6. ZERO ENERGY BUILDINGS

Today, most of the energy[4] used in buildings[5] is derived from fossil fuel sources. However, buildings account for 74% of electricity consumption and 40% of primary energy consumption. For this reason, growing energy demand and increasing uncertainty about the future of fossil fuels and global climate change, and the increasing amount of greenhouse gases (for example carbon dioxide, methane, water vapor, ozone, nitrous oxide) make it necessary to find ways for reducing energy consumption in buildings[6], increasing energy efficiency and using renewable energy[7] sources. Throughout the world, global climate change, initiatives to reduce carbon emissions, oil crises, lack of resources, the rapid increase in energy demand and with it, the fact that buildings take the largest share in energy consumption have expedited researchers who want to solve these problems to head for studies such as zero energy building and passive house.

In order to minimize associated with building energy consumption, "energy design in buildings" today is undergoing a major change process. Zero-energy buildings are an important source of motivation for reducing carbon emissions from the built environment. For existing and new buildings to be built in many countries, achieving zero energy in buildings has been determined as a long-term goal. In this context, the definition, advantages, and examples of zero energy buildings (ZEB) were emphasized in this study for the expansion of zero energy buildings.

6.1. Definition of Zero Energy Building

Today, most buildings use a lot of energy to heat-cool the air, lighting, ventilation, power personal devices and heat water. Therefore, even the installation of solar systems in buildings is not enough to meet the heavy energy burden. As a solution to these problems, some buildings balance energy. As a solution, "Zero Energy Buildings (ZEB)", that balances energy, is recommended.

4 ***Energy:*** *The capacity to do work. It has some forms that can be converted from one into another such as chemical, electrical, mechanical (work) or thermal (heat). Traditional units of measurement are the British thermal unit (Btu), kilowatt-hour (kWh) or Joule (J) (URL-1).*

5 ***Building:*** *A covered structure with completely or partially exterior a roof and walls that serves and provides shelter to people, property or animals (URL-1).*

6 ***Building Energy:*** *Energy consumed at the construction area measured within the site boundaries. It includes systems such as ventilation, heating, outdoor and indoor lighting, cooling, hot water usage, and elevators (URL-1).*

7 ***Renewable Energy:*** *Energy resources that are replenished naturally but with limited flow. Renewable energy resources are hydro (water), geothermal, biomass, wind, solar, tide and ocean heat (Standard, C. E. N. (2008)*

To clarify the description of ZEB, they are buildings that provide a large part of their energy needs from renewable energy technologies and sources, and efficient energy construction techniques are applied in. The basis of the ZEB concept is the idea that buildings meet all energy requirements from renewable sources, locally available, low-cost, non-polluting, (Torcellini, Pless, and Deru, 2006). Zero energy building (ZEB) is defined as showing low primary energy[8] (fossil-based energy) consumption and high energy performance (URL-2). This approach has a significant potential to solve problems such as reducing dependence on fossil fuel energy use and eliminating the threat of carbon emissions, generating at least as much energy as consumed, merging energy-efficient construction techniques with renewable energy technologies.

Zero energy buildings, defined under many different concepts such as zero energy, environmentally friendly, green, sustainable, and ecological, etc.; are ecosystem-sensitive and nature-compatible structures and designed based on the selection of the land on which the building will be built and evaluated in the context of the life cycle, taking into consideration social and environmental criteria. In this context, these structures are buildings that are suitable for climatic data and conditions of their location, that are oriented towards renewable energy sources, that consume as much as they need, and that use natural materials that do not produce waste (Environmentally Friendly Green Buildings Association, 2019).

In summary, ZEB is a type of building that produces as much energy as it consumes during a year and whose annual consumption is equal to its annual production. In these buildings, when weather conditions are not suitable for power generation, the building takes its energy from the electrical grid to meet its energy needs. Renewable energy systems continue to meet the building's energy needs and excess energy is sent back to the power grid when the weather conditions improve. In other words, the building gives back as much energy as it gets. In this context, two different types of zero energy buildings come to the fore. If production exceeds consumption, this building is called a positive energy building. If production is lower than consumption, they are defined as near-zero energy buildings.

6.2. Zero Energy Building Advantages

Zero energy buildings have many important advantages compared to buildings with high energy consumption. Zero-energy buildings behave as energy-efficient, saving 50%-70% more energy than traditional buildings. ZEB, which dependence on fossil fuels and reduce carbon emissions, also reduce their ecological footprint by impacting less greenhouse gases to the atmosphere. In this context, energy-efficient zero-energy buildings will play an important role in creating an energy-safe future by generating as much energy as they consume.

ZEB produce the renewable energy it needs to address the need for annual energy consumption, in this way reducing non-renewable energy use in the construction industry. Cost-effective measures are taken to reduce energy use in these buildings. However, to meet the remaining energy needs, renewable energy sources are integrated into these buildings. These buildings, produced with environmentally friendly approaches, save energy bills throughout the life of the building.

Today, Zero Energy Buildings (ZEB) are constructed by considering significant purposes such as minimum emission, minimum consumption, minimum waste, efficient human-nature relationship, keeping the quality of the internal environment at maximum, healthy indoor environment conditions, productive work environment, ensuring the efficient use of natural resources and keeping adverse environmental conditions at the minimum level. Zero-Energy Buildings, which are built with these criteria, provide environmental benefits such as effective use of rainwater, reduction of consumption of non-renewable energy sources, waste management and reduction of waste amount, protection of air and water quality and natural resources.

8 ***Primary Energy:*** *"Energy that has not been subjected to any conversion or transformation process and obtained from renewable and non-renewable energy" (URL-2)*

To address the economic benefits of these structures, even if the costs are high, it is expected that they will provide long-term efficiency, such as reduced operating costs, when the construction life is taken into account. This situation also provides advantages such as rising building sales and rental values. However, the use of renewable energy sources has an impact on the reduction of energy cost (Yeşilbaş, 2014).

In these buildings, where durability and comfort are high, it provides a healthy and safe interior environment. Another goal of these buildings is to limit damage to the ecosystem and reduce the use of natural resources such as water, soil, energy, and raw materials. The increase in the number of zero energy buildings (ZEB) will contribute greatly in the long term towards reducing current maintenance and operating costs, reducing environmental impacts and improving energy security.

6.3. Zero Energy Building Design

Energy use and efficiency stand out as one of the most important features of zero-energy buildings. A holistic approach is of great importance in the creation of built environments in order to minimize damage to the environment. In this context, the principles to be considered in order to have a minimal environmental impact during the design and development of a building can be listed as follows (URL-3; URL-4)

- Accessibility, security, and proximity to social services;
- Minimal interference to natural resources;
- Positioning and shaping of the building according to the sun, arrangement of openings accordingly and effective use of natural light;
- Reducing cooling, lighting loads and heating with climate-sensitive design and protection applications;
- Passive and active heating/cooling systems integrated into the building;
- High-performance design of building envelope; long-term insulation coating of walls, roofs, doors, windows, and other surfaces according to air tightness performance requirements;
- An integrated ecological landscape design using deciduous trees to reduce the additional heat load to the building and create shade in summer;
- Optimizing building performance by using energy modeling programs during and after the design phase;
- Use of renewable energy sources such as geothermal heating, photovoltaic, groundwater cooling for hot water and solar heating[9];
- Obtaining materials from sustainable sources, using local, natural, and recyclable materials mainly;
- Use of materials without volatile organic components and indoor air quality;
- Use of, on-site renewable energy technologies such as wind turbines, photovoltaics and solar;
- No use of materials that cause CFC (Chlorofluorocarbon)[10], HCFC (Hydrochlorofluorocarbon) and ozone depletion;
- Efficiency in the natural resources and use of energy;
- Collecting and producing energy in the field;
- Low CO_2 emission[11] targets;
- Optimizing system control strategies by using air quality sensors and CO_2;
- Integrating appropriate technologies into the system to save water;
- Minimization of waste during the construction process;

Some systems that can be integrated with structures to ensure energy efficiency and sustainability in the design phase and improvement processes in zero energy building design can be read on the sample building in Figure 6.1.

9 ***Geothermal Energy:*** *Deep earth heat used for thermal energy or electricity generation (URL- 1).*

10 ***CFC:*** *"Chlorofluorocarbon gas. Chlorofluorocarbon, one of the greenhouse gases, is one of the main causes of global warming". (URL-5)*

11 ***CO_2 emission coefficient:*** *"The amount of CO_2 emitted to the atmosphere per unit of delivered energy" (EN 15603; 2008); the coefficient used to calculate CO_2 emissions from primary energy, which varies depending on the type of fuel consumed by the building (Çakmanus, 2011).*

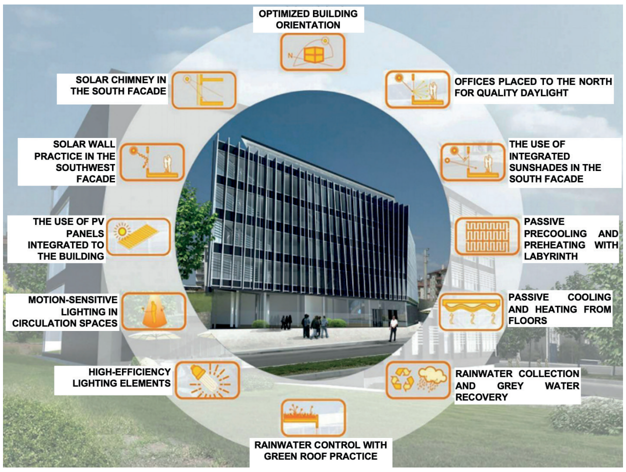

Figure 6.1 Energy efficiency practices in the DGLRC Building of the Turkish Ministry of Environment and Urbanization in Etimesgut, Sincan, Ankara, Turkey (Yöntem, 2016:5)

The energy need shows the energy need for ventilation, heating, lighting, hot water use, cooling and devices within the building. The energy need for heating is due to heat losses. Heat gain and the sun can reduce these losses. *Net energy requirement* in a building is calculated *as=energy requirement - heat gains*. This process is the thermal energy that is generated without any system loss to sustain indoor climatic conditions. Energy for electricity required for household appliances and lighting. Building technical systems meet the net energy requirement of electrical energy, cooling, and heating. The energy given to the building can be supplied from the mains electricity system, natural gas, regional cooling, regional heating, and renewable energy system located outside the building, etc. Renewable energy produced on site without fuels is the energy generated from wind and active solar. However, the energy from the heat sources of heat pumps (air, earth, water) (provided that the electrical energy consumed in the compressor is taken into account) is also accepted as a renewable energy source. In another saying, if the renewable energy produced in the building is exported to other energy networks, net delivered energy is calculated as: net delivered energy = delivered energy[12] -sold/exported energy[13] (Kurnitski, Allard, Braham, Goeders, Heiselberg, Jagemar,... and Seppänen, 2011). Building boundaries, energy definitions required for a building, and energy consumption relations are shown in Figure 6.2.

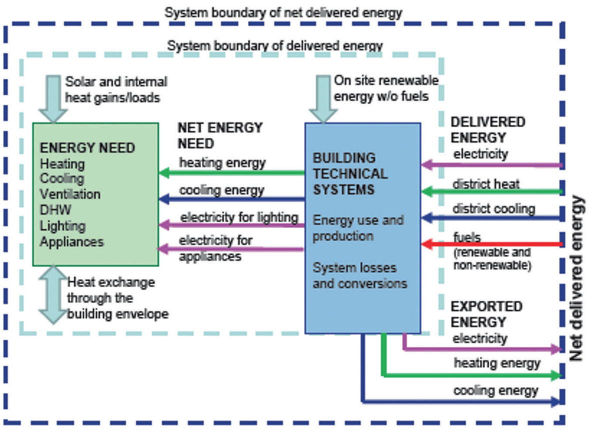

Figure 6.2 Building boundaries[14], energy definitions required for the building and energy consumption relations (Kurnitski vd., 2011)

Net delivered energy boundary and how it forms from energy need are are sum of the on-site renewable energy[15] production, exported energy and delivered energy, energy use of technical systems in the building. The "energy demand" box describes buildings rooms and both system boundary lines can be expressed as the construction site boundary (Kurnitski vd., 2011).

For example, think of an office building located Paris is planned according to the annual net energy requirements below. It is assumed that the specific energy consumptions throughout a year will be as follows: (all

12 ***Delivered energy:*** *"The total energy supplied to the building over the system boundary, to satisfy the uses taken into account (cooling, heating, appliances, ventilation, lighting, domestic hot water etc.) or to produce electricity" (EN 15603; 2008).*
13 ***Sold Energy:*** *Produced in a building and delivered to the outside (EN 15603; 2008).*
14 ***System boundary:*** *"Boundary that includes within it all areas associated with the building (both inside and outside the building) where energy is produced or consumed" (EN 15603; 2008).*
15 ***On-site Renewable Energy:*** *Includes renewable energies used for the energy of a building and collected and produced within the site boundaries and excess renewable energy can be exported to the outside of the site boundaries (URL- 1).*

values are specific values in kWh / (m² a) (Kurnitski, 2011).

- Net heating and ventilation energy : 3.8 kWh/(m² a)
- Net cooling energy: 11.9 kWh/(m² a)
- Appliances electricity: 21.5 kWh/(m² a)
- Lighting electricity: 10.0 kWh/(m² a)

In this context, the distribution of net energy need is shown in Figure 6.3 (Kurnitski, 2011).

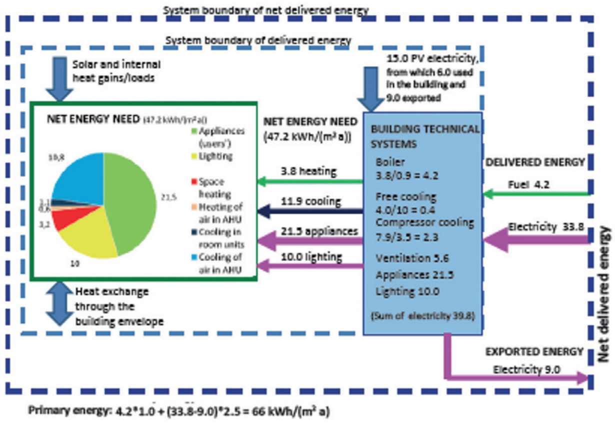

Figure 6.3 Calculation of the energy flows in the nZEB office building (Kurnitski et al., 2011).

A building's energy needs consisting of hot water, heating, ventilation, cooling, lighting and other loads and renewable energy sources or measured primary sources it uses to meet these energy needs are shown in Figure 6.4.

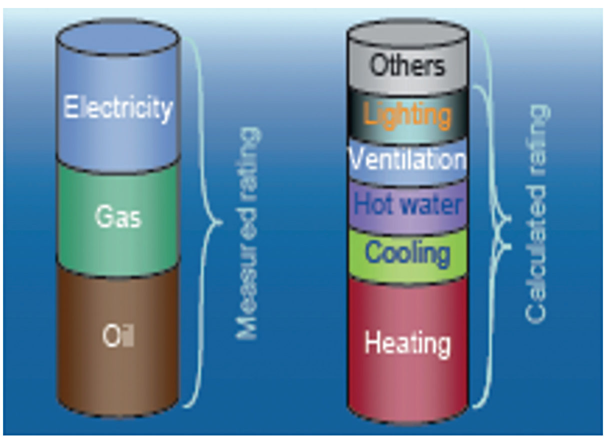

Figure 6.4. The energy needed in the building and used to meet this need (Kurnitski et al., 2011)

In ZEB, a part of the energy requirement of the building is met from renewable energy sources generated within the structure. Whole of the heating and cooling needs of the construction and some of the electrical energy needs will be provided by these systems, and besides, it should be considered that the building insulation is very good and maximum solar heat gain is maximum. Apart from these measures, the energy needed is provided from renewable energy sources (Figure 6.5).

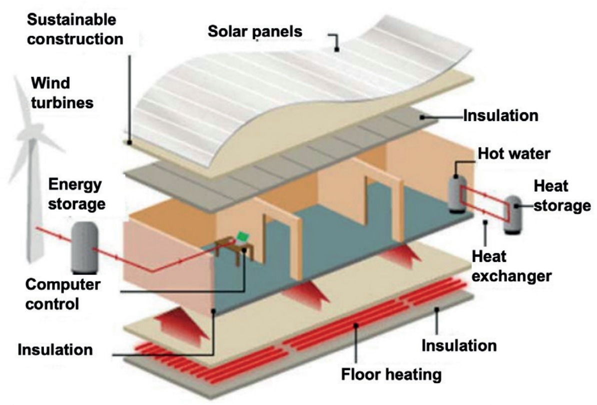

Figure 6.5 An example of zero energy building (Berberoğlu, 2009)

The employment of high-efficiency or renewable energy technologies is a significant criterion in ZEB design. Renewable energy sources used in these buildings contain photovoltaic, wind, solar water heating, geothermal and biomass. The use of renewable energy sources reducing dependence on imported fuels and increases energy security. In these buildings, solar energy should be considered for domestic hot water and heating requirement. In this context, it would be useful to utilize on-site renewable energy sources such as solar water heating and geothermal heat pumps. Renewable energy technologies such as purchasing electricity and wind turbines generated from low polluting sources such as natural gas should be evaluated or renewable sources (URL-6).

In Zero-Energy Buildings, total energy efficiency becomes much more important than in conventional buildings as the net energy need of the building decreases. Because, ZEB are designed and implemented with very low energy demand. Therefore, there is a need for integrated building design and for making the building more compatible with the environment. In other words, the design should shift from energy saving to energy optimization. Here, choosing appropriate materials and shading in architecture is the first step. The remaining cooling needs can be met with active and passive systems (Çakmanus, 2011).

The first thing to focus on in the design of ZEB is the climatic conditions under which the building is located. After the climatic conditions are determined, different solutions are sought for energy consumption in the building. Consideration should be given to how the building should be placed on the land, which direction the building should be faced, and its relation with the existing pattern. Depending on orientation of the building and the location in the land, how it will benefit from wind and solar energy is important for energy efficiency and comfort conditions.

Another important factor in zero energy building design is building form. Building form is defined as geometric variables such as style, height, frontal slope, roof form, and roof slope (Ünsal, 2012). The heat gains and losses occurring in two buildings with similar floor spaces vary by their ratios of width to depth. Heat gain and loss loads may be less in buildings with simple geometric forms (Burberry, 1979:17).

The next phase requires the use of building energy modeling. "Building energy modeling is defined as the creation of an abstract model of building design with required details in a computer environment and testing it under the conditions that will occur during its use." It benefits in taking measures to reduce energy consumption and measuring the building's energy performance. Building energy modeling can be used not only in new buildings but also in renovations of existing structures. The main issue to focus on when building the model is to consider all the factors that lead to energy consumption in the building. These factors can be listed as follows (Moltay, 2012):

- Building positioning and interior configuration
- Heat performance of building envelope elements
- Passive architecture and solar control systems
- Thermal performance, light transmission, and coating rates of facade windows
- Lighting systems and daylight usage opportunities
- Electricity or hot water generation systems from solar energy
- Selection, efficiencies and working scenarios of air conditioning and ventilation systems
- Opportunities to benefit from air or earth heat
- Energy recovery systems
- Cogeneration or micro-cogeneration systems
- Building automation and control scenarios
- All other energy-consuming equipment in the building

Another basic step of ZEB construction is the insulation of floors, ceilings and walls with thicknesses of insulating materials and types that meet the specific needs of each surface for the insulation and tightness of the building envelope. Use of high-insulated windows and doors; selecting an energy-efficient cooling and heating system, energy-efficient lighting installation; selecting energy-efficient devices and electronic products; lighting, cooling and heating systems; use of renewable energy sources that can meet all the energy needs of a house, including devices and hot water are considerations in the design of a ZEB (URL-7).

The energy efficiency measures that can be taken within a building are taken passively and actively. Passive efficiency is about avoiding unnecessary energy use. It is important to use efficient HVAC and lighting systems. An example of passive energy efficiency is converting traditional lighting to LEDs that generate the same amount of light with less energy. Active energy efficiency is about taking energy use control. Continuous monitoring requires two things-using power meters and power monitoring software, and active management, including those responsible for the action plan, and monitoring of results. However, energy efficiency alone is not sufficient and renewable energy sources should also be integrated into the building.

6.4. Zero Energy Building Examples

Building energy consumption is usually recognized as one of the primary sectors contributing to all primary energy consumption and greenhouse gas emissions in the world. This has led to a large increase in public awareness about energy conservation in recent years. Net / nearly - zero energy building (ZEB / NZEB / nZEB), green building, and low-energy building approaches have been developed to ensure the integration of efficient energy system operation, advantages of low energy demand, and renewable energy systems (Li, Wen and Wu, 2014; Sun, Huang and Huang, 2015; (URL-8); Aelenei and Gonçalves, 2014).

The increase in energy efficiency in buildings has the potential to cope with the energy and climate challenges of the 21st century. In this context, studies in many countries, both the USA and Europe, continue to increase. Within the scope of the *Architecture 2030* project, some goals have been set to reach the zero energy target in buildings. In this context, energy consumption will be reduced to 60% by 2010, 70% by 2015, 80% by 2020, 90% by 2025, and zero energy consumption will be reached by 2030 (URL-9).

The targets set ZEB in the United States are being realized and the number of these buildings has been increasing steadily since 2012 as shown in Figure 6.6. According to the 2019 *Getting to Zero Project List* study released by the NBI, a total of 580 certified zero-energy-produced and officially verified projects were achieved in 2019. A 10-fold increase has been observed since 2012 (URL-9).

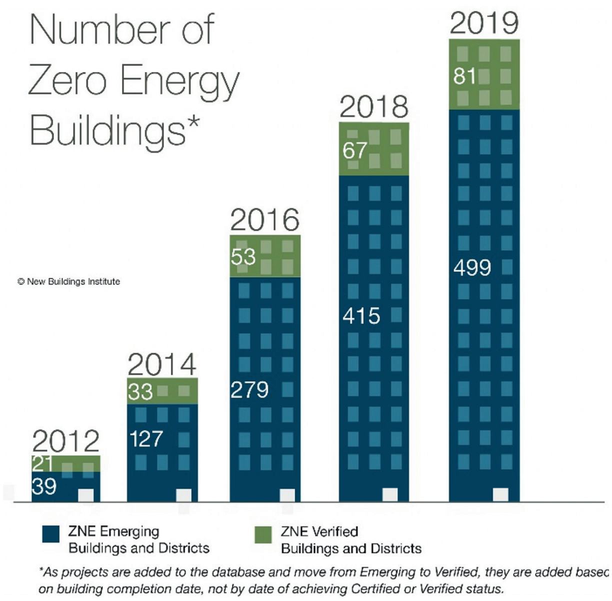

Figure 6.6 Increasingly continuing zero-energy buildings in the US (URL-9).

Minimizing energy consumption of the building stock is seen as one of the key policy objectives of the European Union (URL-10). The buildings marked according to building typology on the map on the website16 were edited and updated until the end of 2013 by Prof. Dr. Eike Musall (URL-11). The structures on the map in Figure 6.7 are particularly dense in European countries.

Figure 6.7 A part of the map of zero-energy buildings that are known throughout the world (URL-11)

Studies on ZEB, which have become part of energy policies during the recent years, have been increasing. In this regard, the "EU Directive on Energy Performance of Buildings (EPBD)" states that all of the new buildings will be "nearly zero energy buildings" until the end of

16 https://batchgeo.com/map/net-zero-energy-buildings

2020 (URL-12). "The strategic goal for the Building Technologies Program of the U.S. Department of Energy (DOE)" is similarly planned to achieve "marketable zero energy homes in 2020 and commercial zero energy buildings in 2025" (URL-13). The Beddington Zero Energy Development, located in Europe and whose sustainability engineering was carried out by Arup Firm, (Figure 6.8) was built in South London in 2002. The project was designed as a mixed-use campus with spaces with functions including approximately 1600 m2 of office space, nursery, 82 residences, medical center, social facility, sports fields, café-bar, etc. This complex is also known as the largest eco-village in the UK. It was terraced so that all the dwellings within it have gardens, was oriented to the south for maximum heat gain, and was designed based on the principles of the passive solar system. The office masses are located behind the terraces and were planned to head north to reduce the need for cooling, prevent excess heating and make optimum use of daylight. The building envelope, produced with high insulation, is 25% more energy efficient compared with similar structures with conventional designs through the use of photovoltaic panels, which were integrated into the facade, wind-driven ventilation chimneys, and cogen system (Yöntem, 2016).

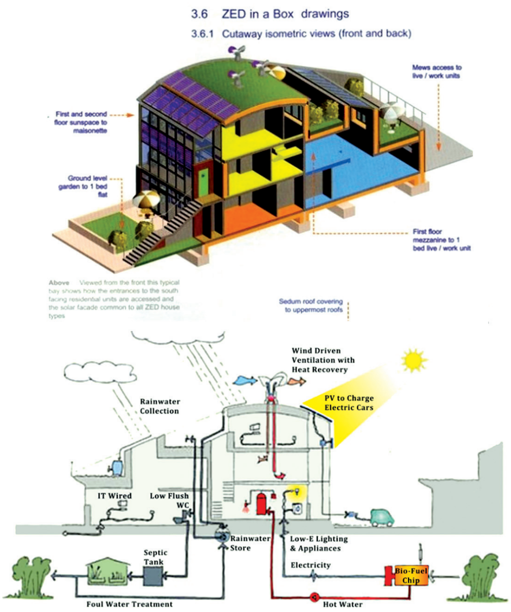

Figure 6.8 The Beddington Zero Energy Development (BedZED), Hackbridge, Londra, İngiltere (URL-14); BedZED zero energy systems [Zhu, Kung and Zhou, 2015]

According to the measurements carried out on BedZED campus in 2003, the following gains were revealed compared with the UK average values:

- 81% less heating requirements
- 45% less electricity usage
- 57% less hot water usage
- 64% less vehicle usage distances
- 25% less per capita electricity usage than average citizens and 11% of these consumptions is produced by solar panels (Yöntem, 2016)

The ZEB Pilot House - Pilot Project (Figure 6.9), built in 2014 in Larvik, Norway, is a residential project designed for a single family and as an example for learning sustainable and new zero-energy building methods. Renewable energy production is carried out with solar panels and photovoltaicintegrated into the building envelope (URL-15).

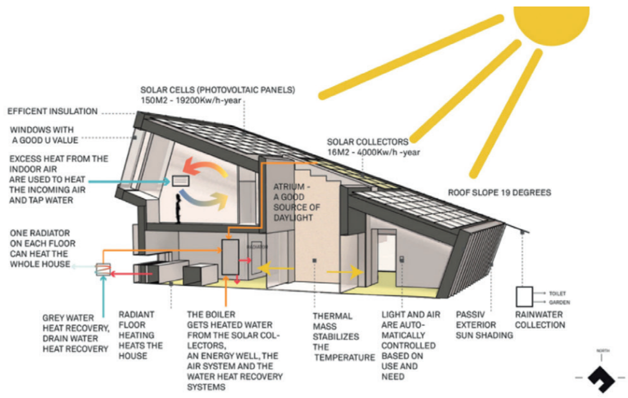

Figure 6.9 ZEB Pilot House - Pilot Project (URL- 15)

It has a characteristic slope toward a sloping roof surface and the southeast covered with solar panels and collectors (Figure 6.10). These meet the energy needs of the housing together with geothermal energy from the energy wells under the ground (URL-15).

Figure 6.10 Characteristic slope towards the southeast (URL-15)

Daylight, landscape orientation, balancing of closed walls and windows stand out in the design. Heating and cooling, placement of glass surfaces, geometry, selection of materials with good thermal properties have been passively resolved. The materials used for the interior surfaces were selected for good air quality and indoor climate as well as their aesthetic qualities. Smart placement and orientation to facilitate the optimum use of energy sources as well as local energy sources, new technologies, construction techniques, materials and other resources at the location have come to the fore (URL-15)

Another example is the Office Building of KfW Bank (Figure 6.11), located in Frankfurt, Germany and awarded “the world’s best tall building by the Council on Tall Buildings and Urban Habitat (CTBIH)” in 2011, was opened in 2010. Designed as 39.000 m^2, the building is one of the first buildings among the tall buildings in the world to operate under 100 kWh/m^2 of primary energy consumption (Yöntem, 2016).

Figure 6.11 Views of Office Building of KfW Bank (URL-16)

The double-walled facade, designed according to the wind direction, has high insulation values. Natural ventilation, natural lighting, lighting optimization and heat recovery, building automation and control system, the trigeneration system, electricity, heating and cooling systems, solar radiation, and rainwater collection system are prominent features of the building. In the same time the building’s energy efficiency has been rised utilizing a geothermal assisted heating system and thermal-enabled floor equipment (Yöntem, 2016).

Oberlin College Environmental Studies Building (Ohio, USA) can also be provided as an example of low and ZEB in the literature (Torcellini, Pless, Deru and Crawley, 2006) (Figure 5.8). In the selection of materials, the designers emphasized low environmental impact and sustainability. Designers’ priorities included concrete wall units for interior walls, low-maintenance products, recyclable steel frames and brick exterior walls (Figure 6.12) (URL-17).

Figure 6.12 Oberlin College Environmental Studies Building (Adam Joseph Lewis Center for Environmental Studies) USA (URL-18), heating, ventilation & air conditioning (URL-17)

More than 4,000 square meters of photovoltaic panels were used from the roof. These photovoltaic panels generate up to 45 kilowatts of electrical power for the building. At the same time the photovoltaic system is connected to the electrical grid. When the photovoltaic system generates more energy than the building

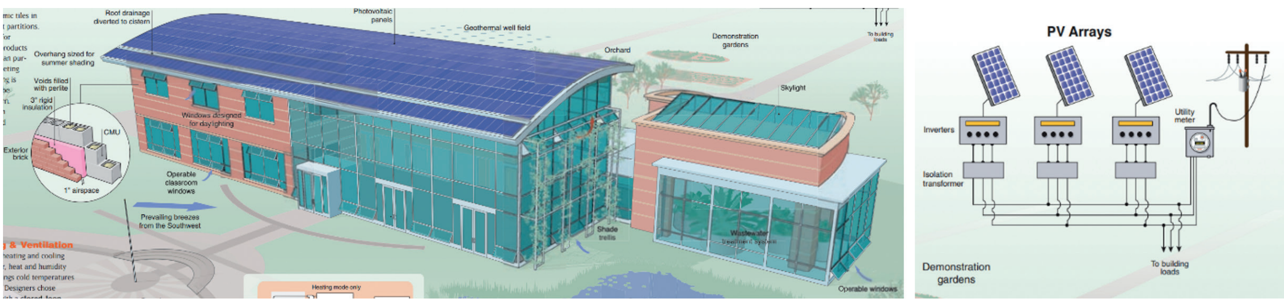

Figure 6.13 Oberlin College Environmental Studies Building and PV arrays (URL-17)

consumes, the building returns that energy to the grid. When the photovoltaic system doesn't produce enough energy to provide the needs of the building, it receives energy from the grid. Integrated building controls manage mechanical, fire, water treatment and safety systems to optimize energy efficiency (Figure 6.13) (URL-17).

The designers have used "a closed-loop groundwater heat pump system" that uses the constant temperature of the earth to cool and heat the building with passive techniques. At the same time to meet passive solar heating during the winter months, the building was oriented on an east-west axis. The winter sun reaches thermal mass from the concrete floor and emerges in the inner walls, which hold and re-emit heat to temper the space. To reduce heat loss, glass panels were treated with a low emission coating. Many trees have been planted in order to isolate the building in the north direction. The extensive drains, wetlands prevent rainfall and cistern in the center from overloading the stormwater collection system in the city during increased rainfall (URL-17).

As another example is the Visitor Center in the Zion National Park, a low-energy sustainable facility

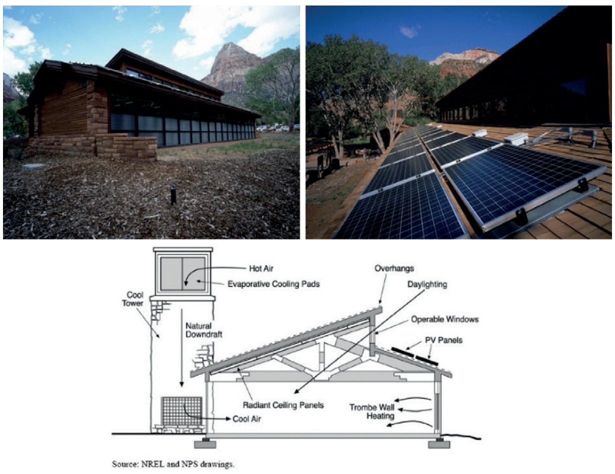

Figure 6.14 The Visitor Center, Zion National Park, Springdale, Utah (URL-19; URL-20)

Efficient lighting, natural ventilation, insulation, effective use of glass, passive downdraft cool towers, trombe walls, energy efficient landscaping, photovoltaics and energy management system design and application resulted in a 70% reduction in energy use. Native lawns and shrubs using less water were used for landscaping. Historical irrigation canals have been restored. The collected rainwater was added to the river water and diverted to the groundwater. To encourage the reestablishment of native vegetation, drip irrigation was done primarily with high-efficiency irrigation techniques and a weather data controller (URL-19).

"The National Renewable Energy Laboratory (NREL)" completed the construction of the 1st phase of support and research facilities in June 2010 (RSF) (Figure 5.11). RSF is located in Colorado and it is currently known as the largest zero-energy building in the United States. The project has reached its energy target through a performance-based design/construction process. At the same time multiple energy efficiency approaches have been applied, including the inclusion of advanced heat recovery technologies designed and developed by researchers in the laboratory and the installation of 1.6 megawatts of photovoltaic power on campus. In addition, daylight lighting, a natural ventilation and "an energy-efficient data center" are shown among other energy features of the building (Figure6.15) (URL-21).

Figure 6.15 NREL Research and Support Facilities Building (URL-21).

The Solar XXI Building project in Lisbon was opened in 2006 and displays better energy performance than office buildings in Portugal. (Figure 6.16). "From the target perspective of nearly zero energy buildings (NZEB), the building is currently recognized as 'plus (electric) energy building' and NZEB in terms of overall building energy consumption" (Erhorn and Erhorn-Kluttig, 2014).

Figure 6.16 Solar XXI Building, Lisbon (Portugal), 2006 (URL-22)

The entire building is externally insulated so that the thermal behavior of the building is maintained, while the impact of thermal bridges[17] has been significantly reduced. The exterior walls of the building consist of 22 cm of brick and a 6 cm external thermal insulation composite systems, a 10 cm insulated concrete roof, a 10 cm extended polystyrene insulated decking and transparent double glazing. The main facade of the Solar XXI building (towards the South) was lined with PV modules and windows of equal proportions. The glazed area (12% of the floor and ~46% of the southern facade) collects direct solar energy and provides natural light. Natural ventilation is provided thanks to crosswinds through openings at the roof level and facade. "The solar thermal collector system on the roof of the building is operate for heating with a storage system in the basement. The system is supported by a natural gas boiler during sunless periods" (Erhorn and Erhorn-Kluttig, 2014).

REFERENCES

Aelenei, L., & Gonçalves, H. (2014). From solar building design to net zero energy buildings: Performance insights of an office building. Energy Procedia, 48, 1236-1243.

Berberoğlu, U., (2009). Sürdürülebilir Mimarlık Anlayışı Çerçevesinde Enerji Verimliliği Kavramının Güncel Konumu ve Yeni Yaklaşımlar, Yüksek Lisans Tezi, MSGSÜ Fen Bilimler Enstitüsü, İstanbul.

Burberry, P. (1979). Building For Energy Conservation. New York: Halsted Press. P: 17.

Çakmanus, İ. (2011) Yaklaşık Sıfır Enerjili Binalar (nnZEB). Yeşil Bina Dergisi, 7. Sayı, 28-31. Retrieved from http://www.yesilbinadergisi.com/yayin/701/yaklasik-sifir-enerjili-binalar-nnzeb-_21118.html#.XbQIQ0UzbGJ Date Accessed: 26.10.2019

Çevre Dostu Yeşil Binalar Derneği (2019) Yeşil Bina Retrieved from https://cedbik.org/tr/yesil-bina-7-pg Date Accessed: 19.08.2019

EN, B. (2008). 15603: 2008 Energy Performance of Buildings—Overall Energy Use and Definition of Energy Ratings. European Committee for Standardization: Brussels, Belgium.

Erhorn, H., & Erhorn-Kluttig, H. (2014). Selected examples of nearly zero-energy buildings. Report of the Concerted Action EPBD, 65-66.

Kurnitski, J., Allard, F., Braham, D., Goeders, G., Heiselberg, P., Jagemar, L., ... & Seppänen, O. (2011). How to define nearly net zero energy buildings nZEB. Rehva Journal, 48(3), 6-12.

Li, X., Wen, J., & Wu, T. (2014). Net-zero energy impact building clusters emulator for operation strategy development. In: 2014 ASHRAE Annual Conference, at Seattle, WA, USA; June 28–July 02.

Lu, Y., Zhang, X. P., Huang, Z., Lu, J., & Wang, C. (2019). Definition and Design of Zero Energy Buildings. In Green Energy Advances. IntechOpen, p. 1-14. Retrieved from http://dx.doi.org/10.5772/intechopen.80708

Moltay, Ö. (2012). Bina Enerji Modellemesi. Yeşil Bina Dergisi, 13. Sayı (Mayıs-Haziran 2012), 30-33.

Ünsal, B. (2012). Bir TOKİ konut örneğinde ısıtma ve soğutma enerji yüklerinin farklıviklim bölgelerine bağlı olarak değerlendirilmesi. İstanbul Teknik Üniversitesi, Fen Bilimleri Enstitüsü (yayımlanmamış yüksek lisans tezi).

Sun, Y., Huang, P., & Huang, G. (2015). A multi-criteria system design optimization for net zero energy buildings under uncertainties. Energy and Buildings, 97, 196-204.

17 The regions where the heat transfer due to material and construction in the building is intense compared to other parts of the building are called thermal bridges.

Standard, C. E. N. (2008). Energy Performance of Buildings—Overall Energy Use, CO Emissions and Definition of Energy Ratings. EN, 15203, 15315. Retrieved from http://www.cres.gr/greenbuilding/PDF/prend/set1/WI_02+04_TC-approval_version_prEN_15203+15315.pdf Date Accessed: 27.10.2019

Torcellini, P., Pless, S., Deru, M., & Crawley, D. (2006). Zero energy buildings: a critical look at the definition (No. NREL/CP-550-39833). National Renewable Energy Lab.(NREL), Golden, CO (United States).

Yeşilbaş, S. (2014) Yeşil Binalarin Yapim ve Yönetim Tekniklerinin Enerji ve Çevre Dostu Tasarimda Liderlik (Leed) Kriterleri Kapsaminda İncelenmesi ve Peyzaj Mimarliği Meslek Disiplini ile İlişkilerinin İrdelenmesi Üzerine Bir Araştirma, Fen Bilimleri Enstitüsü, Ege Üniversitesi, Yüksek Lisans Tezi.

Yöntem, S.T. (2016) Çevre Dostu Binalarda Enerji Verimliliği Örnek Uygulamalar. Retrieved from https://webdosya.csb.gov.tr/csb/dokumanlar/mhgm0004.pdf

Yıldız, Y. (2018). Enerji Verimliliği ve Düşük Enerjili Bina Kavramları. İzmir Enerji Forumu 2018. Retrieved from http://www.emo.org.tr/ekler/d39366edd9757dc_ek.pdf Date Accessed: 13.10.2019

Zhu, D., Kung, M., & Zhou, L. (2015). Analysis of sustainable energy systems in ecovillages: A Review of progress in BedZED and Masdar City. Low Carbon Economy, 6(01), 1.

URL-1: A Common Definition for Zero Energy Buildings, Prepared for the U.S. Department of Energy by The National Institute of Building Sciences Retrieved from https://www.energy.gov/sites/prod/files/2015/09/f26/bto_common_definition_zero_energy_buildings_093015.pdf

URL-2: EPBDrecast,Directive2010/31/EUoftheEuropeanParliamentandoftheCoun- cil of 19 May 2010 on the energy performance of buildings (recast), Official Journal of the European Union, (2010) Retrieved from https://ec.europa.eu/smart-regulation/roadmaps/docs/2016_ener_023_evaluation_energy_performance_of_buildings_directive_en.pdf Date Accessed: 26.10.2019

URL-3: Çevre Dostu Binalarda Enerji Verimliliği Örnek Uygulamalar Retrieved from https://webdosya.csb.gov.tr/csb/dokumanlar/mhgm0004.pdf Date Accessed: 18.08.2019

URL-4: https://www.wbdg.org/design-objectives/sustainable/optimize-energy-use Date Accessed: 10.02.2020

URL-5: https://www.tech-worm.com/kloroflorokarbon-gazlari-cfc-nedir/ Date Accessed: 19.11.2019

URL-6: https://www.wbdg.org/design-objectives/sustainable/optimize-energy-use Date Accessed: 07.02.2020

URL-7: https://zeroenergyproject.org/build/twelve-steps-affordable-zero-energy-home-construction-design/ Date Accessed: 07.02.2020

URL-8: Zebra. Nearly Zero-energy Building Strategy 2020. September 26, 2014. Retrieved from https://zebra2020.eu/ Date Accessed: 23 Ekim 2019

URL-9: https://newbuildings.org/new-construction-guide-and-the-architecture-2030-challenge/ Date Accessed: 07.02.2020

URL-10: The Impact Of Energy Performance Certificates On Property Values And Nearly Zero-Energy Buildings Retrieved from https://www.zebra2020.eu/website/wp-content/uploads/2014/08/ZEBRA2020-Impact-EPCs_final.pdf Date Accessed: 23.10.2019

URL-11: World Map of nZEBs. Retrieved from http://batchgeo.com/map/net-zero-energy-buildings Date Accessed: 23.10.2019

URL-12: EPBDrecast,Directive2010/31/EUoftheEuropeanParliamentandoftheCoun- cil of 19 May 2010 on the energy performance of buildings (recast), Official Journal of the European Union, (2010) Retrieved from https://ec.europa.eu/smart-regulation/roadmaps/docs/2016_ener_023_evaluation_energy_performance_of_buildings_directive_en.pdf Date Accessed: 10.2019

URL-13: US DOE, Building Technologies Program, Planned Program Activities for 2008–2012, Department Of Energy, Retrieved from https://www1.eere.energy.gov/buildings/publications/pdfs/corporate/myp08complete.pdf Date Accessed: 26.10.2019

URL-14: https://www.solaripedia.com/13/299/3357/bedzed_cutaway_illustration.html Date Accessed: 21.08 2019

URL-15: https://www.archdaily.com/773383/zeb-pilot-house-pilot-project-snohetta?ad_medium=gallery Date Accessed: 04.09.2019

URL-16: www.archdaily.com Date Accessed: 18.10.2019

URL-17: https://www.nrel.gov/docs/fy03osti/31516.pdf Date Accessed: 24.10.2019

URL-18: https://www.hpac.com/air-conditioning/adam-joseph-lewis-center-paler-shade-green Date Accessed: 24.10.2019]

URL-19: https://greenbuildingbrain.org/buildings/zion_visitor_center Date Accessed: 24.10.2019

URL-20: http://www.solaripedia.com/13/33/369/zion_national_park_visitors_center_diagram.html Date Accessed: 24.10.2019

URL-21: https://www.archdaily.com/148060/the-research-support-facility-rnl-design Date Accessed: 24.10.2019

URL-22: http://elearning-southzeb.eu/?lang=el Date Accessed: 4.12.2019]