8TH AECEF SYMPOSIUM

NEW ACTIONS AND ROLES OF CIVIL ENGINEERS: SUSTAINABILITY AND ENERGY

5 AND 6 NOVEMBER 2015 PORTO, FEUP

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8TH AECEF SYMPOSIUM

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FEUP FACULDADE DE ENGENHARIA UNIVERSIDADE DO PORTO

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FOREWORD

Sustainability of the world has become a pressing concern for Society, especially for younger generations. Energy is becoming scarce and expensive and the tendency is that these characteristics will worsen in the near future. The Civil Engineering profession has a major responsibility in addressing these two global issues. Civil engineers have the knowledge, attitudes and skills to help the World becoming a better place with positive prospects for the future.

These are the main motivations for the AECEF Symposium in Porto in 2015. Stakeholders of Civil Engineering (teachers, researchers, engineers, companies, government agencies, professional associations, NGOs) are invited to participate, share and debate innovative ideas, experimental results and education curriculum. The AECEF Symposium 2015 is the perfect Forum to get together and prepare proposals for a better endeavor to Civil Engineering.

Porto, November 2015

The Organizing Committee

ENERGY REDUCTION MEASURES IN OFFICE BUILDINGS CONVERGING TO NZEB: THREE CASE STUDIES

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Abstract

The present paper is mainly focused on the energy performance of three office buildings [1], [2], [3], with different floor areas and ages, located in different geographical provinces of Portugal: Coimbra, Castelo Branco and Setúbal.

On a first stage the study consisted on the characterization of the real energy consumption of each building, and the energy consumption partition between HVAC, lighting and equipment. On a second stage several proposals for energy consumption improvement were simulated for each building using Energy Plus/Sketch up models. The simulation models have considered changes in some construction systems and additionally the installation of solar energy generation systems in the buildings. Therefore the best approaches for the reduction of energy consumption in each building were obtained. The analysis of results and related conclusions were focused not only in effective reduction of energy consumption but also in the relationship between the benefits resulting of the implementation of each proposal and respective costs. For each proposal the return on the investment period is also presented.

Based on real cases the present paper pretends to emphasise the need to implement the reduction of energy consumption in buildings and specifically emphasises that some reductions can be developed without stopping the regular operation of the buildings. Some interventions are attractive regarding the factor cost/benefit.

Keywords: Energy Efficiency, NZEB, Energy Efficient Rehabilitation, Office Buildings, Energy Plus model, Sketch up model.

1 INTRODUCTION

The unsustainable way how the world's population currently uses the disposable energy resources has been the focus of major concern in the last decade. Buildings are globally responsible for significant energy consumption, with more expression during its regular operation. The main reason for this scenario in developed countries can be explained by the period of time that occupants spend inside buildings during their daily work life. Therefore significant actions have been carried out in order to intend to reduce energy consumption during the regular operation of buildings [4], [5].

The NZEB (Nearly Zero Energy Building) concept defined in the directive 2010/31/EU [6] transposed into national law by Dec-Lei 118/2013 of 20 August [7] is one of the most recent EU Initiatives in order to achieve reduction of energy consumption in buildings. NZEB concept applies both to new buildings and to renovated ones [7]. This concept can be considered as a milestone because a significant number of buildings in Europe and particularly in Portugal need some kind of renovation [5]. There are great expectations for reduction of energy consumption as result of the sustainable buildings renovation. On 25 October 2012 the Directive 2012/27/EU on energy efficiency was published, which requires Member States to establish a long-term strategy for mobilizing investment in the renovation of the national commercial and residential buildings, both public and private [8].

With regard to the dynamic simulation of energy consumption, EnergyPlus is one of the most sophisticated and commonly used model for this purpose. However, EnergyPlus is incapable to develop the formation of a building in a clear manner. The Google SketchUp software was used to assist these studies, which together with the Legacy OpenStudio (a SketchUp plug-in, with connection to the EnergyPlus), allows a 3D modelling of the building.

2 METHODOLOGY

On a first stage the presented study consisted on the characterization of the real and global energy consumption during the years 2011, 2012 and 2013 of each of the three buildings. Additionally the partition of energy consumption was considered for HVAC, Equipment and Lighting.

The real situation was simulated for each building using Energy Plus/Sketch up models and the validity of the simulation model was evaluated through its calibration comparing it with the real data of consumption.

On a second stage several proposals for energy consumption improvement that is, envelope improvement, LED lighting and solar Photovoltaic generation among others, were simulated. The simulation models have considered changes in some construction systems and additionally the installation of solar energy generation systems in the buildings.

The evaluation of several measures was considered and the correspondent reduction of energy consumption was evaluated. The analysis of results and related conclusions were focused not only in effective reduction of energy consumption but also in the relationship between the benefits resulting of the implementation of each proposal and respective costs as well as maintenance costs. Finally a simple analysis on return of each investment was carried out.

Based on the results, the energy consumption and the annual savings resulting from the implementation of each measure were compared. The practical viability of each implementation measure in order to improve the energy performance of the building was assessed.

3 RESULTS

3.1 Building in Coimbra

The building under consideration is an office building constructed in the year of 2000. Located in the outskirts of Coimbra, at a distance of 38 km of coastline it is deployed to a height of 44m, in a climatic zone I2V2. The ceiling height is 3.6 m and the floor area is 9465 sqm [1]

Tables 1, 2, 3 and 4 regarding the building in Coimbra (Fig. 1) presents summary of the energy consumption in recent years, the partition of energy consumption, measures considered for energy reduction, respective costs and return on the investment periods (ROI).

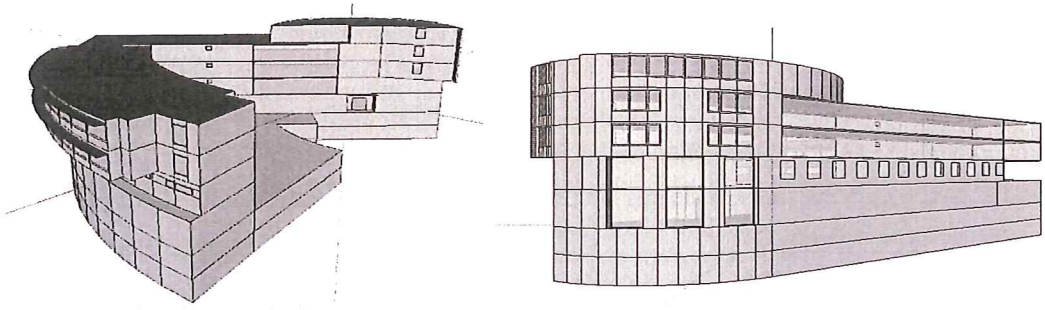


Fig. 1 – Modelling of the building in Coimbra [1].

Table 1 – Energy consumption between 2011 and 2013 Energy partition in 2013 [1].

Energy consumption		
Year	(kWh/year)	kWh/sqm.year
2011	850 957	90
2012	798 842	84
2013	741 260	78

Table 2 – Energy partition in 2013 [1].

Energy partition in 2013	
HVAC	43%
Equipment	33%
Lighting	24%

Table 3 – Energy reduction proposals [1].

Energy reduction proposals	
1	Glazing improvement in Block A
2	Thermal insulation of vertical and horizontal building envelope
3	LED lighting
4	Solar Photovoltaic generation system

Table 4 – Conclusions about simulation results [1]

Conclusions about simulation results					
Proposals		Reduction of energy consumption and generation	Savings or revenues yearly	Costs (€)	ROI (years)
A	Implementation of **measures 1+2**, simultaneously	Reduction of 20% in HVAC energy consumption	10 000.00 € savings	300 000.00	30,0
B	Implementation of **measure 3**	40% reduction of energy consumption in indoor lighting and of 30% in outdoor private space lighting	13 000.00 € savings	30 000.00	2,3
C	Implementation of **measure 4**	Generation of 100 000 kWh annually	revenue: 16 000.00 €	200 000.00	12,5
A+B+C - Implementation of all **measures: 1 + 2 + 3 + 4**		Energy consumption of the building: **47 kWh/sqm.year**	39 000.00 € savings	530 000.00	

3.2 Building in Castelo Branco

The building under consideration, built in 2009, consists only of a ground floor with a floor area of 525 sqm and a weighted ceiling height of 4.8m. It is located in the Castelo Branco industrial area on the outskirts of the city. The building is implanted at an elevation of 349 m at a distance to the coastline of about 120 km and is located in a climate zone I2V3N. The average density of occupancy is 14 sqm per person [2]

Tables 5, 6, 7 and 8 regarding the building in Castelo Branco (Fig. 2) presents summary of the energy consumption in recent years, the partition of energy consumption, measures considered for energy reduction, respective costs and return on the investment periods (ROI).

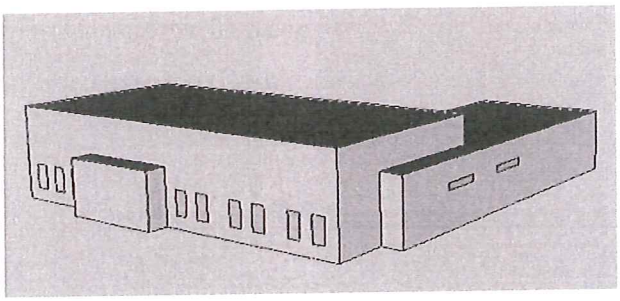


Fig. 2 – Modelling of the building in Castelo Branco [2].

Table 5 – Energy consumption between 2011 and 2013 [2].

Energy consumption		
Year	(kWh/year)	kWh/sqm.year
2011	55 527	106
2012	55 374	105
2013	54 205	103

Table 6 – Energy partition in 2013 [2].

Energy partition in 2013	
HVAC	45%
Equipment	27%
Lighting	28%

Table 7 –Energy reduction proposals [2].

Energy reduction proposals	
1	Replacing desktop computers for laptops
2	Substitution of Glazing
3	LED lighting

Table 8 –Conclusions about simulation results [2].

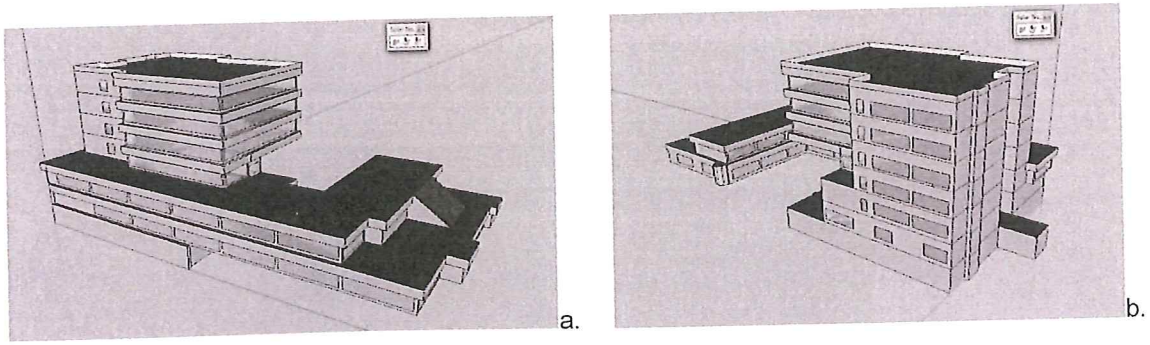
Conclusions about simulation results					
Proposals		Reduction of energy consumption and generation (kWh/year)	Savings yearly	Costs (€)	ROI (years)
A	Implementation of **measure 1**	Reduction of 20% in energy consumption	1 300.00 €	12 800.00	10
B	Implementation of **measure 2**	Reduction of 5,5% in energy consumption	360.00 €	4 000.00	11
C	Implementation of **measure 3**	Reduction of 5% in energy consumption	300.00 €	1 700.00	6
A+B+C - Implementation of all **measures: 1 + 2 + 3**		Energy consumption of the building: **72 kWh/sqm.year**	1 960.00 €	18 500.00	

3.3 Building in Setúbal

The office building was constructed in the 90´s and consists of seven floors above ground and one floor under ground, with 4041 sqm of floor area [3], [8].

The average density of occupancy is 47 sqm / person [3].

Tables 9, 10, 11 and 12 regarding the building in Setúbal (Fig. 3) presents summary of the energy consumption in recent years, the partition of energy consumption, measures considered for energy reduction, respective costs and return on the investment periods (ROI).



a. b.

Fig. 3 – Modelling of the building in Setúbal [3].

Table 9 – Energy consumption between 2011 and 2013 [3].

Energy consumption		
Year	(kWh/year)	kWh/sqm.year
2011	452 000	112
2012	439 000	108
2013	442 500	109

Table 10 – Energy partition in 2013 [3].

Energy partition in 2013	
HVAC	57%
Equipment	21%
Lighting	22%

Table 11 – Energy reduction proposals [3].

Energy reduction proposals	
1	Solar Photovoltaic generation system
2	LED lighting
3	Substitution of Glazing
4	Thermal insulation of vertical and horizontal building envelope

Table 12 – Conclusions about simulation results [3].

Conclusions about simulation results					
Proposals		Reduction of energy consumption and generation	Savings and revenues yearly	Costs (€)	ROI (years)
A	Implementation of **measure 1**	Generation of 33 000 kWh annually	revenue: 4 500.00 €	47 100.00	10
B	Implementation of **measure 2**	Reduction of 7% in energy consumption	4 200.00 € savings	4 000.00	1
C	Implementation of **measure 3**	Reduction of 20% in energy consumption	12 200.00 € savings	102 000.00	8
D	Implementation of **measure 4**	Reduction of 13% in energy consumption	7 900.00 € savings	97 000.00	12
A+B+C - Implementation of all **measures: 1 + 2 + 3 + 4**		Energy consumption of the building: **57 kWh/sqm.year**	28 800.00 € savings	250 000.00	

4 CONCLUSIONS

The energy dependence of Portugal to external energy sources makes it necessary to look to the future with a different perspective of energy consumption. Therefore, energy efficiency plays a key role in this matter.

These three simulation studies make it possible to obtain the following practical conclusions:

- The implementation of LED lighting is the most efficient measure considering the relationship cost-benefit.
- The implementation of a solar photovoltaic generation system is also to be considered since the return on the investment period is approximately 12,5 years, less than the life time period of a solar photovoltaic system (15 to 20 years).
- Measures to reduce energy consumption must be accurately studied using an adequate simulation model.
- Changes of the opaque envelope and also the glazing are measures with a return on the investment period generally very high for this type of architecture.
- Significant energy reductions may imply relatively significant costs.
- An accurate analysis on cost-benefit relationship must be performed.

- Some of reduction measures, according to [7], are not economically viable because they have a return on the investment period of more than eight years. But if those measures allow a significant reduction in the annual building energy consumption they should be accurately evaluated.

Based on real cases the present study pretended to emphasise the need to implement the reduction of energy consumption in buildings and specifically emphasises that some reductions can be developed without stopping the regular operation of the buildings. Some interventions are attractive regarding the factor cost/benefit.

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