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Abstract: Nearly zero-energy building means a building that has a very high energy performance. In its simple concept, net-zero energy building is a building that produces as much energy as it consumes over the year leading to net-zero energy on annual basis. The concept, in practice, is realized using a combination of energy efficiency measures on the building side along with local renewable energy production. Definitions and the basic principles of designing ZEB were briefly analyzed. A case study is performed and very interesting results are given.

Keywords: Zero-Energy Building, energy efficiency, fuzzy control, energy savings

Introduction

The indiscriminate exploitation of the planet's energy sources has nowadays led to an uncontrollable form of climate change, with negative consequences for both man and environment. In an effort to curb this situation, energy savings in both the building sector and other sectors of activity (industry, transport, etc.) is a primary objective and an indispensable component of any modern energy policy. As the building sector consumes 40% of the energy required at European level, the European Union has made considerable efforts to significantly reduce these consumption levels. In addition, a series of European Community Directives (91/2002, 32/2006, 31/2010) have been issued on the control and improvement of the energy performance of buildings. These guidelines give guidance to European Countries and specify the procedures for issuing energy performance certificates for buildings, setting minimum energy requirements for new buildings and other. The European Council adopted a package and the European Parliament voted it and the 27 Heads of State and governments finally agreed to implement the 20-20-20 EU Energy targets: by 2020, reduce by 20% the emissions of greenhouse gases, increase by 20% the energy efficiency in the EU and to reach 20% of renewable energy sources (RES) in total energy consumption in the EU.

In Greece, in recent years, an effort has been made to improve the situation in energy policy and planning issues, focusing on energy savings and the use of renewable energy sources. The first effort was made with the Laws 3661/2008 and 3851/2010 and it received a more complete form with the publication of the Energy Efficiency Regulation of Buildings.

It is characteristic that, as part of the European savings efforts in the building sector, provisions have been incorporated into the requirements of Zero Energy Efficiency Buildings both in the corresponding Community Directives and in Greek legislation (KO 31/2010 and L.33851 / 2010). These provisions provide for the construction of all new buildings by 2021 at the latest with zero consumption standards. In particular, for public new buildings, the time horizon is even less [1].

The present study examines the possibility of integrating two different systems of solar energy utilization into a residential building in the area of Patras in order to achieve its energy self-sufficiency and hence its classification in the category of Zero Energy Building. More

specifically, the integration either of photovoltaic and hybrid photovoltaic - thermal collectors was examined. We decided to examine these systems against other RES technologies because of their easier integration into building infrastructure and the greater familiarity that users of the buildings usually have with both photovoltaic and solar thermal systems.
The modeling of the operation of the two systems was done with the help of the Matlab, taking into account the relevant literature and data available from the manufacturers of related equipment. Different formats were developed to model the two technologies due to the different mathematical equations governing the operation of each of the proposed system. The modeling process was carried out for four representative months of the year (January, April, July and October), and thereafter the annual results were calculated in order to calculate the energy contribution of each system separately.
It was considered a single-family house in the area of Patras with thermo-insulating protection of its structural elements to meet the requirements and specifications of Zero Energy Buildings. Then, using the software for conducting energy inspections and studies, the actual energy needs of the building were calculated for each end-use (heating, cooling and DHW).
The required climatic data (solar radiation and ambient temperature) were obtained from the PVGIS website, from which it is possible to derive such information in a 15-minute increment. For this reason and throughout the computational process, the same time step was followed. In the case of photovoltaic panels, data were required in relation to the nominal output and also the correlation of output power with collector temperature. For the hybrid collector, it has also been necessary to look for data on its thermal efficiency as a function of the intensity of the solar radiation and the flow of water through it. All of these elements were derived from the manufacturer's technical leaflets.
Based on the calculated energy needs of the house, in the case of photovoltaic panels, the annual electricity output of different size arrays was calculated to determine the total array size required for building autonomy. Similarly, in the case of hybrid photovoltaic - thermal collectors, the electrical and thermal production of a different number of connected photovoltaic - thermal collectors was calculated. The appropriate combination of parallel branches was chosen to ensure energy autonomy with the smallest possible number of hybrid collectors.
The results of the computational process have shown that while in the case of photovoltaic panels the performance per unit area is independent of the total number of collectors, for the hybrid collectors both the electrical and thermal efficiency per m2 are decreasing by increasing the total number of series of connected collectors. In addition, the autonomy of the residential building in question is possible with a smaller number of hybrid collectors due to the extra thermal energy available in this case. The cost of each proposed solution, based on the cost per collector as derived from online search, is significantly greater for the hybrid system, despite the smallest total number of collectors required. However, given the fact that in the case of the photovoltaic system the existence of an additional system for heating and production of DHW (for the purposes of the present work was considered a central air-to-water heat pump), the final cost of the two proposed solutions is similar.

ZEB: Definitions, Issues and Challenges

Today there is NOT a common definition accepted for the zero energy building (ZEB) concept. [2] A **zero-energy building**, also known as a **zero net energy** (ZNE) building, **net-zero energy building** (NZEB), or **net zero building**, is a building with zero net energy consumption, meaning the total amount of energy used by the building on an annual basis is roughly equal to the amount of energy created on the site (with any means). These buildings consequently do not increase the amount of greenhouse gases in the atmosphere. They do at times consume non-renewable energy and produce greenhouse gases, but at other times reduce energy consumption and greenhouse gas production elsewhere by the same amount.

Most zero net energy buildings get half or more of their energy from the grid, and return the same amount at other times. Buildings that produce a surplus of energy over the year may be called "energy-plus buildings" (EPB) and buildings that consume slightly more energy than they produce are called "near-zero energy buildings" (NZEB). The zero net energy consumption principle is viewed as a means to reduce carbon emissions and reduce dependence on fossil fuels and although zero-energy buildings remain not very common even in developed countries, they are gaining importance and popularity.

Although most zero-energy buildings use the electrical grid as a backup for energy storage however some are independent of grid. Energy is usually harvested on-site through a combination of energy producing technologies like solar, Photovoltaics and wind. Reducing the overall use of energy is accomplished with highly efficient HVAC and lighting technologies. The last 10 years the zero-energy goal is becoming more practical as the costs of alternative energy technologies decrease and the costs of traditional fossil fuels increase. In addition, smart materials are used for better insolation of the houses thus helping in energy savings.

The development of modern zero-energy buildings became possible not only through the progress made in new energy and construction technologies and techniques, but it has also been significantly improved by academic research, which collects precise energy performance data on traditional and experimental buildings and provides performance parameters for advanced computer models to predict the efficacy of engineering designs. Furthermore, new advanced control methods have been develop such as fuzzy control and Fuzzy Cognitive Map theories which contribute substantially to energy savings. Zero Energy Building is considered as a part of smart grid. The zero-energy concept allows for a wide range of approaches due to the many options for producing and conserving energy combined with the many ways of measuring energy (relating to cost, energy, or carbon emissions).

Construction of Zero Energy Building

For a near-zero energy building, zero energy building or even positive-energy building, it is necessary the design of the building to be according to the principles of bioclimatic architecture, in order to minimize their energy needs and adapt them to environmental requirements [3]. Once the maximum energy savings have been achieved with the bioclimatic design of the building, the application of passive systems and the use of energy efficient appliances, the remaining energy requirements are covered by renewable energy production. At that time, it only becomes meaningful to install RES systems and the building has a truly zero ecological footprint.

Execution of ZEB- Designing Parameters: the design of buildings and spaces (interior – exterior – outdoor) is based on local climate, aimed at providing thermal and visual comfort, making use of solar energy and other environmental sources. Basic elements of this design are passive solar systems which are incorporated onto buildings and utilize environmental sources (for example, sun, air, wind, vegetation, water, soil, sky) for heating, cooling and lighting the buildings. This design takes into account the local climate and includes the following principles:

1. Heat protection of the buildings in winter as well as in summer, using appropriate techniques which are applied to the external envelope of the building, especially by adequate insulation and air tightness of the building and its openings.
2. Use of solar energy for heating buildings in the winter season and for day lighting all year round. This is achieved by the appropriate orientation of the buildings and especially their openings (preferably towards the south), by the layout of interior spaces according to their heating requirements, and by passive solar systems which collect solar radiation and act as “natural” heating as well as lighting systems.

3. Protection of the buildings from the summer sun, primarily by shading but also by the appropriate treatment of the building envelope (i.e. use of reflective colors and surfaces).
4. Removal of the heat which accumulates in summer in the building to the surrounding environment using by natural means (passive cooling systems and techniques), such as natural ventilation, mostly during nighttime.
5. Improvement – adjustment of environmental conditions in the interiors of buildings so that their inhabitants find them comfortable and pleasant (i.e. increasing the air movement inside spaces, heat storage, or cool storage in walls).
6. Ensuring insolation combined with solar control for daylighting of buildings, in order to provide sufficient and evenly distributed light in interior spaces.
7. Improvement of the microclimate around buildings, through the bioclimatic design of exterior spaces and in general, of the built environment, adhering to all of the above principles.

Study Case and Discussion of Results

In this study we examined the performance of two systems of exploitation of solar energy in terms of their contribution to the autonomy of a detached house in the Patras area. More specifically, the performance of photovoltaic as well as hybrid photovoltaic - thermal collectors was investigated.

Calculation methodology:

First the calculation period was considered. The modeling was done for each system for four representative months of the year (January, April, July and October) and the results were recalculated over one year.

The input data was taken from the state records. The climatic data to be used as inputs to the calculations (solar radiation and ambient temperature) were obtained from the PVGIS web site, which provides such data for the calculation of photovoltaic system performance. Here are the change charts of these two parameters for the four months of the year.

Performing a number of simulations some very interesting results were obtained [4]. Unlike the case of photovoltaic panels, the reduction of the electric output of hybrid collectors per kWp and collector surface does not remain stable as their number increases. This is because the next collector always has less output power than the previous collector, because it works at a higher temperature than that due to the in-line hydraulic. Electricity production has a downward trend as the number of collectors increases. For the two scenarios (4 and 8 collectors respectively), the decrease reaches 4%.

An energy analysis was also performed obtaining also some very interesting results. The analysis was done on a small house of a total area of 160 m2, which includes a basement of 80 m2. The building met the requirements of Greek constraints in terms of thermal insulation. Two scenarios were considered.

Scenario 1: Applying a photovoltaic system to enable the study building to fully meet its energy needs. The calculations are made by energy offset in an annual cycle, as would be the case with a system that operates on the netmetering logic and on the basis of the actual energy consumed It is assumed that a heat pump (COP = 3,5) is used to meet heating needs in combination with an under floor emission system. To meet the cooling needs, heat pumps of split type (EER = 3,0) are used, while the same heat pump used for heating the building (COP = 3,5) is utilized to meet the needs of Hot Water.

Scenario 2: Applying the hybrid photovoltaic - thermal system to enable the study building to fully meet its energy needs. Calculations are made just like in Scenario 1. To meet heating needs, the thermal content of the hybrid system is combined with an under floor emission system, while

the installation and an auxiliary system with resistors (efficiency 1) is provided if the output of the hybrid system is not sufficient.
As in Scenario 1, cooling needs are met with split type heat pumps (EER = 3.0). The needs for Hot WaTER are also covered by the thermal content of the hybrid system, with provision for a resistive auxiliary system. For the photovoltaic system there is a requirement to cover electricity consumption of 7120 kWh. It turns out that at least 4.5 kWp of installed capacity is required to meet this consumption, ie 25 photovoltaic panels. The total annual output in this case is 7192 kWh.
In terms of exploiting the results of the analysis that preceded the energy autonomy of a typical house, based on the assumptions made, it has emerged that meeting energy needs can be achieved with a significantly smaller number of hybrid collectors compared to conventional photovoltaic generators.
In particular, 18 units of hybrid collectors are required against 25 units of photovoltaic generators. This is logical, since the hybrid collectors offer additional thermal energy and their electrical output has almost been identical to that of the photovoltaic.
Therefore, in residential installations where there is room space, the selection of hybrid photovoltaic - thermal collectors is clearly preferable to photovoltaic. In this example, 25.69 m2 of hybrid collectors are required against 34.45 m2 of photovoltaic generators.

Closing Remarks

In this study an overview of the new emerging concept of Zero Energy Buildings was provided. Definitions and the basic principles of designing ZEB were briefly analyzed.
In the case of hybrid collectors, the collector-generated power output (kWh / m2) does not remain constant with the increase in the number of collectors but decreases by a small percentage each time a new collector is added to the connected wiring. In the case of photovoltaic panels, the surface-generated power output remains unchanged as the number of panels increases, because the operating temperature depends only on the ambient temperature, the intensity of the solar radiation and the installation conditions, parameters common to all collectors. In the case of hybrid collectors, the same behavior is also present in their thermal production.
Despite the slightly lower nominal electrical efficiency of hybrids (12.4% vs. 13.1%), electricity production per unit area (kWh / m2) over a year is almost identical for both systems, which should be is attributed to the improved temperature conditions under which the hybrid collectors operate.The proposed system is very useful for future studies of Zero Energy Buildings. More research is needed in this scientific field.

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