SOLAR XXI: A Portuguese Office Building towards Net Zero-Energy Building

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Introduction

Solar Building XXI, built in 2006 [1], at LNEG Campus in Lisbon, pretends to be an example of a low energy building using passive systems both for heating and cooling (ground cooling) towards a Net Zero-Energy Building (NZEB) [2]. The main façade has a PV system with heat recovery which assists the heating in winter

time. In summer a ground cooling system (earth tubes) is used to cool the building, together with night cooling strategies. Net Zero-Energy Buildings Performance has gained more attention since the publication in 2010 of the EPBD recast [3]. Successful implementation of such an ambitious target depends on a great variety of factors. For designers and code writers these include: balancing climate driven-demand for space cooling and heating with climate-driven supply for renewable energy resources. With a literature full of theoretical advice and a building industry rife with myths about the value of technologies, the present paper intends to unveil a sustainable framework for sharing insights into NZEB methodology applied to a Portuguese solar office building, SOLAR XXI, currently underway to reach the Net Zero-Energy Goal. Under the common work which is developed also in SHC Task 40-ECBCS Annex 52, "Towards Net Zero Solar Energy Buildings" [4], the authors of this paper are currently engaged in studying possible strategies for "upgrading" Solar XXI to NZEB status.

Table 1. SOLAR XXI Building - general data.

General characteristics	
Location	Lisbon Latitude 38°46'20.27" north Longitude 9°10'39.83" west
Owner	National Energy and Geology Laboratory (LNEG)
Project co-ordinator	Helder Gonçalves helder.goncalves@lneg.pt
Architect	Pedro Cabrita, Isabel Diniz
Building costs (tax included	800 €/m^2
Typology	Office building
Climate data	Temperate Heating period 5.3 month Heating Degree Days 1190°C (Tb 20°C)
Main stimulation of the project	Test, experimental, research
Site context	Urban
Building construction	High
Number of occupants	20 pc
Number of stories	3 pc
Number of buildings	1pc
Heated net floor area	1200 m^2
Gross floor area	1500 m^2
Total envelope area	1436 m^2
Envelope to volume ratio	0.4 m^{-1}

SOLAR XXI Building

Solar XXI building was built in Lisbon in 2006 as a demonstration project [1], [2]. The building is considered a very high efficient building, from the national regulation point of view, with a difference in energy performance 1/10 regarding a standard Portuguese office building. From the NZEB goal perspective, the building, which design is based on a combination of passive design techniques with renewable energy technologies (PV, solar collectors) may be currently considered, a nearly Zero Energy Building. Some of general building characteristics are summarized in **Table 1**.

NZEB concept

Net Zero Energy Building (NZEB) concept may be defined as a building that over a year is neutral (i.e., it delivers as much energy to the supply grids as it uses from the grids) when energy efficiency measures are successfully combined with energy renewable sources. According to this, the net zero-energy performance may be achieved as a result of executing two fundamental steps: first reduce building energy demand, and second, generate electricity or other energy carriers, to get enough credits to achieve the desired energy balance. In the first step passive approaches play a fundamental role in addressing NZEB design, as they affect directly the loads put on the buildings mechanical and electrical systems, and indirectly the strive for renewable energy generation.

Energy efficiency comes first

Thermal optimization of the building envelope

One of the strategies adopted in the design of SOLAR XXI building in order to reduce the thermal loads and provide a good thermal comfort conditions consisted in optimization of building envelope. The characterization of the elements of the building envelope is summarized in **Table 2**. All the building has an external insulation and so the thermal bridges influence was reduced significantly while the building thermal inertia was preserved.

Use of the solar gains

The Solar XXI building main façade (South oriented) is covered by windows and PV modules by equivalent proportions. This large glazing area (about 46% of the south façade and 12% of building conditioned floor area) interact directly with the office rooms permanently occupied, collecting direct solar energy, providing heat and natural light to these spaces. Increasing the solar heat gains in winter time consisted one of the dominant

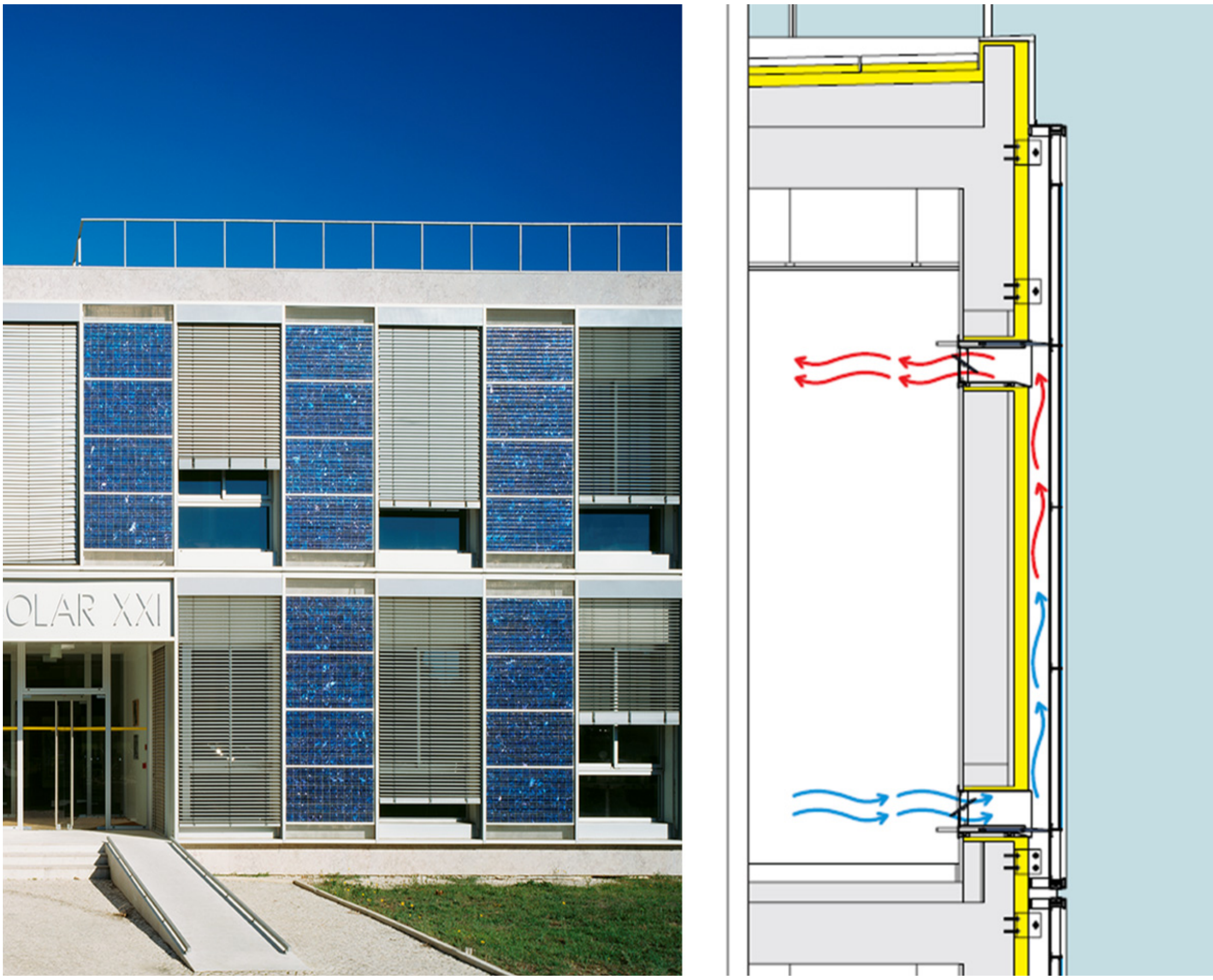

Figure 1. BIPV-T and Windows shading. BIPV-T scheme.

strategies in the building design, by adopting essential features such as location, size and orientation (south) of the main glazing area.

Thermal Building Integrated Photovoltaic (BIPV-T)

In addition to the use of direct solar gains through the windows, the BIPV-T system integrating south building façade is also contributing for the improvement of the indoor climate during heating season in the day time hours, when the heat released in the process of converting solar radiation into power is successfully recovered (**Figure 1**). As a heating strategy, in winter time during the days with high solar radiation, the temperature of the air heated by BIPV-T and insufflated into the offices can rich 30°C [2].

Windows shading

Solar XXI building uses a set of efficient measures and strategies which contribute for diminishing the building cooling loads. The building has no active cooling system and a number of design measures are incorporated to reduce the summertime heat load. Venetian blinds adjustable by the users were placed outside the glazing to limit direct solar gains. When applied externally, become a very important measure for summer period, since they minimize the direct solar incidence.

Table 2. SOLAR XXI Building - Envelope technical data.

Building elements	Material	U value (W/m^{2}K)
External walls	Brick wall + ETICS (6 cm)	0.45
Roof	Concrete with external insulation (10 cm)	0.26
Thermal bridges	Concrete with external insulation (6 cm)	0.55
Windows	Transparent double glazing	3.50
Envelope (average)		**0.88**

Ground Cooling System

A ground cooling system provides incoming pre-cooled air into the building using the earth as a cooling source. The system consists of 32 tubes with 30 cm diameter, buried at 4.5 m depth (**Figure 2**). The ground temperature varies from 13 to 19°C throughout the year, so it represents an excellent cooling source during summer season. The air enters into the tubes array 15 m away from the building, cross the tubes circuit cooling to a temperature near the ground and is injected into the building office rooms by natural convection or forced convection using small fans. The system operates with great efficiency in the hot summer days, when the indoor temperature is significantly higher, by pushing the fresh air from the buried pipes. The air temperature injected inside the office rooms ranges between 22–23°C, resulting in a decrease of the indoor air temperature between 2 and 3°C.

Natural ventilation/Natural lightning

The natural ventilation plays an important role in Solar XXI building in both seasons. Natural ventilation is provided due to cross wind and stack effect via openings in the façade and roof level. The façade openings together with adjustable vents on all office room doors provide the cross ventilation, allowing the air to flow from inside to outside and vice versa. In the building central hall there is a skylight, which allows for natural ventilation by stack effect (**Figure 3**). The set of ventilation strategies (day and night) provide a high comfort level in the summer, especially when applicable during night period minimizing the thermal loads accumulated during daytime within the building and its temperature. The location and dimension of central skylight as a main light distributor in the central hall is fundamental, as also the translucent vents in the doors which communicate from south and north spaces to corridor and the glazing areas

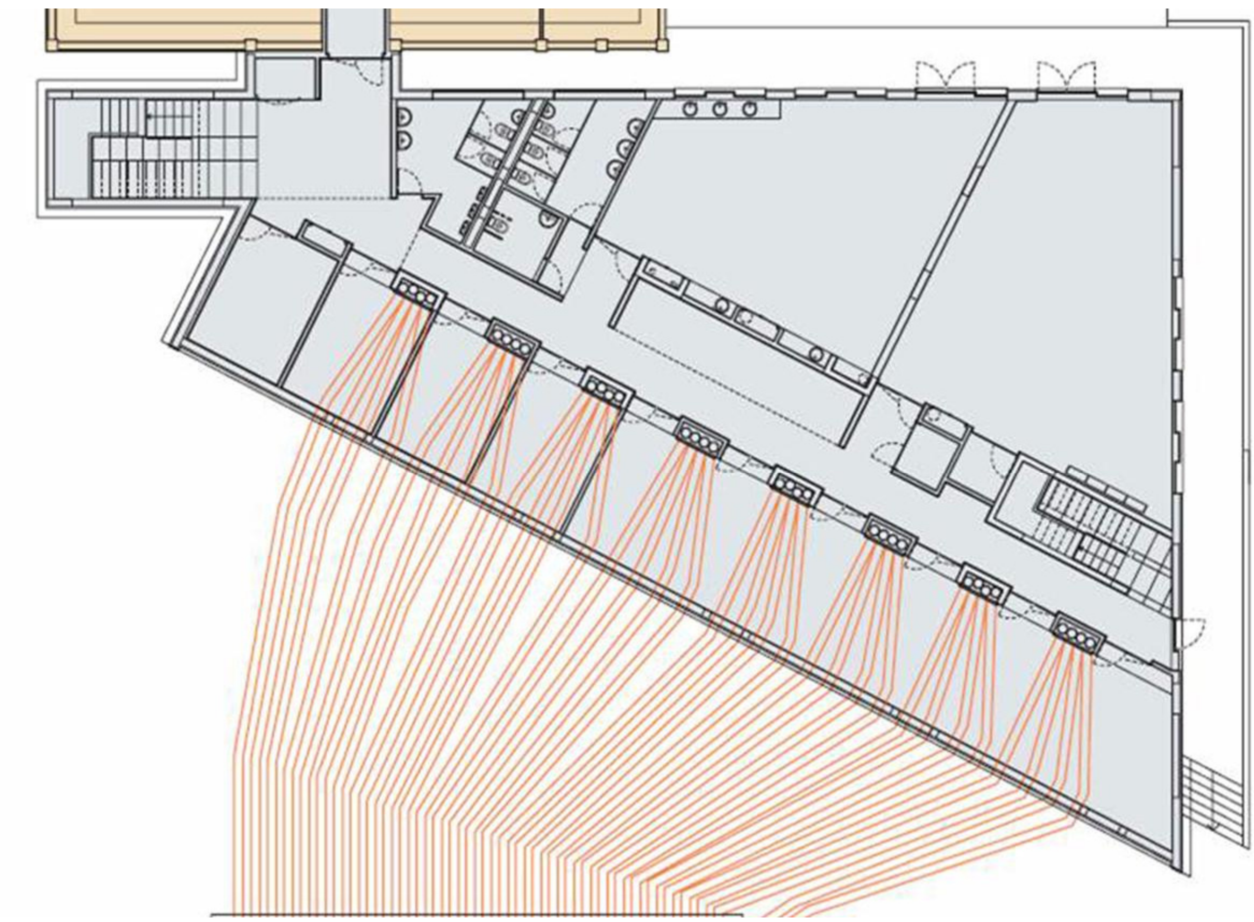

Figure 2. Ground cooling system scheme.

Figure 3. Natural ventilation/Natural lighting.

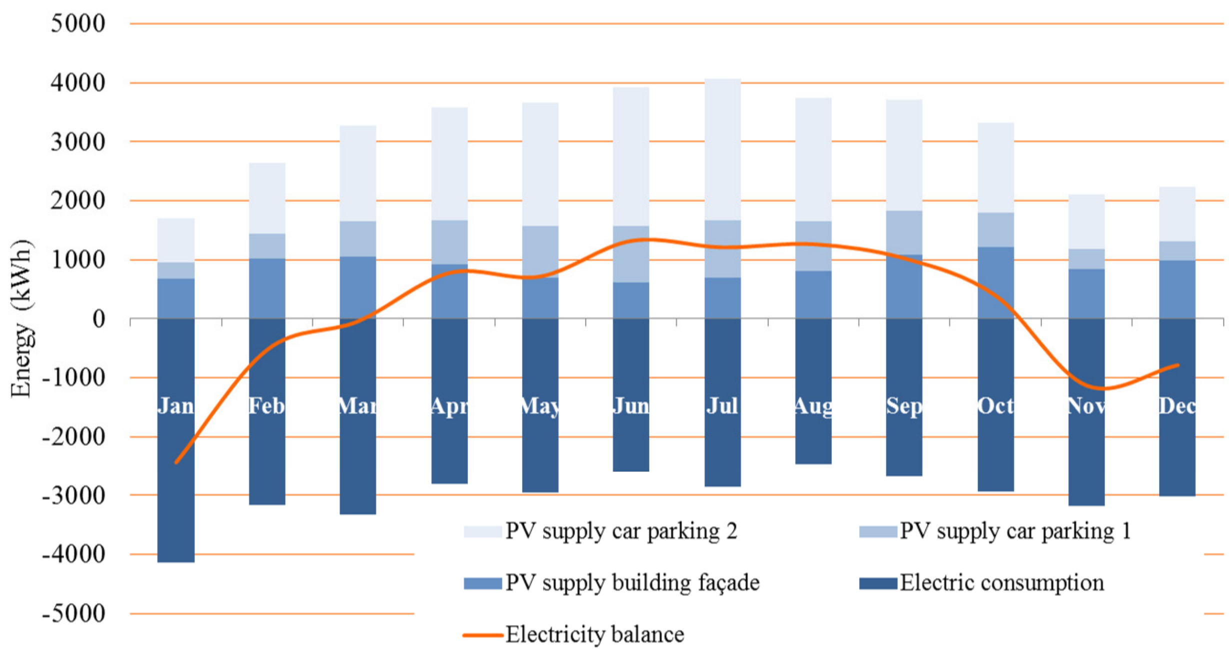

Figure 4. Solar XXI - monthly electric energy consumption/PV (façade + parking) energy supply.

distributed all over the building envelope. These important features adopted in the building design led to a reduction of the electric light building consumption.

Energy supply

The integration of renewable energy systems in the Solar XXI design was one of the main objectives of the project. The SOLAR XXI building Renewable Systems are summarized in **Table 3**. The last monitoring analysis performed in 2011 has shown a total amount of electric energy consumption of 36 MWh, versus an amount of electricity produced by the three PV systems of the almost 38 MWh. The monthly distribution of the electric energy consumed by Solar XXI versus the energy supplied by the PV system (façade + parking) for the 2011 is presented in **Figure 4**.

SOLAR XXI - The path towards NZEB performance

As it has been described above, the Solar XXI integrates efficient solution sets and strategies, from the features reducing building energy demands, to integration of the renewable energies. **Figure 5** shows the Solar XXI performance from an energy balance approach perspective versus the critical steps towards NZEB performance. If designed as a standard office building in accordance with the current Portuguese

Table 3. SOLAR XXI Building - Renewable Energy Systems data.

RES	Integration	Area (m^2)	Installed Peak power (kW)	Productivity (kWh/kW)
76 PV multicristalline silicon modules	Building façade	96	12	1 004
100 PV amorphous silicon	Car parking 1	95	6	1 401
150 PV CIS thin-film modules	Car parking 2	110	12	1 401
CPC Thermal Solar Collectors	Building roof	16	11 MWh, from which 5 MWh being used	

Building Code, Solar XXI would consume approximately 101 kWh/m².y including typical user related loads (**a**). If one would have performed improvements at level of the building envelope (and still continue with typical user related loads), the building would have consumed 90 kWh/m².y (**b**). On the basis of the improved building envelope and the outlined passive techniques and strategies, Solar XXI building annual energy consumption is 43 kWh/m².y (**c**). This consumption is offset with a credit of 35.85 kWh/m².y energy generated by the photovoltaic and solar thermal collectors (**d**), thus, the final balance of the building points out a near zero-energy performance.

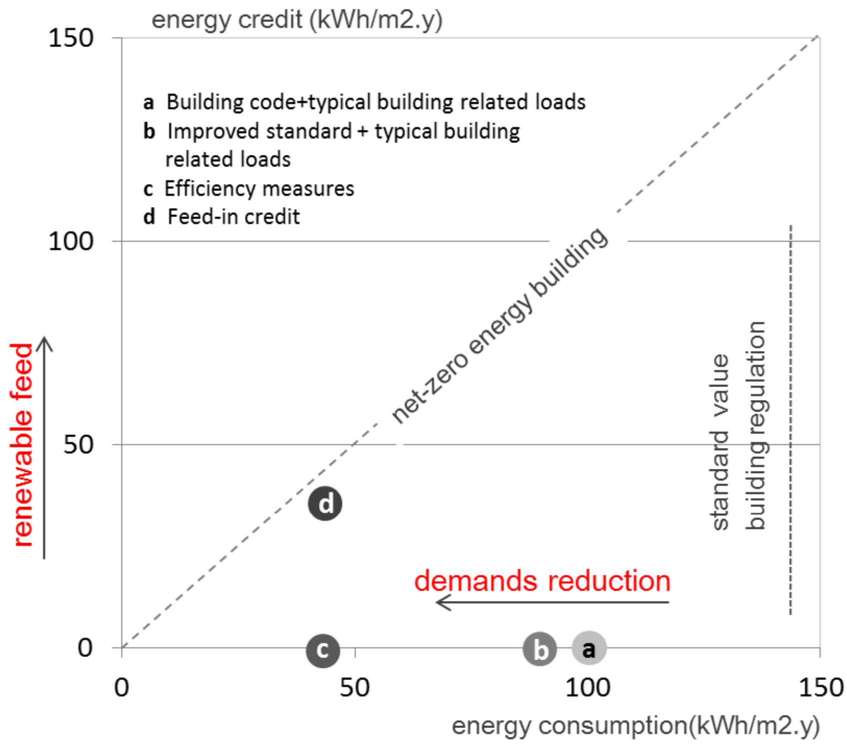

Figure 5. SOLAR XXI - the path to net zero-energy performance.

Conclusion

With this paper the authors were able to share the main findings of the research carried in the design process of an office building currently underway to reach NZEB performance. Along the lines of the paper it has been shown the road traversed by Solar XXI on its way towards reaching zero-energy performance objective. It is believed that the set of solutions adopted the building envelope, the daylighting performance characteristics, the natural ventilation strategies, the passive heating and cooling techniques, together with the integrated renewable energy systems, qualifies the Solar XXI building for exemplary energy performance. Solar XXI building energy performance is about ten times the energy performance of a standard new office building in Portugal [5]. Looking at the energy balance of the building from a NZEB perspective, it was shown that the wise combination of standard and innovative energy performance measures with renewable systems is able to achieve the zero-energy performance without significant efforts. The authors of this work are hoping that the lessons learned during design, construction and operation of the building will provide useful clues to all interested in developing outstanding energy projects in Southern European countries and other countries. At the same time it is also important that this work help policy makers and stakeholders identify (and counteract) the barriers against broader implementation of NZEB´s. 3E

References

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