Chapter

Use of Renewable Energy in Buildings

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Abstract

Owing to factors such as high living standards and digitalization, energy use is growing. However, the proportion of renewable energy sources is also rising in all energy consumption. Given this use of renewable energy, global warming and environmental issues are still rising. Fossil-based energy species are more polluting and resource-stricken than others. Studies on environmental pollution show that fossil-based energies are the most important pollutants. Fossil-based energy source is still the most consumed type of energy. Besides, the renewable energy sources' consumption is very low. Therefore, it is important to increase the use of renewable energy, which creates cleaner and less emissions. Buildings should have the right clean energy use incentives. The needs such as heating, refrigeration, and lighting can be met by renewable energy. This research aims to explore and demonstrate how renewable energy can profit when fulfilling public building functions. Through using both conventional methods and creative methods together, the rate of use of renewable resources such as solar, wind, and geothermal resources in buildings can be increased. Therefore, major contributions to reducing the environmental issues caused by energy consumption can be made.

Keywords: renewable energy resources, sustainable buildings, sustainability, energy efficiency, renewable energy in buildings

1. Introduction

Since buildings are the major energy-consuming sectors in the world causing energy inefficiency, they can act as a promising target with the greatest potential to reach the common goal toward sustainable development. Nevertheless, too high building energy consumption will raise negative impacts on the environment, such as air pollution, greenhouse effect, urban heat island effect, and others, which can even do plenty of harm to human health and social economy development [1].

Fossil-based energies are the most important source of environmental pollutants. However, 84.7% of the total energy consumption in the world is due to fossil-based energy. Energies from renewable and nuclear sources have a share of 5 and 4% in primary energy consumption alone [2].

In a study conducted among International Energy Agency (IEA) countries, buildings are seen as an important energy consumer, and of half of the total consumed electricity, one third of natural gas is consumed in buildings. Again in this study, construction activities are held responsible for one third of the greenhouse gases generated in the world [3].

One of the effective methods of saving energy in buildings is to use renewable energy instead of limited resources. In this way, both preserving and protecting our

resources for future generations and environmental values environmental values are not damaged.

The aim of this study is to emphasize the importance of using renewable energy in buildings and to investigate the possibilities of using renewable energy. For this reason, the usage of renewable energy types in buildings and their benefits have been discussed and appropriate solutions have been proposed.

2. Possibilities of using renewable energy resources in buildings

In the early stage of design, the importance of energy consumption gradually got into engineering consideration. In addition, as of the first decade of the twenty-first century, energy conservation is regarded as the most significant element in system design. Complementing the industrial revolution is certainly the best time for yet another revolution. This transition is about confronting the effects of the last century's exploitation of natural resources. The world must understand that the use of renewable energies due to harmful environmental effects of greenhouse gases and a finite supply of traditional energy supplies (fossil fuels) must be taken seriously. The strategies of reducing energy consumption should also be considered when replacing the nonrenewable energies with the renewable ones [4].

Energy is used for various reasons throughout the building's life cycle. 94.4% of the total energy used in these phases is consumed for heating/ventilation/air conditioning (HVAC) systems that provide comfort conditions during the usage phase [5].

In order to reduce this rate, passive methods and renewable energy sources should be used instead of mechanical systems to provide comfort conditions. In this way, more appropriate physical conditions for human health can be established within the buildings.

Renewable energy sources are the energy obtained from the existing energy flow in the continuous natural processes. In general, the renewable energy source is defined as the ability to renew itself at an equal rate to the energy received from the energy source or faster than the depletion rate of the source [6]. Water energy, wind energy, solar energy, wave and tidal energy, bio (organic) fuel, geothermal energy, hydrogen energy, and ocean energy are renewable energy sources.

The possibility of depletion of the most commonly used energies, such as coal and oil, has led humanity to new energy sources. When selecting energy sources, it is paid attention that it is safe, clean, economical, and most importantly a renewable source which does not harm the environment.

2.1 Use of solar systems in buildings

The sun is an unlimited source of light and heat energy. The basic principle in the designs for using solar energy in buildings is as follows.

The flow of thermal energy of the sun through conduction, convection, and radiation is used. These natural processes are managed through a building design that helps to warm up and cool the building.

The sunrays coming to the building surface are reflected, transmitted, or absorbed by the building material. In addition, the heat generated by the sun causes predictable air movements within the designed areas. This basic effect of solar heat leads to the selection of materials and design of building elements that provide a heating and cooling effect within the building, such as thickness, density (δ) (g/cm^3), heat conduction coefficient (λ) (W/m^0K) specific heat (c) ($Wh/m^3\ ^0K$), surface absorption, and reflection coefficient smoothness or roughness, cavity, and fullness. It is possible to utilize solar energy as active and passive through the measures taken in architecture design.

Rezaie et al. determined that the most effective method for reducing carbon dioxide emissions is mixed systems, where both active and passive systems are used together [4].

2.1.1 Use of passive solar systems in buildings

The use of a building form and shell to accept, store, and distribute energy from renewable sources appropriate for buildings is commonly defined as the passive solar design. passive systems mainly use solar energy and fresh air by means of space heating, cooling, and lighting without mechanical or electronic equipment.

- Passive heating

Passive heating systems are most commonly used in passive solar architecture. With the design applications for passive solar systems, solar heat gains from solar energy can be increased during the winter months. The fundamental concept of using solar energy for heating is to design the elements that shape the exterior of the building for this purpose (the roof, walls, and floor are insulated to a high level) and to allow as much use as possible of solar radiation. The program employs three key components. Those are collectors, storers, and distributors. Solar energy is captured by the collectors and converted into heat. Storages allow heat to be used when there is no solar power. The role of the distributors is to transfer the collected energy to the storage elements and appropriate places via the collectors.

The energy obtained depends on the opening size (windows, skylight, greenhouse, etc.). The conservation of the energy obtained relies on the building envelope's thermal insulation and sealage. The storage of energy depends on the location of the building elements and their thermal performance. The house of philosopher Socrates, who lived between 470 and 399 BC, is the simplest example of the passive heating application (**Figure 1**). His house is opening into the sun, providing optimum productivity with a compact structure and trapezoidal plan scheme with the long side facing the sun, when the northern side has been reduced. The eaves on the south of the roof provide protection when the sun's orbit is in summer and allows the sun below to enter the building in winter. The roof slopes down in the back to avoid winter winds [7].

- Natural lighting

Seventeen percent of all energy used in the world is consumed for lighting purposes. With the right design, 70% of the lighting needs can be obtained from the sun. In ordinary buildings, this rate is 25%. The use of daylight as much as possible in the illumination of spaces in buildings according to visual comfort needs reduces the need for artificial lighting. It enables the buildings to consume less energy during the usage process [8]. The easiest natural lighting approach is to use the sufficient openings left in the building envelope. Below, window arrangements are seen in the traditional housing examples providing adequate natural light (**Figure 2**).

Natural lighting can be provided in places without facades suitable for direct sunlight, through roof windows or light tubes. The natural illumination can be provided by opening skylights on the roofs where the roof element covers the interior space. (**Figure 3**).

Light tubes are bringing daylight from outside to inside. The components and operating principle of a light tube are explained in **Figures 4** and **5**.

A dome-shaped collector sits at the top of the light pipe. The chimney uses light-reinforcing coatings. The light obtained is carried inside by panels at the side edges of the chimney.

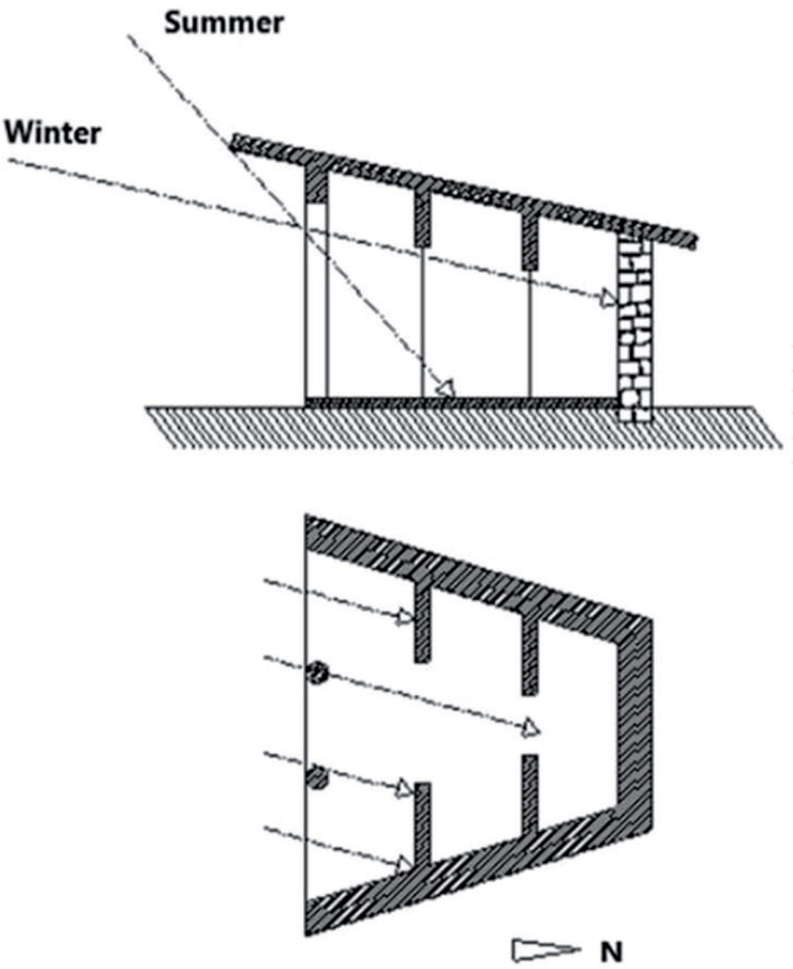

Figure 1.
Socrates's house plan and cross section [7].

Figure 2.
Window arrangements in traditional houses.

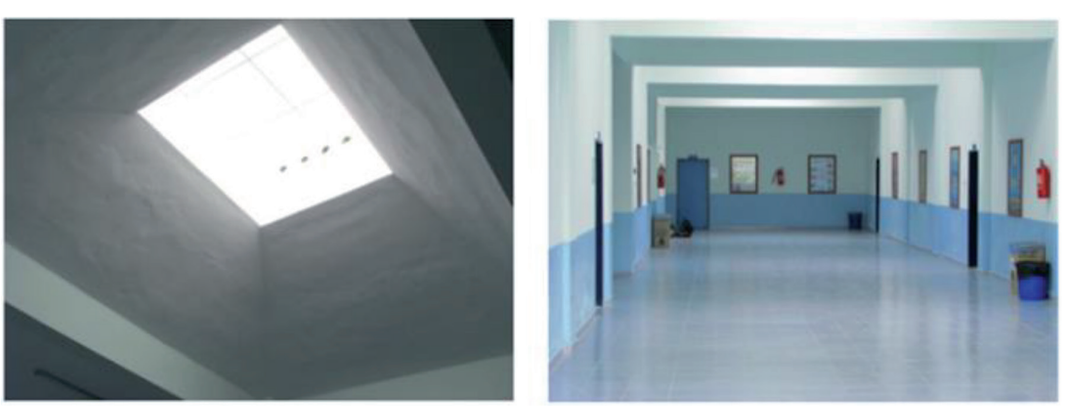

Figure 3.
Illuminated interior space with skylight [9].

Figure 4.
Operating principle of a light tube [10].

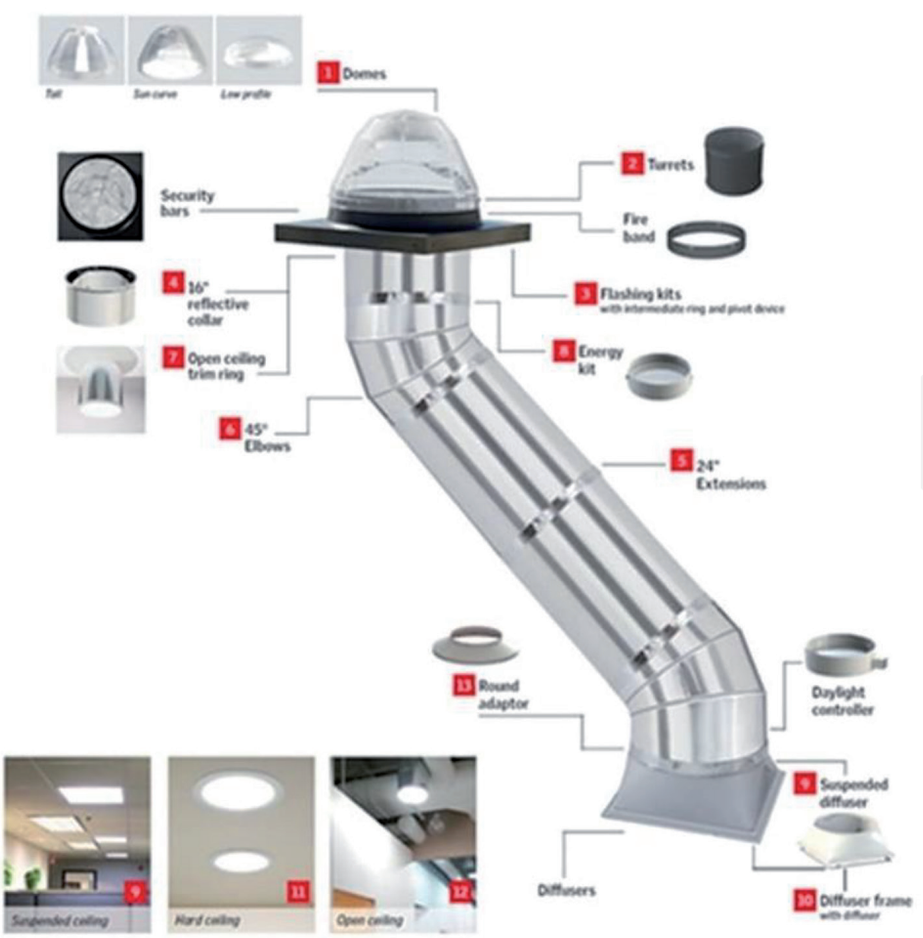

Figure 5.
Components of a light tube [11].

2.1.2 Use of active solar systems in buildings

Active solar systems are distinguished from passive systems, which use the fabric of the building, in terms of collection of solar energy, storage of collected heat, and distribution of heat to spaces. Active systems use components for collection, storage, and funs or pumps for forced distribution of collected and stored heat.

Active systems using solar energy are the systems consisting of the whole of the mechanical and/or electronic elements which convert the solar radiation absorbed by the purpose-produced collectors into the desired form of energy and allow it to be used in the structure. Through these systems, solar radiation can be transformed into heat and electrical energy [12]. These systems are converting solar radiation into energy and according to the energy they produce, they can be divided into two: solar thermal systems, which produce heat energy, and photovoltaic (PV) systems, which generate electrical energy. These systems are briefly described below.

- Solar heating systems

By converting the solar radiation into heat energy with collectors, solar heating systems can heat up water, air, etc. directly with a fluid; or, all mechanical and/or electronic systems that are used in a storage unit for evaluation and use are called "Solar Heating Systems." Solar active heating systems are used in buildings for use/heating of pool water, preheating of air-conditioning air, and space heating [12]. The general working principle of heating systems is based on the collection of heat by means of collectors, storage, and distribution of the collected heat energy to the related areas in order to use it later [13].

- Solar water heating systems

These systems convert solar radiation into heat energy. It uses some elements which store and distribute heat in the water. All solar water heating systems are based on the heating, storage and distribution of water. Depending on the characteristics of the system, the hot water produced by the transformation of solar energy can be used directly to meet the user needs such as washing or it can be used to support the traditional heating system [12].

- Photovoltaic systems

Photovoltaic (PV) systems are all components that generate electricity from solar radiation through collectors and allow the use of this energy. PV systems are used for the production of electricity in many different fields such as road lighting, lighthouses, vehicles, buildings, and power plants, with different or simple configurations. A photovoltaic system generates electrical energy, stores the generated energy when necessary, and reliably transfers it to the fields of use. Photovoltaic batteries are placed in the facades and roofs of buildings and convert the solar energy coming to these surfaces into electrical energy (**Figure 6**). The solar cells used for domestic purposes are connected to the electricity grid via an inverter, thus saving the storage of the generated electricity in the batteries.

2.2 Use of wind energy in buildings

The wind has been used as an energy source for a very long time, and it is an important source of environmental-friendly energy and has become more and more important in the recent years [15].

Figure 6.
Solar panels cover the building's south, west, and top surfaces [14].

It is possible to benefit from wind energy by using passive and active systems. These methods are described below.

2.2.1 Use of wind energy with passive systems in buildings

Passive cooling: By using passive systems, it is possible to provide comfort conditions required for human health and work efficiency in the building in certain proportions without requiring energy use. Especially, the effect of ventilation provided by natural methods is important in creating thermal comfort and indoor air quality.

The basic concept of passive cooling is to prevent the building heat gain. Planning in conjunction with this purpose should be included in the design phase of the house. For preventing building heat gain, high thermal mass and thick sectional structural elements such as a mudbrick or stone and shading elements may be provided.

Different methods of passive cooling were developed for different types of climate, such as the following.

Shading, reflection of solar heat, insulation of building element, ground cooling, wind cooling, water cooling, evaporative cooling, dehumidification, night radiant cooling, night cooling of thermal mass in buildings, exotic passive cooling methods, and seasonal cold storage [16].

Accordingly, passive cooling differs in various locations and conditions. The methods employed depend on the location and environment in question. In any application and set of conditions, not all methods will be useful. Depending on the location, environment, available materials and skills, and economic considerations, different methods of achieving passive cooling can be used separately or combined [16].

Wind catchers are the simplest example of cooling the building with natural ventilation. Thermal chimneys operate as a collector that draws in fresh air outside the building. In this method, the entrance of air from the external environment into the building is accelerated by means of a hot or warm region with an outflow. The use of wind chimneys called "badgir" is very common especially in the examples of traditional architecture of Middle Eastern countries (**Figure 7**).

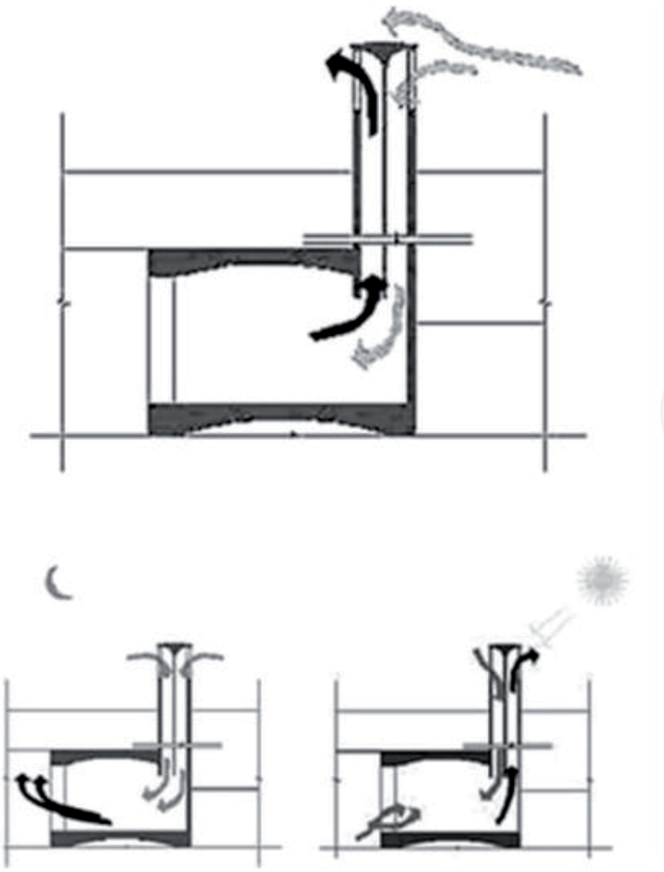

Figure 7.
Traction and suction in wind catcher [17].

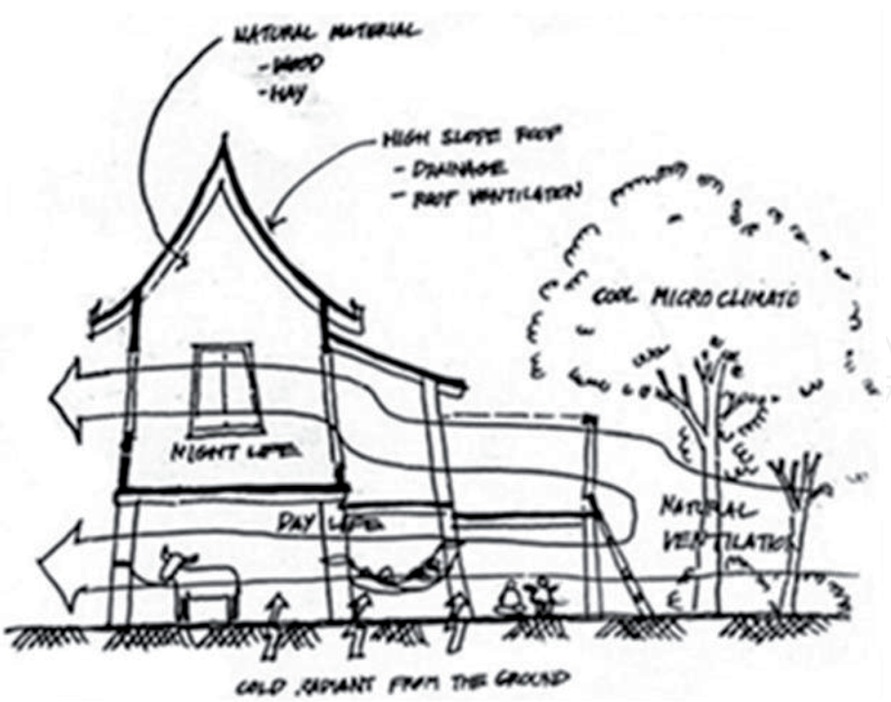

Figure 8.
A traditional tai house providing natural ventilation by taking advantage of pressure differences around the building [18].

The main strategy for passive building cooling in hot humid climates is to provide natural ventilation. The use of openable windows for natural ventilation is the most common (**Figure 8**).

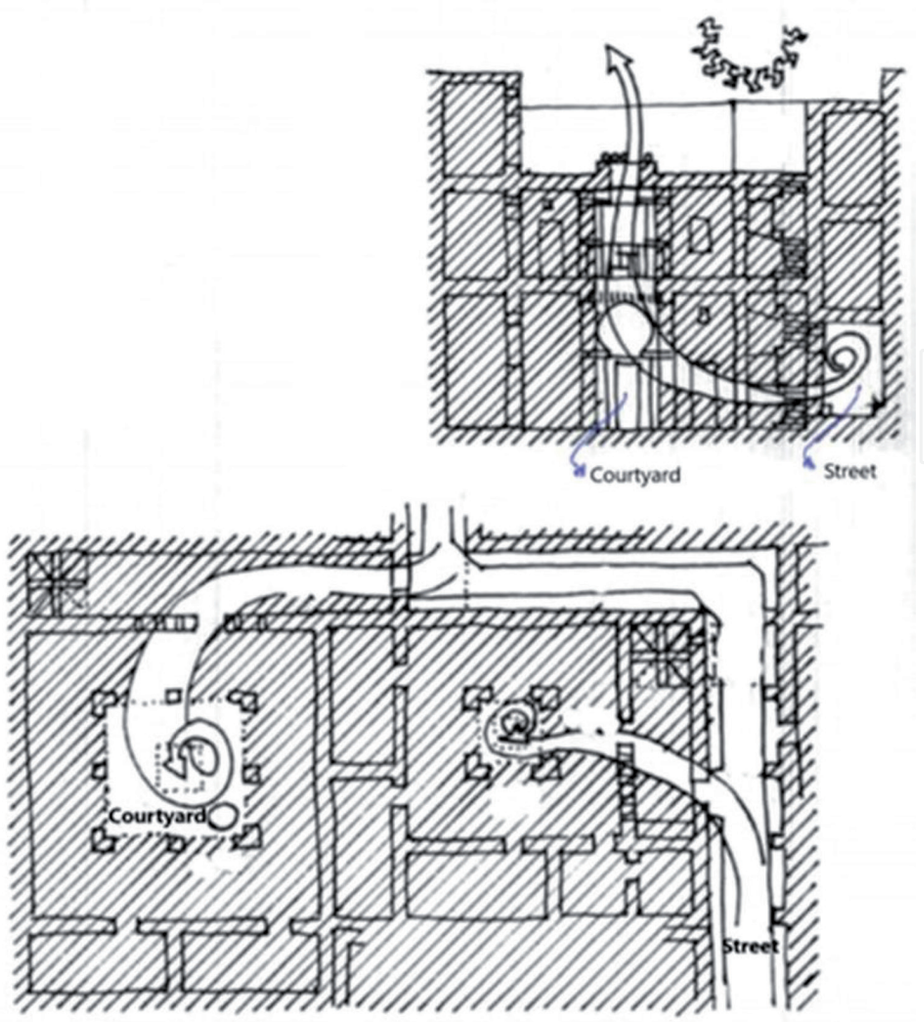

Figure 9.
Plan and section with inner courtyard showing natural ventilation through convection [19].

In addition, an atrium can be designed in the direction of the prevailing wind in the building during the design phase. While the spaces surrounding the atrium fill with cold air through the windows, the atrium collects the hot air and circulates out (**Figure 9**).

2.2.2 Use of wind energy with active systems in buildings

Wind energy is the conversion of kinetic energy of air mass into mechanical energy. Wind energy is natural, inexhaustible, does not produce waste during use, has no radioactive effect and therefore has no negative impact on nature and human health, and is a rapid energy source of technological development [18].

It is possible to obtain electricity from wind on the Earth's surface. In 2040, it is predicted that 40% of the energy of the world will be obtained from the wind [8]. Active wind energy use systems are wind turbines. Medium- and small-scale wind turbines are used in the buildings. These turbines can be placed in a suitable spot in the garden or on the roofs. In multistory high-rise buildings, there are examples of use of wind turbines integrated into the building (**Figure 10**).

2.3 Use of geothermal energy in buildings

Geothermal energy is obtained by the fact that the heat accumulated in the underground is released from the cracks to the earth. Sometimes, it can

be extracted from the underground as hot water, hot water and water vapor mixture, or steam.

Geothermal energy is used in the heating and cooling of houses, greenhouses, and agriculture. According to the application methods of geothermal fluid, geothermal energy systems are applied in three different ways such as heat pumps, in-well heat exchangers, and heat pipes. Common use in buildings is in the form of heat pipes. Heat can also be extracted from the ground at "normal" temperatures using a device called a heat pump.

Another use of geothermal energy is the methods of using soil temperature. The temperature is also between 45 and 75 F (7.22–23.88 C), depending on the latitude of the earth at some level [22]. This soil temperature can be used by water or by air. The air taken through the opened chimneys is transferred to the system at different depths of the soil and the internal volume is brought to the same amount as the soil temperature. Such technology is useful in the context of winter heating and summer cooling (**Figure 11**).

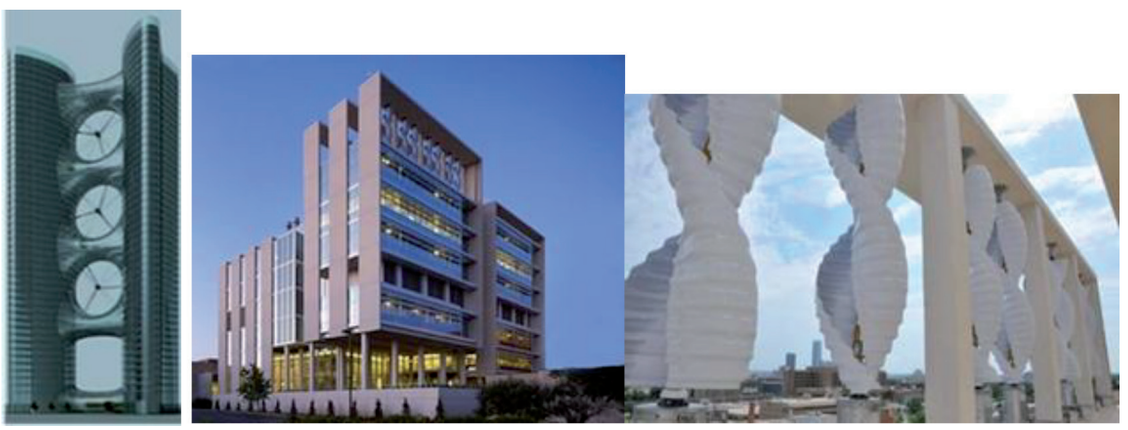

Figure 10.
Wind turbines integrated into the building [20, 21].

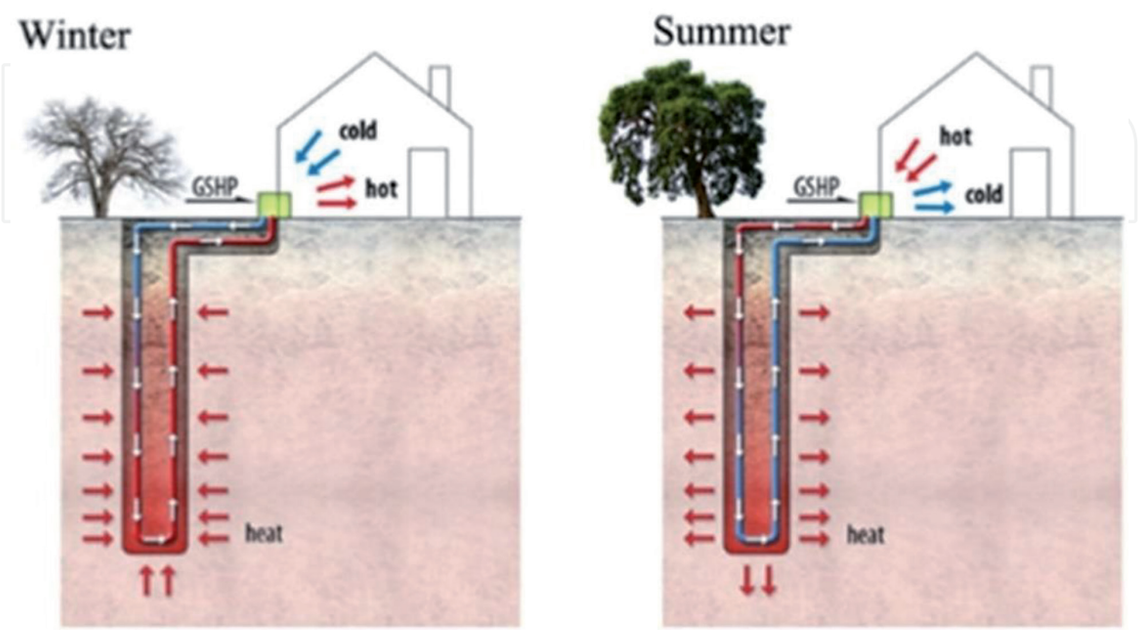

Figure 11.
Operation of the ground source heat pump [23].

2.4 Use of hydrogen energy in buildings

Hydrogen energy can be used for heating the houses, supplying hot water, cooking, and meeting electricity needs. In order to use hydrogen, it must first be produced, stored, and transported. Hydrogen can be produced from renewable energy sources such as solar, hydroelectric, wind, and geothermal.

Today, among the renewable energy sources, the solar-hydrogen hybrid system stands out as the most efficient system. In such a system, components such as photovoltaic panels, electrolyzer, fuel cell, Hydrogen (H2) storage tank, battery group, and inverter (converter) are needed. The operation of the system in the solar-hydrogen house energy system is as follows [24]:

- PV panels generate electricity from solar energy,
- H2 and O2 are produced by electrolyzer,
- gases are taken to the storage tank for ground and water heating,
- heating the air in the ventilation system by burning hydrogen flameless with catalytic hydrogen burner (1.5 kW) in winter,
- the fuel cell is activated if additional electricity is needed, and
- some of the heat released in the fuel cell is also used to heat the water.

2.5 Use of biomass energy in buildings

Bioenergy can also be called vitality energy. All living things use solar energy. For this reason, all kinds of biological materials contain energy, which is released when burned. Plants convert and store solar energy into chemical energy by photosynthesis, thus forming a source of biological mass and organic matter, called biomass [25]. Within the scope of biomass energy technology; wood (energy forests and tree residues), oilseed plants (sunflower, rapeseed, soy, etc.), carbohydrate plants (potato, wheat, corn, beet, etc.), fiber plants (flax, kenaf, hemp, sorghum, etc.), vegetable residues (branches, stalks, straw, roots, bark, etc.), animal wastes, and urban and industrial wastes are evaluated. Biomass is a renewable, strategic source of energy that can be grown everywhere, provides socioeconomic development, is environmentally friendly, can generate electricity, and provides fuel for vehicles. Biomass is evaluated in energy technology either by direct combustion or by increasing the fuel quality through various processes and by obtaining alternative biofuels (easily transportable, storable, and usable fuels) with properties equivalent to the existing fuels.

From biomass, fuel is obtained by physical processes (size reduction—crushing and grinding, drying, filtration, extraction, and briquetting) and conversion processes (biochemical and thermochemical processes) [26]. From biomass source in residences; biogas obtained by airless digestion method is used in electricity generation. Ethanol obtained by pyrolysis method is used for heating purposes, hydrogen obtained by direct burning method is used for heating (**Table 1**).

Biomass resources	Supply systems	Conversion	End use
Conventional forestry	Harvesting	Biochemical	Transportation fuels
Short rotation forestry	Collection	Combustion	Heat
Sawmill conversion products	Handling	Gasification	Electricity
Agricultural crops and residues	Delivery	Pyrolysis	Solid fuels
Oil-bearing plants	Storage	Anaerobic digestion	Renewable construction materials
Animal products		Combined heat and power	Plant-based pharmaceutical
Municipal solid waste		Heating	Renewable chemicals including polymers
Industrial waste		Deoxygenation	
		Depolymerisation	
		Hydrolysis	
		Fermantation	

Table 1.
Breakdown of the main pillars of biomass energy production [27].

3. Discussion and conclusion

Buildings have a significant share of energy consumption globally and regionally. Particularly during the usage phase of the building life cycle, a lot of energy is consumed to provide comfort conditions inside the building. The high proportion of buildings consuming energy also increases the use of fossil-based resources. Environmental issues arising from energy usage are thus also growing. Whereas, buildings appropriate to the use of renewable energy sources can be built using passive or active methods. It is clear that the use of renewable energy sources in buildings will provide environmental and economic benefits. Reducing this amount of energy as much as possible and obtaining it from renewable sources is one of the effective methods that provide buildings with energy efficiency and ecological characteristics.

Renewable energy sources can be utilized from the sun with active and passive methods for heating, cooling, ventilation, natural lighting, and obtaining hot water. Wind energy is also utilized in ventilation and cooling with active and passive systems. Geothermal energy can be used for heating and cooling purposes. It can be used in heating and hot water supply from hydrogen energy, cooking, and for supplying electricity. Biomass energy is beneficial for heating and hot water supply. These resources can be used together if necessary.

In renewable energy use, passive systems should be preferred because it is simpler and more cost-effective. In cases where passive systems are inadequate, they should be supported with active systems. By using renewable energies where these conditions are possible, the use of fossil-based energies is reduced and many environmental and economic benefits are provided. However, in order to spread the use of renewable energy sources in buildings, it is deemed necessary and important for governments to prepare the necessary laws and regulations and to have sanctions and incentives for their implementation.

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