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All enquiries to:

Mrs Eleanor Eaton

Coordinator, Watef Network and
WATEFCON 2018 Conference

Email: info@watefnetwork.co.uk

Or:

Dr Kemi Adeyeye

Lead, Watef Network

Centre for Advanced Studies in Architecture Department of Architecture and Civil Engineering University of Bath

Email: k.adeyeye@bath.ac.uk

Preface

This bi-annual conference is organised by the Water Efficiency Network. The network is a global group of academics, industry practitioners, NGOs, interest groups and members of the public who share a common interest in promoting water resource efficiency and resilience, progressive water policy, useful and usable codes and standards as well as general best practice. The network was established in 2011 with the support of the UK Government's Department for Environment, Food & Rural Affairs (DEFRA) and is still going strong thanks to its many dedicated members and technical committees.

This volume contains the papers presented at the Water Efficiency Conference (WatefCon) 2018 held on September 5-7, 2018 in Aveiro, Portugal. Over 60 submissions were received and managed via the EasyChair online conference management system. Each submission was reviewed by at least 2 scientific committee members which decided to accept 36 papers full papers and others as extended abstracts and poster submissions.

This year's proceedings also include 3 invited keynote speakers and 2 special industry sessions. The first industry session on Water Efficiency Labelling is organised in collaboration with ANQIP: Associação Nacional para a Qualidade nas Instalações Prediais together with leading experts from Europe to discuss this topical issue. The second industry session on Micro Hydro Energy Recovery and System Control towards Smart Water Grids is organised in collaboration with the EU Interreg Atlantic Area project, REDAWN: Reducing Energy Dependencies in Atlantic Area Water Networks. The REDAWN project brings together 15 partners (including the WATEF Network) from 5 countries around the European Atlantic coast to foster the adoption of hydropower energy recovery technology in built water networks in the Atlantic Area. The project is co-financed by the European Regional Development Fund through the Interreg Atlantic Area Programme. Details about the project can be found at www.redawn.eu.

I am grateful to all the contributing authors, presenters, session chairs, the keynote speakers and panel members of the industry sessions. This conference will not be a success without you all. I am also grateful to our sponsors: ANQIP, OLI, ADENE - Agencia para e Energia, HELIROMA Hot water solutions, Agencia Portuguesa do Ambiente and HEABOO disruptive techs.

My sincere thanks to this year's conference chairs: Prof Armando Silva Afonso and Dr Carla Pimental Rodrigues of ANQIP, who in addition to their editorial efforts on the proceedings have helped to make our first conference foray outside of the UK a big success. We also thank our hosts and colleagues at the University of Aveiro.

Lastly, thank you to Eleanor Eaton for going 'over and beyond' in her management of the network and its activities. And to all our technical committee chairs and members, who continue to be generous with their time, expertise and resources to ensure that the network continues to be relevant and effective in delivering our vision and aspirations.

I wish everyone a pleasant time in the charming city of Aveiro, and an enjoyable and productive conference.

July, 2018
Bath UK

Dr Kemi Adeyeye
Lead, Water Efficiency Network

#7. Water efficiency in all sectors; domestic, industry, agriculture etc.

#8. Water-energy, water-energy-food nexus

#6. Water in nature: hydrology, land use, low and high peak trends etc. + Water quality, reuse and recycling

Technical solutions for water reuse in a social and cultural center

Sofia Abrantes[1*], Flora Silva[2], António Albuquerque[1]

[1]Department of Civil Engineering and Architecture, Faculty of Engineering, University of Beira Interior, Calçada Fonte do Lameiro, 6201-001 Covilhã, Portugal.
[2]School of Technology and Management, Polytechnic Institute of Bragança, Campus de Santa Apolónia, 5300-253, Bragança, Portugal.

ABSTRACT

This study evaluated the potential of water reuse in a social and cultural center, proposing solutions for the reduction of potable water consumption and testing the technical feasibility of four water reuse solutions. One of the solutions only suggests the replacement and/or the modification of the equipment, whilst the remaining solutions point out for the use of rainwater for supplying the cleaning water cisterns with variation of the volume.
Any of the solutions can be implemented and would lead to a considerable reduction of the water consumption and the water service cost. However, the use of rainwater to supply flushing cisterns entails very high investment costs compared to the savings achieved, making it unviable for regions of the country with lower water prices.
In a short time period, the solution with the fastest return investment is also the one with the lowest investment costs. However, in a long time period the greatest savings are achieved by combining rainwater harvesting with the installation of more efficient equipment for water consumption.
Therefore, in areas with lower water billing prices, the most viable investment it seems to be the adoption of high water efficiency equipment's. In areas where the billing reaches higher values, it is economically feasible to invest in a rainwater supply system, preferably in conjunction with the use of equipment with good water efficiency.

Keywords: Water reuse, Building water systems, Reduction of water consumption, Technical and economic feasibility

1. INTRODUCTION

Water is the most valuable natural resource on the planet, and its conservation is one of the most important pillars of sustainable development. In regions where the water scarcity is a natural reality, and where population growth and/or climate change are a source of scarcity, sustainable management of water resources implies conservation of these resources, which should include water reuse procedures [1].
The Portuguese National Program for the Efficient Use of Water (PNUEA) [2], which under implementation in the period 2012-2020, establishes measures for the urban, agricultural and industrial sectors that promote the efficient use of water, valuing water resources, not only environmental preservation, but also for its value for economic and social progress. Specific objectives for the urban sector include, for example, the minimization of the use of drinking water in activities that may have the same performance with alternative water quality such as the use of rainwater and the reuse of treated wastewater and the promotion of the use of

* Tel.: +351 968294022
E-mail address: sofia.alexandra.abrantes@hotmail.com

standardized and certified equipment's for the water efficient use, encouraging their production and marketing [2].
In isolated or decentralized zones, the use of rainwater presents great possibilities of use, once these waters are captured in the place where they will be consumed. Rainwater harvesting is done using pre-existing structures, and can be stored in reservoirs or cisterns and used with little or no treatment [3].
Being the shortages of drinking water a increasingly reality on most continents, with high consumption patterns associated with the progressive growth of the world's population, it is of most importance the implementation of alternative sources of water such as a Rainwater Harvesting System (RHS).
According to [4], a RHS consists of six basic components with very specific functions, namely: catchment or collection surface, transport system, filtration, storage, distribution and treatment.
In Portugal, the installation and certification of a RHS, must comply with the conditions established in two technical specifications developed by the National Association for Quality for Building Installations (ANQIP). The Technical Specification ANQIP 0701 (ETA 0701) [5] establishes the technical criteria for the performance of a RHS in buildings, for purposes other than human consumption, and the Technical Specification ANQIP 0702 (ETA 0702) [6] establishes the conditions for Certification of a RHS, performed accordingly [5]. As this type of systems is not yet widely applied in Portugal, these specifications are an important support to the development of RHS.
Due to the high billing of drinking water consumption in the Social and Cultural Center of Santo Aleixo (SCCSA), located in the village of Unhais da Serra (Covilhã, Portugal), the main objective of this study was to find possible solutions to reduce water consumption in the building. The technical and economic feasibility of four solutions and a comparison of these solutions in other areas of the country were also analysed.

2. METHODOLOGY

2.1 Description of the building and characterization of the sanitary equipment's

The SCCSA is a Private Institution of Social Solidarity, formed by a residential building (Fig. 1-a)) and a building of new valences (Fig. 1-b)). The residential building consists of a ground floor and a first floor, having in the surrounding area a garden with about 600 m^2. It has 27 residents, 27 workers and 4 children in pre-school, having 24 sanitary facilities that aim to accommodate the needs of all of them. There are 24 flushing cisterns (with 10 L reservoir), but only 2 have a dual flushing mechanism and 32 conventional single-lever mixer taps (9 L min^{-1}).

Fig. 1. Social and Cultural Center of Santo Aleixo: a) residential building; b) building of new valences

2.2 Solutions to reduce drinking water consumption in the building

Two options were studied to reduce the consumption of drinking water in the building. The first option involved a solution for replacing and modifying of some of the equipment (namely flushing cisterns and taps), and the second option involved the study of three solutions for the reuse of rainwater [7]. An analysis was made for the technical and economic feasibility of the four solutions. A comparison of the same solutions in two other areas of the country (Chaves and Faro counties) was also setup [7].

2.2.1 Option 1 - Replacement and modification of some equipment

In this option, a solution was proposed for reducing water consumption by replacing the existing flushing cisterns by dual flushing cisterns with 6 L/3 L, the 19 conventional taps by timed taps and also by installing flow reducers in other 13 taps.
From an environmental perspective, this measure has as main benefits the reduction of drinking water consumption and the consequent reduction of the volume of associated wastewater discharges.

2.2.2 Option 2 - Rainwater harvesting

In this option, it was proposed to supply the flushing cisterns with rainwater, involving the three following solutions:

- Solution 2-a: direct supplying of the flushing cisterns with rainwater, without making any change in the equipment;
- Solution 2-b: supplying of the flushing cisterns with rainwater and replacing the existing flushing cisterns by dual mechanism flushing cisterns with a capacity of 6 L/3 L.
- Solution 2-c: supplying of the flushing cisterns with rainwater and replacing the existing flushing cisterns by dual mechanism flushing cisterns with a capacity of 6 L/3 L, as well as replacing/modifying the existing taps by a more efficient taps.

2.3 Sizing of the reservoirs for rainwater building supply

For computing the volume of the reservoir for rainwater storing, there were only considered the water needs for flushing all the toilets. The water volume computing it was considered the number of uses per inhabitant per day for 30 days and not the number of flushing toilets.
Taking in account the number of people at the SCCSA (i.e. 27 residents, 27 workers and 4 children) and that they have different residence times at the building, it was considered the following residents-equivalents: the 27 workers are in the SCCSA in 3 work shifts of 8 hours each, which is equivalent to have 9 residents; the 4 children are in the building for 8 hours and have the same water consumption as an adult for 24 hours; the visiting people have a water consumption equivalent to two adults. In total, the building has 40 residents-equivalents [7].
In the solution 2-a, the supply would be made for flushing cisterns with a capacity of 10 L. It was considered 5 uses per day per inhabitant, for 40 residents-equivalents per 30 days, which gives 60 m^3 per month. Thus, a reservoir with 70 m^3 it would be adequate for flushing the toilets during one month [7].
For the solutions 2-b and 2-c, the calculation was made taking into consideration the dual mechanism cisterns with capacity of 6 L/3 L. It was considered one use of 6 L and four uses of 3 L per day per inhabitant, which gives a volume of 21.6 m^3 per month. Thus, a reservoir with a capacity of 30 m^3 it would be adequate for flushing the toilets during one month [7].

2.4 Sizing of the rainwater drainage network and the water supply network with recovered rainwater

The resizing of the building networks was done in accordance with the Portuguese General Regulation of Public and Building Systems of Water Distribution and Wastewater Drainage Systems (Regulatory Decree no. 23/95, of August 23 [8]) and the procedures suggested by [9].
The recovery rainwater for building supply (i.e. for the flushing toilets) will be stored in a reservoir located in a green area in front of the main building. The water will be pumped into the flushing cisterns through a water supply building network.
In the Fig. 2 is presented the building plant with the two building networks.

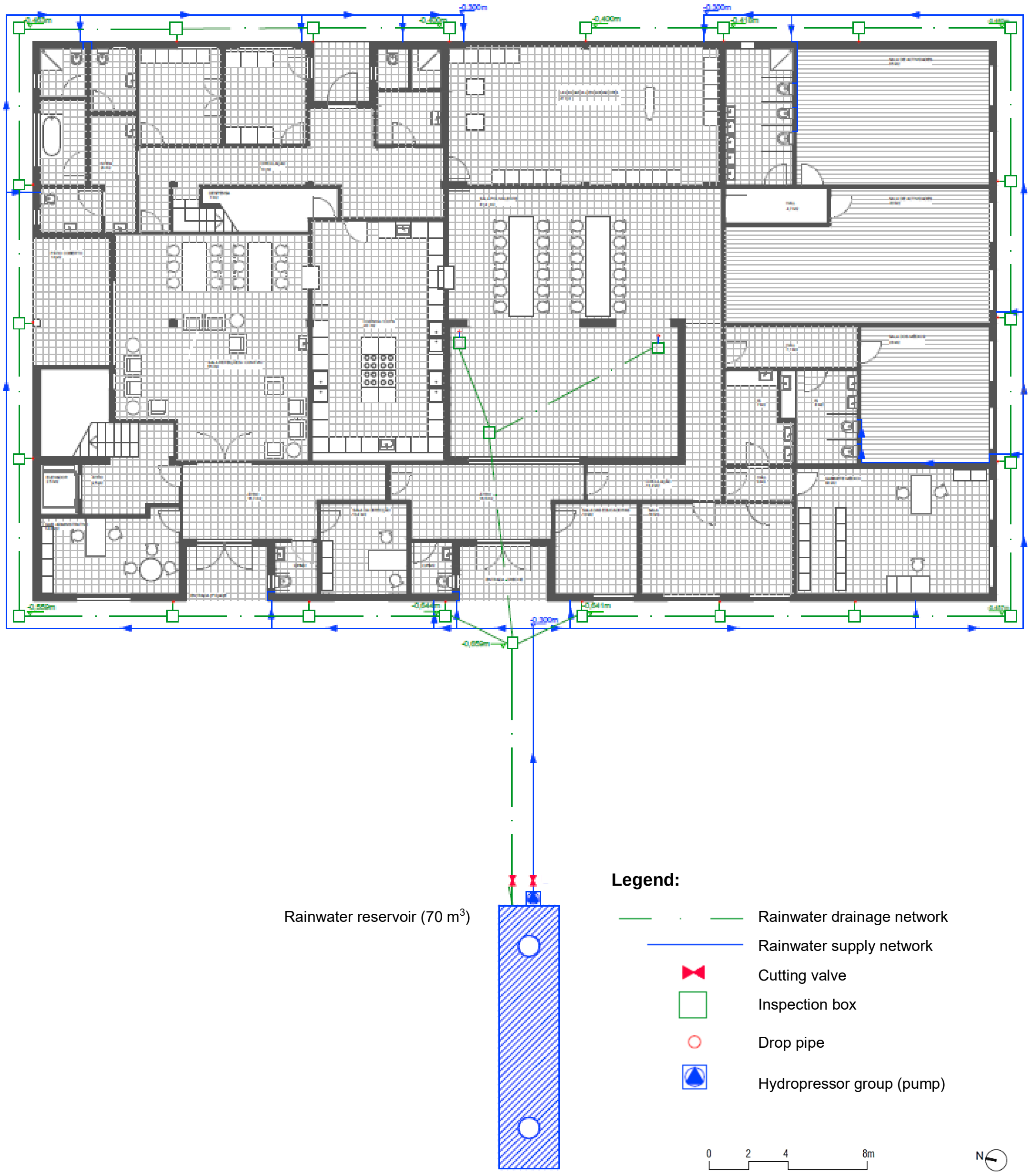

Fig. 2. Rainwater drainage network and rainwater supply network (1st floor) [7]

3. RESULTS AND DISCUSSION

3.1 Technical feasibility

Both options considered for reducing the drinking water consumption in SCCSA can be implemented, from a constructive and hydraulic-sanitary perspective [7].

Regarding the rainwater drainage network, the values of the flow velocities are within the stipulated limits, and the shear stress values are higher and could allow good self-cleaning conditions [7,8].

In the rainwater supply network, the flow rates are within the range indicated by regulation [8], from 0.5 m s^{-1} to 2 m s^{-1}. An hydropressor group (Fig. 2) will guarantee the minimum pressure necessary for the correct operation of the equipment. Therefore, the rainwater supply network is considered technically feasible.

3.2 Economic feasibility

This study was based on the volumes of water saved, on investment, operation, maintenance and inspection costs, energy costs and the time for returning the investment. The most favourable solution was considered the one that presented the greater water savings, associated with a lower investment, lower maintenance and a quick return of the financial investment.

3.2.1 Reduction of the consumed potable water volumes

The calculation of the volumes for water flushing cisterns followed the same criteria used for the volume calculation in the Section 2.3 [7].
For the water consumption in taps, there were considered the duration and average uses for the taps (10 uses per inhabitant per day, for 10 s and 9 L min^{-1}). In the calculation of the water savings were assumed the same criteria, however, it was a reduction of 5.5 L min^{-1} due to the installation of flow reducers.
In bot calculation it was considered an increase of 20% in the consumptions of water for the summer months.
Table 1 presents the average annual water volumes consumed, as well as the potential savings associated to each option.

Table 1. Average annual volumes of potable water consumed and potential savings

	Average annual volumes of potable water consumed (m^3)				
	Current consumption	Option 1	Option 2		
			Solution 2-a	Solution 2-b	Solution 2-c
Flushing cisterns	792	285.12	228.7	39.9	39.9
Taps	285.12	174.24	285.12	285.12	174.24
Total	1077.12	459.36	513.8	325.0	214.1
Savings (%)	0	57.4	52.3	69.8	**80.1**

According to Table 1, regarding savings of water resources, the solution 2-a is the one with the higher water consumption, achieving savings of 52.3%. The solution which would lead to greater savings of potable water is she solution 2-c, with 80.1% of water saving.

3.2.2 Investment Costs

The investment costs, presented in Table 2, include the costs associated with the installation of the rainwater supply network, the installation of building sewers, accessories and manholes, the earth excavation and installation/construction of the reservoir, network elements, equipment, hydropressor group and accessories, and the manpower.

Table 2. Costs associated with the installed equipment and the modification of the building networks

	Option 1	Option 2		
		Solution 2-a [1)]	Solution 2-b [2)]	Solution 2-c [2)]
Replacement and modification of sanitary equipment	5 520,00€	0,00€	3 797,04€	5 520,00€
Rainwater drainage network (including equipment, elements and accessories)	0,00€	7 720,36€	7 720,36€	7 720,36€
Rainwater supply network	0,00€	2 085,12€	2 085,12€	2 085,12€
Equipment and its installation (e.g. reservoir, hydropressor group and accessories)	0,00€	21 169,60€	10 569,60€	10 569,60€
Totals	5 520,00€	30 975,08€	24 172,12€	25 895,08€

[1)] *Considering a reservoir with 70 m^3.*
[2)] *Considering a reservoir with 30 m^3.*

Analysing Table 2, it can be observed that the equipment's for the collection, storage and distribution of rainwater are the expensive ones, namely the cost of the reservoir [7].

3.2.3 Costs and operating requirements

In a rainwater harvesting and supply building network it is necessary to replace the elements of the network, equipment and accessories throughout the operating time. It's considered appropriate the replacement of the hydropressor group and valves every 10 years [7]. The costs associated with the maintenance of equipment and replacement of the elements for each of the options are presented in Table 3.

Table 3. Costs associated with the replacement of elements and equipment maintenance every 10 years

	Option 1	Option 2		
		Solution 2-a	Solution 2-b	Solution 2-c
Equipment maintenance and replacement of elements	0,00€	2 256,00€	2 256,00€	2 256,00€

3.2.4 Reduction of the monthly and annual water billing

In the calculation of the water billing reduction, it was necessary to consult the tariffs in force for the supply of drinking water and the drainage of wastewater at the district of Covilhã, which also considers the tariffs associated with the collection and treatment of solid waste. The water service are provided by the local Council, whilst the management of solid wastes is carried out by the municipal company Águas da Covilhã (ADC) [10].

A similar calculation was computed for other two districts in Portugal (Chaves, in the North, and Faro, in the South), with different costs for services of water, wastewater and solid wastes, in order to compare savings in different areas of the country.
Applying the current tariffs of 2017 in Covilhã (for Unhais da Serra place) [10], Chaves [11] and Faro [12], there were computed the average monthly savings and the annual average savings regarding the water supply, wastewater sanitation and solid waste management for the two options [7]. The municipality of Covilhã is the one which has the highest water billing. The values are shown in Fig. 3-a) and Fig. 3-b), respectively.

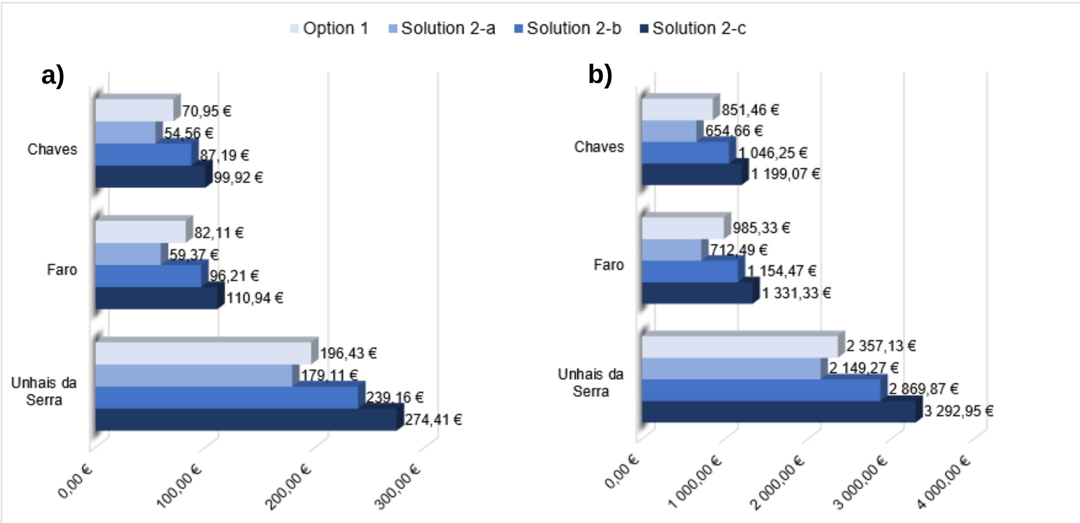

Fig. 3. a) Monthly water savings and b) annual water savings, for Unhais da Serra (Covilhã), Chaves and Faro

Analysing Fig. 3-a) and 3-b), it is possible to observe that any of the options presented is a good solution for reducing water consumption and the associated billing.
These values were calculated considering the volume of water saved and also the monthly average availability of rainfall from January 2001 to August 2017. The rainfall data were collected at the National Water Resources Information System (SNIRH) [13] in the meteorological stations of Covilhã (for Unhais da Serra), São Brás de Alportel (for Faro) and Travancas (for Chaves).

3.2.5 Return of the investments

From an economic point of view, the time for returning the investment is another criterion to consider when choosing the best solution for a reuse system. The time needed to recover the investment it was determined taking into account the total of the investment, the maintenance costs for every 10 years and the savings in the water billings [7].
After analysing all the data, it was verified that the solution most favourable to the saving of water resources, as well as for reducing the billing costs is the solution 2-c [7], whose values for the return of investments is presented in Table 4. The Fig. 4 presents the return time for the three places.

Thus, analysing Table 4 and Fig. 4 it is possible to verify that Unhais da Serra presents the higher values for water savings and also the quickly return on investments (8 years), when compared to Faro (22 years) and Chaves (24 years). For a period of 30 years, the SCCSA can save around 75 000,00 €.

Table 4. Calculation of the return of the investments for the option 2: solution 2-c

	Option 2: Solution 2-c					
	Unhais da Serra					
Years	1	2	3	…	7	**8**
Investment value	25 895,08€	0,00€	0,00€	…	0,00€	**0,00€**
Annual return amount	3 292,95€	3 312,70€	3 332,58€	…	3 413,28€	**3 433,76€**
Balance	-22 602,13€	-19 289,43€	-15 956,85€	…	-2 425,38€	**1 008,38€**
	Faro					
Years	1	2	3	…	21	**22**
Investment value	25 895,08€	0,00€	0,00€	…	2 256,00€	**0,00€**
Annual return amount	1 331,33€	1 339,32€	1 347,35€	…	1 500,53€	**1 509,53€**
Balance	-24 563,75€	-23 224,43€	-21 877,08€	…	-706,21€	**803,33€**
	Chaves					
Years	1	2	3	…	23	**24**
Investment value	25 895,08€	0,00€	0,00€	…	0,00€	**0,00€**
Annual return amount	1 199,07€	1 206,27€	1 213,51€	…	1 367,73€	**1 375,94€**
Balance	-24 696,01€	-23 489,74€	-22 276,23€	…	-929,37€	**446,58€**

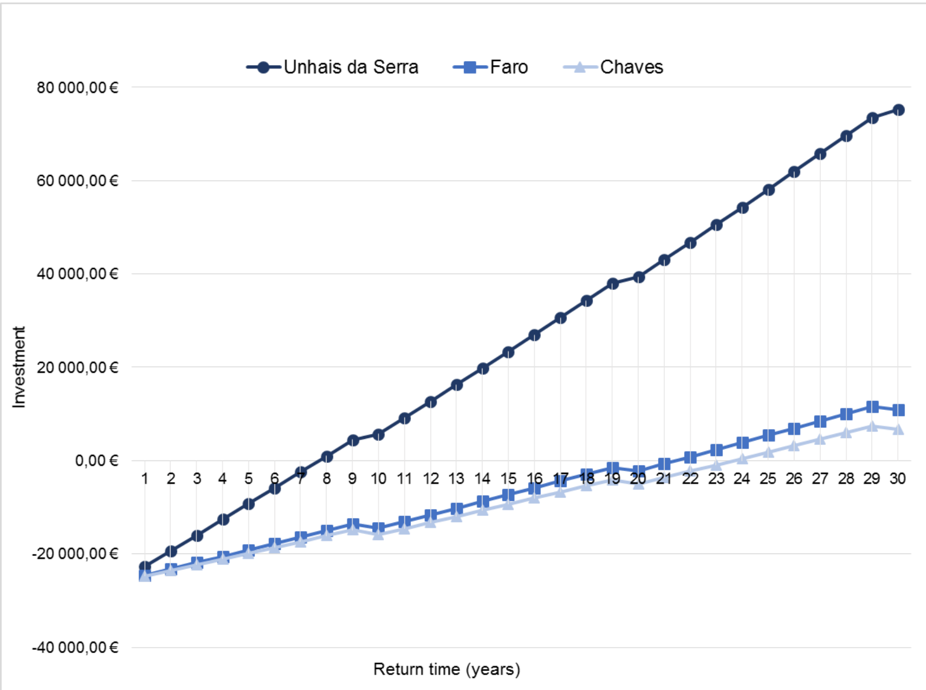

Fig. 4. Returning time for the investment for Unhais da Serra (Covilhã), Faro and Chaves (option 2: solution 2-c)

4. CONCLUSIONS

This study allow concluding that the implementation of rainwater reuse in a collective social center can lead to water savings of 57.4%, only changing equipment's and accessories (option 1).

If there is no storage structure, it is necessary to acquire a reservoir for rainwater storage, which involves a high initial investment (option 2). Rainwater harvesting is not feasible if it is not combined with the introduction of highly water efficient equipment, except when the costs associated with water billing are quite high.

Replacing the existing sanitary equipment, in order to make them more efficient (option 2: solution 2-c), it can lead to water reductions around 80.1%, with the investment being recovered in 8 years. For a period of 30 years the savings can reach around 75 000,00€.

Therefore, in areas where water billing reaches high values, it is economically feasible to invest in a Rainwater Harvesting System, preferably associated to the use of hydraulically efficient equipment's. However, in cases where the water billing prices are lower, the most viable investment could be the adoption of high water efficiency equipment.

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