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DESIGN AND CONCEPTS OF NEARLY-ZERO ENERGY BUILDINGS

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DESIGN AND CONCEPTS OF NEALY-ZERO ENERGY BUILDINGS

ABSTRACT

Global warming and climate change have become increasingly important issues in recent decades. The use of fossil fuels is one cause. The use of fossil fuels causes CO_2 emissions. Therefore, buildings need to be designed with a new strategy on low energy with very high energy efficiency. In order to reduce the dependence of the building on primary energy, the concept of nearly-zero energy building (nZEB) is created. It is recommended that the definition of near-zero energy buildings, renewable energy and efficiency measures work together. The European Union (EU) aims to drastically reduce domestic greenhouse gas (GHG) emissions by 80% by 2050 compared to 1990 levels.

In this work, design strategies, the use of low conductivity materials, the installation of low energy devices to reduce the energy demand of buildings and the necessary additions of renewable energy systems are presented to achieve a near zero energy building design. These aforementioned approaches are implemented in an example building as a case study. The obtained results show that there are many ways to achieve a near-zero energy building, but the cost issue remains the most important decision parameter.

Keywords: Zero Energy Buildings, Nearly-zero Energy Buildings, Energy Efficiency, Green Buildings, Passive Buildings

SIFIRA YAKIN ENERJİ TÜKETEN BİNALARIN TASARIMI VE KAVRAMLARI

ÖZET

Küresel ısınma ve iklim değişikliğinin son birkaç on yılda artan sorunları var. Fosil yakıtların kullanılması bunların bir sebebidir. Fosil yakıtların kullanılması CO_2 emisyonlarına neden olur. Bu nedenle binaların düşük enerjide ve yüksek enerji verimliliğiyle yeni bir strateji ile tasarlanması gerekmektedir. Binanın birincil enerjiye bağımlılığını azaltmak için sıfıra yakın enerji tüketen bina (nZEB) konsepti oluşturulmuştur. Yenilenebilir enerji ve verimlilik önlemleri, sıfıra yakın enerji tüketen binaların tanımında, birlikte çalışması tavsiye edilir. Avrupa Birliği (AB), evsel sera gazı (ESG) emisyonlarında, 1990 seviyelerine kıyasla 2050 yılına kadar 80% oranında önemli ölçüde azaltmayı hedefliyor.

Bu tez kapsamında, binaların enerji taleplerini azaltmak ve yeşil bina tasarım konseptini hayata geçirmek için tasarım stratejileri, malzeme, ekipman ve cihazların kullanımı tanıtıldı. Bu konseptler göz önünde bulundurularak, optimize edilmiş bina modeline ulaşmak için, geliştirilen stratejilerle örnek bir bina tasarlandı ve analiz edildi.

Anahtar Kelimeler: Sıfır Enerji Tüketen Binalar, Sıfıra Yakın Enerji Tüketen Binalar, Enerji Verimliliği, Yeşil Binalar, Pasif Binalar

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NOMENCLATURE

nZEB **:** Nearly Zero Energy Buildings

EPBD **:** Energy Performance of Buildings Directive

BACS **:** Building Automation and Control Systems

EU : European Union

GHG : Greenhouse Gas

PCM : Phase Changing Materials

DHW : Domestic Hot Water

CHP : Combined Heat and Power

LEED : Leadership in Energy and Environmental Design

IAQ : Indoor Air Quality

ASHRAE **:** The American Society of Heating, Refrigerating and Air-Conditioning Engineers

EUI : Energy Use Intensity

SC **:** Shading Coefficient

HVAC **:** Heating, ventilating and air-conditioning

AI **:** Artificial Intelligence

IoT : Internet of Things

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1. INTRODUCTION

Global warming and climate change have become increasingly important issues in recent decades. The use of fossil fuels is one cause. The use of fossil fuels causes CO_2 emissions. Buildings, including commercial and residential buildings, are the major contributors to energy consumption. Buildings require energy such as electricity, which is mostly derived from fossil fuels. Buildings are responsible for about 40% of total energy consumption and 36% of CO_2 emissions (1). Therefore, buildings need to be designed to be low energy with very high energy efficiency with a new strategy. These strategies are considered as an integrated solution to the problems of energy saving, environmental protection and reduction of CO_2 emissions in the building sector. To reduce the dependence of the building on primary energy, the concept of near-zero energy building (nZEB) is created.

Especially, when the energy savings potential on a national level is the matter of concern, it is essential to investigate the existing building stock due to substantially worse energy performance in older buildings than newer ones. (2)

Therefore, the reduction of energy consumption and the use of energy from renewable sources in the building work together are important measures required to reduce energy dependence and greenhouse gas emissions. The emission reduction potential of buildings is important and up to 80% of the operating costs of standard new buildings can be saved through integrated design principles, often at little or no additional cost over the lifetime of the measure.

The EPBD (Energy Performance from Buildings Directive) requires member states to ensure that the optimum energy performance of the building envelope is sought when applying primary energy and weighted factors. Reducing the overall energy demand is a crucial component in optimizing the energy performance of a building. In addition, building services systems and building automation and control systems (BACS) have a greater impact and are most easily optimized in combination with high performance building envelopes. It is recommended that the definition of near-zero energy buildings, renewable energy and efficiency measures should work together (3).

Building energy consumption basically includes the development of building energy efficiency laws, regulations and standards, increasing the efficiency of building subsystems/facilities/equipment such as building thermal performance, heating and ventilation, air conditioning (HVAC) and lighting effect etc. "Focusing on the specific needs in building energy consumption, the research target is mainly the unique features and functions of buildings such as residential, public, hospital and data center, automatic operation of HVAC, specific needs of energy consumption on a regional basis climate, etc. However, in the flow of the Artificial Intelligence (AI) background, the current research structure on the creation of energy efficiency, like some other fields, will inevitably change". (4)

Through to internet-based applications, it has been observed that the building energy consumption of the data center is reduced by 15%. Air conditioners, fans and windows can be used more effectively thanks to energy consumption control (5). In addition to contributing directly to energy efficiency, the carbon emissions of buildings are reduced with the use of artificial intelligence (AI). The biggest factor in this is the internet of things (IoT) technology and the connection of sensors to the network. (6)

Collecting and managing data from sensors with cloud technologies based on IoT environment constitutes an important step in smart building technologies. (7)

The European Union (EU) aims to drastically reduce domestic greenhouse gas (GHG) emissions by 80% by 2050 compared to 1990 levels. The building stock is responsible for a large share of GHG emissions and should achieve an even higher reduction of at least 88% - 91%. Therefore, without consistently exploiting the huge savings potential attributed to the building stock, the EU will miss its reduction targets. More than a quarter of the building stock in 2050 still needs to be built. The energy consumption and associated GHG emissions of these new buildings will need to be close to zero to meet the EU's very ambitious targets. (8)

2. BRIEF REVIEW OF SUSTAINABLE BUILDING CONCEPTS

Architecture is not only designing or constructing a building, but also our living spaces which are a reflection of the lifestyle of society. It is to ensure that it is designed in a way to establish a correct interaction with the environment. Therefore, the duties of architects are increasing against today's environmental problems. It will also provide a permanent solution to consumption of sources and environmental problems within sustainable buildings and using energy efficient.

The lexical meaning of the concept of sustainability is continuity and maintenance of resources. Sustainability is defined as on while continuing to use these resources; on the other hand, being protected to ensure that it can be used by future generations. (9)

In a clearer way; sustainable development approach together ecological balance and economic growth together, ensuring efficient use of natural resources, and attaching importance to environmental quality, that can supply today's needs without endangering future generation's needs.

The main target of ecological architecture, architectural elements and building materials will not harm environment and does not contain toxic substances during their construction, use and demolition.

50% of the energy used and 42% of the water in the world it is used in buildings we live in. Likewise, the existing agricultural areas in the world 42% of the work has been changed as residential areas. (10)

Table 2-1: Rates of resources used in worldwide to in buildings

Sources	Rates of resources used in worldwide to buildings
Energy	50%
Water	42%
Material	50%

In the 90's, it is found out there is no enough results of studies on energy conservation. With the Kyoto Protocol signed in 1996, it was aimed to make more serious breakthroughs. Kyoto Protocol is aimed to promote sustainable development and to reduce the increasing environmental problems. Industrialized countries reduce energy consumption and use renewable energy sources instead of fossil fuels to fulfill its commitments.

United Nations World Meeting in Johannesberg in August 2002, Johannesberg Criteria has been published as a result of the Sustainable Development Summit. According to these criteria, environmental sustainability is one of the main objectives. It is decided to measure energy intensity rather than energy efficiency, carbon dioxide per population and global atmospheric pollution (analysis in the ozone layer, global warming gases collection) to assess sustainable development.

In the prepared action plan in Turkey, pollution prevention and reduction, access of all citizens to environmental infrastructure and services facilitation, encouraging the renewable resources to sustainable use, developing policy, project and program proposals that will make the environment and the economy sustainable together, reduce the exposure of both people and the environment to natural and human-induced risks as much as possible principles are take a part.

Turkey can be considered as the only current regulatory TS 825 Thermal Insulation in Buildings and its rules were published in 1970, revised in 2000 and made mandatory.

2.1. Green Building Concept

Buildings that consume a large amount of fossil fuel during their production and use cause about 40% of greenhouse gas emissions. Therefore, the concept of environmentally friendly Green Buildings emerged in the construction industry. There are 2 widely used Global Certification Systems on assessing green buildings, as briefly described below:

i) LEED (Leadership in Energy and Environmental Design) Certification: as a prerequisite, the prevention of construction pollution in the criteria of sustainable lands, reduction of water consumption in the water efficiency criterion, energy efficiency and minimum energy performance in the atmosphere and the basic fluid method, the collection of materials that can be recycled in the criteria of materials and resources, indoor air quality performance and evaluates tobacco smoke control. Assessment criteria along with allowable maximum points are:

- Sustainable Sites - 10 Points
- Water Efficiency - 11 Points
- Energy and Atmosphere - 33 Points
- Materials and Resources - 13 Points
- Indoor Environmental Quality - 16 Points
- Innovation - 6 Points
- Regional Priority Credits (Regional Priority) - 4 Points
- Location and Transport - 16 Points

For certificate degrees, the ranges of points to be obtained are as follows:

- ➢ LEED Certified 40-49 point,
- ➢ LEED Silver 50-59 point,
- ➢ LEED Gold 60-79 and
- ➢ LEED Platinum 80-110 point

ii) BREEAM (Building Research Establishment Environmental Assessment Model) Certification

- Building Management: Environmental standards attached to management (12%)
- Health and Good Condition: Human health and comfort in buildings (15%)
- Energy: Turning towards renewable resources that reduce energy consumption (19%)

- Water: Systems that reduce water consumption (6%)
- Land Use and Ecology: Encourage land use and biodiversity conservation (10%)
- Transportation: Bicycle and public transport incentive (8%)
- Material: Environmental effects of the materials used (12.5%)
- Waste: Amount of waste and recycling rate (7.5%)
- Pollution: Greenhouse gas emissions, light-noise pollution, soil and water pollution control (6.5%)
- Innovation: Innovative sustainability ideas (10%)

BREEAM degrees and the minimum percentages required for these degrees are as follows:

- BREEAM Pass > 30%
- BREEAM Good > 45%
- BREEAM Very Good > 55%
- BREEAM Excellent> 70%
- BREEAM Outstanding > 85%

2.2. Passive House Concept

Passive houses are designed to increase the level of living comfort in buildings that is solved with insulation systems and details, minimum 90% energy saving can be defined as realizable structures. In other words "Passive House Systems "emerged with the idea of building a house with zero energy requirement, keeping energy inside the building, providing high energy savings, producing its own energy. It is also possible to define them as environmental friendly building technologies.

These buildings are planned to not exceed 15 kWh/m^2 annual heating-cooling requirements and to demonstrate the total primary energy consumption (including household electricity consumption) is less than 50% of energy in traditional new buildings. Passive houses possible to save 90% of their CO_2 emissions compared to traditional buildings by providing high energy savings. Good thermal insulation, reduction of thermal bridges, air tightness and ventilation systems relatively prevents serious structural damage.

Passive buildings take a part in development plans and even laws and regulations of developed countries. It is foreseen that all kinds of buildings to be constructed according to passive house standards in the member countries of the European Union since the beginning of 2019. Between the rates in 75% to 90% energy is saved due to successfully renovated old building with these standards, in many European cities.

2.3. nZEB CONCEPT

According to the US Department of Energy (DoE), a zero energy building has been defined as a building that produces enough renewable energy to meet its own annual energy consumption (11). According to European Union Article 2, a nearly-zero energy building (nZEB) is a building that has a very high energy performance, where a small amount of the building's energy demand should be met to a very large extent from renewable sources, including on-site or nearby generated sources (12).

As a result of this information, the main principles of nZEB are reduction of energy demand, use of renewable energy sources and reduction of greenhouse gas emissions. All these principles should work together. In this content, the principles will be explained one by one in the next chapter.

3. DESIGN PRINCIPLES for nZEBs

3.1. Reducing Energy Requirements

Firstly, we need to define the energy demand of a building and also measure it. A building requires energy for lighting, heating, cooling, ventilation and domestic hot water heating as listed below.

- Heating, cooling and ventilation
- Lighting
- Domestic hot water

These are the main energy requirements of a building. So, if we want to reduce energy requirements, we need to design with new strategies. Most important of them are optimizing building insulation material and some natural methods to ventilation, heating-cooling. In addition of them, increasing of the equipment energy efficiencies has a big part of reducing energy requirements.

Besides of them, the building's location and geometry have important part for the reducing energy requirement. Considering the geometry of the building, relationship between shell and volume are directly proportional. Therefore, shrinkage of the structure has a great effect on energy saving. Less building's shell reduces cost and heat losses.

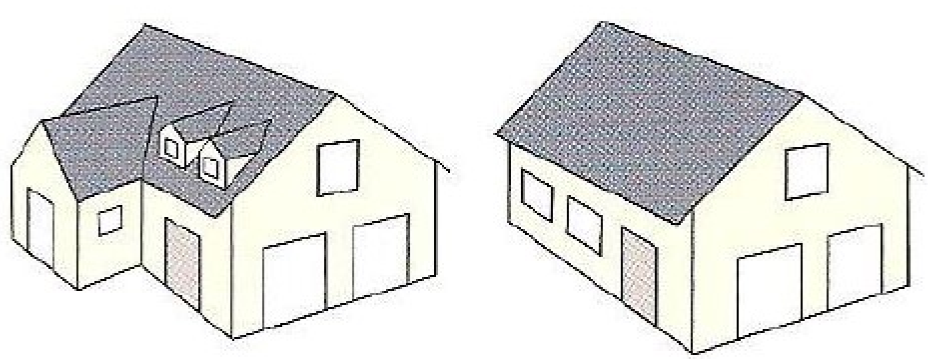

Figure 3-1: A sample of different building's geometries

In the design of buildings that built with passive house standards, the windows are ideally oriented to the south. Since windows facing north will increase energy consumption, should be avoided to open windows in this direction or buildings that require a large amount of windows should not be located on the north facade. Shading is applied to the windows facing east, south and west for preventing unnecessary heating in summer. It should be ensured that the sun rays coming at an oblique angle reach inside by lowering shading in winter.

Positioning of the building need attention for some matters before a passive house is built in order to increase energy savings and use energy effectively. When planning the layout of passive houses, the location of the land in relation to the city center, the character of the roads surrounding the building, the density of the surrounding structure and the topography data are some factors that need to pay attention.

Climatic conditions (amount and duration of sunshine, average temperature, wind, humidity, etc.), vegetation characteristics and the immediate environment geographical elements (such as bumps and holes, water) are factors that affect to locate the building.

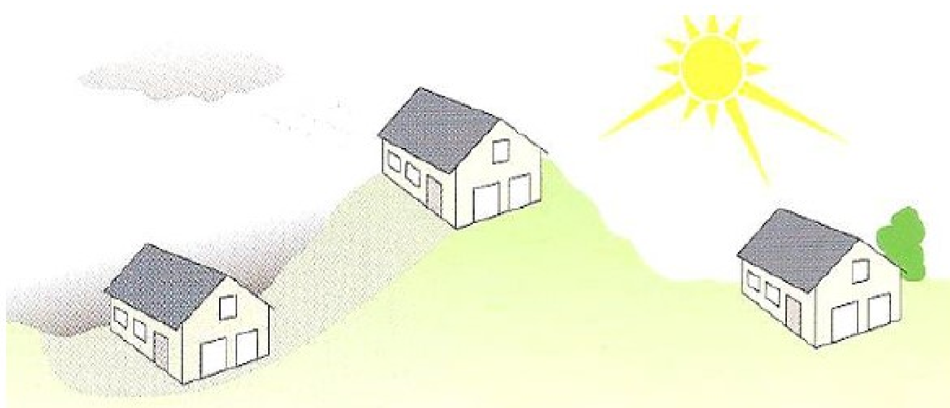

Figure 3-2: A sample of position importance of building

Another point to be considered in the positioning of passive houses is the prevailing wind. The prevailing wind direction and intensity effect is an important input in landscape design and settlement of the house on the land. The wind blows are used in a controlled way that is a tool for cooling and ventilation in the house.

3.1.1. Natural Climatization

The concept of natural air conditioning includes natural ventilation, natural heating and cooling. Ventilation is necessary for human comfort to control humidity and fresh air levels. Normally, ventilation in commercial buildings is done with fans and some air handling units. So, these devices work with electricity. Instead of these devices, natural ventilation methods should be used to avoid energy consumption. Natural ventilation is done due to pressure differences or wind. To increase airflow in warm climates, solar chimneys should be used. Bioclimatic charts, prepared with monthly temperature and relative humidity information, show passive heating and cooling techniques appropriate for the building's climate. The most important characteristic elements are wind towers, wind catchers, chimneys, double façade and buried canals.

This enormous building in Harare, where the principles of natural heating, cooling and ventilation are used, presents a very interesting model for a highly sustainable form of commercial development. Air-conditioned glass facade towers, originally developed for Europe's warm climate, continue to be exported arbitrarily to various parts of the world. Even in Africa, this model is reproduced without thinking, with extreme climatic conditions and resource scarcity. That's why encouraging reports for The Eastgate Center Building in Harare, the capital of Zimbabwe, can provide an inspiring and alternative paradigm for future developments (13).

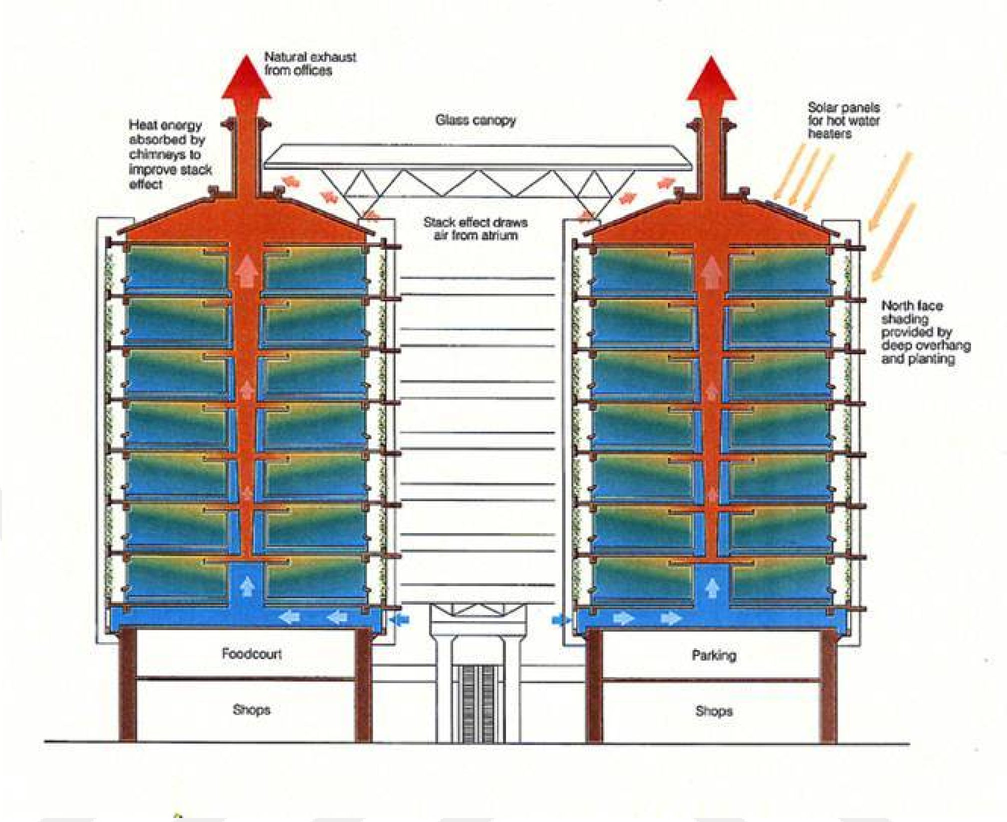

Figure 3-3: The Eastgate Centre Building in Zimbabwe

Besides, there is method to store thermal energy that called thermal energy storage. There are three way to store thermal energy and these are sensible heat storage, latent heat storage with phase changing materials (PCM), thermochemical energy storage. This may use in thermal insulation of building materials. For PCM to be ideal, they must be good latent heat, high thermal conductivity, cheap and non-flammable, have small volume changes, not corrosive and toxic. In thermochemical energy storage, the most important feature of the method is that the selected reaction is reversible (adsorption heat pump). The coco fatty acid with a melting temperature of 22-24 ° C has been determined as a suitable material that can be used in building insulation. Microencapsulated PCM application is used to support the insulation material.

For example in **Reichstag building** renewable energy is stored with thermal energy storage method. Canada's largest underground heat pump, the **University of**

Ontario, supplies 90% of the heating from solar energy. With these techniques, storage can be done in summer/winter or day/night.

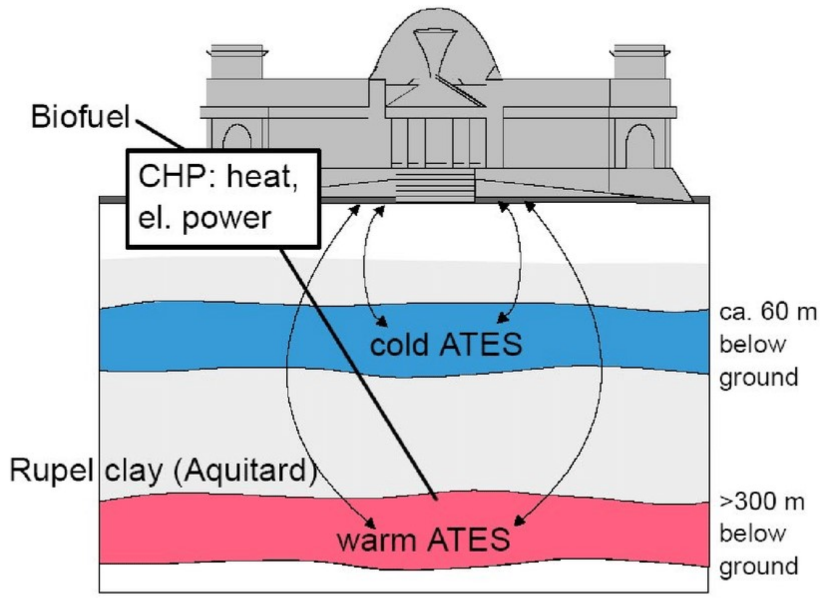

Figure 3-4: Reichstag building thermal energy storage

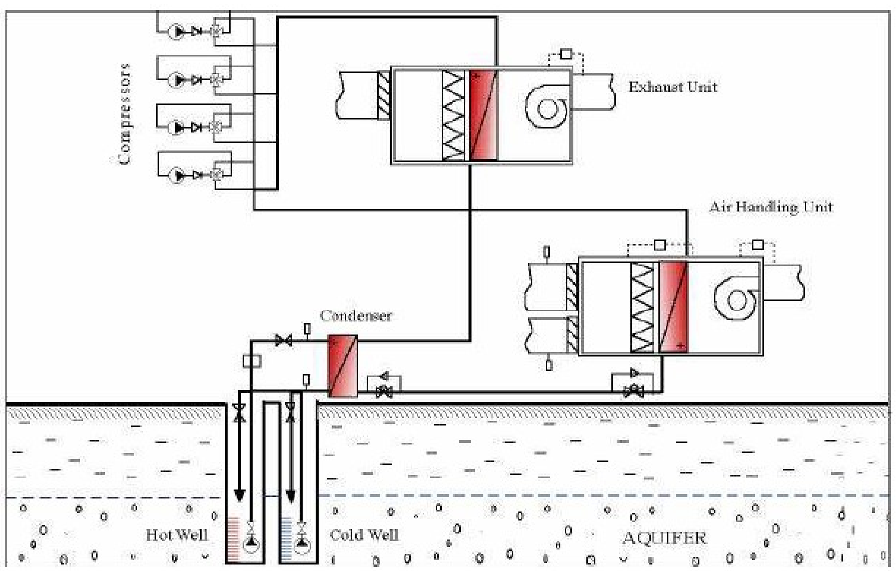

Figure 3-5: A Supermarket Thermal Energy Storage System Diagram in Mersin

3.1.2. Building Insulation Materials and U Values

As mentioned earlier, most of the energy consumed in buildings is for heating and cooling purposes. Therefore, the importance of heat control understands in buildings. In order to maximize the indoor quality of buildings, elements that are in contact with outdoor air must be protected from external effects. The total heat losses in buildings are caused of external shells respectively, 10% in floors (foundations), 10-25% in windows, 25% in roofs, 15-25% infilled walls, 20-50% in heat occurs on thermal bridges.

The qualified heat control in passive houses is provided by a continuous and high quality thermal insulation system, air sealed building wall, avoiding thermal bridges around the building and qualified window systems.

According to the standards TS 825 and DIN 4108 used to increase the thermal resistance of adjacent building materials or minimize heat loss, thermal insulation materials for materials with a thermal conductivity coefficient below 0.060 kcal / mh ^{o}C (0.0698 W/mK) and materials that remain above this value are also used as building materials. Thermal insulation materials can be used in the construction elements that form the walls, roofs and floors of buildings, as well as in the insulation of installation systems. In addition to these materials, qualified carpentry and insulating glass units used in windows are also of great importance for effective thermal insulation. In order to choose the best thermal insulation materials clearly, it is necessary to know the properties of thermal insulation materials.

- The heat transmission coefficients of the thermal insulation materials should be small.
- Thermal insulation materials should be light.
- Thermal insulation materials should be odorless.
- It should have water and moisture absorption feature.
- It should not be suitable for the nesting of bacteria and pests.
- It must be resistant to decay.

- It should not lose its first feature.
- It should not be flammable.
- It should be long-lasting.
- It is convenient to carry and should not harm human health.
- It should be economical and available.

Some insulation materials with their thermal conductivity values are listed below.

Glasswool: 0,040 W/mK - 0,045 W/mk
Rockwool: 0,043 W/mK
Expanded Polystyrene (EPS): 0,033 W/mK
Extruded Polystyrene (XPS): 0,025 W/mK
Polyurethane Foam: 0,046 W/mK
Phenol Foam: 0,04 W/mK - 0,046 W/mK

In passive house systems, the materials that used for insulation have great importance to keep the U value components between 0.1- 0.15 W / m²K. In the structures, in addition to the thermal conductivity values of the materials, the thickness of the materials also plays an important role to reach the values. (14)

Table 3-1: Thermal conductivity values of various materials and thickness

Materials	**Heat Conductivity (W/mK)**	**The required thickness (m) to supply U: 013 (W/m^2K)**
B50 concrete	2.10	15.80
Brick	0.80	6.02
Air Brick	0.40	3.01
Wood	0.13	0.98
Concrete Hollow Block	0.11	0.83
Chaff	0.055	0.410
Glasswool	0.040	0.300
XPS	0.025	0.188
non-porous "super insulation"	0.015	0.113
vacuum insulation (silica)	0.008	0.060
vacuum ins. (high vacuum)	0.002	0.015

When examined in terms of cost, the thermal insulation systems will clearly bring investment cost. However, due to the achieved energy savings, an insulated building will pay for itself between 2 and 3 years, as well as will keep fuel costs which increase rapidly due to energy resources. (15)

In European countries, building materials are better insulated than in Turkey. As you can see in Table 2.3, the U-values (thermal conductivity coefficients) of European countries are lower. So this helps to reduce the energy demand of the buildings. This means that less heating energy and less cooling energy is needed. In Turkey, the buildings need to be more insulated according to the European standards.

Table 3-2: U values of building materials corresponding to countries **(16)**

U VALUE	DENMARK	GERMANY	ITALY	SLOVENIA	TURKEY
Window	0.85 W/m^{2}K	0.82 W/m^{2}K	1.0 W/m^{2}K	1.3 W/m^{2}K	2.4 W/m^{2}K
Ex.Wall	0.15 W/m^{2}K	0.10 W/m^{2}K	0.15 W/m^{2}K	0.15 W/m^{2}K	0.55 W/m^{2}K
Roof	0.10 W/m^{2}K	0.08 W/m^{2}K	0.10 W/m^{2}K	0.10 W/m^{2}K	0.35 W/m^{2}K
Slab	0.10 Wm^{2}K	-	0.10 W/m^{2}K	0.14 W/m^{2}K	0.50 W/m^{2}K

Another reason for heat loss in buildings is air leaks in the building shell. Heat losses in buildings are caused 20% -50% due to air leaks.

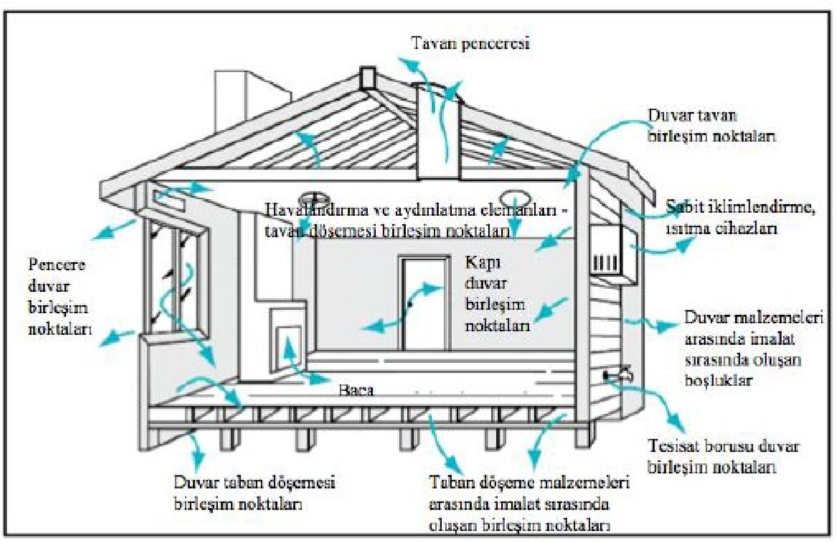

Figure 3-6: The locations of critical air leaks in buildings

Air sealed qualified joinery and insulating glass must be used to prevent air leaks. Double or triple low-e (low emissivity) glazed window systems must be used for passive buildings. The comparison of different type of window systems is shown in table 2.4.

Table 3-3: The comparison of different type of window systems (14)

Type	Single	Double	Low-e glazed double glass	Low-e glazed triple glass
U value	5.6	2.50	1.20	
Surface temperature out -10°C, in 20°C	-1.8°C	9.1°C	15.3 °C	17.5 °C
Sun emissivity	0.92	0.80	0.62	0.48

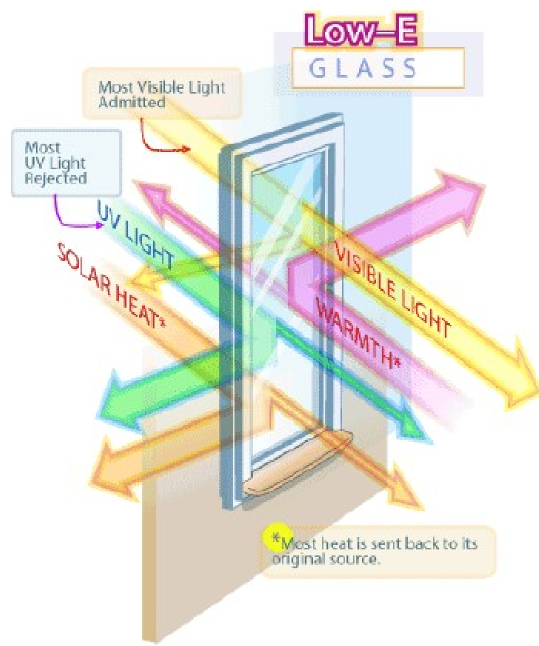

Figure 3-7: Low-e Glass

A passive house preferably stays cool on hot summer days due to less solar radiation is allowed in if the windows are facing south and triple insulated double glazing. In winter, the sun rays pass through the windows with oblique angle and fill the building with its warmth. In the summer, the sun rays come with right angle and cause to reach less heat into the building.

A vacuum gap is created to eliminate the conductive and convective heat transfer effect of the air between the glasses. Hence, thermal heat transfer coefficient of window is reduced to 1 W/m^2K.

In the energy efficiency glazing, glasses must be low – e coating to reduce thermal and UV rays penetrations.

The thermal heat transfer coefficient of triple glazed windows is less than 0.2 W/m_2K with vacuumed gap. (17)

3.1.3. Moisture Control in Building Envelope

Moisture occurs on the building walls from the temperature differences on the inner and outer surfaces of the building walls.The intrusion of water vapor increases the latent heat to be removed from the system, which requires a larger and more expensive air conditioning system; On the other hand, IAQ problems or health problems may arise due to the creation of mold.

As with thermocontrol, building elements can also be used to control and prevent moisture. With humidity control, it will prevent mold and damage that may occur in buildings. This will create a healthier environment. (18)

If water vapor does not pass through airtight and well-insulated facades, water vapor may dry out and cause mold and rot of building envelope. (19)

3.1.4. Lighting and Day Lighting

One of the indispensable things for a building is the need for lighting. Whether artificial or daylight, lighting is one of the most important factors in the design of a building.

It is important to use artificial and daylight together in order to increase the comfort of buildings. A beautiful landscape can also be created with glass and skylights.

Natural or artificial lighting can be placed in every area. But artificial lighting will increase electricity consumption. It can also generate unwanted heat.

"According to research by a lighting company, lighting strategies should be applied both inside and outside of a space, for example new fixtures, sources and lighting controls can reduce the lighting use up to 75%". (20)

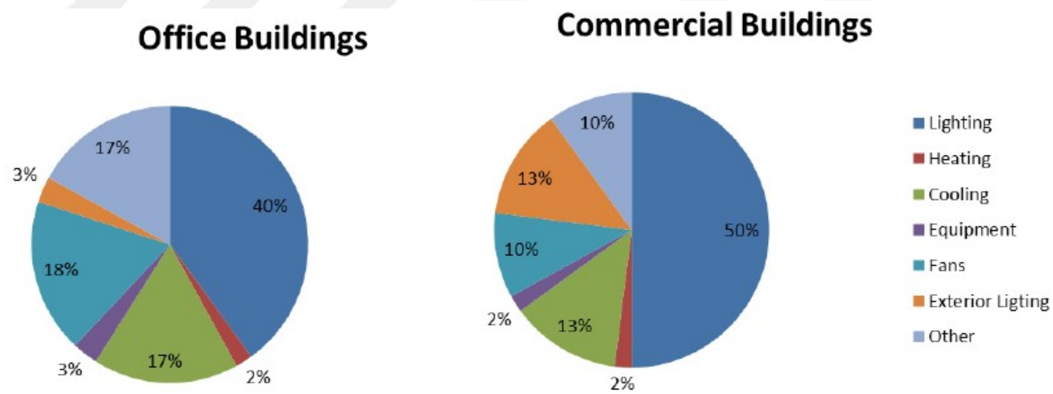

Figure 3-8: Office and Commercial Buildings' Energy Usage Percentage

The most commonly used type in artificial lighting is fluorescent. And it is quite efficient compared to incandescent. In addition, by using sensors for spaces that are not used much, electricity consumption can be further reduced. (20)

By increasing the use of daylight in buildings, the need for artificial light should be reduced and thus the energy consumption of the building should be reduced. (21)

However, daylight cannot be reached at all times and in architectures. In these cases, the most effective solution is to use daylight and artificial lighting at the same time. Lighting from windows and skylights will reduce the artificial lighting load.

Window placement has a significant impact on building geometry and daylight use. It is at the top of the list of things to do for an environmentally friendly building. (22)

3.2. Increase To Use Of Renewable Energy Share

Another thing that needs to be done in order to design an environmentally friendly building is to use renewable energy sources to meet the energy needs of the building. Solar energy, wind energy, biomass are the most important renewable energy sources.

"Photovoltaic systems can be used to store energy and help in shifting the peak load. Wind systems provide energy a very effective cost if the wind is continuous and steady and its speed above 10 mph (4.47 m/s), but it is recommended to be above 25 mph (11.2 m/s)."

Biomass is one of the renewable energy sources because it is environmentally friendly and clean energy. Especially European countries biomass use is common. (23)

Renewable energy resources should be supply <u>50-90</u> % of energy requirements of the building for nZEB design.

- PV Systems
- Wind Turbine
- Biomass

3.3. Reduce Associated Greenhouse Gases (GHG)

The first identified nZEB implication is the need for a uniform definition that should simultaneously contribute to energy and CO_2 emission reduction. Therefore, the minimum energy performance requirements for the building should use an energy indicator that can correctly reflect both the energy consumption and the CO_2 emissions of the building, as the reduced energy consumption should lead to a proportional reduction in CO_2 emissions.

In general, the primary energy consumption of a building accurately reflects the depletion of fossil fuels and is sufficiently proportional to CO_2 emissions. The proportions are distorted only when nuclear power is involved. Nevertheless, if a single indicator is to be used, then the energy performance of the building should be reported in terms of primary energy, as per the current EPBD. However, to reflect the climate relevance of the building operation, CO_2 emissions should be added as complementary information. It should be noted that there are additional requirements to ensure consistency between nZEBs and climate targets. If EU countries are to meet 2050 CO_2 reduction targets, then nZEB requirements for new buildings must include near-zero carbon emissions below approximately $3kgCO_2/m^2yr$. (8)

4. MATERIAL AND METHOD

The European Union has very important plans for zero energy buildings. By 2050, it is both to construct new buildings in accordance with the definition of zero energy building and to renew existing buildings within this scope.

"Starting from CO_2 emissions for the building sector of approximately 1,100 $MtCO_2$ in 1990 (direct and indirect emissions for heating, domestic hot water and cooling purposes) and assuming a useful floor area in 2050 of 3824 billion m^2 in 2050, a 90% decrease of emissions would require an average CO_2 emissions of maximum 3 $kgCO_2/(m^2a)$."

Table 4-1: Mean values of CO_2 emissions and primary energy factors for different energy sources **(16)**

Energy Source	**CO_2 emission [kg/kWh]**	**Primary energy factor [kWh/kWh]**
Gas	0.205	1.00
Electricity	0.567	2.18
District Heating	0.177	0.80
Oil	0.265	1.00

As you see in the Table 3.1; gas, electricity, district heat or oil usage emits CO_2 to supply energy requirements. Currently operating buildings use mix energy sources like electricity and natural gas together to get energy requirements of the building. With these energy sources, it is really hard to achieve that get below the value of 3 $kgCO_2/ (m^2a)$. Therefore, renewable energy sources have a big importance.

"On the one hand, renewable energy integration aiming towards supplying 100% of the energy requirements will provide the lowest amount of greenhouse gas emissions, resulting in a theoretical 100% carbon free energy supply. The renewable energy market and industries have developed significantly over the last decade and, for most of the technologies, it will be possible to reach competitive prices in the near future and consequently to cover a much larger share of the energy requirements." However, there are very important constraints:

- Renewables still have a price and such a solution can be suboptimal in terms of financial performance compared to energy efficiency measures with a similar impact.
- Cost optimality,
- Freely available technology and well introduced technologies to market ,
- Reasonable life-cycle cost for renewable energy.

On the other hand, there are some thresholds about building location and building properties as like: How to deal with different;

- Climate conditions
- Building geometry
- Building Usages

4.1. Power Suppliers

The buildings need energy that called primary energy requirements. Specific primary energy requirements detailed by building services, i.e. heating, cooling, domestic hot water (DHW) and lighting. Different technology options for providing a building's heating, cooling and DHW: air source heat pump, brine source heat pump, biomass boiler, gas condensing boiler, district heating, micro-CHP gas, micro-CHP biomass, multi-split cooling units for residential (COP), central cooling system for offices.

- Biomass micro CHP (Combined Heat and Power)
- Heat pump(air) with heat recovery
- PV Systems
- Brine Heat Pump
- District heating
- Rooftop

Table 4-2: Overview about the considered heating and cooling systems

	Efficiency Heating/Cooling (annual weighted average)	Efficiency Hot water (annual weighted average)
Air Source Heat Pump (SEER)	3.5-4.1*	3.6 – 4.3*
Brine Source Heat pump (SEER)	4.6- 5.4*	3.6 – 4.2*
Biomass Boiler	0.9	0.9
Gas Condensing Boiler	1	0.9
District heating	0.95	0.95
(Micro-) CHP Gas	0.63/0.32**	0.63/0.32**
(Micro-) CHP Biomass	0.63/0.32**	0.63/0.32**
(Multi-)Split cooling units for residential (COP)	3.5	3.5
Central cooling system for office	5.0	5.0

If we include a specific building in Ankara the capital of Turkey, the main heating and DHW demand is supplied burning natural gas. Also, electricity demand is supplied from plants which are 50.2 % natural gas, 25.5 % coal, 15.9 % hydro-electric power, 4.6 % solar energy, 2.7 % biogas. (23)

According to these energy suppliers, big part of the energy requirements has fossil based. However, fossil based energy suppliers emit more CO_2 and it is not available for nZEB concept as in Table 4.2. Therefore, renewable energy like PV systems and biomass boilers are needed to be used.

Table 4-3: Overview about the considered heating and cooling systems

	Off-site, grid electricity	Off-site, grid 'Green' electricity	Natural gas	Biomass	District heating	On-site electricity*
CO_2 factor** [kg/kWh]	0.252	0.0	0.202	0.0	0.107	0.0
Renewable share*** [%]	35	100	0.0	100	54	100
Primary energy factor*** [-]	2.0	0.0	1.1	0.2	0.61	0.0

Solar energy with PV systems and biomass boiler combination should be used together. Biomass boiler are used in Europa and called that biomass CHP-combined heat and power generating boiler. That can be used for single-family houses at the type of micro CHP.

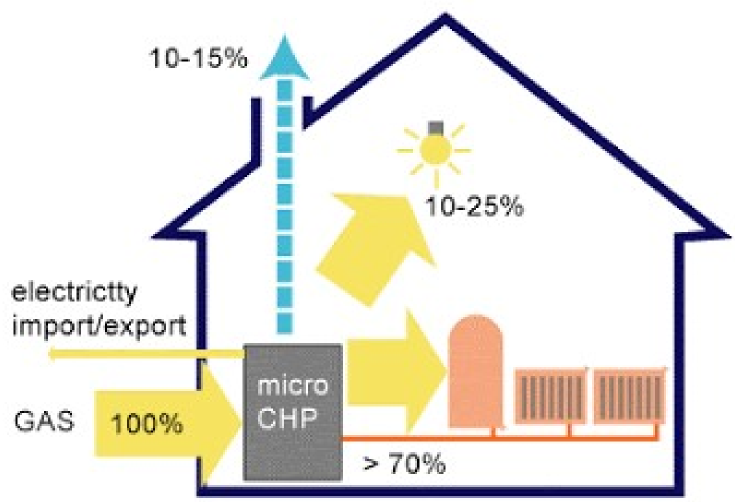

Figure 4-1: Micro CHP boiler system diagram

CHP boilers can be used with other fuels like natural gas. However, the renewable share of the energy requirements has to increase then CHP biomass boiler technology should be supported with PV systems. This will helps to increase renewable energy share of the building and also, helps to achieve $3kgCO_2/m^2yr$ aim.

4.2. Solution Sets

The techniques used to reduce energy requirements, increase renewable energy share and increasing of efficiencies are listed below:

- Argon- filled double glazed windows or triple glazed windows
- XPS-EPS type increased insulation thicknesses
- Vacuum tube solar thermal collectors
- Electrical radiators from PV system
- Hygro-sensible ventilation for human comfort and indoor air quality
- Air tightness windows to prevent heat losses
- Energy efficient taps & showers
- Electric space heating emitters – electric infrared heating panels
- BEMS – Building Energy Management System
    - Energy, cost, maintenance saving
    - Monitoring of building status
    - Environmental conditions like temperature
    - Provision of energy management information
    - Remote monitoring and control service
    - Optimization of building operations
    - Honeywell & Scheider Electric equipments
    - Cloud base solutions BEMS solutions saving 10-25 %.

4.3. The Architecture and Design Data for the Sample Building

Associated with 100 m^2 residential simple architectural design, we aimed to understand a single family house energy requirement in a year. Firstly, the analyses will be done for a house that designed and constructed with existing standard TS 825. Then, the analyses performed according to existing building that is enhanced with some scenarios which are explained detailed below, to reach zero-energy buildings criteria. Some different software's are used to calculate and analyze energy requirements and compare the results.

As a case study, a single family building is given in Fig. 4.2 is designed for an energy analysis using Autodesk Revit collaboration with Autodesk Insight.

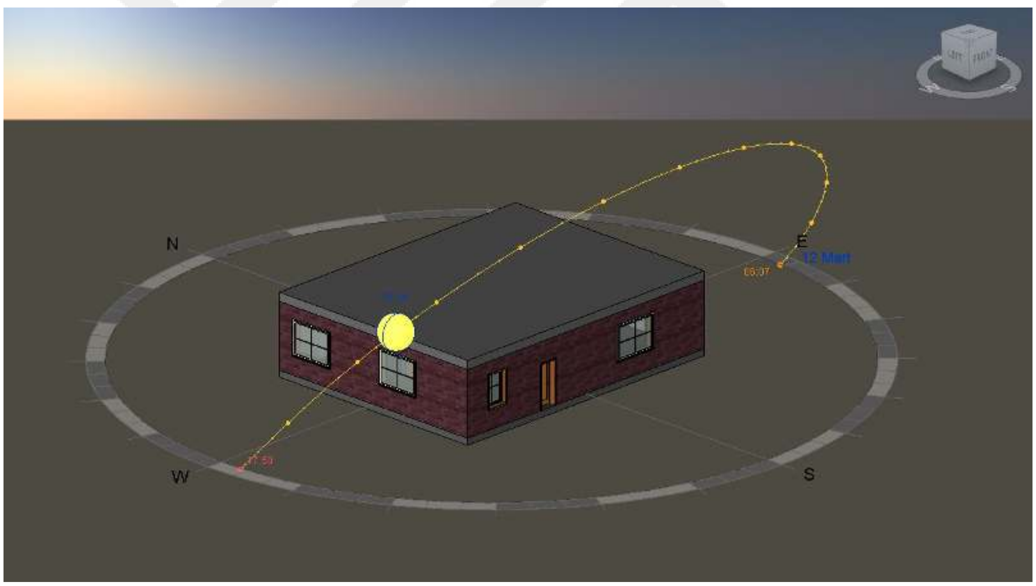

Figure 4-2: 3D model of the sample building

A sample building is located in Ankara/Turkey (see in Fig. 4.3) and energy analysis is calculated with design criteria as below.

Outdoor (winter)	: -12°C, Windy
Outdoor (summer)	: 35°C DB, 21°C WB, 16 °C daily range
Latitude	: 39°, 57' N
Longitude	: 32°, 53' E
Height above sea level	: 895 m
Thermal Insulation Climate Zone	: 3 (TS 825)

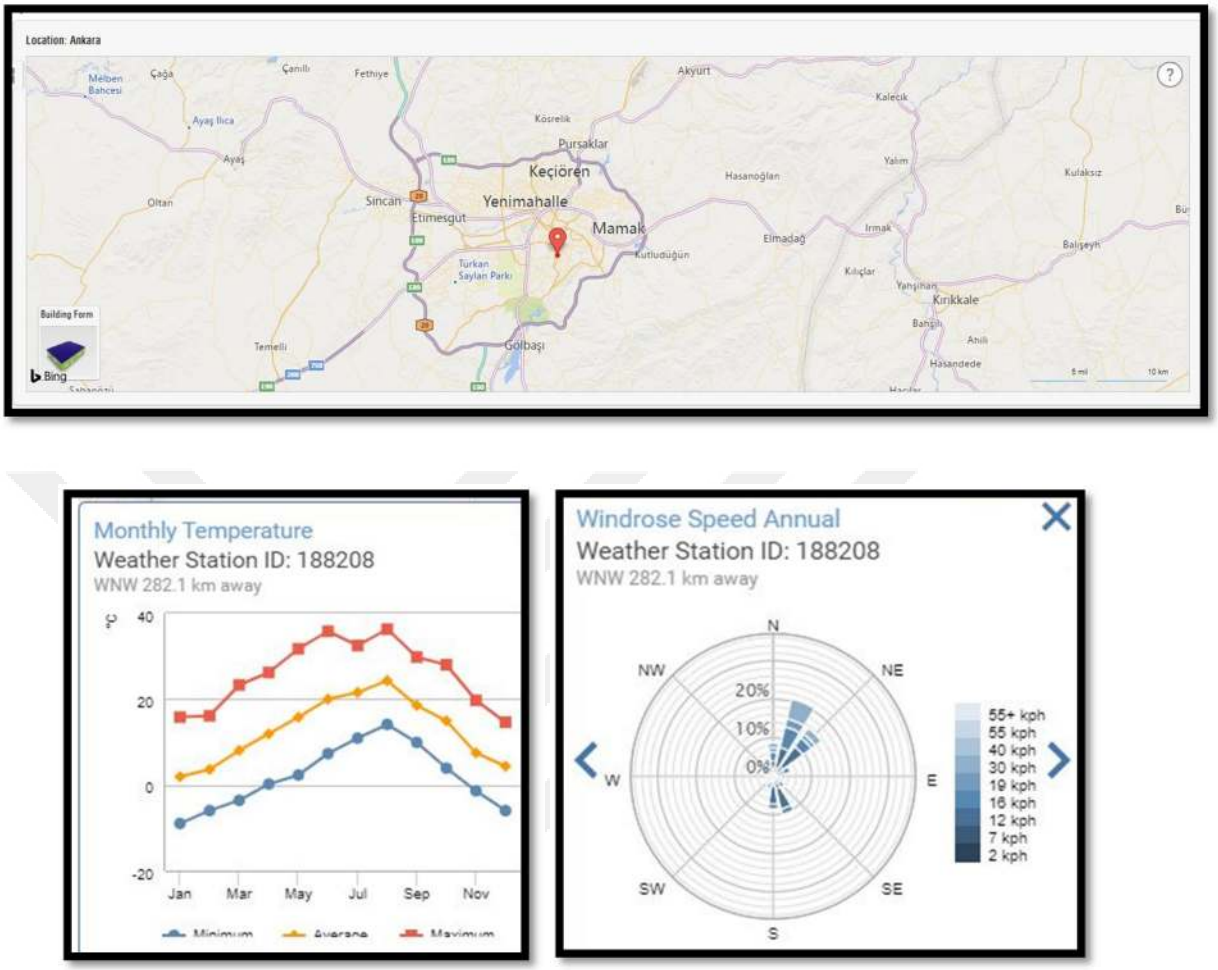

Figure 4-3: The location and climatic values of sample building in Ankara

Indoor room temperatures are set up to 22 °C in winter and 30 °C in summer. Thus the analyses are done according to these indoor room temperature values.

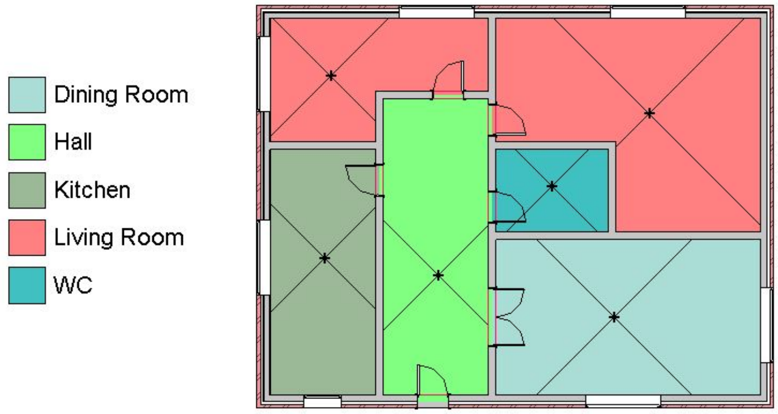

Figure 4-4: Room details of the sample building

Heat gain rates due to occupants and lighting loads for space heat gain are selected from ASHRAE "Fundamentals Handbook 2015" as given below:

Sensible heat gain : 80 W

Latent heat gain : 60 W

Kitchen ; lighting per area: 15 W/m^2, power per area: 25 W/m^2

Dining and leaving room ; lighting per area : 10 W/m^2 , power per area : 15 W/m^2

U-values of the selected building construction elements are taken according to TS 825 thermal insulation climate zone-3 as follows:

Exterior wall : 0,50 $W/m^2.K$

Roof : 0,30 $W/m^2.K$

Floor : 0,45 $W/m^2.K$

Windows : 2,40 $W/m^2.K$ SC : 0,65

The building's room list and envelope orientation information with areas are given respectively in Table 4.4 and Table 4.5.

Table 4-4: Room List

ROOM NAME	**AREA (m^2)**
Kitchen	16 m^2
Dining Room	20 m^2
Living Room 1	14 m^2
Living Room 1	23 m^2
WC	7 m^2
Hall	20 m^2
Total Area	100 m^2

Table 4-5: Building Envelope Information

	North	South	West	East
Exterior Walls	27,5 m^2	28,30 m^2	24,80 m^2	26,70 m^2
Windows	6 m^2	4,5 m^2	6 m^2	3 m^2
Doors	-	1,6 m^2	-	-

5. RESULTS

As a result of analyzing the sample building, energy use intensity (EUI) is found to be 284 kWh/m^2 year as illustrated in Fig. 5.1.

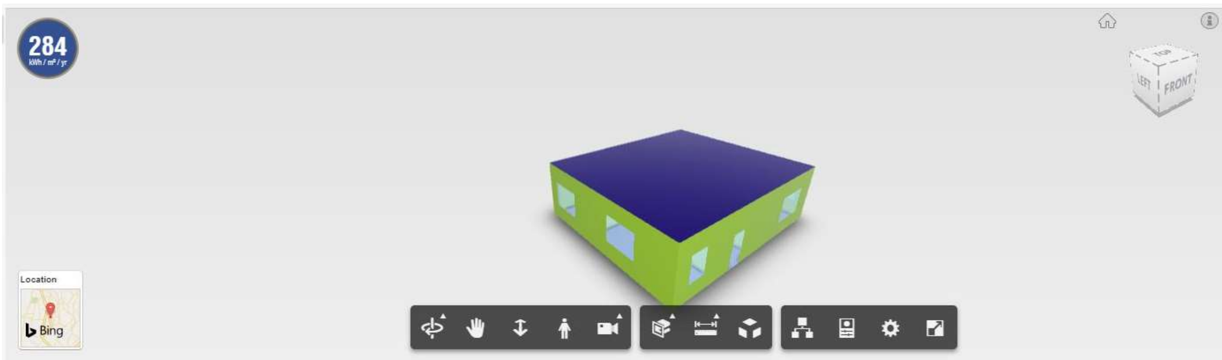

Figure 5-1: Analysis of energy use intensity for the sample building

According to the benchmark comparison to ASHRAE 90.1, the sample building energy use intensity must be maximum 272 kWh/m^2 year, as shown in Fig. 5.2. This result indicates that allowable design conditions in TS 825 do not meet the ASHRAE 90.1 requirements.

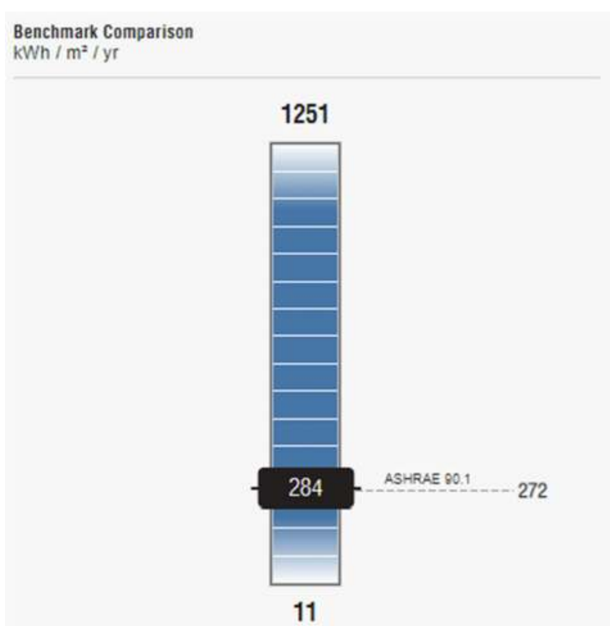

Figure 5-2: Benchmark comparison for the sample

5.1. Reformation Building with Scenarios

In order to reduce energy use intensity value to reach nearly-zero energy level, some scenarios must be applied. In this case study we considered energy efficient solutions on window-wall ratio, window shades, window glasses, envelope construction, infiltration, lighting & power efficiency, HVAC system along with renewable energy solution by installing PV panels.

5.1.1. Window Glass Reformation

Buildings energy use intensity is related to a lot of different parameters. The important one of them is building orientation. Building orientation affects the solar heat gains and heat losses from wind direction.

In this scenario, the windows are optimized to reduce energy values. Window-wall ratio and window shades values are reformed. Windows shades can be reformed by changing with window glass glazing or use external shadings with architectural design.

Energy use intensity (EUI) was 284 kWh/m^2 year at custom. After this scenario the energy use intensity is reduced to 274 kWh/m^2 year.

5.1.2. Reformation of Envelope Construction

The building insulation values take a big part on energy use intensity. At first the building is designed and analyzed with TS 825 standards and their envelope construction's U values mentioned on chapter 4.3. This affects heat transfer values that are from roof, external walls, floor, even with infiltration.

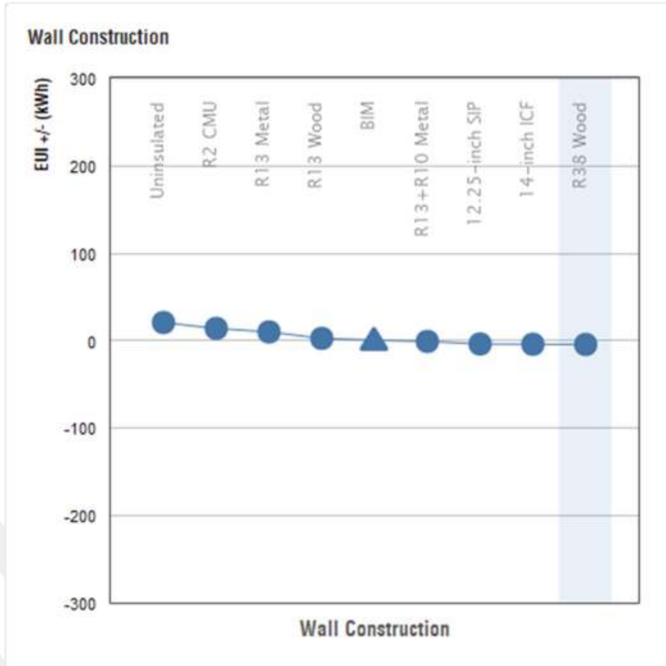

Figure 5-3: Effect of the wall construction material on EUI

According to TS 825 standards exterior wall U value is 0.5 W/m².K. R38 wood material U value is selected which is 0.16 W/m².K to reduce EUI as in figure 5-3.

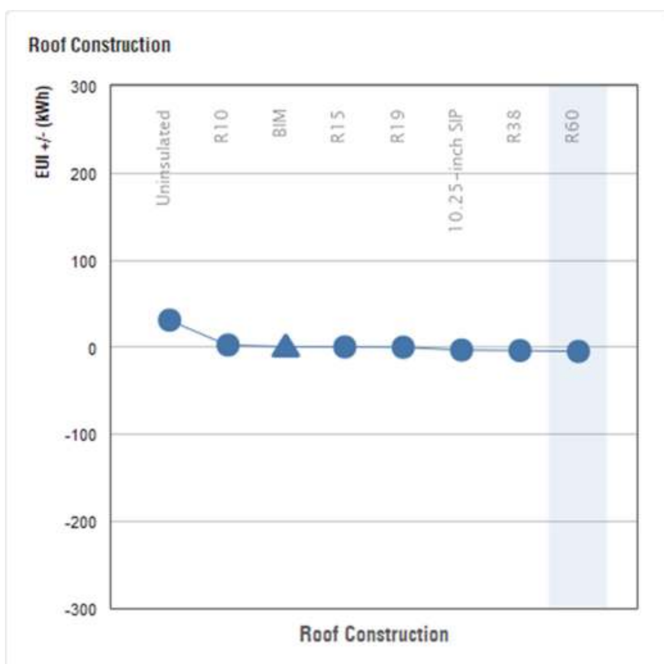

Figure 5-4: Effect of the roof construction material on EUI

According to TS 825 standards roof U value is 0.3 W/m².K. R60 material U value is selected which is 0.10 W/m².K to reduce EUI as in figure 5-4. After this scenario, energy use intensity is reduced to 244 kWh/m^2 year from 274 kWh/m^2 year.

5.1.3. Increasing Efficiencies of Lighting and Power

As mentioned on chapter 4.3 design criteria lighting load and power load per area are respectively 10-15 W/m^2 and 15-25 W/m^2. Lighting load and power load have to be more efficient to reach net zero energy requirements. As in the figure below, lighting load and power load per area values are enhanced.

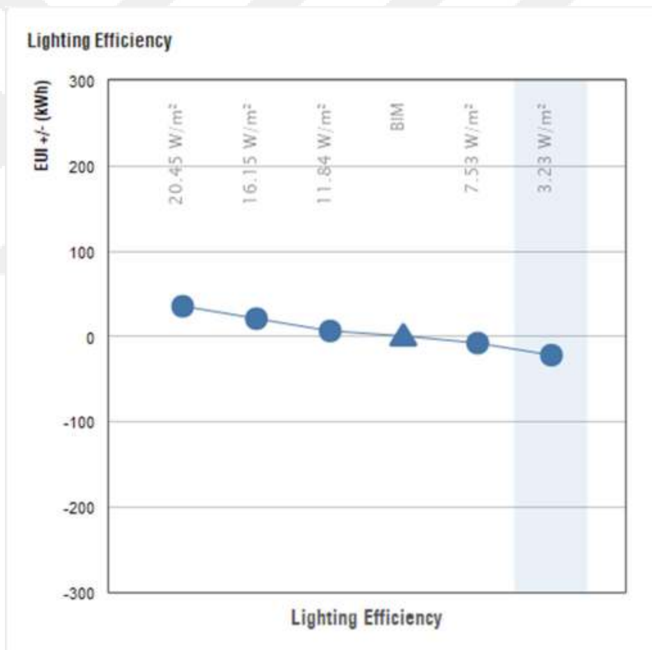

Figure 5-5: Lighting load per area

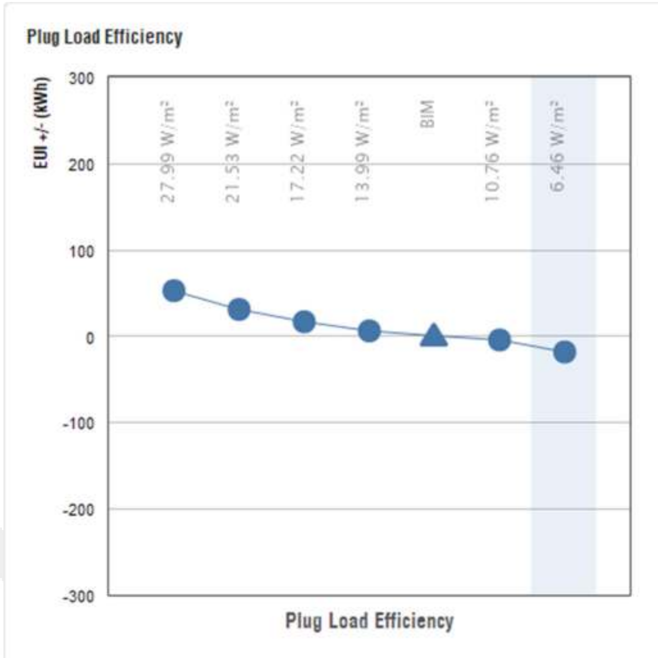

Figure 5-6: Plug (Power) load per area

Lighting load per area and power load per area are respectively enhanced to 3.23 W/m^2 and 6.46 W/m^2. After this scenario, energy use intensity is reduced to 162 kWh/m^2 year from 244 kWh/m^2 year.

5.1.4. HVAC System

HVAC system is required to heat, cool and ventilate. At the first design, split air conditioner system is selected. After energy analysis, ASHRAE package terminal heat pump is used to reduce energy requirement as you see in fig 5-7.

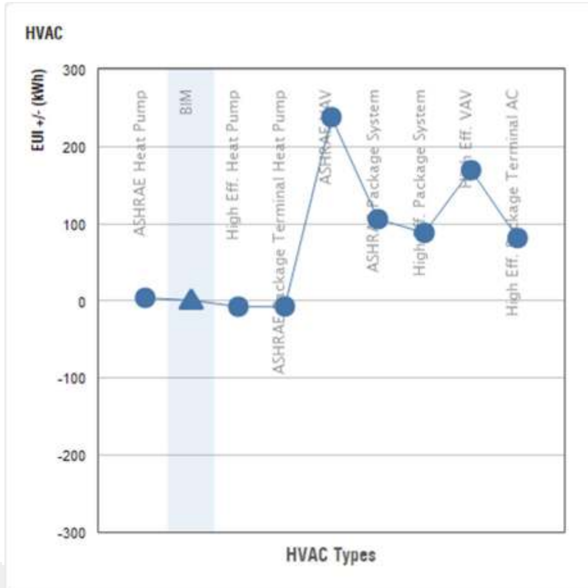

Figure 5-7: HVAC Types

After this scenario, energy use intensity is reduced to 104 kWh/m^2 year from 162 kWh/m^2 year.

5.1.5. PV System

In the previous chapters of 3.1, we reduce energy requirement with energy saving with some methods as we explained. However, these methods are not enough to reach energy requirements. Then we need to supply some energy from external and green sources. For designed building roof PV system is installed.

In terms of size and capacity of the PV system to be installed, we used surface coverage rate and cost graphic as given in Fig. 5-8. We selected coverage ratio of 75% due to using full roof-area for installing rooftop PV panels at optimum yearly slope for the selected location. PV panel efficiency is 18.6%.

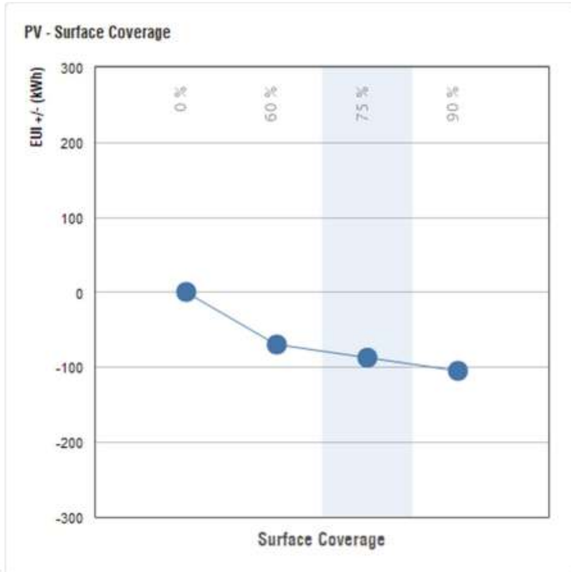

Figure 5-8: Surface coverage ratio versus cost for the PV system

After this scenario, energy use intensity is reduced to 63 kWh/m^2 year from 104 kWh/m^2 year.

However, including to investment cost, we can use the 90% of roof surface to cover with PV system. PV panel system efficiency is increased to 20.4% as in fig.5-9 and fig.5-10.

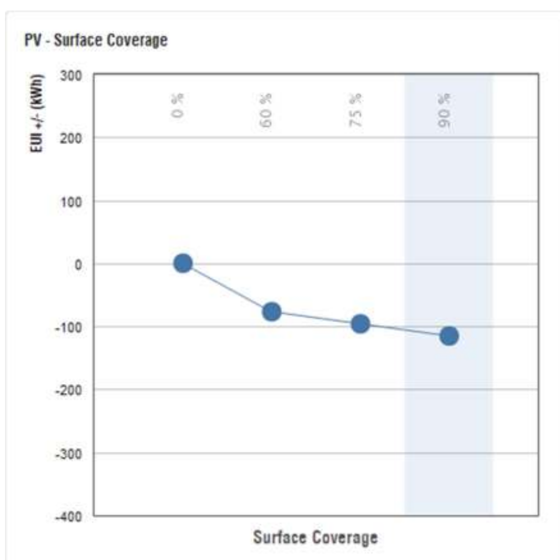

Figure 5-9: PV panel coverage rate

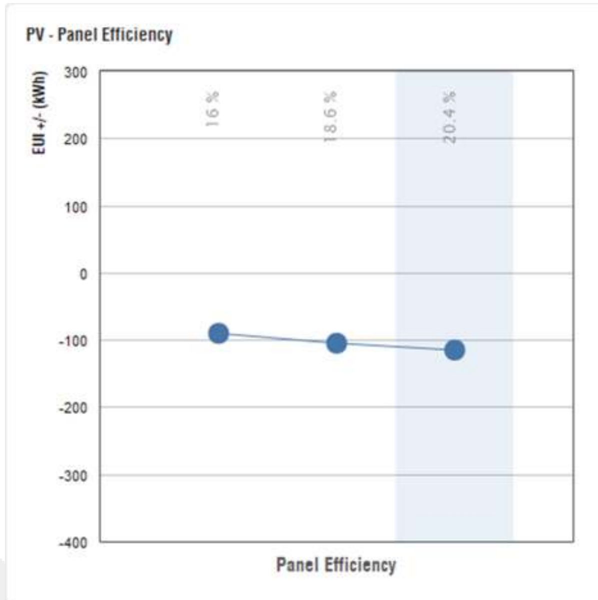

Figure 5-10: PV panel efficiency

After this extra PV system scenario, energy use intensity is reduced to 21,6 kWh/m^2 year from 63 kWh/m^2 year.

The effects of these solutions on the sample building are shown with a comparable graphic in Fig. 5-11.

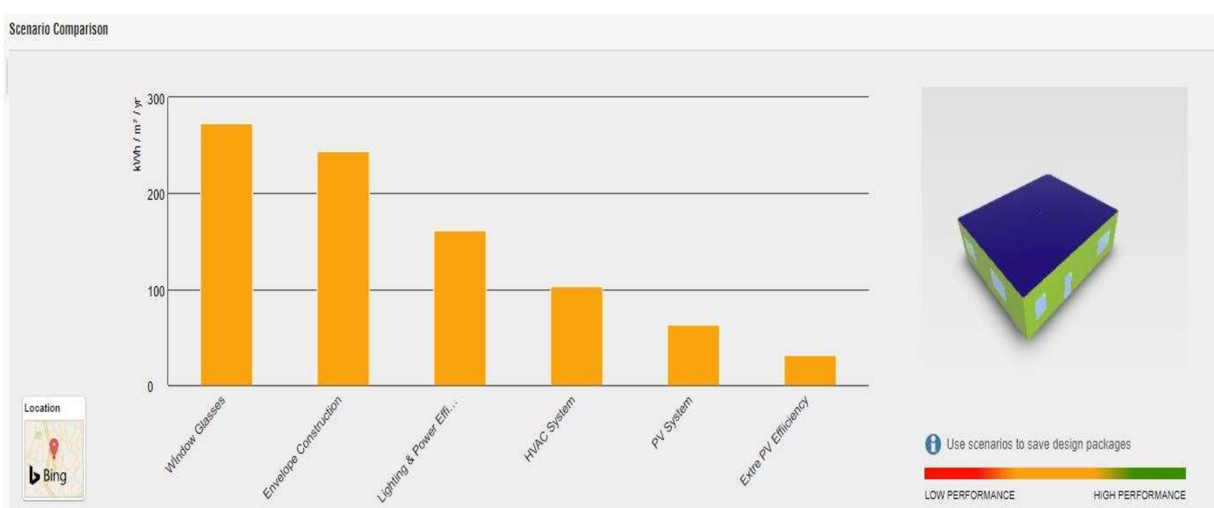

Figure 5-11: Scenario Comparison

As a result of implementation of these scenarios, energy use intensity is reduced from 284 kWh/m^2 year to 21.6 kWh/m^2 year, as indicated in Fig. 5-12. This corresponds to 90% reduction in energy use intensity, resulting in direct reductions in operational cost and CO_2 emission rates. This result indicates that solutions applied here are good steps to approach towards the nZEB design criteria and the European Union targets, since the European Union (EU) aims at drastic reductions in domestic greenhouse gas (GHG) emissions of 80% by 2050 compared to 1990 levels.

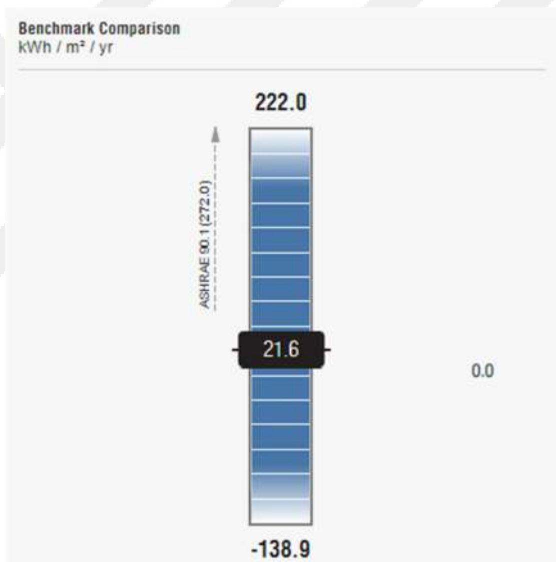

Figure 5-12: Revised benchmark after the proposed solutions are implemented

5.2. Application to Alternative Cities

5.2.1. Istanbul

Alternatively, same building is located in Istanbul/Turkey (see in Fig. 5.13) and energy analysis is calculated with design criteria as below.

Outdoor (winter) : -2°C, Windy
Outdoor (summer) : 32°C DB, 25°C WB, 8 °C
Thermal Insulation Climate Zone : 2 (TS 825)

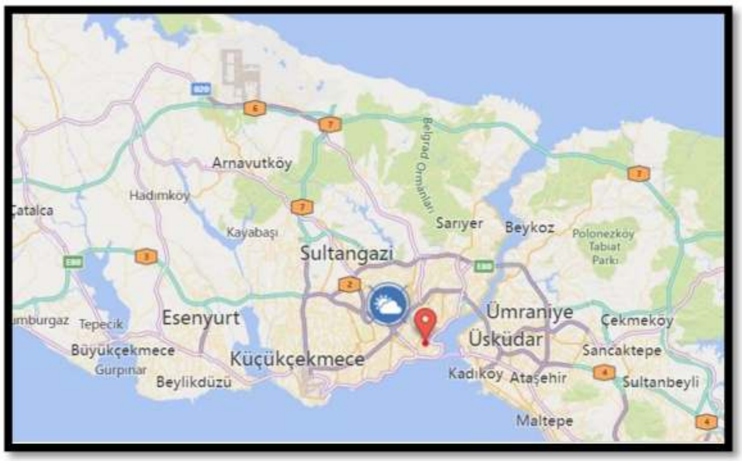

Figure 5-13: The location of sample building in Istanbul

As a result of analyzing the sample building in Istanbul, energy use intensity (EUI) is found to be 256 kWh/m^2 year as illustrated in Fig. 5.14.

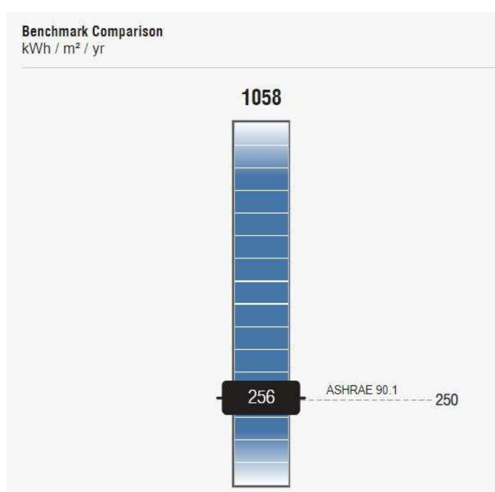

Figure 5-14: Benchmark comparison for the sample

In order to reduce energy use intensity value to reach nearly-zero energy level, same scenarios are applied with city of Ankara.

As a result of implementation of these scenarios, energy use intensity is reduced from 256 kWh/m^2 year to 6.69 kWh/m^2 year, as indicated in Fig. 5-15.

Figure 5-15: Revised benchmark after the proposed solutions are implemented

5.2.2. Erzurum

Alternatively, same building is located in Erzurum/Turkey (see in Fig. 5.16) and energy analysis is calculated with design criteria as below.

Outdoor (winter)	: -17°C
Outdoor (summer)	: 33°C DB, 17°C WB, 20°C daily range
Thermal Insulation Climate Zone	: 4 (TS 825)

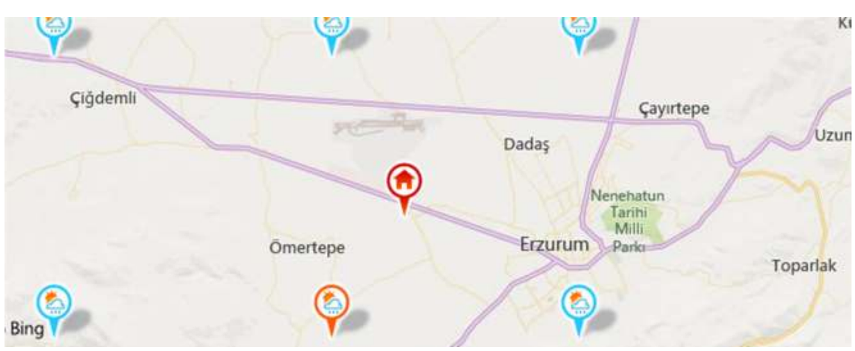

Figure 5-16: The location of sample building in Erzurum

As a result of analyzing the sample building in Erzurum, energy use intensity (EUI) is found to be 421 kWh/m^2 year as illustrated in Fig. 5.17.

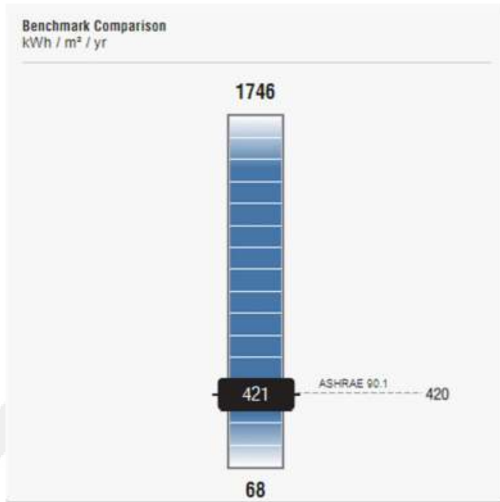

Figure 5-17: Benchmark comparison for the sample

As a result of implementation of these scenarios, energy use intensity is reduced from 421 kWh/m^2 year to 107 kWh/m^2 year, as indicated in Fig. 5-18.

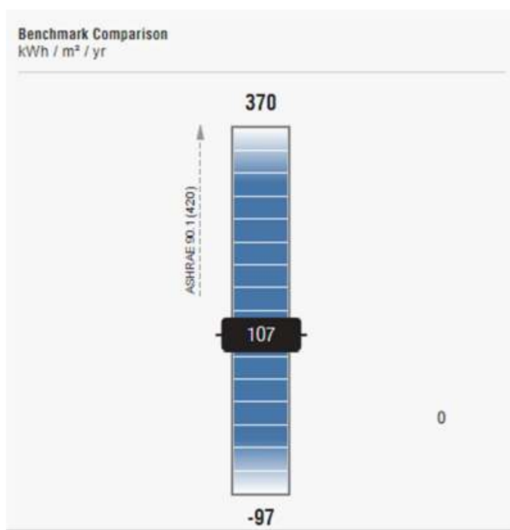

Figure 5-18: Revised benchmark after the proposed solutions are implemented

5.2.3. Antalya

Alternatively, same building is located in Antalya/Turkey (see in Fig. 5.19) and energy analysis is calculated with design criteria as below.

Outdoor (winter)	: 3°C, Windy
Outdoor (summer)	: 39°C DB, 22°C WB, 14°C daily range
Thermal Insulation Climate Zone	: 1 (TS 825)

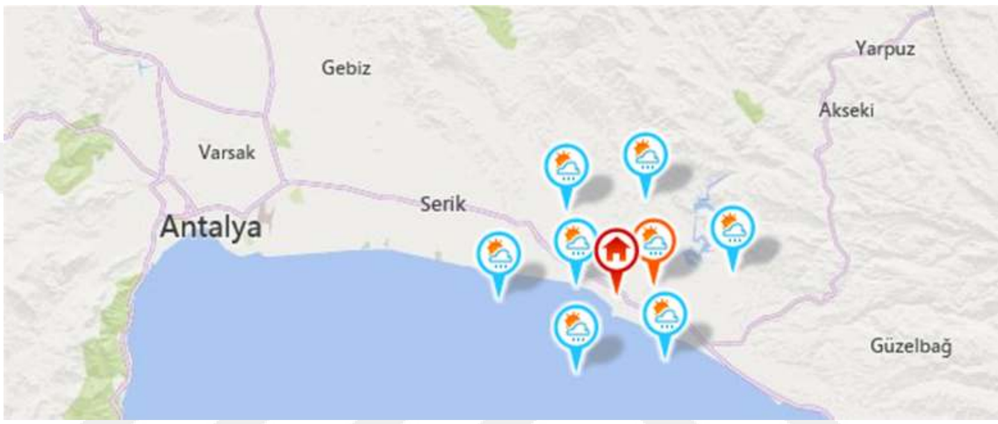

Figure 5-19: The location of sample building in Antalya

As a result of analyzing the sample building in Antalya, energy use intensity (EUI) is found to be 149 kWh/m^2 year as illustrated in Fig. 5.20.

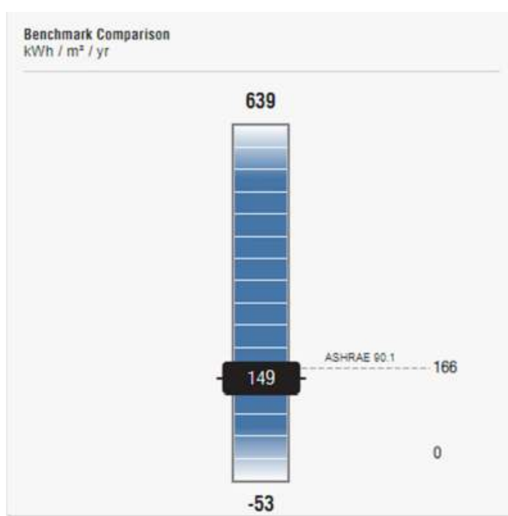

Figure 5-20: Benchmark comparison for the sample

As a result of implementation of these scenarios, energy use intensity is reduced from 149 kWh/m^2 year to -56.7 kWh/m^2 year, as indicated in Fig. 5-21.

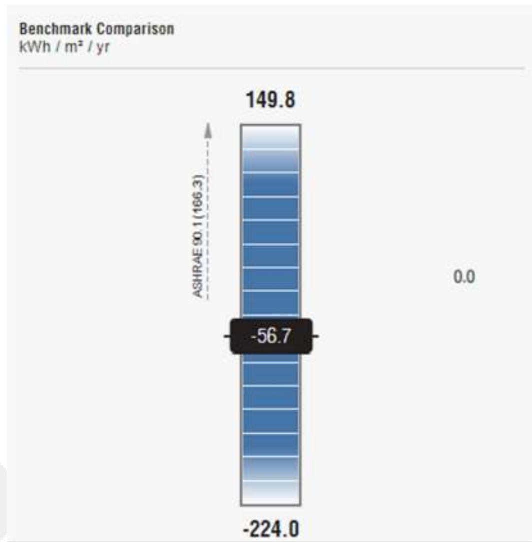

Figure 5-21: Revised benchmark after the proposed solutions are implemented

5.3. Comparison

The energy analyses are done for 4 climatic zones in Turkey these are Ankara, Istanbul, Erzurum and Antalya. These cities have different thermal properties like temperature, humidity and solar properties. Therefore, these cities help us to analyze effectively, Turkey's zero-energy potential.

The same scenarios are implemented for 4 cities. The results are given below respectively situation 1 and 2. So, first situation is energy use intensity value per meter square in a year which is calculated at standard of TS 825 and second situation is energy use intensity value per meter square in a year in which the scenarios are implemented.

Ankara: 284 kWh/m^2/yr ; 21,6 kWh/m^2,yr

İstanbul: 256 kWh/m^2/yr ; 6,69 kWh/m^2,yr

Erzurum: 421 kWh/m^2/yr ; 107 kWh/m^2,yr

Antalya: 149 kWh/m^2/yr ; -56,7 kWh/m^2,yr

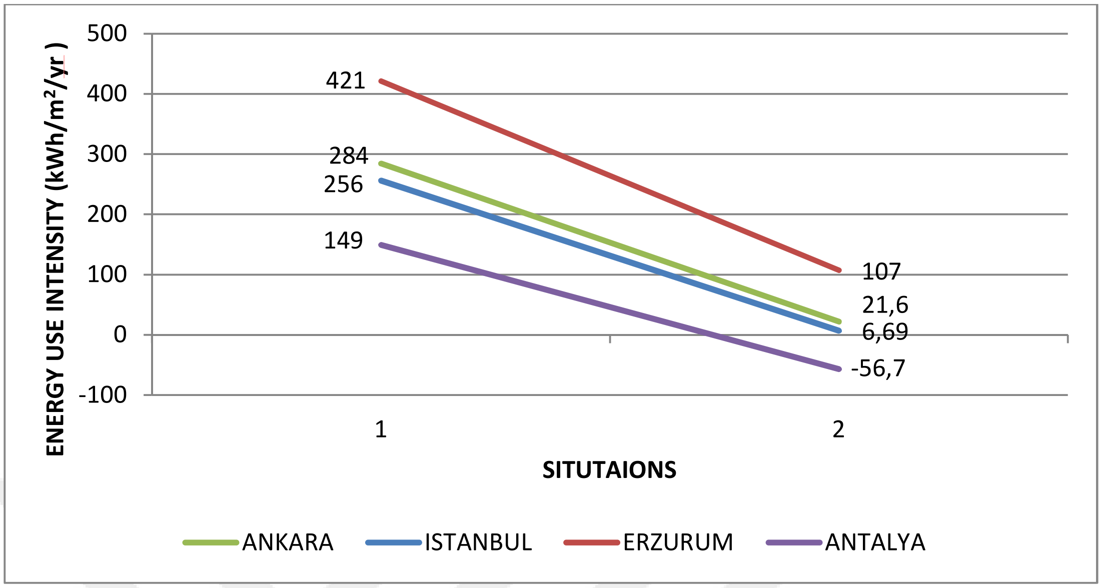

Figure 5-22: The graphic of comparison of cities by situation

Let' look at the Table 5.1 to understand how reduce building envelope heat transfer coefficient with insulation material's thicknesses.

Table 5-1: Building Envelope Insulation Material's Thicknesses

HEAT TRANSFER COEFFICENT (U value)								
ROOF (Roof)								
	TS 825 VALUES				**nZEB VALUES**			
Buildıng component	**thermal conductivity λ (w/mk)**	**thickness d (cm)**	**thermal conductivity coefficient R (M2 K/W)**		**thermal conductivity λ (w/mk)**	**thickness d (cm)**	**thermal conductivity coefficient R (M2 K/W)**	
İnterior film Ri			0,130				0,130	
Reinforcement Concrete	2,5	20	0,080		2,5	20	0,080	
Rockwool Insulation	0,035	**11**	3,143		0,035	**33**	9,429	
Outer Fılm Rd			0,080				0,080	
			3,433				**9,719**	
		U=	**0,291**	W/m²K.		**U=**	**0,103**	W/m²K.

EXTERIOR WALL(Ext.W)								
	TS 825 VALUES				nZEB VALUES			
Buıldıng component	**thermal conductivity λ (w/mk)**	**thickness d (cm)**	**thermal conductivity coefficient R (M2 K/W)**		**thermal conductivity λ (w/mk)**	**thickness d (cm)**	**thermal conductivity coefficient R (M2 K/W)**	
İnterior film Ri			0,130				0,130	
Brick Wall	0,5	20	0,400		0,5	20	0,400	
Rockwool Insulation	0,035	**5**	1,429		0,035	**20**	5,714	
Outer film Rd			0,040				0,040	
			1,999				**6,284**	
		U=	**0,500**	$W/m^2K.$		**U=**	**0,159**	$W/m^2K.$

According to reach zero energy level we need to increase our insulation materials thichnesses. In the first design which is analyzed with TS 825, U values are taken from TS 825. Roof insulation material is rockwool and its thickness is 11 cm, exterior wall insulation material is also rockwool and its thickness is 5 cm. For nZEB design, insulation thichnesses must be more 3-4 times with same insulation materials.

6. CONCLUSION

Our concluding remarks based on this work are briefly given below:

The qualified passive heat control is provided by a continuous and high quality thermal insulation system, air sealed building wall, avoiding thermal bridges around the building and qualified window systems. Air sealed qualified joinery and insulating glass must be used to prevent air leaks. Double or triple low-e (low emissivity) glazed window systems must be used for efficient passive heat control in buildings.

In general, the primary energy use of a building accurately proportional the depletion of fossil fuels and increasing of CO_2 emissions. Renewable energy integration, such as PV systems considered here, have direct and positive effect on decreasing emissions but it still calls high cost concern. Such a solution can be suboptimal in terms of financial performance compared to energy efficiency measures with a similar impact. We hence applied PV system integration in part here, first PV panels which efficiencies 18.6 are covered the 75% surface of the roof. However; it is important to highlight that this ratio can be increased up to 90% level and its efficiency 20.4 if the prices get much lower in the future.

Although analyzes made within the scope of this thesis were made in accordance with the standards and assumptions given in the thesis, they may not reflect the situation in actual operating conditions. For this reason, it is necessary to verify the results by using other software except the software used in this thesis.

On the other hand, detailed cost calculations should be made for the actual implementation of zero-energy buildings, taking into account how much time investment will pay off.

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