YAŞAR UNIVERSITY

GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

MASTER THESIS

SUITABLE ENVELOPE DETAIL SELECTION PROPOSAL FOR ACHIEVING THERMAL, ENVIRONMENTAL AND BUDGET GOALS FOR A HOSPITAL PATIENT ROOM IN IZMIR-TURKEY

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

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ABSTRACT

SUITABLE ENVELOPE DETAIL SELECTION PROPOSAL FOR ACHIEVING THERMAL, ENVIRONMENTAL AND BUDGET GOALS FOR A HOSPITAL PATIENT ROOM IN IZMIR-TURKEY

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Global warming which we have begun to experience significantly over the past few decades have many more reasons. Because of the global warming studies regarding energy efficiency both in our country and in the world are getting increasingly more important.

Hospitals are buildings that consume major energy in various areas such as heating, cooling and lighting. This study was conducted considering these hospital building groups due to the increase in the importance of the energy efficiency in the hospitals both in the world and in our country.

Energy at building envelope, cost, and environmental studies were conducted in this study. Therefore, low cost and reduced energy consuming outer wall model was established by minimizing the environmental effects through establishing the conditions and inputs for a comfortable indoor condition for people/patients with minimum energy consumption.

Depending on the proper construction, TS 825 Thermal Insulation Standard specifies maximum annual energy demand which covers topics such as heating, cooling, ventilation, hot water and lighting. However, in order to provide energy conversation by the building envelope, there is a specific heat transmission coefficient value or U value. Heat transmission coefficient (U) for the city of Izmir was determined as U≤0,70 according to TS 825 Thermal Insulation Standard. It is possible to obtain many details that would procure the U value. Therefore in this study, 24 different details were established within the context of a dissertation in order to provide the minimum U-values which would result in minimum values for building envelope. Consequently, initial investment costs and environmental impacts of each of the details differ.

Material thickness regarding the U value was established by using TS 825 Thermal Insulation program while wall model was created. Providing thermal comfort and being one of the major application fields, thermal insulation was focused on building envelope by examining the environmental impacts with life cycle analyses (LCA) conducted on Simapro program.

An exterior insulation focused, energy effective, cost-effective and environment-friendly wall model was created in this study. The aim is to support the decision-makers by shedding light on the issues that are currently being underrated by the decision-makers and encouraging the consideration of the environmental impact and cost of the building envelope's material selection.

Key words: Thermal Comfort, Insulation Materials, Çevresel etki değerlendirme, Life Cycle Analysis, Energy Consumption, Building Envelope, Hospitals

ÖZET

İZMİR TÜRKİYE'DEKİ BİR HASTANENİN HASTA ODASI İÇİN BÜTÇE, ÇEVRE VE TERMAL HEDEFLERİ YAKALAMAYA YÖNELİK UYGUN KABUK DETAYI SEÇİM ÖNERİSİ

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Son birkaç on yıldır güçlü bir şekilde tecrübe etmeye başladığımız küresel ısınma kökenine ilişkin birçok neden bulunmaktadır. Küresel ısınma sorunuyla birlikte ülkemizde ve dünyada enerji verimliliğine yönelik çalışmalar giderek daha da önem kazanmaktadır.

Hastaneler, ısıtma, soğutma, aydınlatma gibi birçok alanda enerji kullanımının en yoğun olduğu bina gruplarıdır. Dünyada ve ülkemizde hastanlerde enerji verimliliğine yönelik çalışmaların öneminin artması nedeniyle bu çalışma hastane bina grupları göz önüne alınarak yapılmıştır.

Bu çalışmada, bina kabuğunda enerji, maliyet ve çevresel konulara yönelik çalışmalar yapılmıştır. Böylece minumum enerji tüketimiyle insanlara/hastalara konforlu bir iç ortam sağlayan koşulları ve verileri oluşturarak çevresel etkileri minimize edilmiş, düşük maliyetli ve enerji tüketimi azaltılmış, dış duvar modeli oluşturulmuştur.

TS 825 Isı Yalıtım Standardı, uygun inşa edilme durumuna göre ısıtma, soğutma, havalandırma, sıcak su ve aydınlatma gibi konuları kapsayan azami yıllık enerji talebi belirtilmektedir. Fakat bina kabuğundan enerji tasarrufu sağlayabilmek için belirli bir ısı geçirgenlik katsayısı yani bir U değeri vardır. TS 825 ısı yalıtım standartına göre İzmir iline ait ısı geçirgenlik katsayısının (U) U≤0,70 olarak belirtilmiştir. Bu U değerini sağlayacak pek çok detay elde etmek mümkünüdür. Dolaysıyla bu çalışmada bina kabuğuna ilişkin mimumum değerlere ulaşabilmek için minumum U değerini sağlayacak 24 adet detay tez kapsamında oluşturulmuştur. Sonuç olarak, her bir detayın ilk yatırım maliyetleri ve çevresel etkileri değişkenlik göstermektedir.

Duvar modeli oluşturulurken U değerine ilşikin malzeme kalınlıkları TS 825 ısı yalıtımı programından yaralanılarak oluşturulmuştur. Isıl konfor sağlayan önemli uygulama alanlarından biri olan bina kabuğunda, ısı yalıtımı üzerinde durularak, kullanılacak ürünlerin yaşam döngü analizleri (LCA)Simapro programı kullanılarak çevreye etkileri incelenmiştir.

Bu çalışmada dış cephe yalıtım odaklı, enerji etkin, uygun maliyetli ve çevre dostu bir duvar modeli oluşturulmuştur. Şu anda karar vericiler tarafından çok önemsenmeyen konulara ışık tutarak bina kabuk malzemesi seçiminde çevresel etki ve maliyetin de göz önünde bulundurulmasının sağlanmasına yönelik karar vericilere destek olmak amaçlanmaktadır.

Anahtar sözcükler: Termal konfor, Yalıtım malzemeleri, Çevresel etki değerlendirme, Yaşam döngü analizi, Enerji tüketimi, Bina kabuğu, Hastaneler

To my family

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Pelin YETKİN YAZICI

İzmir, 2016

TEXT OF OATH

I declare and honestly confirm that my study, titled "Suitable Envelope Detail Selection Proposal For Achieving Thermal, Environmental And Budget Goals For A Hospital Patient Room in Izmir-Turkey" and presented as a Master's, has been written without applying to any assistance inconsistent with scientific ethics and traditions, that all sources from which I have benefited are listed in the bibliography, and that I have benefited from these sources by means of making references.

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INDEX OF SYMBOLS AND ABBREVIATIONS

Symbols	Explanations
$W / (m \cdot K)$	Thermal conductivity
R_i	Thermal resistance
IPCC	International Panel of Climate Change (United Nations)
UNFCC	The United Nations Framework Convention on Climate Change
EU	European Economic Area
EPD	Environmental Product Declaration
LCA	Life Cycle Assessment
LCC	Life Cycle Cost
CPR	Construction Products Regulation
BWR	Basic Work Requirement
EPBD	Directive on the energy performance of buildings
U-value	Thermal transmittance (W/m2K)
XPS	Extruded polystyrene
EPS	Expanded polystyrene
EPD	Environmental Product Declarations

LCA	Life Cycle Assessment
GHG	Green House Gas
PCR	Product Category Rules (For EPDs)
ISO	International Standards Organization
ASHRAE	American Society of Heating, Refrigerating, and Air-Conditioning Engineers
IEA	International Energy Agency
ECTP	European Construction Technology Platform
LEED	Leadership in Energy and Environmental Design
BREEAM	Building Research Establishment Environmental Assessment Method

1 INTRODUCTION

1.1 Subject of the Thesis

The 1970s and 1980s were the years when the countries of the world, whatever level of development they had, faced environmental and climate change issues. The main source of global warming and climate change issues is the increase in the amount of greenhouse gases in the atmosphere. With the industrial revolution, unplanned use of resources through increased production led to reduction of resources and increased energy needs in manufacturing processes. As a result of acquiring this energy need from fossil fuels, carbon dioxide emission occurs. The increase in the amount of carbon dioxide in greenhouse gases has been affecting the process of global warming in a negative way (Özçağ M.,2011).

In the 1970s, conservation of non-renewable energy resources became a current issue after the oil crisis that emerged at that time. Therefore, desire to live a comfortable life causes an increase in the energy consumption for heating and cooling the buildings and the energy consumed in the buildings corresponds to a large slice in the total energy consumption. The construction sector is responsible for a large consumption of energy (40%) and corresponding CO_2 emissions (ECTP,2005).

Figure 1.1 indicates the sectoral distribution of increased energy consumption. When the sectoral distribution of energy consumption in our country is examined, it is seen that the building sector takes the first place.

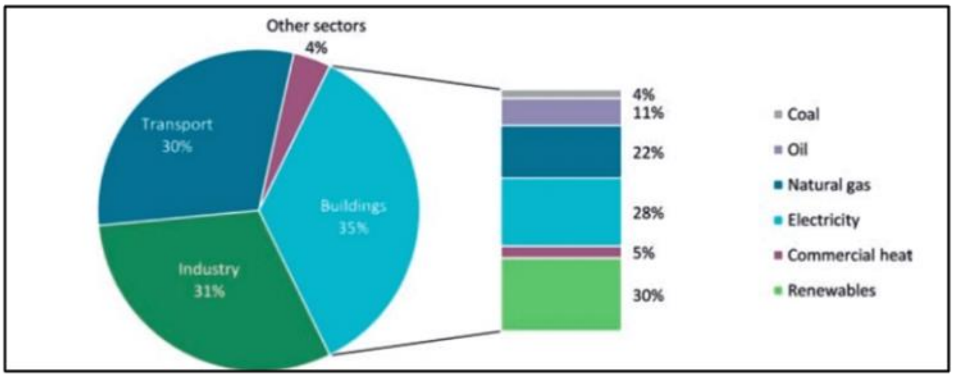


Figure 1.1 Final energy consumption by sector and buildings energy mix, 2010

(IEA, 2013)

Figure 1.2 shows that a significant part of energy consumption in buildings is especially for heating and cooling to ensure comfort conditions.

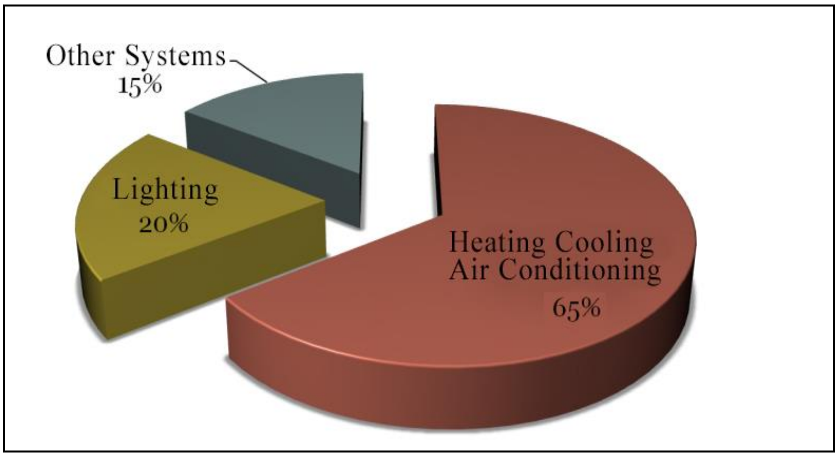


Figure 1.2 Energy consumption of buildings, BEP-Tr

Buildings are structures that have the highest potential in both energy consumption and energy conversation. Among these structures, hospitals are the buildings have the most intense energy consumption. There are many forms of energy consumption are in play such as heating, cooling and lighting.

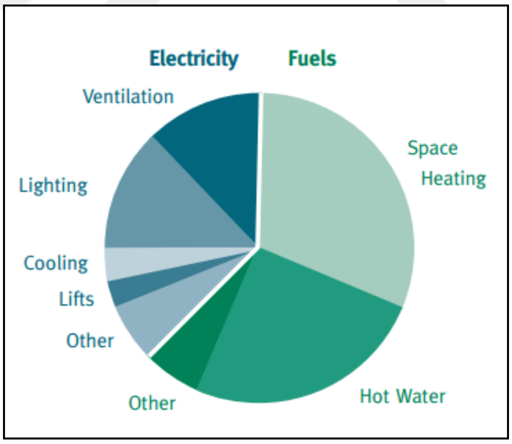


Figure 1.3 Hospital energy consumption by major application (Environment Science Center, 2010)

Carpenter and Hoppszallern (2010) stated, “If hospitals are taking steps in the direction becoming green hospitals, beginning with energy management is a great step.” Identifying the areas and equipment which consume the maximum amount of energy is the first step for energy management. It is shown in Figure 1.3 that the dissipation of energy mostly comes due to heating purposes. Hospitals in Germany produced 4 million tons kWh of CO_2 every year only as a heating cost.

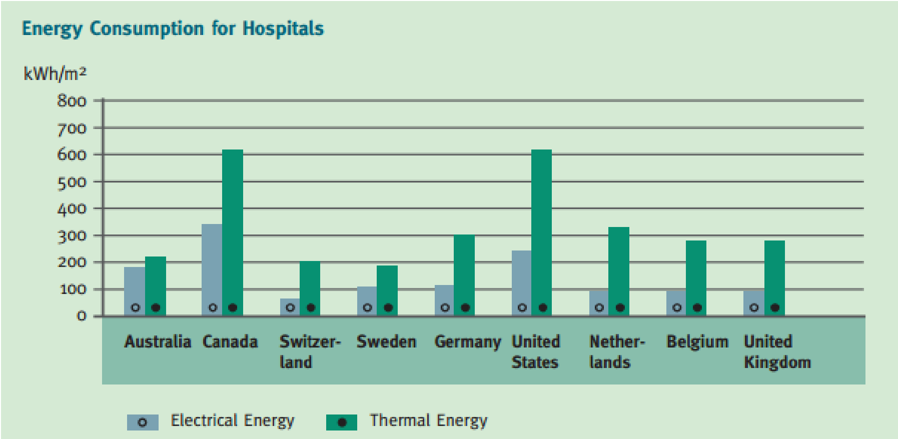


Figure 1.4 Energy consumption for hospitals (kWh/m²)

(Environment Science Center, 2010)

Due to hospitals having significant energy dissipation due to heating and cooling costs, the dissertation is based on this issue and aims to suggest a building envelope which provides comfortable thermal conditions, has minimum energy dissipation, cost-efficient and has low environmental impact. Hospitals being both full-time working and major energy consuming institutions which have greater energy consumption compared to a business organization makes the topic attractive. A study group was formed within the faculty of architecture of Yaşar University towards hospitals. They are providing consulting services for the new service buildings of Tepecik state hospital.

In this study, evaluation of the details, which are chosen with the goal of reducing the energy consumption stemming from the building envelope of a private hospital at the city of Izmir, regarding their environmental impacts and costs is aimed. While the details are being established, according to EPB-TR; the heat transmission coefficients of the components should be either equal or lower than the U-value specified in the TS 825 standard. 24 details, which would provide the minimum value for the building envelope, were established. The environmental impacts and costs of these details differ from each other.

The concept of green building is related to building location, water management, inner air quality, material use, and energy. “Green Hospital” era has begun in Turkey, and LEED was made mandatory by Ministry of Health by making the LEED system, which is an international system of green building certificate, in every hospital which has a capacity of 200 beds or more obligatory. Coming up with an alternative for the resources, encouraging more effective and efficient use of energy, water, and materials, preventing any sort of waste and implementing environment conscious and environment-friendly building designs are aimed with the “green” concept in the hospitals. EPB-TR are the procedures and principles regarding the efficient use of energy and energy sources in buildings, preventing waste and preserving the environment. However, even though the essential building envelope is being standardized by the new EPB regulations, there is no standard regarding its cost or environmental impact. Environmental impacts on the components of the envelope during this process should be evaluated through LCA method. LCA regarding the envelope’s materials was conducted in this study. The performance of the 24 details which provide (≤0,70) the heat transmission coefficient(U) value stated in TS 825, 0,70 U according to the BEP-TR regulations were evaluated, and application costs of the aforementioned details were presented.

Parameters affecting the user’s thermal comfort levels are examined in Chapter 2. Effects of the parameters obtained from the literature on thermal comfort are being examined, and standards and regulations were evaluated within the frame of the results of conducted studies.

24 details regarding the building envelope of the Private Sardes Hospital at the city of Izmir, which is taken as a reference for the dissertation, were established in Chapter 3. The wall thickness and the thickness of the heat insulation materials, which will be applied to the outer wall, on these details are calculated by TS 825 heat insulation program. Moreover, environmental impacts of every detail which are established in this chapter are evaluated by Simapro program. The aim is to produce an environment that is energy effective, cost-efficient, environmentally conscious and thermally comfortable without conceding health and comfort conditions. On the other hand, the goal is to conduct the necessary analyses regarding the procedures on keeping the environmental harm to a minimum and provide information to the operators regarding on both the analyses and the products while meeting these conditions.

In Chapter 4, material details which would prevent the building envelope to transmit the thermal comfort disrupting impacts of the outer environment to the inner environment in order to provide thermal comfort. Material details regarding the improvements on the building envelope were focused in order to improve the thermal comfort. The environmental life cycle of the materials used in that regard was compared, and initial investment costs were calculated through the base prices acquired from Ministry of Environment and Urbanisation.

There are many building blocks that are without insulation and environment conscious design criteria in Turkey. This study enables improving the existing buildings, securing energy conservation, examining the environment consciousness of the materials used in this regard by conducting life cycle analyses (LCA) and improving the indoor thermal comfort with the increases in the energy efficiency. Along with this, the goal is to improve the thermal comfort conditions of the outer building envelope on the topics of environment, energy and investment cost in order for it to provide the optimum performance. Also, energy conservation with the temperature control on the outer wall is a study attempting to improve the user thermal comfort level depending on the quality of the inner environment. For this purpose, calculating methods were used to reach the optimum values in insulation materials, which will be used to provide the interior thermal comfort conditions.

1.2 Methodology

This thesis focuses first on the problematic definitions of thermal comfort. When the literature relating to thermal comfort conditions are examined, there is an increase in studies in this field. Literature studies conducted for correct insulation of existing buildings in İzmir province, which is in the 1st degree day region, and for the purpose of improving thermal comfort levels of interior users were evaluated within the scope of the thesis.

Insulation materials used for improvements in external walls (to increase thermal comfort level) were examined. Heat transfer coefficients of insulation materials were obtained from values suggested in the TS 825 standard/regulation and in principle of specific situation and conditions covered by the standards. The obtained data is the value where thermal transmission coefficient (U) of structural elements are calculated by limiting energy amounts, thus increasing energy efficiency and calculating energy needs in the buildings. For the U values of the materials, the U value table recommended according to degree day regions, identified in TS 825 standard was used. In determining insulation levels and energy savings achieved as a result, the calculation method of the TS 825 was used. In addition to benefits of protection from thermal effects, there will be some costs. During investigation of the costs, unit prices by the Ministry of Environment and Urbanization were used.

The environmental impact of the life cycle of conventional thermal insulation materials used in a building's external walls was determined and evaluated. The environmental assessment was obtained using the Life Cycle Assessment (LCA) methodology. The LCA tool allows the evaluation and interpretation of the environmental impacts associated with the manufacturing of these insulation materials according to different impact categories. Four insulation materials were selected, and the models of their life cycle were simulated in the LCA software SimaPro.

1.3 Research Goal

Urgent intervention is needed when the fact that hospitals are full-time institutions that consume the most energy is taken into consideration. Reduction of energy spent for heating and cooling, improving the building insulation to improve the indoor thermal comfort level, selection of proper materials for thermal insulation target and making the analysis of the costs and environmental impact are the important topics in this thesis.

With the circular issued in October 2012 by the Ministry of Health-Construction and Maintenance Department, it is obliged in hospitals with 200 or more beds to get the LEED certificate. Serious steps have been taken in the U.S. and some Western Europe countries on the environmental effects of hospitals and new laws and regulations have been entered into force. In addition, green building rating systems like LEED and BREEAM have developed special versions for health institutions and have put them into practice. The reason why LEED certificate has been chosen is that only LEED has an international system only for health institutions (LEED for Healthcare). LEED v4 gives permission to project teams to use Life Cycle Assessment for the optimization of the structure.

- LEED v4 is needed to use EPD audited by an independent controller and conforming to ISO standards and to get points under this title. EPDs depend on YDD.
- DGNB uses life cycle analysis in measuring the building performances.
- HQE uses life cycle analysis in increasing the overall evaluation of the building.
- BREEAM uses YDDs not fully conforming to international standards.

İzmir Sardes Private Hospital has been chosen as the sample building in this study. It is needed to increase the thermal performance level of hospitals in order to ensure the best patient comfort. (Insufficient thermal level affects health negatively.) Keeping the expected performance of the architecture / interior architecture products produced by the collaboration of different engineering and disciplines at the maximum level and transferring positive examples to the future is of utmost importance for the study. Providing healthy and comfortable living space for the people, improving the thermal performance of the buildings for the overall energy efficiency, reducing the energy consumption spent for heating and cooling while creating comfortable areas, making it affordable and having the least impact on the environment are the topics aimed in this study.

Energy analysis of these buildings will be realized, and heating and cooling will be more focused on out of other energy items. Making suggestions to ensure the reduction of the energy consumption originating from the building siding, ensuring all or some of building energy consumption by the use of renewable energy sources and lessening the use of fossil fuel will both ensure sustainability and help lessen the environmental effects of the products by making the life cycle analysis. CO2 emission which poses a threat for global warming will be greatly lessened. In addition to this, environmental effects of Resp. organics, Climate change, Radiation, Ozone layer, Ecotoxicity, Acidification/ Eutrophication, Land use, Minerals have been taken into consideration in Life Cycle Analysis.

The aim of this study is to put forth the environmental effects of structural details for the policy makers. In addition, it is aimed to put forward an affordable, energy efficient building siding proposal that will provide thermal comfort conditions.

2 THERMAL, ENVIRONMENTAL AND BUDGET ISSUES

In this part describes; thermal, environmental and budget issues of the building envelope.

2.1 Thermal Comfort

One of the key physical elements that allow the comfort of a person in a space is temperature. The difference between a person's body temperature and the ambient temperature is the cause of feeling comfortable in that environment. When a person cannot establish heat balance easily in an environment, he can feel uncomfortable; therefore a person's comfort level is associated with how easy it is to establish an energy balance between the body and the environment. In other words, thermal comfort is provided when the heat generated by human's metabolism is equal to the heat lost from the body. The ASHRAE Standard 55-2004 and the ISO 7730 thermal comfort, which are international standards, define thermal comfort as 'the condition of mind that expresses satisfaction with the thermal environment'.

Thermal comfort, which is one of the most important factors affecting business efficiency and productivity, expresses satisfaction with the environment (Atmaca İ. & Yiğit A., 2011). For example, people working in a building providing comfortable, enjoyable and healthy conditions have a high level of productivity and people in a comfortable environment have been shown to be less confused and better focus on their works/activities. In addition, in case of an unfavorable thermal level, depending on its psychological and physiological effects, indications such as concentration disorders, reduction of efficiency, growing weakness associated with thermal stress, irritability, muscle cramps etc. can be observed in people. As psychological and physiological changes can vary from person to person, environmental conditions for thermal comfort may not be the same for all. This situation makes it very difficult to provide thermal comfort satisfaction (Altıntaş Esra., 2008). Therefore, ASHRAE has collected extensive laboratory and field information to provide necessary statistical data to define thermal comfort conditions that people can achieve. In the ASHRAE Standards 55–2004 and ISO 7730, which are international standards, acceptable thermal comfort ranges are provided and comfort levels can be defined according to these standards.

According to the ASHRAE Standards 55-2004, there are 6 main factors that determine thermal comfort conditions. These are;

1. Metabolic rate

2. Clothing insulation

3. Air temperature

4. Radiant temperature

5. Air velocity

6. Humidity

The range calculated with combination of these factors provides a good comfort level and it is known as the comfort range. Although these 6 main factors depend on many parameters, we can classify the parameters affecting thermal comfort in the broadest sense as personal and environmental parameters (McQuiston &Parker et al. 1994). While the environmental parameters are named as ambient temperature, ambient air speed, ambient relative humidity and temperature of various surfaces in the environment, the personal parameters consist of a person’s metabolic rate level (level of activity), health status and clothing. Age, gender, adaptation to thermal environment, seasonal and daily rhythms are other factors that affect thermal comfort (Altıntaş Esra., 2008).

Environmental parameters;

- Ambient temperature
- Ambient air speed
- Ambient relative humidity
- Temperature of various surfaces in the environment

Personal parameters;

- Metabolic rate (level of activity)
- Clothing
- Health situation

Other parameters;

- Age
- Gender
- Adaptation to thermal environment
- Seasonal and daily rhythms

The comfort range is determined in operative temperature that can provide acceptable thermal environment conditions. Operative temperature '*the temperature in the walls and air of an equivalent compound that experiments the same heat transfer to the atmosphere by convection and radiation than in an enclosure where these temperatures are different*' (Antonio Orosa García J., 2010). Operative temperature is a temperature that represents both air temperature and average radiation temperature (ASHRAE Standard 55–2004).

The recommendations made by ASHRAE 2004, ISO 7730:2005 and ISO 7726:2002 are seen in these thermal conditions and should ensure that at least 90% of the occupants are comfortable with the ambient temperatures (Charles, K. E., 2003).

In the ISO 7730 standard, heating and cooling periods are recommended separately (Atmaca, İ., & Yiğit, A., 2009).

For summer conditions, i.e. cooling period, the following is recommended;

- Operative temperature 24.5 °C ± 1.5 °C,

• Relative humidity within the range of 30% to 70%,

• A vertical temperature difference less than 3 °C for the heights between 0.1 m to 1.1 m from the floor.

For winter conditions, i.e. heating period, the following is recommended;

• Operative temperature 22 °C ± 2 °C,

• Relative humidity within the range of 30% to 70%,

• A vertical temperature difference less than 3 °C for the heights between 0.1 m to 1.1 m from the floor,

• Floor surface temperatures should remain between 19 °C and 26 °C (but underfloor heating systems can be designed for 29 °C),

• Radiation temperature asymmetry should be less than 10 °C due to windows and other cold surfaces,

• Radiation temperature asymmetry should be less than 5 °C due to ceiling heating.

2.1.1 Parameters of Thermal Comfort

There are four environmental variables that determine our physical thermal comfort: ambient temperature, ambient air speed, ambient relative humidity and average radiation temperature depending on the temperature of various surfaces in the environment. Other variables such as clothing and metabolism are personal variables.

2.1.1.1 Environmental Variables

These 4 environmental parameters are associated with thermo-physical conditions of building envelope, heating, cooling and ventilation systems.

2.1.1.1.1 Ambient temperature

Felt temperature is the temperature that is felt and perceived by human body. As the value of air temperature in the environment changes, feeling and perceiving this temperate varies from person to person. This temperature is affected by climatic environment, heat resistance of clothing, body structure and personal situation as well as four meteorological factors such as bulb temperature, relative humidity, wind and radiation. (Altıntaş Esra., 2008).

Because of heat resistance of clothing, mean radiant temperature, relative air speed, level of the activities carried out, and water vapor pressure of the environment and the air, we can feel air temperature even hotter in hot weathers. Especially in the winter months when the temperature falls below zero, the felt temperature along with strong winds is lower than the measured temperature. This temperature is also called as “wind-chill”.

Human body temperature is stable between 36.5-37 °C. The body is in a constant heat exchange with the environment to keep this value stable. For example, if the ambient temperature is lower than the body temperature, the person loses heat and if the ambient temperature is higher than the body temperature, the person gains heat. This situation affects the comfort level of a person with his environment. When there is a rise in the temperature, the negativities that occur in the thermal comfort level of the person are as follows;

In case the body temperature rises to 41°C;

It can lead to heat stroke caused by excessive sweating, heat fatigue, skin disorders, mood disorders, concentration disorders, hypersensitivity, fatigue with excessive sleepiness and anxiety. It can cause low blood pressure and dizziness, reduced body resistance, heat cramps due to excessive sweating and salt loss, decline in work efficiency, formation of itchy red spots, depression, excessive sensitivity, anxiety and impaired concentration.

At low temperatures, distraction and reduced physical and mental efficiency occur, the body’s internal temperature rises with withdrawal of blood to internal organs, and nutrition and energy need increases with mild chills and shivering. Consequently lethargy, drowsiness, irritability, inattentiveness can be observed.

We know that high and low temperatures have adverse effects on thermal comfort but the effect of low temperature on comfort is not as important as the effect of high temperature because the negative effects of low temperate can be significantly eliminated by increasing clothing diversification.

2.1.1.1.2 Ambient air speed

In order to provide thermal comfort and to remove harmful gases and gases from workplace environment, a suitable airflow speed should be provided. However, air speed in the environment should be well adjusted. Because the heat transfer between the body temperature and the ambient temperature is realized through air flow. Air generates heat losses from the body, if it is cool, and heat gains, if it is hot and this causes heat stresses (Altıntaş Esra., 2008).

Air flows should be taken into consideration for suitable internal thermal environment. Air flows can be felt as disturbing currents in the environments that are exposed to artificial ventilation. For this reason, ventilation systems can be avoided but in this case stagnant air can make people feel airless. The air speed should not exceed 0.3 m to 0.5 m. (Atmaca İ., Yiğit A., 2009).

2.1.1.1.3 Ambient relative humidity

There is a certain amount of moisture in the air. The amount of moisture in the air is expressed as absolute and relative humidity. Absolute humidity is the amount of water present in a unit volume of air. Relative humidity indicates the ratio of absolute humidity in saturated air at the same temperature. As relative humidity is also a measure of absorption of moisture by the air and it affects the amount of heat removed from the body through evaporation, it is very effective on thermal comfort. Relative humidity should not exceed the limit of 30%-80%. 50% is the most acceptable value of relative humidity (Atmaca İ., Yiğit A., 2009).

The average humidity does not have a significant impact on thermal comfort. However, while high relative humidity causes heaviness and low motivation in case of high ambient temperatures, it causes cold and chills in case of low ambient temperatures (Altıntaş Esra., 2008).

2.1.1.1.4 Average radiation temperature depending on the temperature of various surfaces in the environment

Hot surfaces in the environment lead to heat radiation. This heat will affect people in an environment in contact with the sun or when they are close to the heat-emitting object. The method to be protected from thermal radiation is to use a screen in the environment. The screen should be a heat resistant screen (Altıntaş Esra., 2008).

2.1.1.2 Personal Variables

2.1.1.2.1 Metabolic rate (Level of activity)

Our level of physical activity increases and our body generates heat, so our heat production occurs. In cold conditions, physical activity helps the person to get warm and in hot conditions it can increase the effect of heat on the person (Szokolay S., Auliciems A., 1997).

2.1.1.2.2 Clothing

Depending on the situation, clothing insulates us from the environment in lower or higher temperatures and can protect us from the reflected heat. The insulation value of the clothing is not obligatory in a given situation to estimate comfort temperature. Clothing is considered as a function of the climatic and social environment of a person and it is one of the factors that constitute desired conditions (Charles, K. E., 2003).

2.1.1.3 Other Factors

2.1.1.3.1 Age

As metabolism decreases with age, young people and old people do not always use the same preferences to achieve thermal comfort. The elderly usually prefer higher ambient temperature. But some studies on the subject revealed that the both groups sometimes choose the same conditions in the thermal environment of an office. The reason why the elderly prefer higher ambient temperature at home or in any environment can be explained by their lower activity levels (Szokolay S., Auliciems A., 1997).

2.1.1.3.2 Gender

Both women and men can be satisfied with the same thermal conditions. The ASHRAE standards indicate that women's skin temperature and evaporation losses are lower than men. This balance means lower metabolism rate for women. The reason why women dress more lightly than men can be seen as the main reason for their demand for higher temperature.

2.1.1.3.3 Adaptation to thermal environment

Some of the studies conducted on the subject proved that people cannot be adapted to warmer or colder climates. According to ASHRAE, for this reason the acknowledgement that same thermal conditions can be applied all over the world has been established. However, while determining ambient temperature preferred in comfort equation, a clo value that would comply with local dressing habits should be chosen. Thus, adaptation does not really affect user preferences on ambient temperature. However, people who lived or worked in warm climates previously can tolerate higher temperatures more easily to maintain the same level of performance, than those people from colder climates.

2.1.1.3.4 Seasonal and daily rhythms

According to ASHRAE, there is no difference between interior comfort conditions in summer and in winter. But, a person's thermal comfort preferences may change throughout a day, as his body has lower heat rhythm in the early hours of the morning and higher rhythm in the afternoon.

2.1.2 International Standards for Thermal Comfort

Practitioners refer to standards, such as ASHRAE Standard 55 - 2004 and ISO Standard 7730, in order to determine optimal thermal conditions. These standards are primarily based on mathematical models developed by Fanger and colleagues on the basis of laboratory studies.

ASHRAE is an organization devoted to the advancement of indoor environmental control technology in the heating, ventilation, and air conditioning (HVAC) industry. It was founded in 1894 to serve as a source of technical standards and guidelines, and since then it has grown into an international society that offers educational information and publications. ASHRAE also developed a code of ethics for HVAC professionals and provides a connection with the general public (ASHRAE Standard 55, 2004).

ASHRAE Standard 55 presents the thermal environmental conditions for human occupancy. The purpose of this standard is to specify the combination of indoor space environment and personal factors “that will produce thermal environmental conditions acceptable to 80% or more of the occupants within a space” (ASHRAE Standard 55, 2004). Among the more important goals of HVAC design engineers is maintaining thermal comfort for occupants of buildings or other enclosures. The year of publication of a particular standard is important for code compliance because these standards are periodically reviewed, revised, and published.

The heat balance model of the human body assumes that thermal sensation is influenced by four environmental factors—temperature, thermal radiation, humidity, and air speed—and two personal factors—activity and clothing—and Standard 55 is based on this model. The type of space determines the different requirements for those spaces, such as residences, commercial buildings, hotels and dormitories, school buildings, hospitals etc.

The International Standards Organization (ISO) was set up in 1947 and has over 130 member countries. ISO Standards consist of agreed rules and a system of voting by experts from participating countries (Olesen and Parsons, 2002). The standards for thermal comfort, the most important of which being ISO 7730, are set by ISO/TC 159 SC5 WG1. ISO Standards should be valid, reliable, usable and with sufficient scope for practical application. The existing Thermal Comfort Standard EN ISO 7730 is considered in terms of these criteria, and was proposed and supported by a document that explains the requirement, rationale and scope. The standard describes the PMV and PPD indices, exactly as described by Fanger, and specifies acceptable conditions for thermal comfort (Olesen and Parsons, 2002).

2.1.2.1 Standards directly related to thermal comfort and thermal environment:

ASHRAE Standard 55: Thermal environmental conditions for human use

ISO 7730: Determination of moderate thermal environments PMV and PPD indices and thermal comfort conditions (EN ISO 7730). EN ISO 7730 are the basic standards to decide thermal comfort conditions.

ISO 7993: Analytic explanation and determination of thermal stress through the use of warm environments necessary sweat rate calculation

ISO 10551: Evaluation of thermal environmental effect through the use of thermal environmental ergonomics personal judgment scale

2.1.2.2 Standards for the design of interior environment

ASHRAE 62: Ventilation for acceptable interior air quality

CR 1752: Ventilation for buildings – Design criteria for the design of interior environment

2.1.2.3 Standards for the measurement of interior thermal environment parameters

ASHRAE 55: Thermal environmental conditions for human use.

ASHRAE 113: Test method for room air diffusion

ISO 7726: Thermal environmental ergonomics – tools for the measurement of physical quantities.

2.1.2.4 Standards determining personal factors

ISO 8996: Determination of Ergonomics – metabolic heat production

ISO 9920: Thermal insulation and estimating evaporation resistance of a group of outfits

ISO 7730 and ISO 10551 Standards were used as reference to calculate thermal comfort level and to interpret these values

2.1.2.5 ASHRAE 55: Thermal Environmental Conditions for Human Use

It deals with the combinations of personal and environmental conditions of an interior space that would produce acceptable environmental conditions for 80% of the users, or higher, in a standard area. The purpose of the standard is to determine the components of personal and environmental conditions of an interior space providing acceptable thermal environmental conditions for 80% of the users, or higher. The environmental factors of the standard are humidity, air speed and thermal radiation while personal factors are activity and clothing. As space comfort is affected by all the factors, it emphasizes that the criteria stated in the standard need to be used in a combination.

According to the standard, acceptable thermal environmental conditions can be provided with periods not less than 15 minutes in interior spaces for human use in atmospheric pressure equal to altitudes up to 3000 m.

The standard does not include chemical or biological contaminants that would reduce air quality or negatively affect comfort or human health and non-thermal environmental factors such as lighting emitting artificial heat.

2.1.2.6 ASHRAE 62: Ventilation for Acceptable Indoor Air Quality

The purpose of the standard is to determine indoor air quality which is acceptable for human use and designed to avoid unhealthy effects and also minimum ventilation rates.

The scope of the standard is as follows:

The standard applies to all interior spaces that people use and its requirements represent a greater ventilation amount than the ASHRAE 62 standard.

The standard defines requirements for ventilation and air conditioning systems and provides guidance to design such systems.

Ventilation rate procedure: Acceptable air quality is achieved through ventilation of the space where air quality and quantity is determined. Indoor air quality procedure: Acceptable air quality is achieved through controlling known pollutants in the area.

2.1.3 Regulations

The purpose of the Regulation on Heat Isolation in Buildings issued by the Ministry of Public Works and Housing is to regulate procedures and principles related to reducing heat losses, providing energy savings, and implementations.

This regulation applies to all buildings in residential areas including municipalities under the Municipal Act dated 10.07.2004 and numbered 5216.

It states that buildings should be isolated in terms of heat losses according to environmental conditions and needs.

	U_{Wall} (W/m²K)	$U_{Ceiling}$ (W/m²K)	U_{Floor} (W/m²K)	U_{Window} (W/m²K)
1st Region	0,70	0,45	0,70	2,4
2st Region	0,60	0,40	0,60	2,4
3st Region	0,50	0,30	0,45	2,4
4st Region	0,40	0,25	0,40	2,4

Table 2. U values recommended as the maximum values by regions (İ. Güneş, 2012)

	Type of the building to be heated	Temperature (°C)
1	Houses	19
2	Administration buildings	
3	Business and service buildings	
4	Hotels, motels and restaurants	20
5	Education buildings	
6	Theatres and concert halls	
7	Barracks	
8	Prisons and detention houses	
9	Museums and galleries	
10	Airports	
11	Hospitals	22
12	Swimming pools	26
13	Manufacturing and atelier spaces	16

Table 2.1 Type of the building to be heated (The Ministry of Public Works,2008)

Monthly average internal temperature values [0i (°C)] to be used in TS 825 calculations for buildings used for different purposes are shown in the Table 2.1.

2.2 Environmental Issues

The Industrial Revolution is an important turning point for the world's ecology and people's relationship with the environment and it affected every aspect of human life and life style. Industrial production emerged with new inventions and the discovery of steam engine.

As waste products came to the limits of environmental capacity a result of humankind's consuming natural resources which they deemed to be an unlimited supply, with developing technologies, and its adverse effects were begun to be experienced, it was understood that it could not continue that way.

According to Figure 2.1, it is expected that the share of oil, which was 37% in 2005, will reduce to 31% in 2020; the share of electricity energy will increase to 24% from 19%; by the same years, the total share of coal will increase to 24% from 21%; the share of natural gas will increase to 14% from 11%; and the share of renewable energy sources will reduce to 5% from 10% in Turkey (The Ministry of Energy and Natural Resources, 2006).

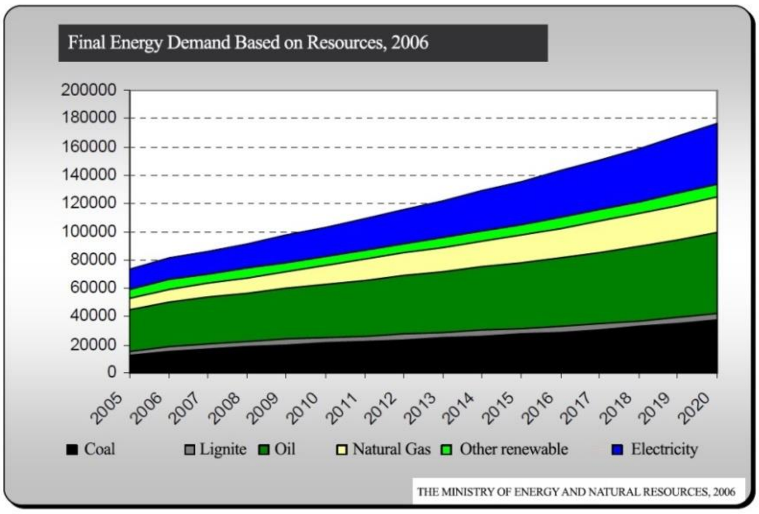


Figure 2.1. Final Energy Demand Based on Resources, 2005-2020 (The Ministry of Energy and Natural Resources, 2006)

Climate change in IPCC (Intergovernmental Panel on Climate Change) usage refers to *"a change in the state of the climate that persists for an extended* *period due to natural variability or as a result of human activity"* (Alley R.,Berntsen T. et. al). Climate change in UNFCCC (United Nations Framework Convention on Climate Change) refers to "*a change of climate that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and that is in addition to natural climate variability observed over comparable time periods*"(Alley R., Berntsen T. et. al). Human-induced climate change and economic activities are in close relationship. Climate change, one of the environmental problems caused by human activities in order to reach an adequate level of income for the purpose of increasing social welfare, also has various effects on economy and environment. In the process of generating a revenue increase, we encounter situations that contribute negatively to climate change such as industrialization and increased energy use.

Humankind's desire to increase level of welfare increased the need for energy and caused changes in the amount of greenhouse gases by using coal, oil, fossil fuels, as an outcome of industrial revolution, in an unplanned manner and disrupted the natural balance. The ecological problems experienced in 1970s appear before us today as human-induced global warming and related climate change issues (DoğanY.,2008). Fossil-based energy use, economic growth, industrialization, population growth etc. are among the leading factors that cause human-induced climate change. Thus, fossil fuels such as coal, oil and natural gas are important sources of the issue of climate change. Increasing demand for energy comes from worldwide economic growth and development. Global total primary energy supply (TPES) increased by almost 150% between 1971 and 2013 mainly relying on fossil fuels (Ahmed Zain A. , Akbari H. et al).

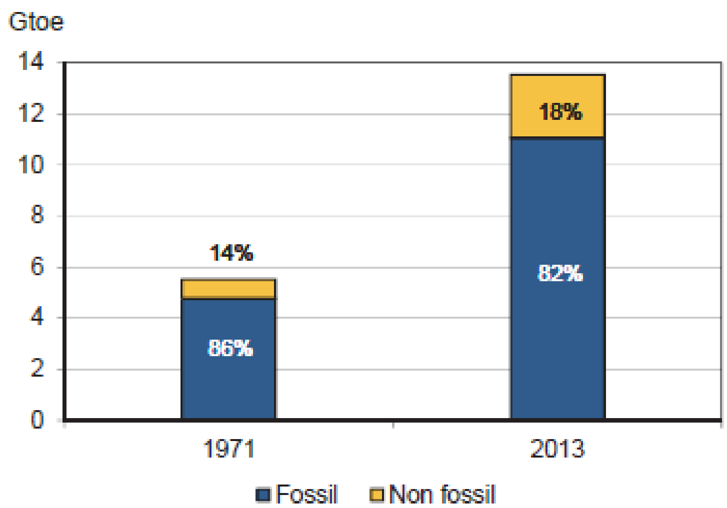


Figure 2.2. World Primary Energy Supply (IEA, 2015)

The growing world energy demand from fossil fuels plays a key role in the upward trend in CO_2 emissions (Figure 2.2). Annual CO_2 emissions from fuel combustion have dramatically increased since the Industrial Revolution, from near zero to over 32 $GtCO_2$ in 2013 (Ahmed Zain A., Akbari H. et al).

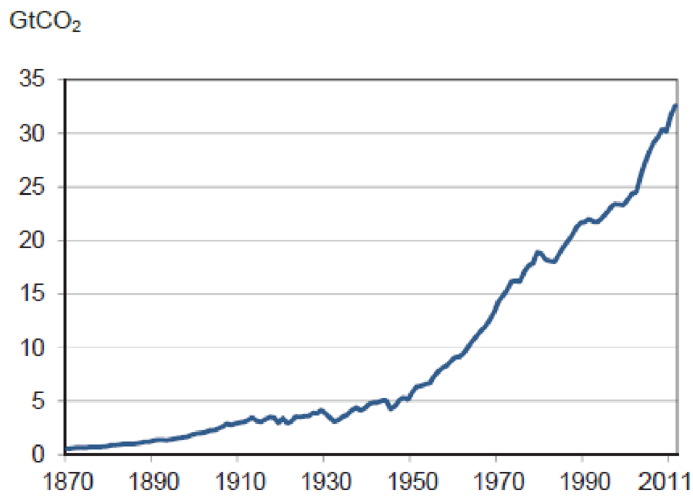


Figure 2.3. Trend in CO_2 Emissions From Fossil Fuel Combustion (IEA, 2015)

A significant amount of carbon dioxide emissions is released as a result of combustion of energy sources and as seen in Figure 2.3 it causes ever increasing quantities of carbon dioxide, one of the most effective greenhouses gases. This situation causes disturbance of the balance of greenhouse gases in the atmosphere and restricts atmospheric permeability even more. Consequently, the increase of greenhouse gases in the atmosphere causes climate change by creating natural greenhouse effect and human activities that cause warming of the Earth's surface disturb natural balance.

The IPCC fourth assessment report, global greenhouse gas emissions have increased by 70% due to human activities between 1970 and 2004 (IPCC, 2007).

According to the greenhouse theory, the increase in greenhouse gases in the atmosphere due to human activities changes climate by creating a natural greenhouse effect. This situation leads to the warming of the earth. The greenhouse gases are water vapor, carbon dioxide (CO2), methane (CH4), nitrogen oxide (N2O) and ozone (O3) gases and fleur compounds such as hydro fluorocarbon (HFC), perfluorocarbon (PFC), sulphur hexafluoride (SF6) that are emitted as a result of industrial production. Greenhouse gases in the atmosphere reflect some of the heat radiation back to the Earth by acting as a mirror. Greenhouse gases like carbon dioxide, which have high concentrations in the atmosphere, return to the earth as heat energy. Although it has a small share in the atmosphere with a percentage of 0.03%, carbon dioxide contributes a great deal, among other greenhouse gases, to emergence of greenhouse effect due to its 100-year retention period.

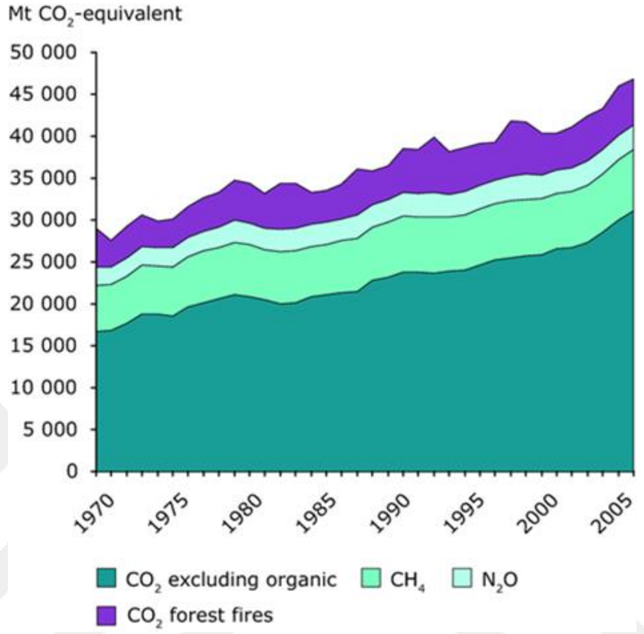


Figure 2.4. Global Greenhouse Gas Emissions by Gas Type, 1970–2005 (IEA, 2015)

Global warming, revealed to be human-induced, and the related climate change environmental problem have been reaching a life-threatening scale. As it was realized that the mankind's desire to satisfy their own needs in an unlimited way by disturbing the ecological balance leads to consequences threatening the future, the governments began to work to take necessary measures. Upon destruction of the ecological balance as a result of the effects of climate change, many changes have been observed such as reduction in natural diversity, temperature increases, droughts, severe water shortages, forest losses, changeable and rising sea levels, severe weather conditions and resulting weather changes. These changes, which occurred in a global scale and reached a level of threat to the natural environment and the natural habitat, encouraged many scientists to make scientific researches and many environmentalist groups and non-governmental organizations to take important steps both domestically and internationally. "Intergovernmental Panel on Climate Change (IPCC)", which was established in 1988 with the support of the United Nations Environment

Program and the World Meteorological Organization, is the first step in the initiation of this process (Karakaya E., 2011). Individuals, societies and states attempt to decrease the emission of greenhouse gases through global initiatives such as Kyoto protocol, develop adaptation strategies to climate change and investigate the ways how to take advantage of the changes that occur as a result of global climate change in the most efficient way. In order to prevent these negativities, IPCC reports that the developed countries should reduce their emissions until 2020 below 25% to 40% of their emission rates in 1990 to restrict global temperature increase to 2-point above the pre-industrial level. These rates were determined as 15% to 30% for the developing countries. It is necessary to determine greenhouse gas emissions and their origins and introduce options that will not limit economic growth (Özçağ M., 2011).

Emission by sector

After the Industrial Revolution, it was entered to a phase of rapid growth and reconstruction activities after the World War II, along with the expansion of the world economy, led to increases in the required amounts of energy (Özçağ M., 2011). Turkey's energy demand has been increasing since the early 1980s. Especially developments in the economy and rapid population growth increased energy needs, and insufficient investments to support energy efficiency for increased energy needs led to overconsumption of oil and natural gas resources. Turkey, which has a consumption of 25.793 million tons of oil equivalent (MTOE) in the building industry in 2001, is the second largest consumer and its oil consumption is projected to reach 41.7 MTOE in 2020. The considerable increase in the demand for new buildings due to rapid population growth can be shown as the main reason for this rapid increase in the oil consumption. Another reason is the insufficient insulation of existing buildings or no insulation at all in terms of energy conservation due to uncontrolled urbanization and construction activities (Yıldız Y., Durmuş A.Z., 2011). While rapid consumption of resources leads countries to investigate alternative energy resources on the one hand, it also requires them to focus on energy efficiency that will allow more efficient use of available resources.

It is reported in many sources that buildings in the developed countries and the developing countries are responsible for more than 40% of global energy use. Considering the fact that in Turkey, industry is responsible for 40% of total energy consumption and buildings are responsible for 32%, it will be beneficial if studies for efficiency is conducted primarily on housing and industry (TOBB, 2011).

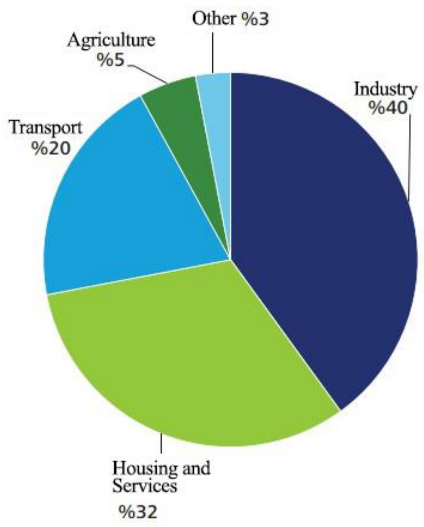


Figure 2.5. Distribution of Total Energy Consumption in Turkey by Sectors

(TOBB, 2011)

Greenhouse gas emissions due to excessive fossil fuel consumption, which has begun with industrialization, leads to severe climatic events by warming up the Earth and make environment and sustainability issues one of the most important items on the agenda. Given the growth in the construction sector, whose economy is in transition worldwide, and the inefficiency of existing building stocks, it is emphasized by sources that the greenhouse gas emissions will be doubled in the next 20 years.

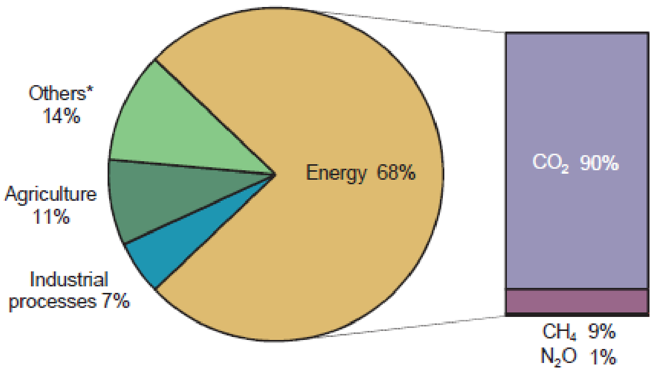


Figure 2.6. Energy emissions, mostly CO_2, account for the largest share of global GHG emissions (IEA, 2015)

Considering natural resource consumption, greenhouse gas emissions due to high fuel and electricity consumption, waste products generated during the production of construction materials, construction of buildings and demolition of structures, the construction and construction materials industries are among the sectors with the most impact on the environment and climate change. Construction industry, which can use technology in many areas including building envelope and components, heating and cooling systems, water heating, lighting systems, products for consumers, office and service applications, introduce us new building materials each passing day with growing consumer demand brought about by capitalism and fashion sense.

Emissions due to uncontrolled productions along with ever increasing product diversity in the construction industry have reached a global threat scale. In order to reduce greenhouse gas emissions, it is necessary to fight against emissions originated from the construction sector and greenhouse gas emissions should be reduced to avoid the worst-case scenarios of climate change.

One-third of global greenhouse gas emissions and 30% of carbon emissions originate from the construction sector (IEA, 2013).

The degree of energy efficiency of a building depends on many factors. Local climate, building design, construction method and materials, heating used in buildings, cooling, ventilation, hot water systems and household appliances are among the factors that determine efficiency criteria. As 80% of the total energy a building uses in the entire life cycle originates from the use of the building, it would provide more effective results to improve energy efficiency in buildings by taking into account the entire life cycle. It was revealed in the studies and researches conducted that through insulation projects carried out in buildings, the heat losses can be avoided by 20% through roof insulation; by 15% through exterior wall insulation (sheathing); by 15% through door-window insulation; and by 10% if sealing measures are taken. Considering that 72% of the energy is used for heating purposes in buildings, efficiency in heating systems will directly contribute greatly to the concept of energy efficiency in buildings.

Construction and construction materials industry are among the sectors with the most significant effects on the environment and climate change throughout the entire life-cycle, both due to their scale and resulting structures are long lived. While the harmonization with the EU acquis through the realization of relevant legislations in Turkey required manufacturers to develop appropriate products in compliance with these legislations and perform manufacturing operations accordingly, it also meant that companies are required to obtain necessary permits/documents/certifications by performing necessary changes in their products and processes according to the relevant legal requirements to continue their exports to the EU.

In a report prepared by the European Construction Technology Platform, it is indicated that about 40% of the total consumption of natural resources is made by the construction industry. In the process of extracting these inputs from the nature, many adverse effects on the ecological balance may occur. As many building materials sub-sectors (cement, iron-steel, lime, brick, glass, ceramics, etc.) are energy intensive, they use a high rate of fuel and electricity and as a result lead to the emergence of greenhouse gases, mainly CO2. In addition to resource use, a great amount of waste is formed during the construction and destruction of buildings. In the same repot, it was reported that the waste generated during the construction and destruction of buildings represents 22% of the total waste and only a very small part of the resulting waste can be used again (European Construction Technology Platform, 2015).

The environmental impact of building materials does not only originate from energy intensity of their production. Building materials have serious environmental impacts throughout their entire life cycle including transportation of these materials to the construction site, their implementation, their use and disposal at the end of their lifetime. Thus, developing products during the design process by taking into account the entire life cycle costs and impacts of materials, and using sustainable products in buildings are essential.

Life Cycle Stage	Impact Fields and Possible Strategies
Design	- Development of products providing energy efficiency in buildings, taking into account the entire life cycle costs and carbon footprints of materials - Design of sustainable materials for zero-energy or passive houses
Production	- Protection of natural resources in production (water, green spaces, etc.) - Reduction of use of resources in production (raw materials, water, energy, etc.) and reclamation of fields where raw materials are extracted (e.g., quarries, reservoirs, etc.) - Reduction of CO2 emission in production processes through increasing energy efficiency

Production	- Use of environmentally less damaging alternative fuels - Encouraging the use of renewable energy resources such as Sun and wind - Waste management
Logistics	- Utilizing local production options to minimize the energy used during logistics - Development of lighter products to reduce logistics costs - Development of recyclable packaging approaches
Application	Development of products providing easy application and increased occupational safety Zero-waste construction and reclamation of construction fields
Use	- Preference of products reducing energy use in buildings - Development of products using renewable energy sources - Reduction of maintenance and repair needs through developing durable and long lived products - Development of products meeting health, hygiene and safety expectations (e.g., reduction of volatile organic compounds)
Recycle	- Ensuring the reuse of materials emerging during the destruction of buildings through recycling.

Table 2.2 Construction Materials Life Cycle Perspective (Turkey Construction Materials Industry Report, 2011)

Taking into account the entire life cycle of construction materials (design, manufacturing, logistics, application, use and recycling) in the construction sector helps to identify new innovation opportunities that would benefit not only the production processes but also the entire lifetime of these products. Indeed, while calculating carbon footprints and energy efficiencies of products, not only their production phase but also their use and disposal are taken into account. Life cycle perspective also benefits the elimination of the issue of high initial investment costs, which is one of the factors making innovations difficult in the construction industry and construction materials. As a result of innovations, if the gains obtained through the entire life cycle of construction materials are correctly pictured, it will also justify assessment of initial investment costs. For example, development of more easily applicable materials will ensure shortening of the construction periods; new approaches providing energy efficiency will make it possible to reduce energy costs; smart materials will allow the products to be preferred by customers with their production costs and safety advantages.

Information that will enable making decisions which address the environmental impacts of buildings and other construction works are in demand by manufacturers of construction products, designers, users and owners of buildings, and others active in the building and construction sector. An increasingly common solution is to create ISO Type III environmental product declarations (EPD) providing quantified environmental data for predetermined indicators using an independently verified life cycle assessment (LCA).

Life cycle assessment (LCA) is a methodology for assessing the environmental aspects. LCA enables the estimation of the cumulative environmental impacts resulting from all stages in the product life cycle, often including impacts not considered in more traditional analyses (e.g., raw material extraction, material transportation, ultimate product disposal, etc.).

By including the impacts throughout the product life cycle, LCA provides a comprehensive view of the environmental aspects of the product or process and a more accurate picture of the true environmental trade-offs in product and process selection.

The LCA process is a systematic, phased approach and consists of four components (Ecobilan,2008) :

1. Goal Definition and Scoping - the product, process or activity are defines and describes. Identify the system boundaries and environmental effects to be reviewed for the assessment and establish the context in which the assessment is to be made.

2. Inventory Analysis - Energy, water and materials usage and environmental releases are identify and quantify (e.g., air emissions, solid waste disposal, waste water discharges).

3. Impact Assessment - Assess the potential human and ecological effects which are energy, water, and material usage and the environmental releases identified in the inventory analysis.

4. Interpretation - Evaluate the results of the inventory analysis. And impact assessment to select the preferred product, process or service.

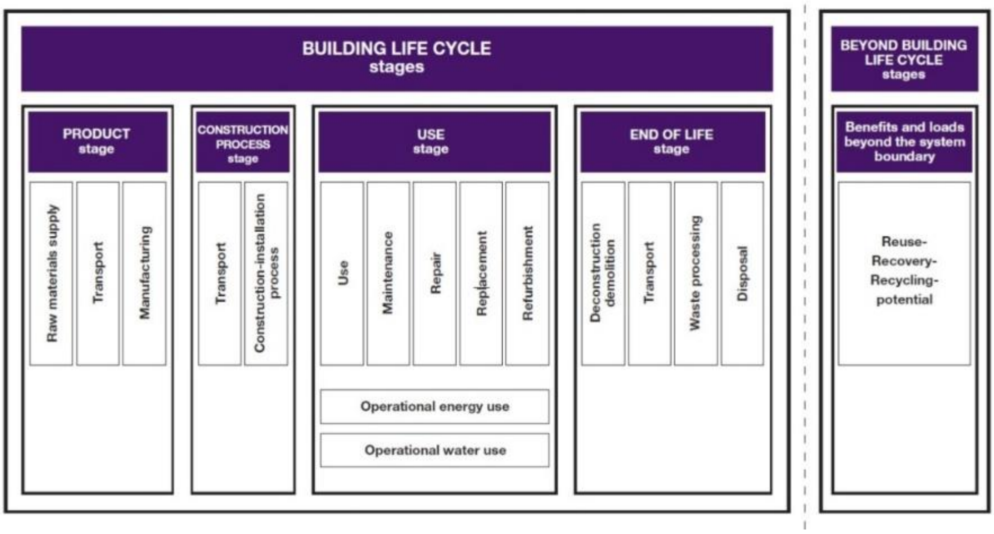


Table 2.3 Building life cycle stages (BRE, 2014)

Product-stage is one of the carbon emission calculation stages. It depends on the quantity of the materials constituting a building and is the second most significant area of carbon emissions in the life cycle of a building (after operational emissions). These carbon emissions are associated with energy consumption (embodied energy) and chemical processes during the extraction, manufacture, transportation, assembly, replacement and deconstruction of construction materials or products. Emissions from materials or products manufactured cradle to-gate are associated with the production of construction products/materials. The emissions arise from the energy used in extracting materials, refining them (i.e. primary manufacture), transporting and processing them to create a finished product (i.e. secondary manufacture). The CO_2 emissions resulting from these processes are often referred to as embodied carbon.

The calculation requires a given building element to be broken down into its components for which embodied carbon factors need to be sourced. Factors representing the embodied carbon for construction materials are being researched and published, usually in the following format: kg CO_2 per kg material. There is also a range of publications where average factors have been compiled into one database. Some manufacturers have included embodied carbon factors on product datasheets or in Environmental Product Declarations (EPDs) in response to market demand (RICS QS & Construction Standards,2012).

EPDs present quantified environmental information, found on the back of food packets, on the life cycle of a product, i.e. the environmental impact caused throughout its life. In Europe, EPDs for construction products are derived according to requirements of EN 15804, which designates the sustainability of construction work, enviromental product declarations, and core rules for the product category of construction products. EN 15804 is part of a suite of standards for the assesment of the sustainability of construction works at both the product and building levels (BRE,2014). It is a system providing promotion of environmentally friendly products and based on a voluntary basis. The label is given to the products that meet the ecological requirements from product development to selection of raw materials, from manufacturing to distribution, from consumption to disposal by the competent authorities.

Standards, labels, product specifications, collectively named sustainability information tools specify products in terms of their environmental and social characteristics and provide end users with the information about sustainability of the product with the obtained values. They help developing more sustainable products with the information obtained about the environmental and social processes of the products (BRE, 2014).

The information source for the life cycle of the product has benefits in terms of increase of efficiency, reduction of production costs, manageability of the chain, a relationship with the suppliers based on trust, brand and environmental and social developments as well as reputation and reliability of the company.

2.3 Budget Cost

Energy is an important factor for social and economic developments of societies. Energy saving has become an important part of national energy strategies with the energy crisis that occurred in 1973. Increase in population rate and urbanization increase energy consumption. While building sector is the most energy-consuming sector, it is responsible for one-third of ultimate energy consumption and one-third of global carbon emissions ("Transition to Sustainable Buildings Strategies and Opportunities to 2050" International Energy Agency).

In the report of Panel on Climate Change (IPCC) 2007, it was indicated that the construction sector has a great potential to reduce greenhouse gas emissions at low cost. According to the report, the greenhouse gas emissions of new and existing buildings can be reduced by 30% to 50% with current technology without increasing investment costs.

Growing population and changing demographic needs increase housing needs even more each passing day. According to the GYODER reports, annual housing need is about 600 thousands and the number of residences that should be constructed by 2023 is 7,560,000 units. Newly constructed buildings' meeting energy efficiency criteria is of great importance. According to the UNEP report, it was stated that reduction energy consumption at low cost is possible. Therefore, if a path with a low carbon emission is followed, a 25% energy reduction can be achieved. While designing new buildings, studies about the amount of energy to be spent per square meter for different building typologies, greenhouse emissions and maximum cost per square meter should be conducted. Design teams should carry out their designs integrated within the framework of these limit values, independently from other criteria. In order to achieve this purpose, LCCA (life cycle cost analysis) should be carried out.

In Figure 2.7 we see that buildings spend energy for heating most.

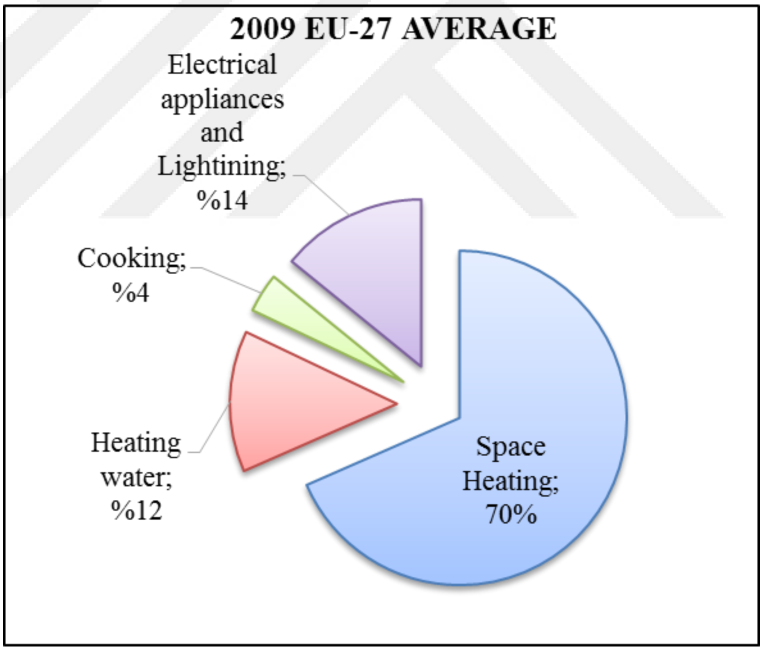


Figure 2.7. Percent of the energy consumed

Heat losses can be reduced in many ways. One of them is exterior wall insulation application. Heating and cooling costs can be reduced by 17% by 2050 through thermal improvements on the exterior walls of buildings. This 17% reduction equals to 3.2 Gt CO_2 (gigaton). Therefore, it is important to improve the existing building stock (Transition to Sustainable Buildings Strategies and Opportunities to 2050" International Energy Agency).

As in all manufacturing fields, achievement of the lowest overall cost—including both the initial investment cost and the life-cycle cost—is an important consideration in building construction. Life-cycle costing (LCC) is a concept which aims to optimise the total costs required to both build and operate a project throughout its lifetime (Bull, 1993, Kleyner and Sandborn, 2007). Studies have equally shown that with the commercial building industry under heavy financial stress, more architects and engineers are increasingly looking to life-cycle cost analyses internationally to help reduce costs as much as possible (Kirk and Dell'Isola, 1995, Dunk, 2004). However, institutions of higher education, as well as an increasing number of architectural offices and construction firms, continue to produce or support managers who lack awareness of the importance of LCC (Kayaş E., 2009).

While designing new buildings, the amount of energy to be spent per square meter for different building typologies, greenhouse emissions and maximum cost per square meter should be given. Design teams should carry out their designs integrated within the framework of these limit values, independently from other criteria.While getting informed of environmental performances and energy values of insulation materials, it may be possible to have the opportunity to evaluate cost analyses together with these features. There is not an adequate inventory to conduct LCC in Turkey.

3 THERMAL, ENVIRONMENTAL, BUDGET CONSTRAINTS RELATED WITH ENVELOPE DETAILS FOR A CASE STUDY: Sardes Hospital

The environmental, thermal and budget issues on the wall layer of the selected hospital structure were examined.

3.1 Sardes Hospital

The architectural design was prepared by the Ulusal Yatırım company and the attached interior design projects were introduced as proposed projects.

3.1.1 Introduction

Increased expectations regarding comfort and health issues and demand for better living standards, the fact that hospitals are different with many features in terms of regular comfort applications have made heating and cooling applications more specific. International standards require increased comfort conditions and continuously better comfort conditions. Hospitals are places where people seek healing and in this regard air conditioning systems for hospitals are naturally beyond merely a demand for comfort.

Construction of Sardes Hospital with a 14578 m² gross construction area has begun in Çiğli district of İzmir province in 2014. Improvements on the exterior wall of the hospital were elaborated in the scope of the thesis.

The hospital consists of 74 patient rooms including 200 beds, 30 intensive care unit, 35 outpatient clinics, 4 maternity units, tube baby unit and 8 operating rooms.

3.1.2 Description of Building Sardes Hospital in Çiğli

1. Building Name	Sardes Private Health Services
2. Built Year	2014
3. Building Feature	Hospital
4. Land Area	5299 m²
5. Total Construction Area	14578 m²
6. Floor Number	7

Table 3. Building Information

Figure 3.1.Patient Room

The 0.20 m wall structure layers were from outside to inside 0.030 m concrete plaster, 0.03 m extruded polystyrene and 0.02 m plaster. The U-value of the structure was 0.068 W/m2K. The original windows had double glazing.

Figure 3.2 Patient Room Corridor and Hospital Entrance

3.1.3 Technical Projects of The Sardes Hospital

In this section inculdes technical project about Sardes Hospital. These are; Site Plan, Floor Plans and Sections.

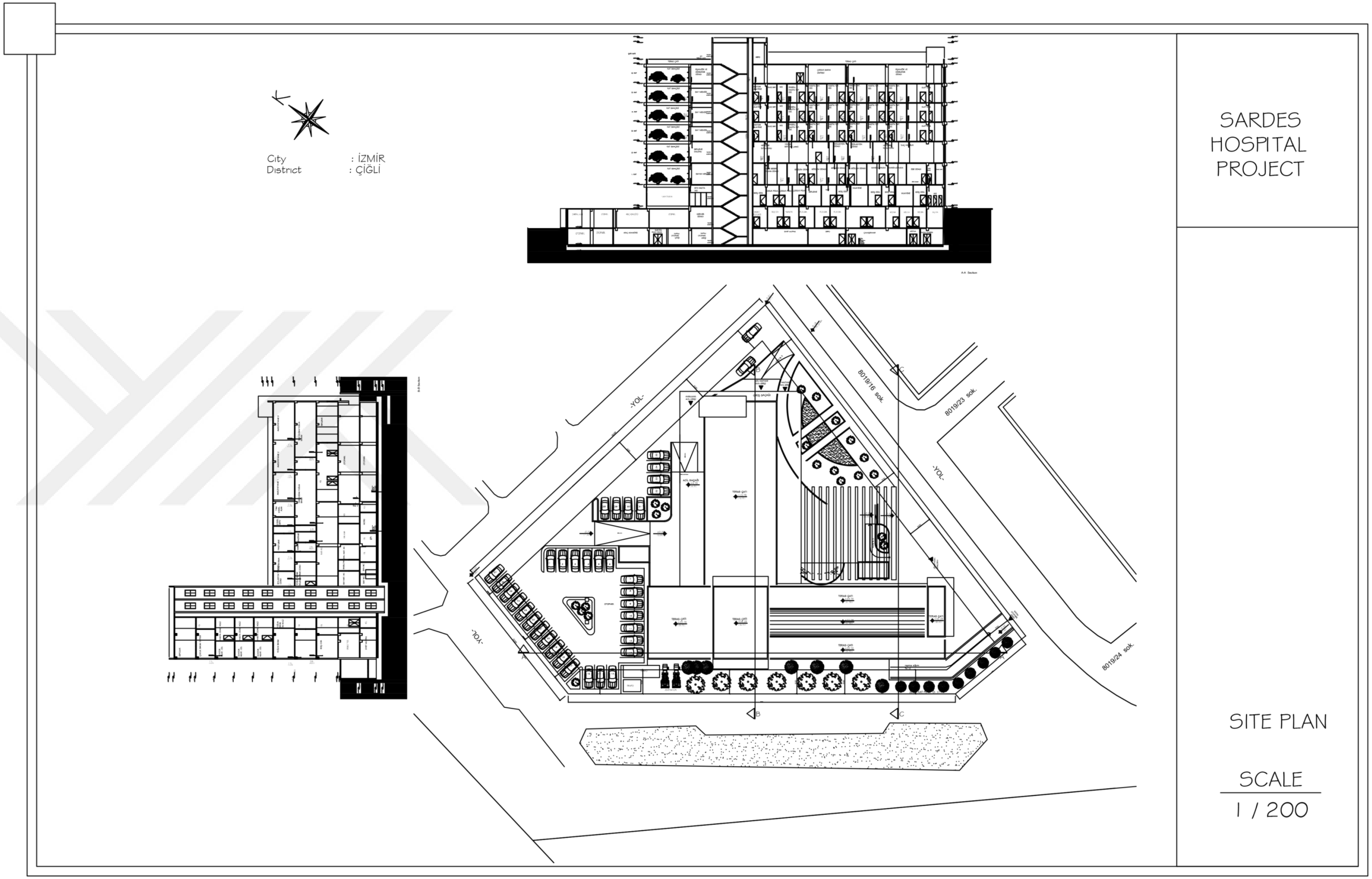


Figure 3.3 Site Plan

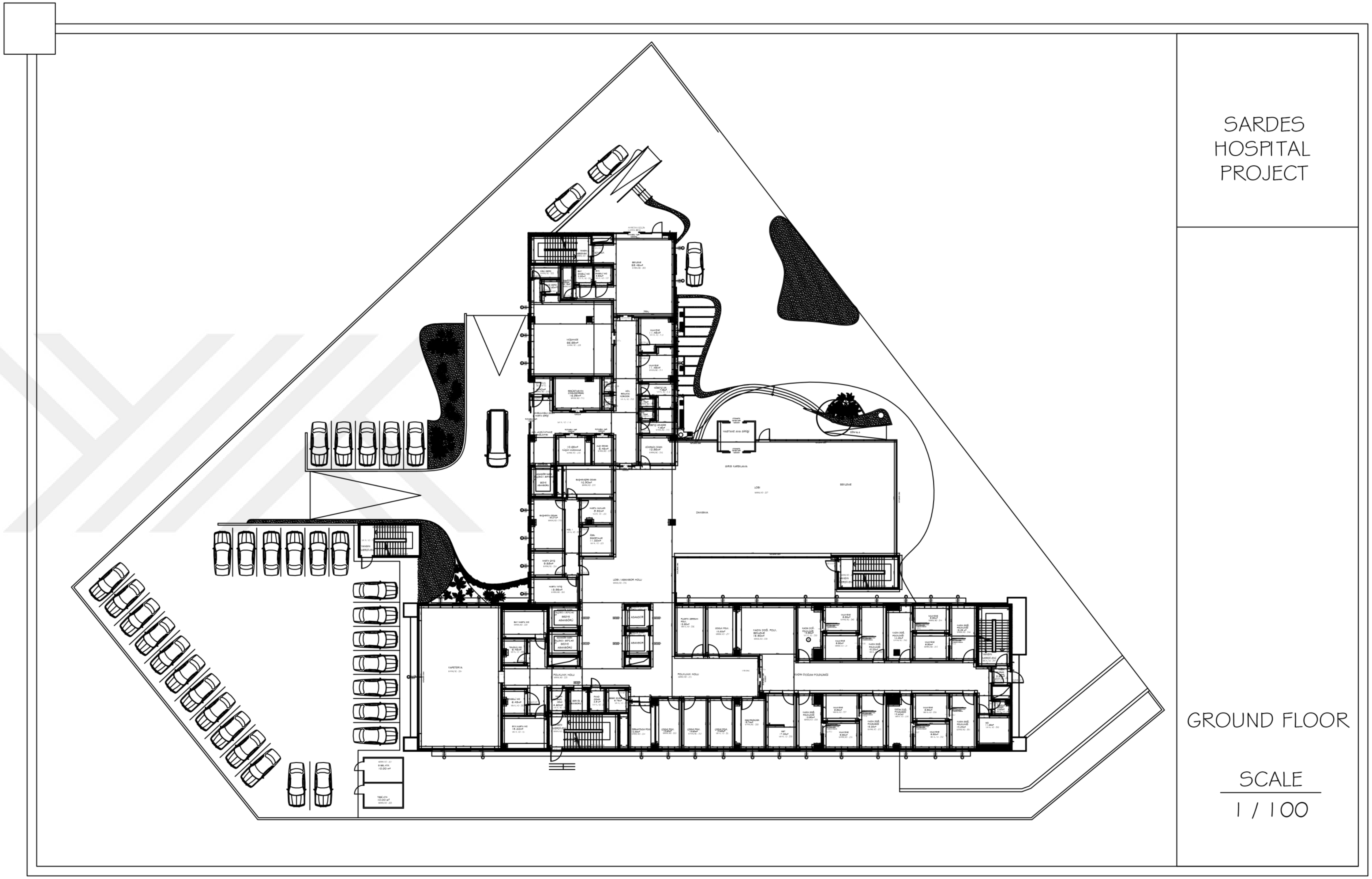


Figure 3.4 Ground Floor Plan

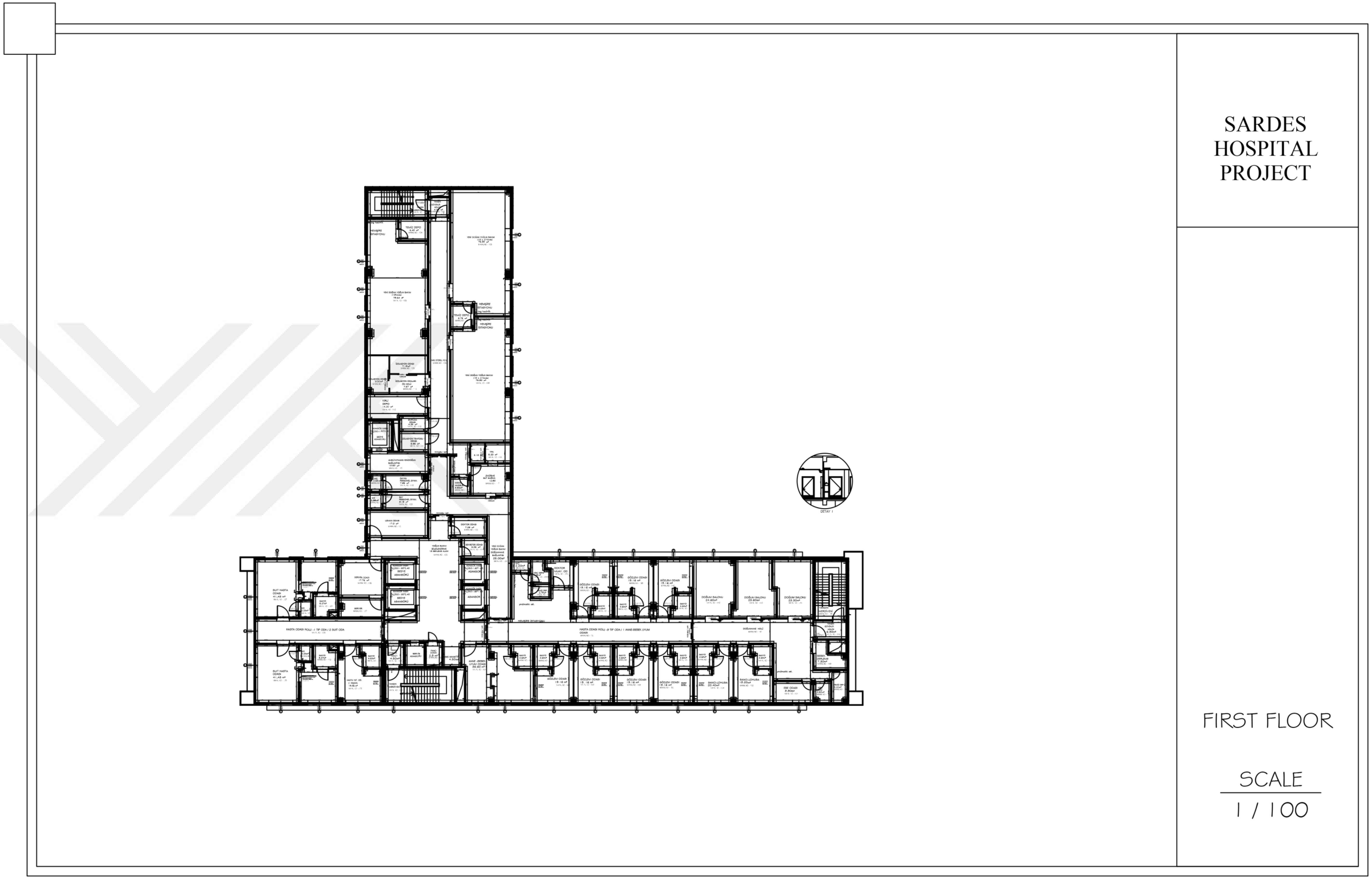


Figure 3.5 First Floor Plan

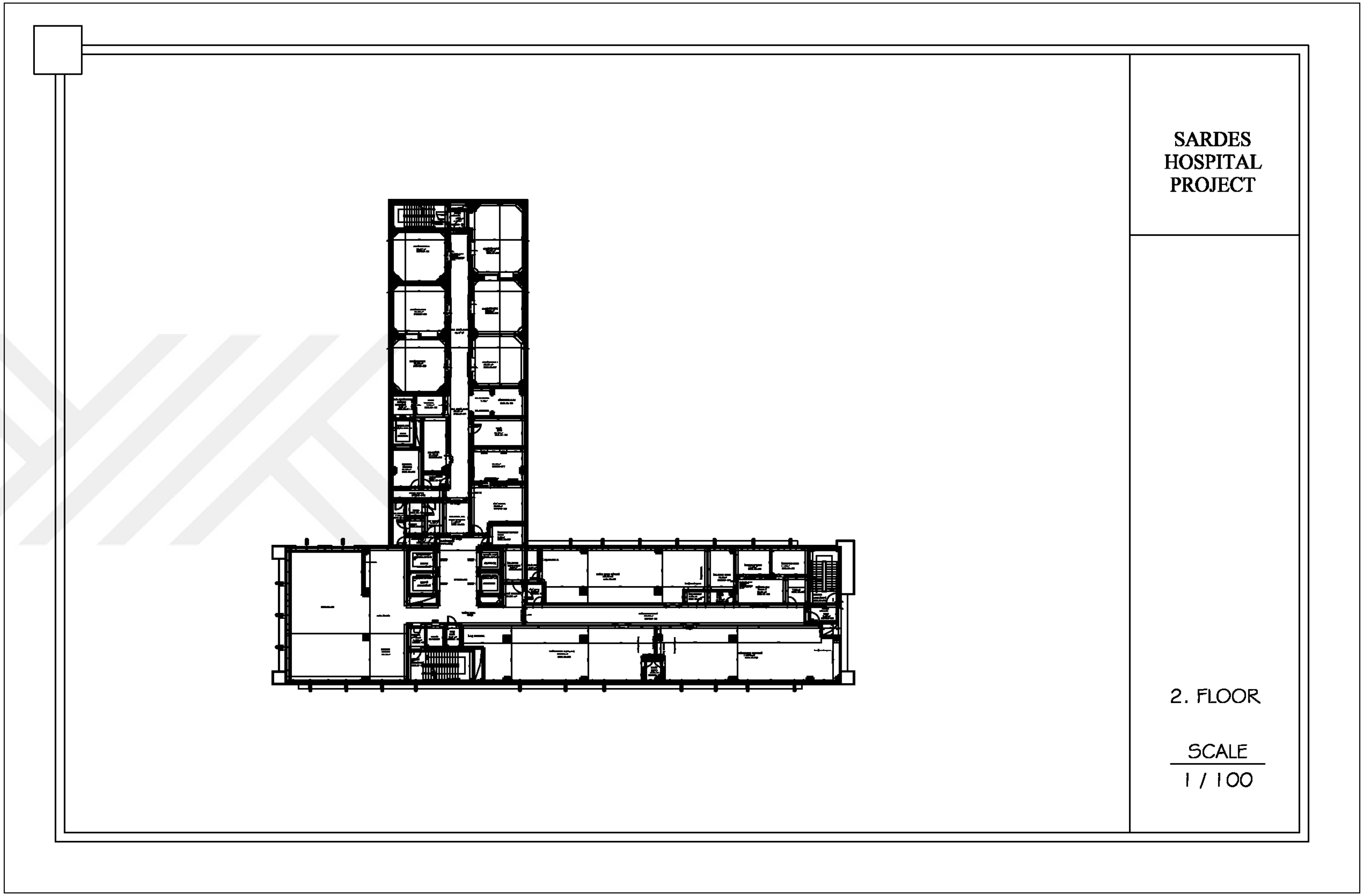


Figure 3.6 Second Floor Plan

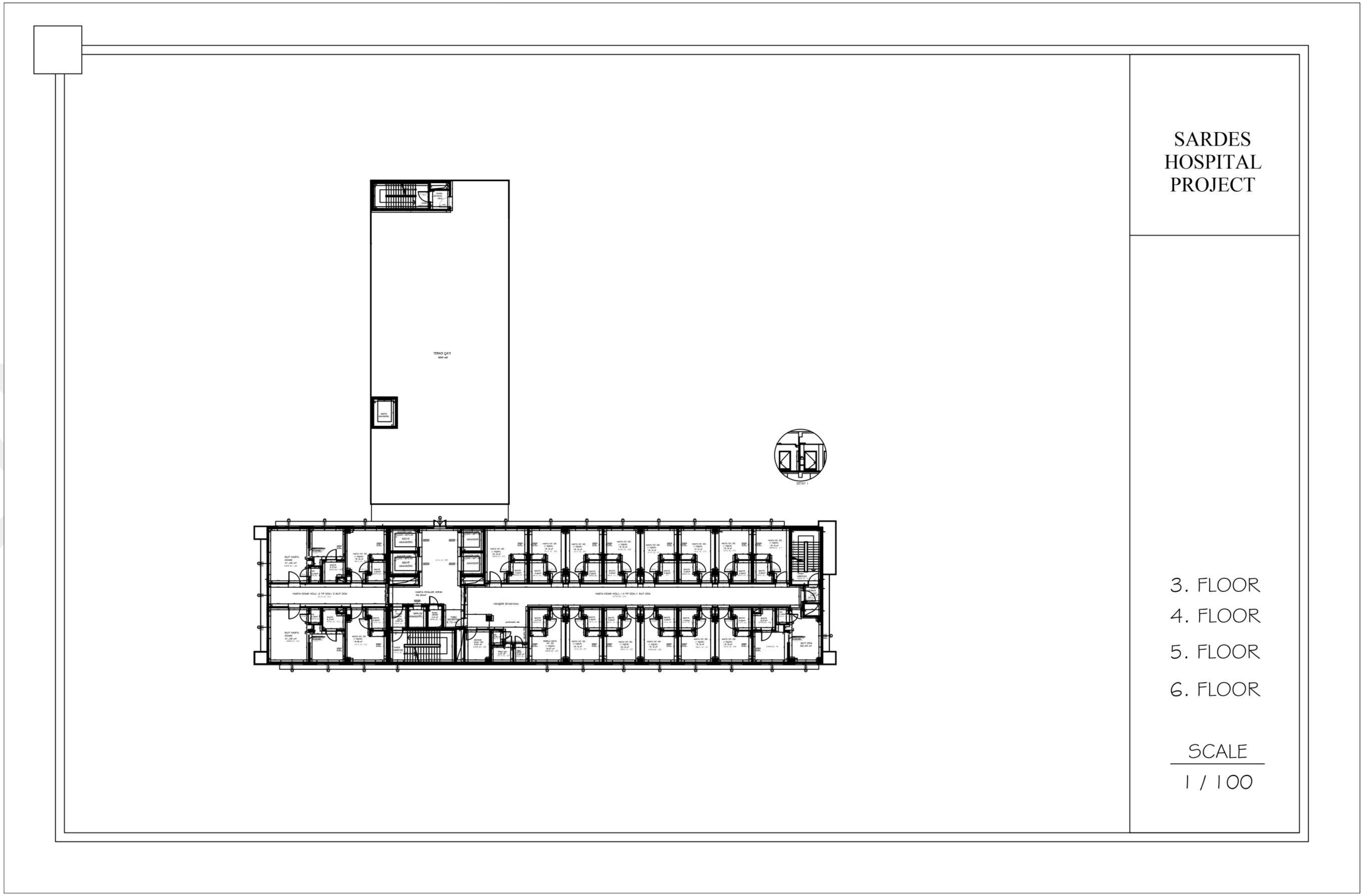


Figure 3.7 3-4-5 and 6 Floor Plans

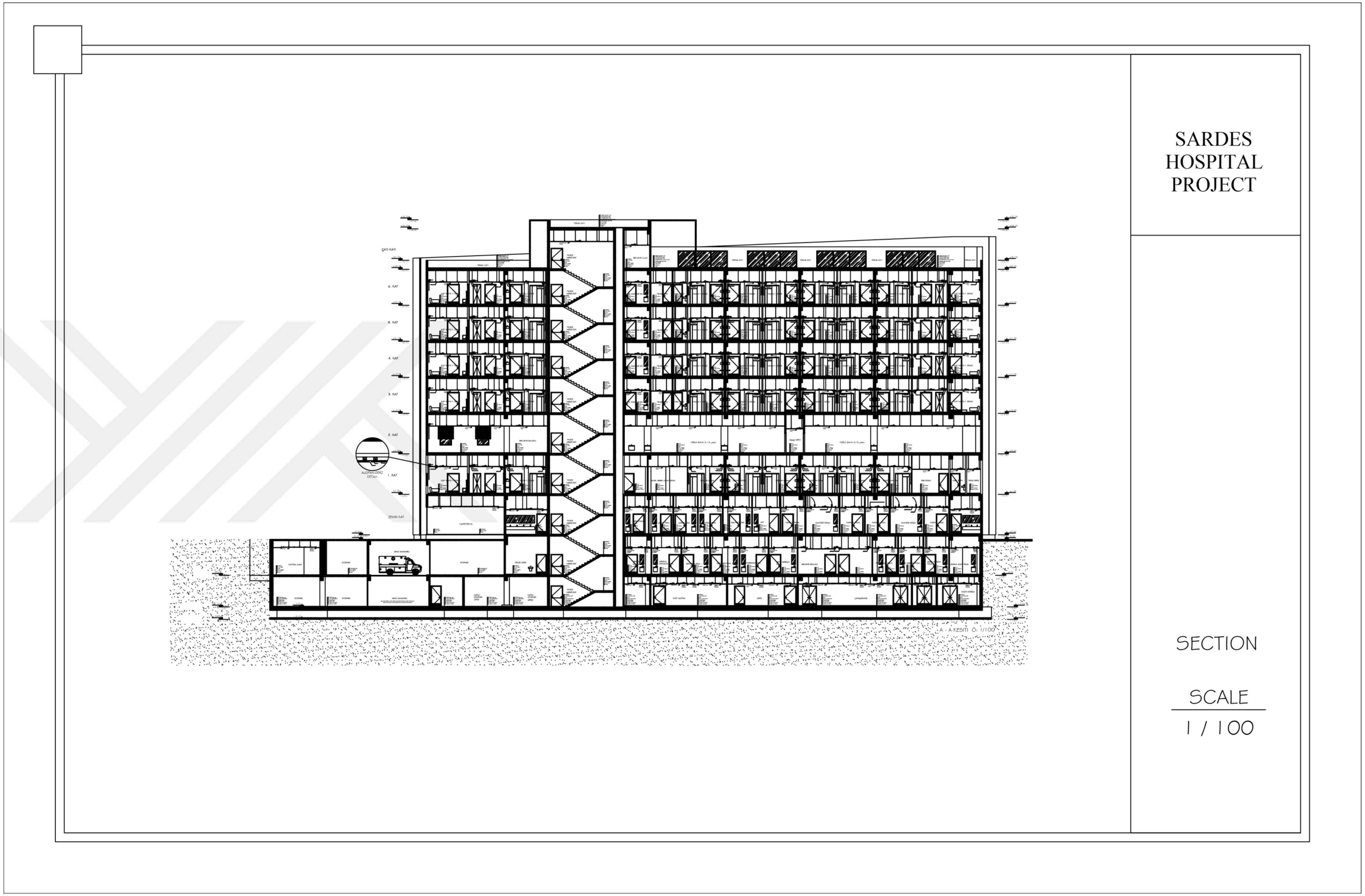


Figure 3.8 Section

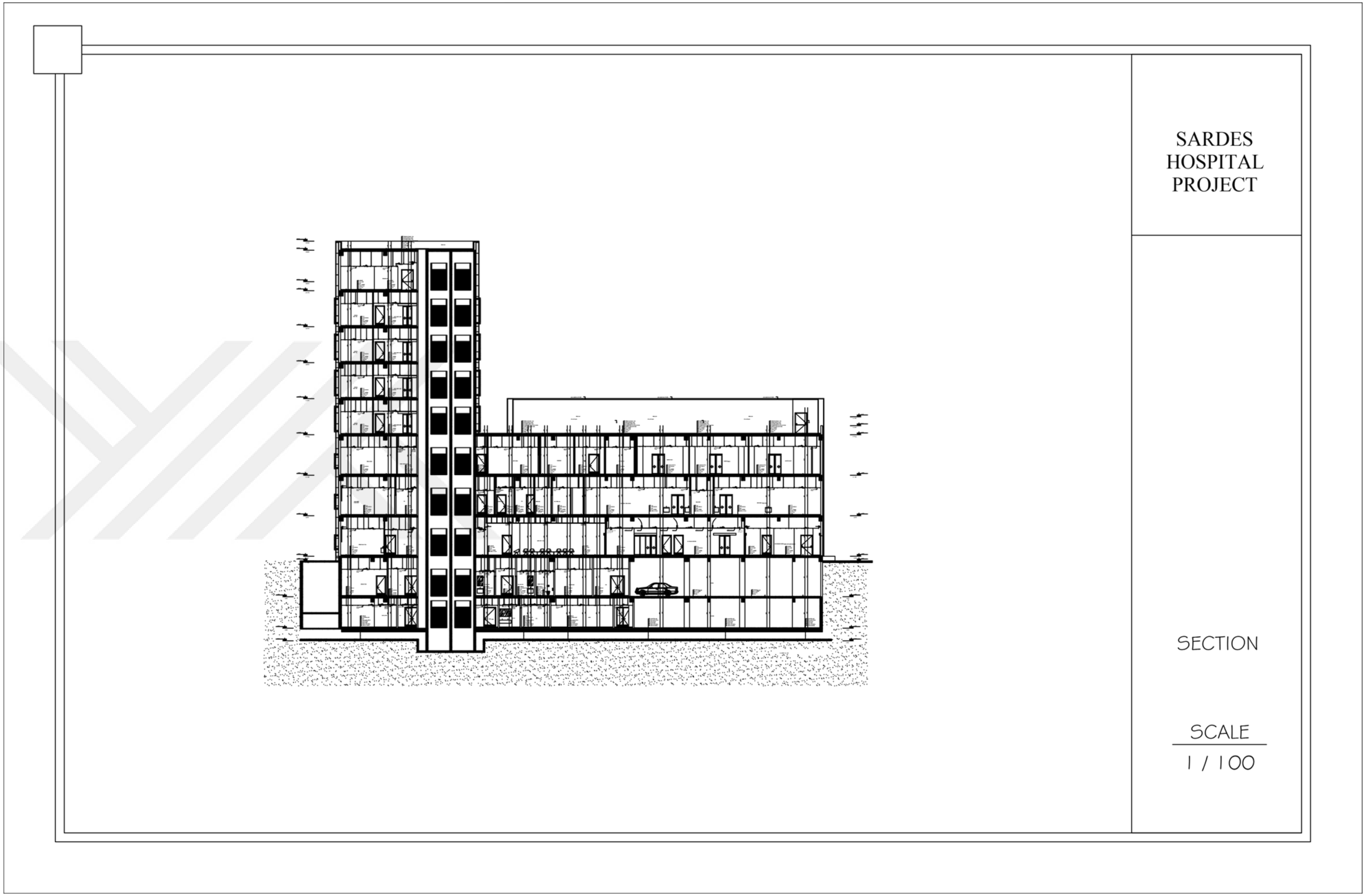


Figure 3.9 Section

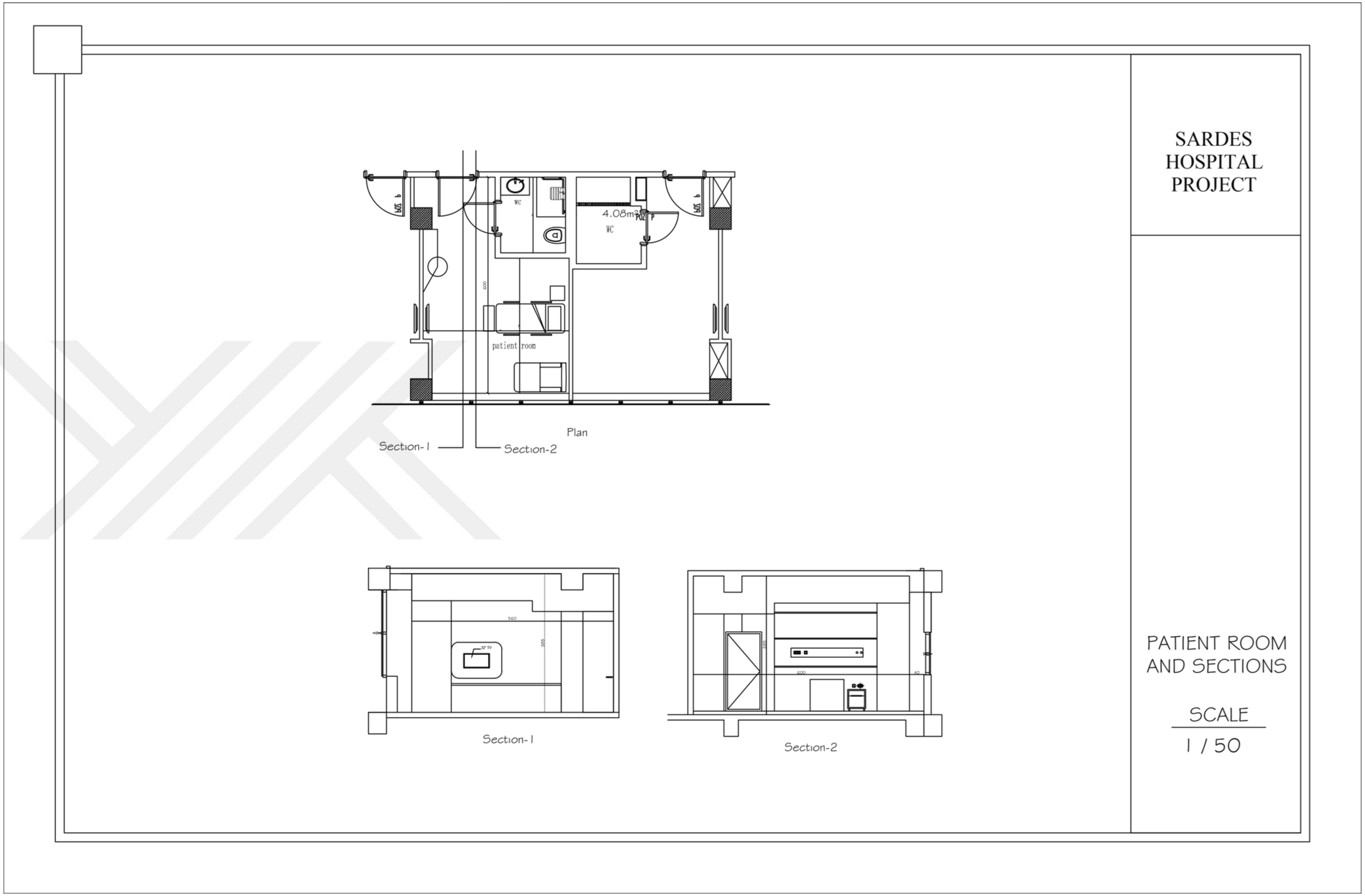


Figure 3.10 Patient Room and Section

3.2 Thermal properties of envelope detaıls

The envelope of Sardes Hospital design details was developed based on this study.

3.2.1 Common envelope components

3.2.1.1 Insulation materials

Thermal insulation materials can be described as materials that are used for reducing heat transfer between two environments with different temperatures. In other words; specific materials with high thermal resistance and low heat transmission coefficient are named thermal insulation materials (Akıncı, 2007). In order to make a good choice in thermal insulation materials, it is necessary to know the insulation material with every aspect and know application properties of this material. Performance of a thermal insulation material is evaluated based on main features such as its thermal conductivity and thermal resistance coefficient, compressive strength, tensile strength, vapor diffusion resistance, water and moisture resistance, incombustibility and flame resistance, density, dimensional stability and chemical stability.

The main purpose of insulation products is to increase heat conduction resistance of structure elements. Therefore, insulation property of these products is determined by heat transmission coefficient. According to the International Organization for Standardization – ISO and the European Committee for Standardization-CEN, heat transmission coefficient of thermal insulation products should be lower than 0.065 W/mK. It is possible to classify thermal insulation materials in various ways according to their different aspects.

There are many different insulation materials in the market. The characteristics of these materials may be very similar but their prices may vary. Incorrect use of thermal insulation materials in the building envelope causes low energy efficiency as well as decreased cost efficiency. This study is important in terms of correct material selection for cost and energy efficiency and for proper implementation. The thermal insulation layer designed in the building envelope serves as a main layer that prevents or reduces heat losses and allows the design of energy-efficient buildings. Selecting correct thermal insulation materials that would help meeting the requirements of buildings at the lowest cost is important.

Insulation materials are a part of the complex structural elements forming the building envelope. They are systems interwoven with design and construction. Thermal insulation materials have an important role in providing indoor thermal comfort and energy efficiency.

The insulation materials selected for this dissertation are the most traditional insulation materials used in Turkey and include Extruded Polystyrene (XPS), Expanded Polystyrene (EPS), Glasswool and Rockwool.

3.2.1.2 Extruded polystyrene (XPS)

It is a foam material with a homogenous cell structure, manufactured and used for thermal insulation. Depending on the purpose of the place of use, it can be manufactured as a sheet or mold in different sizes and technical specifications, with different edge and surface patterns. XPS's thermal conductivity varies with temperature, moisture content and mass density.

3.2.1.3 Expanded polystyrene (EPS)

EPS is composed of small spheres of polystyrene, derived from crude oil, and includes an expansion agent, for example pentane $C6H12$, that expands by heating with water vapour. It is a petroleum-derived, thermoplastic material. EPS contains a slightly open pore structure. EPS's thermal conductivity varies with temperature, moisture content and mass density.

3.2.1.4 Glasswool

It is obtained through melting silica, which is its inorganic raw material, at 1200ºC - 1250ºC and turning it into fiber. According to its place of use and purpose, it can be manufactured as a sheet, plate, pipe or casting in different sizes and specifications with different coating materials.

3.2.1.5 Rockwool

Rockwool is obtained through melting basalt stone and transforming it into fiber. It is a thermal insulation material that is acquired through melting mineral and inorganic stones obtained from volcanic rocks found in nature at1500-1600 ºC and transforming into fiber and it contains 98% natural fiber.

3.2.2 Common wall materials

On an exterior wall structure, the structure of the main material of the wall is important. Because, all calculations are made according to its main component. The most commonly used main wall elements are brick, pumice concrete block and aerated concrete. The necessary properties of main material of a wall are resistance, low thermal conductivity coefficient, not forming a thermal bridge, lightweight, easy to mount, having a homogeneous structure and being economical.

3.2.2.1 Autoclaved Aerated Concrete Block

It is a mineral-based thermal insulation material. This product can be used both in the interior and exterior surfaces of buildings with thermal insulation purposes and it can be applied to both old and new buildings.

3.2.2.2 Bimsblock

Bimsblock are block elements that are made of pumice concrete that is obtained from volcanically generated natural pumice aggregates. Pumice concrete is a lightweight concrete type where pumice aggregates are used and quartz sand is added when needed. Structural elements made of pumice concrete are manufactured through compressing pumice aggregates together with cement and water by vibration and by adding quartz sand when necessary.

3.2.2.3 Brick

It is a construction material that is obtained from baked or dried clay-based soil and used in wall construction by missing with mortar.

3.2.3 Suitable Envelope details with common materials according to thermal comfort goals

In this study, the results that were obtained as a result of insulating in different ways the wall sections of Sardes Hospital, located in the 1^{st} degree day region were examined. 4 different insulation materials were applied on the wall sections. In addition, 4 different insulation materials were compared by changing the wall types. On the sample wall section, an insulation providing $U \leq 0.70$ were applied to the selected building and it was evaluated according to principles and provisions of TS825. According to TS825, U value was calculated and insulation thicknesses providing U value of the sample building were determined.

The comparisons of U values recommended for walls by TS 825 and optimum U values that were calculated using the heating degree days of the General Directorate of Meteorology are shown in the table below (İ.Güneş, 2012).

	U_D(W/m²K)	
	TS 825	**Optimum for Turkey conditions according to the ECOFYS Report**
1st Region	0.70	0,30
2st Region	0,60	0,24
3st Region	0,50	0,2
4st Region	0,40	0,17

Table 3.1 U values in the standard TS 825 (İ.Güneş, 2012)

In the thermal insulation calculations, on the exterior wall cement blended plaster and on the interior wall gypsum plaster were determined; wall sections were formed for calculations.

		Surface Emittance, ε					
		Nonreflective		Reflective			
	Direction of	ε = 0.90		ε = 0.20		ε = 0.05	
Position of Surface	**Heat Flow**	h_i	R	h_i	R	h_i	R
Still Air							
Horizontal	Upward	9.26	0.11	5.17	0.19	4.32	0.23
Sloping at 45°	Upward	9.09	0.11	5.00	0.20	4.15	0.24
Vertical	Horizontal	8.29	0.12	4.20	0.24	3.35	0.30
Sloping at 45°	Downward	7.50	0.13	3.41	0.29	2.56	0.39
Horizontal	Downward	6.13	0.16	2.10	0.48	1.25	0.80
Moving Air (any position)		h_o	R				
Wind (for winter) at 6.7 m/s	Any	34.0	0.030	—	—	—	—
Wind (for summer) at 3.4 m/s	Any	22.7	0.044	—	—	—	—

Table 3.2 Surfece Conductances and Resistances for Air

$$R_{exterior\ wall} = R_{exterior\ plaster} + R_{foam} + R_{brick} + R_{gypsum} = \frac{d\ outer\ plaster}{\lambda\ outerplaster} + \frac{dfoam}{\lambda foam} + \frac{dbrick}{\lambda brick} + \frac{dplaster}{\lambda plaster}$$

$$R_{total} = R_o + R_{exteiror\ wall} + R_i$$

$$U_{total} = 1/R_{total}$$

In the above equations; R exterior plaster, R foam, R brick, R gypsum, R exteiror wall, Ro, R_i are thermal resistance coefficients of the components shown in the sub-indices. O and I sub-indices refer to external and internal environment air layer. ‘d’ is the thickness (m) of the components shown in the sub-indices; ‘λ’ is heat transmission coefficient (W/mK) of the components shown in the sub-indices (Koçak S., Atmaca İ., 2011).

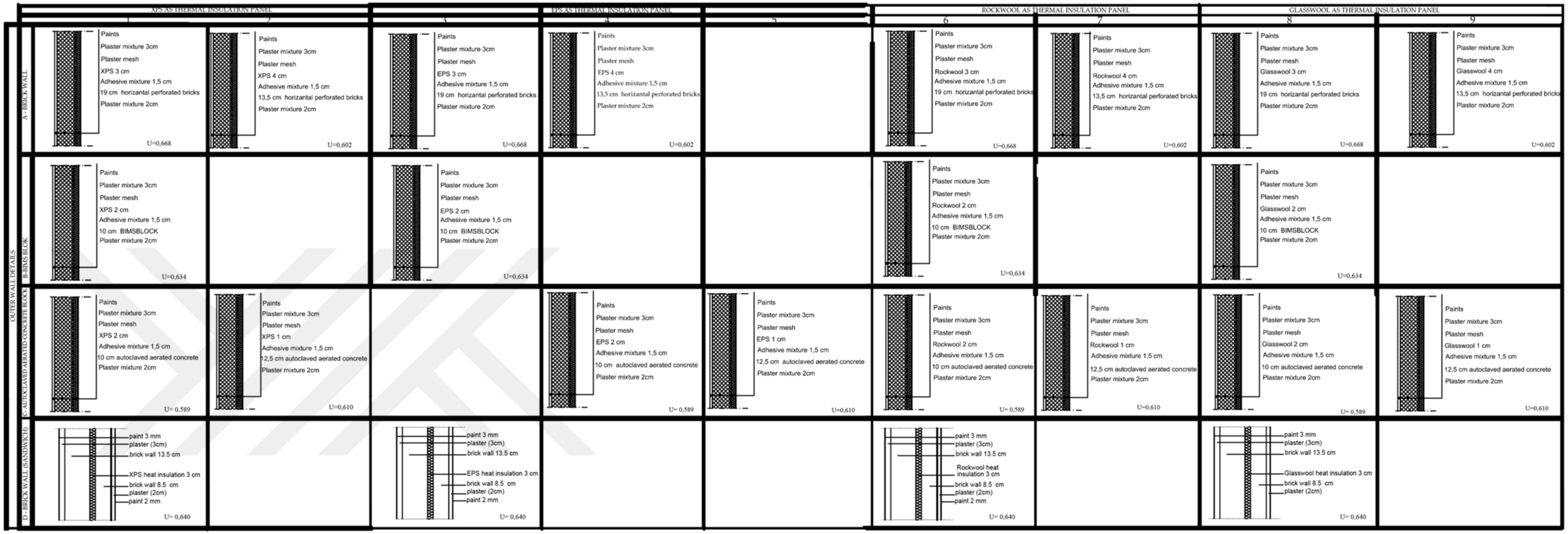


Table 3.3 Wall Details

3.2.3.1 Ts 825 Heat Insulatıon Program

When the program is run, we see the form where the project data is entered.

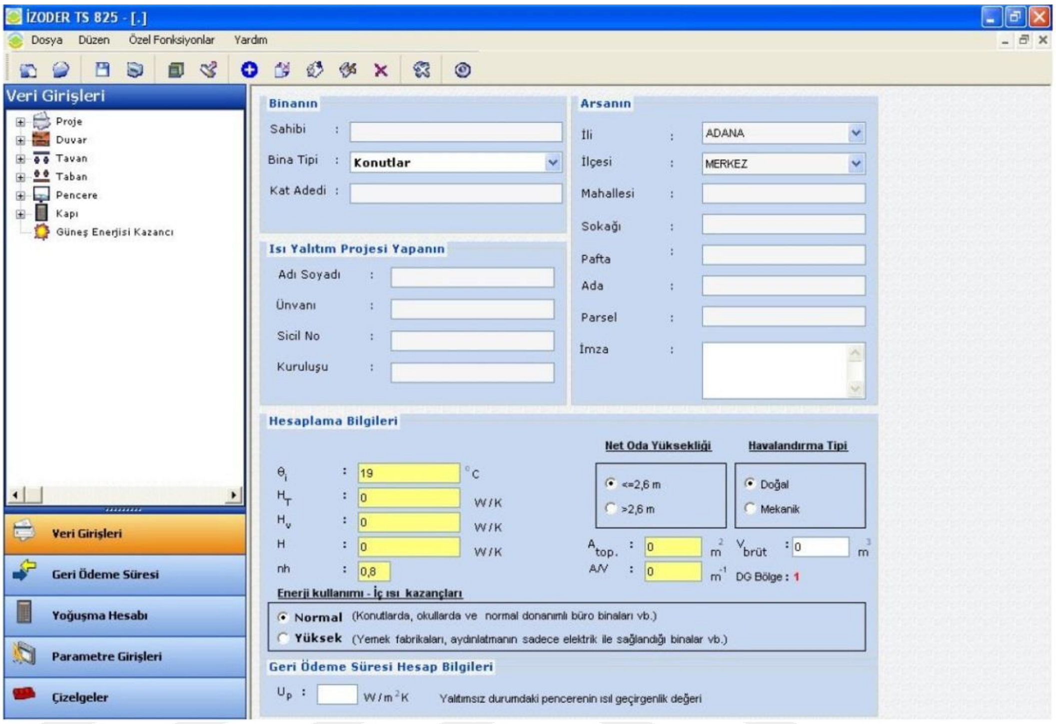


Figure 3.11 Data entry page

Figure 3.12 It is the left menu of the Project entry page. On the left side of the screen is a tree-type menu that allows you to easily move in the program. It is possible to easily reach the sub-titles of the process steps listed under the main titles. Data entries consist of main titles of project, wall, ceiling, floor, window, door and solar energy gain. The calculations made within the scope of the thesis are calculated using wall section and sub-titles.

Figure 3.12 Project entry page

The screen that will be opened by double clicking the wall, ceiling or floor components on the left access panel is shown in Figure 3.13.

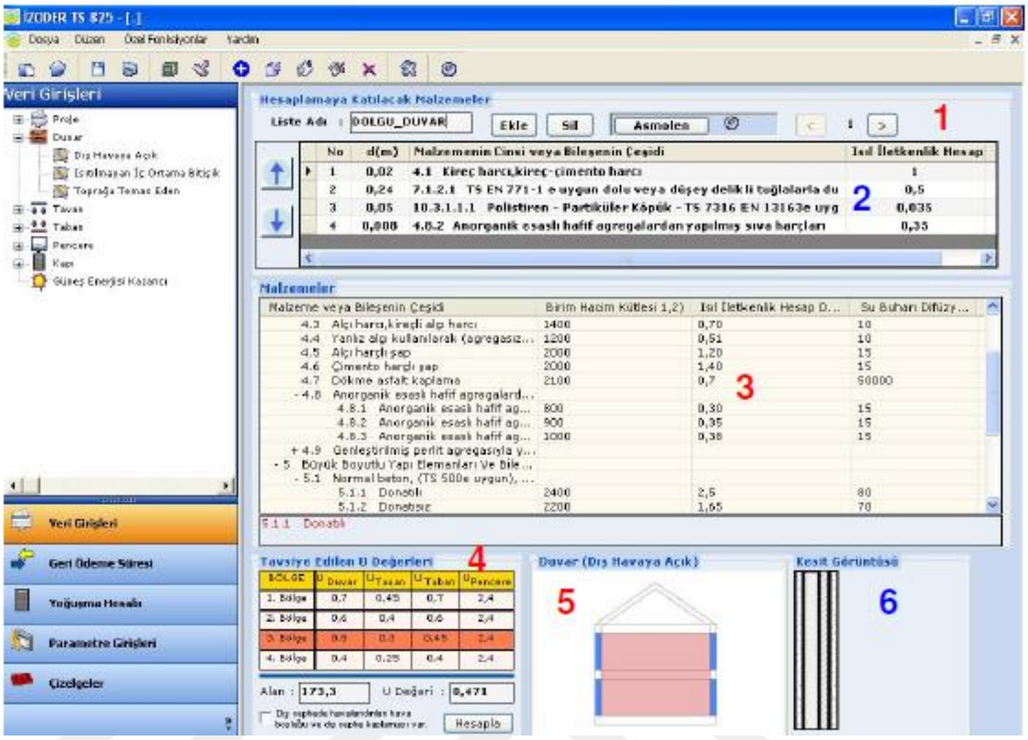


Figure 3.13 Material entry screen

In Figure 3.13, when the materials constituting building component, their thickness and field data of the components are entered and calculate button is pressed, total heat transmission coefficient (U) is calculated.

1: In this section; the building component to be added to the List Name is named. When Add button is pressed, a new building component is created. The added building component can be deleted with Delete button. With the arrow keys on the right, it can be navigated among building components of the related building element. (Between the arrow keys is a label showing which building element you are on).

2: In this section; Building and insulation materials selected from the material list indicated with number 3 are assigned through the list and building component is defined as materials' thickness values are entered by the user. In order to make arrangements in the order of building materials used in the building elements, there are "replacement arrows" allowing moving the materials up and down. When these arrows are clicked after selecting a building material, the selected building material is replaced with the building material in the upper or lower line. During the assignment of projected details, the material entry must be from inside out.

3: This is the section where building and insulation materials that will be used in the construction of building elements are listed. The desired material is selected by double clicking on the materials to be used. Right below this section is a space where full name of the selected building material is shown.

4: This is the section where identified building element area is entered and heat transmission efficiency (U) is calculated. In this section, there is also a U values table identified and recommended by TS 825 standards according to degree day regions and an option box that identifies that the designed detail includes ventilation layer.

5: This is the section where a schematic illustration for the location of the building element, which is selected on the left panel, within the building. If the calculation result is in compliance with the recommended U values table, the areas shown in orange will turn to blue.

6: This is the section where the sectional images of the building elements that are formed by selecting construction and insulation materials from the material list are given.

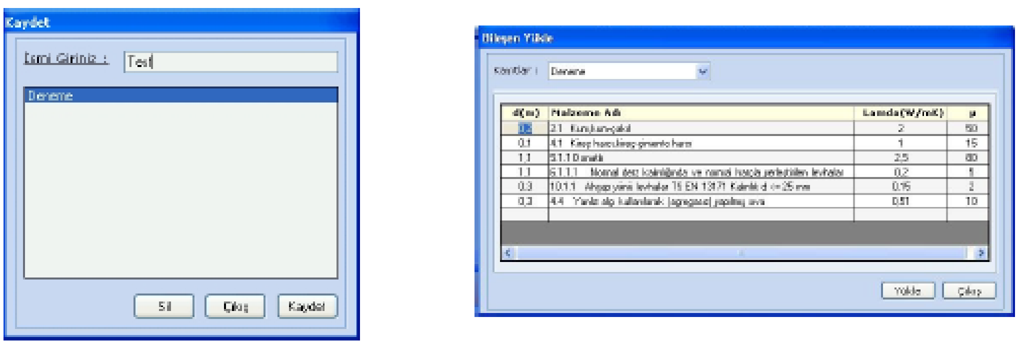


Figure 3.14 Material information entry page

The area d(m) to which material information is needed to be entered by the user (Material Thickness) is assigned “0” as an initial value, and this value must be replaced with a proper value for the project. Thickness data must be entered in “meter”.

3.3 Environmental Properties of Envelope Details

The exterior wall structure of buildings is important because it is directly related to energy saving and thermal comfort. Materials in the insulation layer as one of the exterior wall layers provide significant energy efficiency during use as their main function and significantly reduce carbon dioxide (CO_2) emissions due to energy consumption, which causes climate change. However, when we consider production phase of insulation materials, we see that these products require a certain amount of raw materials, water, energy and chemical consumption and hence cause waste/wastewater production. These products are transformed into solid wastes that, similar to other building materials and auxiliary materials, wait to be recycled or taken back to landfill sites. Therefore, it is necessary to analyze and evaluate environmental effects of these products. Life Cycle Analysis (LCA), one of the analyses that have been applied for many years to thermal insulation materials like many other products, can be used to analyze their environmental effects.

The main objective of this part is to determine and evaluate the environmental impact of the lifecycle of chosen thermal insulation materials used in building the external walls of Sardes Hospital. The insulation materials selected for this part are XPS, EPS, glasswool, and rock wool, because they are the most widely used ones in the construction sector. A gate-to-gate Life Cycle Assessment (LCA) methodology is applied to these insulation materials.

An increasingly common solution is to create ISO Type III environmental declarations (EPD), which provide quantified environmental data for predetermined indicators using independently verified LCAs. EPDs are similar to the nutritional information found on the back of food packets. They present quantified environmental information on the life cycle of a product, i.e., the impact caused by the product throughout its life. In Europe, EPDs for construction products are derived according to the requirements of EN 15804, which include the sustainability of construction works, environmental product declarations and core rules for the product category of construction products. EN 15804 is part of a suite of standards for the assessment of the sustainability of construction work at both the product and building levels (BRE,2014).

We know that the building sector accounts for 40% of the primary energy use and 36% of the energy-related CO_2 emissions among industrialised countries. These emissions are mainly related to the use phase of buildings while emissions from the production of building materials. The purpose of the Construction Products Regulation (CPR) is to ensure reliable information about construction products and materials in relation to their performance, which is used for marketing these products in the EU. CPR provides reliable information about performances of building materials and products that are used in the markets. CPR aims at facilitating trade of construction materials by providing uniform and transparent methods for assessing their performances. It ensures architects, engineers etc. to pick the most suitable products for the intended use in their construction works (BRE,2014).

The minimum amount of information that the manufacturer is obliged to provide is set up in Basic Work Requirements. Currently, there are six of them, but a seventh—BWR7: Sustainable use of natural resources—is added to this list.

1. Mechanical resistance and stability;

2. Safety in case of fire;

3. Hygiene, health, and the **environment;**

4. Safety in use;

5. Protection against noise;

6. Energy economy and heat retention;

7. Sustainable use of natural resources.

BWR3: projects must be designed and built in such a way that, throughout their lifecycle, they will not be a threat to the hygiene or health and safety of workers, occupants or neighbours, nor will they have an exceedingly high impact on the environmental quality or the climate during their construction, use, and demolition. (BRE,2014).

BWR7: projects must be designed, built and demolished in such a way that the use of natural resources is sustainable and, in particular, ensure the reusability or recyclability of the projects’ materials and parts after demolition, the durability of the projects themselves, and their use of environmentally compatible raw and secondary materials (BRE,2014).

BWR3 and BWR7 focus on health and the environmental aspects of construction, specifically during the use phase of a building. BWR3 extends to the entire lifecycle of a product or material. The implications of this lifecycle approach for BWR3 are also relevant for BWR7, which also takes the entire lifecycle of the product or material into account. (BRE,2014).

The sustainability of construction works is responsible for the development of voluntary lateral standardised methods for the assessment of the sustainability aspects of new and existing construction projects, and for standards for the EPDs of construction products.

The existing standards provide the lateral standardised methodology and indicators for the sustainability assessment of buildings using a lifecycle approach in a transparent way. Last year CEN/TC 350 finalised EN 15804—Sustainability of construction works, Environmental product declarations, and Core rules for the product category of construction products—as well as EN 15978—Sustainability of construction works, Assessment of environmental performance of buildings, and Calculation method—which governs the scope and the requirements for the application of EPDs in Building Assessment.

Environmental impacts can be defined as a change in the environment caused by human activities that have a negative effect on the ecosystem, human health, and resources. LCAs provide a good framework for determining the environmental impacts of currently available products during their complete life cycle.

Taking the entire life cycle of construction products into account by using LCAs should also qualify the environmental benefits or impacts of reusing or recycling the products. The type of materials and products selected in the design phase influence the level of sustainability during the construction, use and demolition phase of the construction work. The type of material and product also determine the possibilities for recycling and reuse of materials.

Simply making a material or product more durable does not inevitably lead to a more sustainable use of natural resources, as is the case with reuse and recycling. For this reason, the implications of the use of material during its entire life cycle should be taken into account when considering the durability of a product or construction work. It could be, for example, that the choice of a more durable material or product leads to additional emissions during the fabrication or demolition phase.

With respect to determining the environmental impact of a product or material, we recommend considering using an LCA, as well as EN 15804:2012 and the EU's 'Product Environmental Footprint' program. Both are setting a standard for calculating the environmental impacts of products during their life cycle, and both use LCAs for calculating the environmental impacts of products during their total lifetime. During the process of making LCAs several assumptions and considerations should be made. The purpose of the EN 15804:2012 standard, which describes the rules for performing a life cycle assessment for construction products, is to limit the number of these assumptions.

We recommend using the life cycle assessment methodology according to the rules described in the EN 15804:2012 standard for calculating the environmental impact of the use of natural resources. A life cycle assessment according to this standard will give a solid overview of the different environmental impacts and relevant indicators of a construction product.

Environmental indicators used in EN 15804 compliant EPD are shown. There are seven environmental impact indicators, ten resource indicators, three waste indicators, and four output flow indicators.

The environmental indicators used in EN 15804 compliant EPD relating to the basic requirements of the BWR7.

Environmental impact indicators are;

· Global Warming Potential (GWP)

· Ozone Depletion Potential (ODP)

· Acidification potential (AP)

· Eutrophication potential (EP)

· Formation potential of tropospheric ozone (POCP)

· Abiotic depletion potential for non-fossil resources (ADP-elements)

· Abiotic depletion potential for fossil resources (ADP-fossil fuels)

BWR3 and BWR7 both include the environmental performance of construction works and construction materials and products, but the environmental performance of BWR3 is mainly focused on the reduction of dangerous emissions of substances/gasses to indoor air, soil, water and outdoor air (greenhouse gasses) while BWR7 is focused more on reducing the depletion of raw materials and natural resources.

In this study, the LCC analysis applied to insulation applications. A representative building approach is used in order to determine the optimum insulation thicknesses. The insulation application is applied to Sardes Hospital in Izmir.

The LCA methodology supports the concept and is a powerful tool for comparing various insulation materials with regard to their environmental performance. We recommend using the life cycle assessment methodology according to the rules described in standard EN 15804:2012 for calculating the environmental impact of the use of natural resources. A life cycle assessment according to this standard will give a solid overview of the different environmental impacts and relevant indicators of a construction product.

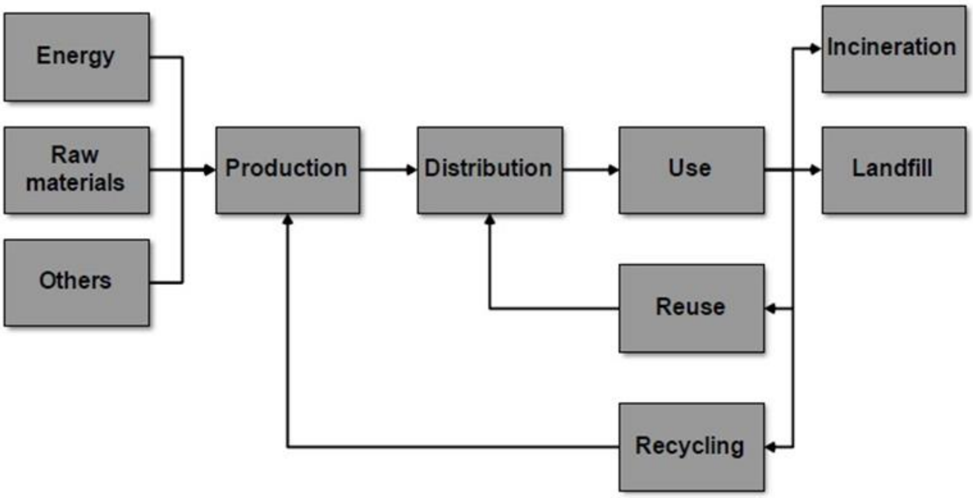


Figure 3.15 Major phases related with the life cycle of a product

(Correia Pargana N.G.S.,2012)

Environmental Impact indicators are Global Warming Potential (GWP), Ozone Depletion Potential (ODP), Acidification Potential (AP), Eutrophication Potential (EP), Formation Potential of Tropospheric Ozone (POCP), Abiotic Depletion Potential for Fossil Resources (ADP-fossil fuels), and Abiotic Depletion Potential for Non-fossil Resources (ADP-elements).

3.3.1 Life Cycle Calculating program of SimaPro

The SimaPro program provides a unique opportunity to get hands-on experience with life cycle assessments. SimaPro, is a LCA tool. It is helpful for putting metrics behind sustainable product development, sustainability goals, or research. Based on these metrics, solid decisions can made to positively change a product’s lifecycle. The simaPro is used by industry, consultancies, and research institutes in more than 80 countries.

The index on the left-hand side provides access to all types of data. The buttons at the top of the page provide access to the most important functions.

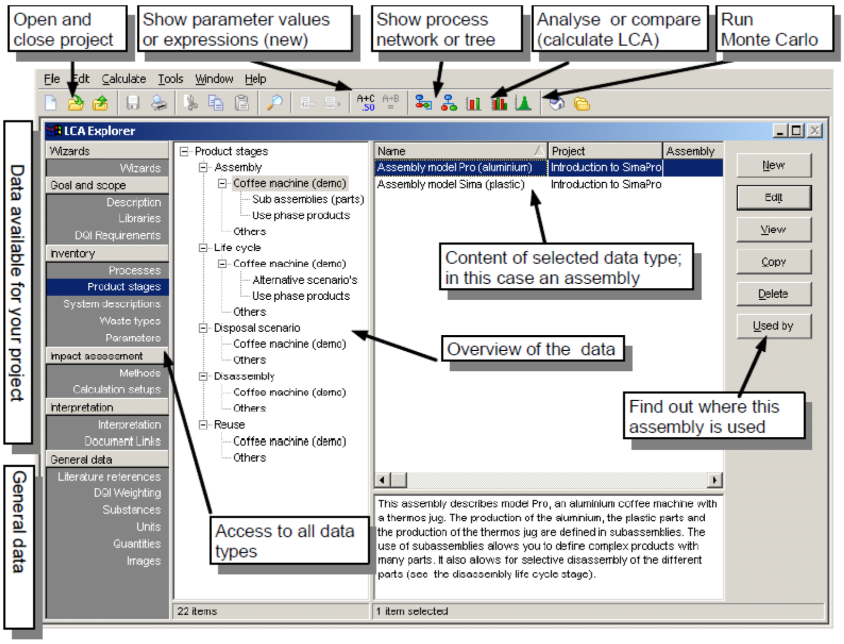


Figure 3.16 The use interface (Goedkoop, Schryver, Oele, Durksz & Roest, 2010)

The Analyze toolbar button to see the inventory and impact assessment results, as well as the process contributions (see figure 3.16).

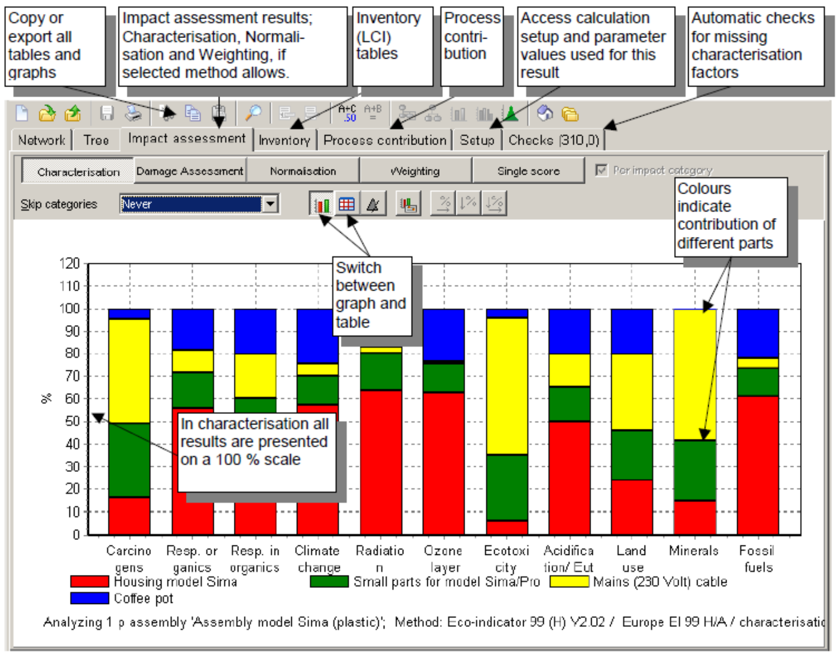


Figure 3.17 Characterisation results (Goedkoop, Schryver, Oele, Durksz & Roest, 2010)

Figure 3.17 shows the characterisation results. As all impact categories have different units.Impact categories are plotted on a percent scale. The colours indicate the relative contribution for different parts of the product.Inspect the relative contribution of the life cycle stages.

A network presentation of the SimaPro model can be generated. Different figures can be achieved according to indicators

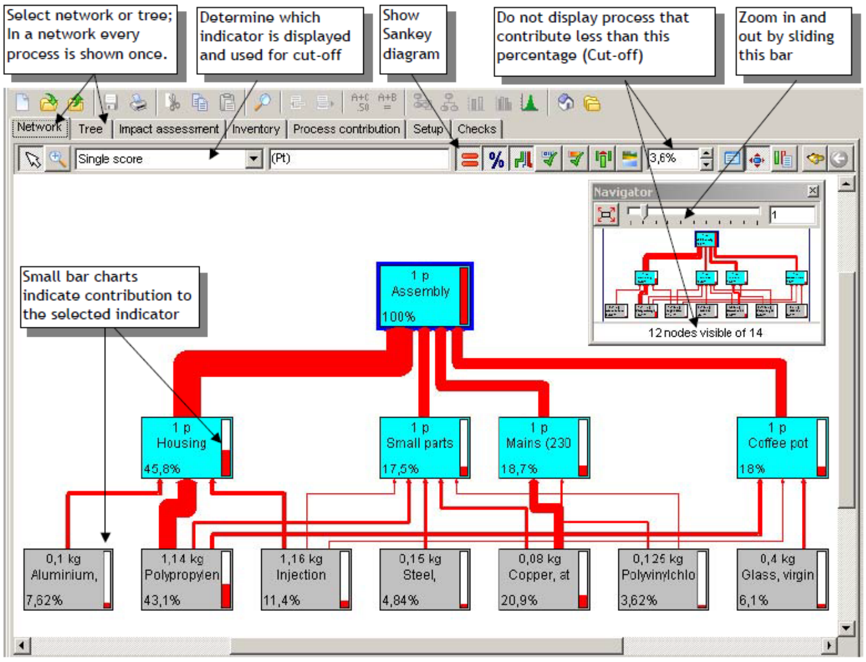


Figure 3.18 Network Screen (Goedkoop, Schryver, Oele, Durksz & Roest, 2010)

Each grey box represents a process, each blue box represents a (sub)assembly. The small red bar charts indicate the environmental load generated in each process and its upstream processes. This is a very useful feature, as you can trace the origins of the environmental load and identify hotspots.

Network tab to get the window below. You will be able to see the assembly, the use processes, and the disposal processes. The filter and the packaging are both defined as an additional life cycle, each with their own assembly and disposal stage.

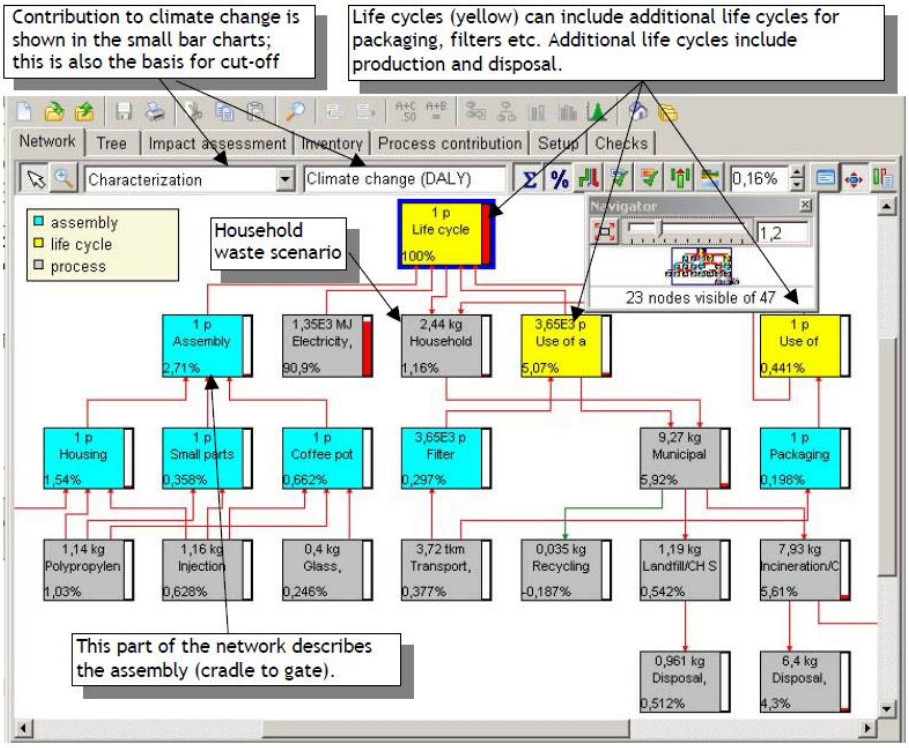


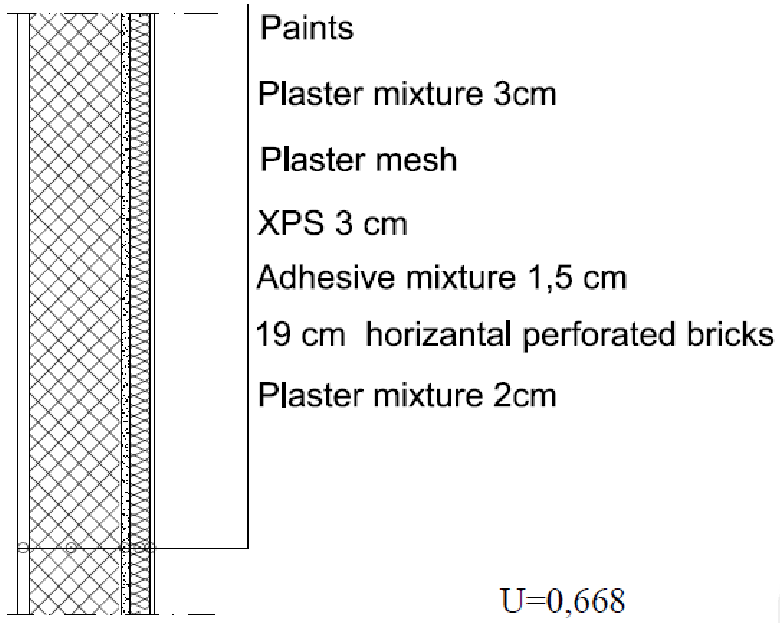
Figure 3.19 Analysing the full life cycle

3.3.2 Detail Results of SimaPro

In this part, the TS 825 obtained by calculation utilizing the details of the program material life cycle analysis carried out and obtained information on the environmental impact.

Environmental impact categories per product and subassemblies (which show the results according to the method Eco-indicator 99 (I) V2.08 / Europe EI 99 I/I and with indicator “weighting”.)

24 wall details of environmental impact categories per product and the total impacts of each detail has been collected. According to the total impacts of each detail a value has been calculated. Tables are given as an example for 24 wall details.

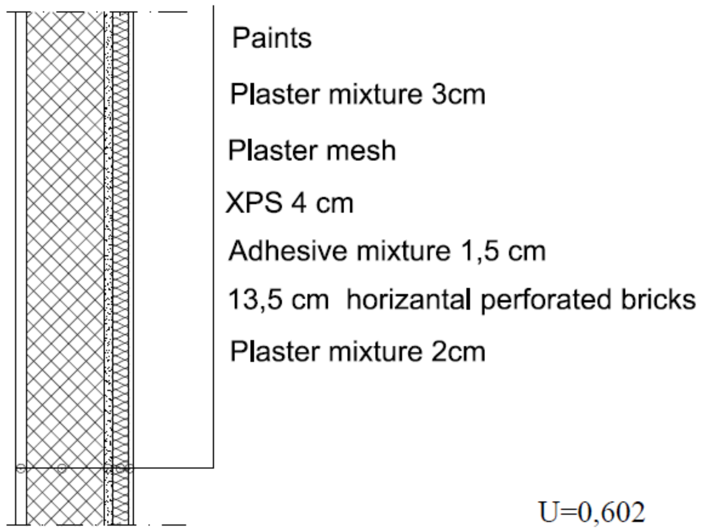


XPS AS THERMAL INSULATION PANEL

A1	BRICK WALL
Calculation:	Analyze
Results:	Impact assessment
Product:	Slab With Heat Insulation_Ceramic
Method:	Eco-indicator 99 (I) V2.08 / Europe EI 99 I/I
Indicator:	Single score

Impact category	**Unit**	**Total**	**Alkyd Paint**	**Plaster 3mmcm(6kg)**	**brick, at plant/DE U 98,5 kg**	**XPS 3 CM**	**Cement Based Adhesive Mortar 1,5 cm**	**Plaster 2 cm**	**Alkyd Paint**
Total	Pt	1,568041027	0,038559741	0,05622809	1,275143697	0,104926824	0,004642409	0,049980525	0,038559741
Carcinogens	Pt	0,154708661	0,00106558	0,000364353	0,150674631	0,001171303	4,33432E-05	0,000323869	0,00106558
Resp. organics	Pt	0,00166707	4,26328E-05	5,06282E-05	0,000916452	0,000565141	4,58022E-06	4,50029E-05	4,26328E-05
Resp. inorganics	Pt	0,32423152	0,016786167	0,014982605	0,218613427	0,042467009	0,001278274	0,013317871	0,016786167
Climate change	Pt	0,516349173	0,00861539	0,034762545	0,374790976	0,055967096	0,002697737	0,03090004	0,00861539
Radiation	Pt	0,000128344	7,14678E-06	2,62172E-05	6,20159E-05	2,20385E-07	2,29287E-06	2,33042E-05	7,14678E-06
Ozone layer	Pt	0,000202374	5,00446E-06	5,53261E-06	0,000178057	3,36898E-06	4,88594E-07	4,91788E-06	5,00446E-06
Ecotoxicity	Pt	0,001330428	4,19945E-05	5,1255E-05	0,000975469	0,000168459	5,69596E-06	4,556E-05	4,19945E-05
Acidification/ Eutrophication	Pt	0,012178515	0,000331869	0,000664255	0,009075427	0,00113071	5,39372E-05	0,000590449	0,000331869
Land use	Pt	0,209049289	0,003758597	0,000231995	0,200990794	6,70537E-06	9,63824E-05	0,000206218	0,003758597
Minerals	Pt	0,348066202	0,007905359	0,005088704	0,318736996	0,003446812	0,000459678	0,004523293	0,007905359

Table 3.4 Total impacts of the XPS insulation on the brickwall detail

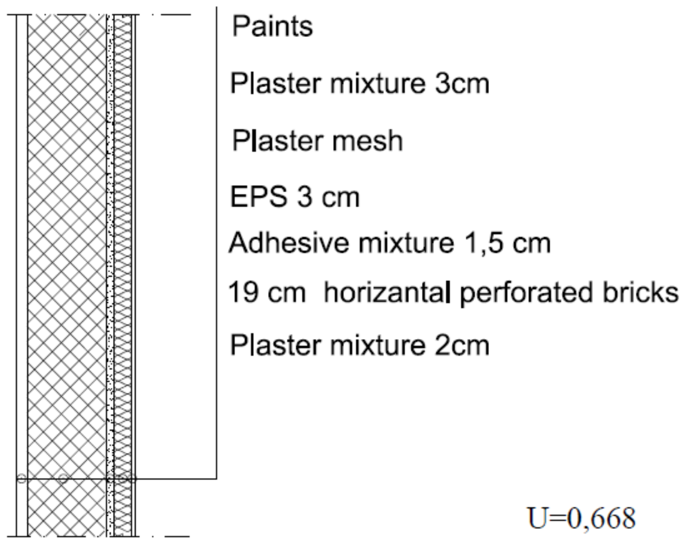


XPS AS THERMAL INSULATION PANEL

A2	BRICK WALL
Calculation:	Analyze
Results:	Impact assessment
Product:	Slab With Heat Insulation_Ceramic
Method:	Eco-indicator 99 (I) V2.08 / Europe EI 99 I/I
Indicator:	Single score

Impact category	**Unit**	**Total**	**Alkyd Paint**	**Plaster 3mmcm(6kg)**	**Brick, at plant/DE U 70 kg**	**XPS 4 CM**	**Cement Based Adhesive Mortar 1,5 cm**	**Plaster 2 cm**	**Alkyd Paint**
Total	Pt	1,234066429	0,038559741	0,05622809	0,90619349	0,139902432	0,004642409	0,049980525	0,038559741
Carcinogens	Pt	0,111513754	0,00106558	0,000364353	0,10708929	0,001561738	4,33432E-05	0,000323869	0,00106558
Resp. organics	Pt	0,00159035	4,26328E-05	5,06282E-05	0,000651352	0,000753521	4,58022E-06	4,50029E-05	4,26328E-05
Resp. inorganics	Pt	0,275149333	0,016786167	0,014982605	0,15537557	0,056622679	0,001278274	0,013317871	0,016786167
Climate change	Pt	0,426589856	0,00861539	0,034762545	0,26637596	0,074622794	0,002697737	0,03090004	0,00861539
Radiation	Pt	0,000110478	7,14678E-06	2,62172E-05	4,40767E-05	2,93847E-07	2,29287E-06	2,33042E-05	7,14678E-06
Ozone layer	Pt	0,000151991	5,00446E-06	5,53261E-06	0,000126551	4,49198E-06	4,88594E-07	4,91788E-06	5,00446E-06
Ecotoxicity	Pt	0,001104409	4,19945E-05	5,1255E-05	0,000693297	0,000224612	5,69596E-06	4,556E-05	4,19945E-05
Acidification/ Eutrophication	Pt	0,009930188	0,000331869	0,000664255	0,006450197	0,001507613	5,39372E-05	0,000590449	0,000331869
Land use	Pt	0,15091133	0,003758597	0,000231995	0,1428506	8,94049E-06	9,63824E-05	0,000206218	0,003758597
Minerals	Pt	0,257014743	0,007905359	0,005088704	0,2265366	0,00459575	0,000459678	0,004523293	0,007905359

Table 3.5 Total impacts of the XPS insulation on the brickwall detail

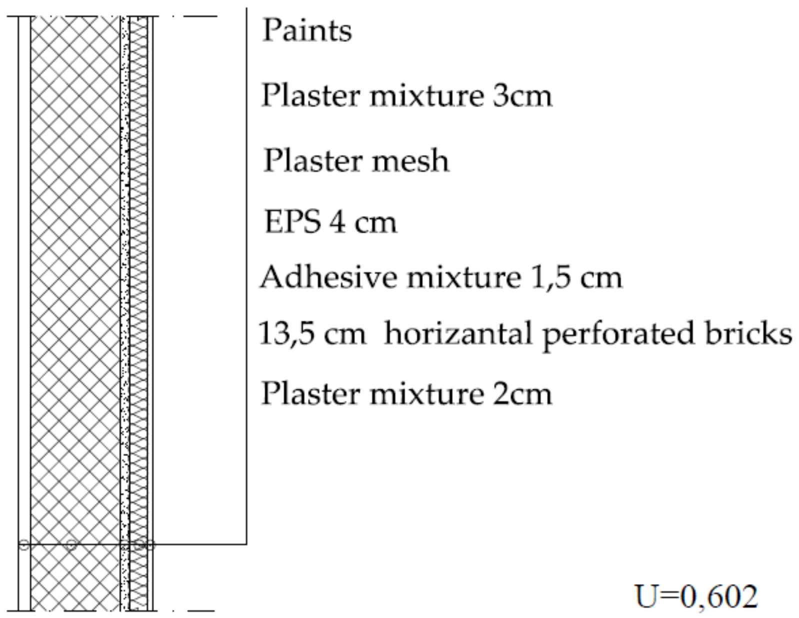


EPS AS THERMAL INSULATION PANEL

A3	BRICK WALL
Calculation:	Analyze
Results:	Impact assessment
Product:	Slab With Heat Insulation_Ceramic
Method:	Eco-indicator 99 (I) V2.08 / Europe EI 99 I/I
Indicator:	Single score

Impact category	**Unit**	Total	Alkyd Paint	Plaster 3mmcm(6kg)	**brick, at plant/DE U 98,5 kg**	**EPS 3 CM**	Cement Based Adhesive Mortar 1,5 cm	Plaster 2 cm	Alkyd Paint
Total	Pt	1,520570288	0,038559741	0,05622809	1,275143697	0,069951216	0,004642409	0,037485394	0,038559741
Carcinogens	Pt	0,154237259	0,00106558	0,000364353	0,150674631	0,000780869	4,33432E-05	0,000242902	0,00106558
Resp. organics	Pt	0,001467439	4,26328E-05	5,06282E-05	0,000916452	0,000376761	4,58E-06	3,37522E-05	4,26E-05
Resp. inorganics	Pt	0,306746383	0,016786167	0,014982605	0,218613427	0,02831134	0,001278274	0,009988403	0,016786167
Climate change	Pt	0,489968464	0,00861539	0,034762545	0,374790976	0,037311397	0,002697737	0,02317503	0,00861539
Radiation	Pt	0,000122445	7,14678E-06	2,62172E-05	6,20E-05	1,46923E-07	2,29E-06	1,74782E-05	7,15E-06
Ozone layer	Pt	0,000200021	5,00446E-06	5,53261E-06	0,000178057	2,24599E-06	4,89E-07	3,68841E-06	5,00E-06
Ecotoxicity	Pt	0,001262885	4,19945E-05	5,1255E-05	0,000975469	0,000112306	5,70E-06	3,417E-05	4,20E-05
Acidification/ Eutrophication	Pt	0,011654	0,000331869	0,000664255	0,009075427	0,000753806	5,39372E-05	0,000442837	0,000331869
Land use	Pt	0,208995499	0,003758597	0,000231995	0,200990794	4,47027E-06	9,63824E-05	0,000154663	0,003758597
Minerals	Pt	0,345786442	0,007905359	0,005088704	0,318736996	0,002297875	0,000459678	0,003392469	0,007905359

Table 3.6 Total impacts of the EPS insulation on the brickwall detail

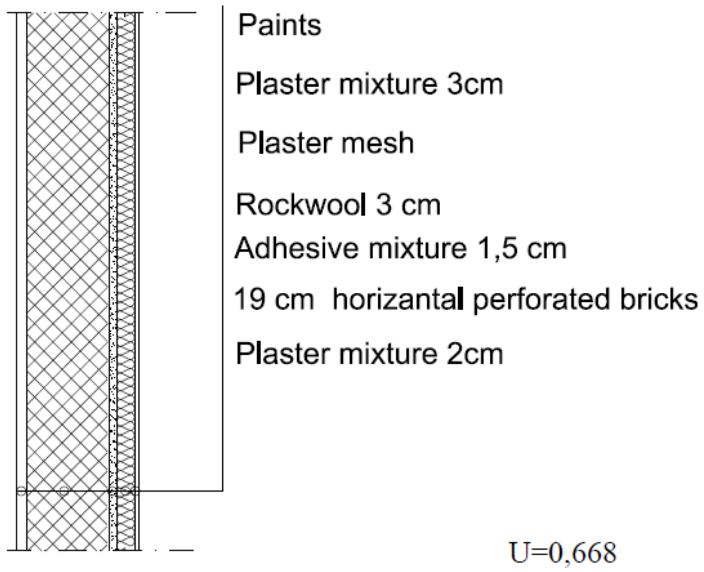


EPS AS THERMAL INSULATION PANEL

A4	BRICK WALL
Calculation:	Analyze
Results:	Impact assessment
Product:	Slab With Heat Insulation_Ceramic
Method:	Eco-indicator 99 (I) V2.08 / Europe EI 99 I/I
Indicator:	Single score

Impact category	Unit	Total	Alkyd Paint	Plaster 3mmcm(6kg)	brick, at plant/DE U 70 kg	EPS 4 CM	Cement Based Adhesive Mortar 1,5 cm	Plaster 2 cm	Alkyd Paint
Total	Pt	1,174937154	0,038559741	0,05622809	0,90619349	0,093268288	0,004642409	0,037485394	0,038559741
Carcinogens	Pt	0,110912207	0,00106558	0,000364353	0,10708929	0,001041158	4,33432E-05	0,000242902	0,00106558
Resp. organics	Pt	0,001327925	4,26328E-05	5,06282E-05	0,000651352	0,000502348	4,58E-06	3,37522E-05	4,26E-05
Resp. inorganics	Pt	0,252945639	0,016786167	0,014982605	0,15537557	0,037748453	0,001278274	0,009988403	0,016786167
Climate change	Pt	0,393990581	0,00861539	0,034762545	0,26637596	0,04974853	0,002697737	0,02317503	0,00861539
Radiation	Pt	0,000104554	7,14678E-06	2,62172E-05	4,40767E-05	1,95898E-07	2,29E-06	1,74782E-05	7,15E-06
Ozone layer	Pt	0,000149264	5,00446E-06	5,53261E-06	0,000126551	2,99465E-06	4,89E-07	3,68841E-06	5,00E-06
Ecotoxicity	Pt	0,001018148	4,19945E-05	5,1255E-05	0,000693297	0,000149741	5,70E-06	3,417E-05	4,20E-05
Acidification/ Eutrophication	Pt	0,009280038	0,000331869	0,000664255	0,006450197	0,001005075	5,39372E-05	0,000442837	0,000331869
Land use	Pt	0,150856795	0,003758597	0,000231995	0,1428506	5,96036E-06	9,63824E-05	0,000154663	0,003758597
Minerals	Pt	0,254352004	0,007905359	0,005088704	0,2265366	0,003063833	0,000459678	0,003392469	0,007905359

Table 3.7 Total impacts of the EPS insulation on the brickwall detail

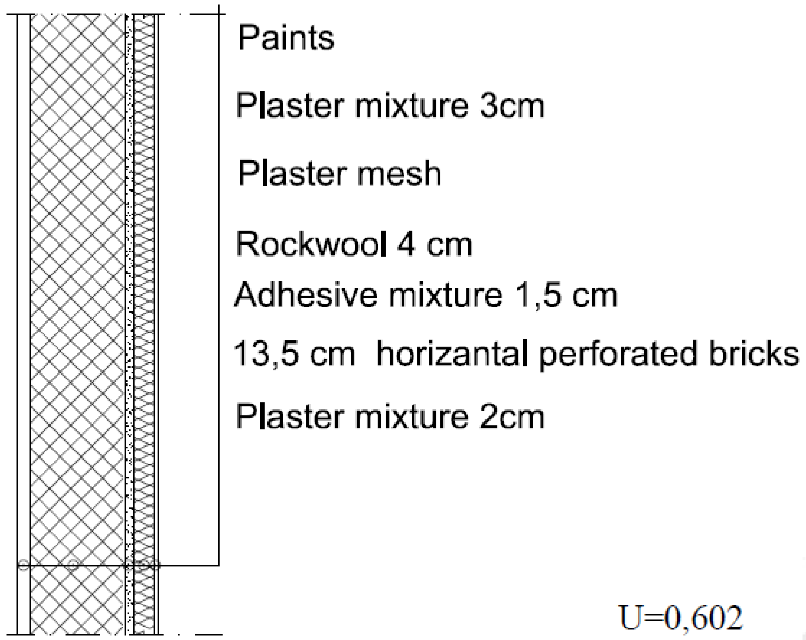


ROCKWOOL AS THERMAL INSULATION PANEL

A6	BRICK WALL
Calculation:	Analyze
Results:	Impact assessment
Product:	Slab With Heat Insulation_Ceramic
Method:	Eco-indicator 99 (I) V2.08 / Europe EI 99 I/I
Indicator:	Single score

Impact category	**Unit**	**Total**	**Alkyd Paint**	**Plaster 3mmcm(6kg)**	**brick, at plant/DE U 98,5 kg**	**ROCKWOOL 3 CM**	**Cement Based Adhesive Mortar 1,5 cm**	**Plaster 2 cm**	**Alkyd Paint**
Total	Pt	2,921266903	0,038559741	0,05622809	1,275143697	1,4581527	0,004642409	0,049980525	0,038559741
Carcinogens	Pt	0,157889956	0,00106558	0,000364353	0,150674631	0,004352598	4,33432E-05	0,000323869	0,00106558
Resp. organics	Pt	0,001822071	4,26328E-05	5,06282E-05	0,000916452	0,000720142	4,58022E-06	4,50029E-05	4,26E-05
Resp. inorganics	Pt	1,409844161	0,016786167	0,014982605	0,218613427	1,12807965	0,001278274	0,013317871	0,016786167
Climate change	Pt	0,571018166	0,00861539	0,034762545	0,374790976	0,110636089	0,002697737	0,03090004	0,00861539
Radiation	Pt	0,000246131	7,14678E-06	2,62172E-05	6,20E-05	0,000118007	2,29287E-06	2,33042E-05	7,15E-06
Ozone layer	Pt	0,000220123	5,00446E-06	5,53261E-06	0,000178057	2,11181E-05	4,88594E-07	4,91788E-06	5,00E-06
Ecotoxicity	Pt	0,001496197	4,19945E-05	5,1255E-05	0,000975469	0,000334229	5,69596E-06	4,556E-05	4,20E-05
Acidification/ Eutrophication	Pt	0,016408775	0,000331869	0,000664255	0,009075427	0,00536097	5,39372E-05	0,000590449	0,000331869
Land use	Pt	0,21805239	0,003758597	0,000231995	0,200990794	0,009009807	9,63824E-05	0,000206218	0,003758597
Minerals	Pt	0,544139486	0,007905359	0,005088704	0,318736996	0,199520096	0,000459678	0,004523293	0,007905359

Table 3.8 Total impacts of the rockwool insulation on the brickwall detail

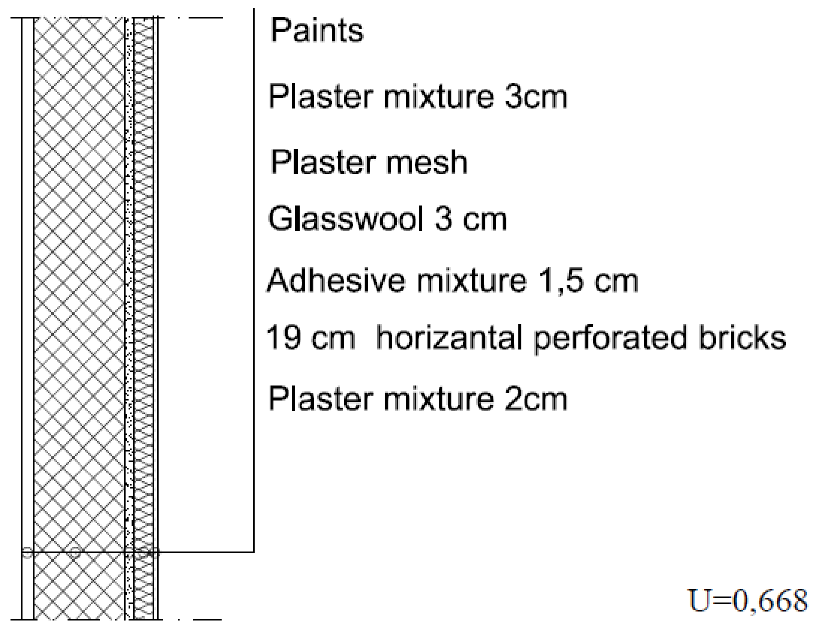


ROCKWOOL AS THERMAL INSULATION PANEL

A7	BRICK WALL
Calculation:	Analyze
Results:	Impact assessment
Product:	Slab With Heat Insulation_Ceramic
Method:	Eco-indicator 99 (I) V2.08 / Europe EI 99 I/I
Indicator:	Single score

Impact category	**Unit**	**Total**	**Alkyd Paint**	**Plaster 3mmcm(6kg)**	**brick, at plant/DE U 70 kg**	**ROCKWOOL 4 CM**	**Cement Based Adhesive Mortar 1,5 cm**	**Plaster 2 cm**	**Alkyd Paint**
Total	Pt	3,038367597	0,038559741	0,05622809	0,90619349	1,9442036	0,004642409	0,049980525	0,038559741
Carcinogens	Pt	0,115755481	0,00106558	0,000364353	0,10708929	0,005803465	4,33432E-05	0,000323869	0,00106558
Resp. organics	Pt	0,001797018	4,26328E-05	5,06282E-05	0,000651352	0,000960189	4,58E-06	4,50029E-05	4,26E-05
Resp. inorganics	Pt	1,722632854	0,016786167	0,014982605	0,15537557	1,5041062	0,001278274	0,013317871	0,016786167
Climate change	Pt	0,499481846	0,00861539	0,034762545	0,26637596	0,147514785	0,002697737	0,03090004	0,00861539
Radiation	Pt	0,000267527	7,14678E-06	2,62172E-05	4,41E-05	0,000157343	2,29E-06	2,33042E-05	7,15E-06
Ozone layer	Pt	0,000175656	5,00446E-06	5,53261E-06	0,000126551	2,81575E-05	4,89E-07	4,91788E-06	5,00E-06
Ecotoxicity	Pt	0,001325435	4,19945E-05	5,1255E-05	0,000693297	0,000445638	5,70E-06	4,556E-05	4,20E-05
Acidification/ Eutrophication	Pt	0,015570535	0,000331869	0,000664255	0,006450197	0,00714796	5,39372E-05	0,000590449	0,000331869
Land use	Pt	0,162915465	0,003758597	0,000231995	0,1428506	0,012013076	9,63824E-05	0,000206218	0,003758597
Minerals	Pt	0,518445789	0,007905359	0,005088704	0,2265366	0,266026795	0,000459678	0,004523293	0,007905359

Table 3.9 Total impacts of the rockwool insulation on the brickwall detail

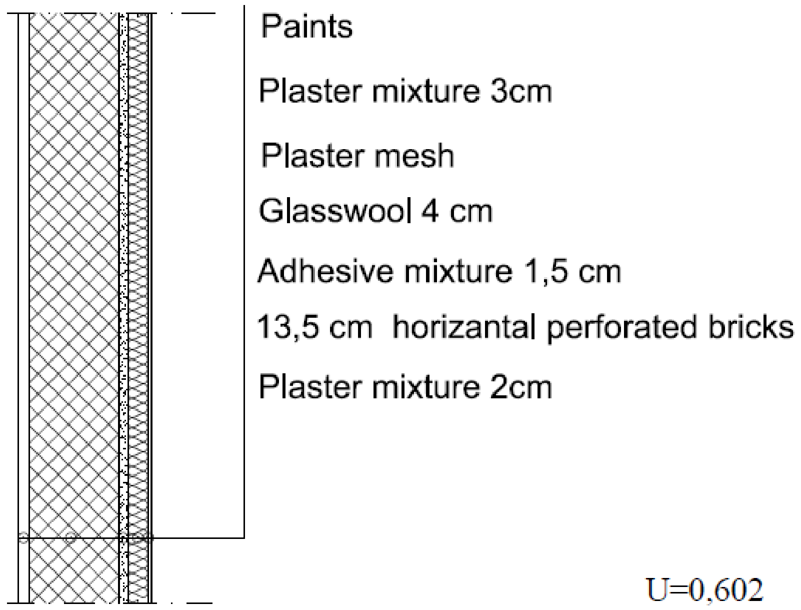


GLASSWOOL AS THERMAL INSULATION PANEL

A8	BRICK WALL
Calculation:	Analyze
Results:	Impact assessment
Product:	Slab With Heat Insulation_Ceramic
Method:	Eco-indicator 99 (I) V2.08 / Europe EI 99 I/I
Indicator:	Single score

Impact category	**Unit**	**Total**	**Alkyd Paint**	**Plaster 3mmcm(6kg)**	**brick, at plant/DE U 98,5 kg**	**GLASSWOOL 3CM**	**Cement Based Adhesive Mortar 1,5 cm**	**Plaster 2 cm**	**Alkyd Paint**
Total	Pt	1,533065419	0,038559741	0,05622809	1,275143697	0,069951216	0,004642409	0,049980525	0,038559741
Carcinogens	Pt	0,154318226	0,00106558	0,000364353	0,150674631	0,000780869	4,33432E-05	0,000323869	0,00106558
Resp. organics	Pt	0,001478689	4,26328E-05	5,06282E-05	0,000916452	0,000376761	4,580E-06	4,50029E-05	4,26E-05
Resp. inorganics	Pt	0,310075851	0,016786167	0,014982605	0,218613427	0,02831134	0,001278274	0,013317871	0,016786167
Climate change	Pt	0,497693474	0,00861539	0,034762545	0,374790976	0,037311397	0,002697737	0,03090004	0,00861539
Radiation	Pt	0,000128271	7,14678E-06	2,62172E-05	6,20E-05	1,46923E-07	2,29E-06	2,33042E-05	7,15E-06
Ozone layer	Pt	0,000201251	5,00446E-06	5,53261E-06	0,000178057	2,24599E-06	4,89E-07	4,91788E-06	5,00E-06
Ecotoxicity	Pt	0,001274275	4,19945E-05	5,1255E-05	0,000975469	0,000112306	5,70E-06	4,556E-05	4,20E-05
Acidification/ Eutrophication	Pt	0,011801612	0,000331869	0,000664255	0,009075427	0,000753806	5,39372E-05	0,000590449	0,000331869
Land use	Pt	0,209047054	0,003758597	0,000231995	0,200990794	4,47027E-06	9,63824E-05	0,000206218	0,003758597
Minerals	Pt	0,346917265	0,007905359	0,005088704	0,318736996	0,002297875	0,000459678	0,004523293	0,007905359

Table 3.10 Total impacts of the glasswool insulation on the brickwall detail

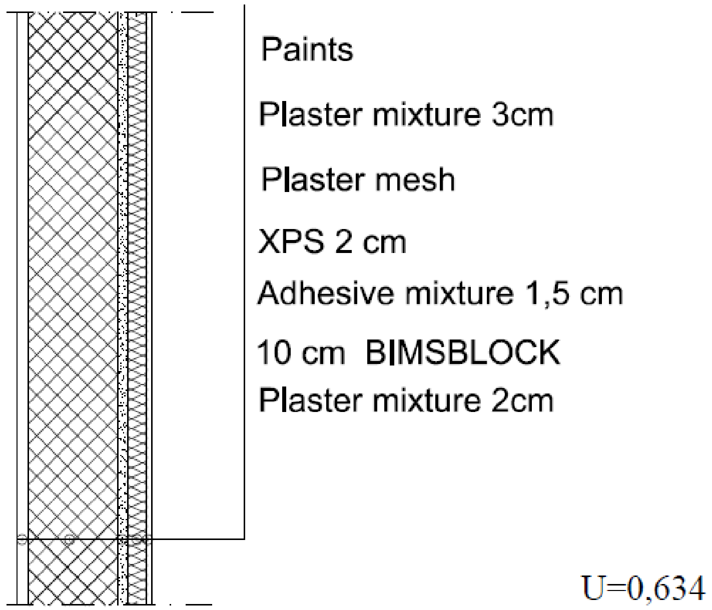


GLASSWOOL AS THERMAL INSULATION PANEL

A9	BRICK WALL
Calculation:	Analyze
Results:	Impact assessment
Product:	Slab With Heat Insulation_Ceramic
Method:	Eco-indicator 99 (I) V2.08 / Europe EI 99 I/I
Indicator:	Single score

Impact category	Unit	Total	Alkyd Paint	Plaster 3mmcm(6kg)	brick, at plant/DE U 70 kg	GLASSWOOL 4CM	Cement Based Adhesive Mortar 1,5 cm	Plaster 2 cm	Alkyd Paint
Total	Pt	1,187432285	0,038559741	0,05622809	0,90619349	0,093268288	0,004642409	0,049980525	0,038559741
Carcinogens	Pt	0,110993175	0,00106558	0,000364353	0,10708929	0,001041158	4,33432E-05	0,000323869	0,00106558
Resp. organics	Pt	0,001339176	4,26328E-05	5,06282E-05	0,000651352	0,000502348	4,58E-06	4,50029E-05	4,26E-05
Resp. inorganics	Pt	0,256275107	0,016786167	0,014982605	0,15537557	0,037748453	0,001278274	0,013317871	0,016786167
Climate change	Pt	0,401715591	0,00861539	0,034762545	0,26637596	0,04974853	0,002697737	0,03090004	0,00861539
Radiation	Pt	0,00011038	7,14678E-06	2,62172E-05	4,41E-05	1,95898E-07	2,29E-06	2,33042E-05	7,15E-06
Ozone layer	Pt	0,000150493	5,00446E-06	5,53261E-06	0,000126551	2,99465E-06	4,89E-07	4,91788E-06	5,00E-06
Ecotoxicity	Pt	0,001029538	4,19945E-05	5,1255E-05	0,000693297	0,000149741	5,70E-06	4,556E-05	4,20E-05
Acidification/ Eutrophication	Pt	0,009427651	0,000331869	0,000664255	0,006450197	0,001005075	5,39372E-05	0,000590449	0,000331869
Land use	Pt	0,15090835	0,003758597	0,000231995	0,1428506	5,96036E-06	9,63824E-05	0,000206218	0,003758597
Minerals	Pt	0,255482827	0,007905359	0,005088704	0,2265366	0,003063833	0,000459678	0,004523293	0,007905359

Table 3.11 Total impacts of the glasswool insulation on the brickwall detail

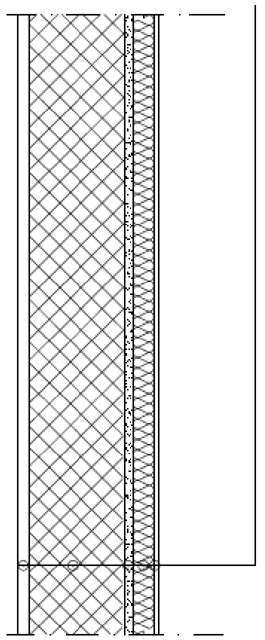


XPS AS THERMAL INSULATION PANEL

B1	BIMS BLOCK
Calculation:	Analyze
Results:	Impact assessment
Product:	Slab With Heat Insulation_Ceramic
Method:	Eco-indicator 99 (I) V2.08 / Europe EI 99 I/I
Indicator:	Single score

Impact category	**Unit**	**Total**	**Alkyd Paint**	**Plaster 3mmcm(6kg)**	**BIMS, at plant/DE U 35 kg**	**XPS 2 CM**	**Cement Based Adhesive Mortar 1,5 cm**	**Plaster 2 cm**	**Alkyd Paint**
Total	Pt	0,711018468	0,038559741	0,05622809	0,453096745	0,069951216	0,004642409	0,049980525	0,038559741
Carcinogens	Pt	0,05718824	0,00106558	0,000364353	0,053544645	0,000780869	4,33432E-05	0,000323869	0,00106558
Resp. organics	Pt	0,000887913	4,26328E-05	5,06282E-05	0,000325676	0,000376761	4,58022E-06	4,50029E-05	4,26328E-05
Resp. inorganics	Pt	0,169150209	0,016786167	0,014982605	0,077687785	0,02831134	0,001278274	0,013317871	0,016786167
Climate change	Pt	0,256090479	0,00861539	0,034762545	0,13318798	0,037311397	0,002697737	0,03090004	0,00861539
Radiation	Pt	8,82931E-05	7,14678E-06	2,62172E-05	2,20383E-05	1,46923E-07	2,29287E-06	2,33042E-05	7,14678E-06
Ozone layer	Pt	8,64693E-05	5,00446E-06	5,53261E-06	6,32753E-05	2,24599E-06	4,88594E-07	4,91788E-06	5,00446E-06
Ecotoxicity	Pt	0,000645454	4,19945E-05	5,1255E-05	0,000346648	0,000112306	5,69596E-06	4,556E-05	4,19945E-05
Acidification/ Eutrophication	Pt	0,005951283	0,000331869	0,000664255	0,003225098	0,000753806	5,39372E-05	0,000590449	0,000331869
Land use	Pt	0,07948156	0,003758597	0,000231995	0,0714253	4,47025E-06	9,63824E-05	0,000206218	0,003758597
Minerals	Pt	0,141448569	0,007905359	0,005088704	0,1132683	0,002297875	0,000459678	0,004523293	0,007905359

Table 3.12 Total impacts of the XPS insulation on the bimsblock detail

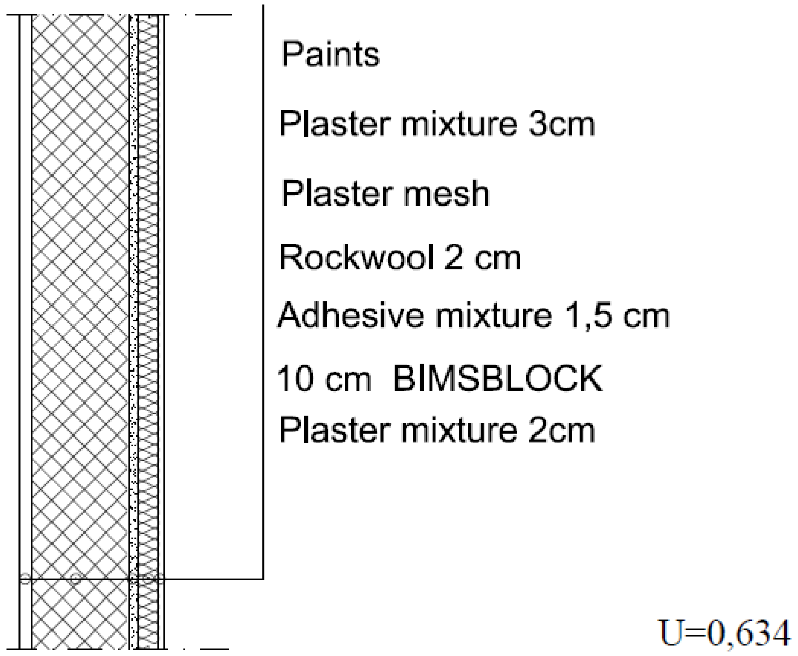


EPS AS THERMAL INSULATION PANEL

B3	BIMS BLOCK
Calculation:	Analyze
Results:	Impact assessment
Product:	Slab With Heat Insulation_Ceramic
Method:	Eco-indicator 99 (I) V2.08 / Europe EI 99 I/I
Indicator:	Single score

Impact category	Unit	Total	Alkyd Paint	Plaster 3mmcm(6kg)	BIMS, at plant/DE U 35 kg	EPS 2 CM	Cement Based Adhesive Mortar 1,5 cm	Plaster 2 cm	Alkyd Paint
Total	Pt	0,687701396	0,038559741	0,05622809	0,453096745	0,046634144	0,004642409	0,049980525	0,038559741
Carcinogens	Pt	0,056927951	0,00106558	0,000364353	0,053544645	0,000520579	4,33432E-05	0,000323869	0,00106558
Resp. organics	Pt	0,000762327	4,26328E-05	5,06282E-05	0,000325676	0,000251174	4,58022E-06	4,50029E-05	4,26328E-05
Resp. inorganics	Pt	0,159713095	0,016786167	0,014982605	0,077687785	0,018874226	0,001278274	0,013317871	0,016786167
Climate change	Pt	0,243653346	0,00861539	0,034762545	0,13318798	0,024874265	0,002697737	0,03090004	0,00861539
Radiation	Pt	8,82442E-05	7,14678E-06	2,62172E-05	2,20383E-05	9,79489E-08	2,29287E-06	2,33042E-05	7,14678E-06
Ozone layer	Pt	8,57207E-05	5,00446E-06	5,53261E-06	6,32753E-05	1,49733E-06	4,88594E-07	4,91788E-06	5,00446E-06
Ecotoxicity	Pt	0,000608019	4,19945E-05	5,1255E-05	0,000346648	7,48706E-05	5,69596E-06	4,556E-05	4,19945E-05
Acidification/ Eutrophication	Pt	0,005700015	0,000331869	0,000664255	0,003225098	0,000502538	5,39372E-05	0,000590449	0,000331869
Land use	Pt	0,07948007	0,003758597	0,000231995	0,0714253	2,98018E-06	9,63824E-05	0,000206218	0,003758597
Minerals	Pt	0,14068261	0,007905359	0,005088704	0,1132683	0,001531917	0,000459678	0,004523293	0,007905359

Table 3.13 Total impacts of the EPS insulation on the bimsblock detail

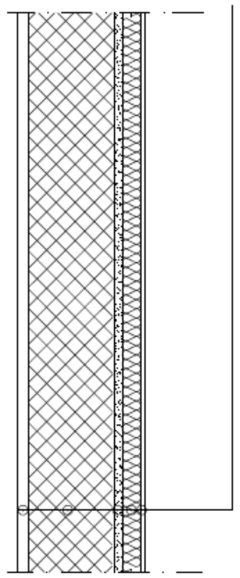


ROCKWOOL AS THERMAL INSULATION PANEL

B6	BIMS BLOCK
Calculation:	Analyze
Results:	Impact assessment
Product:	Slab With Heat Insulation_Ceramic
Method:	Eco-indicator 99 (I) V2.08 / Europe EI 99 I/I
Indicator:	Single score

Impact category	**Unit**	**Total**	**Alkyd Paint**	**Plaster 3mmcm(6kg)**	**BIMS, at plant/DE U 35 kg**	**ROCKWOOL 2 CM**	**Cement Based Adhesive Mortar 1,5 cm**	**Plaster 2 cm**	**Alkyd Paint**
Total	Pt	1,613169052	0,038559741	0,05622809	0,453096745	0,9721018	0,004642409	0,049980525	0,038559741
Carcinogens	Pt	0,059309104	0,00106558	0,000364353	0,053544645	0,002901732	4,33432E-05	0,000323869	0,00106558
Resp. organics	Pt	0,000991247	4,26328E-05	5,06282E-05	0,000325676	0,000480095	4,58022E-06	4,50029E-05	4,26328E-05
Resp. inorganics	Pt	0,892891969	0,016786167	0,014982605	0,077687785	0,7520531	0,001278274	0,013317871	0,016786167
Climate change	Pt	0,292536474	0,00861539	0,034762545	0,13318798	0,073757393	0,002697737	0,03090004	0,00861539
Radiation	Pt	0,000166818	7,14678E-06	2,62172E-05	2,20383E-05	7,86713E-05	2,29287E-06	2,33042E-05	7,14678E-06
Ozone layer	Pt	9,83021E-05	5,00446E-06	5,53261E-06	6,32753E-05	1,40787E-05	4,88594E-07	4,91788E-06	5,00446E-06
Ecotoxicity	Pt	0,000755967	4,19945E-05	5,1255E-05	0,000346648	0,000222819	5,69596E-06	4,556E-05	4,19945E-05
Acidification/ Eutrophication	Pt	0,008771457	0,000331869	0,000664255	0,003225098	0,00357398	5,39372E-05	0,000590449	0,000331869
Land use	Pt	0,085483627	0,003758597	0,000231995	0,0714253	0,006006538	9,63824E-05	0,000206218	0,003758597
Minerals	Pt	0,272164091	0,007905359	0,005088704	0,1132683	0,133013398	0,000459678	0,004523293	0,007905359

Table 3.14 Total impacts of the rockwool insulation on the bimsblock detail



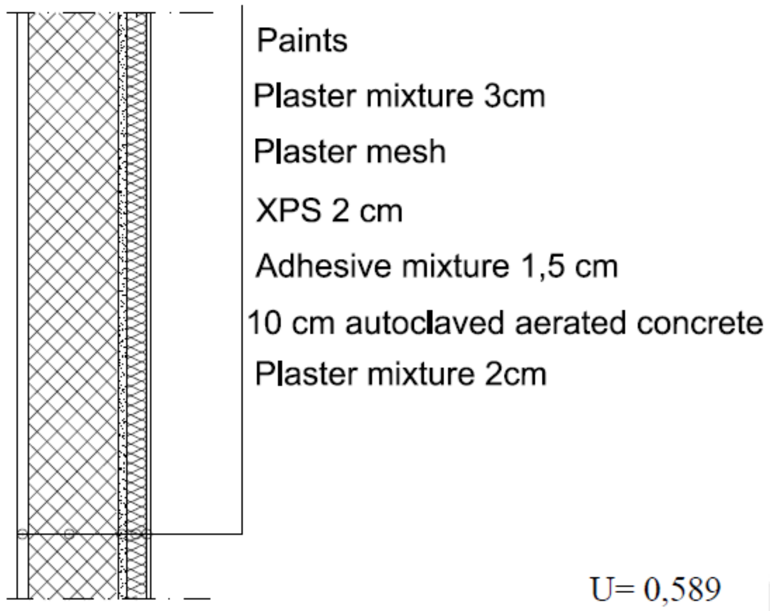
U=0,634

GLASSWOOL AS THERMAL INSULATION PANEL

B8	BIMS BLOCK
Calculation:	Analyze
Results:	Impact assessment
Product:	Slab With Heat Insulation_Ceramic
Method:	Eco-indicator 99 (I) V2.08 / Europe EI 99 I/I
Indicator:	Single score

Impact category	Unit	Total	Alkyd Paint	Plaster 3mmcm(6kg)	BIMS, at plant/DE U 35 kg	GLASSWOOL 2 CM	Cement Based Adhesive Mortar 1,5 cm	Plaster 2 cm	Alkyd Paint
Total	Pt	0,687701396	0,038559741	0,05622809	0,453096745	0,046634144	0,004642409	0,049980525	0,038559741
Carcinogens	Pt	0,056927951	0,00106558	0,000364353	0,053544645	0,000520579	4,33432E-05	0,000323869	0,00106558
Resp. organics	Pt	0,000762327	4,26328E-05	5,06282E-05	0,000325676	0,000251174	4,58022E-06	4,50029E-05	4,26328E-05
Resp. inorganics	Pt	0,159713095	0,016786167	0,014982605	0,077687785	0,018874226	0,001278274	0,013317871	0,016786167
Climate change	Pt	0,243653346	0,00861539	0,034762545	0,13318798	0,024874265	0,002697737	0,03090004	0,00861539
Radiation	Pt	8,82442E-05	7,14678E-06	2,62172E-05	2,20383E-05	9,79489E-08	2,29287E-06	2,33042E-05	7,14678E-06
Ozone layer	Pt	8,57207E-05	5,00446E-06	5,53261E-06	6,32753E-05	1,49733E-06	4,88594E-07	4,91788E-06	5,00446E-06
Ecotoxicity	Pt	0,000608019	4,19945E-05	5,1255E-05	0,000346648	7,48706E-05	5,69596E-06	4,556E-05	4,19945E-05
Acidification/ Eutrophication	Pt	0,005700015	0,000331869	0,000664255	0,003225098	0,000502538	5,39372E-05	0,000590449	0,000331869
Land use	Pt	0,07948007	0,003758597	0,000231995	0,0714253	2,98018E-06	9,63824E-05	0,000206218	0,003758597
Minerals	Pt	0,14068261	0,007905359	0,005088704	0,1132683	0,001531917	0,000459678	0,004523293	0,007905359

Table 3.15 Total impacts of the glasswool insulation on the bimsblock detail

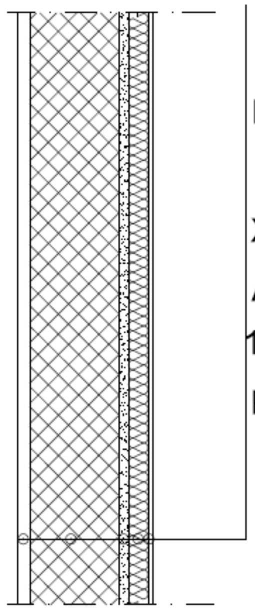


XPS AS THERMAL INSULATION PANEL

C1	AUTOCLAVED AERATED CONCRETE BLOCK
Calculation:	Analyze
Results:	Impact assessment
Product:	Slab With Heat Insulation_Ceramic
Method:	Eco-indicator 99 (I) V2.08 / Europe EI 99 I/I
Indicator:	Single score

Impact category	Unit	Total	Alkyd Paint	Plaster 3mmcm(6kg)	Concrete Block, at plant/CH U 10 cm 40 kg	XPS 2 CM	Cement Based Adhesive Mortar 1,5 cm	Plaster 2 cm	Alkyd Paint
Total	Pt	1,062134473	0,038559741	0,05622809	0,80421275	0,069951216	0,004642409	0,049980525	0,038559741
Carcinogens	Pt	0,013104124	0,00106558	0,000364353	0,009460529	0,000780869	4,33432E-05	0,000323869	0,00106558
Resp. organics	Pt	0,001245743	4,26328E-05	5,06282E-05	0,000683505	0,000376761	4,58022E-06	4,50029E-05	4,26328E-05
Resp. inorganics	Pt	0,328673789	0,016786167	0,014982605	0,237211365	0,02831134	0,001278274	0,013317871	0,016786167
Climate change	Pt	0,511011219	0,00861539	0,034762545	0,38810872	0,037311397	0,002697737	0,03090004	0,00861539
Radiation	Pt	0,000279395	7,14678E-06	2,62172E-05	0,000213141	1,46923E-07	2,29287E-06	2,33042E-05	7,14678E-06
Ozone layer	Pt	0,000111267	5,00446E-06	5,53261E-06	8,80732E-05	2,24599E-06	4,88594E-07	4,91788E-06	5,00446E-06
Ecotoxicity	Pt	0,000793786	4,19945E-05	5,1255E-05	0,000494981	0,000112306	5,69596E-06	4,556E-05	4,19945E-05
Acidification/ Eutrophication	Pt	0,009310715	0,000331869	0,000664255	0,00658453	0,000753806	5,39372E-05	0,000590449	0,000331869
Land use	Pt	0,013386378	0,003758597	0,000231995	0,005330119	4,47025E-06	9,63824E-05	0,000206218	0,003758597
Minerals	Pt	0,184218039	0,007905359	0,005088704	0,15603777	0,002297875	0,000459678	0,004523293	0,007905359

Table 3.16 Total impacts of XPS insulation on the autoclaved aerated concrete block detail

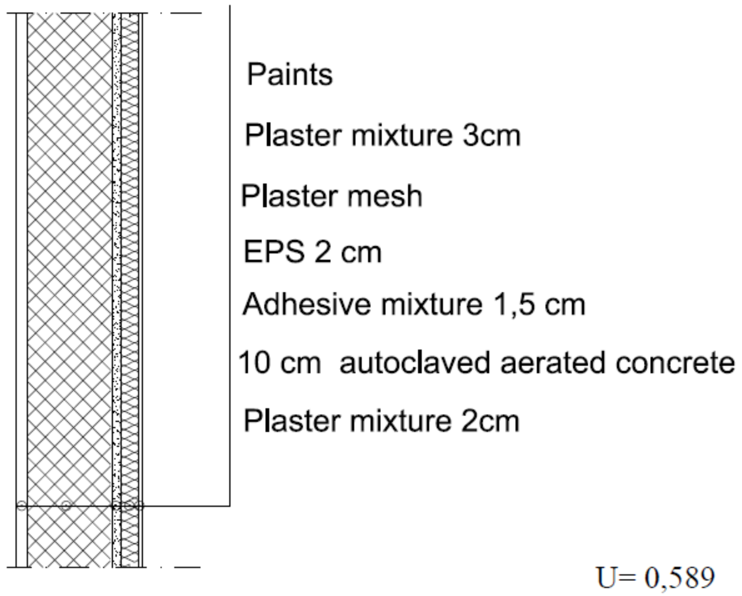


XPS AS THERMAL INSULATION PANEL

C2	AUTOCLAVED AERATED CONCRETE BLOCK
Calculation:	Analyze
Results:	Impact assessment
Product:	Slab With Heat Insulation_Ceramic
Method:	Eco-indicator 99 (I) V2.08 / Europe EI 99 I/I
Indicator:	Single score

Impact category	Unit	Total	Alkyd Paint	Plaster 3mmcm(6kg)	Concrete Block, at plant/CH U 12,5 cm 50 kg	XPS 1 CM	Cement Based Adhesive Mortar 1,5 cm	Plaster 2 cm	Alkyd Paint
Total	Pt	1,228212052	0,038559741	0,05622809	1,005265938	0,034975608	0,004642409	0,049980525	0,038559741
Carcinogens	Pt	0,015078822	0,00106558	0,000364353	0,011825661	0,000390434	4,33432E-05	0,000323869	0,00106558
Resp. organics	Pt	0,001228239	4,26328E-05	5,06282E-05	0,000854382	0,00018838	4,58022E-06	4,50029E-05	4,26328E-05
Resp. inorganics	Pt	0,37382096	0,016786167	0,014982605	0,296514206	0,01415567	0,001278274	0,013317871	0,016786167
Climate change	Pt	0,5893827	0,00861539	0,034762545	0,4851359	0,018655699	0,002697737	0,03090004	0,00861539
Radiation	Pt	0,000332607	7,14678E-06	2,62172E-05	0,000266426	7,34617E-08	2,29287E-06	2,33042E-05	7,14678E-06
Ozone layer	Pt	0,000132162	5,00446E-06	5,53261E-06	0,000110092	1,12299E-06	4,88594E-07	4,91788E-06	5,00446E-06
Ecotoxicity	Pt	0,000861379	4,19945E-05	5,1255E-05	0,000618726	5,6153E-05	5,69596E-06	4,556E-05	4,19945E-05
Acidification/ Eutrophication	Pt	0,010579944	0,000331869	0,000664255	0,008230662	0,000376903	5,39372E-05	0,000590449	0,000331869
Land use	Pt	0,014716673	0,003758597	0,000231995	0,006662648	2,23512E-06	9,63824E-05	0,000206218	0,003758597
Minerals	Pt	0,222078544	0,007905359	0,005088704	0,195047213	0,001148937	0,000459678	0,004523293	0,007905359

Table 3.17 Total impacts of XPS insulation on the autoclaved aerated concrete block detail



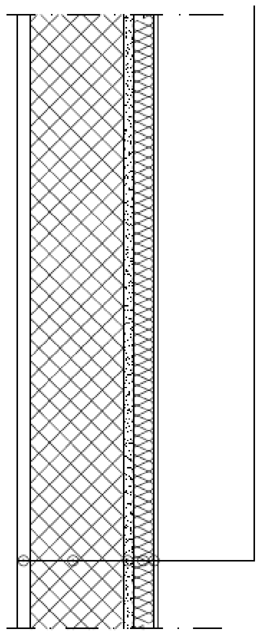
U= 0,589

EPS AS THERMAL INSULATION PANEL

C4	AUTOCLAVED AERATED CONCRETE BLOCK
Calculation:	Analyze
Results:	Impact assessment
Product:	Slab With Heat Insulation_Ceramic
Method:	Eco-indicator 99 (I) V2.08 / Europe EI 99 I/I
Indicator:	Single score

Impact category	**Unit**	**Total**	**Alkyd Paint**	**Plaster 3mmcm(6kg)**	**Concrete Block, at plant/CH U 10 cm 40 kg**	**EPS 2 CM**	**Cement Based Adhesive Mortar 1,5 cm**	**Plaster 2 cm**	**Alkyd Paint**
Total	Pt	1,02632227	0,038559741	0,05622809	0,80421275	0,046634144	0,004642409	0,037485394	0,038559741
Carcinogens	Pt	0,012762867	0,00106558	0,000364353	0,009460529	0,000520579	4,33432E-05	0,000242902	0,00106558
Resp. organics	Pt	0,001108905	4,26328E-05	5,06282E-05	0,000683505	0,000251174	4,58E-06	3,37522E-05	4,26E-05
Resp. inorganics	Pt	0,315907208	0,016786167	0,014982605	0,237211365	0,018874226	0,001278274	0,009988403	0,016786167
Climate change	Pt	0,490849076	0,00861539	0,034762545	0,38810872	0,024874265	0,002697737	0,02317503	0,00861539
Radiation	Pt	0,00027352	7,14678E-06	2,62172E-05	0,000213141	9,79489E-08	2,29E-06	1,74782E-05	7,15E-06
Ozone layer	Pt	0,000109289	5,00446E-06	5,53261E-06	8,80732E-05	1,49733E-06	4,89E-07	3,68841E-06	5,00E-06
Ecotoxicity	Pt	0,000744961	4,19945E-05	5,1255E-05	0,000494981	7,48706E-05	5,70E-06	3,417E-05	4,20E-05
Acidification/ Eutrophication	Pt	0,008911834	0,000331869	0,000664255	0,00658453	0,000502538	5,39372E-05	0,000442837	0,000331869
Land use	Pt	0,013333334	0,003758597	0,000231995	0,005330119	2,98018E-06	9,63824E-05	0,000154663	0,003758597
Minerals	Pt	0,182321257	0,007905359	0,005088704	0,15603777	0,001531917	0,000459678	0,003392469	0,007905359

Table 3.18 Total impacts of EPS insulation on the autoclaved aerated concrete block detail

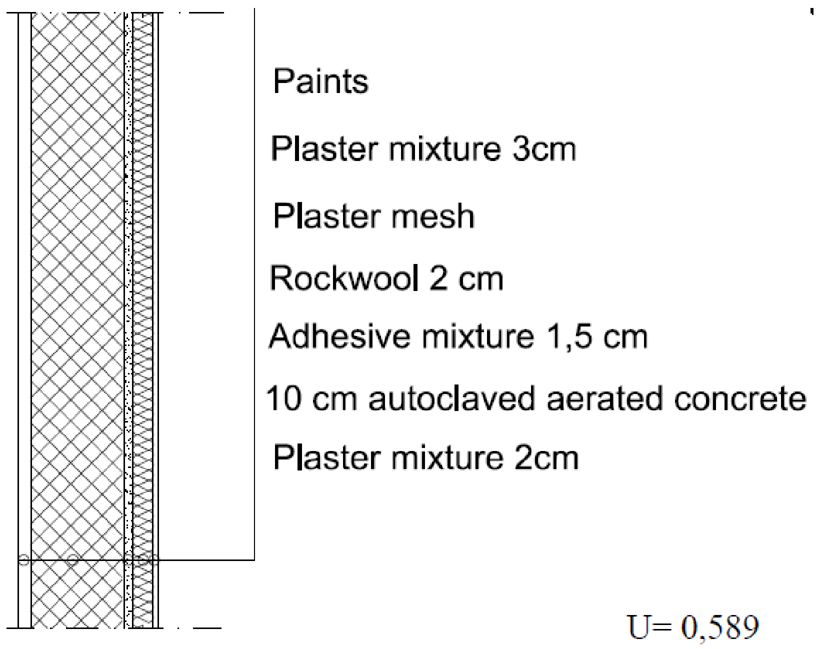


EPS AS THERMAL INSULATION PANEL

C5	AUTOCLAVED AERATED CONCRETE BLOCK
Calculation:	Analyze
Results:	Impact assessment
Product:	Slab With Heat Insulation_Ceramic
Method:	Eco-indicator 99 (I) V2.08 / Europe EI 99 I/I
Indicator:	Single score

Impact category	**Unit**	**Total**	**Alkyd Paint**	**Plaster 3mmcm(6kg)**	**Concrete Block, at plant/CH U 12,5 cm 50 kg**	**EPS 1 CM**	**Cement Based Adhesive Mortar 1,5 cm**	**Plaster 2 cm**	**Alkyd Paint**
Total	Pt	1,192399849	0,038559741	0,05622809	1,005265938	0,011658536	0,004642409	0,037485394	0,038559741
Carcinogens	Pt	0,014737565	0,00106558	0,000364353	0,011825661	0,000130145	4,33432E-05	0,000242902	0,00106558
Resp. organics	Pt	0,001091401	4,26328E-05	5,06282E-05	0,000854382	6,27934E-05	4,58E-06	3,37522E-05	4,26E-05
Resp. inorganics	Pt	0,361054379	0,016786167	0,014982605	0,296514206	0,004718557	0,001278274	0,009988403	0,016786167
Climate change	Pt	0,569220558	0,00861539	0,034762545	0,4851359	0,006218566	0,002697737	0,02317503	0,00861539
Radiation	Pt	0,000326732	7,14678E-06	2,62172E-05	0,000266426	2,44872E-08	2,29E-06	1,74782E-05	7,15E-06
Ozone layer	Pt	0,000130184	5,00446E-06	5,53261E-06	0,000110092	3,74332E-07	4,89E-07	3,68841E-06	5,00E-06
Ecotoxicity	Pt	0,000812553	4,19945E-05	5,1255E-05	0,000618726	1,87177E-05	5,70E-06	3,417E-05	4,20E-05
Acidification/ Eutrophication	Pt	0,010181063	0,000331869	0,000664255	0,008230662	0,000125634	5,39372E-05	0,000442837	0,000331869
Land use	Pt	0,014663628	0,003758597	0,000231995	0,006662648	7,45046E-07	9,63824E-05	0,000154663	0,003758597
Minerals	Pt	0,220181762	0,007905359	0,005088704	0,195047213	0,000382979	0,000459678	0,003392469	0,007905359

Table 3.19 Total impacts of EPS insulation on the autoclaved aerated concrete block detail

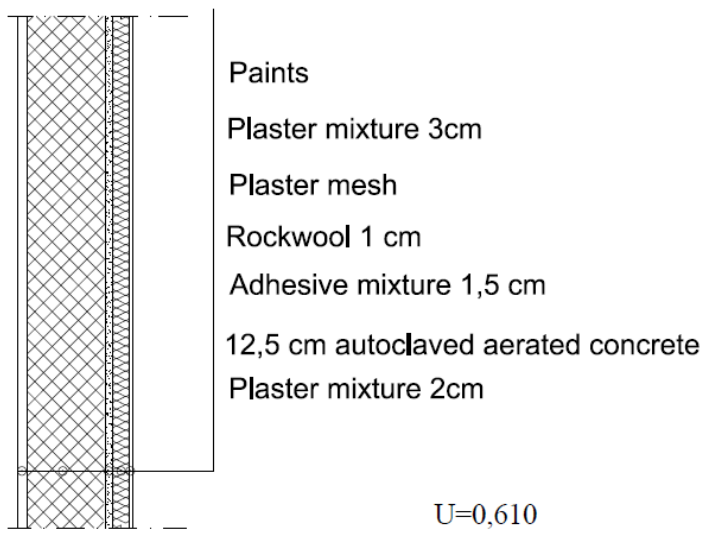


ROCKWOOL AS THERMAL INSULATION PANEL

C6	AUTOCLAVED AERATED CONCRETE BLOCK
Calculation:	Analyze
Results:	Impact assessment
Product:	Slab With Heat Insulation_Ceramic
Method:	Eco-indicator 99 (I) V2.08 / Europe EI 99 I/I
Indicator:	Single score

Impact category	Unit	Total	Alkyd Paint	Plaster 3mmcm(6kg)	Concrete Block, at plant/CH U 10 cm 40 kg	ROCKWOOL 2 CM	Cement Based Adhesive Mortar 1,5 cm	Plaster 2 cm	Alkyd Paint
Total	Pt	1,964285057	0,038559741	0,05622809	0,80421275	0,9721018	0,004642409	0,049980525	0,038559741
Carcinogens	Pt	0,015224988	0,00106558	0,000364353	0,009460529	0,002901732	4,33432E-05	0,000323869	0,00106558
Resp. organics	Pt	0,001349077	4,26328E-05	5,06282E-05	0,000683505	0,000480095	4,58022E-06	4,50029E-05	4,26328E-05
Resp. inorganics	Pt	1,052415549	0,016786167	0,014982605	0,237211365	0,7520531	0,001278274	0,013317871	0,016786167
Climate change	Pt	0,547457214	0,00861539	0,034762545	0,38810872	0,073757393	0,002697737	0,03090004	0,00861539
Radiation	Pt	0,00035792	7,14678E-06	2,62172E-05	0,000213141	7,86713E-05	2,29287E-06	2,33042E-05	7,14678E-06
Ozone layer	Pt	0,0001231	5,00446E-06	5,53261E-06	8,80732E-05	1,40787E-05	4,88594E-07	4,91788E-06	5,00446E-06
Ecotoxicity	Pt	0,0009043	4,19945E-05	5,1255E-05	0,000494981	0,000222819	5,69596E-06	4,556E-05	4,19945E-05
Acidification/ Eutrophication	Pt	0,012130888	0,000331869	0,000664255	0,00658453	0,00357398	5,39372E-05	0,000590449	0,000331869
Land use	Pt	0,019388446	0,003758597	0,000231995	0,005330119	0,006006538	9,63824E-05	0,000206218	0,003758597
Minerals	Pt	0,314933561	0,007905359	0,005088704	0,15603777	0,133013398	0,000459678	0,004523293	0,007905359

Table 3.20 Total impacts of rockwool insulation on the autoclaved aerated concrete block detail

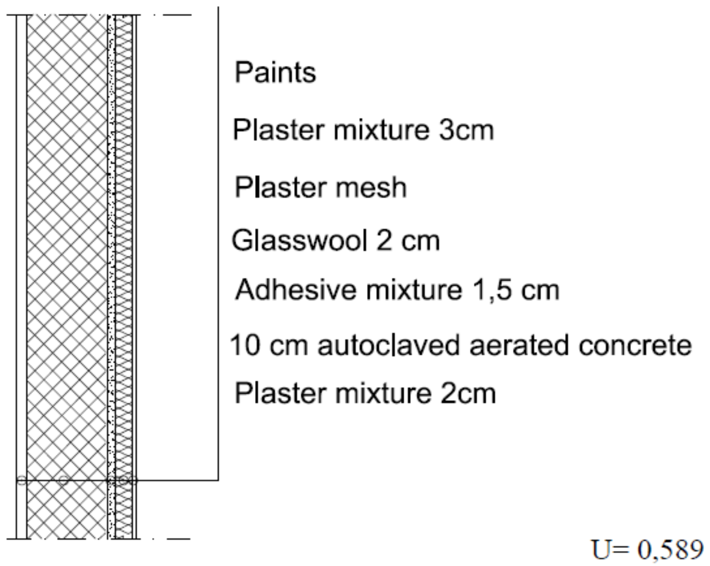


ROCKWOOL AS THERMAL INSULATION PANEL

C7	AUTOCLAVED AERATED CONCRETE BLOCK
Calculation:	Analyze
Results:	Impact assessment
Product:	Slab With Heat Insulation_Ceramic
Method:	Eco-indicator 99 (I) V2.08 / Europe EI 99 I/I
Indicator:	Single score

Impact category	**Unit**	**Total**	**Alkyd Paint**	**Plaster 3mmcm(6kg)**	**Concrete Block, at plant/CH U 12,5 cm 50 kg**	**ROCKWOOL 1 CM**	**Cement Based Adhesive Mortar 1,5 cm**	**Plaster 2 cm**	**Alkyd Paint**
Total	Pt	1,679287344	0,038559741	0,05622809	1,005265938	0,4860509	0,004642409	0,049980525	0,038559741
Carcinogens	Pt	0,016139254	0,00106558	0,000364353	0,011825661	0,001450866	4,33432E-05	0,000323869	0,00106558
Resp. organics	Pt	0,001279906	4,26328E-05	5,06282E-05	0,000854382	0,000240047	4,58022E-06	4,50029E-05	4,26328E-05
Resp. inorganics	Pt	0,73569184	0,016786167	0,014982605	0,296514206	0,37602655	0,001278274	0,013317871	0,016786167
Climate change	Pt	0,607605698	0,00861539	0,034762545	0,4851359	0,036878696	0,002697737	0,03090004	0,00861539
Radiation	Pt	0,000371869	7,14678E-06	2,62172E-05	0,000266426	3,93356E-05	2,29287E-06	2,33042E-05	7,14678E-06
Ozone layer	Pt	0,000138079	5,00446E-06	5,53261E-06	0,000110092	7,03937E-06	4,88594E-07	4,91788E-06	5,00446E-06
Ecotoxicity	Pt	0,000916635	4,19945E-05	5,1255E-05	0,000618726	0,00011141	5,69596E-06	4,556E-05	4,19945E-05
Acidification/ Eutrophication	Pt	0,01199003	0,000331869	0,000664255	0,008230662	0,00178699	5,39372E-05	0,000590449	0,000331869
Land use	Pt	0,017717706	0,003758597	0,000231995	0,006662648	0,003003269	9,63824E-05	0,000206218	0,003758597
Minerals	Pt	0,287436305	0,007905359	0,005088704	0,195047213	0,066506699	0,000459678	0,004523293	0,007905359

Table 3.21 Total impacts of rockwool insulation on the autoclaved aerated concrete block detail



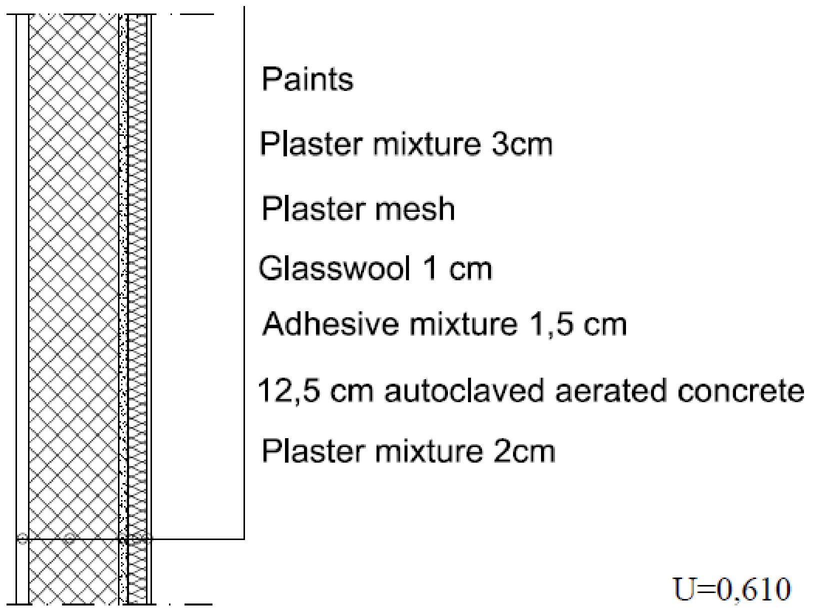
U= 0,589

GLASSWOOL AS THERMAL INSULATION PANEL

C8	AUTOCLAVED AERATED CONCRETE BLOCK
Calculation:	Analyze
Results:	Impact assessment
Product:	Slab With Heat Insulation_Ceramic
Method:	Eco-indicator 99 (I) V2.08 / Europe EI 99 I/I
Indicator:	Single score

Impact category	**Unit**	**Total**	**Alkyd Paint**	**Plaster 3mmcm(6kg)**	**Concrete Block, at plant/CH U 10 cm 40 kg**	**GLASSWOOL 2 CM**	**Cement Based Adhesive Mortar 1,5 cm**	**Plaster 2 cm**	**Alkyd Paint**
Total	Pt	1,038817401	0,038559741	0,05622809	0,80421275	0,046634144	0,004642409	0,049980525	0,038559741
Carcinogens	Pt	0,012843835	0,00106558	0,000364353	0,009460529	0,000520579	4,33432E-05	0,000323869	0,00106558
Resp. organics	Pt	0,001120156	4,26328E-05	5,06282E-05	0,000683505	0,000251174	4,58022E-06	4,50029E-05	4,26328E-05
Resp. inorganics	Pt	0,319236675	0,016786167	0,014982605	0,237211365	0,018874226	0,001278274	0,013317871	0,016786167
Climate change	Pt	0,498574086	0,00861539	0,034762545	0,38810872	0,024874265	0,002697737	0,03090004	0,00861539
Radiation	Pt	0,000279346	7,14678E-06	2,62172E-05	0,000213141	9,79489E-08	2,29287E-06	2,33042E-05	7,14678E-06
Ozone layer	Pt	0,000110519	5,00446E-06	5,53261E-06	8,80732E-05	1,49733E-06	4,88594E-07	4,91788E-06	5,00446E-06
Ecotoxicity	Pt	0,000756351	4,19945E-05	5,1255E-05	0,000494981	7,48706E-05	5,69596E-06	4,556E-05	4,19945E-05
Acidification/ Eutrophication	Pt	0,009059446	0,000331869	0,000664255	0,00658453	0,000502538	5,39372E-05	0,000590449	0,000331869
Land use	Pt	0,013384888	0,003758597	0,000231995	0,005330119	2,98018E-06	9,63824E-05	0,000206218	0,003758597
Minerals	Pt	0,18345208	0,007905359	0,005088704	0,15603777	0,001531917	0,000459678	0,004523293	0,007905359

Table 3.22 Total impacts of glasswool insulation on the autoclaved aerated concrete block detail

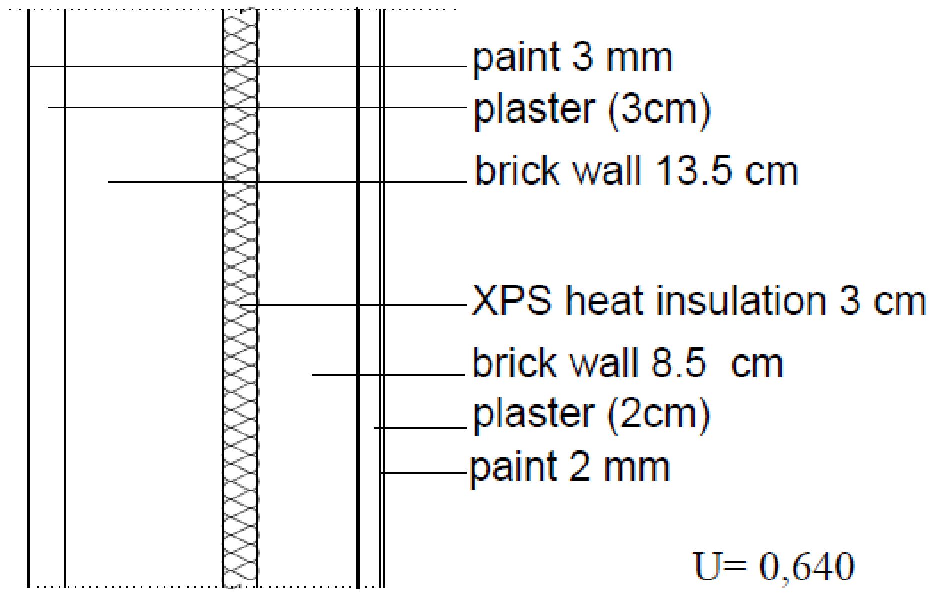


GLASSWOOL AS THERMAL INSULATION PANEL

C9	AUTOCLAVED AERATED CONCRETE BLOCK
Calculation:	Analyze
Results:	Impact assessment
Product:	Slab With Heat Insulation_Ceramic
Method:	Eco-indicator 99 (I) V2.08 / Europe EI 99 I/I
Indicator:	Single score

Impact category	**Unit**	**Total**	**Alkyd Paint**	**Plaster 3mmcm(6kg)**	**Concrete Block, at plant/CH U 12,5 cm 50 kg**	**GLASSWOOL 1 CM**	**Cement Based Adhesive Mortar 1,5 cm**	**Plaster 2 cm**	**Alkyd Paint**
Total	Pt	1,216553516	0,038559741	0,05622809	1,005265938	0,023317072	0,004642409	0,049980525	0,038559741
Carcinogens	Pt	0,014948677	0,00106558	0,000364353	0,011825661	0,00026029	4,33432E-05	0,000323869	0,00106558
Resp. organics	Pt	0,001165445	4,26328E-05	5,06282E-05	0,000854382	0,000125587	4,58022E-06	4,50029E-05	4,26328E-05
Resp. inorganics	Pt	0,369102404	0,016786167	0,014982605	0,296514206	0,009437113	0,001278274	0,013317871	0,016786167
Climate change	Pt	0,583164134	0,00861539	0,034762545	0,4851359	0,012437132	0,002697737	0,03090004	0,00861539
Radiation	Pt	0,000332583	7,14678E-06	2,62172E-05	0,000266426	4,89744E-08	2,29287E-06	2,33042E-05	7,14678E-06
Ozone layer	Pt	0,000131788	5,00446E-06	5,53261E-06	0,000110092	7,48663E-07	4,88594E-07	4,91788E-06	5,00446E-06
Ecotoxicity	Pt	0,000842661	4,19945E-05	5,1255E-05	0,000618726	3,74353E-05	5,69596E-06	4,556E-05	4,19945E-05
Acidification/ Eutrophication	Pt	0,010454309	0,000331869	0,000664255	0,008230662	0,000251269	5,39372E-05	0,000590449	0,000331869
Land use	Pt	0,014715928	0,003758597	0,000231995	0,006662648	1,49009E-06	9,63824E-05	0,000206218	0,003758597
Minerals	Pt	0,221695564	0,007905359	0,005088704	0,195047213	0,000765958	0,000459678	0,004523293	0,007905359

Table 3.23 Total impacts of glasswool insulation on the autoclaved aerated concrete block detail

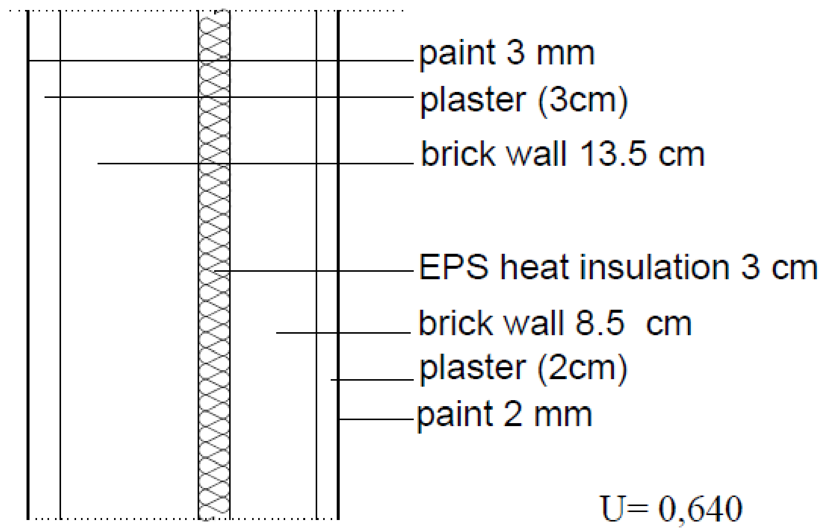


XPS AS THERMAL INSULATION PANEL

D1	BRICK WALL (SANDWICH)
Calculation:	Analyze
Results:	Impact assessment
Product:	Slab With Heat Insulation_Ceramic
Method:	Eco-indicator 99 (I) V2.08 / Europe EI 99 I/I
Indicator:	Single score

Impact category	**Unit**	**Total**	**Alkyd Paint**	**Plaster 3cm(66kg)**	**brick, at plant/DE U 70 kg**	**XPS 3 CM**	**brick, at plant/DE U 46.25 kg**	**Plaster 2 cm**	**Alkyd Paint**
Total	Pt	2,62645833	0,038559741	0,56369013	0,90619349	0,104926824	0,598734984	0,37579342	0,038559741
Carcinogens	Pt	0,187234949	0,00106558	0,003652663	0,10708929	0,001171303	0,070755424	0,002435109	0,00106558
Resp. organics	Pt	0,002578034	4,26328E-05	0,000507551	0,000651352	0,000565141	0,000430357	0,000338368	4,26328E-05
Resp. inorganics	Pt	0,584409692	0,016786167	0,150201552	0,15537557	0,042467009	0,102658859	0,100134368	0,016786167
Climate change	Pt	1,096400058	0,00861539	0,348496692	0,26637596	0,055967096	0,175998402	0,232331128	0,00861539
Radiation	Pt	0,000525762	7,14678E-06	0,00026283	4,40767E-05	2,20385E-07	2,91221E-05	0,00017522	7,14678E-06
Ozone layer	Pt	0,000315984	5,00446E-06	5,54648E-05	0,000126551	3,36898E-06	8,36138E-05	3,69765E-05	5,00446E-06
Ecotoxicity	Pt	0,002260207	4,19945E-05	0,000513834	0,000693297	0,000168459	0,000458071	0,000342556	4,19945E-05
Acidification/ Eutrophication	Pt	0,023605048	0,000331869	0,0066592	0,006450197	0,00113071	0,004261737	0,004439467	0,000331869
Land use	Pt	0,248634206	0,003758597	0,002325765	0,1428506	6,70537E-06	0,094383432	0,00155051	0,003758597
Minerals	Pt	0,480494396	0,007905359	0,051014578	0,2265366	0,003446812	0,149675968	0,034009719	0,007905359

Table 3.24 Total impacts of XPS insulation on the sandwichwall

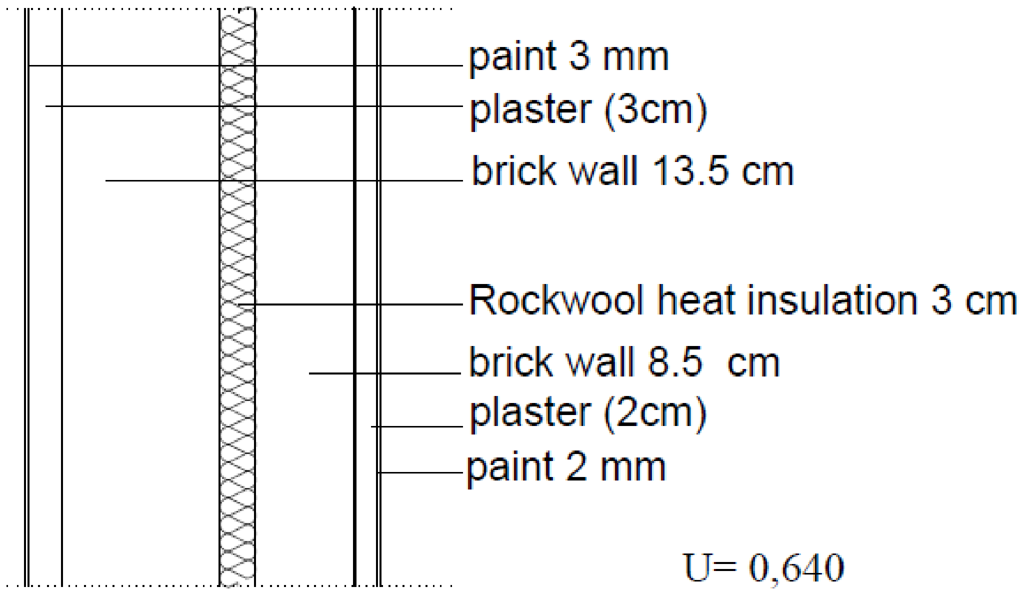


EPS AS THERMAL INSULATION PANEL

D3	BRICK WALL (SANDWICH)
Calculation:	Analyze
Results:	Impact assessment
Product:	Slab With Heat Insulation_Ceramic
Method:	Eco-indicator 99 (I) V2.08 / Europe EI 99 I/I
Indicator:	Single score

Impact category	Unit	Total	Alkyd Paint	Plaster 3cm(66kg)	brick, at plant/DE U 70 kg	EPS 3 CM	brick, at plant/DE U 46.25 kg	Plaster 2 cm	Alkyd Paint
Total	Pt	2,591482722	0,038559741	0,56369013	0,90619349	0,069951216	0,598734984	0,37579342	0,038559741
Carcinogens	Pt	0,186844515	0,00106558	0,003652663	0,10708929	0,000780869	0,070755424	0,002435109	0,00106558
Resp. organics	Pt	0,002389654	4,26328E-05	0,000507551	0,000651352	0,000376761	0,000430357	0,000338368	4,26328E-05
Resp. inorganics	Pt	0,570254022	0,016786167	0,150201552	0,15537557	0,02831134	0,102658859	0,100134368	0,016786167
Climate change	Pt	1,077744359	0,00861539	0,348496692	0,26637596	0,037311397	0,175998402	0,232331128	0,00861539
Radiation	Pt	0,000525688	7,14678E-06	0,00026283	4,40767E-05	1,46923E-07	2,91221E-05	0,00017522	7,14678E-06
Ozone layer	Pt	0,000314861	5,00446E-06	5,54648E-05	0,000126551	2,24599E-06	8,36138E-05	3,69765E-05	5,00446E-06
Ecotoxicity	Pt	0,002204054	4,19945E-05	0,000513834	0,000693297	0,000112306	0,000458071	0,000342556	4,19945E-05
Acidification/ Eutrophication	Pt	0,023228144	0,000331869	0,0066592	0,006450197	0,000753806	0,004261737	0,004439467	0,000331869
Land use	Pt	0,248631971	0,003758597	0,002325765	0,1428506	4,47027E-06	0,094383432	0,00155051	0,003758597
Minerals	Pt	0,479345459	0,007905359	0,051014578	0,2265366	0,002297875	0,149675968	0,034009719	0,007905359

Table 3.25 Total impacts of EPS insulation on the sandwichwall

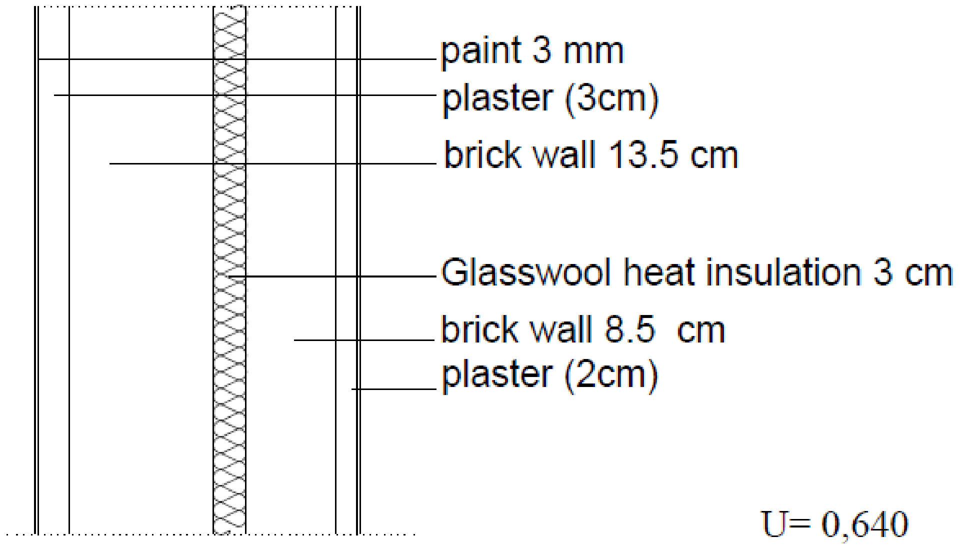


ROCKWOOL AS THERMAL INSULATION PANEL

D6	BRICK WALL (SANDWICH)
Calculation:	Analyze
Results:	Impact assessment
Product:	Slab With Heat Insulation_Ceramic
Method:	Eco-indicator 99 (I) V2.08 / Europe EI 99 I/I
Indicator:	Single score

Impact category	**Unit**	**Total**	**Alkyd Paint**	**Plaster 3cm(66kg)**	**brick, at plant/DE U 70 kg**	**ROCKWOOL 3 CM**	**brick, at plant/DE U 46.25 kg**	**Plaster 2 cm**	**Alkyd Paint**
Total	Pt	3,979684206	0,038559741	0,56369013	0,90619349	1,4581527	0,598734984	0,37579342	0,038559741
Carcinogens	Pt	0,190416244	0,00106558	0,003652663	0,10708929	0,004352598	0,070755424	0,002435109	0,00106558
Resp. organics	Pt	0,002733035	4,26328E-05	0,000507551	0,000651352	0,000720142	0,000430357	0,000338368	4,26328E-05
Resp. inorganics	Pt	1,670022333	0,016786167	0,150201552	0,15537557	1,12807965	0,102658859	0,100134368	0,016786167
Climate change	Pt	1,151069051	0,00861539	0,348496692	0,26637596	0,110636089	0,175998402	0,232331128	0,00861539
Radiation	Pt	0,000643548	7,14678E-06	0,00026283	4,40767E-05	0,000118007	2,91221E-05	0,00017522	7,14678E-06
Ozone layer	Pt	0,000333733	5,00446E-06	5,54648E-05	0,000126551	2,11181E-05	8,36138E-05	3,69765E-05	5,00446E-06
Ecotoxicity	Pt	0,002425977	4,19945E-05	0,000513834	0,000693297	0,000334229	0,000458071	0,000342556	4,19945E-05
Acidification/ Eutrophication	Pt	0,027835308	0,000331869	0,0066592	0,006450197	0,00536097	0,004261737	0,004439467	0,000331869
Land use	Pt	0,257637308	0,003758597	0,002325765	0,1428506	0,009009807	0,094383432	0,00155051	0,003758597
Minerals	Pt	0,67656768	0,007905359	0,051014578	0,2265366	0,199520096	0,149675968	0,034009719	0,007905359

Table 3.26 Total impacts of rockwool insulation on the sandwichwall



GLASSWOOL AS THERMAL INSULATION PANEL

D8	BRICK WALL (SANDWICH)
Calculation:	Analyze
Results:	Impact assessment
Product:	Slab With Heat Insulation_Ceramic
Method:	Eco-indicator 99 (I) V2.08 / Europe EI 99 I/I
Indicator:	Single score

Impact category	Unit	Total	Alkyd Paint	Plaster 3cm(66kg)	brick, at plant/DE U 70 kg	GLASSWOOL 3 CM	brick, at plant/DE U 46.25 kg	Plaster 2 cm	Alkyd Paint
Total	Pt	2,591173782	0,038559741	0,56369013	0,90619349	0,069642276	0,598734984	0,37579342	0,038559741
Carcinogens	Pt	0,188224613	0,00106558	0,003652663	0,10708929	0,002160967	0,070755424	0,002435109	0,00106558
Resp. organics	Pt	0,002156575	4,26328E-05	0,000507551	0,000651352	0,000143682	0,000430357	0,000338368	4,26328E-05
Resp. inorganics	Pt	0,567996275	0,016786167	0,150201552	0,15537557	0,026053592	0,102658859	0,100134368	0,016786167
Climate change	Pt	1,059389531	0,00861539	0,348496692	0,26637596	0,018956569	0,175998402	0,232331128	0,00861539
Radiation	Pt	0,000621771	7,14678E-06	0,00026283	4,40767E-05	9,62291E-05	2,91221E-05	0,00017522	7,14678E-06
Ozone layer	Pt	0,000324564	5,00446E-06	5,54648E-05	0,000126551	1,19495E-05	8,36138E-05	3,69765E-05	5,00446E-06
Ecotoxicity	Pt	0,002169218	4,19945E-05	0,000513834	0,000693297	7,74697E-05	0,000458071	0,000342556	4,19945E-05
Acidification/ Eutrophication	Pt	0,023503313	0,000331869	0,0066592	0,006450197	0,001028975	0,004261737	0,004439467	0,000331869
Land use	Pt	0,249138935	0,003758597	0,002325765	0,1428506	0,000511434	0,094383432	0,00155051	0,003758597
Minerals	Pt	0,497648989	0,007905359	0,051014578	0,2265366	0,020601405	0,149675968	0,034009719	0,007905359

Table 3.27 Total impacts of glasswool insulation on the sandwichwall

3.4 Initial costs of selected details

A major part of the energy used is used as heating energy. Heat insulation of buildings has become more important to prevent heat losses in buildings and reduce energy consumption. A large part of energy consumed for heating can be recovered with a correctly implemented thermal insulation. Correct selection of insulation material and implementing it with appropriate thickness is important in terms of costs.

In this section, the implementation costs of 4 different insulation materials (rock wool, glass wool, EPS, XPS) applied to 4 different wall models (aerated concrete, brick, pumice block and sandwich wall) on sample walls were calculated separately. This comparison was performed for the 1st temperature region. For cost analyses, the sections in section 3 were used. In heating cost analysis, the annual heating costs for 1 m2 building usage area for aerated concrete, brick, pumice block and sandwich walls by changing the U values of exterior walls using wall sections of Sardes Hospital are calculated below.

3.4.1 Brick Wall System

Insulation cost that different materials applied over 19 cm thickness of the brick wall

a) Rockwool

Brick 19 x19 x 13.5 cm (28 pieces) ……………………………………..30, 14 TL

Mortar 200 kg (0,025 m3/m2) ……………………………………………1, 68 TL

Wall craft. ……………………………..7.90 TL

Plaster mesh (160gr/m2)………………………...1, 43 TL

Insulation adhesive (4kg /m2)………………...1, 32 TL

Insulation plaster (5 kg /m2) ....4,95 TL

Peg (6 piece / m2)……………………………………………………….0, 72 TL

Sheat crafting (incl.insulation panel)……………………………………41, 80 TL

Scaffolding (incl. material and crafting)…………………………………..4, 83 TL

Exterior plaster (cement mortar 3cm)………………………………………..10 TL

Exterior plaster craft …………………………………………………..20, 88 TL

Interior plaster (Plaster mortar2 cm)…………………………………….....10TL

Interior plaster crafting…….. ……………………………………………18, 70 TL

TOTAL………………………………………………………………… **154, 35 TL**

b) Glasswool

Brick 19 x19 x 13.5 cm (28 pieces) ………………………….............30,14 TL

Mortar 200 kg (0,025 m3/m2) ………………………………....................1,68 TL

Wall craft. ……………………………..7,90 TL

Plaster mesh (160gr/m2)……………………..1,43 TL

Insulation adhesive (4kg /m2)………………...1, 32 TL

Insulation plaster (5 kg /m2) ....4,95 TL

Peg (6 piece / m2)…………………………………………………………0,72 TL

Sheat crafting (rockwool 3cm) …………………………………………..41, 80 TL

Scaffolding (incl. material and crafting)…………………………………..4, 83 TL

Exterior plaster (cement mortar 3cm)…………………………………..…10 TL

Exterior plaster craft …………………………………………………… 20, 88 TL

Interior plaster (Plaster mortar 2 cm)……………………………………...10 TL

Interior plaster crafting…………………………………………………...18, 70 TL

TOTAL……………………………………………………………...**154, 35 TL**

c) XPS

Brick 19 x19 x 13.5 cm (28 pieces) ……………………………............. 30,14 TL

Mortar 200 kg (0,025 m3/m2) ………………………………...................1, 68 TL

Wall craft. ……………………………..7,90 TL

Plaster mesh (160gr/m2)………………………...1,43 TL

Insulation adhesive (4kg /m2)………………..1, 32 TL

Insulation plaster (5 kg /m2) ....4,95 TL

Peg (6 piece / m2)………………………………………………………… 0, 72 TL

Sheat crafting …………………………………………………………… 35, 54 TL

Scaffolding (incl. material and crafting)………………………………… 4, 83 TL

Exterior plaster (Cement mortar 3cm)……………………………..……...10 TL

Exterior plaster craft …………………………………………………. 20, 88 TL

Interior plaster (Plaster mortar 2 cm)……………………………………..10 TL

Interior plaster crafting………………………………………………   18, 70 TL

TOTAL………………………………………………………………….. **148.09 TL**

d) EPS

Brick 19 x19 x 13.5 cm (28 pieces) ………………………….................30,14 TL

Mortar 200 kg (0,025 m3/m2) ……………………………….....................1, 68 TL

Wall craft. ……………………………..7,90 TL

Plaster mesh (160gr/m2)……………………...1, 43 TL

Insulation adhesive (4kg /m2)……………….. 1, 32 TL

Insulation plaster (5 kg /m2) ....4,95 TL

Peg (6 piece / m2)……………………………………………………… 0,72 TL

Sheat crafting ………………………………………………………… 31, 80 TL

Scaffolding (incl. material and crafting)…………………………………..4, 83 TL

Exterior plaster (Cement mortar 3cm)……………………………………….10 TL

Exterior plaster craft …………………………………………………. 20, 88 TL

Interior plaster (Plaster mortar 2 cm)……………………………………...10 TL

Interior plaster crafting………………………………………………...18, 70 TL

TOTAL…………………………………………………………...**144, 35 TL**

Insulation cost that different materials applied over 13,5 cm thickness of the brick wall

a) Rockwool

Brick 19 x13.5 x 19 cm   (28 pieces) ………………………….................25,50 TL

Mortar 200 kg (0,025 m3/m2) ……………………………….....................1, 68 TL

Wall craft. ……………………………..7,90 TL

Plaster mesh (160gr/m2)………………………...1,43 TL

Insulation adhesive (4kg /m2)………………..1, 32 TL

Insulation plaster (5 kg /m2) ....4,95 TL

Peg (6 piece / m2)……………………………………………………… 0,72 TL

Sheat crafting ……………………………..……………………… 41, 80 TL

Scaffolding (incl. material and crafting)………………………………...4,83 TL

Exterior plaster (Cement mortar 3cm)……………………………………10 TL

Exterior plaster craft …………………………………………………. 20, 88 TL

Interior plaster (Plaster mortar 2 cm)…………………………………...10 TL

Interior plaster crafting ………………………………..……………....18,70 TL

TOTAL……………………………………………..………………**149.71 TL**

b) Glasswool

Brick 19 x13.5 x 19 cm (28 pieces) …………………………............ 25,50 TL

Mortar 200 kg (0,025 m3/m2) ……………………………….....................1, 68 TL

Wall craft. ……………………………..7, 90 TL

Plaster mesh (160gr/m2)………………………...1, 43 TL

Insulation adhesive (4kg /m2)………………..1, 32 TL

Insulation plaster (5 kg /m2) ....4, 95 TL

Peg (6 piece / m2)………………………………………………………… 0,72 TL

Sheat crafting ………………………………..…………………… 41, 80 TL

Scaffolding (incl. material and crafting)…………………………………. 4, 83 TL

Exterior plaster (Cement mortar 3cm)……………………………………….10 TL

Exterior plaster craft …………………………………………………. 20, 88 TL

Interior plaster (Plaster mortar 2 cm)……………………………………...10 TL

Interior plaster crafting……...……………………………………………18, 70 TL

TOTAL…………………………………………………………...**149, 71 TL**

c) XPS

Brick 19 x13.5 x 19 cm (28 pieces) …………………………............... 25,50 TL

Mortar 200 kg (0,025 m3/m2) ……………………………....................1, 68 TL

Wall craft. ……………………………...7,90 TL

Plaster mesh (160gr/m2)……………………....................................... 1, 43 TL

Insulation adhesive (4kg /m2)……………….. 1, 32 TL

Insulation plaster (5 kg /m2) ....4,95 TL

Peg (6 piece / m2)………………………………………………………… 0,72 TL

Sheat crafting ………………………………………………………… 35, 54 TL

Scaffolding (incl. material and crafting)…………………………………. 4, 83 TL

Exterior plaster (Cement mortar 3cm)……………………………………….10 TL

Exterior plaster craft …………………………………………………. 20, 88 TL

Interior plaster (Plaster mortar 2 cm)………………………………………...10 TL

Interior plaster crafting………..…………………………………………18, 70 TL

TOTAL…………………………………………………………...**143, 45 TL**

d) EPS

Brick 19 x13.5 x 19 cm (28 pieces) ………………………….............25, 50 TL

Mortar 200 kg (0,025 m3/m2) ……………………………….....................1, 68 TL

Wall craft. ……………………………...7,90 TL

Plaster mesh (160gr/m2)…………………….......................................1, 43 TL

Insulation adhesive (4kg /m2)……………... 1, 32 TL

Insulation plaster (5 kg /m2) ....4,95 TL

Peg (6 piece / m2)……………………………………………………… 0,72 TL

Sheat crafting ………………………………………………………… 31, 80 TL

Scaffolding (incl. material and crafting)…………………………………..4, 83 TL

Exterior plaster (Cement mortar 3cm)…………………………………….10 TL

Exterior plaster craft …………………………………………………. 20, 88 TL

Interior plaster (Plaster mortar 2 cm)………………………………………...10 TL

Interior plaster crafting…………………………………………………...18, 70 TL

TOTAL…………………………………………………………...**139, 71 TL**

3.4.2 Bimsblock

Insulation cost that different materials applied over 10 cm thickness of the bimsblock

a) Rockwool

10x 39 x 18.5 cm bimsblock (25 pieces) ………………..………….........6, 85 TL

Wall craft (incl.glue)………………………………………………….……...7, 90 TL

Plaster mesh (160gr/m2)……………………..................................... 1, 43 TL

Insulation adhesive (4kg /m2)………………...1, 32 TL

Insulation plaster (5 kg /m2) ....4,95 TL

Peg (6 piece / m2)…………………………………………………………0, 72 TL

Sheat crafting ………………………………………………………… 41, 80 TL

Scaffolding (incl. material and crafting)………………………………… 4, 83 TL

Exterior plaster (Cement mortar 3cm)……………………………………10 TL

Exterior plaster craft ……………………………………………………. 20, 88 TL

Interior plaster (Plaster mortar 2 cm)…………………………………….....10 TL

Interior plaster crafting……………………………………………….....18, 70 TL

TOTAL…………………………………………………………...**129, 38 TL**

b) Glasswool

10x 39 x 18.5 cm bimsblock (25 pieces) ……………………….……........6, 85 TL

Wall craft (incl.glue)………………………………….…….....................7, 90 TL

Plaster mesh (160gr/m2)…………………….. 1, 43 TL

Insulation adhesive (4kg /m2)………………...1, 32 TL

Insulation plaster (5 kg /m2) ....4,95 TL

Peg (6 piece / m2)…………………………..…………………………0, 72 TL

Sheat crafting ………………………………………………………… 41, 80 TL

Scaffolding (incl. material and crafting)…………………………………. 4, 83 TL

Exterior plaster (Cement mortar 3cm)………………………………………10 TL

Exterior plaster craft ………………………………………………….. 20, 88 TL

Interior plaster (Plaster mortar 2 cm)……………………………………….....10 TL

Interior plaster crafting……………………………………………….....18, 70 TL

TOTAL……………………………………………………………...…....129, 38 TL

c) XPS

10x 39 x 18.5 cm bimsblock (25 pieces) ……………………..…………. 6, 85 TL

Wall craft (incl.glue)……………………………..………………… 20, 68 TL

Plaster mesh (160gr/m2)…………………….. 1, 43 TL

Insulation adhesive (4kg /m2)……………….. 1, 32 TL

Insulation plaster (5 kg /m2) ....4,95 TL

Peg (6 piece / m2)……………………………………………………… 0,72 TL

Sheat crafting ………………………………………………………… 35, 54 TL

Scaffolding (incl. material and crafting)…………………………………. 4, 83 TL

Exterior plaster (Cement mortar 3cm)……………………………………….10 TL

Exterior plaster craft …………………………………………………. 20, 88 TL

Interior plaster (Plaster mortar 2 cm)……………………………………...10 TL

Interior plaster crafting…………………………………………………...18, 70 TL

TOTAL…………………………………………………………...**135, 90 TL**

d) EPS

10x 39 x 18.5 cm bimsblock (25 pieces) …………………………………6, 85 TL

Wall craft (incl.bims block)…………………………….…….……........20, 68 TL

Plaster mesh (160gr/m2)…………………….. 1, 43 TL

Insulation adhesive (4kg /m2)……………….. 1, 32 TL

Insulation plaster (5 kg /m2) ....4,95 TL

Peg (6 piece / m2)……………………………………………………… 0, 72 TL

Sheat crafting ……………………………………………………… 31, 80 TL

Scaffolding (incl. material and crafting)…………………………………..4, 83 TL

Exterior plaster (3cm)……………………………………………………..10 TL

Exterior plaster craft …………………………………………………. 20, 88 TL

Interior plaster (2 cm)……………………………….…………………..10 TL

Interior plaster crafting………………………………………………….. 18, 70 TL

TOTAL…………………………………………………………...**132, 16 TL**

3.4.3 Autoclaved Aerated Concrete Block

Insulation cost that different materials applied over 10 cm thickness of the autoclaved aerated concrete block ;

a) Rockwool

Autoclaved areted concrete block 10 cm ……………………..……..13, 50 TL

Wall craft (with glue)……………………………………………….28, 59 TL

Plaster mesh (160gr/m2)……………………...0, 94 TL

Insulation adhesive (4kg /m2)……………….. 1, 32 TL

Insulation plaster (5 kg /m2) ....2,2 TL

Peg (6 piece / m2)…………………………………………………...2,1 TL

Sheat crafting ………………………………………………………… 41, 80 TL

Scaffolding (incl. material and crafting)……………………………..4, 83 TL

Exterior plaster (3cm)………………………………………………..10 TL

Exterior plaster craft …………………………………………………. 20, 88 TL

Interior plaster (2 cm)……………………………….………………..10 TL

Interior plaster crafting……………………………………………….. 18, 70 TL

TOTAL………………………………………………………………...**154, 86 TL**

b) Glasswool

Autoclaved areted concrete block 10 cm ……………………..………13,50 TL

Wall craft (with glue)……………………………………………….28, 59 TL

Plaster mesh (160gr/m2)……………………...0, 94 TL

Insulation adhesive (4kg /m2)……………….. 1, 32 TL

Insulation plaster (5 kg /m2) ....2,2 TL

Peg (6 piece / m2)…………………………………………………….....2,1 TL

Sheat crafting ………………………………………………………… 41, 80 TL

Scaffolding (incl. material and crafting)…………………………………..4, 83 TL

Exterior plaster (3cm)……………………………………………………..10 TL

Exterior plaster craft …………………………………………………. 20, 88 TL

Interior plaster (2 cm)……………………………….……………………..10 TL

Interior plaster crafting………………………………………………...18, 70 TL

TOTAL…………………………………………………………….**153, 86 TL**

c) XPS

Autoclaved areted concrete block 10 cm ………………………..…….13, 50 TL

Wall craft (with glue)………………………………………………..28, 59 TL

Plaster mesh (160gr/m2)……………………...0, 94 TL

Insulation adhesive (4kg /m2)………………...1, 32 TL

Insulation plaster (5 kg /m2) ....2,2 TL

Peg (6 piece / m2)……………………………………………………..2, 1 TL

Sheat crafting ………………………………………………………….35, 54 TL

Scaffolding (incl. material and crafting)…………………………………..4, 83 TL

Exterior plaster (3cm)……………………………………………………..10 TL

Exterior plaster craft ……………………………………………………. 20, 88 TL

Interior plaster (2 cm)……………………………….…………………..10 TL

Interior plaster crafting……………………………………………….. 18, 70 TL

TOTAL………………………………………………………………….. **148, 60 TL**

d) EPS

Autoclaved areted concrete block 10 cm ……………………...………13,50 TL

Wall craft (with glue)……………………...…………………………...28,59 TL

Plaster mesh (160gr/m2)……………………..0, 94 TL

Insulation adhesive (4kg /m2)……………….. 1, 32 TL

Insulation plaster (5 kg /m2) ....2,2 TL

Peg (6 piece / m2)……………………………………………………...2,1 TL

Sheat crafting ………………………………………………………… 31, 80 TL

Scaffolding (incl. material and crafting)…………………………………..4, 83 TL

Exterior plaster (3cm)……………………………………………………..10 TL

Exterior plaster craft ……………………………………………………. 20, 88 TL

Interior plaster (2 cm)……………………………….…………………..10 TL

Interior plaster crafting……………………………………………….. 18, 70 TL

TOTAL……………………………………………………….……….**144, 86 TL**

Insulation cost that different materials applied over 12,5 cm thickness of the autoclaved aerated concrete block ;

a) Rockwool

Autoclaved areted concrete block 12,5 cm ……………………..…….16,25 TL

Wall craft (with glue)……………………..………………………...28,59 TL

Plaster mesh (160gr/m2)……………………..................................0, 94 TL

Insulation adhesive (4kg /m2)………………...1, 32 TL

Insulation plaster (5 kg /m2) ....2,2 TL

Peg (6 piece / m2)………………………………………………………...2,1 TL

Sheat crafting ………………………………………………………… 41, 80 TL

Scaffolding (incl. material and crafting)…………………………………..4, 83 TL

Exterior plaster (3cm)…………………………………………………..10 TL

Exterior plaster craft ………………………………………………… 20, 88 TL

Interior plaster (2 cm)………………………………….………………..10 TL

Interior plaster crafting………………………………………………….. 18, 70 TL

TOTAL………………………………………………………………...**157, 61 TL**

b) Glasswool

Autoclaved areted concrete block 12, 5 cm……………………...……16, 25 TL

Wall craft (with glue)……………………..………………………….. 28,59 TL

Plaster mesh (160gr/m2)……………………..0, 94 TL

Insulation adhesive (4kg /m2)………………..1, 32 TL

Insulation plaster (5 kg /m2) ....2, 2 TL

Peg (6 piece / m2)………………………………………………………….. 2, 1 TL

Sheat crafting …………………………………………………………… 41, 80 TL

Scaffolding (incl. material and crafting)…………………………………..4, 83 TL

Exterior plaster (3cm)…………………………………………………………..10 TL

Exterior plaster craft ……………………………………………………. 20, 88 TL

Interior plaster (2 cm)…………………………………….……………………..10 TL

Interior plaster crafting………………………………………………….. 18, 70 TL

TOTAL………………………………………………………………….. **157, 61 TL**

c) XPS

Autoclaved areted concrete block 12, 5 cm………………………..…...16, 25 TL

Wall craft (with glue)……………………...………………………….. 28,59 TL

Plaster mesh (160gr/m2)……………………... 0, 94 TL

Insulation adhesive (4kg /m2)………………... 1, 32 TL

Insulation plaster (5 kg /m2) ....2,2 TL

Peg (6 piece / m2)…………………………………………………….…. 2, 1 TL

Sheat crafting …………………………………………………………… 35, 54 TL

Scaffolding (incl. material and crafting)…………………………………..4, 83 TL

Exterior plaster (3cm)……………………………………………………...10 TL

Exterior plaster craft …………………………………………………. 20, 88 TL

Interior plaster (2 cm)…………………………………….……………..10 TL

Interior plaster crafting……………………………………………….. 18, 70 TL

TOTAL…………………………………………………………...…**151, 35 TL**

d) EPS

Autoclaved areted concrete block 12,5 cm ……………………...……16,25 TL

Wall craft (with glue)……………………...…………………………...28,59 TL

Plaster mesh (160gr/m2)……………………....................................... 0, 94 TL

Insulation adhesive (4kg /m2)………………... 1, 32 TL

Insulation plaster (5 kg /m2) ....2,2 TL

Peg (6 piece / m2)……………………………………………………….. 2, 1 TL

Sheat crafting ……………………… ……………………………......31, 80 TL

Scaffolding (incl. material and crafting)…………………………………..4, 83 TL

Exterior plaster (3cm)…………………………………………………..10 TL

Exterior plaster craft …………………………………………………. 20, 88 TL

Interior plaster (2 cm)…………………………………….……………..10 TL

Interior plaster crafting……………………………………………….. 18, 70 TL

TOTAL…………………………………………………………………..**147, 61 TL**

3.4.4 Sandwich wall

a) EPS

19 x13.5 x 19 cm brick (38 pieces)…………………………..………...9,88 TL

19 x19x8.5 cm brick (26 pieces) ……………………………………………5.2 TL

Mortar 250 (0,04 m3/m2)………………………………………..…..75.48 TL

Wall craft……………………...………………………………..……15.80 TL

Rod…………………………...………………………………………12.08 TL

Sheat crafting ……………………………………………………...…...51,54 TL

Scaffolding (incl. material and crafting)…………………………………..4, 83 TL

Exterior plaster (3cm)……………………………………………………..10 TL

Exterior plaster craft ……………………………………………………. 20, 88 TL

Interior plaster (2 cm)…………………………………..…………………..10 TL

Interior plaster crafting……………………………………………….. 18, 70 TL

TOTAL..…………………………..……………………………………**234,39 TL**

a) EPS

19 x13.5 x 19 cm brick (38 pieces)…………………………..………...9,88 TL

19 x19x8.5 cm brick (26 pieces) ……………………………………………5.2 TL

Mortar 250 (0,04 m3/m2)………………………………………..…..75.48 TL

Wall craft………………………...……………………………...……15.80 TL

Rod…………………………...……………………………………12.08 TL

Sheat crafting …………………………………………………...…...51,54 TL

Scaffolding (incl. material and crafting)…………………………………..4, 83 TL

Exterior plaster (3cm)……………………………………………………..10 TL

Exterior plaster craft ……………………………………………………. 20, 88 TL

Interior plaster (2 cm)………………………………………………………..10 TL

Interior plaster crafting……………………………………………….. 18, 70 TL

TOTAL...……………………………..……………………………**234,39 TL**

a) Rockwool

19 x13.5 x 19 cm brick (38 pieces)…………………………..………...9,88 TL

19 x19x8.5 cm brick (26 pieces) ……………………………………………5.2 TL

Mortar 250 (0,04 m3/m2)……………………………………………..…..75.48 TL

Wall craft………………………...……………………………...……15.80 TL

Rod…………………………...……………………………………12.08 TL

Sheat crafting …………………………………………………...…...71,54 TL

Scaffolding (incl. material and crafting)…………………………………..4, 83 TL

Exterior plaster (3cm)……………………………………………………..10 TL

Exterior plaster craft ……………………………………………………. 20, 88 TL

Interior plaster (2 cm)…………………………………….…………………..10 TL

Interior plaster crafting……………………………………………….. 18, 70 TL

TOTAL..……………………………..…………………………………254,39 TL

b) Glasswool

19 x13.5 x 19 cm brick (38 pieces)…………………………..………...9,88 TL

19 x19x8.5 cm brick (26 pieces) ……………………………………………5.2 TL

Mortar 250 (0,04 m3/m2)……………………………………………..…..75.48 TL

Wall craft…………………………...…………………………………..……15.80 TL

Rod…………………………………..………………………………………12.08 TL

Sheat crafting ……………………………………………………………...…...71,54 TL

Scaffolding (incl. material and crafting)…………………………………..4, 83 TL

Exterior plaster (3cm)………………………………………………………..10 TL

Exterior plaster craft ……………………………………………………. 20, 88 TL

Interior plaster (2 cm)…………………………………….…………………..10 TL

Interior plaster crafting……………………………………………….. 18, 70 TL

TOTAL …………...…………………………………………………254,39 TL

4 CONCLUSION

4.1 Achieved Results

These sample models composed the wall section of Sardes Hospital which is located in the first degree-day region. The wall samples were insulated in various ways by examining 24 different types. The insulation which will ensure a value of U≤0, 70 on the wall section was applied to the related building and evaluated as per principles and terms of TS825 heat insulation programme. The U value were calculated according to TS825 and the insulation thicknesses which ensure the U value of the sample building were determined.

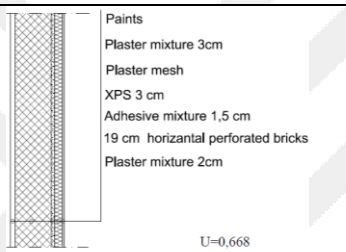
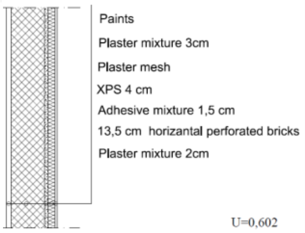
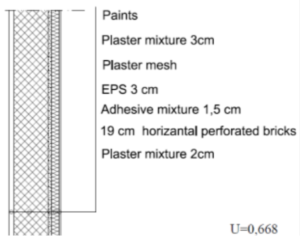
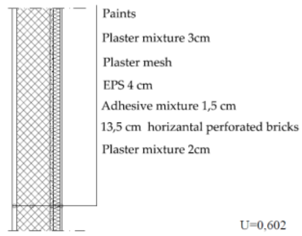
	Details	U Value (W/m²K)	Total Environmental Impacts (pt)	Cost (TL)
1		0,668	1,568041027	143,45
2		0,602	1,234066429	148,09
3		0,668	1,520570288	139,71
4		0,602	1,174937154	144,35

Table 4. 24 Sample wall models

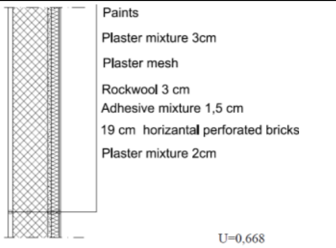
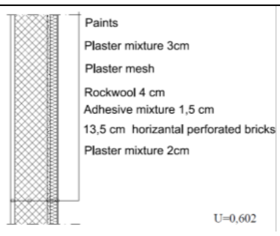
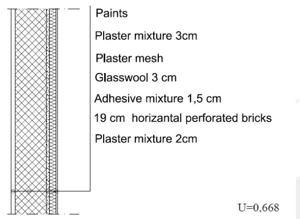
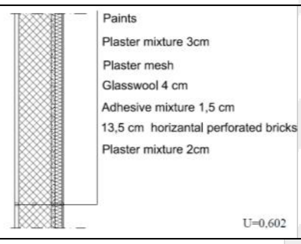
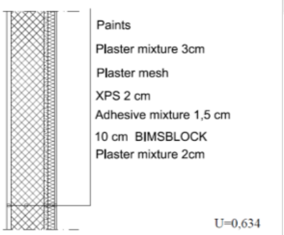
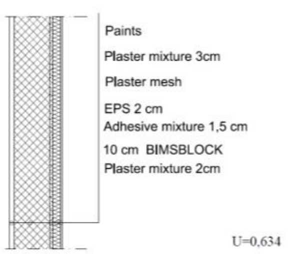
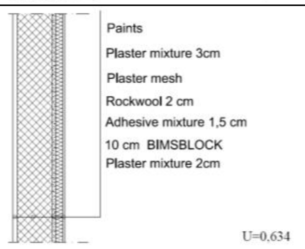
5		0,668	2,921266903	149,71
6		0,602	1,174937154	154,35
7		0,668	1,533065419	149,71
8		0,602	1,187432285	154,35
9		0,634	0,711018468	135,90
10		0,634	0,687701396	132,16
11		0,634	1,613169052	129,38

Table 4. 24 Sample wall models

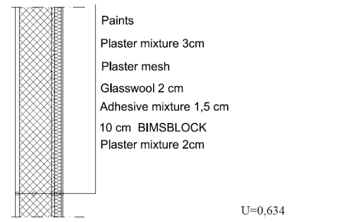
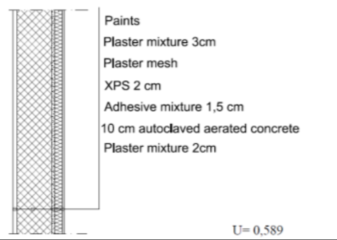
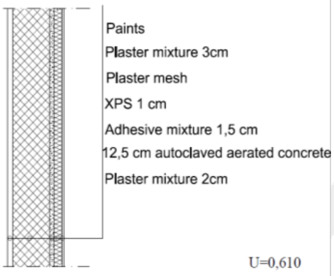
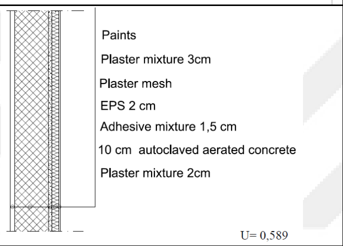
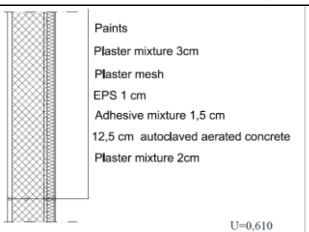
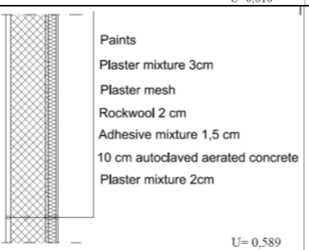
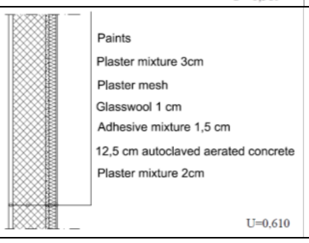
12		0,634	0,687701396	129,38
13		0,589	1,062134473	148,60
14		0,610	1,228212052	151,35
15		0,589	1,02632227	144,86
16		0,610	1,192399849	147,61
17		0,589	1,964285057	154,86
18		0,610	1,679287344	157,61

Table 4. 24 Sample wall models

<table>
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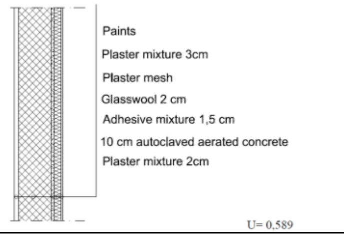
<tr><td>19</td><td>
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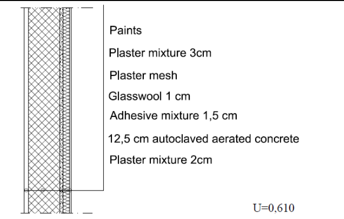
<tr><td>20</td><td>
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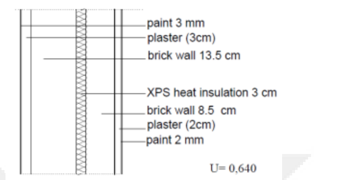
<tr><td>21</td><td>
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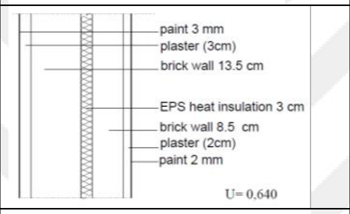
<tr><td>22</td><td>
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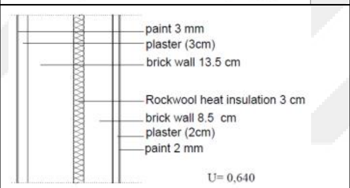
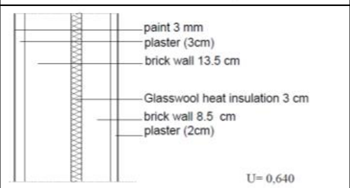
<tr><td>23</td><td>
</td><td>0,640</td><td>3,979684206</td><td>254,39</td></tr>
<tr><td>24</td><td>
</td><td>0,640</td><td>2,591173782</td><td>254,39</td></tr>
</table>

Table 4. 24 Sample wall models

24 sample models were composed according to LCA analysis and then the data are acquired in terms of their effects on the environment. The outcomes of the comparison between the best and worst ones among 24 models: the rock wool insulated model applied to sandwich wall affected the environment at most, while the EPS insulated model applied to 10 cm bimsblock affected at the least in figure 4.1.

Impact category is a very important part of the environmental. This thesis gives informations about energy efficient and environmentally-friendly of insulation materials. In addition stress is put on promotion of quality,which includes:

- Quality of the indoor environment
- Quality of building material

Selection of materials is performed with the least environmental impact taking into account the complete lifetime.

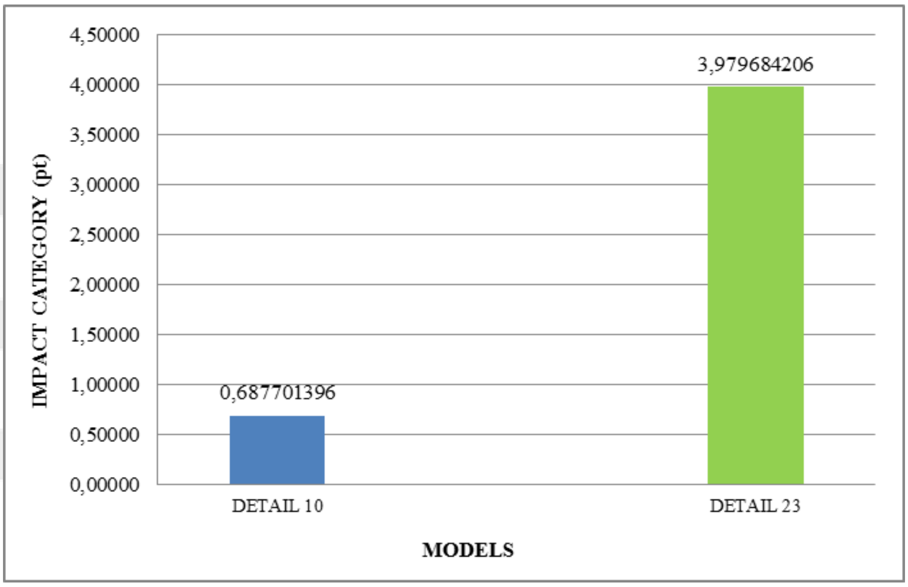


Figure 4.1 The best and the worst environmental impact

Detail 10, the bimsblock, having U value of 0.634, with EPS insulation is the best in terms of environment. Detail 23, the sandwich wall, having U value 0,640, with rockwool insulation is worst in terms of environment.

When we look at the detail 21, 22, 23, and 24; we see, in these details, the highest cost and the biggest environmental impact. Details 23 and 24 are models that have the highest cost.

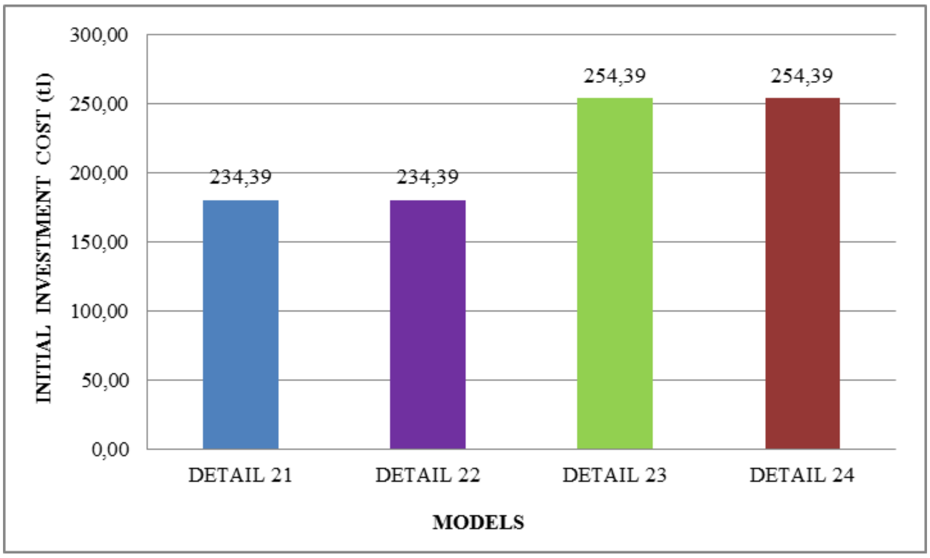


Figure 4.2 The comparison of initial investment cost the sandwich wall details

In figure 4.2, it is determined that as initial investment costs, the details 21 and 22 are cost-effective whereas initial investment cost of the details 23 and 24 are high.

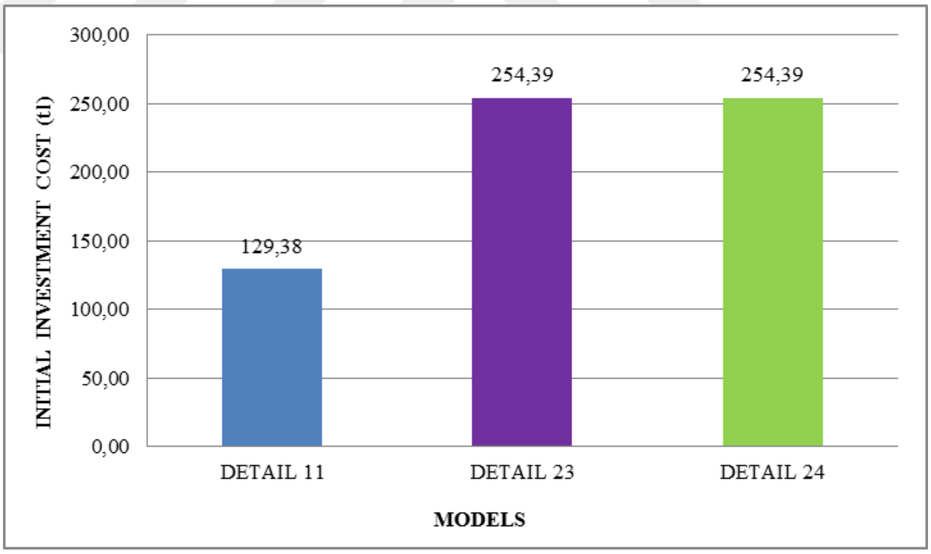


Figure 4.3 Initial investment cost of wall details

Comparing to cost analyses of the other models, we conclude that the detail 11 is the model of wall that has the most cost-effective initial investment.

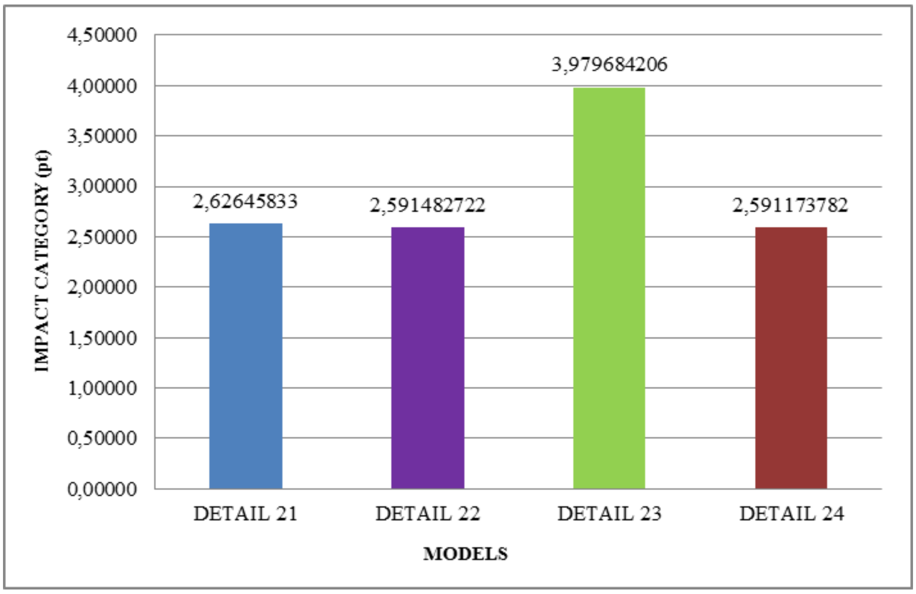


Figure 4.4 The comparison of environmental impacts of sandwich wall details

The most harmful model of wall for environment is the detail 23 whereas the detail 24, among others, is the most environment-friendly model of wall.

If we analyze environmental impact of all models of wall, as has been seen in the figure 4.5, we see that the detail 23 is model that has the biggest environmental impact. Whereas, the most environment-friendly model of wall is the detail 10.

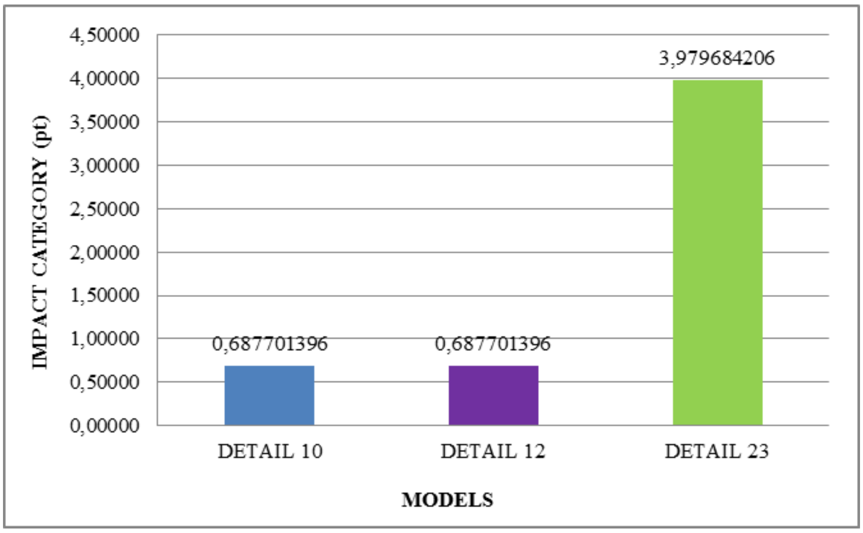


Figure 4.5 The comparison of the environmental impacts of wall details

In the light of acquired knowledge, models of sandwich wall compared to other models, are the details that have the highest rates both in terms of environment-friendliness and of initial investment cost. The reason is material excess used as understood from the sections and the reason is that the model is created with both 13,5 cm and 8,5 cm brick walls. We should consider loss of m2 (field) caused by this model.

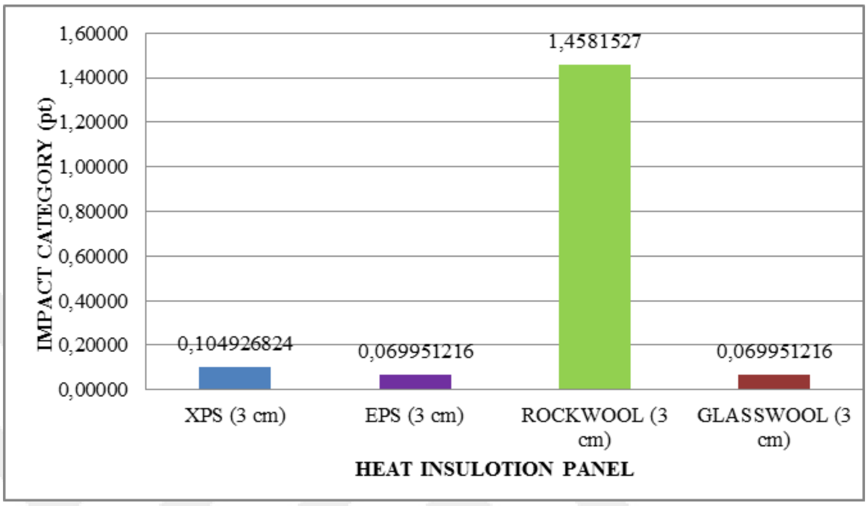


Figure 4.6 The comparison of the environmental impact of heat insulation panels

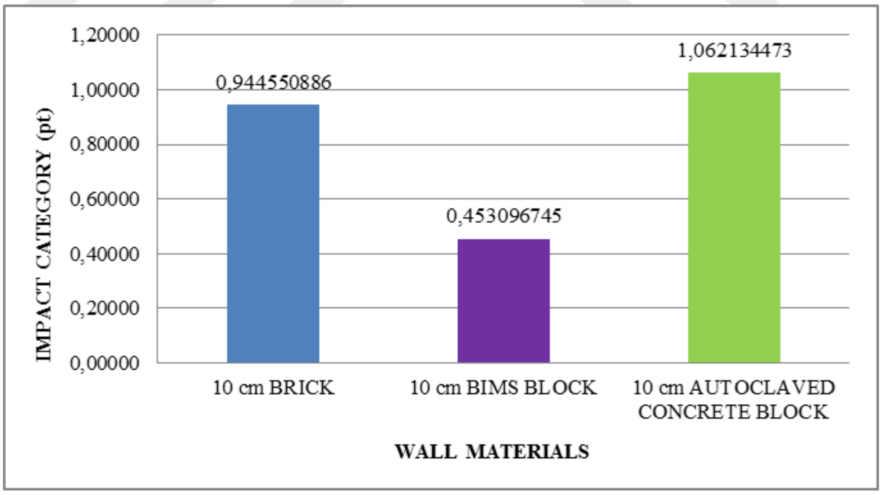


Figure 4.7 The comparison of the environmental impacts of wall details

The details 11 and 12 are the most appropriate models for initial investment cost. If we look at their environmental impact, the details 10 and 12 are the most environment-friendly models. Regarding to both initial cost and environmental impact, it is concluded that the detail 12 is best exemplar model.

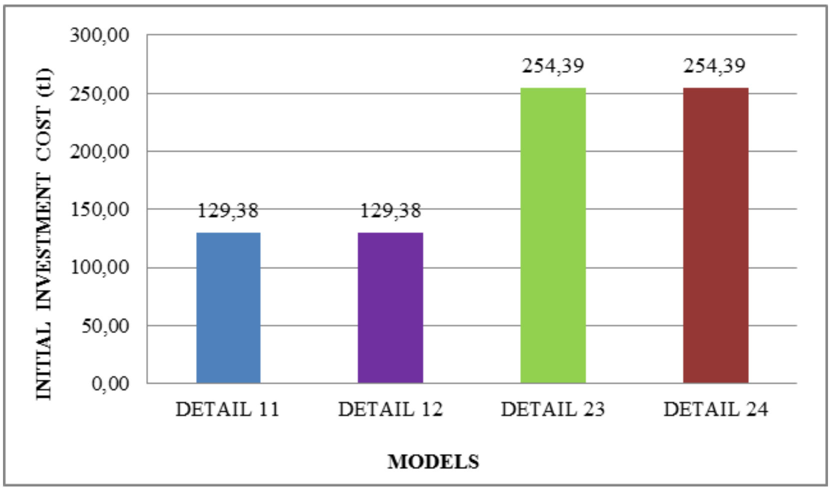


Figure 4.8 The comparison of the initial investment cost of wall details

The cost of insulation applied to walls, bimsblock and brick walls were compared with that of autoclaved concrete block wall system. The cost analysis was carried out according to the data obtained from Construction and current unit price list by The Ministry of Environment and Urbanization. Costs were calculated for use of 1m² of the building. In this context, it was concluded that rockwool and glasswool insulation panel applied to 10 cm of bimsblock had the lowest cost.

According to the results of the conducted studies, the applications on bimsblock are more advantageous both in terms of investment cost environment-friendliness.

4.2 Suggestions

It is important that environmental impacts to be revealed, by the method used in the thesis, in building assessments to be conducted in Turkey. Therefore, it is recommended, in further studies, that all the details used in constructions to be compared in a database to be created.

This study needs to be conducted on life cycle cost. But, analysis of initial investment cost has been made due to the lack of database related to this issue in our country. It is also suggested that subsequent studies should be conducted on LLC.

Since pumice, raw material of bimsblock, is a natural stone and to be found in our country, it is a material which has favorable investment cost and low environmental impact.

REFERENCES

Altıntaş Esra., 2008, ‘The Evaluation of Thermal Comfort on the Primarily School Classrooms by Thermal Sensation Scale’, Msc Thesis, Ktü University of Architecture .

Alley R., Berntsen T., Bindoff N., Chen Z. et.al.,2007, IPCC WGI Dördüncü Değerlendirme Raporu,Paris.

Atmaca, İ., & Yiğit, A., 2011, ‘Isıl Konfor ile İlgili Mevcut Standartlar ve Konfor Parametrelerinin Çeşitli Modeller ile İncelenmesi’.

Atmaca İ., 2006, ‘Investigation of The Effect of Thermal Comfort Parameters on Human Body’, PhD Thesis, Uludağ University of Science.

Auliciems A., Szokolay S. V., 1997, ‘Thermal Comfort, Passive and Low Energy Architecture International’, The University of Queensland, Department of Architecture.

ANS/ASHRAE Standard 55-2004, 2004, ‘Thermal Environmental Conditions for Human Occupancy’.

Ateş D., 2008, ‘INDUSTRIAL REVOLUTION: Impetus Behind the Globalization Process.,’ vol.15, no.2, pp.31-48.

Başbakanlık Mevzuatı Geliştirme ve Yayın Genel Müdürlüğü, 2008, BİNALARDA ISI YALITIMI YÖNETMELİĞİ, Sayı : 27019

Batan M., 2014, ‘Global Climate Change and Inevitable Conclusions’, Phd Thesis, University of Dicle.

Boll Illerup I., Nielsen O., Winther M., Hjorth Mikkelsen M., Lyck E., Nielsen M., Hoffmann L., Gyldenkærne S.,Thomsen M., 2007, ‘Projection of Greenhouse Gas Emissions – 2005 to 2030’, National Environmental Research Institute, University of Aarhus, Denmark.

BRE, 2014, ‘PCR for Construction Products EPD’,PN514 issue 0.1.

REFERENCES (CONTINUE)

Charles, K.E., 2003, ‘Fanger’s Thermal Comfort and Draught Models’,IRC, National Research Council Canada.

Chwieduk D.,2002, ‘Towards sustainable-energy buildings’, Warsaw, Poland.

Dagsöz, A.K., Bayraktar, K.G., 2001, “Isıtma ve Soğutma Sistemlerinde Isı Yalıtımıyla Sağlanan Kazançlar”, Tesisat Mühendisliği Dergisi, Mart-Nisan.

Dombaycı Altan Ö., 2007, ‘The environmental impact of optimum insulation thickness for external walls of buildings’, vol.42, pp.3855- 3859, Denizli,Turkey.

Doğan Y., 2008, ‘Ecological Crisis of Humanity: A Case Study About Global Climate Change’, Msc thesis, University of Istanbul.

Ecoplatform, 2016, ‘Position Paper on the introduction of an EU-initiated PEF-methodology into the construction sector’.

ECOFYS, 2013, ‘Basic Work Requirement 7 in the Context of Existing Regulation’, Nertherlands.

Environment Science Center, 2010, ‘Greener Hospitals’

European Commission, DG Environment-G2, B-1049, 2010,’Green Public Procurement –Thermal Insulation Technical Background Report’, Brussels.

European Construction Technology Platform (ECTP), 2005, ‘Challenging and Changing Europe’s Built Environment’.

García, J. A. O. (2010), ‘A review of general and local thermal comfort models for controlling indoor ambiences. Air Quality. InTech, Rijeka.

German C., 2010, ‘Comparison of Thermal Insulation Materials for Building Envelopes of Multi-storey Buildings in Saint-Petersburg’.

IEA, 2015, ‘CO2 Emissions From Fuel Combustion’,IEA Statistic.

REFERENCES (CONTINUE)

IEA,2015, ‘Transition to Sustainable Buildings’

İnan G.,2012, ‘TST 825 Standart Tasarısı’, Gebze, Kocaeli.

Kahraman İ., 2013, “A Sustainable Building Assessment Model Proposal For New Residential Buildings in Turkey”, Phd Thesis, Science Department of Architecture, Dokuz Eylul University

Kayaş E., 2009, ‘Life Cycle Cost Awareness Among Architects: The Case of Turkey’, Msc Thesis,Science Department of Architecture, İzmir Institute of Technology

Kaynaklı Ö., 2012 ,‘Optimum Thermal Insulation Thicknesses and Payback Periods for Building Walls in Turkey’, Science Department of Engineering and Architecture, Uludağ University,Bursa.

Konstantinou T., 2014, ‘Façade Refurbishment Toolbox’.

Koçak E.,Atmaca İ.,2011, ‘TS 825’e Uygun olarak yalıtılan bir binanın teknik ve ekonomik olarak incelenmesi’, X.Ulusal Tesisat Mühendisliği Kongresi, İzmir.

Kürekçi A., Bardakçı A., Çubuk H., Emanet Ö., 2012, ‘Türkiye’nin Tüm İlleri İçin Optimum Yalıtım Kalınlığının Belirlenmesi’,sayı.131,Tesisat Mühendisliği Bölümü.

ODTÜ, 2014, ‘Blok Malzeme Kullanılan Duvarlar İçin Maliyet Analizi’, İnşaat mühendisliği Bölümü.

Olesen, B. W. and G.S. Brager, 2004, ‘A Better Way to Predict Comfort: The New ASHRAE Standard 55-2004. ASHRAE Journal’, August.

Ozel M.,2011, ‘Thermal performance and optimum insulation thickness of building walls with different structure materials’, Vol 31,pp. 3854-3863, Department of Mechanical Engineering, Firat University, Elazığ, Turkey.

REFERENCES (CONTINUE)

Özçağ M., 2011, “Anthropogenic Climate Change and Economic Growth: An Analysis on Turkey”, University of Adnan Menderes.

Papadopoulos A.M., 2005, ‘State of the art in thermal insulation materials and aims for future developments’,Vol 37,pp 77-86.

RICS Professional Information, 2012, ‘Methodology To Calculate Embodied Carbon of Materials’, UK

Soykan E., 2009, ‘Thermal Comfort Evulation In Intelligent Buildings; Case Study In Darüşşafaka Residence’, Msc thesis, University of İzmir Institute of Technology.

Terekli T., Özkan O., Bayın G., 2013, ‘Çevre Dostu Hastaneler: Hastaneden Yeşil Hastaneye’, Vol 12, No 2, Ankara.

TOBB, 2011, ‘Türkiye İnşaat MalzemeleriSektor Gorunum Raporu’.

TTMD, 2014, ‘HVAC, Refrigeration, Fire Fighting and Sanitary Journal’.

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Pelin Yetkin Yazıcı was born in Ankara. She is currently interior designer at Ulusal Yatırım in İzmir since 2014. She received her BSc degree in Landscape Architecture from Ege University in 2011 and she attended her MSc degree in Interior Architecture from Yasar University Architecture Faculty. She has taken the courses about various topics, Simapro during her Masters