Energy efficiency and renewable energy mix in municipal pools refurbishment

Case analysis of the Barreiro Municipal Pool

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Abstract

The rising energy costs and budgetary constraints, particularly in the public sector, has created great constraints on public budgets, resulting in the need to reduce operating costs with the public buildings, without thereby diminish the quality of service offered to its citizens.

This study aims to reduce energy consumption in the Municipal Pool of Barreiro (a Portuguese Municipality in Setubal District), since this old facility presents significant expenses to the municipality. For this purpose, a survey of the state of the building has been done on of its equipment and the behaviour of its occupants in order to determine the origin of the high cost on power and consequently the improvements that should be adopted, so that we can effectively reduce cost. In order to simulate the behaviour of the building in its current configuration, as well as amended improvements, it was used the software DesignBuilder.

After determining a solution that meets the objective of cost reduction, the software HOMER was used, to determine a solution for local renewable energy production, with particular focus on hybrid solutions, e.g. two or more sources of renewable energy, with the intention of creating a system that can minimize the problem of intermittency of renewable energies, in this case, of solar and wind origin.

Finally, this study is seen as a comprehensive approach to the demand for energy efficiency and local renewable production, e.g. not limited on one area of intervention (constructive, mechanical, electrical, etc.), but in a search for a solution in which various areas of engineering are integrated.

Keywords: Energy Efficiency, Renewable Energy, Electric Hybrid Production, Pool, Economic Return, Passive Refurbishment, Energy Audit

1. Introduction

The concept of energy efficiency can have multiple perspectives, such as ratio between an output of performance, service, goods or energy, and the energy used for this purpose (Directive nº 2006/32 / EC of the European Parliament and Council of 5 April 2006).

Overall and common to multiple perspectives is this logic that energy efficiency is the optimization of energy consumption (Adene, 2015), involving sometimes just demand, e.g. energy consumption, and sometimes the offer e.g. the production of energy, especially renewable energy.

The Energy Policy (EC, 2010) in Europe is based on a secure, competitive and sustainable energy strategy. The Energy Strategy 2030 proposes an improvement of energy efficiency, increased renewable energy use and the reduction of greenhouse gases in the period between 2020 and 2030. The goal by 2030 (EC, 2015) is to achieve a reduction of 40 % of greenhouse gas emissions compared to emissions in 1990 to 27% of energy in Europe will be from renewable sources and 30% improvement in energy efficiency.

At a time of great concern to the European and national economy, the approach to energy efficiency by the perspective of cost-effectiveness may explore new technologies and approaches to planning consumption and energy exploitation of European economies.

The swimming pools, although they are a sporting infrastructure of difficult economic return, since they have high maintenance costs, should be seen in a social perspective, that is, measuring the social profitability they have (Aragon, 2006; Pires & Sarmento, 1999a, 1999b).

Power management in the pools appears as a present problem, but also in the near future

(Barbosa, 2007; Beleza et al, 2007; Costa, 2000; Constantino, 1999; Pires & Sarmento, 1999a and 1999b; Sarmento, 2004; Trianti-Stourna et al, 1998), since both the products and energy are becoming more expensive, which raises concern for the manager. The importance of energy consumptions in pools challenges managers, entities, public and private to refurbishment and manage making an integrated approach and optimize its energy performance.

2. Objective and methodology

Barreiro Municipal Equipment Division intended to have a study on improvement measures of energy consumption in the City of Barreiro Public Pool. The author made an internship in the city aiming to identify the potential for energy improvements to municipal pool, both in terms of reducing consumption, and identify the potential to supply energy from renewable sources. This thesis presents that approach and analysis.

The methodology used for this approach began by reviewing the literature on energy efficiency, hybrid electric production, pools, economic return, passive rehabilitation, energy audit, with particular emphasis on the possibility of adopting renewable energy in Mix logic (production call hybrid).

Then characterized the pool, systematizing the consumption, audits up its energy situation, which analyses the various types of consumption as a base to support the improvements to be analysed. For those points we analyse the possibilities of solutions to adopt in order to improve energy performance, by searching for the systems efficiency improvement from the perspective of consumption, passive performance (constructive solutions of the building), and forms to supply energy from a renewable basis, whether solar heating of hot water, as for photovoltaic, wind power and sometimes biomass or other.

For each of the solutions was systematized their characteristics and investment costs, operation and benefits. All projects requiring investment, whether public or private, should always be subject to a previous analysis of economic viability. It should be estimate the return time of that investment. Feasibility studies, helps outline investment priorities. The study conducted will determine the following parameters: Net Present Value; Internal rate of return; Payback period and profitability index.

After reducing consumption we seek to identify the renewable energy mix, for this purpose using the HOMER program (in order to define which energy sources to consider, including quantitative supply and their viability). Thereafter we discuss the approach performed and results obtained, and findings are systematized, and potential future developments and references used throughout the thesis. The thesis also includes a set of annexes which complements the information presented.

3. Energy Efficiency

3.1 Reducing consumption

There are today a large number of research papers on energy conservation approaches. These methods can be classified into five broad categories: Policies, regulations and programs; efficient technologies; building design and efficient materials; renewable energy sources and behaviour change.

The passive energy rehabilitation of buildings is one of the essential basic components to be adopted in order to achieve minimize losses and undesirable gains (Baker, et al., 1992). Katsaprakakis (2015) when analysing cases of pools, states that the passive component can be extended to the supply of energy, highlighting in this case that a passive solar system can reduce up to 90% of thermal loads. The thermal insulation of opaque façade and glazing will have a key role. The balance between heating, cooling and natural lighting is an important consideration in choosing the orientation and size of the openings (Goulding et al., 1993).

The glazed areas may account for about 30-40% of total heat loss from buildings in winter and in summer may be responsible for inner overheating problems and for much of the cooling needs (Pinto, 2002).

The way to examine the energy consumption of a building can have a different level of complexity. There are several approaches used one of the possible and usual cases is energy audit. There are several approaches and Almeida (et al, 2007) states that it is desirable to divide the conduct of an audit in four phases: Documentary data collection and analysis of evidence obtained; site visit with examination of the equipment; analysis of the data collected and preparation of the Audit Report.

A complementary way is to highlight the use of energy simulation tools allowing the improvement of the studies and the consequent optimization of energy performance of buildings, as is the case with DesignBuilder software, an interface for dynamic thermal simulation program EnergyPlus. It allows a quick and easy introduction of geometries and provides a set of tools that make it easy modelling of buildings.
The CNQ Directive No. 23/93 of quality in pools for public use is specific about the quality of air that the swimming pools are required to have. The main energy consumptions derived from heating the pool water and the space air conditioning (Trianti-Stourna et al., 1998), which in turn require spending high levels of electricity and fuel, making these, the most important parts in the energy bill of a pool (Beleza et al., 2007).

3.2 Renewable energy

As it is increasingly been witnessing, the application of renewable energy in various types of enterprises, including swimming pools, as exemplified by, among others Katsaprakaki (2015) examines the implementation of renewable energy for heating a swimming pool.
In recent years, several studies were made on the viability of hybrid power systems. The present state simulation, optimization and direct control of solar-wind hybrid systems with storage batteries is described by Wei Zhou et al. (2010).
The increased complexity compared to a simple power source system, namely: its complicated the design of hybrid systems, nonlinear characteristics of components, high number of variables and parameters that should be considered to optimize the design, and the fact that the optimized configuration and control strategy are independent, makes hybrid systems difficult to be planned and analysed.
The need to measure and evaluate what are the best solutions has given rise to the emergence of various models and support programs, with emphasis on different methods of optimization of hybrid systems (Arribas et al. 2011), such as PV-SPS, RETScreen, TRNSYS, INSEL and HOMER.
Of all the programs analysed, HOMER turned out to be suitable to simulate not only photovoltaic systems, as well as wind farms, hydroelectric generators of small scale and using various types of fuels such as diesel, ethanol, biomass and hydrogen.

4. Barreiro Municipal Pool

4.1 Major characteristics

The building in question is located on the northern waterfront of the city of Barreiro. The original project was designed in 1971. The building was designed to make the most of local solar conditions, with large windows to the south and west (figure 1).

Figure 1- Pool façade

The space is divided between the Municipal Swimming Pool, level 0, and the Pensioners Association of Barreiro occupying the first floor of the building. This was designed to serve up to 300 users, today, after several modernization works, it can serve up to 400 users, with the daily average, according to officials, approximately 350 users, with a peak 60 in the evening.
Having been designed in the '70s, the walls solution is a simple masonry wall with plaster and brick. More recently, thermal performance improvement measures were made investment to subsidize the simple glazing with new double glazing. The cover was also changed from the original design concrete shells for sandwich panels (Figure 2).

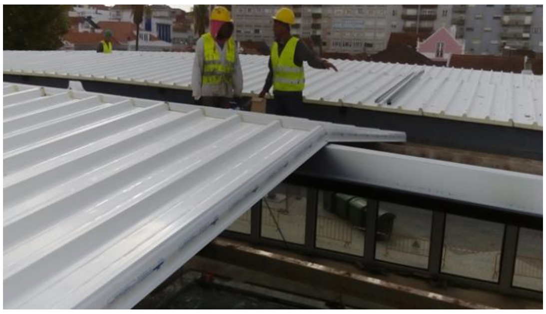

Figure 2- Roof replacement

4.2 Consumption

The pool has the following characteristics, an area of 1485 m² and an average of users of 4000 per year, annually has a consumption of 89440.50 kWh costing 51,453.71 € in the form of electricity and natural gas, 68% of the turnover is due to consumption of gas for heating of sanitary hot water and water replacement in the pool. In early September 2015 the author carried out the audit of the building, there were several visits, in which it was done a survey of all equipment, whether lighting, HVAC or other, existing to determine the installed power and create a computer model of the thermal behaviour and energy of the building, in order to study possible solutions. In order to assess the type of use of equipment, and hence their spending, interviews were conducted with employees in order to determine the usage patterns. The use of the building is entirely dependent on their opening hours, the building being used every day of the week, with different schedules is thus expected that has considerable energy expenditure.

4.3 Energy performance analyse

To disaggregate the intake and based on the obtained information, a Base Model was created (figure 3) which represents the building and existing systems. After the simulation of the Base model, you can identify how energy expenses are distributed (figure 4).

Figure 3 -Model of Building

It is found that the large consumption is due by the electric pump and dehumidifier, the separation of the two equipment consumption is possible by multiplying the power of the electric pump for 8760 hours, since it works all year at full power.

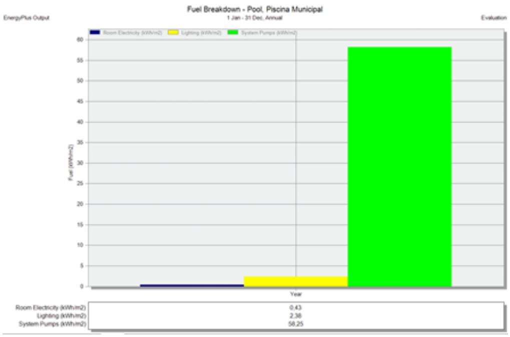

Figure 4 -Consumption example of output

The solar gains (figure 5) will influence more spending, since the south and west surroundings are mostly glazed is expected large solar gains, and these can reach 196.62 MW in a year.

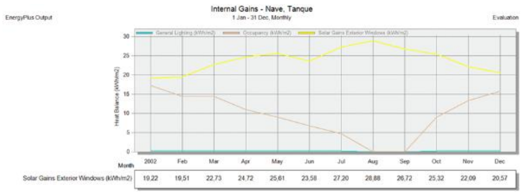

Figure 5 – Major solar gains in the base model

5. Measures to reduce consumption

There was proposed and analysed four solutions, those seeking to solve the excess solar irradiation and large variations of temperature of indoor air, in all solutions there was integrated the profile of use of an E-speed Variator in the electric pump. The temperature of the water in the tank is changed to 26 °C. The proposed solutions are: 1: indoor temperature control through automatic climate control; 2: Same as solution 1, with the addition of shading flaps in the glazing; 3: Same as solution 1, with simple walling of a part of the glazing area; 4: Same as 3 but with walling solution with ETICS.
Upon completion of the phase of possible solutions simulation, it is possible to compare the reduction of expected consumption for each solution. It should always be borne in mind that the ultimate goal is to reduce overall costs of electricity and gas, with particular attention to costs gas since these represent 68% of the total. The consumption reduction predictions are displayed in Table 1

Consumption [MWh]			
Solution	Electricity	Gas	Totals
Base	88.28	373.36	461.64
1	67.60	194.19	261.79
2	62.08	164.48	226.56
3	73.81	328.08	401.89
4	46.87	313.19	360.07

Table 1. Comparison of consumption of the various solutions

The consumption presented show that all solutions have reduced when compared with the current state, or base, of the building. It should be noted as a reduction of the glazed area in Solution 3 leads to a higher power consumption than that observed in the solutions 1 and 2, which associated with higher losses by convection, which promotes higher evaporation rates will lead to higher gas consumption by boiler to compensate for the evaporated water. Solutions 3 and 4 have great convective losses, even Solution 4 showing a great improvement in the consumption of electrical due to convective losses. After this, an investment analysis was performed to the two best solutions, 1 and 2.

The analysis of investment costs and return of the solutions shows that both solutions feature improvements over the current situation, both solutions recover your investment in less than four years, to the advantage of Solution 1, however Solution 2 quickly pays off their higher initial investment. The lower cost of solution 2 leads to a higher return over the years, in annual accumulation of operating costs.

Solution	Operational	Investment	Return on Investment
Base	315,073.30 €	-	-
1	192,558.25 €	36,577.66 €	71,306.32 €
2	168,565.66 €	48,749.03 €	78,258.99 €

Table 2. Summary of investment and return solution

The tested solution 2 is the most effective solution for reducing energy consumption, and consequently the reduction of costs for the municipality. In the next chapter we analyse the ability to meet the electricity needs for the building in its current state and to Solution 2, for this is use the HOMER software.

6. Supply renewable energy with hybrid systems

To get a real sense of system costs, we chose to look for existing equipment in the domestic market. As such, we analyse the photovoltaic equipment and wind turbine provided by the manufacturing sector, Americo Carreira, Renewable Energys, a company that sells all the equipment needed for hybrid production solutions.

The choice of equipment is made by the benefit (power) that they produce for every euro invested by changing the logic of choosing the cheapest equipment to the equipment that produces more for the same cost. It consumption of the Base Model is estimated at 245kW /day.

The results indicate that the best solution is a non-hybrid system, comprising three wind turbines.

For the Solution 2, knowing the expected consumption to be around 156kW/day, the results indicate a hybrid solution, composed of three wind turbines and four photovoltaic panels. This solutions predicts that it can provide an average of 75% of the total energy demanded.

7. Results discussion

The Mix energy analysis is conclusive that the recommended solution has great potential for improving energy consumption in relation to the building, as it exists today. The investments required for the implementation of the proposed solution is of 48,700 € for passive and active solutions discussed in Chapter 4, and 33,300 € foreseen in chapter 5 for the power generation mix, amounting to a total investment of 82,100 €, however the combined return on investment is 125,000 €. This massive investment for a municipality in difficulty can be done in stages, but it must take into account the order in which these steps can be done, since there is interdependence between the different components of the solution. The correct phasing of the adoption of the solution gives the expected profit.

The first intervention to be done is the installation of electronic variable speed, this little device allows savings of 38,000.00€ per year by reducing the use of electric pump. Then we must invest in the placement of a

new air conditioning system (HVAC) to control the temperature difference between the air inside the pool and the water temperature. Third will be the laying of exterior shading, these by limiting the direct irradiation on the pool, will made the work HVAC system more efficient.
The final intervention is the renewable Mix, not because it's not capable of supplying the original solution, the renewable sizing pointed out as ideal for solution 2, three wind turbines and four photovoltaic panels are the same, except the photovoltaic panels, pointing to meet 48% of the electrical needs of the current building.
The only suggestion in order to introduce all other interventions is gaps in information (see paragraph the following limitations) and in addition a weight of investment.
Thus it is considered that one should not take the risk of acquiring a "white elephant", associated with the image a wind turbine that does not work properly. This is a counterproductive idea for the taxpayer, brings with it political consequences, not only directly through votes, but also to the municipal management team, that can become very resistant to adopting energy production measures, even if properly supported in technical and economic point of view. Therefore, the time between each intervention should be used to obtain data for at least one year, of wind availability and solar actual site.
The analysis of the current energy balance and the proposals of suggested measures highlight the increasing energy efficiency, making the reduction of consumption of the order of 51%. In the limit of the new consumption can be achieved providing local renewable energy on the order of 75%.

8. Conclusions and further development

The built environment in general, and the pools in particular are important in energy consumption, leading the charge to seek to ensure their energy efficiency (optimization of energy consumption) this was the question that arises in the pool of the Municipality of Barreiro.
The rising energy costs and budgetary constraints, Particularly in the public sector, has created great constraints on public budgets, Resulting in the need to reduce operating costs with the public buildings, without Thereby to diminish the quality of service offered to its citizens.
This study aims to reduce energy consumption in the Municipal Pool of Barreiro, since this old facility presents significant expenses to the municipality. For this purpose, a survey of the state of the building the done, on its equipment and the behaviour of its occupants in order to determine the origin of the high spending on power and consequently the improvements that should be adopted, so can effectively reduce spending.
In order to simulate the behaviour of the building in its current configuration, as well as improvements amended, it was used the EnergyPlus with the DesignBuilder software as an interface.
After determining the solution that meets the objective of cost reduction, it was used the HOMER software, to determine the solution for local renewable energy production, particularly with focus on hybrid solutions, e.g. two or more sources of renewable energy, with the intention of creating the system that can minimize the problem of intermittency of renewable energies, in this case, of solar and wind origin.
Finally, this study is seen as a comprehensive approach to the demand for energy efficiency and renewable production site, e.g. not limited on one area of intervention (constructive, mechanical, electrical and others), but in the search for a solution in various areas of engineering are integrated.
It should be emphasized that due to the lack of any measurement equipment makes all this fundamentally a theoretical exercise, it is not possible to make direct comparisons of the calculations with reality, this is especially worrying in gas costs, there is no way to be sure of consumption in the pool, the lack of accountants in the circuits of the tank and spas does not determine whether the calculated amounts of energy required for the tank are within the real, or rather far out of reality. This leads to potential design errors of the HVAC system for the interior of the ship, which may be oversized or undersized, with the expenses that this entails.
Among the information gap is to highlight: the lack of local data on the local climate,

which is the basis for the smooth operation of the wind turbine proposals that is the major contributor in the production of the suggested solution; missing data using the pool as well as data on how to use the equipment proved as limitations. To overcome these limitations an approach is done to equivalent data and users to fit existing assumptions.

As future developments in academics is recommended: Deeper research of passive solutions for pools and development of optimization models built for the management of everyday life, the deepening of climatic local studies to support wind power solutions as well as ways to enhance using an energy mix, that considers as geothermal and other biomass same as complementary shape.

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