth. Climates are dominant in large areas. These areas are sometimes confined to a latitude and sometimes to natural boundaries such as the sea, the mountains, the ocean. Since the surface of the earth receives sun rays at different degrees, great differences have emerged in the climate of the earth. In addition, winds and various other events have been effective in shaping the climate.

Although there are many methods used to classify climates, Köppen-Geiger climate classification is one of the most widely used climatic classifications in the world. The method created by Wladimir Petrovich Köppen in 1918 was developed with the contributions of Rudolf Geiger (Köppen, 1918, 1936; Köppen and Geiger, 1954).

One of the most important characteristics of this climate classification is that the 5 basic climate types (A, B, C, D, E) used in the classification are compatible with the large vegetation groups.

A) Humid tropical: No winter season and average temperature of all months is 18 ° C. $T_{min} \geq +18$ ° C

B) Dry: Evaporation is more than precipitation and there is a constant lack of water

Yearly <10xDown

C) Temperate winters moderate latitude The average temperature of the coldest month is below 18 ° C and below 0 ° C. above, the average temperature of the hottest month is above 10 ° C. Tmax> 10 ° C and 0 ° C <Tmin <+ 18 ° C

D) Moderate winters cold latitude (Continental climate): The average temperature of the coldest month is equal to or below 0 ° C and the maximum The average temperature of the hot month is above 10 ° C. Tmax> 10 ° C and Tmin ≤ 0 ° C

E) Polar: There is no summer and the average temperature of the hottest month is 10 ° C. Below. Tmax <+10 ° C

Although the method generally uses stations with an observation period of more than 30 years, it has been used in stations with an observation period of less than 10 years (Peel et al., 2007). In addition, climatic zones are established in 10-year periods in order to examine shifts in climatic zones. Of the 512 meteorological stations used in this study, 284 had an observation period of more than 30 years, while 69 had an observation period of 30-20 years. Of the stations with an observation period of more than 10 years, 159 stations were used which are consistent with the meteorological stations that make spatial observations. These stations generally correspond to closed small meteorological stations.

4.3. Climates in Turkey

Turkey is located between the temperate zone and subtropical zone. Turkey is surrounded by sea on three sides, to show the extent of the diversity of the mountains and landforms, climate has led to the emergence of different types of property. The coastal regions of our country have more mild climate characteristics due to the effects of the seas. For this reason, continental climate characteristics are seen in the inner parts of our country. The following climatic types can be distinguished in our country on the basis of the criteria used in the classification of climate in the world scale. (Sensoy Serhat, Demircan and Mesut, 2016)

For Köppen climate classification, monthly temperature and precipitation data of 252 meteorological stations in our country were obtained. From the data set for the period 1981-2010, 30-year data and monthly average values were calculated and the data set to be used in the study was obtained. Up to four years of deficiencies in the data set for 12 stations were also considered. In addition, calculations were made for Karabük, Osmaniye and Şırnak Stations using the available data.

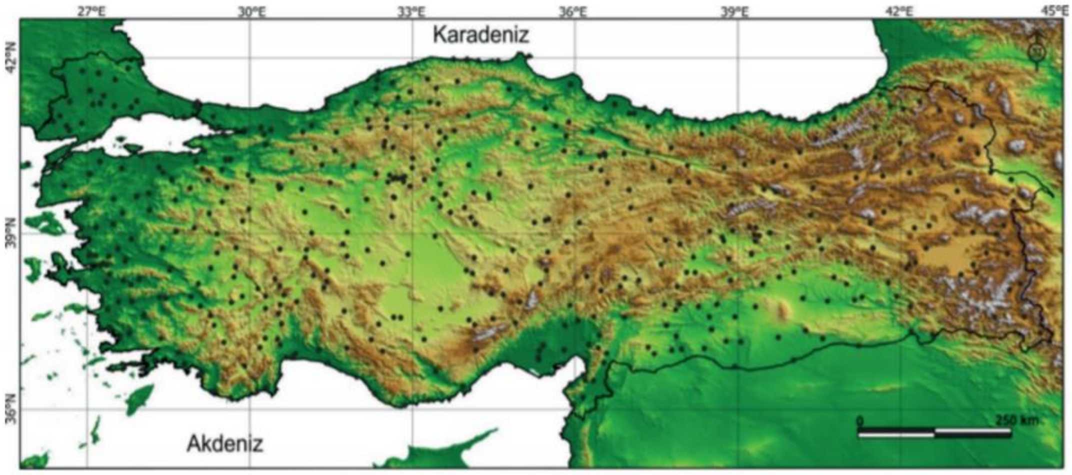


Figure 5: Meteorology Stations in Turkey

Source: (Ozturk, Muhammed Zeynel, Çetinkaya, Gülden, Aydin, Selman, 2017)

According to the Köppen-Geiger climate classification Turkey in humid tropical (A) and polar (E) is not observed climate types. According to the map of the main climate types, arid climate (B) type is dominant in the inner parts. This type of climate in the world, with the largest domain (Peel et al., 2007) is seen in 18% of Turkey. The type of climate covering a large area in the Central Anatolia Region is in the inner parts of the Western Taurus Mountains and the Central Black Sea Region, in the southern parts of the Southeastern Anatolia Region (the Middle Euphrates Section), in the south of the Upper Euphrates Section in Eastern Anatolia and in Iğdır.

The main characteristics of these areas are being away from sea and sea effect and dry hot summer and dry cold winter seasons.

The most common type of climate in Turkey (43%) humid temperate mid-latitudes in winter climates (C) includes all coastal areas and most of the Southeast Anatolia. The climate zone, which extends as a narrow strip in the Black Sea Region and the Central

Taurus Belt, where the mountains lie parallel to the coast, covers larger areas in areas where orographic conditions are favorable, for example in the Marmara, Aegean, Central Black Sea and Southeastern Anatolia regions. The widest spread is the reaches the segments.

The second largest domain winters cold damp climates in the world with a mid-latitude climates (D) or continental climate (Peel et al., 2007) is Turkey's second most common type of climate (39%). This type of climate occurs in the mountainous areas of Central Anatolia and Southeastern Anatolia, almost all of Eastern Anatolia, on the Central Taurus Mountains and on the mountainous areas of the inner parts of the Black Sea Region. This climate type corresponds to areas where annual temperature differences and terrestrial degrees are highest.

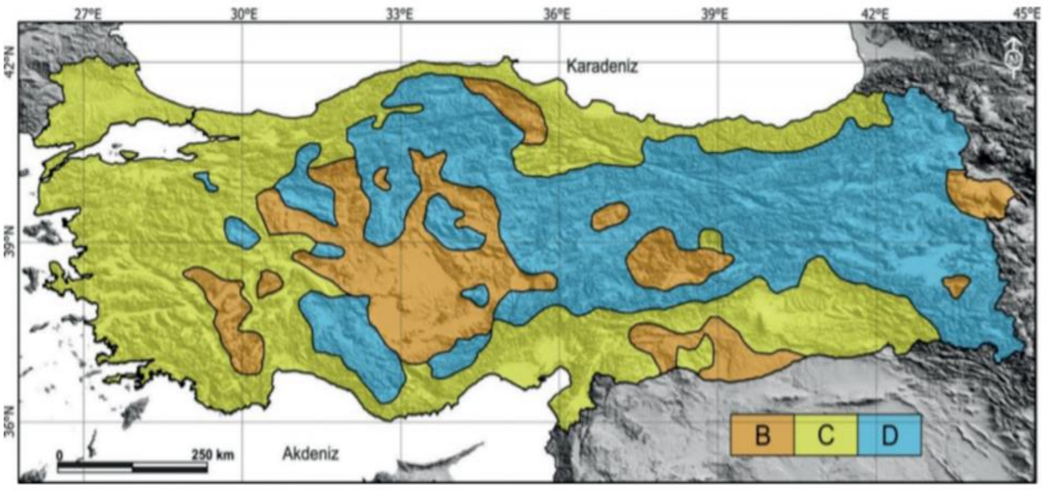


Figure 6: Turkey's Climate Regions according to Köppen
Source: (Ozturk, Muhammed Zeynel, Çetinkaya, Gülden, Aydin, Selman, 2017)

According to the average of 83 stations in climate B, 293 stations in climate C and 136 stations in climate D, the precipitation and temperature diagrams reveal the difference between climate types more clearly. The driest climate type (B) has the lowest precipitation value and the average annual total rainfall is 322 mm. The wettest climate is mild winters with moderate latitude (C) and the average annual rainfall is 689 mm. The average annual rainfall in the climate of cold humid latitude (D) in winter is 507 mm.

4.3.3. Climate Of İzmir

The Mediterranean climate prevails in İzmir. Summers are dry and hot winters are mild and rainy. July-August months are the hottest and January-February are the coldest months. The number of days below zero does not exceed 10 days. Nearly 100 days of the year is over +30 degrees. There is almost no snowfall. The annual rainfall varies between 700-1200 mm depending on the region. In the hot summer months, the wind called “imbat getir brings coolness. This wind, which consists of the difference of heating and cooling between land and sea day and night, belongs only to this wind. It brings a sweet coolness to Izmir on scorching summer days. Kemâlpaşa district is the region with the most rainfall. The temperature ranges from + 42.7 ° C to -8.4 ° C.

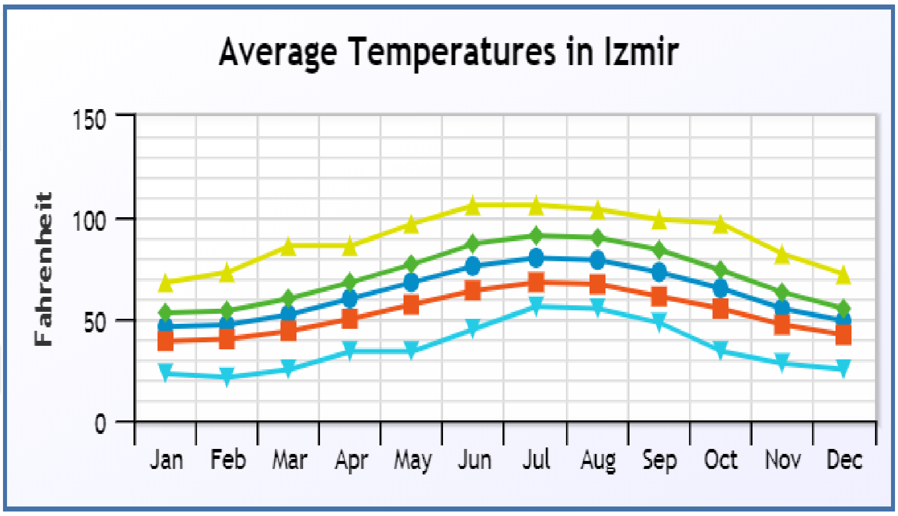


Figure 7: Average Temperature of İzmir

Source: (Ozturk, Muhammed Zeynel, Çetinkaya, Gülden, Aydin, Selman, 2017)

İzmir province is green in summer and winter. There is very little green field in Izmir. But the surrounding vegetation is abundant. About 50% of the province's land is covered with forests and heaths. 33% are cultivated and planted, and 15% are meadows and pastures. The non-arable portion is two percent. Red pine, pine pine, larch, cypress, scrub and olive trees are abundant in the vegetation. The vineyard and orchards occupy quite a large space. Kozak Mountain, is one of Turkey's largest pine nut production areas.

4.3.4. Climate Of Erzurum

This type of climate zone covers from scope for the most part east of the 100th meridian in North America. In any case, it very well may be found as far north as 54°N, and further west in the Canadian Prairie Provinces and underneath 40°N in the high Appalachians. In Europe this subtype achieves its most northerly scope at about 61° N. Territories including this subtype of the mainland atmosphere have a normal temperature in the hottest month underneath 22°C (22°F). Summer high temperatures in this zone normally normal between 21-28°C (70-82°F) during the daytime and the normal temperatures in the coldest month are commonly far beneath the - 3 °C (27°F) mark.

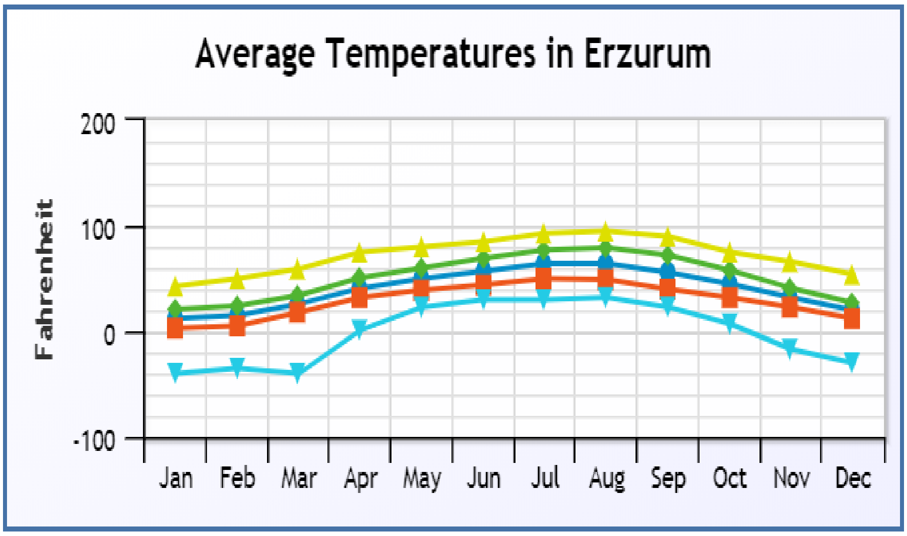


Figure 8: Average Temperatures in Erzurum

Source: (Ozturk, Muhammed Zeynel, Çetinkaya, Gülden, Aydin, Selman, 2017)

Erzurum is one of Turkey's highest and coldest cities. The harsh land climate prevails. Winters are very cold and snowy, summers are very hot and dry. 150 days of the year is covered with snow. Precipitation is 460 mm. Melting snow feeds the streams.

Erzurum is green in spring, white in winter, yellowish in summer and autumn (steppe). Forests and heaths are 9% of the area. It consists of pine and oak trees at an altitude of 1900-2000 m. Meadows and pastures cover 68% of the land, while the cultivated and planted land is 18%. Forests are on the south-facing slopes of the mountains in the north.

CHAPTER 5
GLASS

5.1. What is Glass?

Glasses are liquids with a high viscosity even at high temperatures, which solidify without crystallization at normal temperature. It has the properties of liquid bodies as well as mechanical properties and is an inorganic based silicate system. The main substance of the glass is the silicon dioxide (SiO2) which is melted and dispersed in the amorphous structure which provides transparency. Glass base material is silica (SiO2), inorganic based, very high temperature flux which is hardened when it cools. It has an amorphous structure because it cools rapidly during production. This speciality imparts transparency and effectiveness of glass. The first glass materials produced by the humankind were found in "Egypt and Eastern Mesopotamia in 3500 B.C." (Çınardali-Kararslan 2012) Approximately 2000 years after the discovery of the glass, the blown glass technique was found so that it was possible to make durable thin transparent sheets for the windows. Today, together with the developing technology, the glass offers a design freedom and uniqueness to the designers from both technical and aesthetic aspects.

Glasses are amorphous internally structured, especially resistant to mechanical, lateral effects, atmospheric effects and heat changes, transparent refractory materials which have the ability to refract light and pass through to solar radiation. Glass has a higher transparency than most transparent plastic. It can respond to environmental demands such as light transmittance, reflection, color, solar heat, heating energy and noise control and security through secondary processes such as tinting, tempering, lamination, insulating glass units, solar and heat control coatings.

In the 20th century, with the help of colored additives, thin film coatings, interlayers or surface treatments; plain or multi-storey; It is used directly or indirectly in the control of daylight of buildings, climate control, protection from UV rays, heat and electricity production from sun rays. In the 21st century, glass undertook even greater tasks within the scope of all these functions and gained a position to react automatically to environmental conditions with thermo-chromic and electro-chromic properties.

Figure 9: A Glass Facade

Source: Facade of a glass building (Taywade & Shejwal, 2015)

Since the raw material used in the production of glass is obtained from nature, there is no possibility of exhaustion. In this respect, it is a local material. As with other natural materials, it also harms the natural environment during the production of raw materials. Glass making materials are mixed and melted at really high temperatures. The melted glass is then cooled to a certain degree and shaped according to the type of glass to be produced.

Warmth moves through a window in three different ways: conduction, convection, and radiation. Conduction is warmth going through fluid, gas or liquid. Convection is the exchange of warmth by the development of gases or fluids, as warm air ascending from a light fire. Radiation is the development of energy through space without depending on conduction through the air or by development of the air, the manner in which you feel the warmth of a flame.

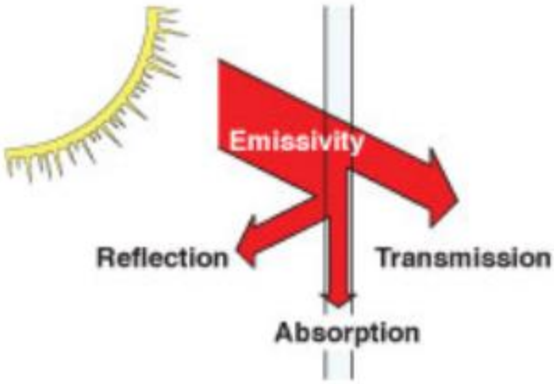


Figure 10: Glass Energy Transfer

Source: (Yamane & Asahara, 2000)

U-factor. At the point when there is a temperature contrast among inside and outside, heat is lost or increased through the window outline and glazing by the consolidated impacts of conduction, convection, and long-wave radiation. The U-factor of a glazing presents to its general warmth exchange rate or value of insulation.

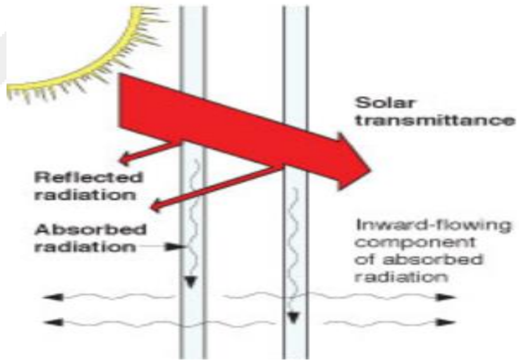


Figure 11: Solar Heat Gain Coefficient

Source: (Yamane & Asahara, 2000)

Solar Heat Gain Coefficient (SHGC) in spite of the temperature outside, warmth can be accumulated by windows with direct or indirect radiation. Solar heat gain coefficient means this. Glazing type, number of panes and if there is glass coating than they all change the values of SHGC. The numbers can vary between 80 to 20 percent according to these glazing's.

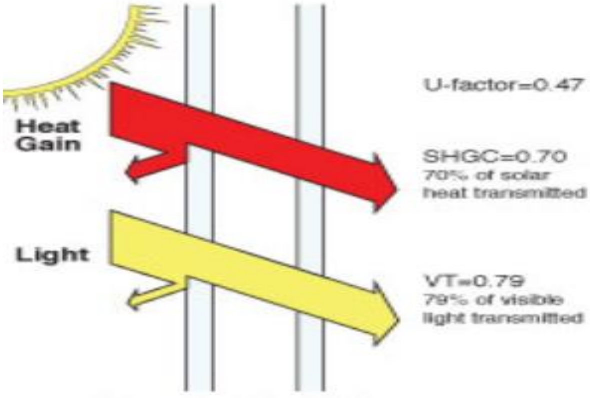


Figure 12: VT Rate in Double Glaze Glass

Source: (Yamane & Asahara, 2000)

Visible Transmittance (VT) can be described as visible light transmittance of the glass. By this property of the glass, material inside lightning can be reduced. Glazing type, number of panes and if there is glass coating than they all change the values of VT.

Air Leakage. If there are little cracks or sashes on or around the windows or its frames than there would be air leakage, which will result in letting air inside which can lead to gaining or losing heat.

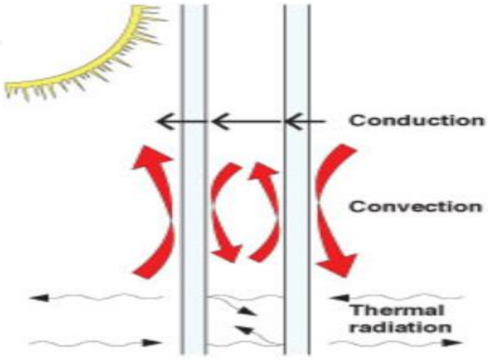


Figure 13: U Factor

Source: (Yamane & Asahara, 2000)

U-factor is the standardized way of qualifying the overall heat flow. The U-factor of the coating part of the window unit is influenced fundamentally by the all out number of coating layers (sheets), their measurement, the sort of gas inside their empty space, and the type for coatings on the different glazing exteriors.

5.2. Mechanical and Physical Properties

Normal glass is a non-crystalline, brittle material that shows linear elastic behavior up to the moment of fracture. Fracture of the glass is caused by cracks on the glass surface. In most cases, these cracks are too small to be seen. There is also a change in fracture stresses due to the change in crack lengths. Short-time stress values can range from 20-200 MPa. Stress differences in glass are caused by many factors. These factors include environmental conditions, glass type, production effects, moisture content.

The feature of changing the length of the object under temperature is related to the linear dilatation coefficient. This coefficient determines the amount of change of length. This value of the glass material is 8.7x10-6. This coefficient, when compared with that of other materials, is very close to that of -6 steel (11x10) and quite small than that of aluminum (23x10 -6).

Hardness is the resistance of one object to the mechanical action of another. There are various measurements such as diamond scratch hardness, sharpening hardness, Mohs comparison hardness. According to Mohs, the mineral-hardness table is used for comparison purposes. This measurement is based on the fact that the plot is harder than the plot. The hardness of the glass is between 60-120 kg / mm² on the Mohs hardness scale. (Jelena, Djuric Mijovic, & Bogdanovic, 2013)

The compressive strength is determined by measuring the deformations caused by the force applied to the surfaces, for example by placing them between two parallel steel surfaces in the form of cubes or cylinders taken from the material being tested. In other words, it is the connection between the surface and a force that is large enough to cause the rigid body to break. The compressive strength of the glass is 10000 kgf / cm² as fracture load.

Tensile strength or tensile strength is tested by tearing a rod-shaped sample of an object without bending. As a result of the tensile test, the mechanical behavior of the object is determined. The tensile strength of the glass is 400-600 kgf / cm² as fracture load. The breaking load of the tempered glass should be taken as 5x10 7.

The glass material is made resistant to mechanical shocks by tempering process. Tempered glasses are mechanically tested with Bil High Ball Drop Test. Tempered 6 mm glass, falling from a height of 2.00 m 500 gr. weight is broken with the effect of a steel ball, the same experiment in the non-tempered glass 30-40 cm from the height of the ball is broken with the same weight. Thus, the impact resistance of tempered glass increases approximately 7 times and the bending strength increases 5 times. (Jelena, Djuric Mijovic, & Bogdanovic, 2013)

5.3. Optical Properties

The reflection of the light coming to the surface of a material by the material is called back. The reflection ratio, which describes the reflection property as a numerical value, is the ratio of the reflected light intensity to the incoming light intensity. It can be said that the reflection rate is low in transparent solids. The reflection rate for glass is about 10-12%.

The light coming to the surface of a material is partially absorbed and reduced in intensity as it travels through the mass. The absorption state of the material depends on the wave tolerance of the light and the type of material. For glass, this value is around 5%. By adding different elements to the structure of glass, this value can be reduced and reproduced.

5.4. Durability to Fire

It is necessary to ensure the safety of people in case of any fire in the building. In particular, the windows are exposed to very high temperatures during a fire and after a certain heat they explode and spread around. In this case, the glass must be heat resistant and should not be scattered in case of fire. Fire-resistant glass is of great importance both for the life of individuals and for the valuable materials in the building. These glasses lose their transparency during the fire, prevent the passage of fire and smoke, and thus delay the spread of the fire.

Glass facades, which are widely used in high buildings, pose a great risk to fire. As well as the quality of the glass used, it is important to select thermal insulation materials from materials that are not flammable.

5.5. Glass Types

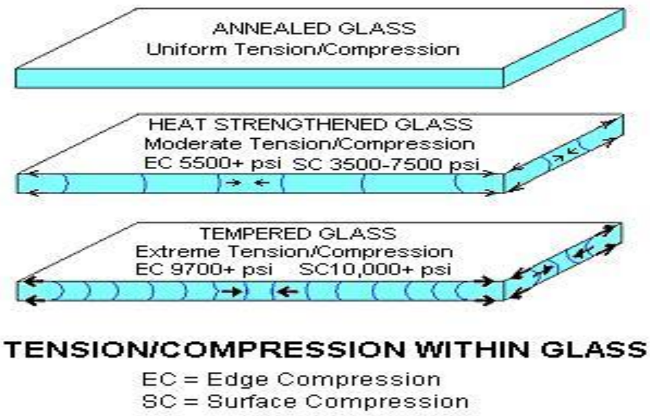


Figure 14: Glass Types

Source: (Elinwa, Ugochukwu, Radmehr Mehrshad, Ogbeba and John Emmanuel 2017)

Annealed glass is the most usually utilized structural glass. It has great surface levelness on the grounds that it isn't warm treated and thusly not exposed to contortion commonly created during glass hardening. On the drawback, toughened glass breaks into sharp, risky shards. Warmth reinforced and completely safety glass are heat-treated glass items, warmed and extinguished in such an approach to make remaining surface pressure in the glass. The surface pressure gives the glass commonly higher protection from breakage than strengthened glass.

Heat strengthened glass has at any rate double the quality and protection from breakage from wind burdens or warm anxieties contrasting with toughened glass. The fundamental warmth treatment for the most part results in some contortion contrasted with tempered glass. Like tempered glass, heat-fortified glass can break into enormous shards.

It gives in any event multiple times the quality of tempered glass, which gives it better obstruction than glass breakage. It is buoy or reinforced glass that has been warmed and quickly cooled, expanding its intrinsic quality and flexibility. Like warmth fortified glass, the warmth treatment by and large outcomes in some bending. In the event that it breaks, completely treated glass breaks into numerous little sections, which makes it appropriate as security coating under specific conditions. It is utilized for windows that are presented to high wind weight or outrageous warmth or cold.

5.6. Exterior Systems of Glass

5.6.1. SILICONE EXTERIOR SYSTEM

It is completely glass-looking, curtain wall system with structural silicone application. It is formed by combining the horizontal and vertical profiles to be used after determining the Jx and Jy values by considering the cladding facade profiles and building design factors (floor height, openings and wind load).

Figure 15: Silicone Exterior
Source: (Al Dakheel, J. and Tabet Aoul, 2017)

Aluminum structural cladding facade is formed according to vertical and horizontal axle dimensions with determined profiles. The prepared carcass is mounted to the floor concrete with movable u anchors. The point to be considered during the assembly stage is to make the assembly in the same plane both vertically and horizontally. Dilatation should be left on each floor.

5.6.2. STICK CURTAIN WALLING SYSTEM

It is the system where cover profiles are formed on the vertical, horizontal or single plane of the printing profiles used in glass assembly. It is formed by combining the horizontal and vertical profiles to be used after determining the Jx and Jy values by considering the cladding facade profiles and building design factors (floor height, openings and wind load). Aluminum structural cladding facade is formed according to vertical and horizontal axle dimensions with determined profiles.

Figure 16: Curtain Wall System
Source: (Al Dakheel, J. and Tabet Aoul, 2017)

The prepared carcass is mounted to the floor concrete with movable U anchors. The point to be considered during the installation phase; vertical and horizontal mounting in the same plane. Dilatation should be left on each floor. The system can be made as a facade with cover and half cover.

5.6.3. PANEL GLASS FAÇADE SYSTEM

It is generally preferred in high buildings. The highest performance in facade impermeability belongs to the panel system. Horizontal and vertical aluminum structural curtain wall elements of the panel systems whose frame structure is different from the bar system are manufactured in the factory, one or two axle widths and manufactured in the factory and shipped to the construction site as a modular panel.

Figure 17: Panel Glass System
Source: (Al Dakheel, J. and Tabet Aoul, 2017)

Prepared modular panels, glass and all accessories are assembled and finished building elements. Assembly process is carried out with the help of rail carrier system, mounting platform and crane.

5.6.4. PLANER GLASS FAÇADE SYSTEM

In projects where transparency is important, it is a glass façade technique made frameless by using different designed carrier systems. The difference of transparent glass façade systems from other façade systems is that the sub-carrier system consists of glass or stainless elements instead of aluminum profiles.

Figure 18: Planer Glass System

Source: (Al Dakheel, J. and Tabet Aoul, 2017)

Transparent facades are mostly used in shopping malls and shops. In this way, the customer can easily see the interior. It is an indispensable system on modern facades. Thanks to its transparency, it provides an aesthetic and rich appearance to the façade when viewed from inside and outside.

5.7. Photovoltaic System

In architectural designs, the use of glass contributes to thermal insulation and energy saving as well as electricity can be obtained by placing photovoltaic cells. The photovoltaic (PV) systems placed between two glasses or just behind a windscreen contribute to the operating costs by generating electricity from daylight .

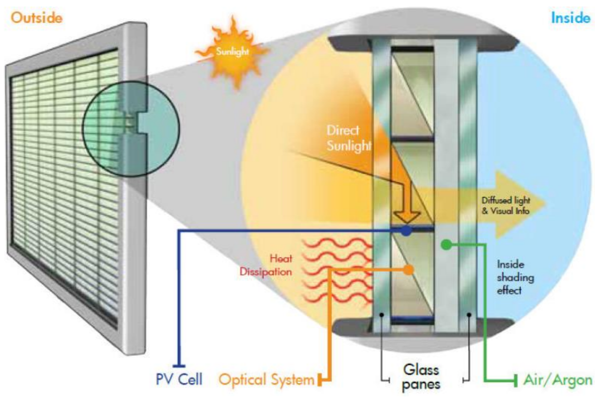


Figure 19: Photovoltaic Glass

Source: (Elinwa, Ugochukwu, Radmehr Mehrshad, Ogbeba and John Emmanuel 2017)

Photovoltaic modulated layers (PVs) are used to convert solar energy into they make active use possible and with addition, they also show a passive form of sun protection . Although PV batteries are not yet economically more competitive with other energy production methods, the environment provides a generally sufficient basis for solving increasing problems in the name of supporting regulations and financial aid from public capital.

5.8. Examples of Structures with Glass

30 ST Mary Axe the building is located in London, United Kingdom. It's construction is completed in 2003, and it is opened in 2004. It is designed by Norman Foster with a aerodynamic shape which allows wind flow around the building and its façade. It's cylindrical shape allows it to pass the wind. Core columns maximum design load is 33,266 kN. Thanks to its core, it resists gravity loads. HSS steel members and also rigid node connectors are used.

Figure 20: 30 ST MaryAxe

Source: (Şen, 2013)

It has forty one storey and it has a capacity of 46,400 square meters net of office space and also shops and cafes. From the top of the building there is a 360^0 panoramic view.

Basque health department headquarters (Bilbao, Spain) Previously building needed an energy proficient update, yet rather than tearing down the entire structure and beginning once again. Designer gave the current structure a faceted glass façade that not just protects the structure, lights up it up and empowers ventilation, yet in addition owns an emotional road side expression. The surprising state of the veneer was in part the aftereffect of severe city zoning rules. A twofold exterior settles zoning rules prerequisites as well as energetic, fire-safe and acoustic protection ones. This component permits breathing the structure.

Figure 21: Basque Health Department Headquarters

Source: (Şen, 2013)

On the other hand, that collapsed component creates numerous perspectives on the city, and changing its appearance relying upon the perspective, the hour and the season. The target of this component is presenting the alterability. A twofold facade tackles zoning rules prerequisites as well as fiery, heat proof and acoustic protection.

Louvre Pyramid (Paris, France) The Louvre Museum that is the first state museum of France opened in 1793. It hosts an average of 25,000 visitors a day and is among the most visited museums in the world in 2015. It’s architecture which resembles the pyramids attract attention of its guests.

Figure 22: Louvre Museum

Source: (Şen,2013)

Appointed by the President of France, François Mitterrand, in 1984, it was planned by the designer I. M. Pei. The structure, which was built completely with glass portions and metal posts, achieves a tallness of 21.6 meters (71 ft). Its square base has sides of 34 meters (112 ft) and a base surface region of 1,000 square meters (11,000 sq ft). It comprises of 603 rhombus-formed and 70 triangular glass segments. The pyramid structure was designed by Nicolet Chartrand Knoll Ltd. of Montreal (Pyramid Structure/Design Consultant) and Rice Francis Ritchie of Paris (Pyramid Structure/Construction Phase)

CHAPTER 6 ETFE (ETHYLENE/TETRAFLUOROETHYLENE COPOLYMER)

6.1. What is ETFE?

ETFE is used as a general solution for glass; courtyard and skylights as roof and facade cladding material that carries daylight into volume. However, in some special cases (structures with large spans, structures without proper geometry.), alternative building materials were searched for glass. As a substitute to the glass, the transparent ETFE transparent material was produced. The aim of the emergence is primarily the non-architectural structure of ETFE, which has become the preferred roof and facade cladding material in recent years with its positive aspects to architecture.

Ethylene Tetrafluoroethylene (ETFE), provides modern architecture style with an economical solution for coating materials, and enables a wide range of applications in cases where glass-like materials are not used. It is a very light and transparent material. One of the most important features of ETFE is light permeability and high service life. Increasingly in today's architecture, it is an important material draws attention with its use.

6.1.1. CHEMICAL AND MECHANICAL PROPERTIES OF ETFE

The main component of ETFE material is fluoride combined with hydrogen sulfate and chloroform. These compounds form chlorodifluoromethane, which is converted to tetrafluoroethylene (TFE), which is a colorless odorless gas by thermal decomposition.

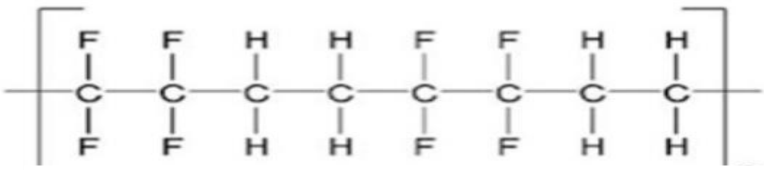


Figure 23: Molecuar Structure of ETFE

Source: Chemical Formula: (C4H4F4)n (Zaidi & Matsuura, 2010)

Combination of Combination of tetrafluoroethylene with ethylene results in the ETFE copolymer. Thanks to its material properties, it is possible to form a plastic type that can be easily shaped, molded and non-sticky. Thanks to its chemical properties, ETFE is a highly resistant material against chemical elements and UV rays. (Lecuyer, 2008)

ETFE as being a light-permeable, durable and needs minimal maintenance and is at times preferred like glass. However, the light permeability of a 6 mm thick glass is 89%, while in ETFE coatings this value is obtained as 94-97%. At the same time, when the ETFE material is considered acoustically, a suitable acoustic environment is provided in areas where ETFE coatings are used, as opposed to the high reflective environment formed by glass surfaces as transparent building material.

Manufacturing process of ETFE is done by heating resin to temperatures that are higher than 380°C where it melts. There are also two possible ways to give it shape, which are blowing or extrusion.

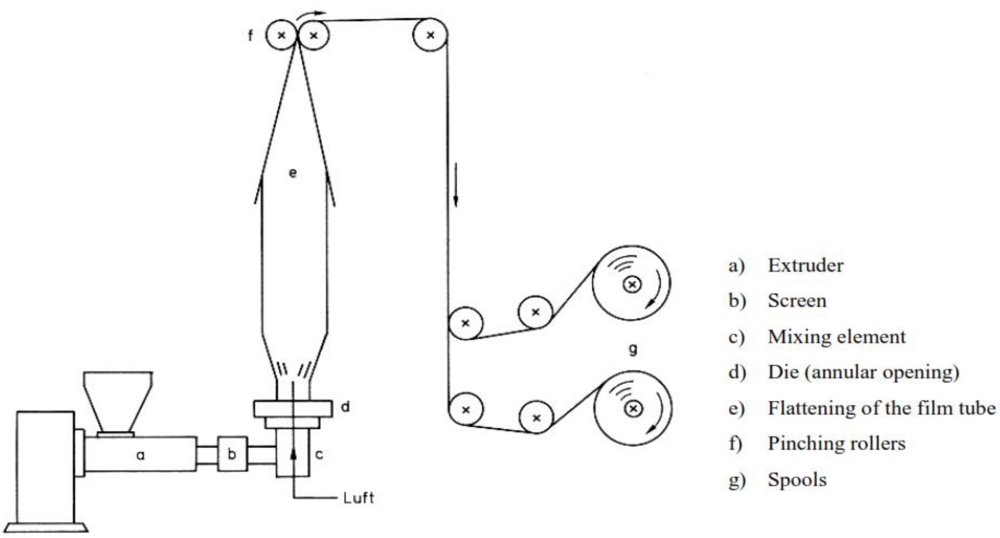


Figure 24: Blown ETFE Film Schematic

Source: (Moritz, 2007)

Process of blowing and making a film; "by passing the molten resin over a ring," creates a tube shape that is widened by the inflation of air. After this process, the tube is "cut lengthwise to form flat sheets." (Seidel, 2009).

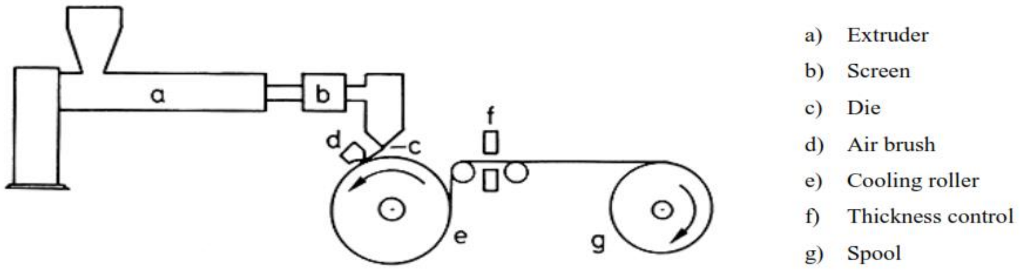


Figure 25: Extruded ETFE Film Schematic

Source: (Moritz, 2007)

Other process, which is extrusion, has a better outcome as a product. By passing the resin through rollers to create thin films up to 2200 mm wide" (LeCuyer, 2008). According to Seidel, compared to extrusion blowing is a cheaper way but extrusion has higher features such as; "transparency, crystalline, stiffness, homogeneity in the longitudinal and transverse directions and thickness tolerance" (2009).

The producers pass the ETFE material, which is sold as granular, at 170° C and passes the softened form through the molding machine. Large ETFE films with a thickness of 50-100-150-200 microns are obtained. ETFE, inflatable airbags or monolayer stretch wrapping methods are used to assemble the structure to steel carriers. ETFE air pillow method has 2-3 ETFE layers. Air pressure of 250-400 Pa is pumped between the layers in order to ensure the inflating cushions are swollen. The ETFE cushions are usually dimensioned in widths of 150-450 cm, lengths 6090 cm. For single-layer ETFE curved surface applications, the surface must be pre-defined with steel cable elements and the pre-tensioning force must be applied to the ETFE elements to be applied.

Because of the reasons above for the architectural solutions, extruded films are preferred. In order to prevent toxic fumes, films are cut by blades instead of lasers, because lasers operate with high temperatures but blades do not need high temperatures. Fusing two sheets together is called "melt bond welding process" which is done by applying heat and pressure to the both sides of the sheets.

Solution of edge details of cushion is generally with PVC or polyester rope which is welded in factory into folded over sleeve ETFE. The materials are slipped or clamped to extruded aluminium frame.

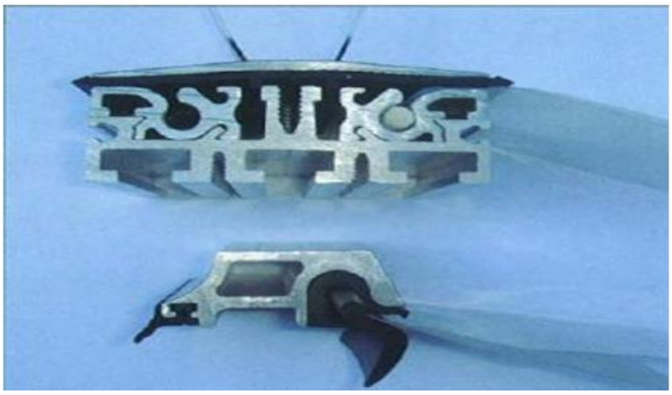


Figure 26: Slipped and Clamped Frames
Source: (Moritz, 2007)

Double or more layered ETFE's which are inflated have air valves that are established into the foils in factory.

Figure 27: ETFE Cushion Air Valve
Source:(Moritz, 2007)

Additionally, a supply air tube which connects cushions to a unit that inflates units and keep them in a constant air pressure. Also to transport heat water is provided and extracted from the absorber through a channel for water between collector and channels inside the membrane. Conduction process and convection is done through the layers of ETFE film.

6.1.2. INSULATION

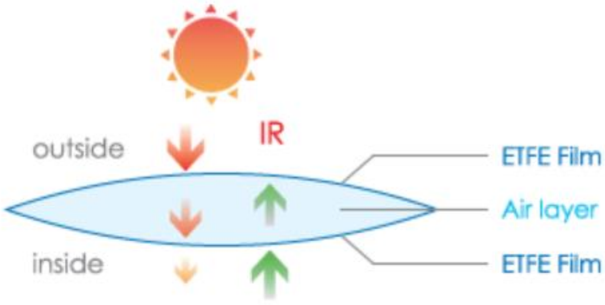


Figure 28: ETFE Insulation Sketch

Source: (Hu et al., n.d.)

Insulation performance of ETFE is regarded as excellent due to its single, double or triple layer cushions. The cushions that are pressurized give ETFE a unique way for insulation and also stability. One of the most important traits of sustainable design is to control the heat and cold inside buildings. ETFE design helps a building in winter to keep the cold outside and in summer it can cool the water that brings a well balanced insulation.

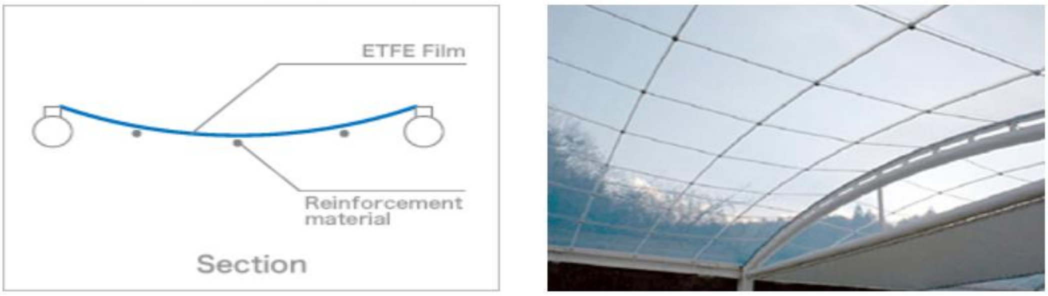


Figure 29: Single layered ETFE

Source: (Sert, 2016)

To make the structure stable, internal and external stress is used in harmony to get the required tension. The cushions are located to the aluminum profile mounted to the carrier structure by means of special elevating devices. Through the vent pipes connected from the inside or outside of the upgrade apparatus, the air flow is provided to the pads at the specified pressure and the cushion is provided to take the prescribed inflatable form. Single layer ETFE is reinforced by wire cables, aluminium or lightweight steel.

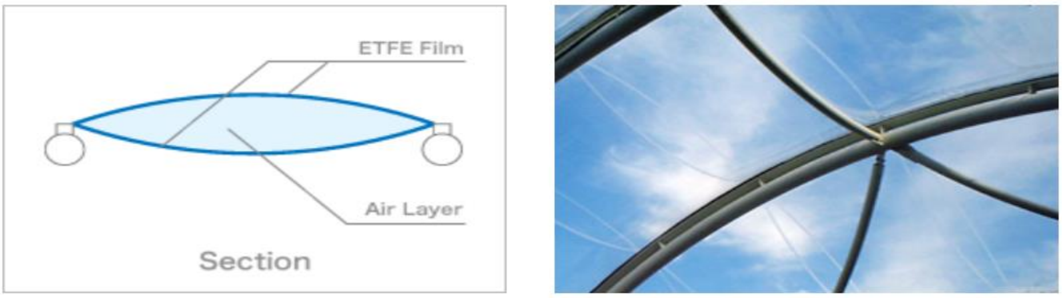


Figure 30: Double layered ETFE
Source: (Sert, 2016)

These cushions are filled with low-pressure air, which maintains thermal resistance, and stability. Different surface treatments and radiation methods can be applied on ETFE material and additional cushions can be suited in order to limit the light transmission. Mass of ETFE is 1.75 g/cm (Moritz, 2007) which means minimum weight per square metre of a cushion, made from two layers of 50 µm foil, would be about 1.72 N/m. The amount of weight per square meter of a cushion that is a double layer weighs $0.70/m^2$. Compared with glass which a single layer glass (6mm thickness) weighs 15 kg/m^2. Because of the reasons above ETFE would need less support material and also support materials expenditure will be less.

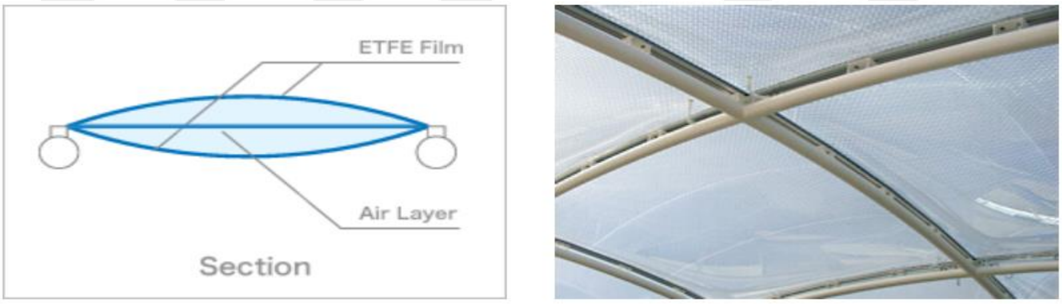


Figure 31: Triple layered ETFE
Source: (Sert, 2016)

As the figure above shows there are various numbers of layers which are determined by calculations for any environment, regarding the exterior that ETFE is going to be constructed. These layers are transparent to infrared radiation and light are visible. When layers come together depending on the calculations they insulate infrared and benefit from the light.

When compared with glass or other materials these traits give ETFE a better chance for building coverings and roofs. (Poirazis, Kragh, and Hogg, 2009) With its non-sticky surface feature, ETFE roofs and facades are cleaned less frequently than glass surfaces. This reduces the cleaning needs of the building and the budget to be allocated to water, cleaning materials. At the same time, the roofs and facades used in ETFE prevent the use of artificial lighting during the day with high light transmittance.

6.1.3. PATTERNS OF ETFE

It is realized that day-lighting systems can both decrease electric energy interest for lighting just as limit stacks on the cooling hardware because of overheating. Day-lighting configuration must be done with incredible consideration. In order to acquire assorted special visualizations, ETFE Foil can be treated in various ways. In particular, light transmission properties could be controlled by printing, tinting, surface treatment, radiation and including layers. Printing (fritting) implies that the outside of the foil is secured with layers of examples to decrease sun oriented increase while holding translucency.

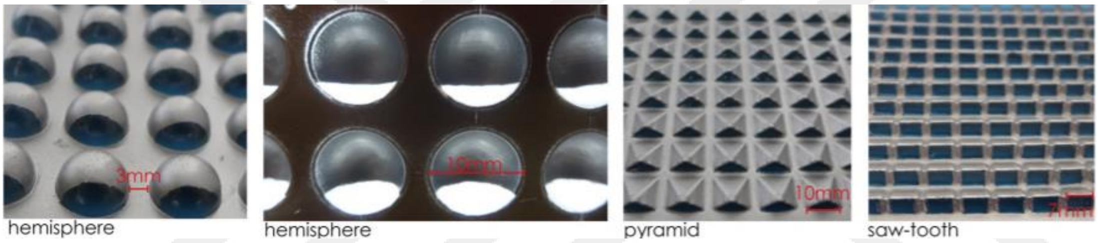


Figure 32: Printable ETFE patterns

Source: (Cremers & Marx, 2017)

Along these lines, the energy transmission can be changed by fluctuating the level of inclusion and thickness of the ink. The foil can be over printed with various treatments to influence transmission. Tinted and coloured foils can be utilized nearby clear foil to fuse marking and huge scale imagery. Likewise, white ETFE foil can be utilized to decrease glare keeping the light transmission and imbue protection properties. Surface treatments attempted during the assembling procedure can shift the properties of the foil and permit light transmission control. These treatments render the foil matt in appearance and in this way give a decent projection surface to light shows and pictures. The foil could be adapted with a scope of radiation treatments which can decrease the dimensions of infrared and bright beams transmitting through the layer skin. Inclusion of extra ETFE foil layers to a pad additionally enables light transmission and sun oriented increase to be controlled.

6.1.4. DURABILITY TO FIRE

Fire classification of ETFE is; "DIN 4102 B1, flame retardant, EN 13501-1 / B-s1, d0" which gives it the unique value that is fire resistant. Regarding the durability to fire, categories can be determined as A1, A2, B1, B2, B3 and C. The A1 and A2 non-flammability classes are applicable for mineral wool, mineral wool and glass wool. Class B grades are suitable for polyurethane plates. In category A, the category A is considered as "Flameproof". Non-flammable materials are not carried out on the flame in any way even if the fire source is not removed. The class B2 material is considered to be fire resistant B2. When the flame source is removed, the material goes out by itself. Polyurethane foam made of a quality material should be included in the B2 non-combustibility class. In combination with the material used (as a system) the sandwich panel shall be in the B1 non-flammability class. The foams in the non-flammable class B2 shall not give toxic (gaseous) gas to the environment as combustion products due to their non-flammability classes. Meta Panel polyurethane (foam) is classified as B2 non-flammability and has been certified by Warrington Fire Research Met.

6.1.5. ETFE LOAD BEARING

Cushions of ETFE are a kind of pneumatic membrane forms. The expression "membrane" shows that all burdens created in the material demonstrate parallel to the neighborhood surface, and are consistent all through the thickness of the surface. (Koch, 2004). On account of ETFE, just as other tractable surface structures, these burdens are proposed to be exclusively pliable anxieties. Most layer structures must be planned with thought of material direction. In textures, there are two essential material bearings, relating to the directions of the weave: twist and fill, where the twist is the course along the length of the roll and fill is the heading opposite to the length of the roll.

Preferably, texture structures ought to be designed to such an extent that the twist and fill bearings of the material compare to the headings of foremost flow of the surface. In ETFE foil, or different kinds of films, the proportional bearings to warp and fill are the longitudinal and transverse course of the film (Koch, 2004). Because of the almost isotropic nature of ETFE, it isn't as critical to think about the material bearings in plan. However, it is still great practice to have the longitudinal and transverse headings of film harmonize with the essential headings of curves and flows, as the assembling procedure can result in particles being adjusted toward extrusion.

The expression "pneumatic" alludes to the utilization of gas, fluid, foam, or mass materials to make a weight distinction to settle the layer. (Roland, 1970) On account of ETFE and in most other structure applications, pneumatic stress is utilized with air pressure. The most widely recognized types of pneumatic film structures are extensive spaces encased by domed or semi-round formed layers balanced out by higher than atmospheric air tension inside the whole space. These structures must stay under airtight chamber to keep up steady interior weight and pressure. Under inner weight alone, the film creates prestress.

Air is inflated between the layers of film (or foil, on account of ETFE) to blow them into pads. The air causes prestress to frame in the foils, similarly as with any pneumatic structure. At the point when remotely stacked, the outside layer of foil is the first to hold up under the heap. At the point when the load is coordinated inwards (or downwards, on account of rooftops), at that point this load is passed to the air stash by making the cushion to become compressed. At the point when the last layer of foil is reached, the load is exchanged to the casing through pressure in the base layer or the cushion. At the point when the load is outwards (or upwards, for rooftops), at that point the load is basically carried in by strain in the top layer of the cushion. This load case goes with a lessening in weight inside the cushion, and a relating emptying of the lower layers of foil. The essential distinction between cushion structures and inside pressurized single-film structures is that cushion structures don't depend air to convey the whole burden, yet rather to build the load conveying limit of the layer, which exchanges the load to the structure frame. Completely pneumatic structures don't require ordinary structure frames, as the load is exchanged to the ground through air tension alone.

6.1.6. INSTALLATION OF PHOTOVOLTAIC COMPONENT ON ETFE

Because of the worldwide direction towards the utilization of sustainable power sources and the way that reaping sunlight based vitality utilizing a photovoltaic board costs more than consuming petroleum derivatives has taken the looks into to concentrate more on the natural sun based cells. The OPV cost reserve funds originate from the likelihood of utilizing adaptable substrates, printable natural inks for the dynamic layers, low temperature and encompassing weight manufacture, and lower materials costs. In any case, the productivity of the created cell isn't the objective of the exploration. The exploration imaginative thought is utilizing fluoropolymers as substrate and embodying material and furthermore supplanting the regular ITO cathode with Carbon Nano-tubes (CNT).

Figure 33: Photovaltaic Aparatus

Source: (Cremers & Lausch, 2008)

Being a variation of formless silicon slim film innovation the procedure requires fundamentally less silicon and energy contrasted with the creation of sun based cells from mono-or polycrystalline silicon. The light ingestion produces excitons, electron-gap matches that are bound together and thus not allowed to move independently. To create free charge bearers, the excitons must be separated. This can occur within the sight of high electric fields at the interface between two materials that have an adequate jumble in their vitality levels.

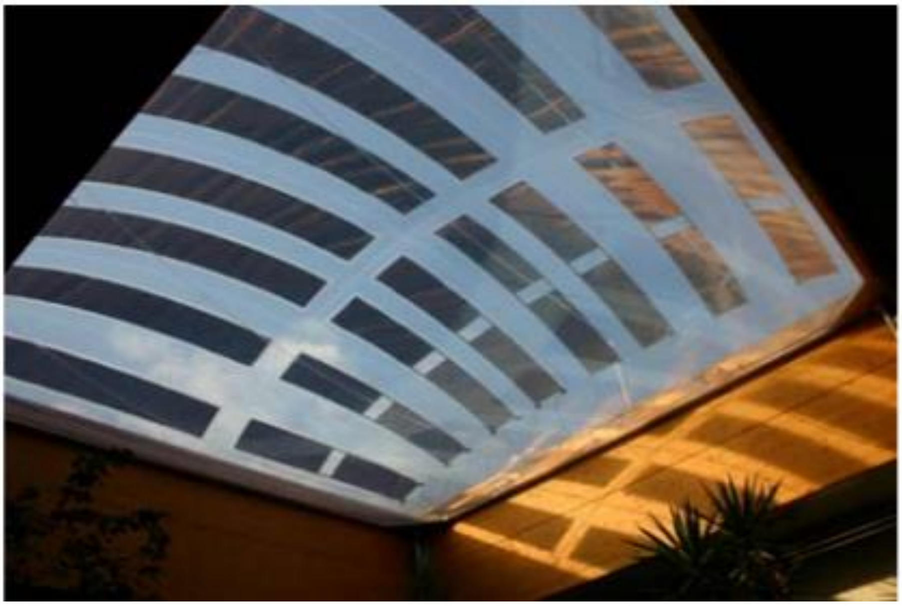


Figure 34: Photovoltaic Apparatuss on ETFE

Source: (Cremers & Lausch, 2008)

In this way, a natural sun oriented cell can be made with the following layered structure: positive terminal/electron giver/electron acceptor/negative cathode. An exciton made in either the electron giver or electron acceptor layer can diffuse to the interface between the two, prompting electron move from the contributor material to the acceptor, or opening exchange from the acceptor to the benefactor.

6.1.7. ENVIROMENTAL BENEFITS OF ETFE

The materials that are used for building ETFE are eco-friendly, and can be recycled. Foils which have a defect can turn into resin and from there on processed into new material. (Cripps et al., 2001) Additionally, out of old ETFE materials; tubing, castings and wires can be produced. Furthermore, one of the best advantage of the material is its lightweight feature which can both reduce the transportation costs and carbon footprint. (LeCuyer, 2008). As being a self cleaning material, ETFE seems to have advantages along environmental benefits.

6.1.8. COMPARISON OF ETFE WITH OTHER MATERIALS

As all of the materials have their own properties and specialities for the most efficient design, a lot of information should be known about the materials that are going to be used. In order to do this, comparison of different materials are needed to be analysed thoroughly.

Properties	ETFE foil (0.2 mm)	Glass (6 mm thk.)
Ultimate tensile strength (N/mm^2)	40 - 46	50 – 100
Yield stress (N/mm^2)	30 – 35*	-
Visible light transmission	95%	85%
Weight (kg/m^2)	0.35	14.40
U-value (W/m^2K)	1.9	6.3
Thermal Resistance (m2 • °C/W)	0.16	0.16
EE (MJ/m2)	27.0	300

Table 5: Physical properties of ETFE and Glass

Source:(Srisuwan, 2017)

As it can be seen in the table above insulation rates of ETFE are better than glass. Also visible light transmission is 95 percent in ETFE and 85 percent in glass. Also weight can be seen as a major difference for ETFE. U value of ETFE is around 1.9 W/m2K while U-value of glass is 6.3 W/m2K. Embodied energy rates also have a lot of difference between ETFE and glass, which is 27.0 MJ/m2 for ETFE and 300 MJ/m2 for the glass.

Attributes Sustainability issues	ETFE inflated cushions (triple layered)	PTFE coated fiberglass fabric	PTFE fabric	Double glazed unit
Light transmittance	Approx. 90% max. (83-88% of UV; scattered light 12%)	7-29%, depending on fabric thickness. Typically 65-75% is reflected and up to 8% absorbed.	20% (variable)	78% (81% single glazing)
U-value	1.9 W/m^2K (5.1 W/m^2K for a single layer system)	4-5 W/m^2K (additional layers can decrease the U-value)	4.6 W/m^2K	2.7-3.1 W/m^2K (5.5 W/m2K for single glass) horizontal application
Embodied energy	27 MJ/m^2	All architectural fabrics have been found to have a lower embodied energy compared to traditional materials	All architectural fabrics have been found to have a lower embodied energy compared to traditional materials	300 MJ/m^2
Recyclability	Yes	Yes	Yes	Yes
Weight	1 kg/m^2	1 kg/m^2	1 kg/m^2	30 kg/m^2
Primary structure (steel)	25-35 kg/m^2	30-40 kg/m^2	30-40 kg/m^2	45-65 kg/m^2
Cleaning	Self cleaning	Self cleaning but degrades over time as surface texture holds dirt	Requires regular manual cleaning	Not self cleaning
Durability	Approx. 35–40 years	20-30 years	15 years	15-30 years

Source: (Srisuwan,2017)

Table 4: Comparison of ETF, PTFE coated fiberglass fabric, PTFE fabric and Double glazed unit

As table 4 indicates light transmittance of ETFE triple layered cushion has the biggest number of all which is 90 percent. After ETFE double glazed unit has 78 percent, then PTFE coated fibreglass fabric has 65-75 percent and the last one on the table is PTFE fabric with 20 percent. U-Value for ETFE gets lower when the layer is thickened. For embodied energy it is stated that innovated materials lower embodied energy rates. All of the materials above can be recycled. ETFE, PTFE coated fibreglass fabric and PTFE fabric has the same weight and glass has 30 times more weight than all other 3 materials for m^2.Usage of membrane gives opportunity for different varieties of deflections and primary structure kilograms also have lower numbers in ETFE which is 25-35 kilo grams. PTFE coated fibreglass fabric and PTFE fabric has the same primary structure weight 20-40 kilograms. Glass has 45-65 kilogram primary structure weight per m^2. Both ETFE and PTFE coated fibreglass fabric has self cleaning however, the latter one degrades over time. Durability of ETFE is the maximum when compared with the other materials that are shown in the figure.

Textile membrane has an important role for the demands of sustainable architecture because of saving energy, efficient architecture and cost efficiency. That's why ETFE is an alternative material compared to conventional materials.

6.2. Examples of Structures with ETFE

National Aquatics Center,(Beijing, China) The design of the "Water Cube structure was made by PTW (Peddle Throp & Walker) Architecture for the 2008 Summer Olympic Swimming Games. The building, which has a total area of 70.000 m^2, has a capacity of 17.000 people. Water is very important for Chinese culture therefore, in the design of the facade and roof covering of the structure were established with water bubbles. For desired design, the form of the structure was studied by sampling the repetitive natural formation of soap foams. With the mathematical formulas produced, a system containing regular junction points was obtained.

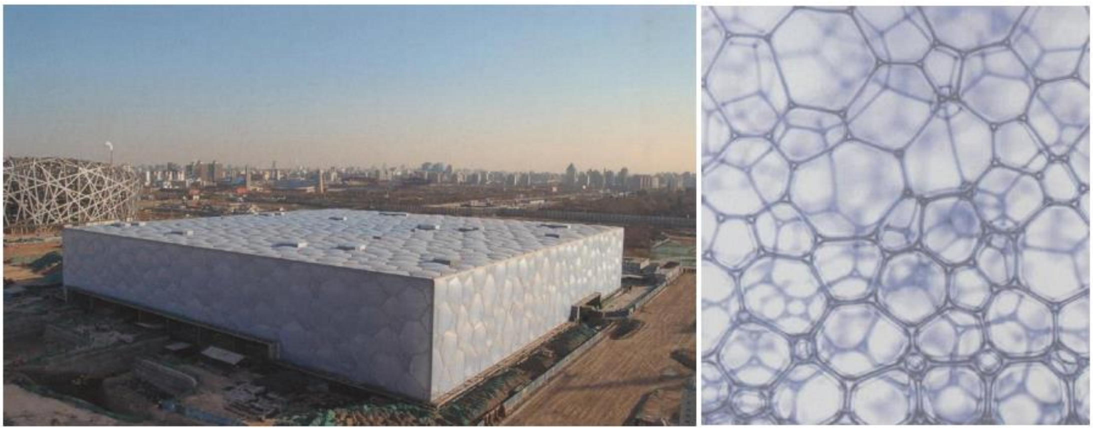


Figure 35: National Aquatic Sturcture

Source: exterior and soap bubbles (National aquatic center, 2019)

A total of 22,000 pipe-profile steel elements (16.8 to 61 cm in diameter) and 12,000 knot centers were used for the conveyor system, which was exposed to 190 different loading conditions (National aquatic center, 2019). With the steel elements used in the construction of the building, flat nets that can be welded in the construction area can be formed. The wall thickness of the building is 3.6 m and the roof thickness is 7.2 m. The roof structure was closed by using 4-layer ETFE cushions with 4-layer internal and external wall structures. ETFE pillows used for roof and façade of the building have a total area of 100.000 m². The structure is harmonized with ETFE material and the main theme of the Beijing Olympics is the ’green Olympics Structure.

Figure 36: National Aquatic Structure

Source: exterior and sectional drawing (National aquatic center, 2019)

Thanks to ETFE coated roof and facade surfaces, a high degree of daylight is taken into the interior of the building. The energy required to heat the pool water is provided by solar energy. At the same time, electricity costs were reduced by providing natural lighting with daylight taken into the structure. 80% of the water used in the structure is recycled and used in swimming pools. ETFE cushions provide acoustic insulation in the high volume of sound energy due to the high reflective materials used in the interior volume of the building and the intensity of the audience. In this context, a total of 30%energy consumption reduced in total, 55%lighting energy saved, 20%solar energy is trapped and used for heating. (National aquatic center, 2019)

Alllianz Arena, (Munih, Germany) The Allianz Arena, developed in 2005, is home to Munich's two football clubs and was one of the arenas used to have the 2006 FIFA World Cup. The arena has a limit of up to 66,000 people. The façade, including the dividers and the rooftop covering the spectator seating zones, is covered with 66,500 m of ETFE cushions that are fitted with bright lights enabling them to change from white to blue to red to suit the home football team using the arena.

Figure 37: Allianz Arena

Source: Germany, Munich (Allianz-arena.de, 2019)

The area over the pitch is open, permitting rainfall and daylight onto the field. The arena was structured by designers Herzog and De Meuron. Arup finished the challenge configuration plot for the design plan of the whole structure and the development structure for the bowl divide. The development plan of the rooftop was finished by Sailer Stephan und Partner, the veneer auxiliary structure was finished by R+R Fuchs and the pneumatic skin plan estimations were finished by Engineering + Design. The ETFE cushions were made by KfM GmbH (LeCuyer, 2008).

Eden Project, (Cornwall, UK) The first Kingsdale School building was built during the 1950s, and preceding its £12 million remodel in 2003, it was in a bad shape. Student's situation and conduct was comparably poor (Vector Foiltec, 2011a).

Figure 38: Eden Project

Source: photo taken by Andreas Braun (Vector Foiltec, 2011a)

Redesign of the school was a piece of the Architecture Foundation's School Works activity, which tried to watch the effect of building condition on student performance. The activity was funded by the Department for Education and Skills. De Rijke Marsh Morgan Architects were granted the agreement to redesign the school and Michael Hadi Associates played out the basic designing for the venture. The school contained an extensive 80 m long by 40 m wide patio at its center; it was chosen that a noteworthy part of the redesign would be to cover this patio with an ETFE rooftop, with foils provided and designed by Vector Foiltec.

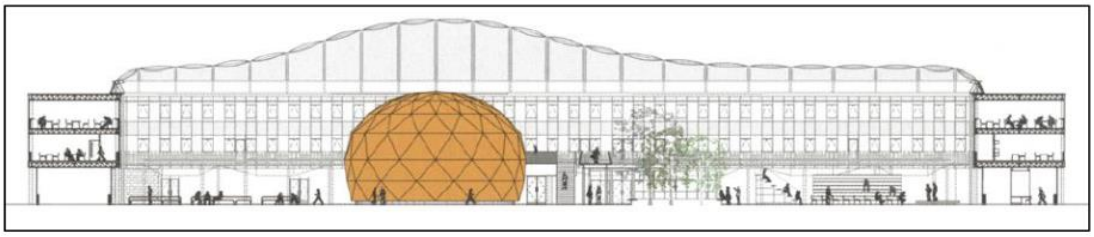


Figure 39:Kingsdale School Design Sketch
Source: (Lecuyer, 2008)

Shallow rounded steel curves length the patio and bolster the ETFE pads. The light weight of the pads and their help structure implies they are effectively bolstered by the structure of the current structure without broad fortification.

The yard is secured with three layer pads with examples imprinted on the best two layers, blocking shifting measures of light contingent upon which assemblies of the pads are expanded (Kennet, 2004). The most extreme light transmittance into the patio is half, when both air chambers in the three-layer ETFE pads are swelled and the base light transmittance is 5%, when just the upper chamber is expanded.

The utilization of Variable Skin cushions takes into consideration more warmth gain in the winter than the late spring, managing the temperatures in the yard. The ground level target temperatures for the yard were no under 14 C in winter and close to 30 C in summer. Temperature control is helped by the establishment of six 12 m by 2.5 m ETFE folds at either end of the rooftop, which are controlled naturally by cylinders to open and close transmittance upon climate and temperature conditions (Kennet, 2004). In this project, energy efficient ETFE roof and a structure has been achieved by spending the least amount of energy on building renovation. The system expects a good insulation feature and prevents it from leaving the breeze outside the building in cold months. It reduces the amount of energy used to heat such a structure in the previous order. Additionally, a more dynamic, aesthetic and energy efficient interior volume was obtained with the use of patterned ETFE cushions.

Khan Shatyry is a multi-purpose entertainment center finished in 2010 in Astana, Kazakhstan, which incorporates an indoor park, shopping mall, entertainment and a retreat. The structure is a tent-formed link structure clad in delicately printed ETFE foil cushions. It has a 200 m circular base and a 150 m tall pole, from which the vertical links are suspended (Vector Foiltec, 2011b). At this tallness, it is right now the world's tallest elastic structure. The vertical links are intended to oppose wind weights, while flat link circles oppose wind suction (LeCuyer, 2008). Sir Norman Foster and Partners were the task designers and Buro Happold were the basic designers. Vector Foiltec provided and designed the ETFE foil pads (Vector Foiltec, 2011b).

Figure 40: Khan Shatyry Entertainment Center
Source: (Vector Foiltec, 2011b).

Designed in an area where the temperature is +35 in summer and -35 in winter ETFE cushions, which have a good insulation feature provides protection of the structure from harsh climatic conditions and have a high rate of sunlight inside the structure, are placed between the cable networks in 3 layers. The size of the ETFE pillows used is 3.5 x 30 m.

CHAPTER 7 METHODOLOGY

Energy is one of the most important inputs for providing the desired living standards without sacrificing comfort conditions in buildings. Depending on the technological developments, a continuous and high-quality energy demand will be required to ensure the desired comfort conditions and sustainability. Because of the increase in energy use in line with industrialization, the reduction of existing energy resources and increasing environmental pollution have brought energy efficiency to the agenda. Energy efficiency includes the efficiency in the production and transmission of energy, as well as the effectiveness of energy in use. While less energy and less primary resources are being used to obtain more energy, more work is done with the same amount of energy or the same work is done by using less energy.

Climate-Related Parameters In order to provide the desired internal climatic conditions (climatic comfort conditions) via external climatic conditions (outside air temperature, outside air humidity, wind and solar radiation), a number of measures are taken regarding the design parameters in the building and settlement units or in the selection of the materials. In order to take these measures, it is necessary to first obtain the values of the external climate parameters and to bring them into a usable form, in other words to compile the climatic data these conditions are needed. Therefore, the characteristics of the external climate parameters such as solar radiation, outside air temperature, outside air humidity and wind should be determined according to the actual atmosphere conditions for the characteristic day on which the design is based.

For the species that live on a specific environment, one of the most important elements is temperature. In this context, climatic data has an impact on living beings and objects living on earth. The optical and thermo-physical properties of the building shells are important for energy efficient building designs. Optical and thermo-physical properties are the determinants of the amount of heat lost and gained by the external air temperature and solar radiation effects from the unit area of the building shell. The internal environmental climatic condition and sustenance of heating and air conditioning loads vary, depending on the total heat amount gained and lost from the building shell. In this context, thermal performance is an important determinant for sustainability.

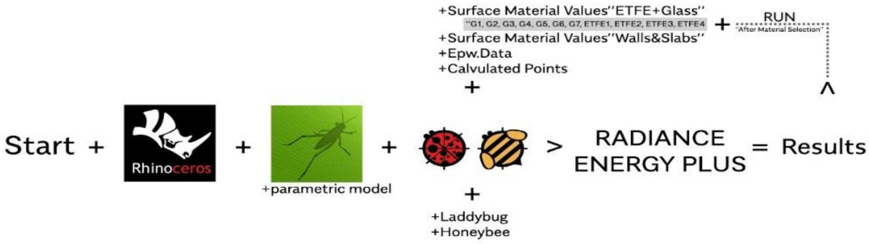


Figure 41: Parametric Model Simulation Progress

For this reason, architectural design is a complex array of input and output with multiple design parameters and constraints. In particular, early architectural design includes important decision-making processes that largely define the annual energy demand of the building. In the discipline of design, besides ethics and aesthetics, scientific modeling or account / evidence-based design and structure-making technique developed. Given these simulation-centered models and the early design steps and results, it is possible to obtain a more sustainable - appropriate structure.

By means of computer simulations, it is possible to obtain designer and user-friendly results, additionally design ideas can be limited. As a result of the simulations made, the designer can make the right choices with the data of the different building materials with the data that is presented by the model.

With these bonds, it is expected to test the materials that are going to be selected and explain the results of the simulation center while the building facade is being designed. With these performance results, it is aimed to reveal the materials that will be sustainable and the energy usage that will occur during the life of the structure. Simulation outputs include daylight data (LUX), energy performance, indoor thermal and visual comfort. Two different criteria are considered with this simulation tool. These metrics include daylight illuminance and total energy consumption (heating and cooling energy consumptions). The main objective of this study is to determine which material is more advantageous or handicapped in terms of daylight illuminance and total energy consumption.

As can be seen in Figure 33, the fallow chart is on the backbone of this study. Results were obtained using the parametric modeled test box Laddybug and Honeybee plugins radiance-Energy plus. Energy efficiency and daylight usage results are collected by following this path.

Etfe Inflatable panel formation panel parametric model concave and convex surfaces modelled. The ETFE cleaning system was then modeled as a flat surface. The concave and convex surfaces on the ETFE surface will differ particularly in relation to UDI data. This part has to be a limitation of the model in the thesis. These surfaces were likely to be optically changing or refracting daylight refraction. Since the parametric one could not be constructed the model was put on the test medium as if it were a flat surface.

In addition, thermal data and material data were entered into the model for all layered systems of the ETFE cushion system.

7.1. Total Energy Consumption and Energy Plus

Model that is used in the thesis bears total energy output consumptions, which include heating and cooling. When calculating the energy consumption Ladybug and Honeybee plugins were used as interface. The plugins that are mentioned use EnergyPlus for the interface. They are all created by Grasshopper Algorithmic Modeling Platform that serves as a part of Rhinoceros CAD software.

The new EnergyPlus recreates energy and expands on the intensity of both BLAST and Doe-2. In addition, EnergyPlus incorporates another code which was developed in Fortran 90. There are a variety of simulation processes that EnergyPlus can make. For example, it makes heat equalization and burden figurings, framework and plant estimations at the same time. Furthermore, users can also configure it which has a compatible option that gives them to create new simulation modules.

EnergyPlus’graphical interface can be a bit abrupt which means it is sometimes not user friendly. Data is presented in text files format.

Energy examinations and heat burden reproductions are made in this program. Heating and cooling loads are additionally determined so as to convey thermal solace set-points. There are some key abilities in this product for example: it can incorporate with vast arrangements incontinently, sunlight can be controlled, it can create warm thermal models, it can coordinate heat a mass exchange, and it can calculate distinctive window formats.

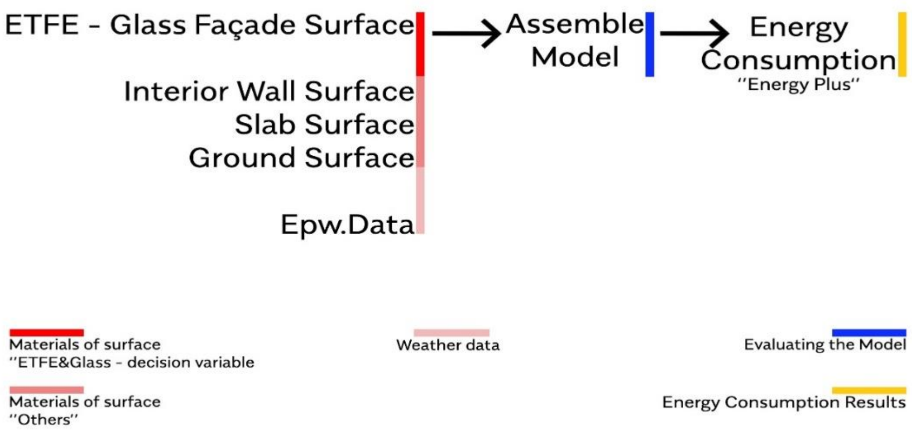


Figure 42: Energy Consumption Calculation Progress

7.2. Useful Daylight Illuminance (UDI) and Radiance

The Useful Daylight Illumination is introduced by Mardaljevic and Nabil in 2005 comes from the annual definition of the amount of light that exists along the working plane and which is considered to be beneficial to the users. Generally, the levels of light between 300 lux and 2000 lux are considered to be useful for users in the space. As a result of the studies done on office buildings, the usefulness ranges determined for the work places are as follows. (Mardaljevic, Nabil 2005)

- Insufficient daylight (<100 lux),
- Daylight luminous illumination (100 <x <500 lux) with insufficient lighting;
- Desirable daylight brightness (500 <x <2000 lux),
- Daylight illumination leading to thermal and visual disturbance exceeding desired limits (> 2000 lux)

Lighting recreations can be made and pictures for lighting configuration can be displayed. So as to evaluate precise enlightenment levels and configuration spaces by means of counterfeit and common lighting advances, designers and architects use Radiance. The product presents interfaces for demonstrating and deciphering space geometry, luminaire information and material qualities to make simulations. Lady Bug for Rhino Grasshopper utilizes Radiance as an interface. Radiance is a physical rendering framework which satisfies the requests of lighting structure and architecture.

So as to unravel the rendering under most conditions, the simulation utilizes a light-backwards ray-tracing technique with expansions. By consolidating any dimension in any environment, for example, complicated and curved geometries, it makes specular, diffuse and directional diffuse reflection and transmission. Besides, so as to succeed the best harmony among speed and accuracy in its local and worldwide light strategies, the simulation utilizes deterministic ray-tracing techniques.

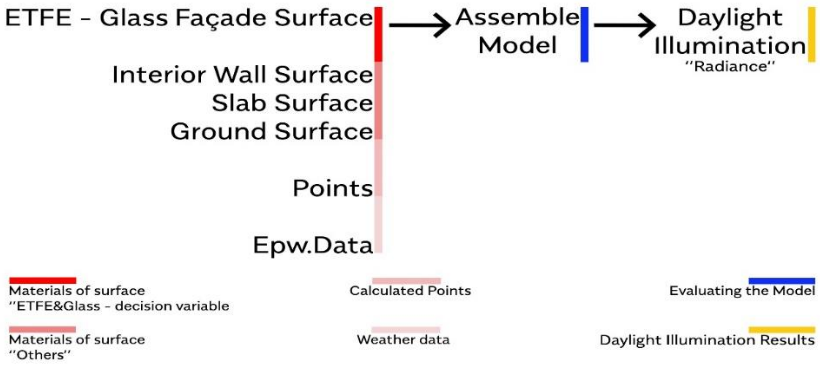


Figure 43: Daylight Illumination Calculation Progress

As seen in Figure 46, this study is going on in the fallow chart backbone to be followed. Results were obtained using the parametric modeled test box Laddybug and Honeybee plug-ins. Following this path, each material will be simulated at its core for the results of daylight use.

7.3. Case Study

In the case study cities of İzmir and Erzurum, both of which are located in Turkey is taken into account. There is a modeling of ETFE cushions also glass to the façade of an imaginary office which is located in İzmir and also in Erzurum. The data gathered from the modeling will be presented below. Furthermore, comparison between ETFE and the glass as an envelope material is analyzed and studied. The choice of İzmir and Erzurum cities are due to their climate conditions. İzmir is located in the western part of Turkey and has nearly 300 sunny days in a year. Erzurum is located on the north-west part of Turkey and has a colder climate.

7.3.1. SITE LOCATION

Site location and other informations which are needed for the case study are presented below:

Location Name:

Izmir – TURKEY,

38.50, - Latitude {N+ S-}

27.02, - Longitude {W- E+}

2.00, - Time Zone Relative to GMT {GMT+/-}

5.00; - Elevation {m}

Location Name:

Erzurum - TURKEY,

39.957, - Latitude {N+ S-}

41.170, - Longitude {W- E+}

3.0, - Time Zone Relative to GMT {GMT+/-}

1756.6; - Elevation {m}

7.3.2. PARAMETRIC MODEL

The main setup for the parametric model is an office-functional model which is designed in Izmir. This model is designed as a possible office structure considering the regulations in Izmir. For this reason, the volume determined as the test area (x): 10m, depth (y) 8m and the height of the structure (z) is designed as 3m.

Designed as a test volume, 10m of this area is arranged to be facing south and the sunshine façade is considered as a variable for glass / ETFE and ETFE cushion system. In this context, the surface set as south façade is taken as test variable for glass and ETFE and ETFE cushion systems. In order to measure our UDI values on a platform located at a height of 75 cm from the ground within this model, 6 test points were placed in a parametric environment.

This test model is designed by running on the Grasshoper Plug-in which is in Rhino program. Ladybug and Honeybee extensions, whose dimensions and design are structured as given above, and working on the model Grashoper Plug-in, have been used. These extensions are combined for energy efficiency and daylight simulations. In order to obtain the results and test accuracy of this 3-dimensional test model, EPW.DATA provides the necessary climate constraints / data to be included in the model. Energy efficiency and daylight simulations were selected on a year-on-year basis and summer and winter days were chosen to be more focused and understandable in the study. These will be expanded to include two days before or behind. For the winter months, the selected 17 January will be examined for 24 hours on a day-by-day basis and will be controlled with 24-hour cycles on 17-18-19 January. For the summer months, it is June 21 and it is 2 on a day basis and its stability will be monitored on 20-21-22 June. All the values of ETFE and glass materials which are to be compared among the done in parametric test model are entered into the test environment separately and all results have been obtained. In this encapsulation, the tube materials are provided with the necessary energy efficiency and daylight related simulations and the results are evaluated. Outputs for each material are collected using the Grashoper panels, and the graphics are compiled in the computer environment. The outputs we have collected with selected material variables support a study for the use of a more accurate product for the Izmir climate. The whole Grashoper model works in its context and the whole process is seen with the visualization of the logic at the bottom.

This test model, designed in computer environment, can be cascaded into the construction of a Parametric model, energy efficiency and daylight model requirements completion, material selection, simulation and results. This sequence (Fig. 36) is as shown. This model starts with the first step and firstly the mass is formed with the corresponding dimensions. This three-dimensional model was then defined by Ladybugg and Honeybee plug-in. This is the step in which the necessary data for energy efficiency and daylight use is entered. Then, each material is simulated and the result parts are taken. This is done for all selected ETFE inflatable systems and glassware.

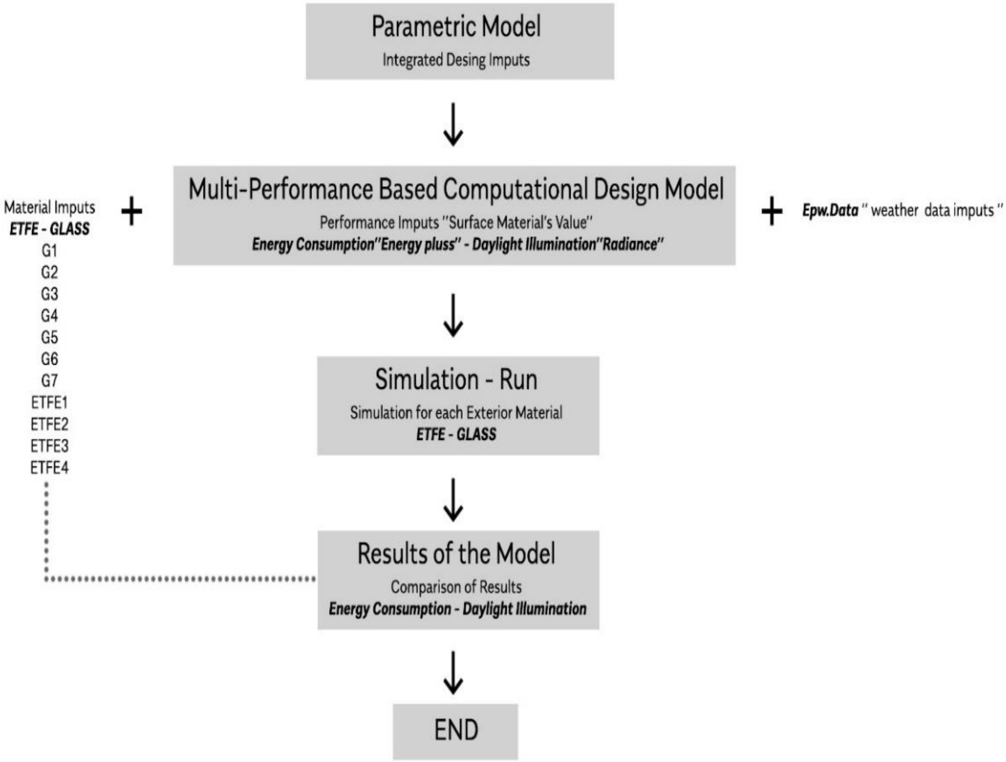


Figure 44: Method of the Research''Parametric Model'' - as schematic flowchart

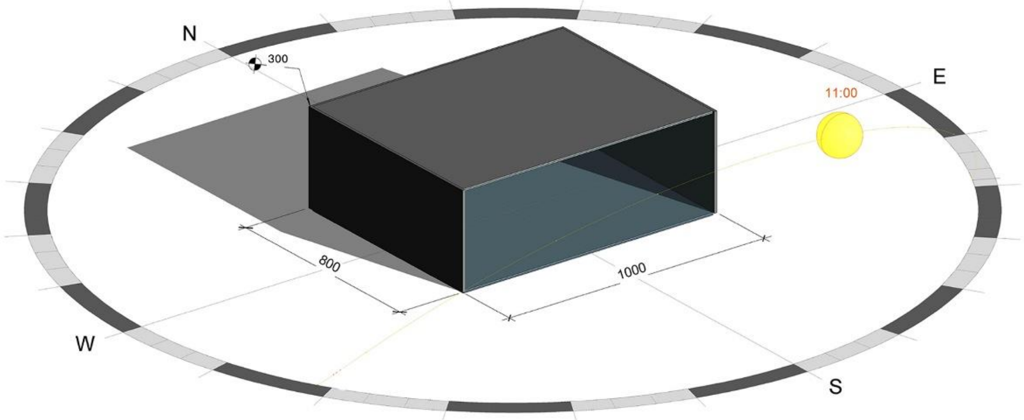


Figure 45: 3D Test Room - 17 January 2019 at 11:00 ''By Autodesk Revit''

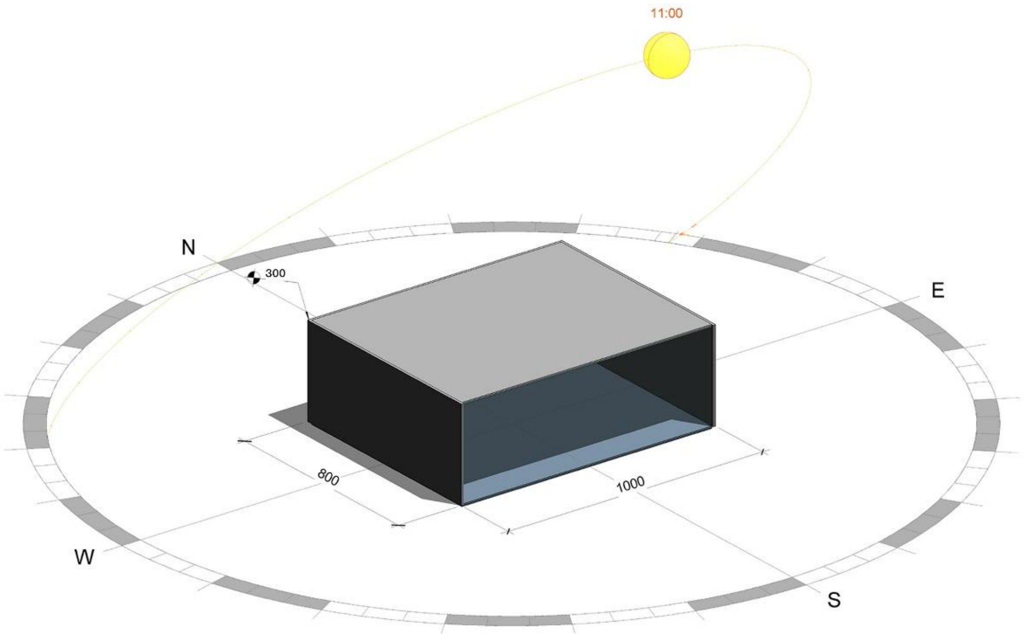


Figure 46: 3D Test Room - 21 June 2019 at 11:00 ''By Autodesk Revit''

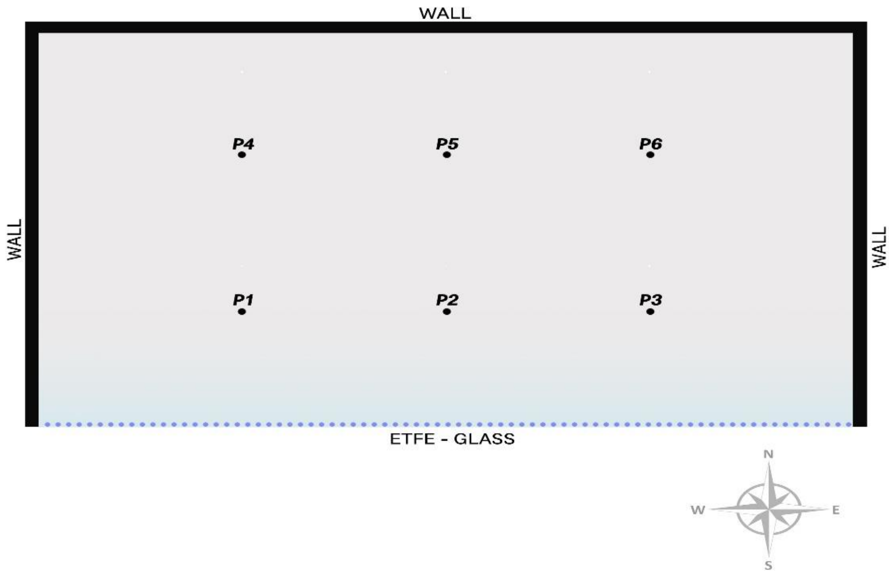


Figure 47:Test Room's Plan – For Measurement Points

For this study, ETFE systems to be tested and material properties for glass are entered. With these value changes, each material has its own output and the test will stop at a realistic point. Material values for G1, G2, G3, G34, G5, G6, G7 glass system and ETFE1, ETFE2, ETFE3, ETFE4 ETFE systems are as follows (Figure 40). In this section, U-Value, SHGC, UV and DT values for the materials to be simulated for glass and ETFE systems will be put into the model as shown in the table. In the scope of the study, related materials will be called as G1, G2, G3, G34, G5, G6, G7 glass system and ETFE1, ETFE2, ETFE3, ETFE4 ETFE systems and their abbreviations will be used. The test mass, which is the subject of parametric model made in Rahino and Grasshoper, is formed by using Box component as 10 meters width, 8 meters depth and 3 meters height. This test medium was broken down into surfaces and identified as walls, ground-floors, roofs and windows (modified surfaces for glass and ETFE systems). This distinction is designed in order to put the material information imposed on the model to the right surfaces in the later stages of the parametric model.

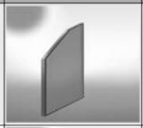
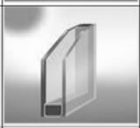
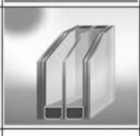
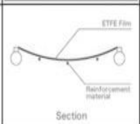
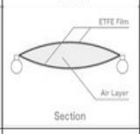
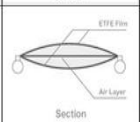
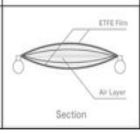
NAME	IMAGE	LAYERS Glass - ETFE Configuration	U-VALUE W/(m2K)	SHGC Solar Heat Gain Coefficient	UV UVTransmission	DT Daylight Transmittance
G1		***PANE:*** Şişecam Tentesol 4mm Silver (Surface2)	**5,8**	**55%**	**21%**	**40%**
G2		***PANE:*** Şişecam Ultra Clear Laminated Glass (4+0,38+4)mm Clear44.1	**5,7**	**86%**	**8,6%**	**90%**
G3		***PANE:*** Şişecam Tentesol 8mm Bronze(Surface2)	**5,6**	**39%**	**3,7%**	**18%**
G4		***OUTHER PANE:*** Şişecam Low-E Glass 8mm Neutral (Surface2) ***CAVITY1:*** 6mm Cavity (Argon) ***INNER PANE:*** Şişecam Ultra Clear Float Glass 8mm Ultra Clear	**2,0**	**53%**	**31%**	**77%**
G5		***OUTHER PANE:*** Şişecam Low-E Glass 8mm Neutral (Surface2) ***CAVITY1:*** 16mm Cavity (Argon) ***INNER PANE:*** Şişecam Low-E Glass 8mm Neutral Clear	**1,1**	**52%**	**31%**	**52%**
G6		***OUTHER PANE:*** Şişecam Low-E Glass 8mm Neutral (Surface2) ***CAVITY1:*** 6mm Cavity (Air) ***MIDDLE PANE:*** Şişecam Clear Float Glass 12mm Clear ***CAVITY2:*** 6mm Cavity (Air) ***INNER PANE:*** Şişecam Low-E Glass 8mm Neutral (Surface5)	**1,5**	**44%**	**15%**	**63%**
G7		***OUTHER PANE:*** Şişecam Laminated Low-E Glass (6+0,76+6)mm 66.2 (Surface2) ***CAVITY1:*** 27mm Cavity (Air) ***MIDDLE PANE:*** Şişecam Clear Float Glass 12mm Clear ***CAVITY2:*** 27mm Cavity (Air) ***INNER PANE:*** Şişecam Laminated Low-E Glass (6+0,76+6)mm 66.2 (Surface5)	**0,6**	**40%**	**0.42%**	**60%**
ETFE-1		***OUTHER LAYER:*** Ethylene Tetrafluoroethylene, ETFE	**5,6**	**55%**	**60%**	**95%**
ETFE-2		***OUTHER LAYER:*** Ethylene Tetrafluoroethylene, ETFE ***CAVITY1:*** (Air) ***INNER LAYER:*** Ethylene Tetrafluoroethylene, ETFE	**2,9**	**50%**	**50%**	**85%**
ETFE-3		***OUTHER LAYER:*** Ethylene Tetrafluoroethylene, ETFE ***CAVITY1:*** (Air) ***MIDDLE LAYER:*** Ethylene Tetrafluoroethylene, ETFE ***CAVITY2:*** (Air) ***INNER LAYER:*** Ethylene Tetrafluoroethylene, ETFE	**1,9**	**45%**	**45%**	**80%**
ETFE-4		***OUTHER LAYER:*** Ethylene Tetrafluoroethylene, ETFE ***CAVITY1:*** (Air) ***MIDDLE LAYER:*** Ethylene Tetrafluoroethylene, ETFE ***CAVITY2:*** (Air) ***MIDDLE LAYER:*** Ethylene Tetrafluoroethylene, ETFE ***CAVITY3:*** (Air) ***INNER LAYER:*** Ethylene Tetrafluoroethylene, ETFE	**1,4**	**35%**	**10%**	**75%**

Figure 48: Collated ETFE and Glass Material's Values

Material information related to glass and ETFE inflatable systems has been designed to describe the material as a material for the grasshopper program. As we have seen, there is no material data that can be used in the grasshopper library related to the glass and ETFE inflatable systems we have used. We put the material properties we need into the model together with the grasshopper components as in the visual. The name of the material related to glass and ETFE inflatable systems is UWalowMat by setting values such as U_value water, SHGC value and VT information as input to the material and put it into my parametric model. (Figure 51). . We also put this in the Library of the Model and record it for the editing to be used. After this process, we obtain the values of EPConstruction (material properties we have entered) into the glazinCreator as a data for the window surfaces we have previously separated. In this way, we change the glass and ETFE inflatable systems that we have set for the Southern part via EPConstruction. The values we have made for this part have been edited in the internal walls and upper / lower floors of the building. This differs from the values we make for glass material and is designed as EPOpaqueMat. (Figure 51). As can be seen, these values are not variable and are kept constant for each simulation.

All simulations were obtained and recorded one by one. We have obtained results for glass and ETFE swelling systems. In this way, annual results are obtained for each material on an annual basis. As simulation outputs, we take outdoor air temperature, indoor surface temperature, indoor air temperature and Surface Energy lose and gain on hour basis. By registering these data as Exel file, it is possible for us to evaluate each hourly monthly or periodically.

As seen in the (Figure 51) same results are made in daylight analysis. The results of the simulations for glass and ETFE swelling systems are obtained from the calculation points that we have planned as P1, P2, P3, P4, P5, P6. This is on an hourly basis and is controlled separately for each point.

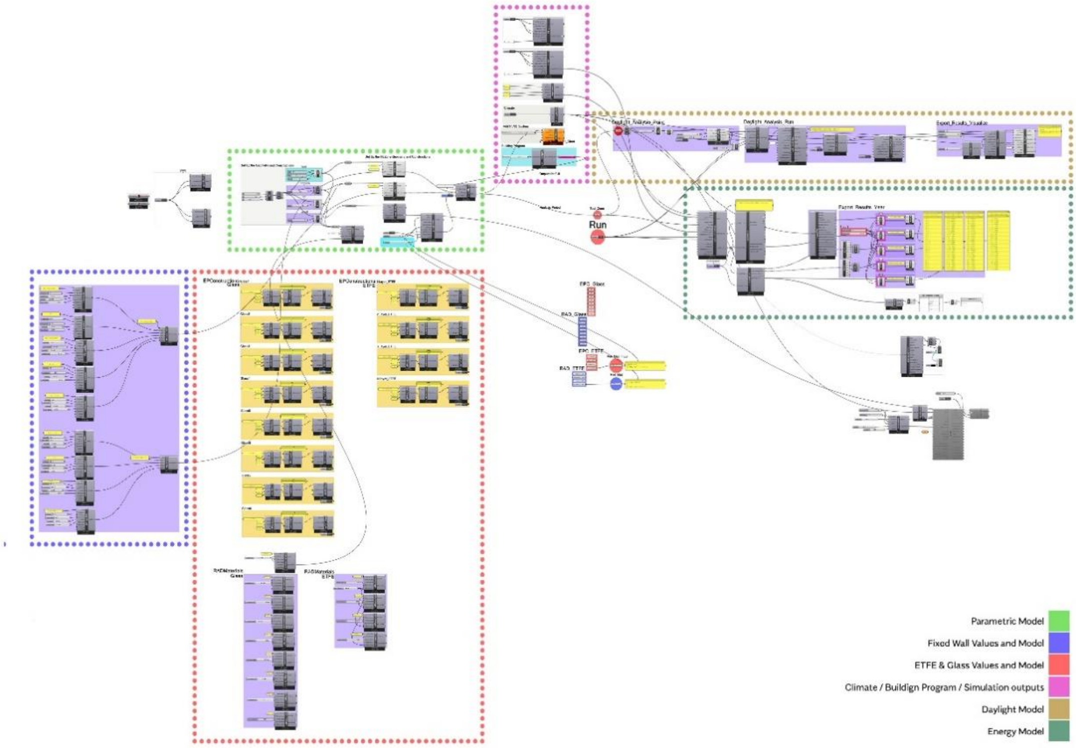


Figure 49: Complete Grasshoper Model of Case Study

CHAPTER 8
RESULTS AND DISCUSSION

8.1. Results for İzmir Region

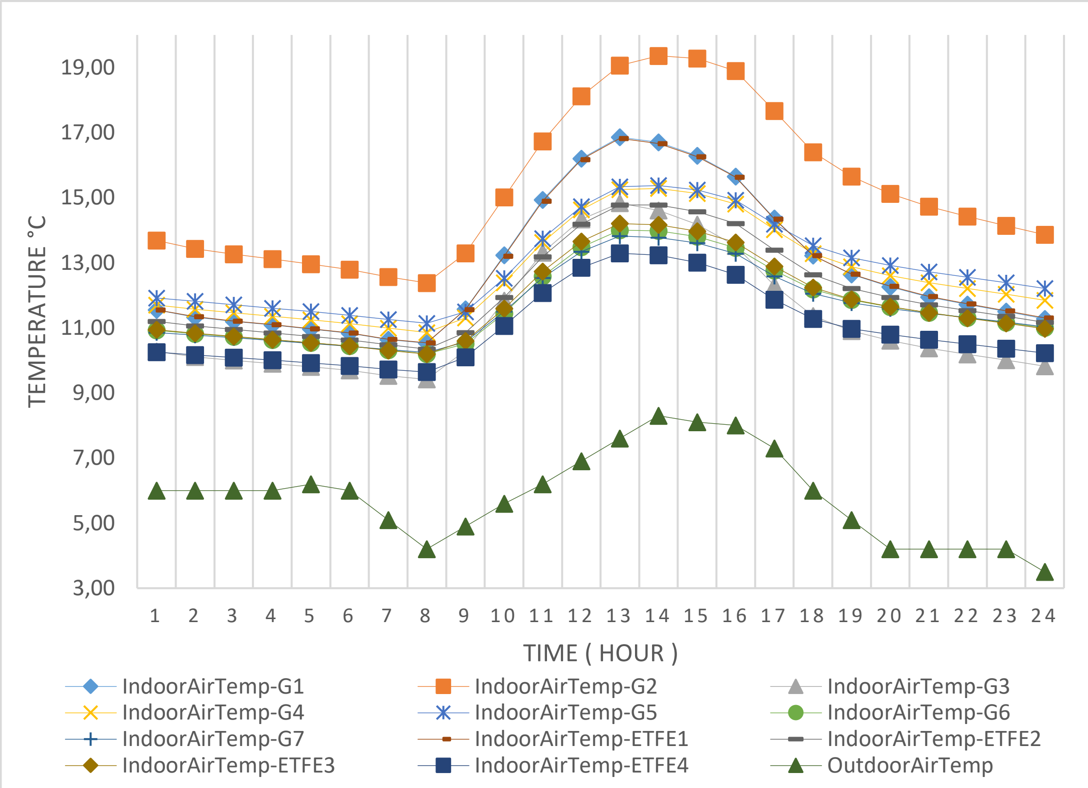


Figure 50: 17 January – Indoor Air Temperature

As seen in (Figure 53), the indoor air temperatures are on January 17th, 13,68^{0}C; 11,98 ^{0}C; 11,70 ^{0}C; 11,56 ^{0}C; 11,55^{0}C; 11,19 ^{0}C; 10,92 ^{0}C; 10,86 ^{0}C; 10,27 ^{0}C; 10,26 ^{0}C; for G2, G5, G4 ,ETFE1, G1, ETFE2, ETFE3, G6, G7, G3 and ETFE4 respectively while the outdoor air temperature is 6^{0}C at 01:00. They drop down to 12,38 ^{0}C; 11,14 ^{0}C; 10,86 ^{0}C; 10,54^{0}C; 10,53 ^{0}C; 10,35 ^{0}C; 10,24^{0}C; 10,20^{0}C; 10,19 ^{0}C; 9,64^{0}C and 9,42 ^{0}C at 08:00 for G2, G5, G4, ETFE1, G1, ETFE2, G7, G6, ETFE3, ETFE4 and G3 respectively while the outdoor air temperature is 4,2^{0}C at 08:00. The indoor air temperatures start to increase up to 19,06 ^{0}C; 16,86 ^{0}C; 16,82^{0}C; 15,33 ^{0}C; 15,25 ^{0}C; 14,83 ^{0}C; 14,77 ^{0}C; 14,20 ^{0}C; 14,00 ^{0}C; 13,82 ^{0}C and 13,29 ^{0}C for G2, G1, ETFE1, G5, G4, G3, ETFE2, ETFE3, G6, G7 and ETFE4 at 13.00 respectively while the outdoor air temperature is 7,6 ^{0}C at 13:00. The indoor air temperature drop down to 15,65 ^{0}C; 13,16 ^{0}C; 12,88 ^{0}C; 12,65 ^{0}C; 12,64 ^{0}C; 12,21 ^{0}C; 11,88 ^{0}C; 11,86 ^{0}C; 11,77 ^{0}C; 10,98 ^{0}C and 10,91 ^{0}C for G2, G5, G4, ETFE1, G1, ETFE2, ETFE3, G6, G7, ETFE4 and G3 at 19:00. When looking at the indoor temperature graphs, G2, ETFE1 and G1 are closest to the indoor comfort temperature. G5, G4 and ETFE 2 are then followed. When interpreted with the values of these materials, radiation permeability and quicker heating in winter months are closer to the comfort of the interior. It is seen as more useful for winter months or months when heating loads can be high.

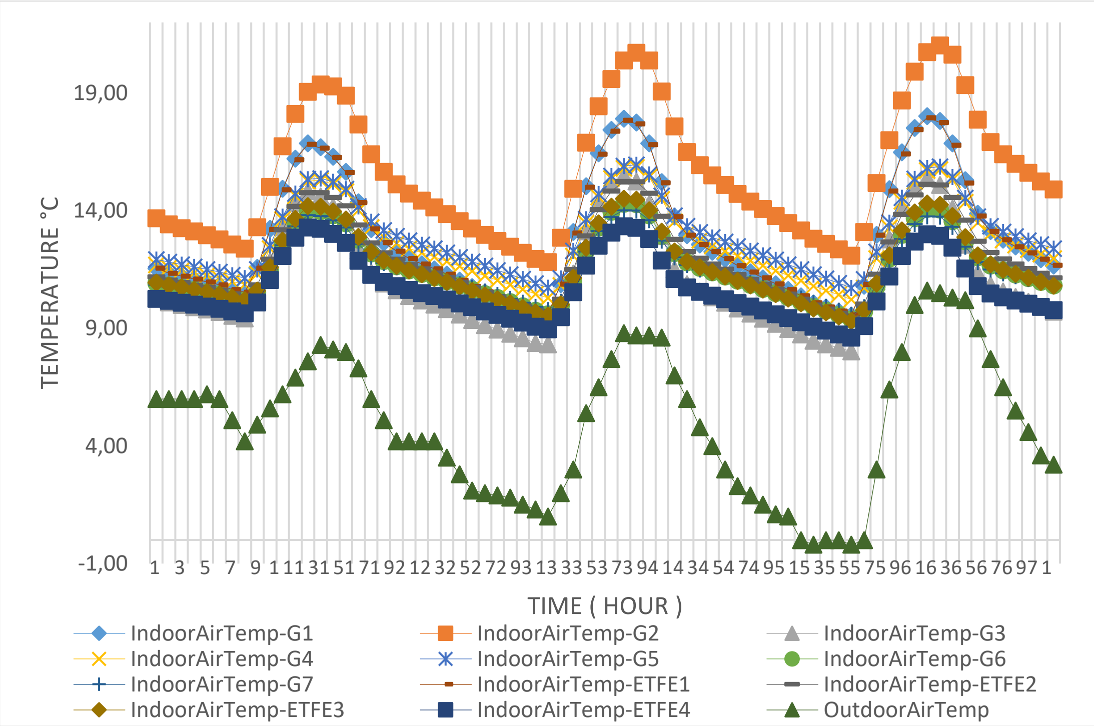


Figure 51: 17-19 January – Indoor Air Temperature

The hourly indoor air temperature variations for 17-19 January is seen in (Figure43). Simulation evaluation that have made in (Figure 54) January 17th can also be made for days January 18th and January 19th. For winter period, G2 has the highest indoor air temperature values but the hourly indoor air temperature variations throughout the whole day are so high; that's why it is not thermally comfortable enough. G1 and ETFE1 have similar behaviour and provide thermally more comfortable indoor environment. The difference between the pick points for the indoor air temperature throughout the whole day is supposed to be minimum if there is no additional mechanical heating system but as the indoor air temperature of the selected glass and ETFE cushion samples do not provide thermally comfortable indoor environment by themselves, additional mechanical mechanic heating system should be used. Thus G2, G1 and ETFE1 might be used recommended to be used with additional mechanical heating system for less energy consumption.

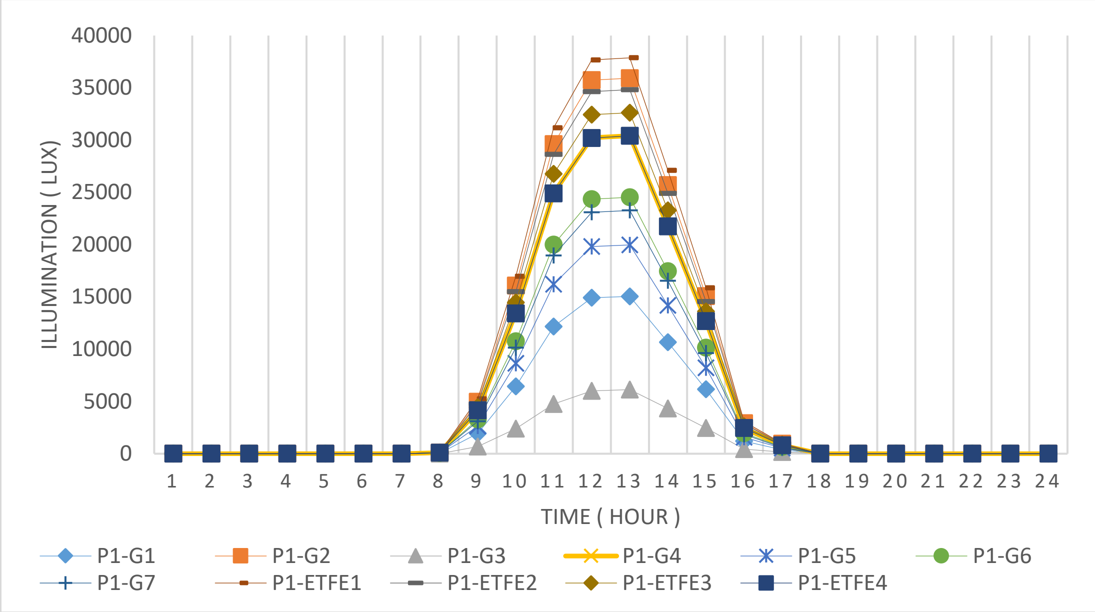


Figure 52: 17 January – Indoor P1 Illumination

As seen in (Figure *55*), the illumination values start increasing at 08.00, reach to their maximum amounts at 13.00, and drop down to minimum at 18.00. The illumination values are 37866 Lux, 35920 Lux, 34827 Lux, 32619 Lux, 30414 Lux, 30406 Lux, 24532 Lux, 23269 Lux, 19972 Lux, 15050 Lux and 6132 Lux for ETFE1, G2, ETFE2, ETFE3, G4, ETFE4, G6, G7, G5, G1 and G3 respectively while the Illumination for P1 at 13:00. Looking at the P1 point for January 17, the G3 glass system yields better results. Since P1 point is closer to the façade, its values are very high. All the remaining glass and ETFE inflatable systems require sunshade systems and are far from the comfort of daylight.

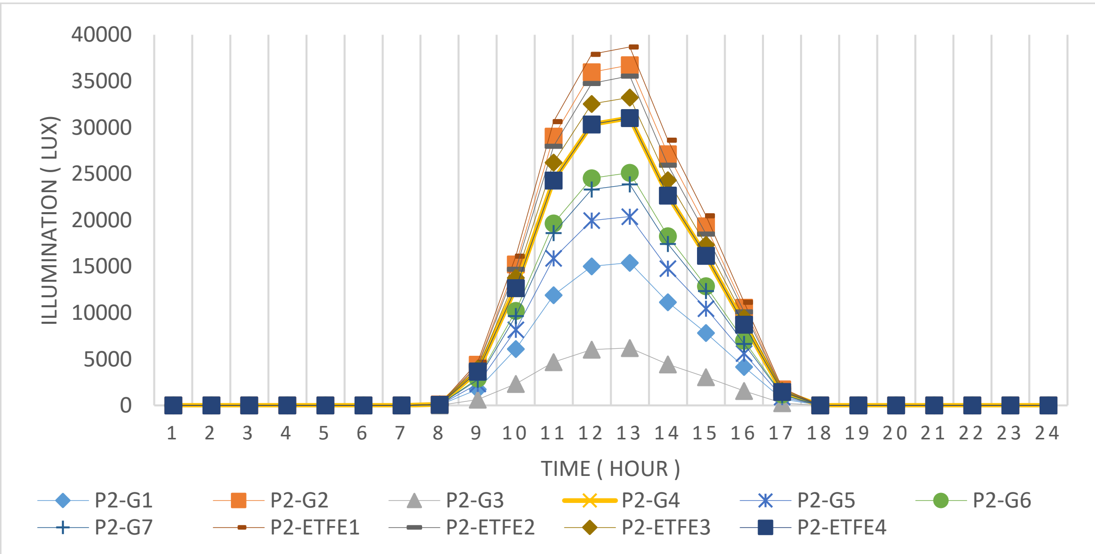


Figure 53: 17 January – Indoor P2 Illumination

As seen in (Figure *56*), the illumination values start increasing at 08.00, reach to their maximum amounts at 13.00, and drop down to minimum at 18.00. The illumination values are 38684 Lux, 36734 Lux, 35563 Lux, 33240 Lux, 31032 Lux, 31037 Lux, 25112 Lux, 23853 Lux, 20384 Lux, 15409 Lux and 6200 Lux for ETFE1, G2, ETFE2, ETFE3, G4, ETFE4, G6, G7, G5, G1 and G3 respectively while the Illumination for P2 at 13:00. Looking at the P2 point for January 17, the G3 glass system gives better results. Since the point P2 is closer to the façade, its values are very high. All the remaining glass and ETFE inflatable systems require sunshade systems and are far from the comfort of daylight.

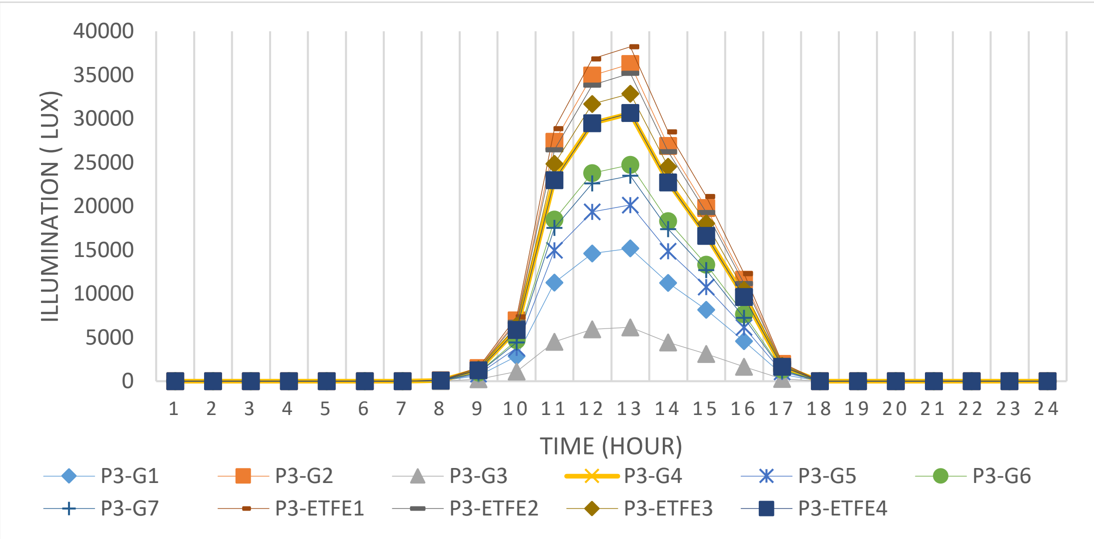


Figure 54: 17 January – Indoor P3 Illumination

As seen in (Figure *57*), the illumination values start increasing at 08.00, reach to their maximum amounts at 13.00, and drop down to minimum at 18.00. The illumination values are 38227 Lux, 36261 Lux, 35186 Lux, 32869 Lux, 30611 Lux, 30659 Lux, 24733 Lux, 23480 Lux, 20148 Lux, 15176 Lux and 6168 Lux for ETFE1, G2, ETFE2, ETFE3, G4, ETFE4, G6, G7, G5, G1 and G3 respectively while the Illumination for P3 at 13:00. Looking at the P3 point for January 17, the G3 glass system yields better results. Since the P3 point is closer to the façade, its values are very high. All the remaining glass and ETFE inflatable systems require sunshade systems and are far from the comfort of daylight.

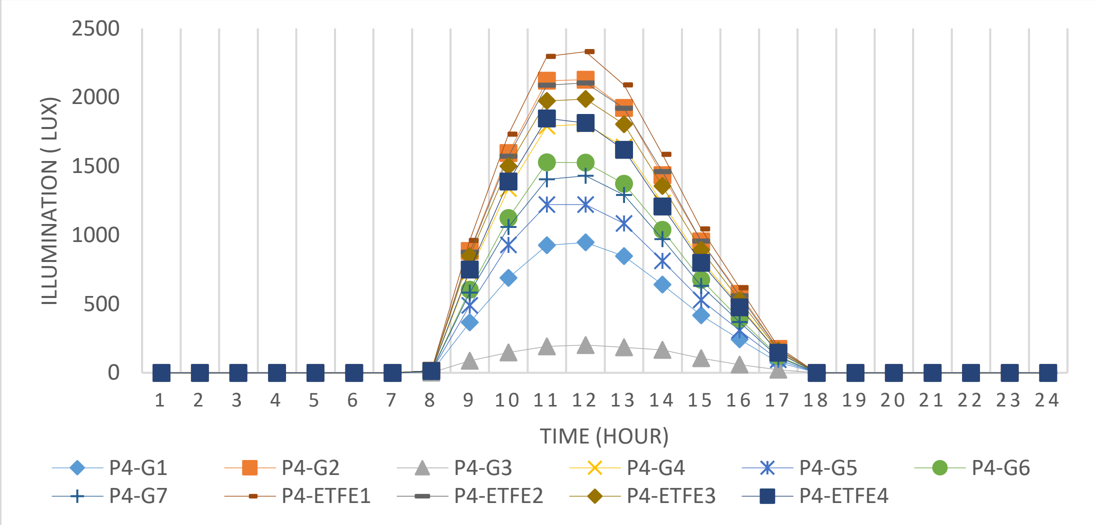


Figure 55: 17 January – Indoor P4 Illumination

As seen in (Figure *58*), the illumination values start increasing at 08.00, reach to their maximum amounts at 12.00, and drop down to minimum at 18.00. The illumination values are 2331 Lux, 2128 Lux, 2105 Lux, 1987 Lux, 1813 Lux, 1805 Lux, 1525 Lux, 1430 Lux, 1220 Lux, 946 Lux and 202 Lux, for ETFE1, G2, ETFE2, ETFE3, ETFE4, G4, G6, G7, G5, G1 and G3 respectively while the Illumination for P4 at 12:00. Looking at the P4 point for January 17, the G3 and G1 glass system yields better results. However, it can be said that the values do not receive direct sunlight. Since the point P4 is farther away from the façade, its values decrease and remain in a more controllable range. In addition, the G3 glass system values are in poor illumination range, so artificial lighting is required. All remaining glass and ETFE inflatable systems require sunshade systems and do not have the comfort of daylight.

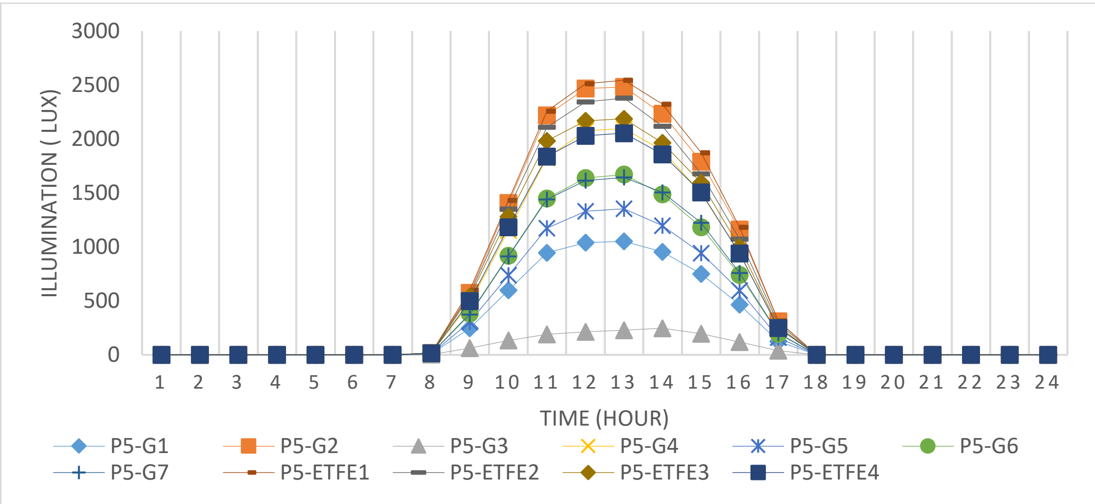


Figure 56: 17 January – Indoor P5 Illumination

As seen in (Figure 59), the illumination values start increasing at 08.00, reach to their maximum amounts at 12.00, and drop down to minimum at 18.00. The illumination values are 2544 Lux, 2481 Lux, 2378 Lux, 2186 Lux, 2095 Lux, 2054 Lux, 1670 Lux, 1643 Lux, 1353 Lux, 1051 Lux and 227 Lux, for ETFE1, G2, ETFE2, ETFE3, G4, ETFE4, G6, G7, G5, G1 and G3 respectively while the Illumination for P5 at 13:00. Looking at the P5 point for January 17, the G3 and G1 glass system yields better results. However, it can be said that the values do not receive direct sunlight. Since the point P5 is farther away from the façade, its value decreases and stands in a more controllable range. In addition, the G3 glass system values are in poor illumination range, so artificial lighting is required. All remaining glass and ETFE inflatable systems require sunshade systems and do not have the comfort of daylight.

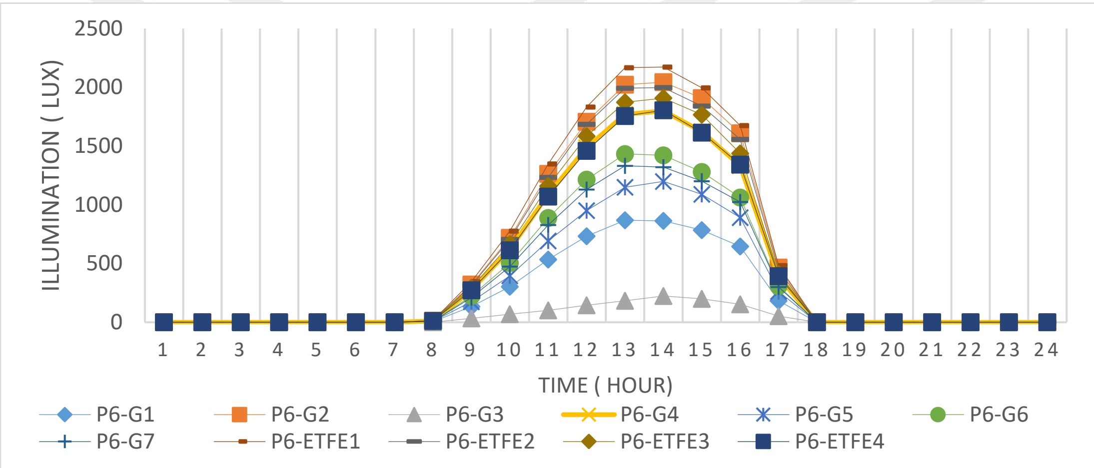


Figure 57: 17 January - Indoor P6 Illumination

As seen in (Figure 60), the illumination values start increasing at 08.00, reach to their maximum amounts at 12.00, and drop down to minimum at 18.00. The illumination values are 2165 Lux, 2022 Lux, 1991 Lux, 1873 Lux, 1769 Lux, 1756 Lux, 1433 Lux, 1332 Lux, 1148 Lux, 868 Lux and 182 Lux for ETFE1, G2, ETFE2, ETFE3, G4, ETFE4, G6, G7, G5, G1 and G3 respectively while the Illumination for P6 at 13:00. Looking at the P6 point for January 17, the G3 and G1 glass system yields better results. However, it can be said that the values do not receive direct sunlight. Since the point P6 is farther away from the façade, its value decreases and stands in a more controllable range. In addition, the G3 glass system values are within the range of insufficient illumination therefore makes the lighting necessary. All remaining glass and ETFE inflatable systems require sunshade systems and do not have the comfort of daylight.

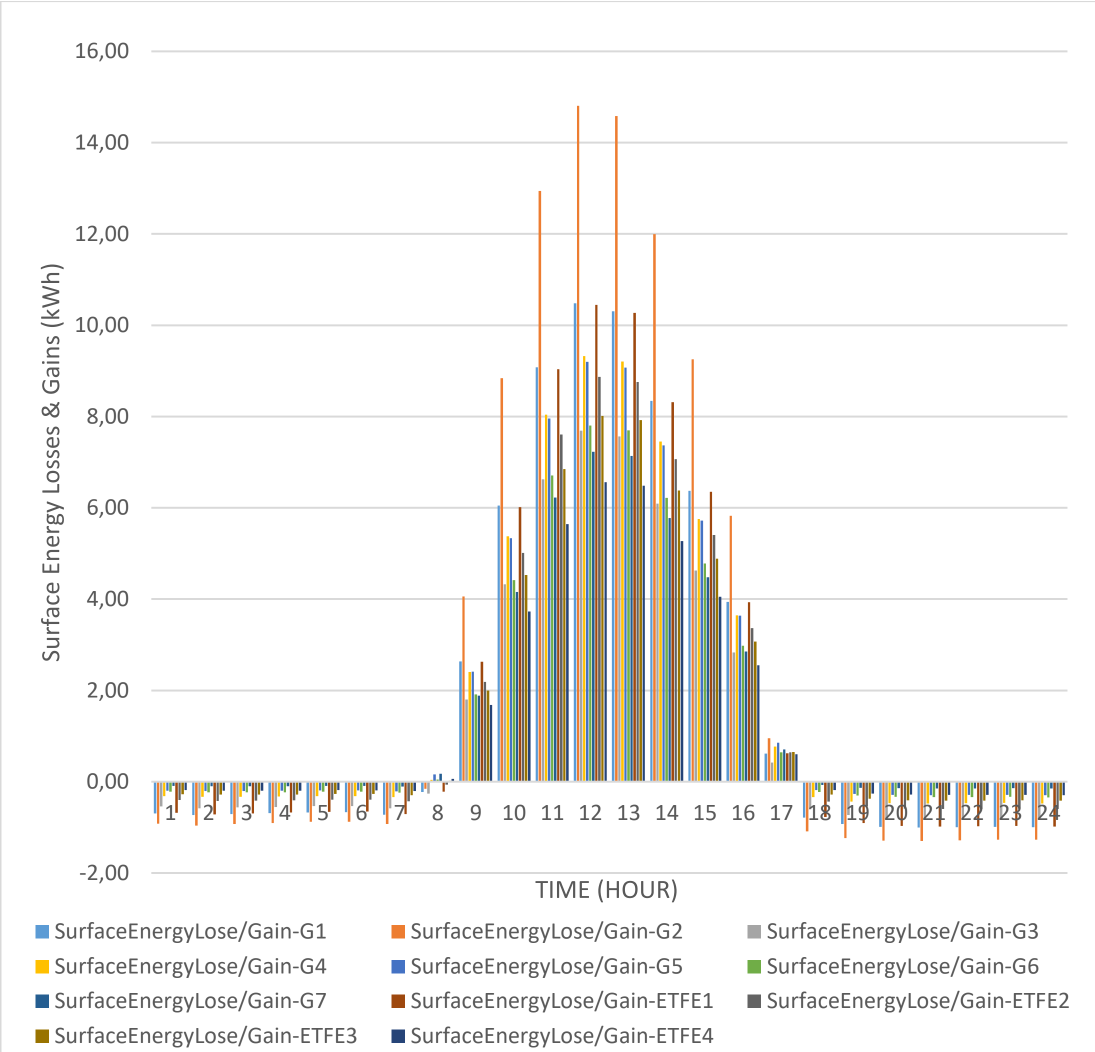


Figure 58: 17-19 January - Surface Energy Losses&Gain

As seen in (Figure 61), the results were taken as 24 hours for January 17, January 18 and January 19 and evaluated. The observation and correctness of the stability on 17 January was checked. As you can see, the materials in question lose the heat in the interior from 24:00 until 09:00 in the morning. Similarly and depending on the same conditions, heat loss from inside to outside was observed from 18:00 to 24:00. From 9:00 am to 6:00 pm, the heat transfer is from the outside to the interior. In this context, the possible heat gain and burning of the materials during the heating months will be as shown in the figure. The stability of the materials and the same reactions and the surface energy loss-gain of the materials during İzmir's heating months proceed with the same logic.

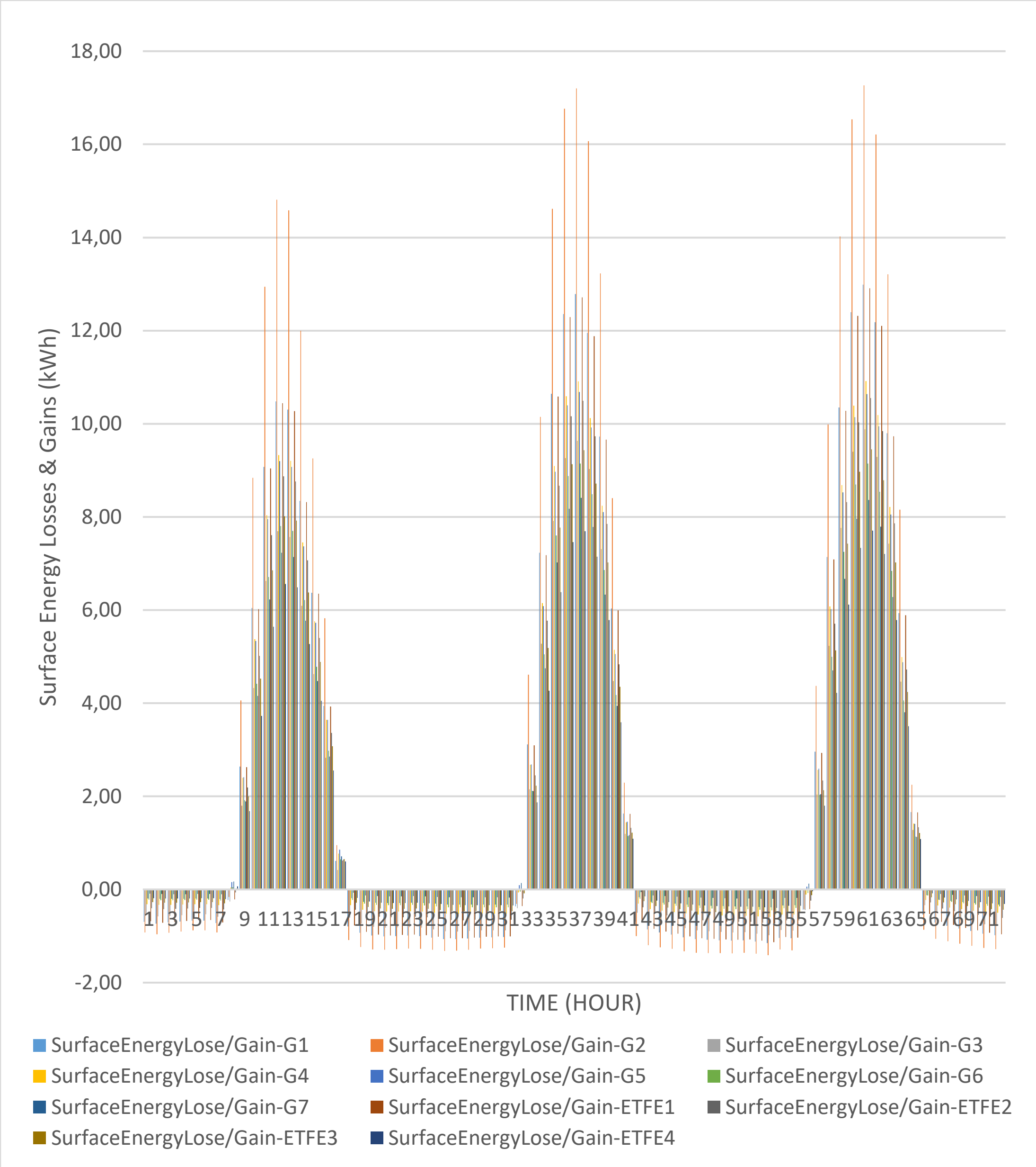


Figure 59: 17-19 January - Surface Energy Losses&Gains

As seen in (Figure 51), the results were taken as 24 hours for January 17, January 18 and January 19 and evaluated. The observation and correctness of the stability on 17 January was checked. As you can see, the materials in question lose the heat in the interior from 24:00 until 09:00 in the morning. Similarly and depending on the same conditions, heat loss from inside to outside was observed from 18:00 to 24:00. From 9:00 am to 6:00 pm, the heat transfer is from the outside to the interior. In this context, the possible heat gain and burning of the materials during the heating months will be as shown in the figure. The stability of the materials and the same reactions and the surface energy loss-gain of the materials during İzmir's heating months proceed with the same logic.

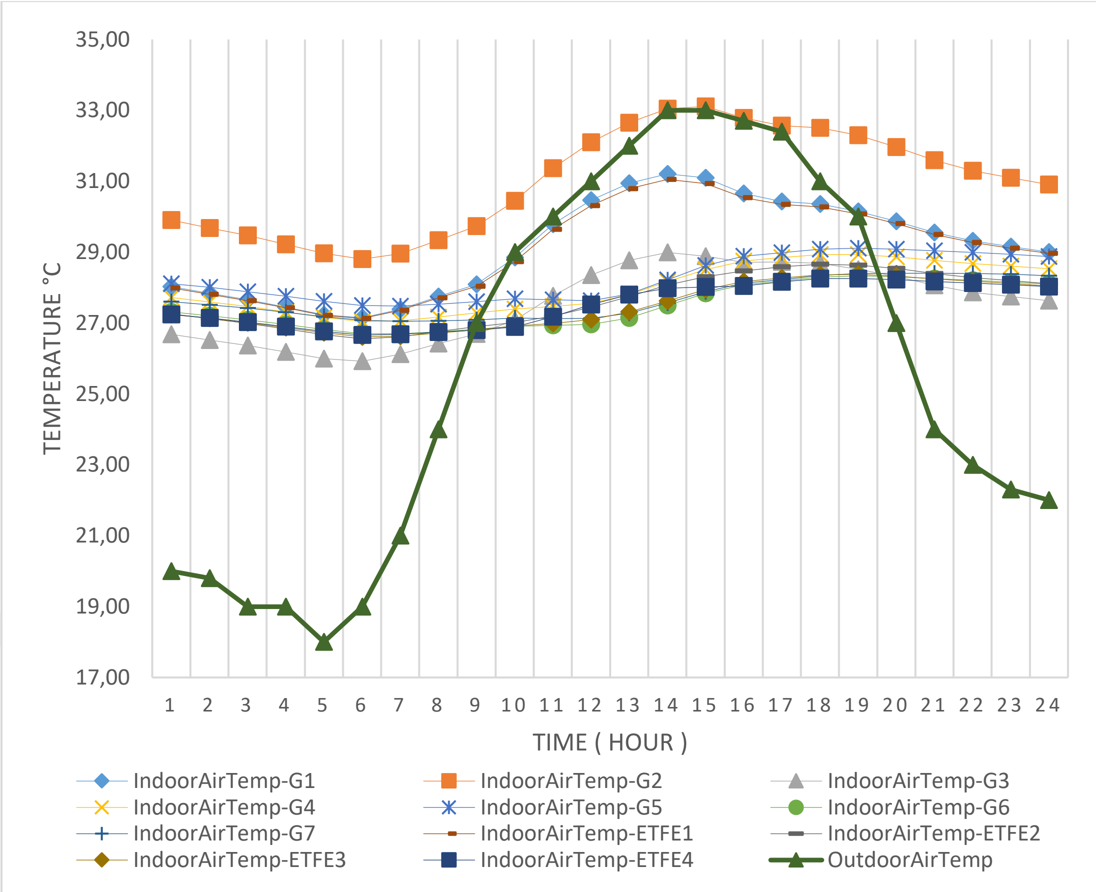


Figure 60: 21 June – Indoor Air Temperature

As seen in (Figure 63), the indoor air temperatures are on June 21th, 29,90 ^{0}C; 28,11^{0}C; 28,02 ^{0}C; 27,99 ^{0}C; 27,72 ^{0}C; 27,60 ^{0}C; 27,31 ^{0}C; 27,26 ^{0}C; 27,25 ^{0}C; 27,24 ^{0}C and 26,68 ^{0}C for G2, G5, G1, ETFE1, G4, G7, G6, ETFE2, ETFE3, ETFE4 and G3 respectively while the outdoor air temperature is 20 ^{0}C at 01:00. They drop down to 28,80 ^{0}C; 27,49 ^{0}C; 27,15 ^{0}C; 27,13 ^{0}C; 27,08 ^{0}C; 27,04 ^{0}C; 26,70 ^{0}C; 26,66 ^{0}C; 26,61 ^{0}C; 26,55 ^{0}C and 25,92 ^{0}C at 08:00 for G2, G5, G1, ETFE1, G7, G4, G6, ETFE4, ETFE3, ETFE2 and G3 respectively while the outdoor air temperature is 19 ^{0}C at 08:00. The indoor air temperatures start to increase up to 33,05 ^{0}C; 31,21 ^{0}C; 31,05 ^{0}C; 28,99 ^{0}C; 28,22 ^{0}C; 28,18 ^{0}C; 28,07 ^{0}C; 27,99 ^{0}C; 27,62 ^{0}C; 27,57 ^{0}C; and 27,50 ^{0}C for G2, G1, ETFE1, G3, G5, G4, ETFE2, ETFE4, ETFE3, G7 and G6 at 14.00 respectively while the outdoor air temperature is 33^{0}C at 14:00. The indoor air temperature drop down to 32,30 ^{0}C; 30,15 ^{0}C; 30,08 ^{0}C and 28,52 ^{0}C; for G2, G1, ETFE1 and G3 at 19.00. The indoor air temperature increasing up to 29,91^{0}C; 28,93^{0}C; 28,63^{0}C; 28,26^{0}C; 28,37^{0}C; 28,40^{0}C and 28,33^{0}C for G5, G4, ETFE2, ETFE4, ETFE3, G7 and G6 respectively while the outdoor air temperature is 30 ^{0}C at 19:00. When looking at the indoor temperature graphs, G6, ETFE3, G7 and ETFE 4 are closest to the indoor comfort temperature. In addition, the G3 glass performs better in the evening when the daylight is not present, but its performance becomes worse from 9:00 to 20:00. It is more convenient to use these three materials in the summer when interpreted with the values of these materials. Considering room comfort temperature, these materials will require less cooling load.

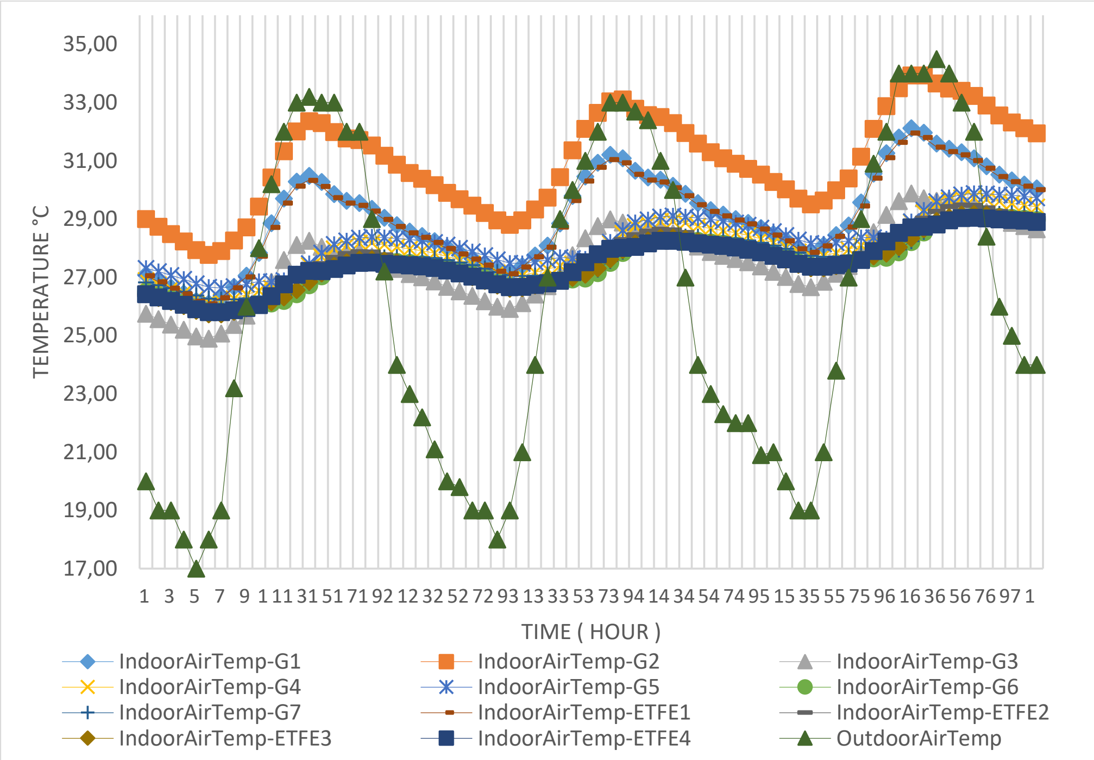


Figure 61: 20-22 June – Indoor Air Temperature

The hourly indoor air temperature variations for 20-22 June is seen in (Figure53). Simulation evaluation that have made in (Figure 64) June 21th can also be made for days June 20th and June 22th. For summer period, G2 has the highest indoor air temperature values but the hourly indoor air temperature variations throughout the whole day are so high; that's why it is not thermally comfortable enough. G6, G7, ETFE3 and ETFE4 have similar behaviour and provide thermally more comfortable indoor environment. The difference between the pick points for the indoor air temperature throughout the whole day is supposed to be minimum if there is no additional mechanical cooling system but as the indoor air temperature of the selected glass and ETFE cushion samples do not provide thermally comfortable indoor environment by themselves, additional mechanical mechanic cooling system should be used. Thus G6, G7, ETFE3 and ETFE4 might be used recommended to be used with additional mechanical heating system for less energy consumption.

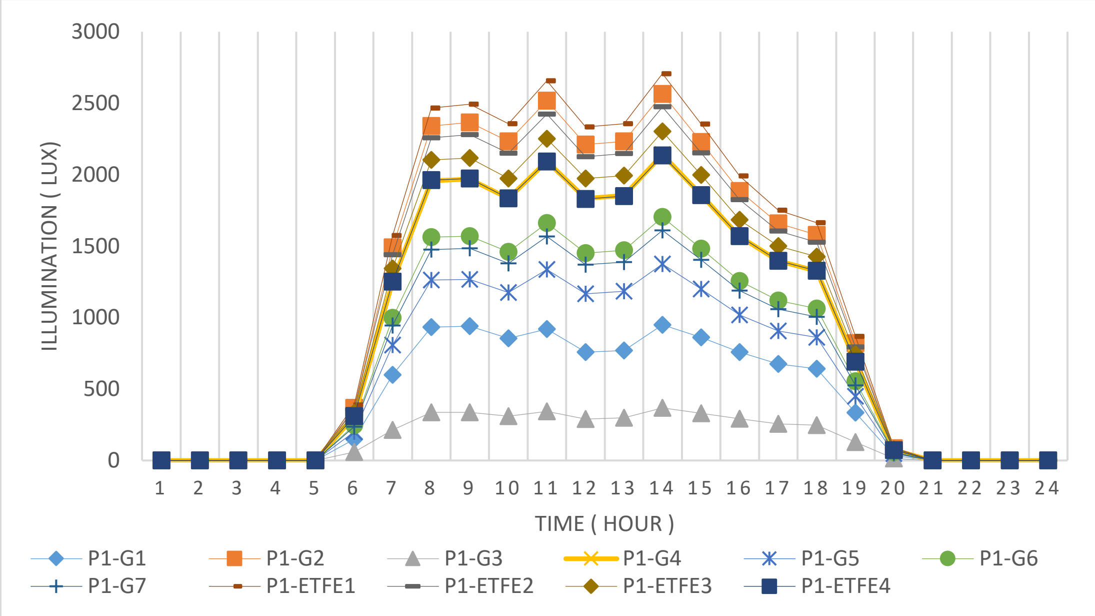


Figure 62: 21 June – Indoor P1 Illumination

As seen in (Figure 65), the illumination values start increasing at 05.00, reach to their maximum amounts at 14.00, and drop down to minimum at 21.00. The illumination values are 2707 Lux, 2565 Lux, 2474 Lux, 2302 Lux, 2141 Lux, 2134 Lux, 1703 Lux, 1610 Lux, 1375 Lux, 949 Lux and 368 Lux, for ETFE1, G2, ETFE2, ETFE3, G4, ETFE4, G6, G7, G5, G1 and G3 respectively while the Illumination for P1 at 14:00. Looking at the P1 point for June 21, the G3 glass system yields better results. Since P1 point is closer to the façade, its values are very high. All the remaining glass and ETFE inflatable systems require sunshade systems and are far from the comfort of daylight.

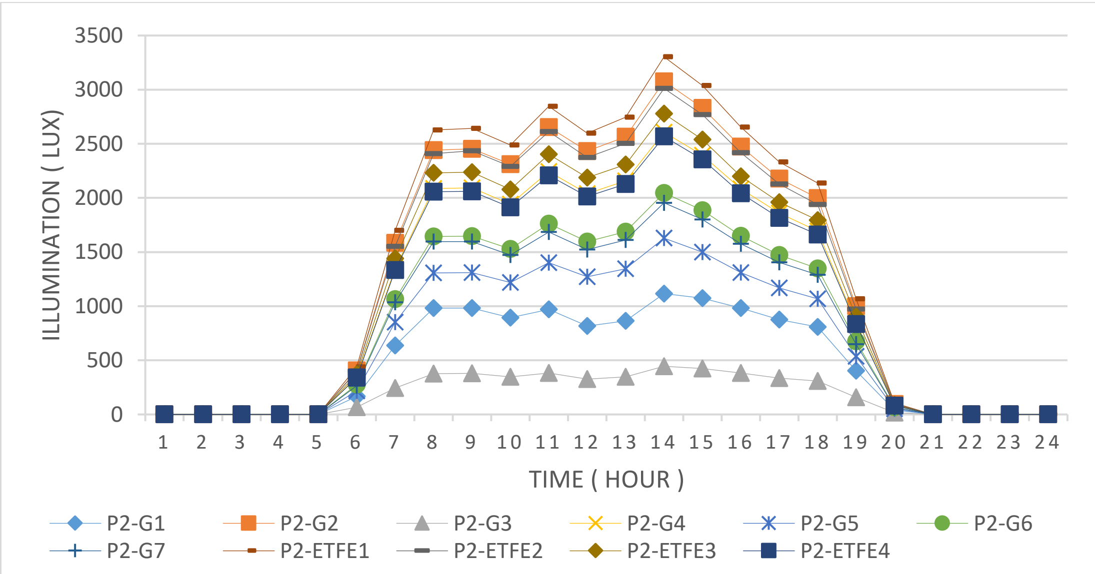


Figure 63: 21 June – Indoor P2 Illumination

As seen in (Figure 66), the illumination values start increasing at 05.00, reach to their maximum amounts at 14.00, and drop down to minimum at 21.00. The illumination values are 3303 Lux, 3077 Lux, 3011 Lux, 2777 Lux, 2607 Lux, 2567 Lux, 2046 Lux, 1955 Lux, 1628 Lux, 1116 Lux and 445 Lux, for ETFE1, G2, ETFE2, ETFE3, G4, ETFE4, G6, G7, G5, G1 and G3 respectively while the Illumination for P2 at 14:00. Looking at the P2 point for June 21, the G3 glass system gives better results. Since the point P2 is closer to the façade, its values are very high. All the remaining glass and ETFE inflatable systems require sunshade systems and are far from the comfort of daylight.

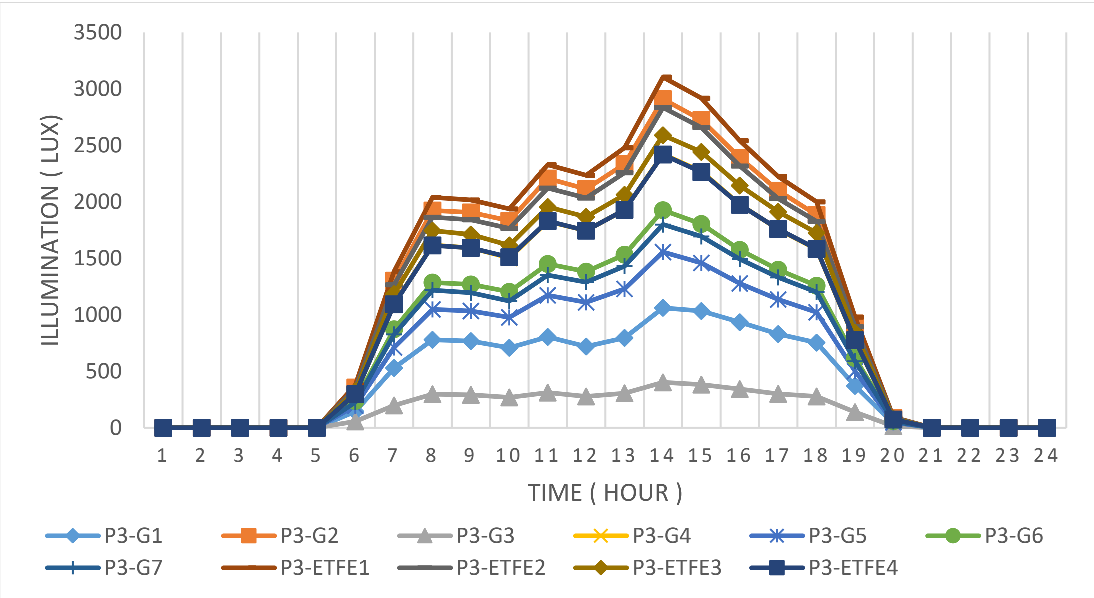


Figure 64: 21 June – Indoor P3 Illumination

As seen in (Figure *67*), the illumination values start increasing at 05.00, reach to their maximum amounts at 14.00, and drop down to minimum at 21.00. The illumination values are 3104 Lux, 2910 Lux, 2835 Lux, 2590 Lux, 2422 Lux, 2418 Lux, 1926 Lux, 1800 Lux, 1556 Lux, 1061 Lux and 402 Lux, for ETFE1, G2, ETFE2, ETFE3, G4, ETFE4, G6, G7, G5, G1 and G3 respectively while the Illumination for P3 at 14:00. Looking at the P3 point for June 21, the G3 glass system yields better results. Since the P3 point is closer to the façade, its values are very high. All the remaining glass and ETFE inflatable systems require sunshade systems and are far from the comfort of daylight.

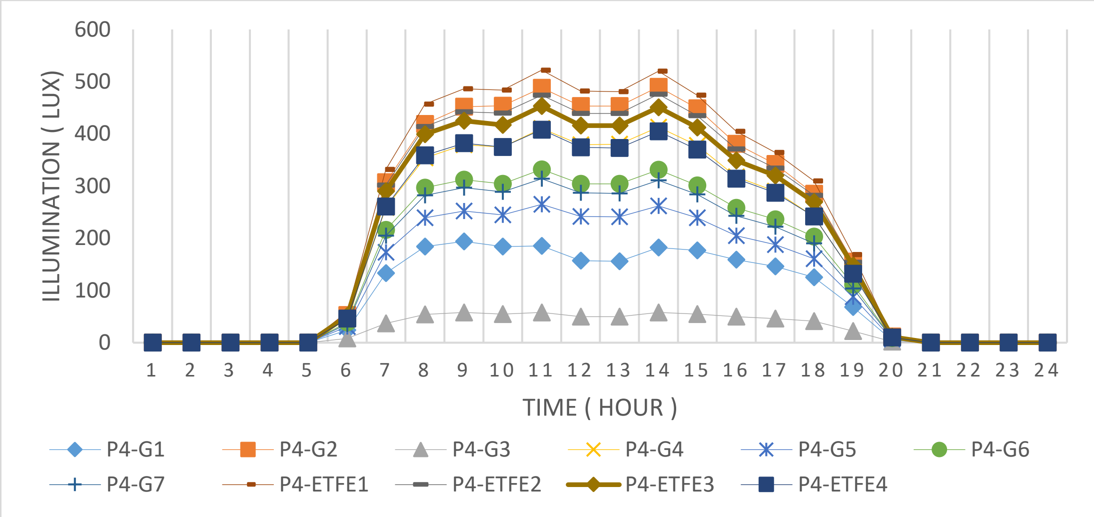


Figure 65: 21 June – Indoor P4 Illumination

As seen in (Figure *68*), the illumination values start increasing at 05.00, reach to their maximum amounts at 14.00, and drop down to minimum at 21.00. The illumination values are 520 Lux, 490 Lux, 476 Lux, 451 Lux, 413 Lux, 405 Lux, 331 Lux, 311 Lux, 262 Lux, 182 Lux and 58 Lux, for ETFE1, G2, ETFE2, ETFE3, G4, ETFE4, G6, G7, G5, G1 and G3 respectively while the Illumination for P4 at 14:00. Looking at the P4 point for June, the G5 glass system yields better results. Since P4 point is farther away from the façade, its values are very low. Very close to G7 and G6 glass systems are also available point G1 and G3 glass except all the remaining glass and ETFE inflatable systems need shading systems and far away from the comfort of daylight. Artificial lighting is required for G1 and G3 glass systems.

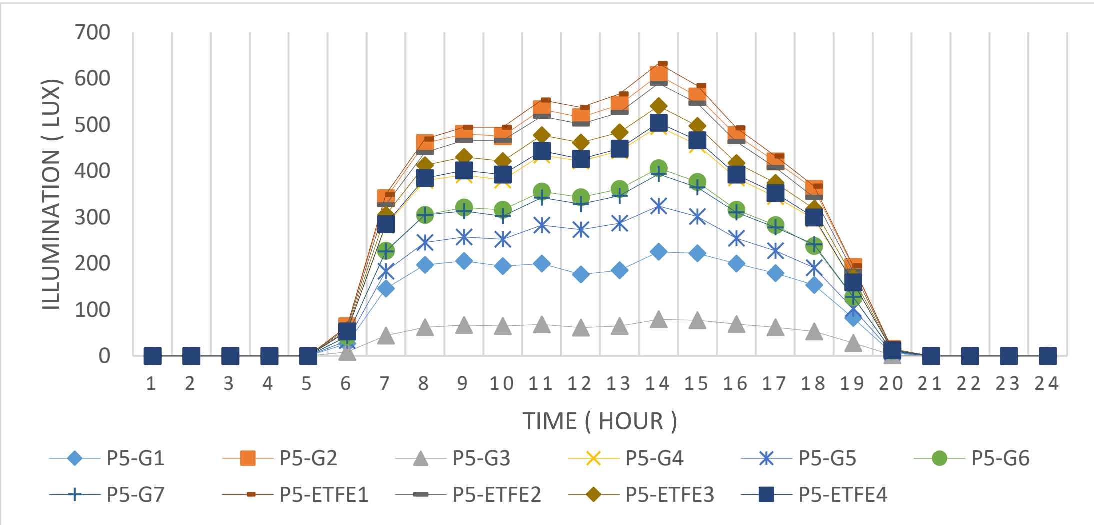


Figure 66: 21 June – Indoor P5 Illumination

As seen in (Figure *69*), the illumination values start increasing at 05.00, reach to their maximum amounts at 14.00, and drop down to minimum at 21.00. The illumination values are 632 Lux, 607 Lux, 589 Lux, 540 Lux, 504 Lux, 496 Lux, 406 Lux, 393 Lux, 324 Lux, 225 Lux and 79 Lux, for ETFE1, G2, ETFE2, ETFE3, ETFE4, G4, G6, G7, G5, G1 and G3 respectively while the Illumination for P5 at 14:00. Looking at the P5 point for June, the G5 glass system yields better results. Since P5 point is farther away from the façade, its values are very low. Very close to G7 and G6 glass systems are also available point G1 and G3 glass except all the remaining glass and ETFE inflatable systems need shading systems and far away from the comfort of daylight. Artificial lighting is required for G1 and G3 glass systems.

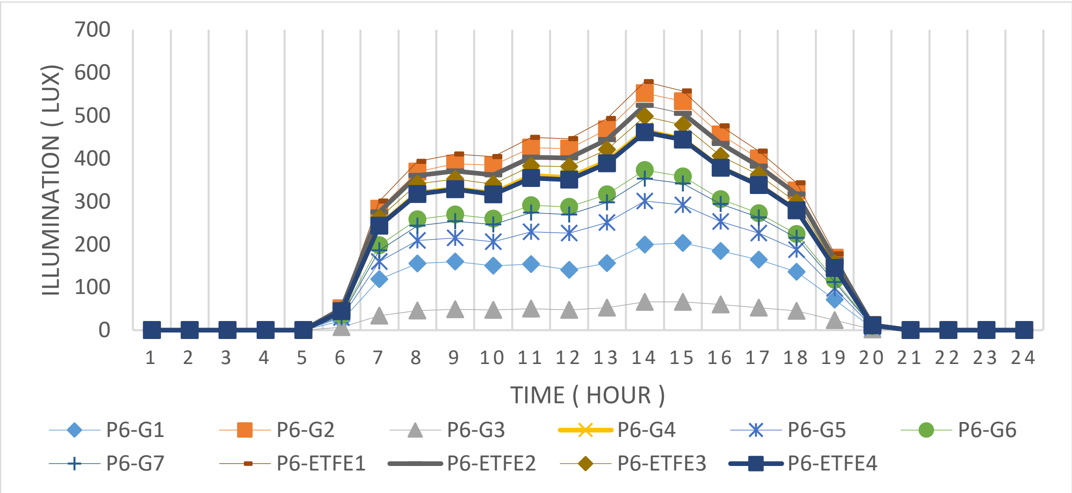


Figure 67: 21 June – Indoor P6 Illumination

As seen in (Figure 70), the illumination values start increasing at 05.00, reach to their maximum amounts at 14.00, and drop down to minimum at 21.00. The illumination values are 579 Lux, 552 Lux, 524 Lux, 498 Lux, 465 Lux, 373 Lux, 353 Lux, 301 Lux, 199 Lux and 66 Lux, for ETFE1, G2, ETFE2, ETFE3, ETFE4, G4, G6, G7, G5, G1 and G3 respectively while the Illumination for P6 at 14:00. Looking at the P6 point for June 21, the G5 glass system yields better results. Since P6 point is further away from the façade, its values are very low. Very close to G7 and G6 glass systems are also available point G1 and G3 glass except all the remaining glass and ETFE inflatable systems need shading systems and far away from the comfort of daylight. Artificial lighting is required for G1 and G3 glass systems.

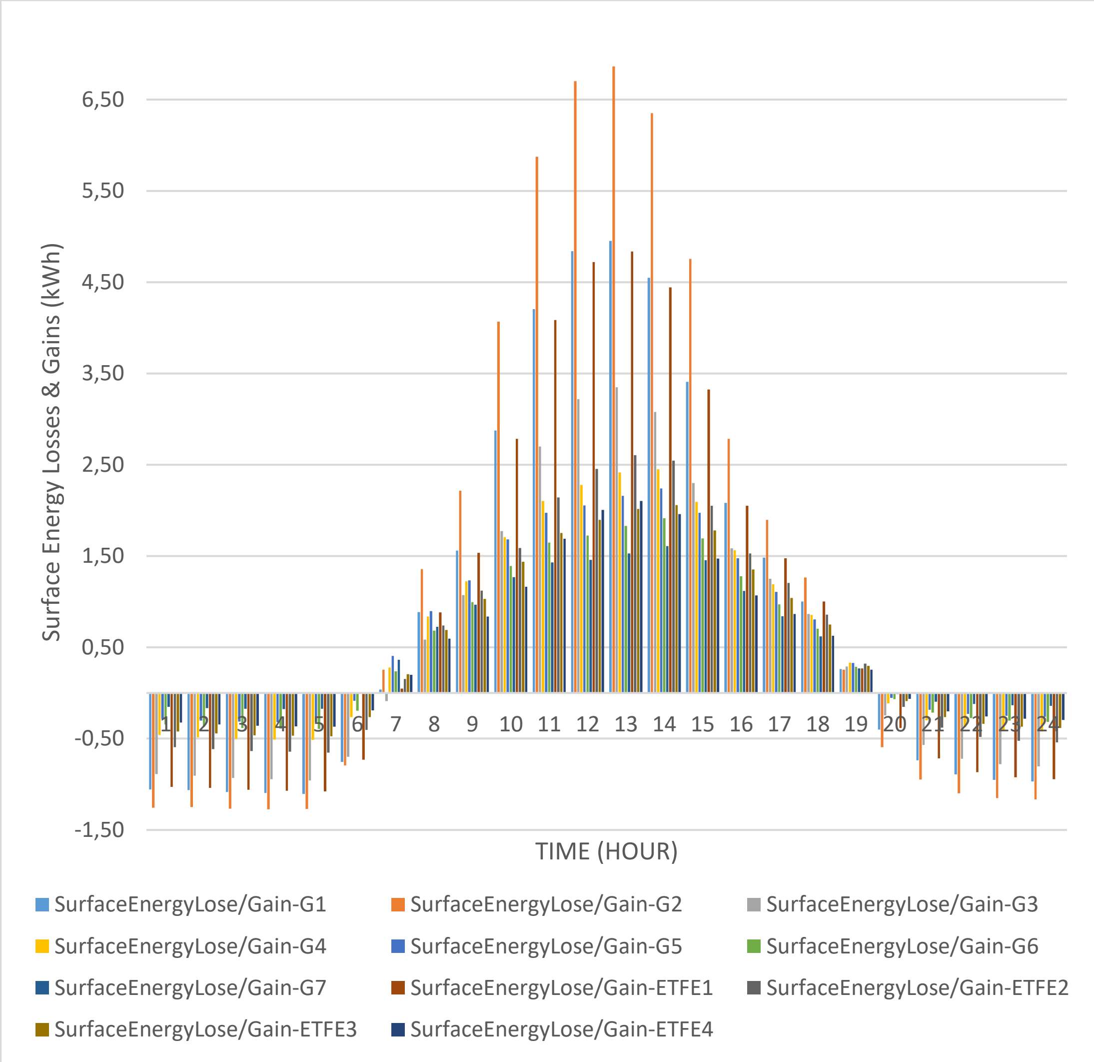


Figure 68: 21 June - Surface Energy Losses&Gains

As seen in (Figure 71), the results were taken as 24 hours for 21 June and evaluated. The interior of the materials in question from 24:00 to 07:00 in the morning environment is losing heat. The reason for this is that the interior temperature value is higher than the outdoor temperature because the volume is heated by solar energy throughout the day. The heat transfer takes place from the high temperature to the low temperature. For this reason, the heat loss occurred from 24:00 to 07:00 in the morning from the interior to the outside. Similarly and depending on the same conditions, heat loss from inside to outside was observed from 19:00 to 24:00. The heat transfer from 07:00 to 19:00 in the morning is carried out from the outside to the interior. When the surface heat losses and gains of the materials are examined, the material which has the most loss at night and whic has the most heat gain during the day appears as G2 glass, followed by G1 glass and ETFE1 cushion system respectively. Considering the İzmir climate and summer months, it stops at a negative point due to the fact that the material heats up more quickly and provides passage. When the outdoor temperatures and indoor temperatures of the summer months are revealed, this can be interpreted as negative. Considering that the summer of Izmir is hot and long, it is not considered appropriate to use materials with high energy gains according to these results. Many energy losses and uptake in the course of the day create a heat bridge for the structure and this is not a positive situation. When these two reasons are taken into consideration, less energy loss and less materials are more suitable for summer months in İzmir. For this reason, G7cam system gives better performance during cooling months. The G6 glass system is followed by the ETFE4 and ETFE5 swelling systems.

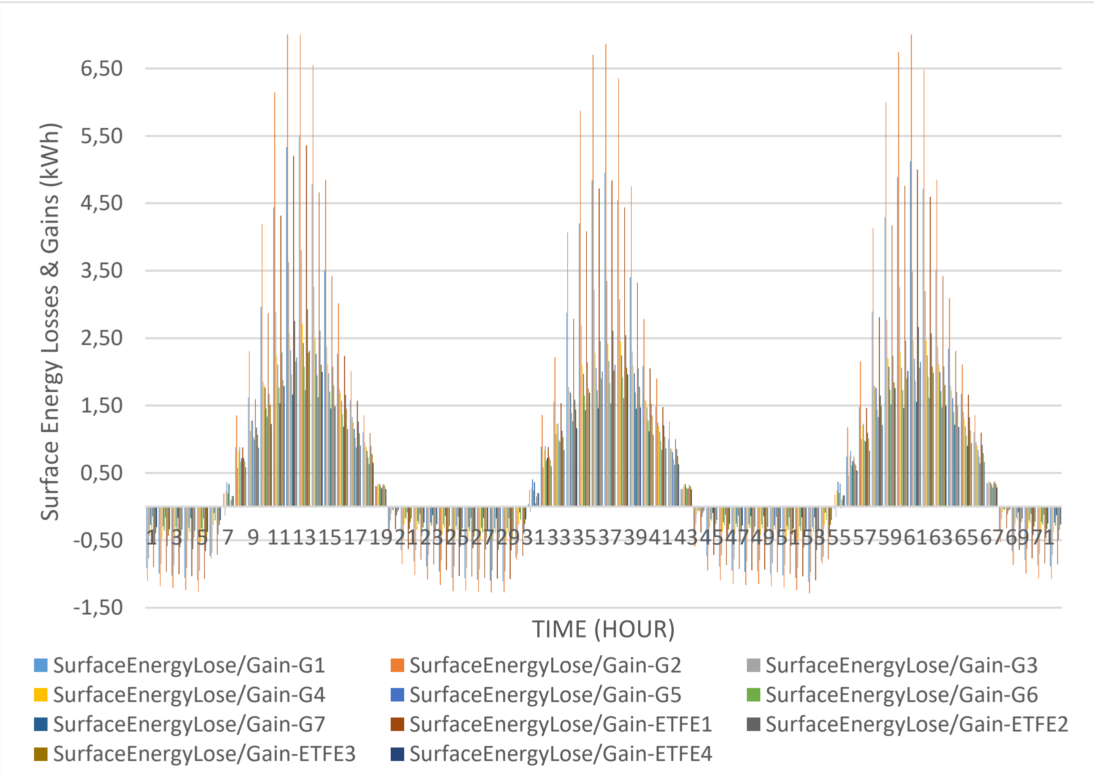


Figure 69: 20-22 June - Surface Energy Losses&Gains

As seen in (Figure 72), the results are taken as 24 hours for June 20, June 21 and June 22 and are evaluated. The monitoring and accuracy of the 21st June were checked. As can be seen from the night of 24:00 in the morning until 07:00 in the indoor environment is losing heat. Similarly and depending on the same conditions, heat loss from inside to outside was observed from 19:00 to 24:00. The heat transfer from 07:00 to 19:00 in the morning is carried out from the outside to the interior. In this context, the possible heat gain and fuel graph of the materials during the cooling months will be as in the figure.

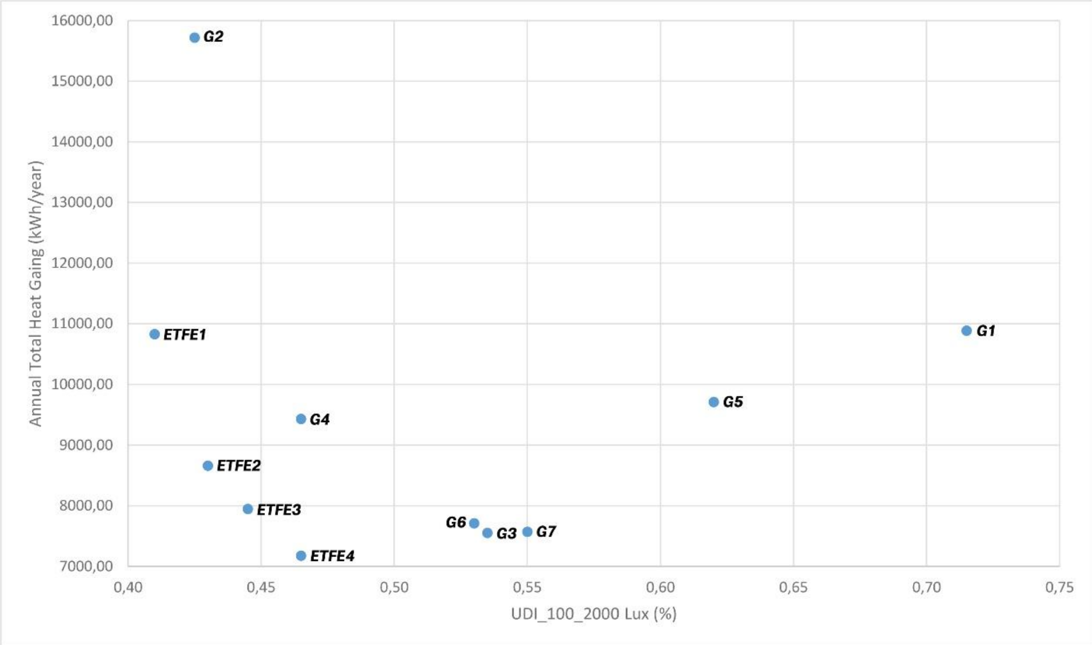


Figure 70: Annual Total Heat Gains and UDI Values for Each Material

As seen in (Figure 73), G1 has an annual total heat gain of 10886.40 kWh/year and 72% UDI interior space of the selected volume. G2 has an energy use of 15717,44 kWh/year and 43% UDI interior space of the selected volume. G3 has an energy use of 7548,76 kWh/year and 54% UDI interior space of the selected volume. G4 has an energy use of 9429,17 kWh/year and 47% UDI interior space of the selected volume. ETFE2 cushions systems has an energy use of 8627,57 kWh/year and 43% UDI interior space of the selected volume. G5 has an energy use of 7708,2 3kWh/year and 62% UDI interior space of the selected volume. G6 has an energy use of 9707,83 kWh/year and 53% UDI interior space of the selected volume. G7 has an energy use of 7566,69 kWh/year and 55% UDI interior space of the selected volume. G5 has an energy use of 9707,83 kWh/year and 62% UDI interior space of the selected volume. ETFE1 cushions systems has an energy use of 10826,44 kWh/year and 41% UDI interior space of the selected volume. ETFE3 cushions systems has an energy use of 7945,23 kWh/year and 45% UDI interior space of the selected volume. ETFE4 cushions systems has an energy use of 7175,33 kWh/year and 47% UDI interior space of the selected volume. This means that highest amount of daylight is transmitted in to the volume. The heat gain for this sample is second highest with 10886.40 kWh/year. After sample G2 has an energy use of 15735.44 kWh/year and 43% UDI interior space of the selected volume. Even the heat gain of the selected sample is height the UDI value is the second lowest. G5 has an energy use of 9707.81 kWh/year and 62% UDI interior space of the selected volume. This is one of the optimal values but for ETFE1, ETFE2, ETFE3 and ETFE4 the UDI values between 100-2000Lux seem to be lower than the other samples. But UDI values over 2000 Lux are quite higher for ETFE samples (Figure 73). This means that UDI values between 100-2000 Lux for ETFE samples might be increased by using patterns over ETFE samples or transparency values of ETFE samples might be incrust thus the thermal and Illumination performances of the ETFE samples will be optimized.

When the graph (Figure 73) is analysed alone, it is seen that G1 and G2 glasses give good results and G5 is considered optimal. However, it is necessary to separate the model according to cooling and heating time rather than thinking for total heat gain. In addition, ETFE cushion systems are left behind in this graph because th of the higher permeability of daylight and therefore the percentage of 2000 Lux is above the remaining.

In terms of regional and climate features of İzmir considered, it is not recommended to use materials with a high total annual heat gain in terms of long cooling periods and hot summers. The G7, G3, G6, ETFE4 and ETFE3 systems provide a better thermal result, but they do not perform better in terms of UDI values. Properties Due to better daylight transmittance values for ETFE swelling systems, UDI values cannot be collected between 100 and 2000 Lux.

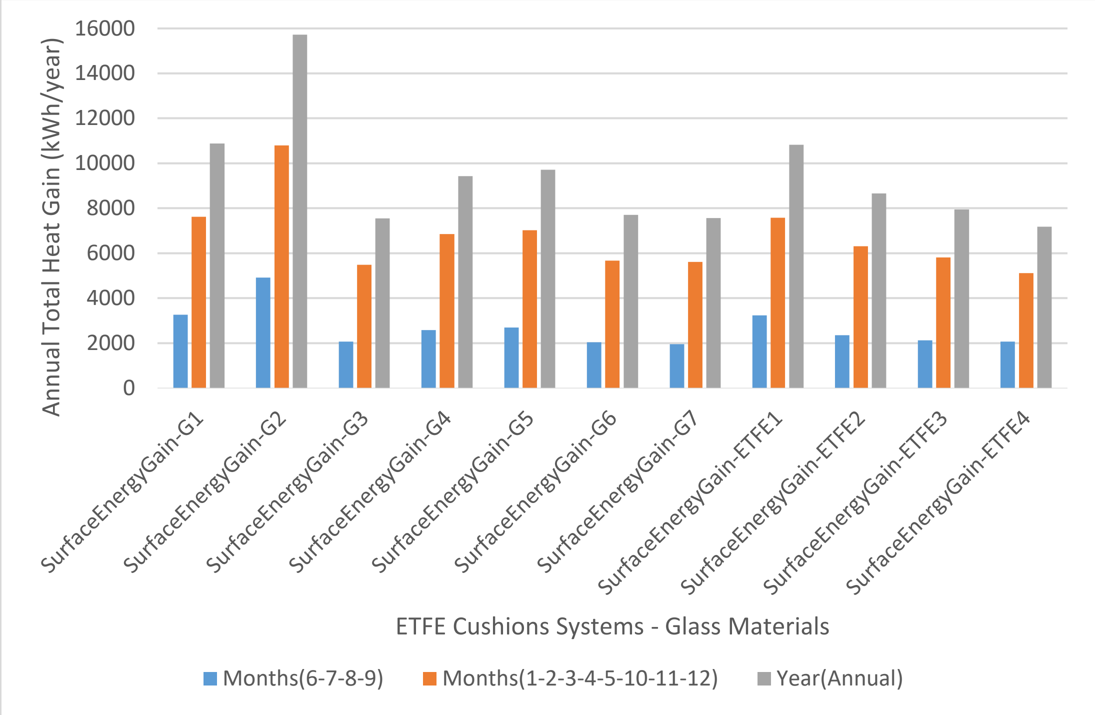


Figure 71:Annual Total Heat Gains for each Material

In Figure (Figure 74), annual ETFE swelling systems and glass material cooling periods and total annual heat gains for heating periods are shown. Since the simulation was created for İzmir, the months of June (6), July (7), AUGUST (8) and September (9) were taken into consideration for the cooling months. The remaining January (1) was considered as February (2), March (3), April (4), May (5), October (10), November (11), range (12). The energy consumption for the G1 glass cooling period was 3270,89 kWh / year, for the heating period 7615,50 kWh / year, total 10886,39 kWh / year and gathered 72% UDI. The energy consumption for the G2 glass was 4922.61 kWh / year, for the cooling period 10794.83 kWh / year for the heating period, total 15717.44 kWh / year and gathered 43% UDI. The energy consumption for the G3 glass was for the cooling period 2069,42 kWh/year, for the heating period7615,50 kWh/year, total 7548,76 kWh/year and gathered 54% UDI. The energy consumption for the G4 glass was for the cooling period 2581,40 kWh/year, for the heating period6547,77 kWh/year, total 9429,17 kWh/year and gathered 47% UDI. The energy consumption for the G5 glass was for the cooling period 2691,15 kWh/year, for the heating period 7016,68 kWh/year, total 9707,83 kWh/year and gathered 62% UDI. The energy consumption for the G6 glass was for the cooling period 2044,65 kWh/year, for the heating period 5663,58 kWh/year, total 7708,23 kWh/year and gathered 53% UDI. The energy consumption for the G7 glass was for the cooling period 1948,13 kWh/year, for the heating period 5618,56 kWh/year, total 7566,69 kWh/year and gathered 55% UDI.

The energy consumption for the ETFE1 inflatable system was cooling period 3241.79 kWh / year, for the heating period 7584.65 kWh/year, total 10826.44 kWh / year and gathered 41% UDI. The energy consumption for the ETFE2 inflatable system was cooling period 2348,09 kWh / year, for the heating period 6309,18 kWh/year, total 8657,27 kWh / year and gathered 43% UDI. The energy consumption for the ETFE3 inflatable system was cooling period 2128,57 kWh / year, for the heating period 5816,66 kWh/year, total 7945,23 kWh / year and gathered 45% UDI. The energy consumption for the ETFE4 inflatable system was cooling period 2063,25 kWh / year, for the heating period 5112,08 kWh/year, total 7175,33 kWh / year and gathered 47% UDI. The chart is referred to by the number of months in the year. The lowest values for cooling loads were found in G3, G6, G7, ETFE2, ETFE3 and ETFE4 materials. In terms of heating loads, G2, G1 and ETFE1 perform high performance however, they are far out of thermal comfort in terms of cooling loads. It is not recommended to use G1, G2 glasses and ETFE1 system by looking at daylight and thermal results. The performances of G3, G4, G5 and ETFE2 are in good condition and are close to each other. G6, G7 ETFE3 and ETFE4 (which can be incorporated into ETFE2) show close heating and cooling values. Therefore these materials can be recommended for usage. ETFE2, ETFE3 and ETFE4 can be improved by adding patterns to them, changing their colour and darkness levels, as well as their luminosity which will lead to thermal comfort. As a result, ETFE2, ETFE3, ETFE4 systems can be recommended as they provide the most design flexibility.

As shown in (Figure 74), outputs of the glass and ETFE swelling systems UDI are seen. ETFE inflatable systems were better exposed to daylight transmission values than glass. It is more than 2000 lux and more than desired. This negativity can be solved by its own design differences.

According to the function of the structure to be applied in terms of indoor light intensity and thermal comfort values are taken as a criterion and according to this scenario can be designed at the design stage for ETFE systems. Therefore, it is recommended to use ETFE with special designs and orders according to daylight usage and energy requirements of buildings.

Materials	UDI_Less_100 (%)	UDI_100_2000 (%)	UDI_More_2000 (%)	Annual Total Heat Gaing (kWh/year)
G1	0.03	0.715	0.25	10886,39
G2	0.01	0.425	0.56	15717,44
G3	0.35	0.535	0.1	7548,76
G4	0.01	0.465	0.52	9429,17
G5	0.03	0.62	0.35	9707,83
G6	0.03	0.53	0.44	7708,23
G7	0.02	0.55	0.42	7566,69
ETFE1	0.01	0.41	0.57	10826,44
ETFE2	0.01	0.43	0.55	1422,10
ETFE3	0.01	0.445	0.54	7945,23
ETFE4	0.01	0.465	0.52	7175,33

Figure 72: UDI values and annual total heat gain for each material

As it is seen in the table above, when we look at the annual total heat gain and UDI results for the İzmir climate, we see the most optimal results. The ETFE 4 swelling system and the G7 glass system provide the best results in terms of annual total heat gain. In addition, UDI results do not shade.

8.2. Results for Erzurum Region

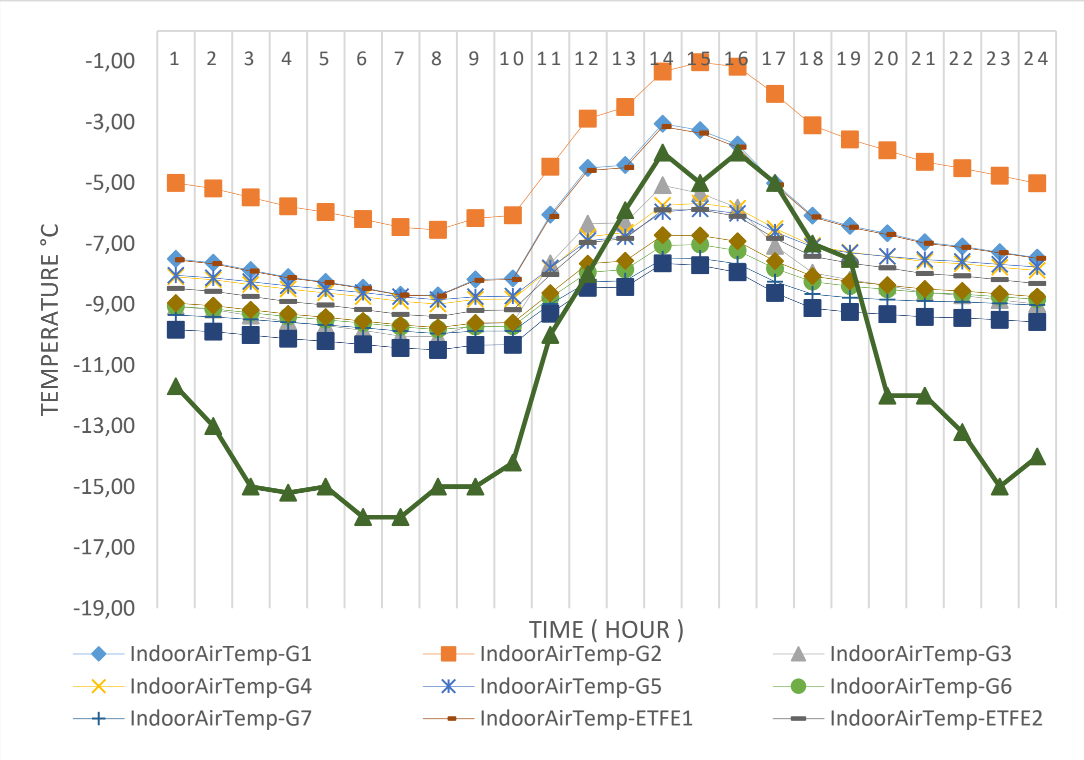


Figure 73: 17 January – Indoor Air Temperature

As seen in (Figure 76), the indoor air temperatures are on January 17th, -5,01 ^{0}C; -7,50^{0}C; -7,53 ^{0}C; -8,04 ^{0}C; -8,09 ^{0}C; -8,47 ^{0}C; -8,83 ^{0}C; -8,93 ^{0}C; -9,07 ^{0}C; -9,07 ^{0}C and -9,34 ^{0}C for G2, G1, ETFE1, G5, G4, ETFE2, ETFE4, ETFE3, G3, G6 and G7 respectively while the outdoor air temperature is -11,7 ^{0}C at 01:00. They drop down to -6,55 ^{0}C; -8,71 ^{0}C; -8,72 ^{0}C; -8,83 ^{0}C; -8,84 ^{0}C; -8,99 ^{0}C; -9,40 ^{0}C; -9,76 ^{0}C; -9,96 ^{0}C;-10,06^{0}C and -10,49 ^{0}C at 08:00 for G2, G1, ETFE1, G6, G5, G4, ETFE2, ETFE3, G7, G3 and ETFE4 respectively while the outdoor air temperature is -15 ^{0}C at 08:00. The indoor air temperatures start to increase up to -1,03 ^{0}C; -3,27 ^{0}C; -3,36 ^{0}C; -5,34 ^{0}C; -5,64 ^{0}C; -5,84 ^{0}C; -5,88 ^{0}C; -6,73 ^{0}C; -7,03 ^{0}C; -7,49 ^{0}C and -7,71 ^{0}C for G2, G1, ETFE1, G3, G4, G5, ETFE2, ETFE3, G6, G7 and ETFE4 at 13.00 respectively while the outdoor air temperature is -5 ^{0}C at 13:00. The indoor air temperature drop down to -3,57 ^{0}C; -6,42 ^{0}C; -6,48 ^{0}C; -7,28 ^{0}C; -7,30 ^{0}C; -7,64 ^{0}C; -8,19 ^{0}C; -8,24 ^{0}C; -8,40 ^{0}C; -8,78 ^{0}C and -9,25 ^{0}C for G2, G1, ETFE1, G4, G5, ETFE2, G3, ETFE3, G6, G7, and ETFE4 at 19:00. When looking at the indoor temperature graphs, G2, G1 and ETFE 1 are the closest to the indoor comfort temperature. In addition, the G3 glass performs poorly in the evening when daylight is lost, but its performance becomes better from

9:00 to 20:00. When interpreted with the values of these materials, it is more appropriate to use these three materials in winter. Considering the room comfort temperature, these materials will require less heating load.

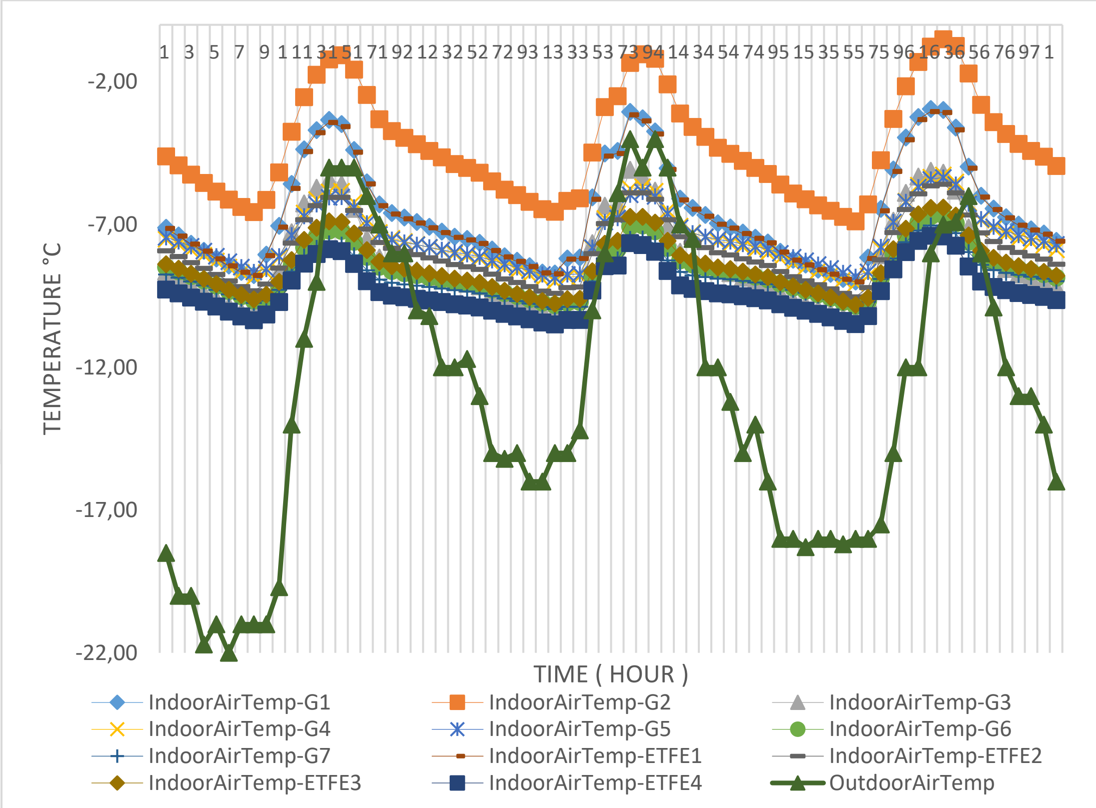


Figure 74: 16-18 January – Indoor Air Temperature

The hourly indoor air temperature variations for 16-18 January is seen in (Figure43). Simulation evaluation that have made in (Figure 77) January 17th can also be made for days January 18th and January 19th. For winter period, G2 has the highest indoor air temperature values but the hourly indoor air temperature variations throughout the whole day are so high; that's why it is not thermally comfortable enough. G1 and ETFE1 have similar behaviour and provide thermally more comfortable indoor environment. The difference between the pick points for the indoor air temperature throughout the whole day is supposed to be minimum if there is no additional mechanical heating system but as the indoor air temperature of the selected glass and ETFE cushion samples do not provide thermally comfortable indoor environment by themselves, additional mechanical mechanic heating system should be used. Thus G2, G1 and ETFE1 might be used recommended to be used with additional mechanical heating system for less energy consumption.

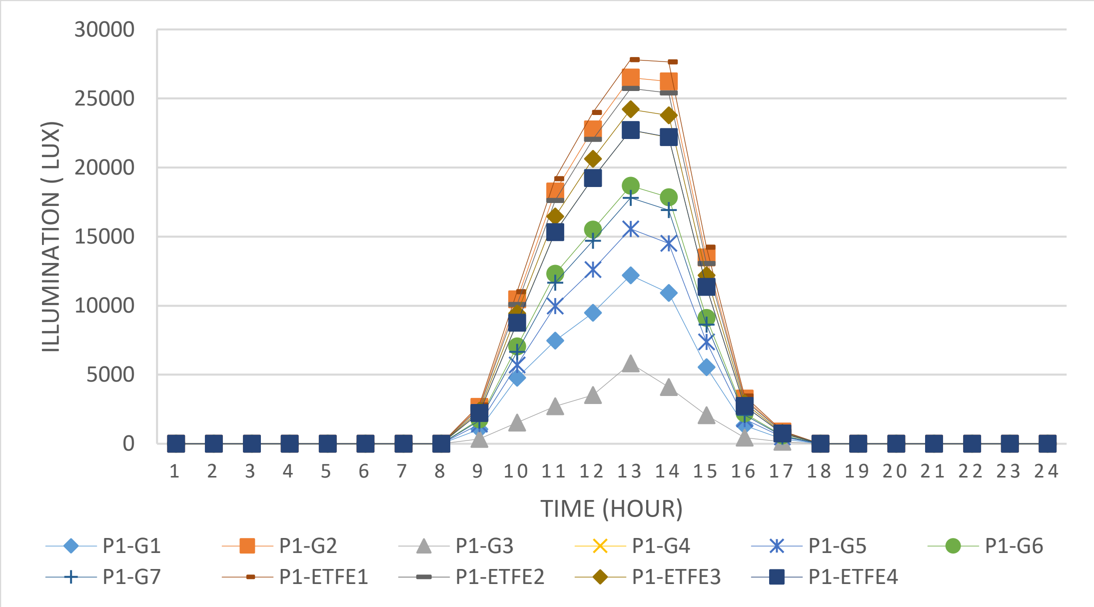


Figure 75: 17 January – Indoor P1 Illumination

As seen in (Figure 78), the illumination values start increasing at 08.00, reach to their maximum amounts at 13.00, and drop down to minimum at 18.00. The illumination values are 27818 Lux, 26504 Lux, 25728 Lux, 24208 Lux, 22713 Lux, 22707 Lux, 18674 Lux, 17809 Lux, 15559 Lux, 12200 Lux and 5814 Lux for ETFE1, G2, ETFE2, ETFE3, G4, ETFE4, G6, G7, G5, G1 and G3 respectively while the Illumination for P1 at 13:00. Looking at the P1 point for January 17, the G3 glass system yields better results. Since P1 point is closer to the façade, its values are very high. All the remaining glass and ETFE inflatable systems require shading systems and are far from the comfort of daylight.

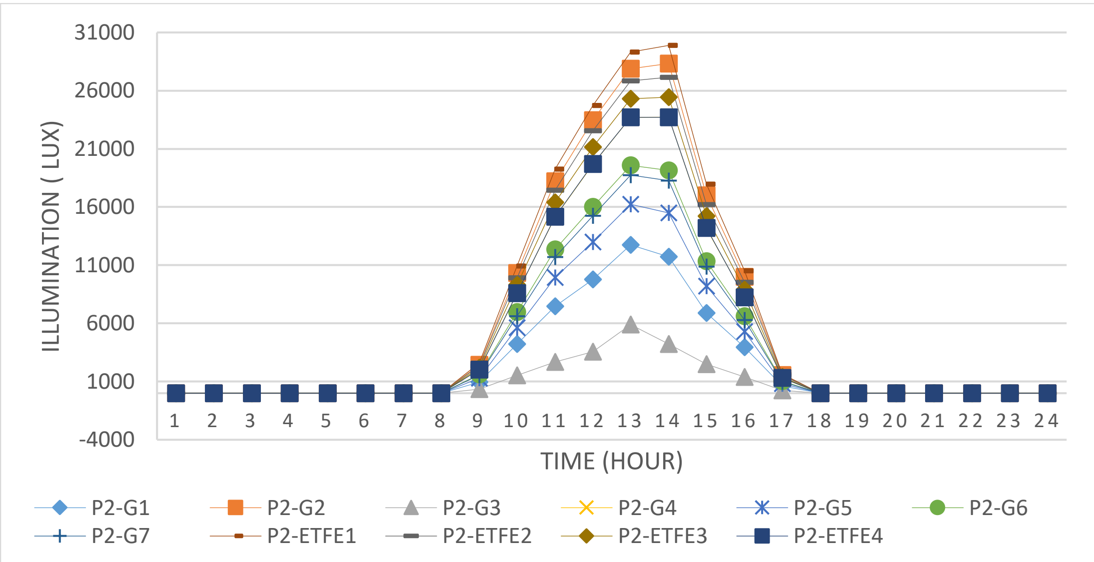


Figure 76: 17 January – Indoor P2 Illumination

As seen in (Figure 79), the illumination values start increasing at 08.00, reach to their maximum amounts at 13.00, and drop down to minimum at 18.00. The illumination values are 29308 Lux, 27889 Lux, 26852 Lux, 25293 Lux, 23701 Lux, 23698 Lux, 19579 Lux, 18744 Lux, 16236 Lux, 12745 Lux and 5894 Lux for ETFE1, G2, ETFE2, ETFE3, G4, ETFE4, G6, G7, G5, G1 and G3 respectively while the Illumination for P2 at 13:00. Looking at the P2 point for January 17, the G3 glass system gives better results. Since the point P2 is closer to the façade, its values are very high. All the remaining glass and ETFE inflatable systems require shading systems and are far from the comfort of daylight.

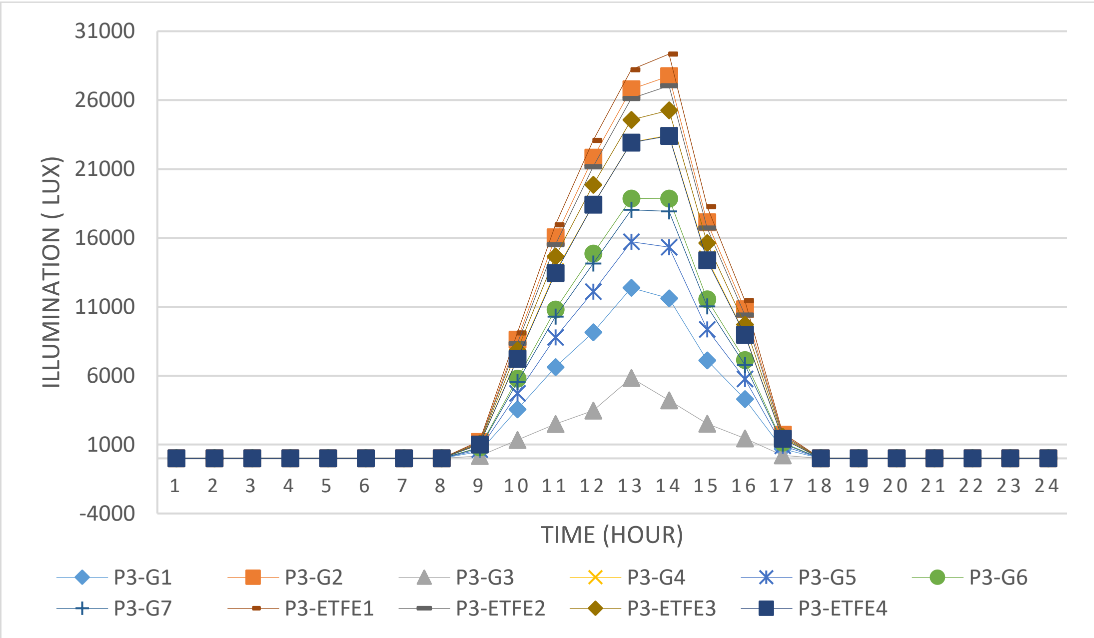


Figure 77: 17 January – Indoor P3 Illumination

As seen in (Figure 80), the illumination values start increasing at 08.00, reach to their maximum amounts at 13.00, and drop down to minimum at 18.00. The illumination values are 28219 Lux, 26789 Lux, 26114 Lux, 24556 Lux, 22935 Lux, 22912 Lux, 18862 Lux, 18037 Lux, 15720 Lux, 12377 Lux and 5839 Lux for ETFE1, G2, ETFE2, ETFE3, G4, ETFE4, G6, G7, G5, G1 and G3 respectively while the Illumination for P3 at 13:00. Looking at the P3 point for January 17, the G3 glass system yields better results. Since the P3 point is closer to the façade, its values are very high. All the remaining glass and ETFE inflatable systems require shading systems and are far from the comfort of daylight.

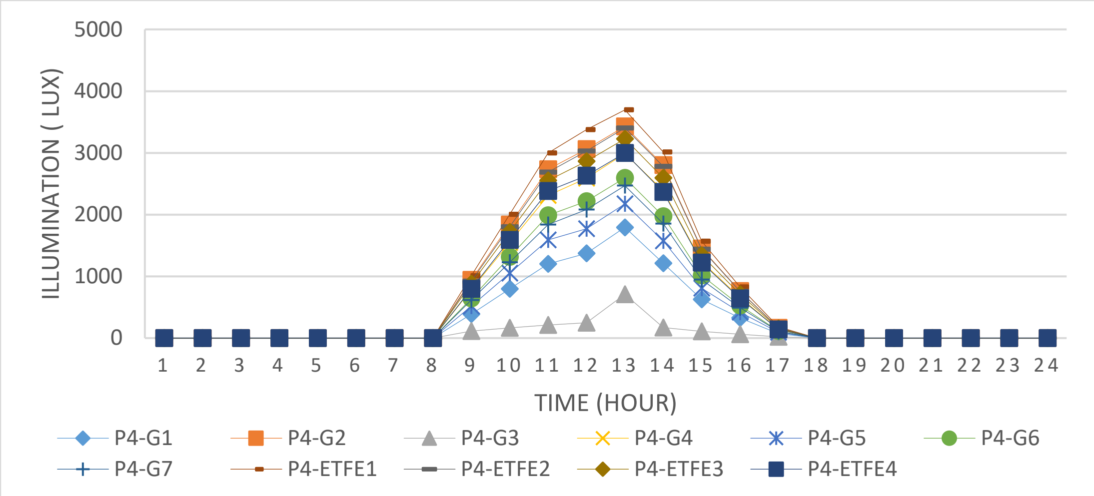


Figure 78: 17 January – Indoor P4 Illumination

As seen in (Figure 81), the illumination values start increasing at 08.00, reach to their maximum amounts at 12.00, and drop down to minimum at 18.00. The illumination values are 3696 Lux, 3429 Lux, 3404 Lux, 3228 Lux, 2998 Lux, 2990 Lux, 2595 Lux, 2468 Lux, 2174 Lux, 1794 Lux and 709 Lux, for ETFE1, G2, ETFE2, ETFE3, ETFE4, G4, G6, G7, G5, G1 and G3 respectively while the Illumination for P4 at 12:00. Looking at the P4 point for the hob G3 and G1 glass system gives better results. However, it can be said that the values do not receive direct sunlight. Since the point P4 is farther away from the façade, its values decrease and remain in a more controllable range. In addition, the G3 glass system values are in poor illumination range, so artificial lighting is required. All remaining glass and ETFE inflatable systems require shading systems and do not have the comfort of daylight.

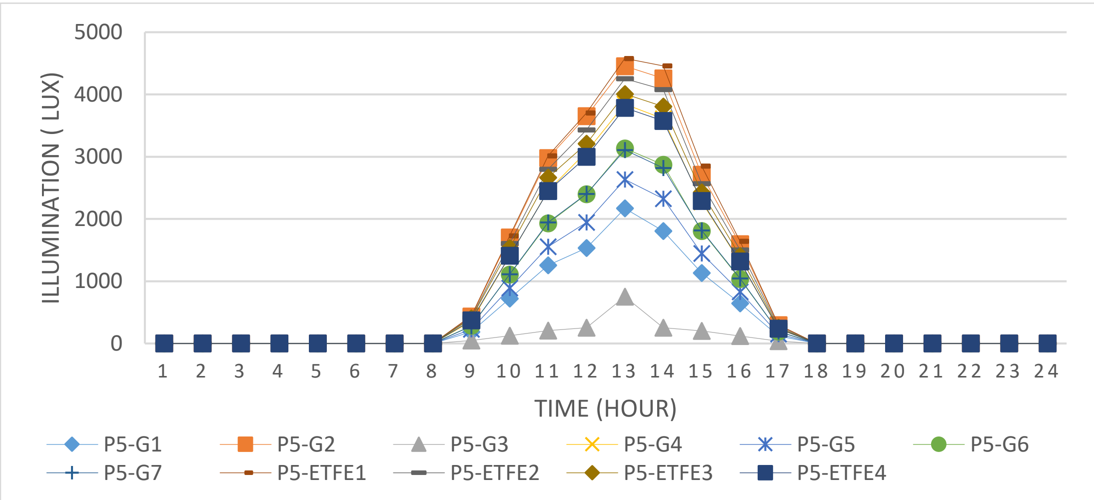


Figure 79: 17 January – Indoor P5 Illumination

As seen in (Figure 82), the illumination values start increasing at 08.00, reach to their maximum amounts at 12.00, and drop down to minimum at 18.00. The illumination values are 4579 Lux, 4455 Lux, 4253 Lux, 4008 Lux, 3786 Lux, 3845 Lux, 3134 Lux, 3109 Lux, 2634 Lux, 2634 Lux, 2169 Lux and 752 Lux, for ETFE1, G2, ETFE2, ETFE3, G4, ETFE4, G6, G7, G5, G1 and G3 respectively while the Illumination for P5 at 13:00. Looking at the P5 point for June 21, the G5 glass system gives better results. Since P5 point is farther away from the façade, its values are very low. Very close to G7 and G6 glass systems are also available point G1 and G3 glass except all the remaining glass and ETFE inflatable systems need shading systems and far away from the comfort of daylight. Artificial lighting is required for G1 and G3 glass systems.

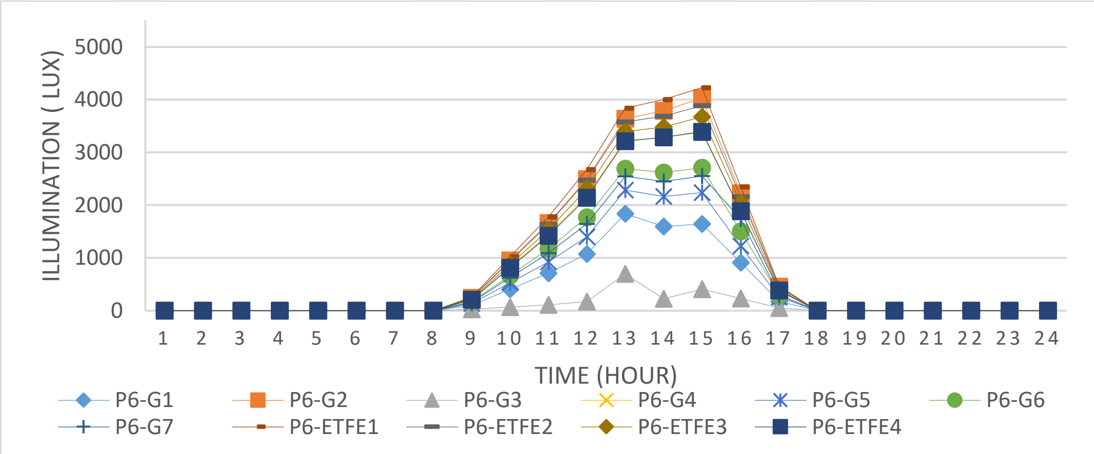


Figure 80: 17 January - Indoor P6 Illumination

As seen in (Figure 83), the illumination values start increasing at 08.00, reach to their maximum amounts at 12.00, and drop down to minimum at 18.00. The illumination values are 3840 Lux, 3640 Lux, 3582 Lux, 3396 Lux, 3214 Lux, 3228 Lux, 2694 Lux, 2548 Lux, 2286 Lux, 1837 Lux and 968 Lux for ETFE1, G2, ETFE2, ETFE3, G4, ETFE4, G6, G7, G5, G1 and G3 respectively while the Illumination for P6 at 13:00. Looking at the P6 point for January 17, the G3 and G1 glass system yields better results. However, it can be said that the values do not receive direct sunlight. Since the point P6 is farther away from the façade, its value decreases and stands in a more controllable range. In addition, the G3 glass system values are within the range of insufficient illumination therefore makes the lighting necessary. All remaining glass and ETFE inflatable systems require shading systems and do not have the comfort of daylight.

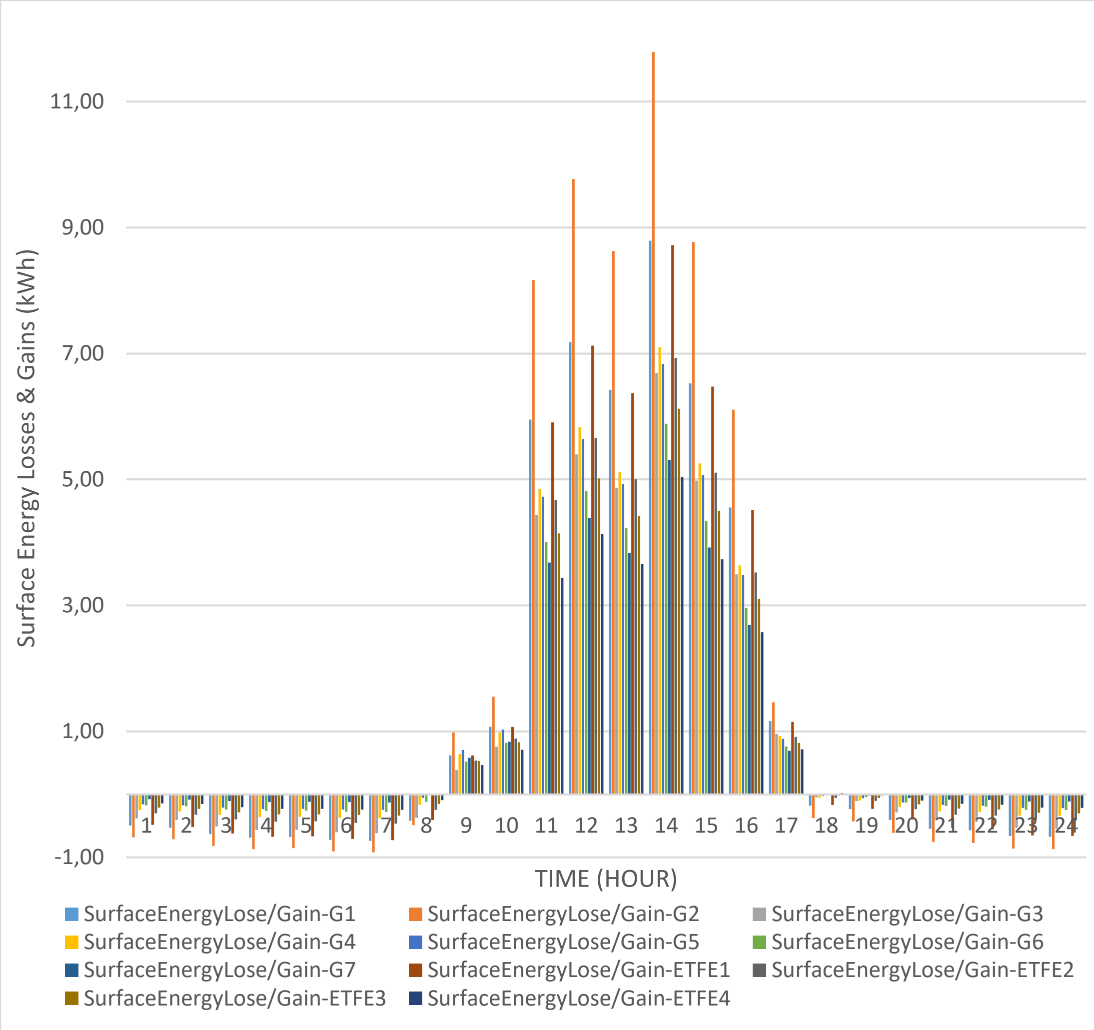


Figure 81: 17 January - Surface Energy Losses&Gains

As seen in (Figure 84), As can be seen, the results were taken as 24 hours for the date of 17 January and evaluated. The interior of the materials in question from the night 24:00 to 9:00 in the morning environment is losing heat. The reason for this is that the interior temperature value is higher than the outdoor temperature because the volume is heated by solar energy throughout the day. The heat transfer takes place from the high temperature to the low temperature. For this reason, the heat loss occurred from 24:00 to 09:00 in the morning from the interior to the outside. Similarly and depending on the same conditions, heat loss from inside to outside was observed from 18:00 to 24:00. From 9:00 am to 6:00 pm, the heat transfer takes place from the outside to the inside. When the surface heat losses and gains of the materials are examined, the material which is the most lost at night and the most heat gain during the day appears as G2 glass, followed by G1 glass and ETFE1 swelling system. Considering the İzmir climate and the winter months, it stands at a positive point due to the fact that the material heats up faster and provides the transition. This can be interpreted as positive when we show the outdoor temperatures and indoor temperatures of the winter months. Considering the harsh winter of İzmir, it is considered more appropriate to use materials with high energy gains according to these results. During the day, so much energy loss and uptake constitutes a heat bridge for the structure, which is not a positive situation.

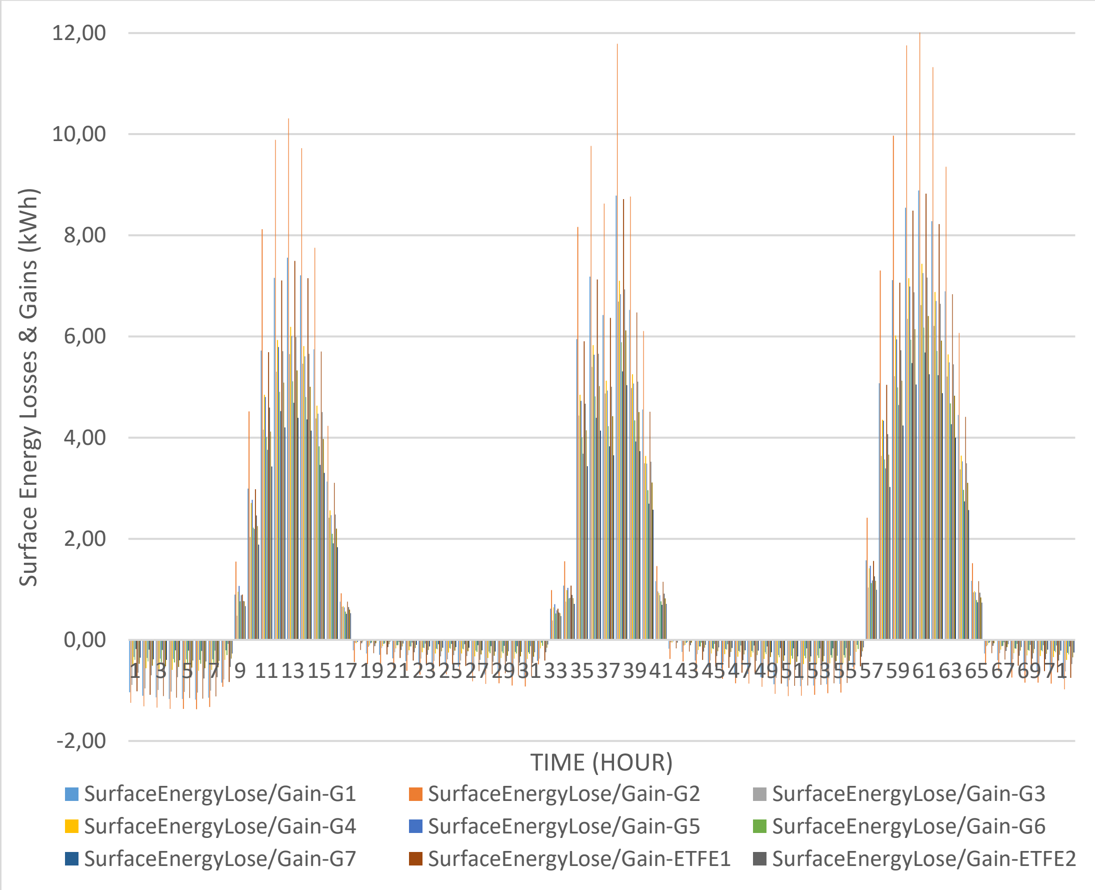


Figure 82: 17-19 January - Surface Energy Losses&Gains

As seen in (Figure 85), the results were taken as 24 hours for January 17, January 18 and January 19 and evaluated. The observation and correctness of the stability on 17 January was checked. As you can see, the materials in question lose the heat in the interior from 24:00 until 09:00 in the morning. Similarly and depending on the same conditions, heat loss from inside to outside was observed from 18:00 to 24:00. From 9:00 am to 6:00 pm, the heat transfer is from the outside to the interior. In this context, the possible heat gain and burning of the materials during the heating months will be as shown in the figure. The stability of the materials and the same reactions of the materials during the heating months for İzmir and the surface energy loss-gains are proceeding in the same logic.

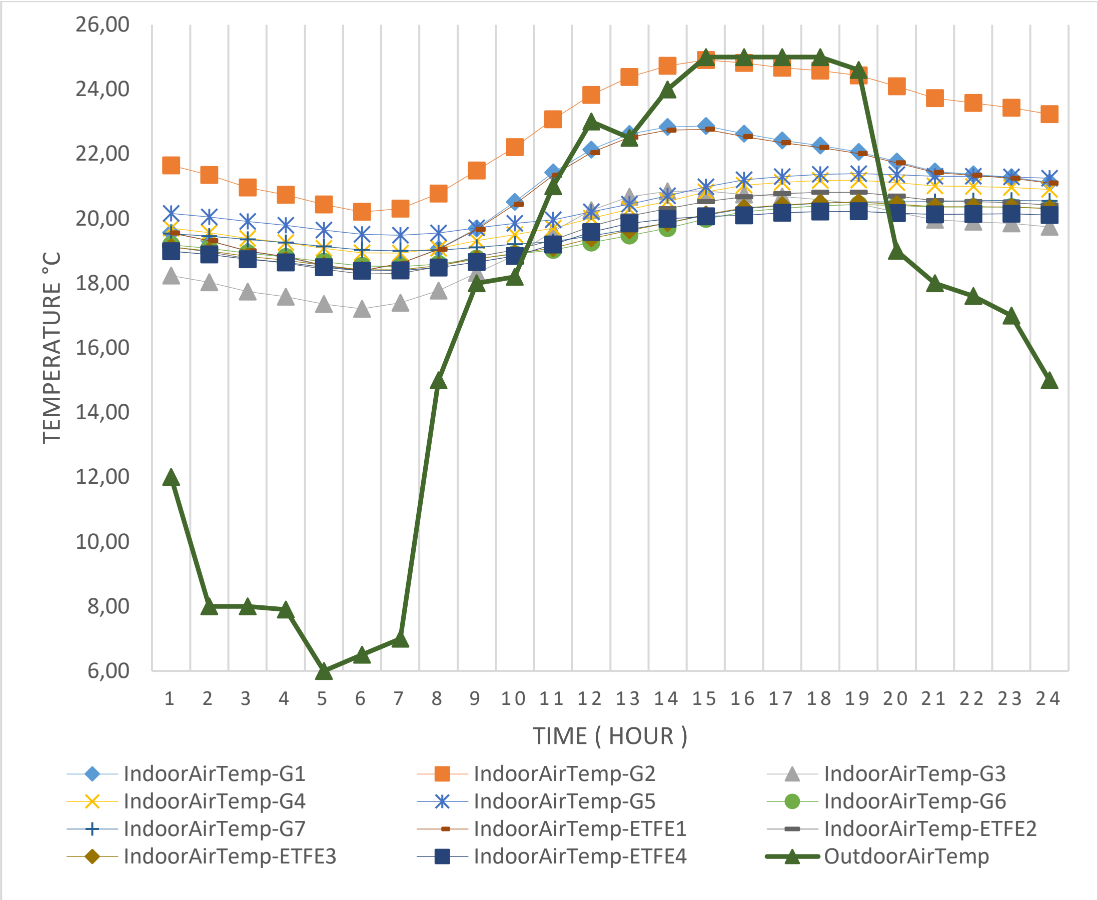


Figure 83: 21 June – Indoor Air Temperature

As seen in (Figure 86), the indoor air temperatures are on June 21th, 21,64 ^{0}C; 20,16 ^{0}C; 19,74 ^{0}C; 19,56 ^{0}C; 19,56 ^{0}C; 19,53 ^{0}C; 19,18 ^{0}C; 19,13 ^{0}C; 19,12 ^{0}C; 18,99 ^{0}C; and 18,24 ^{0}C for G2, G5, G4, G1, ETFE1, G7, G6, ETFE2, ETFE3, ETFE4 and G3 respectively while the outdoor air temperature is 12 ^{0}C at 01:00. They drop down to 20,31 ^{0}C; 19,51 ^{0}C; 19,03 ^{0}C; 18,94 ^{0}C; 18,54 ^{0}C; 18,42 ^{0}C; 18,39 ^{0}C; 18,38 ^{0}C; 18,37 ^{0}C; 18,29 ^{0}C and 17,21 ^{0}C at 06:00 for G2, G5, G7, G4, G6, ETFE3, ETFE1, ETFE4, G1, ETFE2 and G3 respectively while the outdoor air temperature is 6,5 ^{0}C at 06:00. The indoor air temperatures start to increase up to 24,91 ^{0}C; 22,87 ^{0}C; 22,76 ^{0}C; 20,98 ^{0}C; 20,86 ^{0}C; 20,82 ^{0}C; 20,52 ^{0}C; 20,13 ^{0}C; 20,11 ^{0}C; 20,07 ^{0}C and 19,99 ^{0}C for G2, G1, ETFE1, G5, G3, G4, ETFE2, ETFE3, G7, ETFE4 and G6 at 15.00 respectively while the outdoor air temperature is 25^{0}C at 15:00. The indoor air temperature drop down to 23,72 ^{0}C; 21,46 ^{0}C; 21,43 ^{0}C; 21,31 ^{0}C; 21,01 ^{0}C; 20,56 ^{0}C; 20,53 ^{0}C; 20,37 ^{0}C; 20,13 ^{0}C and 19,96 ^{0}C; for G2, G1, ETFE1, G5, G4, ETFE2, G7, ETFE3, G6, ETFE4 and G3 at 21.00 respectively while the outdoor air temperature is 18 ^{0}C at 21:00. When looking at the indoor temperature graphs, G3, G4, ETFE 2 and ETFE 3 are the closest to the indoor comfort temperature. It is more convenient to use these three materials in the summer when interpreted with the values of these materials. Considering room comfort temperature, these materials will require less cooling load.

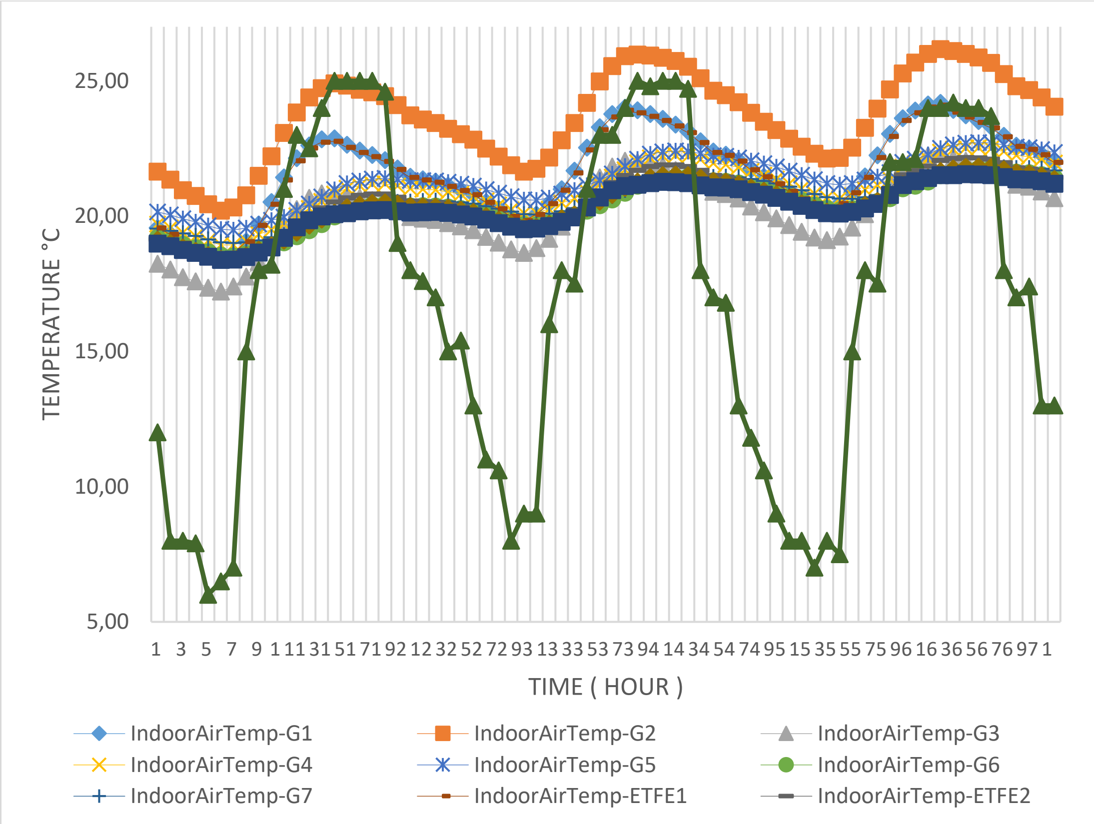


Figure 84: 20-22 June – Indoor Air Temperature

The hourly indoor air temperature variations for 20-22 June is seen in (Figure 87). Simulation evaluation that have made in (Figure 87) June 21th can also be made for days June 20th and June 22th. For summer period, G2 has the highest indoor air temperature values but the hourly indoor air temperature variations throughout the whole day are so high; that's why it is not thermally comfortable enough. G6, G7, ETFE3 and ETFE4 have similar behaviour and provide thermally more comfortable indoor environment. The difference between the pick points for the indoor air temperature throughout the whole day is supposed to be minimum if there is no additional mechanical cooling system but as the indoor air temperature of the selected glass and ETFE cushion samples do not provide thermally comfortable indoor environment by themselves, additional mechanical mechanic cooling system should be used. Thus G6, G7, ETFE3 and ETFE4 might be used recommended to be used with additional mechanical heating system for less energy consumption.

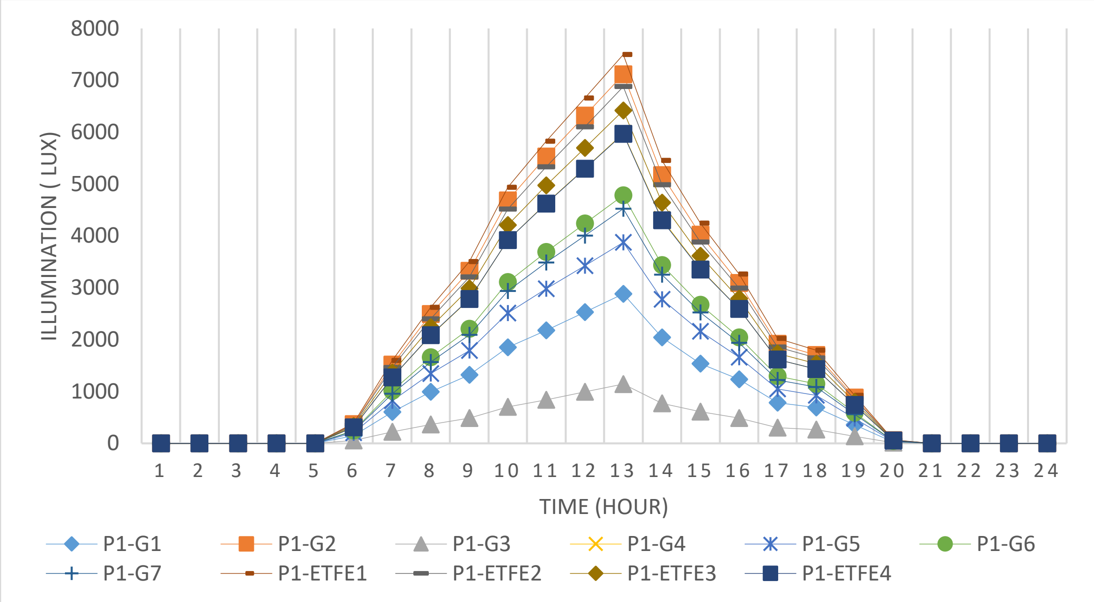


Figure 85: 21 June – Indoor P1 Illumination

As seen in (Figure 88), the illumination values start increasing at 05.00, reach to their maximum amounts at 13.00, and drop down to minimum at 21.00. The illumination values are 7496 Lux, 7114 Lux, 6878 Lux, 6419 Lux, 5977 Lux, 5966 Lux, 4783 Lux, 4724 Lux, 3875 Lux, 2883 Lux and 1144 Lux, for ETFE1, G2, ETFE2, ETFE3, G4, ETFE4, G6, G7, G5, G1 and G3 respectively while the Illumination for P1 at 13:00. Looking at the P1 point for June 21, the G3 glass system yields better results. Since P1 point is closer to the façade, its values are very high. All the remaining glass and ETFE inflatable systems require shading systems and are far from the comfort of daylight.

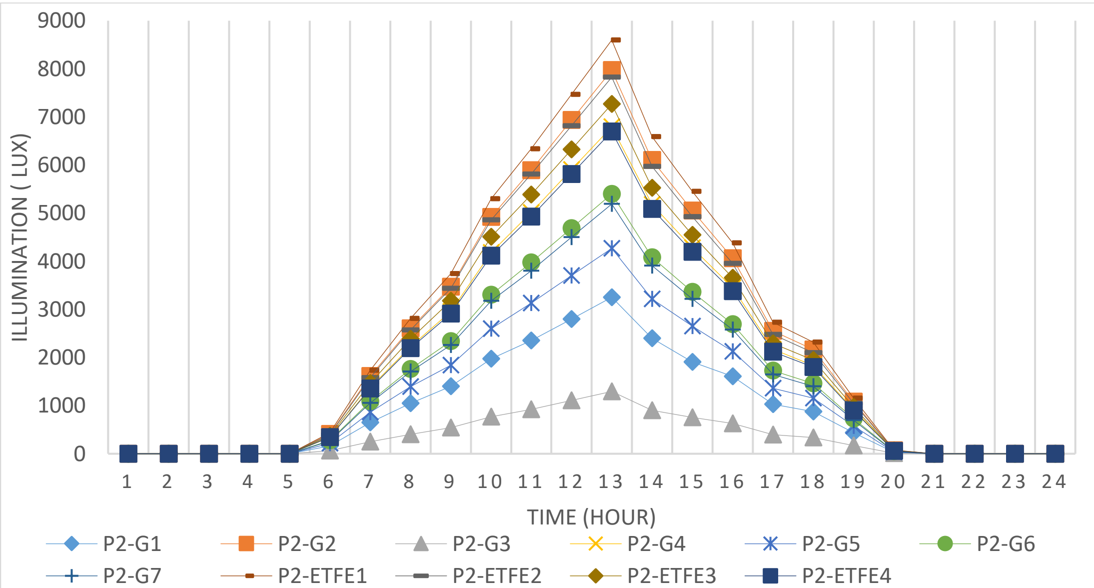


Figure 86: 21 June – Indoor P2 Illumination

As seen in (Figure 89), the illumination values start increasing at 05.00, reach to their maximum amounts at 13.00, and drop down to minimum at 21.00. The illumination values are 8598 Lux, 7971 Lux, 7826 Lux, 7268 Lux, 6793 Lux, 6697 Lux, 5400 Lux, 5190 Lux, 4269 Lux, 3253 Lux and 1295 Lux, for ETFE1, G2, ETFE2, ETFE3, G4, ETFE4, G6, G7, G5, G1 and G3 respectively while the Illumination for P2 at 13:00. Looking at the P2 point for June 21, the G3 glass system gives better results. Since the point P2 is closer to the façade, its values are very high. All the remaining glass and ETFE inflatable systems require shading systems and are far from the comfort of daylight.

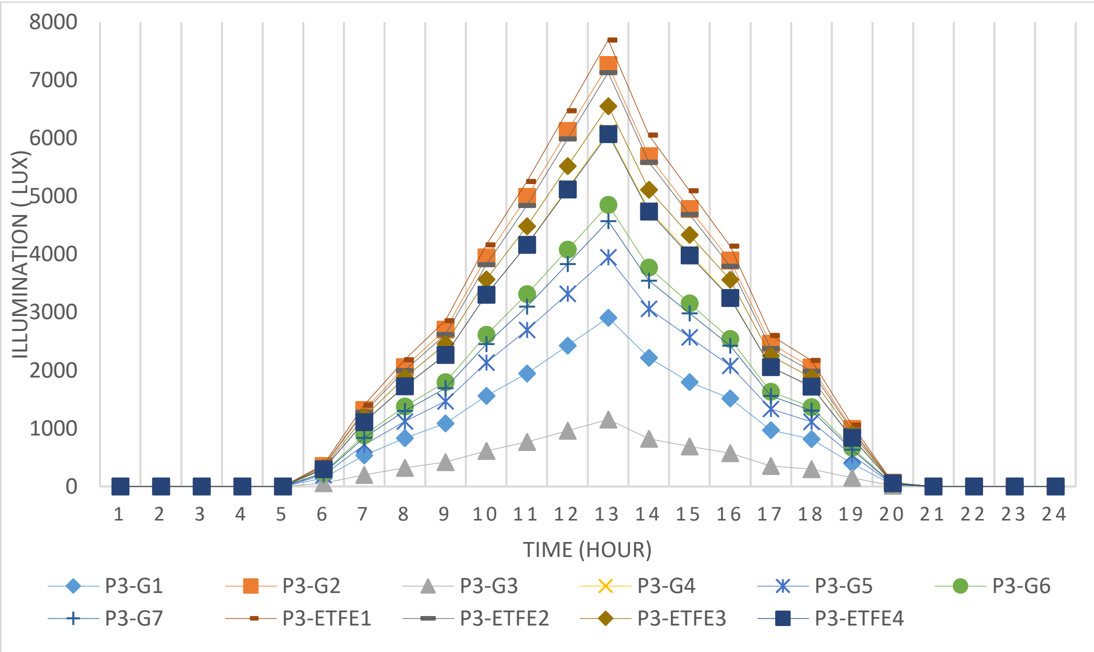


Figure 87: 21 June – Indoor P3 Illumination

As seen in (Figure 90), the illumination values start increasing at 05.00, reach to their maximum amounts at 13.00, and drop down to minimum at 21.00. The illumination values are 7692 Lux, 7260 Lux, 7131 Lux, 6552 Lux, 6107 Lux, 6073 Lux, 4851 Lux, 4572 Lux, 3950 Lux, 2908 Lux and 1155 Lux, for ETFE1, G2, ETFE2, ETFE3, G4, ETFE4, G6, G7, G5, G1 and G3 respectively while the Illumination for P3 at 13:00. Looking at the P3 point for June 21, the G3 glass system yields better results. Since the P3 point is closer to the façade, its values are very high. All the remaining glass and ETFE inflatable systems require sunshade systems and are far from the comfort of daylight.

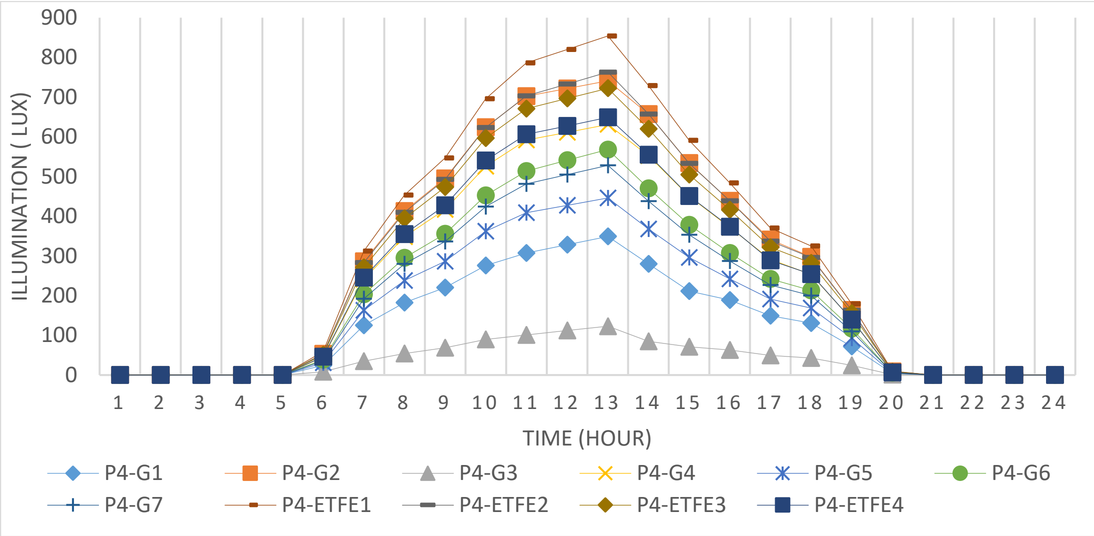


Figure 88: 21 June – Indoor P4 Illumination

As seen in (Figure 91), the illumination values start increasing at 05.00, reach to their maximum amounts at 13.00, and drop down to minimum at 21.00. The illumination values are 854 Lux, 741 Lux, 763 Lux, 722 Lux, 649 Lux, 641 Lux, 568 Lux, 528 Lux, 446 Lux, 349 Lux and 123 Lux, for ETFE1, G2, ETFE2, ETFE3, G4, ETFE4, G6, G7, G5, G1 and G3 respectively while the Illumination for P4 at 13:00. Looking at the P4 point for June 21, the G1 glass system yields better results. Since P4 point is farther away from the façade, its values are very low. Very close to the G5 and G7 glass systems are available at the point where G5 and G3 glass except all the remaining glass and ETFE inflatable systems need sunshine systems and far away from the comfort of sunlight. Artificial lighting is required for G3 glass systems.

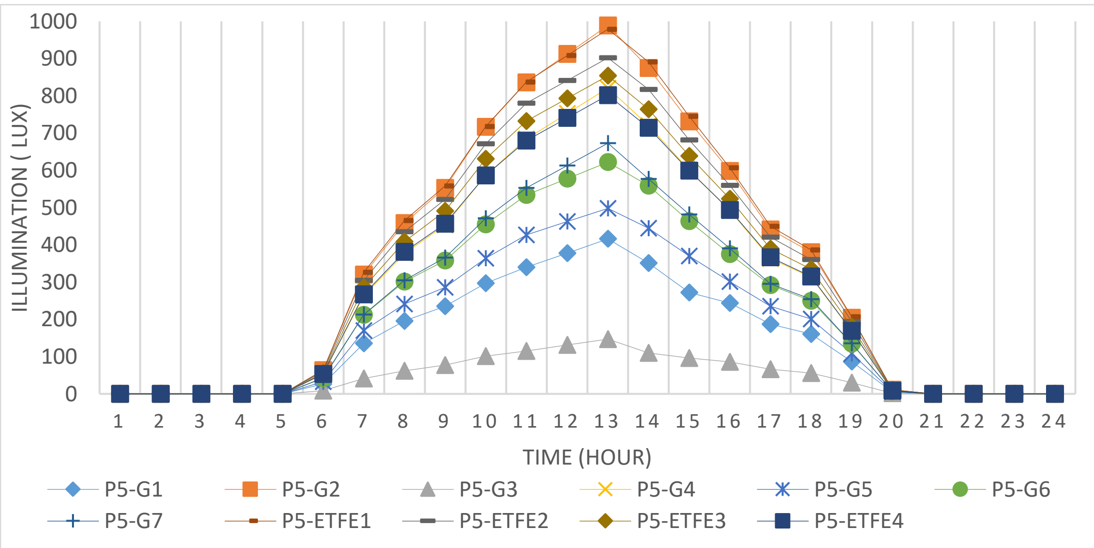


Figure 89: 21 June – Indoor P5 Illumination

As seen in (Figure 92), the illumination values start increasing at 05.00, reach to their maximum amounts at 13.00, and drop down to minimum at 21.00. The illumination values are 989 Lux, 979 Lux, 902 Lux, 854 Lux, 821 Lux, 802 Lux, 672 Lux, 620 Lux, 498 Lux, 416 Lux and 147 Lux, for ETFE1, G2, ETFE2, ETFE3, ETFE4, G4, G6, G7, G5, G1 and G3 respectively while the Illumination for P5 at 13:00. Looking at the P5 point for June 21, the G1 glass system yields better results. Since P5 point is farther away from the façade, its values are very low. Very close to the G5 and G7 glass systems are available at the point where G5 and G3 glass except all the remaining glass and ETFE inflatable systems need sunshine systems and far away from the comfort of sunlight. Artificial lighting is required for G3 glass systems.

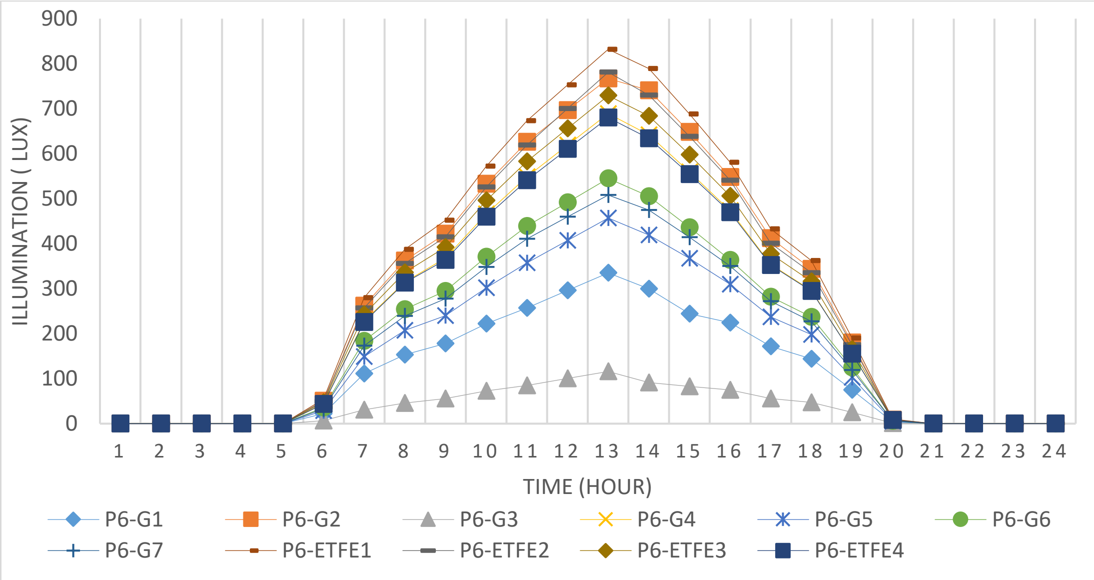


Figure 90: 21 June – Indoor P6 Illumination

As seen in (Figure 93), the illumination values start increasing at 05.00, reach to their maximum amounts at 13.00, and drop down to minimum at 21.00. The illumination values are 832 Lux, 767 Lux, 781 Lux, 729 Lux, 689 Lux, 680 Lux, 545 Lux, 508 Lux, 457 Lux, 335 Lux and 116 Lux, for ETFE1, G2, ETFE2, ETFE3, ETFE4, G4, G6, G7, G5, G1 and G3 respectively while the Illumination for P6 at 13:00. Looking at the P6 point for June, the G1 glass system yields better results. Since P6 point is further away from the façade, its values are very low. Very close to the G5 and G7 glass systems are available at the point where G5 and G3 glass except all the remaining glass and ETFE inflatable systems need shading systems and far away from the comfort of sunlight. Artificial lighting is required for G3 glass systems.

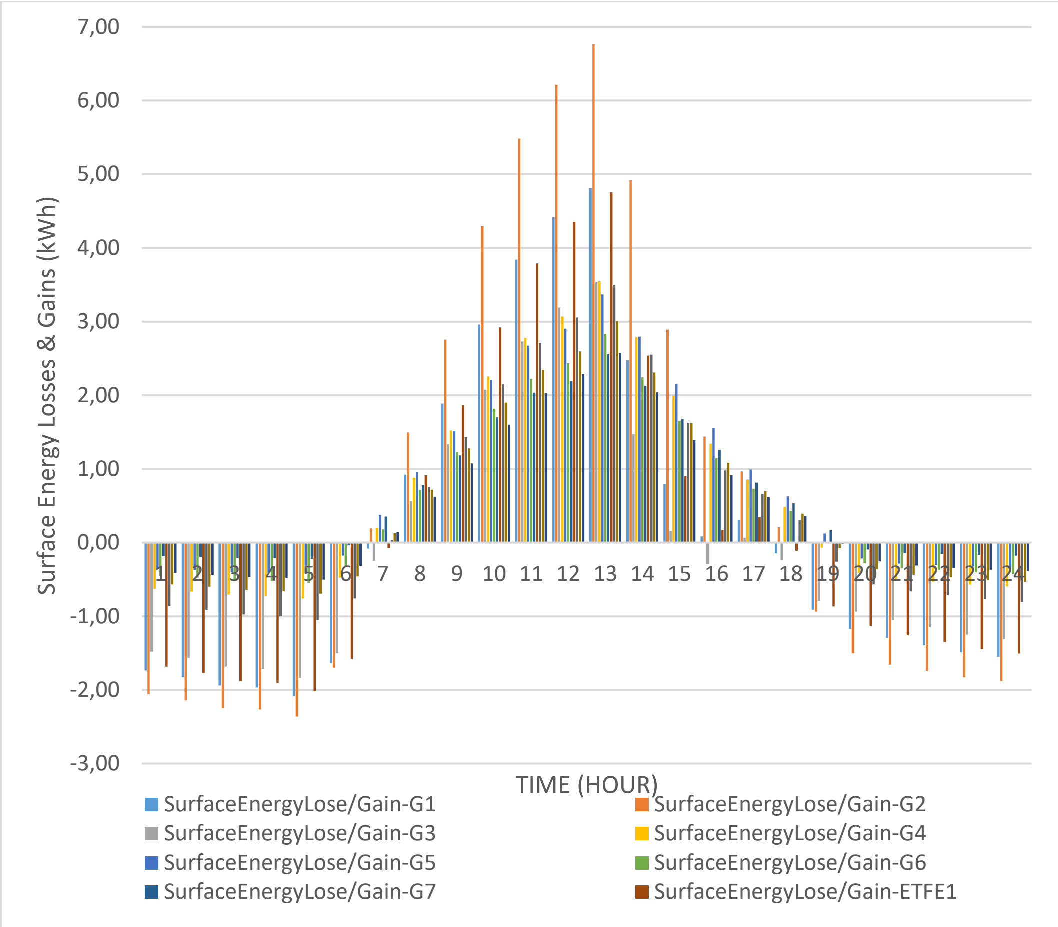


Figure 91: 21 June - Surface Energy Losses&Gains

As seen in (Figure 94), the results were taken as 24 hours for 21 June and evaluated. The interior of the materials in question from 24:00 to 07:00 in the morning environment is losing heat. The reason for this is that the interior temperature value is higher than the outdoor temperature because the volume is heated by solar energy throughout the day. The heat transfer takes place from the high temperature to the low temperature. For this reason, the heat loss occurred from 24:00 to 07:00 in the morning from the interior to the outside. Similarly and depending on the same conditions, heat loss from inside to outside was observed from 19:00 to 24:00. The heat transfer from 07:00 to 19:00 in the morning is carried out from the outside to the interior. When the surface heat losses and gains of the materials are examined, the material which is the most lost at night and the most heat gain during the day appears as G2 glass, followed by G1 glass and ETFE1 swelling system respectively. Considering the İzmir climate and summer months, it stops at a negative point due to the fact that the material heats up more quickly and provides passage. When the outdoor temperatures and indoor temperatures of the summer months are revealed, this can be interpreted as negative.

Considering that the summer of Izmir is hot and long, it is not considered appropriate to use materials with high energy gains according to these results. Many energy losses and uptake in the course of the day create a heat bridge for the structure and this is not a positive situation. When these two reasons are taken into consideration, less energy loss and less materials are more suitable for summer months in İzmir. For this reason, G7cam system gives better performance during cooling months. The G6 glass system is followed by the ETFE4 and ETFE5 swelling systems.

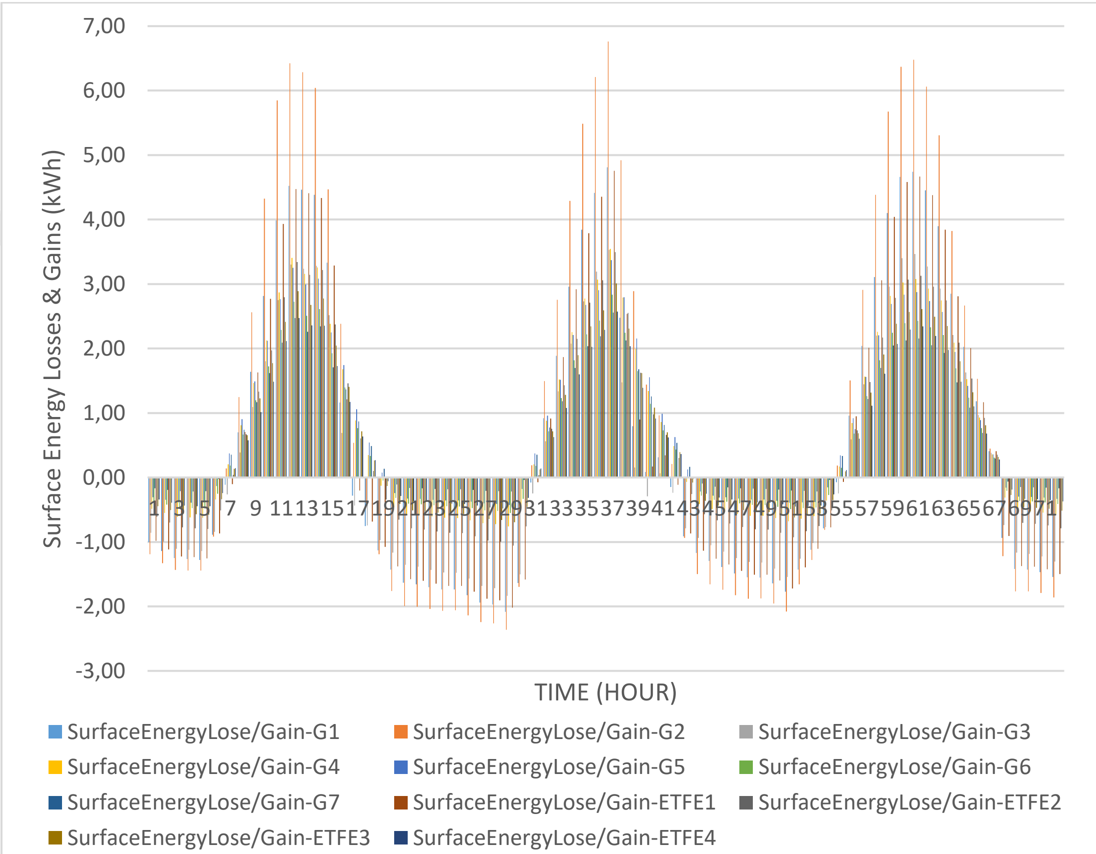


Figure 92: 20-22 June - Surface Energy Losses&Gains

As seen in (Figure 95), the results are taken as 24 hours for June 20, June 21 and June 22 and are evaluated. The monitoring and accuracy of the 21st June were checked. As can be seen from the night of 24:00 in the morning until 07:00 in the indoor environment is losing heat. Similarly and depending on the same conditions, heat loss from inside to outside was observed from 19:00 to 24:00. The heat transfer from 07:00 to 19:00 in the morning is carried out from the outside to the interior. In this context, the possible heat gain and fuel graph of the materials during the cooling months will be as in the figure.

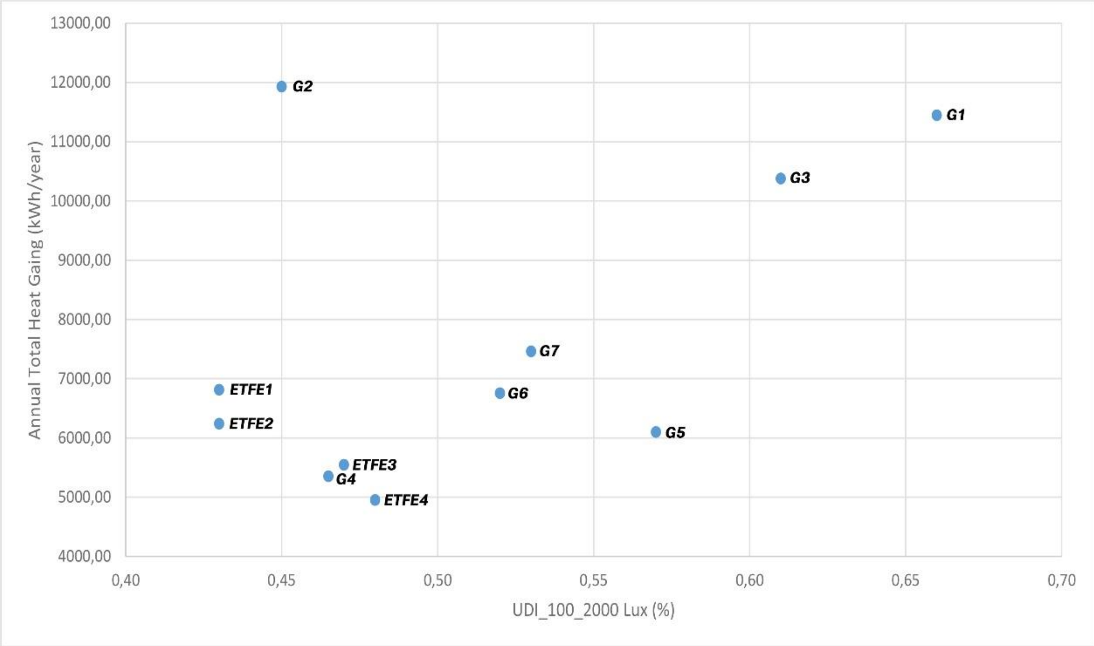


Figure 93: Annual total heat gains and UDI values for each material

As seen in (Figure 96), G2 has an annual total heat gain of 11925,71 kWh/year and 66% UDI interior space of the selected volume. G1 has an energy use of 11441,55 kWh/year and 45% UDI interior space of the selected volume. G3 has an energy use of 10373,56 kWh/year and 61% UDI interior space of the selected volume. G7 has an energy use of 7457,50 kWh/year and 53% UDI interior space of the selected volume. ETFE1 cushions systems has an energy use of 6806,50 kWh/year and 43% UDI interior space of the selected volume. G6 has an energy use of 6750,24 kWh/year and 52% UDI interior space of the selected volume. ETFE2 cushions systems has an energy use of 6234,49 kWh/year and 43% UDI interior space of the selected volume. G5 has an energy use of 6093,05 kWh/year and 57% UDI interior space of the selected volume. ETFE3 cushions systems has an energy use of 5539,82 kWh/year and 47% UDI interior space of the selected volume. G4 has an energy use of 5348,77 kWh/year and 47% UDI interior space of the selected volume. ETFE4 cushions systems has an energy use of 4948,62 kWh/year and 48% UDI interior space of the selected volume. This means that highest amount of daylight is transmitted in to the volume. The heat gain for this sample is second highest with 11925,71 kWh/year for G2. After sample G1 has an energy use of 11441,55 kWh/year and 45% UDI interior space of the selected volume. Even the heat gain of the selected sample is height the UDI value is the second lowest. ETFE1 cushions systems has an energy use of 6806,50 kWh/year and 43% UDI interior space of the selected volume. ETFE2 has an energy use of 6234,49 kWh/year and 43% UDI interior space of the selected volume. This is one of the optimal values but for ETFE1, ETFE2, ETFE3 and ETFE4 the UDI values between 100-2000Lux seem to be lower than the other samples. But UDI values over 2000 Lux are quite higher for ETFE samples (Figure 96). This means that UDI values between 100-2000 Lux for ETFE samples might be increased by using patterns over ETFE samples or transparency values of ETFE samples might be incrust thus the thermal and Illumination performances of the ETFE samples will be optimized.

When the graph (Figure 96) is analysed alone, it is seen that G5, G6, G7 ETFE3 and ETFE4 give good results and G5 is considered optimal. However, it is necessary to separate the model according to cooling and heating time rather than thinking for total heat gain. In addition, ETFE cushion systems are left behind in this graph because th of the higher permeability of daylight and therefore the percentage of 2000 Lux is above the remaining.

In terms of Erzurum region and climate, it is recommended to use materials with a high annual total heat gain in terms of long heating months and cold winters. The G2, G1, G3, G7 and ETFE1 systems are thermally better, but they perform better in terms of UDI values except ETFE. Properties Due to better daylight transmittance values for ETFE swelling systems, UDI values cannot be collected between 100 and 2000 Lux.

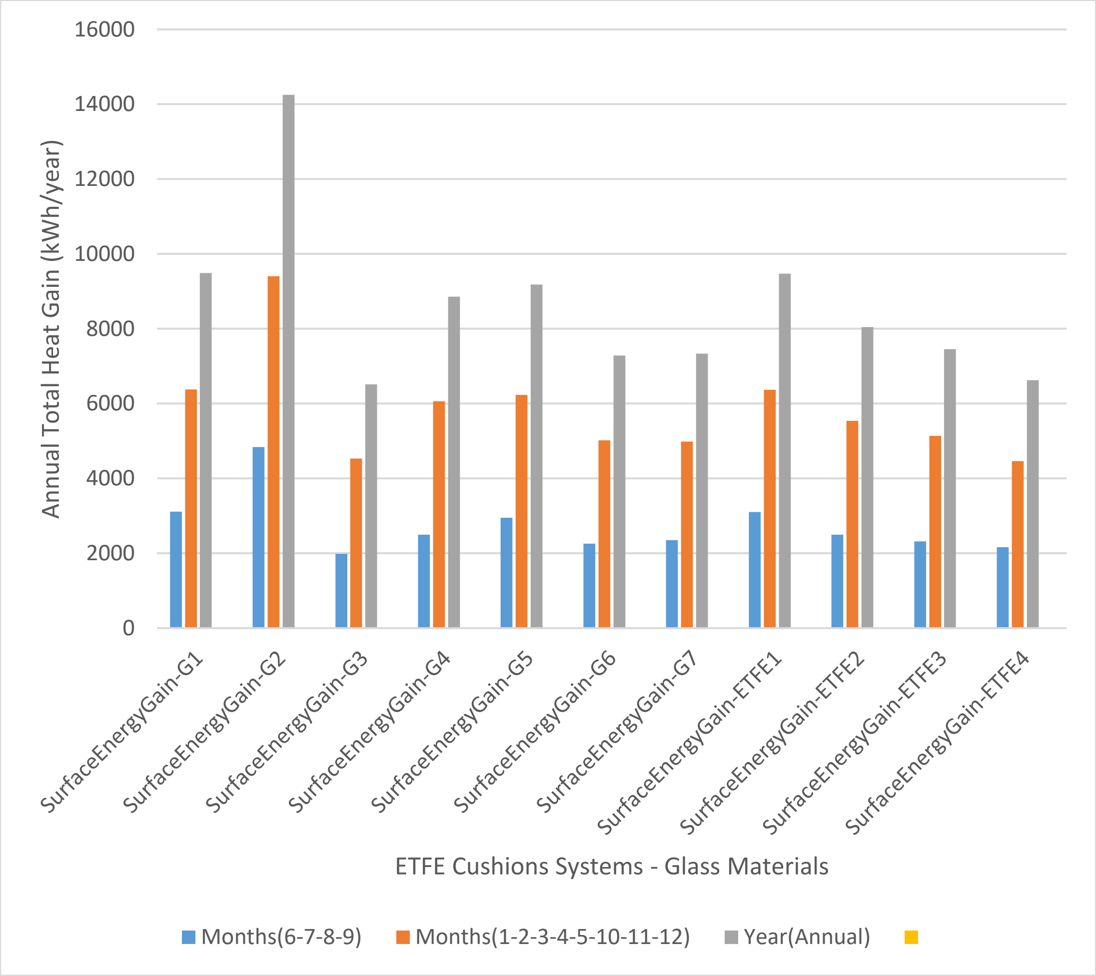


Figure 94: Annual total heat gains for each material

In Figure (Figure 97), annual ETFE swelling systems and glass material cooling periods and total annual heat gains for heating periods are shown. Since the simulation was created for Erzurum, the months of June (6), July (7), AUGUST (8) and September (9) were taken into consideration for the cooling months. The remaining January (1) was considered as February (2), March (3), April (4), May (5), October (10), November (11), range (12). The energy consumption for the G1 glass cooling period was 3110,30 kWh / year, for the heating period 6380,16 kWh / year, total 9490,54 kWh / year and gathered 66% UDI. The energy consumption for the G2 glass was 4841,44 kWh / year, for the cooling period 9407,75 kWh / year for the heating period, total 14249,20 kWh / year and gathered 45% UDI. The energy consumption for the G3 glass was for the cooling period 1981 kWh/year, for the heating period 4531,90 kWh/year, total 6513,86 kWh/year and gathered 61% UDI. The energy consumption for the G4 glass was for the cooling period 2500,11 kWh/year, for the heating period 6061,81 kWh/year, total 8862,10 kWh/year and gathered 48% UDI.

The energy consumption for the G5 glass was for the cooling period 2952,24 kWh/year, for the heating period 6232,10 kWh/year, total 9184,25 kWh/year and gathered 57% UDI. The energy consumption for the G6 glass was for the cooling period 2259,95 kWh/year, for the heating period 5023,55 kWh/year, total 7283,50 kWh/year and gathered 52% UDI. The energy consumption for the G7 glass was for the cooling period 2354,38 kWh/year, for the heating period 4984,20 kWh/year, total 7338,59 kWh/year and gathered 55% UDI.

The energy consumption for the ETFE1 inflatable system was cooling period 3100,64 kWh / year, for the heating period 6372,67 kWh/year, total 9473,31 kWh / year and gathered 43% UDI. The energy consumption for the ETFE2 inflatable system was cooling period 2498,72 kWh / year, for the heating period 5543,06 kWh/year, total 8041,78 kWh / year and gathered 43% UDI. The energy consumption for the ETFE3 inflatable system was cooling period 2319,17 kWh / year, for the heating period 5138,32 kWh/year, total 7457,49 kWh / year and gathered 47% UDI. The energy consumption for the ETFE4 inflatable system was cooling period 2165,03 kWh / year, for the heating period 4462,99 kWh/year, total 6628,02 kWh / year and gathered 48% UDI. The chart is referred to by the number of months in the year. The lowest values for cooling loads were found in G3, G6, G7, ETFE2, ETFE3 and ETFE4 materials. In terms of heating loads, G2, G1 and ETFE1 perform high performance however, they are far out of thermal comfort in terms of cooling loads. It is not recommended to use G1, G2 glasses and ETFE1 system by looking at daylight and thermal results. The performances of G3, G4, G5 and ETFE2 are in good condition and are close to each other. G6, G7 ETFE3 and ETFE4 (which can be incorporated into ETFE2) show close heating and cooling values. Therefore these materials can be recommended for usage. ETFE2, ETFE3 and ETFE4 can be improved by adding patterns to them, changing their colour and darkness levels, as well as their luminosity which will lead to thermal comfort. As a result, ETFE2, ETFE3, ETFE4 systems can be recommended as they provide the most design flexibility.

As shown in (Figure 97), outputs of the glass and ETFE swelling systems UDI are seen. ETFE inflatable systems were better exposed to daylight transmission values than glass. It is more than 2000 lux and more than desired. This negativity can be solved by its own design differences.

According to the function of the structure to be applied in terms of indoor light intensity and thermal comfort values are taken as a criterion and according to this scenario can be designed at the design stage for ETFE systems. Therefore, it is recommended to use ETFE with special designs and orders according to daylight usage and energy requirements of buildings.

Materials	UDI_Less_100 (%)	UDI_100_2000 (%)	UDI_More_2000 (%)	Annual Total Heat Gaing (kWh/year)
G1	0.03	0.66	0.31	9490,54
G2	0.03	0.45	0.52	14249,2
G3	0.3	0.6	0.1	6513,87
G4	0.03	0.47	0.52	8862,01
G5	0.03	0.57	0.4	9184,26
G6	0.03	0.52	0.46	7283,5
G7	0.02	0.53	0.44	7338,59
ETFE1	0.03	0.43	0.54	9473,31
ETFE2	0.03	0.43	0.55	8041,79
ETFE3	0.03	0.47	0.5	7457,49
ETFE4	0.03	0.48	0.49	6628,02

Table 6: UDI values and annual total heat gain for each metarial

As seen in the table above, when we look at the annual total heat gain and UDI results for the İzmir climate, we see the most optimal results. The G2 glass system, the G1 glass system and the ETFE1 swelling system seem to give the best results in terms of annual total heat gain.

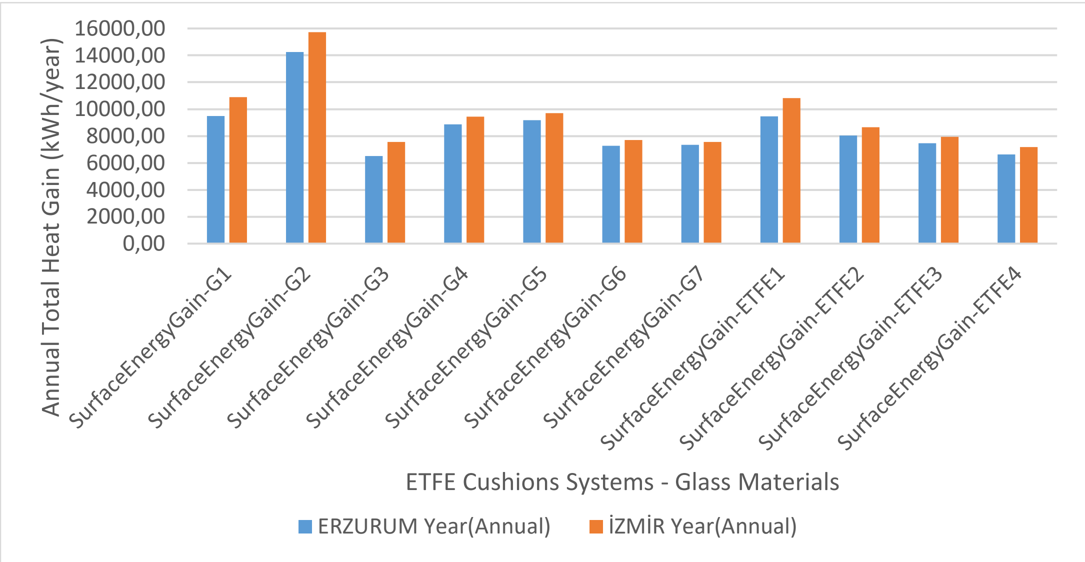


Figure 95: Annual total heat gains for each material

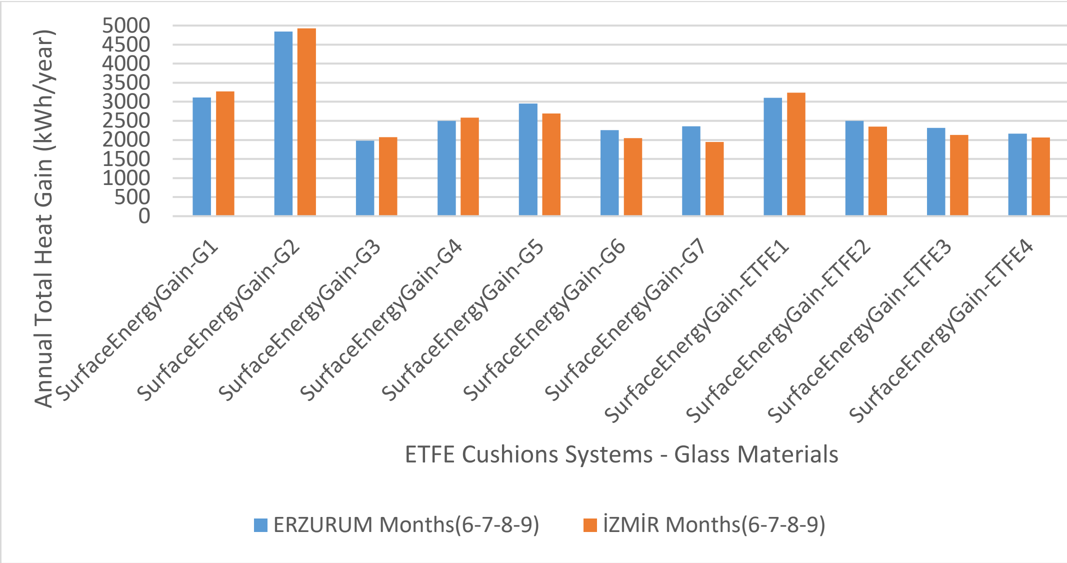


Figure 969: Annual total heat gains for each material

In the study conducted for glass and ETFE systems constructed as façade system, annual total heat gain is seen (Figure 98). When all glass and ETFE cushion systems are examined, annual total heat gain is seen higher for izmir. G1 glass material for Izmir Annual total heat gain is 9490,54 kWh / year, while for Erzurum it is 10886.39 kWh / year. Likewise, the ETFE1 cushion system is due to the longer cooling climate for the Buddha izmir. When the annual total heat gains graph is considered, the fact that a material for İzmir climate in general is annual total heat gains is more negative, considering that the cooling months are long. Considering the opposite, for a cold place like Erzurum, the fact that the annual total heat gains data which is low creates negativity due to the length of the heating months.

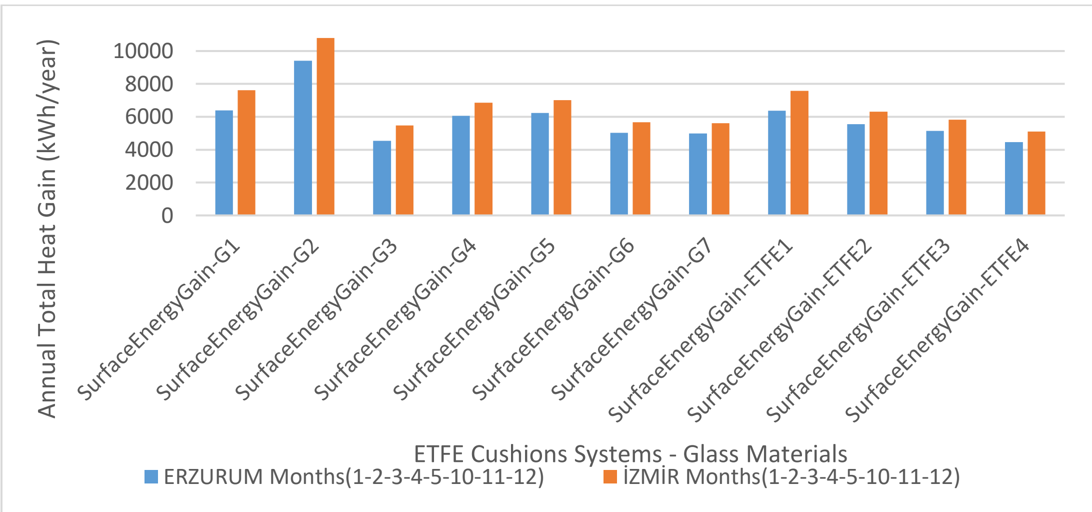


Figure 100: Annual total heat gains for each material

CHAPTER 9 CONCLUSION

As a result of the rapid increase in the world population, the natural environment and resources can no longer meet the needs of the people, it has revealed the necessity of taking measures in every field. The rapid development of technology in any period of life brings with it many problems. The rapid depletion of natural resources, the need for fossil fuels as an energy source, greenhouse gas emissions resulting from the use of these sources, ozone depletion, global warming, climate change, climate, air, water and environmental pollution have caused the deterioration of the ecological balance. All these negativities made it necessary to be careful in all areas of life and to use the resources efficiently.

Energy is one of these sources and the loss of resources has increased the importance given to energy. Efficient and productive use of energy is very important. Since the construction sector is one of the sectors with the most significant share in energy consumption, measures should be taken to ensure the efficient use of energy in this area. The aim is to take advantage of renewable energy sources and to take measures to protect the energy used. They are expected to use the energy efficiently by integrating the possibilities of technology and using smart buildings that respond to the user's needs at the maximum level. In such building designs compatibility with the environment, efficient methods such as minimizing heating and cooling requirements, using solar and wind energy actively and passively are gaining importance. At this point, the facade designs, which are a static component of the building under the changing climatic conditions and which constitute a large percentage of the building shell, gain importance. By filtering out the negative features of the outdoor environment, energy efficient façade applications such as ETFE that works as an intelligent filter should become widespread.

ETFE1 and ETFE cushions systems seem to have lower UDI values compared to other samples but as mentioned above the UDI performances of the ETFE samples might be increased by using patterns over them or transmissivity values ETFE samples might be increased thus the thermal and illuminations performances of the ETFE samples will be optimized.

- ETFE inflatable systems perform favourably in energy efficient maintenance compared to glass systems, while daylight is in a worse rank in terms of performance.
- While daylight and thermal performances are evaluated with low-e, permeability rates or colours in glass systems, ETFE gives poor performance at some points compared to glass systems, since ETFE is only comparable to layer differences for swelling systems. In this regard, a simulation on ETFE swelling systems with a simulation on the degree of permeability and colour between the glass will give better results.
- The ETFE system can be brought to better points in terms of permeability and performance by factors such as colour, dark textures to be used on the surface, so that a shading element may not be needed compared to glass.
- The ETFE inflatable system is recommended to be used in cold climates such as Erzurum, where the sunshine duration is long and the summers are very hot.
- Daylight control is mandatory for all glass systems and ETFE inflatable systems. It is recommended that this negative performance be supported with an overhang, shading element that is to be added to the facade design.
- In terms of shading and solar control, glass and ETFE inflatable systems can be a positive point to achieve good results when the carrier system or profiles are deeper organized. From this perspective, design differences can be created with more specific, given and optimal results at points such as weight and form of ETFE swelling system.
- Since P1, P2 and P3 points are closer to the outside (glass and ETFE swelling systems), very high results are obtained. P4, P5 and P6 remain in point. Designed as an office space, the floor height and flooring work as a shading system, so we get more thoughtful data from our back points. However, the data of Erzurum gives better results than Izmir. It is closer to the data required for the office environment and artificial lighting is needed at fewer points.

It is necessary to discover the design alternatives and to make the right choices in the early architectural steps with the design basket with these concerns at the architectural project design stages. For this reason, the architectural design process is complex in which the designer and many other disciplines are combined. In today's Architecture construction techniques and construction processes, the fastest-growing construction process has become the most used / known product glass. Even if glass is preferred even in different building functions, the criteria such as the difficulties of the application of the glass, the weight for the building or the energy that the structure will spend for life are ignored by the designers and the investors.

In this thesis, a study was carried out on energy efficiency and daylight usage between ETFE systems and glassware. It is clear that the sunbathing process, which can be put forward as a disadvantage of a flat ETFE or glass facade in summer, becomes an advantage in winter. In this context, the thermal performance of the product to be chosen comes to the fore because there is no shadow crusher element.

Within the scope of the thesis, a study has been conducted within the whole year related to performance evaluation between ETFE system and glass for İzmir climate. This observation and test was prepared for a hot and humid city which is Izmir. In line with this, climatic endpoints were evaluated daily and hourly for January and June. In the early design steps, a selection and comparison of the energy needs and sunlight values were discussed. Here, the results are presented for the designer to use the right product and to achieve a lower carbon footprint with the end user. With these results, the average weight of the ETFE cushion system is around 2-3kg m2. It has a great advantage compared to glass with these properties.

It has a great advantage compared to glass with these properties. In this context, when selected as building material, it will be possible to encounter much more economical solutions because of its weight, when it is applied to the facade or top cover, it will have less load increase and much less requirements in the carrier system which is likely to be more economic for the construction. As being a flexible material, ETFE is advantageous. Regarding any disadvantage that may arise during construction or during the use of the structure; ETFE is not a product that breaks, explodes, or falls from the ETFE frame in the face of any error or vandalism, so it has advantages like these.

The single-skinned ETFE has a light transmittance of around 85-90%, as well as printing systems to meet the needs of daylight or thermal comfort. In this context, the percentages of the prints used on the building material or the density of the ink and the energy and daylight inputs can be changed.

Considering the dimensions of the glass, it is produced in average 200x300cm dimensions considering the ease of application and the concerns in the usage process. Considering the production ways and the methods of combining the ETFE, offers a lot of facilities for the application in the desired dimensions and thus for the convenience and application of the designer. Considering all these aspects, it can become a more useful and more desirable construction material for the designer. With these in total, it becomes a more original material in future researches or construction activities. With this material, it is a candidate to be more original and a structural element that does not restrict the designer. It will support a more specific parametric design and is a serious advantage for projects designed. ETFE swelling systems with self-cleaning feature, dust on the surface and so on. due to the adherence of the substances in very little rain has the ability to self-cleaning. Cleaning the systems with rain water reduces the cost of periodical maintenance and cleaning.

ETFE systems are construction materials that can be chosen because they are flexible, light, they have color options, periodic maintenance, lifespan, 100 percent recycling, energy and daylight performances. Especially with the carbon footprint and the new limits given to the designer, there is a chance that they will be able to play a role in the emergence of new structures for tomorrow and future. In this context, it is a building element that can consume less in our future world and give new design - spatial experiences to the users.

In future studies, ETFE inflatable cushion systems can be analyzed in computer environment and optimization of these complex data can be made with many unknowns. In this way, by taking more and more results, more quickly and more accurate when compared to human brain which is impossible to even compare the variations are vast. These variables can be discussed between structural elements such as bearing systems, building floor heights, etc. In addition to the work on the material made, in this study, ETFE can also be transformed into a shadow element as part of the design and frame.

CURRICULUM VITAE

He was born in May 31, 1990 in Istanbul. In 2008, he got a scholarship from Girne

American University and graduated with honour degree in 2013. From 2013 to 2018, he worked as a professional architect in Ankara and İzmir, and worked as a project manager. In 2016, he started his graduate studies in Yaşar University, Department of Architecture on sustainable architecture and computational design. He worked as a part-time lecturer in the same university between 2017 and 2018. In 2018, he left the office where he was working as Project Manager and founded Zero Architecture in İzmir Bayraklı. He continues her work in Zero Architecture where he is a founding and design partner. In addition to national and international architectural competitions, he continues to work in the center of energy efficiency and sustainable architecture.

International Conference Papers

Selim Karaman, Berk Ekici, Cemre Cubukcuoglu, Basak Kundakci Koyunbaba, İlker Kahraman (2017) **Design of Rectangular Façade Modules Intelligence:** Case of Common Space in Healthcare Building **Published in:** 2017 IEEE Congress on Evolutionary Computation (CEC), **DOI:** 10.1109/CEC.2017.7969420

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APPENDIX 1 –