Extended Abstract

Selection of energy and water efficiency solutions
Analysis of the Setúbal Camping Park case

Pedro Duarte Alves da Cunha Silva Miguel

Introduction

Nowadays, our society is going through a big problem in terms of sustainability. The exponential increase in population accompanied by a great industrial development has not only increased energy consumption values, increasing the release of harmful gases into the environment, but also increased water consumption values.

Therefore, the theme of sustainability has gained more relevance in recent times. It is intended in this way to create solutions that respond to current needs. Some of the solutions to these problems are the investment in the use of energy from renewable sources, the use of equipment with greater water efficiency and the reuse of wastewater.

Oil reserves are estimated at 3 trillion barrels, and this amount is capable of generating 1.7×10^{22}J of energy. This energy value is equal to that generated by the sun every day and a half on Earth. On the other hand, current annual energy consumption is around 4.6×10^{20}J, which corresponds to the energy delivered by the sun every hour (Crabtree & Lewis, 2007)

That said, it is understood that in the future a new approach should be taken with regard to the use of fossil fuels, since the energy delivered by the sun annually is more than enough to eliminate the need for human consumption (Monteiro, 2018)

A good example of a sector that consumes too much fossil energy is civil construction. This industry is one of the most important in Europe, being responsible for the production of 30% of the carbon emissions of the entire industry (Torgal & Jalali, 2007). Taking these values as a reference, it is easy to see that sustainability and energy efficiency have gained a lot of importance in recent years. Sustainability and energy efficiency are defined as the optimization and rationalization of available resources in order to guarantee the needs of the present without compromising the needs of future generations.(Nazaré, 2019)

Due to this emerging need, building assessment and certification systems such as LEED (in the United States of America - USA), BREEAM® (in the United Kingdom) and HQE™ (in France) began to emerge in the 1990s.). These systems came to encourage construction to meet certain levels of sustainability and energy performance. Thus, there has been a tendency in construction to adopt constructive measures and options that will contribute to a more efficient use of available means and resources.

A sustainable solution on which we have been committed is modular construction, a type of construction that saves time, financial resources and reduces energy consumption.

The constructive phase of traditional houses is responsible for a large part of the total energy consumption throughout the building's life cycle. Modular solutions can be built in a much shorter period of time, which is an asset to consumption at this initial stage. Another added value of this solution is the greater control of the materials used in the process, thus avoiding waste. It is the very nature of a modular house that allows for greater rigor in the design and construction phase even in the factory. This attention to detail in an early phase, prevents constructive errors that create expenses and energy waste (such as heat losses due to linear thermal bridges, among others). The absence of these construction errors generates greater energy efficiency, avoiding, for example, the use of temperature regulating devices(Kamali & Hewage, 2017)

In addition to energy use, another problem associated with construction is the efficient use of water resources. As is known, only 2.5% of the water present on our planet is fresh water and 2/3 of this water is stored in the polar ice caps, that is, only 0.77% of the water is available for human consumption(Grassi & Cantarell, 1973). It is, therefore, imperative to adopt a strategy to control the reuse of available drinking water. The measures that must be adopted for a more efficient use are the reduction of consumption levels, losses and the use of alternative waters (ocean water, rainwater and the reuse of wastewater) (Afonso, 2010).

In this dissertation, the problem analyzed is how to incrementally and sustainably rehabilitate a campsite, the case study presented is the modular bungalows of the Ecoparque do Outão da Serra da Arrábida and its symbiosis and integration in the park itself. These bungalows are part of a rehabilitation project, whose objective is to make the park more sustainable and attractive. The method of analyzing the sustainability of the bungalows and the park was based on the certification system created in Portugal known as LiderA®

Case Study

The case study presented in this dissertation is the Ecoparque do Outão in Serra da Arrábida and, in particular, the modular bungalows installed here. This campsite is in a privileged area for the use of solar and water resources. Since this is a park that promotes sustainability, an analysis will be made of its effective contribution to this theme and what changes can be made to contribute to the development of sustainability.

Objectives

The objective of this study is to assess the sustainability in terms of energy consumption and water efficiency of the bungalows installed in the Ecoparque do Outão, in Serra da Arrábida, and then transpose this sustainability assessment to the entire Ecoparque.

This sustainability analysis focuses on three main evaluation criteria. These are the energy efficiency criterion, the passive design criterion (which is directly related to the above) and the water supply system criterion. These criteria are based on the LiderA® assessment and certification system.

Thus, the aim is to assess and identify the park's water and energy consumption zones and propose solutions that improve environmental performance.

As an ultimate result, it is intended to reduce energy consumption from fossil fuels, thus reducing carbon dioxide emissions into the atmosphere. It is also intended to reduce the consumption of potable water from the supply network. In this way, the ambition is for the Ecoparque do Outão to become an example in the development of sustainability.

Methodology

Initially, it was determined the water and energy consumption areas in the bungalows. Then, it was estimated the water consumption, considering the equipment’s water flow and the average time use per user. This consumption projection was based on the current occupation of the Ecoparque. At this stage, the annual energy needs for both heating and cooling were also calculated. Transmission heat losses, solar gains, and gains from air renewal were taken into account.

After all the calculations, the proposed solutions for reducing the consumption of water and energy for the bungalows were presented. Regarding water consumption, the solutions included the introduction of a flow reducer in the bathroom tap, the replacement of the shower system with a more efficient one, and the application of a gray water recycling module. Regarding energy, the proposed solution included the installation of three solar panels of 250 W in each bungalow. Subsequently, it was made a cost estimation, and the respective payback period was calculated. Ultimately, an assessment of the passive performance of the bungalows was carried out and changes were proposed that contribute to the reduction of annual energy needs.

Subsequently, based on the study carried out in the bungalows, the solutions were applied to the entire park. The Ecoparque's consumption zones were initially determined, both in terms of energy and water, and similarly to what had been done before, a consumption scenario was drawn up for current occupancy levels. Having estimated the average monthly consumption of water and energy, it was proposed to install two gray water recycling modules, one in each bathhouse, and to apply a set of 45 panels of 400 W. Subsequently, technical and economic feasibility of the proposed solutions was evaluated.

Bungalows Consumption Zones

The water consumption solutions and equipment present in the bungalows were studied. The objective was to estimate the average water consumption and present improvement solutions to reduce consumption.

In the five bungalows there are four different water consumption devices (Table 1).

Table 1 - Number of water consuming equipments in the bungalows

Equipment	Number of equipments
Washbasin faucet	5
Sink faucet	5
Shower	5
Toilets	5

To estimate the current water consumption in the bungalows, it was carried out an *in situ* measurement of the flows corresponding to each equipment (Table 2).

Table 2 - Water consumption of each equipment in the bungalow and respective ANQIP water efficiency rating

Equipamento	Consumption (L/min)	ANQIP water efficiency class
Washbasin faucet	5,3	A
Sink faucet	9,3	D
Shower	7,7	B
Toilets	6	C

Once it was established the water consumption scenario for each equipment and taking into account the average times of use, it was calculated the total average daily consumption. It was possible to verify that the device with the highest daily consumption is the shower system. **492.85 litters** of water are consumed daily and each person consumes an average of **98.57 litters of water per day**.

Then, the same analysis was performed for electrical consumption equipment. First, it was determined the annual energy needs for both heating and cooling.

In a first stage, it was determined the heat transfer by transmission through the determination of the material thermal conductivities in the bungalows. The value obtained for the heat transfer coefficient by transmission in the bungalows was **83.24** (W/ºC).

In addition to the transmission heat transfer made directly to the outside, it was necessary to also account heat transfers by air renewal and solar gains. Heat transfer by air renewal, both in winter and in summer, can be obtained using the formula (1).

$$Hve = Rph, i, v \times Floor\ useful\ area \times Hight \qquad \textbf{(1)}$$

It was thus obtained for the heating season a value of Hve, i = **8.58 (W/°C)** and for the cooling season a value of Hve, v = **10.51 (W/°C)**.

Regarding solar gains, it was important to evaluate the type of windowpane, its orientation, the type of horizontal and vertical shading and the opaque exterior surroundings.

Therefore, it was possible to calculate the thermal gains in the heating season and in the cooling season. These gains are calculated as the sum of the internal thermal gains and the solar gains.

In the heating season:

$$Qg, i = Qsol, i + Qint, i \ = 639{,}94 + 278{,}84 = 918{,}79\ kWh/ano \qquad \textbf{(2)}$$

In the cooling season:

$$Qg, v = Qsol, v + Qint, v \ = 417{,}80 + 280{,}34 = 698{,}14\ (kWh/ano) \qquad \textbf{(3)}$$

Having determined the values of heat transfer by transmission, air renewal and solar gains, it is possible to calculate the annual energy needs through formulas (3) and (4).

In the heating season:

$$Nic \ = \frac{Qtr, i \ + \ Qve, i \ - \ Qgu, i}{Ap} \quad (kWh/m2 \cdot ano) \qquad \textbf{(4)}$$

In the cooling season:

$$Nvc = (1 - \eta v) Qg, v / Ap \qquad (kWh/m2 \cdot ano) \qquad \textbf{(5)}$$

The values obtained were **58.31 (kWh/m2·year)** and **7.67 (kWh/m2·year)**, respectively.

During a visit to the Ecoparque do Outão, it was determined the electric power values of each equipment present in the bungalow. For the consumption calculation, an estimate of the average time of daily use of each equipment was used. In the case of the refrigerator, the value given by the supplier was assumed and for the air conditioning the value was estimated based on the heating and cooling needs calculated previously.

Therefore, there was a monthly consumption per bungalow of **415.3 kWh**.

Proposed solutions for *bungalows*

Efficient Devices

To achieve greater water efficiency in the bungalows, it is proposed to adopt measures to reduce water consumption. For example, it was suggested to apply flow reducers to washbasin taps and to replace shower systems. The application of these devices led to a reduction in annual consumption of **35.37 m^3** of water, equivalent to an annual saving of **€315.7.**

Use of gray water

To reduce water consumption, the installation of a modular system for the reuse of gray water was also proposed. The goal would be to use the water from the washbasin tap and shower system for the flushing toilets. The installation of this system leads to a reduction in consumption of **43.2 m^3** per year, equivalent to an annual saving of **€385.6**.

Photovoltaic System

Regarding energy, the proposed solution to reduce consumption was the installation of 3 photovoltaic modules in each bungalow. The dimensioning of this solution was elaborated with the help of the PvSyst 7.1 program. This solution would lead to annual savings of **1283.6 kWh/year** equivalent to **€249 per year**.

Application of modular systems at Ecoparque

Subsequently, it was evaluated the possibility of installing the modular systems in the remaining Ecoparque. For this it was necessary to study the consumption zones, both in terms of water and energy.

Consumption zones in the Ecoparque

Water Consumption

The areas responsible for water consumption in the Ecoparque are two bathhouses and a laundry. Table 3 shows the number of existing water consuming equipment.

Table 1 - No. of Water-consuming Equipment in the Ecopark

	Bungalows	**Laundry**	**Bathhouse 1**	**Bathhouse 2**	**Total**
Washbasin faucet	5	-	16	16	37
Sink faucet	5	-	-	-	5
Shower	5	-	17	17	39
Toilets	5	-	16	16	37
Washing machine	-	18	-	-	18

Taking into account the average time of use of the equipment and the average number of users in the park (41 people/day), it was possible to estimate water consumption. In total, it is estimated that around 6617.4 liters of water are consumed per day, corresponding to 161.4 liters per person per day.

Energy consumption

Regarding energy consumption, it was possible to ascertain, through data provided by the park managing entity, that in 2018 were consumed 52216 kWh, in 2019 were consumed 82135 kWh and in 2020 the value was 54779 kWh until the month of October (table 4).

Table 2 - Energy Consumption at Ecoparque in 2018, 2019 and 2020.

	Empty normal (kWh)	Super Empty (kWh)	Peak (kWh)	Flood (kWh)	Total (kWh)
2018	12787	7297	10606	21526	**52216**
2019	21195	11776	16725	32439	**82135**
2020	15822	9979	9905	19073	**54779**
Total (kWh)	**49804**	**29052**	**37236**	**73038**	**189130**

Having these base values for water and energy consumption, it was possible to dimension the modular solutions.

Proposed solutions for the Ecopark

Similar to what was proposed for the bungalows, the installation of a gray water recycling system was also proposed for the Ecoparque.

Water is collected from outdoor showers, washbasins and indoor showers. The water is then sent to the treatment plant and subsequently sent to all toilets and washing machines. The figure shows a simplified scheme of the system installation model.

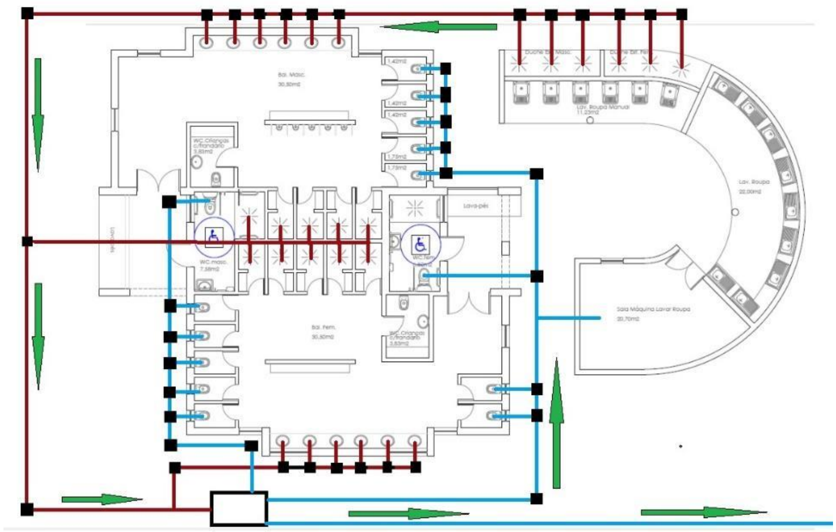

Figure 1 - Simplified diagram of the gray water recycling system installation model.

With the installation of a gray water recycling model in each bathhouse, it was possible to determine that the annual water saving is equivalent to 752.76 m^3, in other words, a saving of €6719.14 per year.

Table 5 - Monthly and annual costs after installing the Gray Water Reuse System at EcoParque

	Monthly consumption (m^3/month)	Anual consumption (m^3/ano)	Coast (€/month)		Anual coast	Total
Before Instalation	198,5	2382,26	Water	445,88	5350,56	21264,09
			Collection	1326,13	15913,52	
After instalation	135,8	1629,5	Water	304,99	3659,87	14544,95
			Collection	907,1	10885,09	

Regarding energy, the proposed solution was to install 3 series of 15 panels (400 W each), thus giving a total of 45 solar panels. The installation of this system, according to the PvSyst 7.1 analysis program, injects 29 858 kWh/year into the system. This value is calculated taking into account the database consulted for local radiation and for the efficiency of the chosen panels and their orientation.

The average energy consumed annually during the hours of sunshine in the last three years was 26744.3 kWh/year, so the value obtained in the simulation is sufficient to guarantee the annual energy needs of the Ecoparque. This solution led to annual savings of **€5792.50.**

Conclusion

Regarding the bungalows, it can be concluded that the proposed solution of applying more efficient devices, such as the flow reducer in the washbasin tap and changing the shower system, produced a 20% reduction in consumption with a period of 4.4 months return on investment. Which made the investment quite viable.

For the gray water recycling system in the bungalows, it was found that the reduction in consumption was 30%, but the payback period on the investment was quite long, assuming a value of 23.8 years, thus making the initial investment unfeasible.

Regarding the set of 3 photovoltaic panels proposed for the bungalows, it was found that there was a reduction in consumption of around 50% and that the payback period was 3.8 years, thus making this proposal viable.

Some considerations could also be made about the passive design of the bungalows. Through the calculations carried out, it was found that there were conditions to reduce existing heat losses and maximize solar gains. It was therefore proposed: a reinforcement of isolation in the zones of linear thermal bridges (which would lead to a decrease in the annual energy requirements for heating from 58.31 kWh/m^2·year to 33.31 kWh/m^2·year), the elimination of the pergola at the entrance of the bungalow (in order to reduce vertical and horizontal shading), the orientation of the bungalows to the south and the adoption of a darker tone for the exterior finishing of the bungalows.

In short, if only the most immediate solutions were adopted to replace less efficient equipment and the installation of the photovoltaic system in the bungalows, it would lead to savings of around €546.71 per year, with a payback period of 3, 8 years.

Contrary to what happened in the bungalows, the application of gray water recycling modules in the Ecoparque bathhouses led to a much shorter payback period, of 4.41 years, with an annual savings of 6719.14 euros. It is thus concluded that it is a very attractive proposal.

With regard to photovoltaic modules, two scenarios were analysed. In the first scenario, the energy produced by the photovoltaic system is used at 100% and an annual saving of €5792.5 is obtained, with a payback period of 3.1 years. For the second scenario, it is assumed that the energy consumption of the park throughout the year is equivalent to the amount consumed when it is closed. In this scenario, an annual saving of €4128.94 is obtained, with a payback period of 4.36 years.

In short, it is concluded that photovoltaic modular solutions are investments with quite acceptable payback periods and that translate into significant savings throughout the year. Regarding gray water recycling systems, it was concluded that the proposals are interesting for higher water consumption levels.

Bibliography

Afonso, A. S. (2010). Uso Eficiente da Água nos Sistemas Prediais. *Seminário– Aveiro, 12 de Fevereiro de 2010*.

Crabtree, G. W., & Lewis, N. S. (2007). Solar energy conversion. *Physics Today*, *60*(3), 37–42. https://doi.org/10.1007/978-90-481-3830-2_7

Grassi, G., & Cantarell, F. S. (1973). *La construcción lógica de la arquitectura*. Colegio Oficial de Arquitectos de Cataluña y Baleares.

Kamali, M., & Hewage, K. (2017). Development of performance criteria for sustainability evaluation of modular versus conventional construction methods. *Journal of Cleaner Production*, *142*, 3592–3606. https://doi.org/10.1016/j.jclepro.2016.10.108

Monteiro, A. C. (2018). *Aplicação de painéis solares em edifícios públicos para autoconsumo fotovoltaico*. Instituto Superior de Engenharia de Lisboa.

Nazaré, M. (2019). *Definição de Soluções Viáveis para a Gestão Sustentável da Água no Edificado. Caso de Estudo do Ecoparque de Campismo do Outão*. Instituto Superior Técnico.