Standard Unretrofitted Buildings and Net Zero-Energy Concept

Daniel Aelenei[1*], Laura Aelenei[2] and Filipe M. C. da Costa Santos[1]

[1] Faculty of Science and Technology, Universidade Nova de Lisboa, 2829-516, Caparica, Portugal

[2] National Energy and Geology Laboratory (LNEG), Paço do Lumiar 22, 1649-038 Lisboa, Portugal

[*] Corresponding Author, daniel@fct.unl.pt

Abstract

There are many different possible combinations of building envelope, utility equipments and on-site energy generation equipments that can lead to net zero-energy performance. For instance, a building with standard design can offset its energy demand by adding a large amount of photovoltaic cells or by improving its energy efficiency rating first and then adding a smaller amount of photovoltaic cells. Despite the second strategy being considered the roadmap to net zero-energy status, the first scenario is also possible in the actual Portuguese context where laws favor conditions for the installation of PV´s and solar thermal systems.

This paper intends to discuss the implications of this fact from a national perspective coupled with the IEA SHC Task 40 - ECBCS Annex 52 vision where authors are active participants.

1. Introduction

The energy consumption in buildings in member states of the OECD is responsible for approximately 35 % of the total end use. Given the existent potential for reducing the buildings' energy requirements, and the great impact exerted by building sector on society (as the scale of energy efficiency in buildings is large enough to influence security policy, climate preservation and public health on a national and global scale), European Union named energy efficiency as the best way to establish energy security over a longer term [1]. With respect to building sector, it is estimated that the combination of energy efficient measures with on-site energy renewable sources (e.g. solar) has the potential to achieve net zero-energy buildings (i.e. when the energy demand is equal the energy supplied to the grids). It was in this context that recast of Energy Performance of Buildings Directive (EPBD), which requires all new buildings to become near zero-energy by 31 December 2020, was published on 18 June 2010 [2].

Portugal, as a member state committed to consolidate and strengthen the actions foreseen in the National Energy Efficiency Action Plans is now interested to explore and anticipate the technical orientations and programmatic strategies that will respond better, in the European context, to above identified EPBD recast goal. The accomplishment of this goal is strongly dependent on the how international and national networks, central administration and local authorities are going to set the sustainable energy policies at local level, which in turn depend on the road ahead prepared by experts who are aiming to identify the tools necessary to design, construct and operate these buildings.

If the roadmap to net zero-energy performance in the case of new buildings is clear in the sense that a net zero-energy building (NZEB) should first have an outstanding thermal behaviour on the basis of efficiency energy measures adopted, with respect of existing buildings, the challenges are linked in particular to the semantic frame. Should retrofitting be compulsory for existing buildings to further qualify for the integration of renewable systems, and be labelled as NZEB, or zero-energy performance definition should have a more basic physical meaning and be reduced to a simple energy balance demonstration? The results of this work are expected to provide guidance to these questions.

2. Net Zero-Energy Buildings Challenges

There are many different possible combination of building envelope, utility equipments and on-site energy generation equipments that can lead to net zero-energy performance. For instance, a building with standard design can offset its energy demand by adding a large amount of photovoltaic cells or by improving its energy efficiency rating first and then adding a smaller amount of photovoltaic cells. Despite the second strategy being considered the roadmap to net zero-energy status, the first scenario is also possible in the actual Portuguese context where the Renewables-on-Demand law introduced a generous feed-in scheme that created the favourable conditions for the installation of PV´s and solar thermal systems, given the payback time being actually estimated at about 6 years [3]. Under the feed-in scheme applied currently to renewable sources, which requires all the electricity produced to be sold to the electricity supplier and the installation of a solar water heating system, 2,23 MW were installed in 2008 and further 8,9 MW in 2009 [4]. Studies done so far in some selected cases are pointing out that houses benefiting from photovoltaic and solar thermal systems apparently produce more than consume, despite of lack of any improvements of thermal characteristics of building envelope. This fact is of particular interest for the authors of this paper who, in addition of being participants in the IEA SHC Task 40 - ECBCS Annex 52 “Towards Net Zero Energy Solar Buildings”, are also involved in the review process of the national building codes. The authors of this work intend to discuss the implications of this particular issue by bringing into focus results from measurements and simulations performed in the case of a single family detached unretrofitted home which has installed both photovoltaic and solar thermal systems.

3. Study Case Description

3.1. Building physical characteristics

The building analysed is located in Almada, a satellite city of Lisbon, in a residential area mostly consisting of single family homes (Figure 1).The house, built up in the decade of 70´s, long before the first national code on building energy efficiency, is a 140m^2, two-story brick masonry and cast-in-place concrete columns and slabs. The building, which is fitted with clear single-glazed aluminium windows which incorporate exterior adjustable shading devices, consists of one kitchen, one living room, one office, four bedrooms, two restrooms and three unconditioned spaces (garage, attic and stairs). The main façades are NW/SE oriented. The building envelope physical characteristics in terms of U-value are estimated at 1,3 W/m^2 K (brick masonry walls) and 4,8 W/m^2 K (windows). The building shape factor is 0,36 m^2/m^3.

3.2. Climate characteristics

The Almada climate is generally warm and sunny with a heating period of 5.3 month and about 4 month cooling period. The monthly average temperature varies between 10.6ºC (January) to 22.6ºC (August). The average number of heating degree days (HDD) is 1160ºC.days. In summer time, the solar radiation can reach values of more than 6.5 kWh/m^2 per day and extreme temperature values of about 35ºC or higher, however the maximum average air temperature in the summer is around 28ºC. Almada winter climate can be humid but mild, with average minimum temperature between 8 to 10ºC.

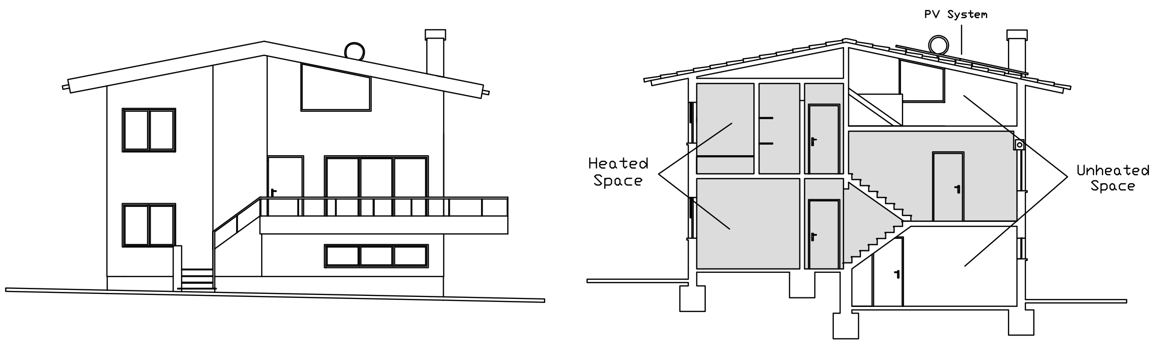

Fig. 1. Schematic drawing of the building: NW front side (left) and vertical cross-section (right)

3.3. Heating, cooling and hot-water systems

The house is currently occupied by three adults and a child. The heating system installed is based on electric resistance although the living room may benefit from heating delivered by a fire place which uses wood as fuel (not accounted in the energy balance). No cooling system is installed. In the phase previous to installation of the renewable energy systems, the hot-water production was provided by a gas burning boiler.

3.4. Renewable energy systems

The PV system installed on the house roof consists of a 27,6 m^2 array of 14 modules PV monocrystalline silicon cells with an installed power of 3,92 kWp. Since under the feed-in law applied currently to renewable sources the installation of a solar water heating system is compulsory, after the installation of the PV system, the hot-water production start to be produced by a solar collector, thermosyphon type 2,23 m^2, with the tank located above the collector (280 l) which uses for backup an electric resistance water heater (2000W). The annual solar energy production of the water heating system is estimated at 2.586 kWh.

4. Energy Performance

4.1. Energy performance calculation method

The method of calculating the energy performance of single-family homes in Portugal is based on the European standard EN ISO 13790 “Thermal performance of buildings – calculation of energy use for space heating” and is set out in the form of an Excel workbook, accompanied by a series of tables. According to the Portuguese building code specifications, the factors which accounted in the energy balance of the building are [5]: building envelope characteristics (U-value, thermal bridges, thermal storage and air leakage), heating installation, air-conditioning installation, ventilation, hot water supply, passive systems, outdoor climate, solar protection and renewable energy sources. The calculation of the heat to be delivered within the boundary of the building (assumed as a single-zone where heated space consists of all the building elements separating it from external environment or from adjacent dwellings or unheated spaces) is calculated assuming an ideal heating system to maintain the set-point temperature (20ºC) during the winter time period (5,3 months for Almada). The heating demand is reported on an annual basis as kWh per square meter of heated area.

For simplicity reasons and reduced interest, the procedures followed for calculating the cooling and hot water needs are not described here.

The heating, cooling and hot water supply energy needs are further weighted according to primary energy factors associated to the fuel used by the real systems used and heating and cooling use, and reported in units of kilogram of oil equivalent per square meter, year (kgep/m^2 year).

4.2. Energy performance – estimated results

The application of the above described calculation method to the house estimates a value for energy demand for heating equal to 132 kWh/m^2 year, which indicates a building with a very poor thermal performance. This value means that on average, the monthly energy required to maintain the set-point temperature of the house to 20ºC is approximately 3.486 kWh (based on the duration of the winter period in the city of Almada, 5,3 months). In practice, however, the occupants seldom make use of the heating system (either because they are out or because the climate is relatively warm) and that is the reason why in the Portuguese building code the heating demand under real conditions is estimated at only 10% of the total value. Based on this assumption, the house should indicate values of energy consumption for heating equivalent to 348,6 kWh/month.

4.3. Energy performance – measured results

In this section are presented and discussed the results obtained on the basis of the measured monthly electric energy bills. Figure 2 shows the electric energy consumption versus the electric energy generated by the PV system together with the energy balance beginning October 2009 (when the renewable systems were installed).

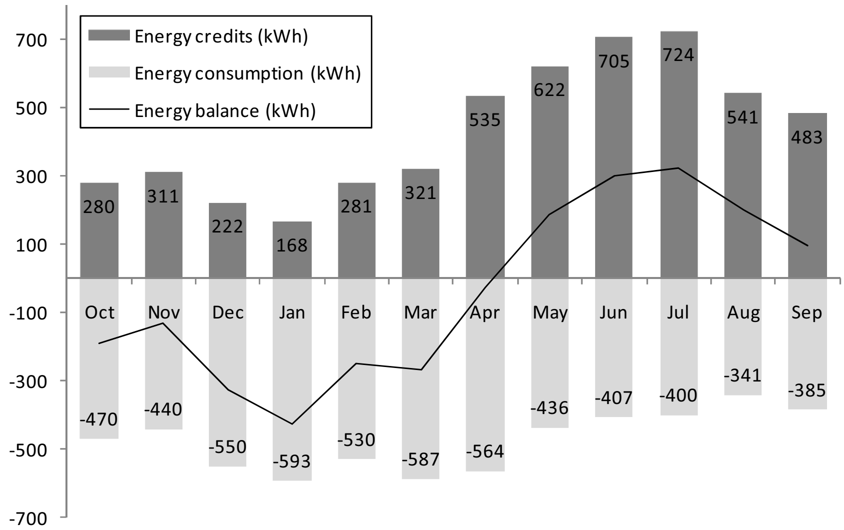

Fig. 2. Monthly electric energy consumption vs. energy supply from PV system.

Since at the time when this work was reported two months were missing to complete one year (August and September), the corresponding data was replaced with measurements available from electric energy bills from the year before (energy consumption) and with results estimated using a simulation tool (energy delivered by the PV array) [6]. As it can be seen from Figure 2, the results obtained indicate a mismatch of 500 kWh at the end of the first year, which means that the house is very close to reach the net zero-energy performance. This, however, should be interpreted in line with the assumptions of the study and the unfavourable weather conditions recorded on site during last winter. The weather during last winter has been mostly cloudy with precipitation values 200% greater than the normal expected values, a fact which caused a significant reduction in electric energy production (as seen in Figure 2).

While a direct correspondence between the estimated results (section 4.2) and the measured results is difficult to establish (the measured electric energy bills, in addition of heating and hot-water system, also include energy for lighting and electric appliances), it is interesting to observe that the electricity consumption is, on average, 160 kWh higher in winter than in summer. If one assumes that this portion was used for ambient heating, then one can conclude that in this specific case the heating systems is used in a proportion of 5%, which is half the estimative of the Portuguese building code.

5. Final Conclusions

This work bring into focus the energy performance of an unretrofitted single family detached home which has installed both photovoltaic and solar thermal systems. The interest in this case is driven by the needs of drawing a line of demarcation between the levels of effort invested in efficient building strategies and the amount of energy required from renewable, and the semantics with respect of the NZEB issue.

The results of the work are pointing the fact that unretrofitted buildings are likely to reach the zero-energy performance under normal circumstances (it is worth mentioning the lack of any passive solar technologies or other energy efficient strategies with regard of the building, as well as the lack of sensibility of occupants with the topic under analysis whose habits were not influenced in any way along the study).

Although the results suggest that an unretrofitted building is likely to achieve the zero-energy performance, one fundamental question which needs to be addressed is whether unretrofitted buildings should be labelled as NZEB under these circumstances. The authors of this work estimate that the application of a set of energy retrofitting measures (external thermal insulation, high performance double glazed windows and controlled natural ventilation) has the potential to reduce the energy demand for heating down to 30 kWh/m^2 year, a much lower value than the actual (132 kWh/m^2 year). Since much of the answer lies in the analysis of the economic feasibility of both renewable systems and retrofitting measures, it is important that future studies address this issue.

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Aknowledgements

The authors of this paper wish to thank Mr. Vasco Belchior for his kindness in collaborating in this study.