Evaluation of water saving measures in hotels: A Spanish case study

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ABSTRACT

Water is an essential factor of production for hotel activities. Water consumption per person staying at a hotel tends to be high, and can be as much as three times the average consumption of people living at home. Thus, in the context of growing pressure on this scarce and strategic natural resource, the study of water consumption in hotels, and water saving possibilities, is of interest. This work deals with the case of a hotel in the city of Zaragoza (Spain) where equipment was retrofitted with water-saving technologies in order to reduce the amount of water consumed. The work analyses the impact of such retrofitting on consumption, and its financial and economic profitability. The results show how a small investment can lead to a very significant reduction in water consumption, and in the costs associated with it (especially energy costs).

KEYWORDS: Water use in hotels; Water saving measures; Profitability analysis; Cost-benefit analysis

1. Introduction

Water is an essential factor of production for the hotel industry (including hotels, boarding houses and campsites). Water consumption per person staying at these establishments tends to be high, and can be as much as three times the average consumption of people living at home (Ministerio de Medio Ambiente, 2007). However, this consumption can vary widely depending on the type of establishment, being highest in hotels, where water consumption per guest is double that of a boarding house and triple that of a campsite (Hamele and Eckardt, 2006).

The use of water in hotels can become a significant environmental and economic problem in territories where the number of beds available is very high and where there are problems of water scarcity. In these cases, the use of measures to improve the efficiency of water use is obviously in the public interest, as it contributes to mitigating shortages and to the sustainability of tourism. This is borne out in Spain, where there are 14,838 hotels offering 1,398,900 beds (Instituto Nacional de Estadística, 2010), and where the regions with the greatest water shortages largely coincide with the areas attracting the most tourism, and the greatest supply of hotel places (Ministerio de Medio Ambiente, 2007).

Water use is also of considerable interest for hotel companies, as it affects their bottom line. First, by the cost of purchasing this resource. Although in Spain the price of urban water is relatively low in the context of OECD countries (OECD, 2010), it has still risen faster than the rate of inflation since statistics have been available on the subject. From 2000 to 2009, the quotient between payments received for urban water services (water supply and sewage sanitation) and the volume of water consumed by users increased by 48.7% in real terms, to €1.42/m3 (Instituto Nacional de Estadística, 2011). The real price borne by most hotels is significantly higher, because they are large consumers of water, and due to the structure of the water tariffs normally applied in Spain cities: two-part tariffs, obtained by combining fixed and volumetric (metered) water charges with prices rising according to the consumption level (increasing block tariff) (Arbués and Barberán, 2012). Also, water in most high-tourism regions is clearly more expensive than the national average (for example, the quotient between payments received and the volume of water consumed in the Balearic Islands is €2/m3, and in the Canaries, €1.9/m3).

Finally, the use of water in hotels has other indirect consequences for the bottom line of the companies. This is because the environmental policies of tourism companies and their associated image affect the level and type of their demand. This can be explained in general terms as the image which customers have of a company influencing their intention to buy and their willingness to pay more for the services it offers (Han et al., 2009). Thus, it has been shown that adopting a strategy of environmental responsibility improves hotel profitability, as tourists increasingly value environmental variables when choosing destinations and accommodation (Álvarez et al., 2001; Ayuso, 2006; Tarí et al., 2010).

This work examines one case: a hotel in the city of Zaragoza (Spain) which has retrofitted its equipment to introduce water saving technology, for which we have full and detailed information. The work will analyse how introducing these new technologies impacts the water consumption of hotels, and to assess their financial and economic profitability.

The work is in five sections, including this introduction. Section 2 reviews the literature on water consumption and on the introduction of technical improvements to conserve water. Section 3 presents the study case, describing the characteristics of the hotel, its water consumption before and after retrofitting, and what changes were made. Section 4 discusses the methodology and results of the statistical analysis measuring the impact of the retrofit on water consumption. Section 5 is devoted to financial and economic analysis, identifying and assigning a monetary value to the consequences of the retrofit in terms of costs and benefits, and calculating profitability. The work closes with our conclusions.

2. Review of the literature

Studies of water consumption in hotels show that there is a great deal of variation, not only between countries but also between hotels in the same country. Whereas in Barbados, Charara et al. (2011) obtained an average water consumption of 863 L/person/day, in Jamaica it ranges from 438 to 1326 L/person/day, according to Meade and González-Morel (1999), and in Europe, Bohdanowicz and Martinac (2007) obtained consumption of 215 and 515 L/person/day for Hilton and Scandic hotels, respectively. Hamele and Eckardt (2006), in a study referring to fifteen European Union countries and analysing 119 hotels, showed that the average consumption level was 231 L/client/day. In Spain, Cobacho et al. (2005) studied consumption in rooms, which was estimated to be 83 L/day/room/guest (55 L of cold water and 28 L of hot water).

There are also some works that analyse water consumptions in other collective accommodation, such as schools and hospitals. According to Oduro-Kwarteng et al. (2009), for boarding schools in Ghana, consumption was 115 L/person/day, and, Bujak (2010), based on the monitoring of activity in the wards of two hospitals in Poland, found that hot water consumption was 5 L/h/bed, which equals 120 L/day/bed.

This water consumption also appears to somewhat seasonal. Thus, in South African hotels, Rankin and Rousseau (2006) observed that water consumption is 30–40% higher in summer, while the fraction of hot water used is lower. They also found that 60% of hot water was consumed from 6 am to 1 pm. Similarly, Charara et al. (2011) note that water consumption in Barbados hotels is usually higher in July and August. Thus, the season appears to be a key factor.

For the factors determining expected consumption, Redlin and de Roos (1990) found in American hotels that consumption varies from a median value of 382 L/room/day for hotels with fewer than 75 rooms to 786 L/room/day for hotels with more than 500 rooms, and between 356 and 961 L/room/day depending on the category of the hotel and their facilities. Moreover, Bohdanowicz and Martinac (2007) also found that in European hotels, water consumption increases depending on whether the hotel is classed as luxury, the climate (Mediterranean countries have higher water consumption), hotel size (m2), the number of nights stayed and the number of meals served. According to these authors, size is one of the most important factors, more so in luxury than in mid-rated hotels. However, Deng (2003) affirms that hotel size should not be taken into account when assessing the efficiency of water consumption. Charara et al. (2011) also conclude that it is not important, finding that the determining variables are the number of rooms, the hotel category (average water consumption in luxury and mid-rated hotels is 927 and 553 L/person/day respectively), and particularly the number of employees. Thus, the relationship between hotel size and water consumption is not absolutely clear, while climate, category, number of rooms and occupancy seem to be determining factors in most studies. Meanwhile, Meade and González-Morel (1999) conclude that there is an inverse relationship between occupancy and water consumption per guest. This seems to indicate that alongside the water consumed by guests, there is also a fixed consumption associated with cleaning and maintenance.

Other studies have focused on studying the structure of water usages. In this type of analysis, whether the hotel has a laundry is a key factor, as, according to Deng and Burnett (2002), in hotels with laundries, 47% of the water used goes to the laundry, 30% to the rooms and 22% to the kitchen. However, hotels without laundries consume 55% of their water in the kitchen and 44% in the rooms. As the current trend is for certain hotel services to be gradually outsourced, including laundry services, when evaluating water consumption and conservation measures it is advisable to focus mainly on guests and hotel catering services. Along these lines, Cobacho et al. (2005) analyse the final uses of water in the rooms of Spanish hotels: 45% of the water goes to the washbasin, 33% to the shower and 22% to the toilet. Cold water is mainly used in washbasins (38%), toilets (35%) and showers (27%). In the case of hot water, the greatest consumption is in washbasins (58%), followed by showers (42%). The study by Oduro-Kwarteng et al. (2009) for boarding schools also revealed that 62% of the water was consumed by showers and 30% by toilets.

All these studies of water consumption in hotels and their factors are ultimately intended to reveal the efficiency of water use in this sector. However, there have been very few studies analysing the benefits of introducing water-saving measures. The UK Environmental Agency (2004) ran a study of this type in 8 hotels, introducing changes such as new toilets with a lower flush capacity, infra-red taps in rooms and kitchens, modernised watering systems in gardens, and repairing leaks. These changes led to water savings of 15–58%, with an average saving of 25% per person per day. A similar project was carried out in the Jamaican hotels, according to Meade and González-Morel (1999), introducing water conservation measures in rooms, such as low flow showers and aerators in taps, and projects to encourage the reuse of bed linen and towels when the same person spends more than one night in the same room. Estimating consumption before and after these measures seems to indicate a 30% reduction. For the case of Spain, Hamele and Eckardt (2006) reveal that installing water saving devices in taps and dual flush toilets in a hotel on the island of La Gomera (Spain) produced a reduction of 33% in the first year. In addition, as indicated by Meade and González-Morel (1999), most of these devices cost less than $10/room.

The study by Oduro-Kwarteng et al. (2009) revealed that installing ecological devices in taps and toilet cisterns for boarding schools could mean water savings of 30% (about 36 L/person/day). Furthermore, according to Kats (2006), while the construction of ecological schools costs 2% more than traditional schools, the benefits in terms of saving resources (water, energy) and reducing emissions are 20 times greater than those additional costs. Similarly, though referring to Chinese restaurants, Lo et al. (2011) find that using a thawing machine or microbubble machine instead of a traditional cold-water thawing method could save 20% and 13% of that water, respectively; they also perform a cost-benefit analysis to determine the machines' payback period for restaurant operators.

3. The case study

This work studies the Silken Reino de Aragón Hotel, in the historic city centre of Zaragoza (Spain). Zaragoza is in the centre of the north-eastern quadrant of the Iberian Peninsula.

This hotel, opened in 1996, is a four-star hotel with 117 rooms and 191 beds. Its clientele is mainly associated with business travel, except in holiday periods and at weekends, when the clientele is travelling to visit the city or take part in family events. Therefore, during the week, room occupancy is usually single, and in holiday periods rooms are usually taken as doubles. Occupancy is considerably lower in holiday periods, especially in August. However, September is usually the busiest month, as there are many trade fairs and conferences in the city.

The hotel has a restaurant, a cafeteria, several banqueting rooms seating 250 people, various rooms equipped for events holding up to 350 people, a gymnasium, an outdoor terrace and parking garage. It does not have a swimming pool and the laundry service is outsourced.

In 2008, its average daily consumption of water was 50,975 L, of which 18% corresponded to hot water consumption and 82% to cold water, with an average daily consumption per guest of 396.5 L. This consumption meant an average daily cost for water of €115.6, as well as the subsequent costs of electricity and gas for pumping and heating hot water.

In this context, the owner decided to undertake a general renovation of the hotel during the first half of 2009, which would include replacing taps, to install taps with water saving devices. Specifically, taps with ecological cartridges and a dual flow system (if the tap lever is raised until it meets a slight resistance, only 60% of total flow is obtained) and aerators limiting the flow to 6 L/min were fitted to the washbasins and bidets (see Fig. 1 in Appendix A). Also, discs limiting the flow to 9 L/min were fitted in the showers (see Fig. 2 in Appendix A). These changes, carried out from March to May 2009, affected guest bathrooms and toilets and washrooms in the public areas (reception, restaurant, lounges, gymnasium and management offices). Also, in October, further retrofitting took place in the kitchen, consisting of replacing pre-wash shower heads with others limiting the flow to 9 L/min, and replacing the devices controlling the flow of water to the dishwashing station, which is used only for banquets and similar events, and consumes only hot water (no change was made to the kitchen and cafeteria dishwashers, which are used every day and consume cold water).

After this retrofitting, the data for 2010 show an average daily water consumption of 39,118 L (16.5% hot water and 83.5% cold water), equivalent to 378.6 L per guest per day. However, these data refer to the water used throughout the hotel by guests and other people using its services apart from accommodation, and by hotel employees (53 workers). To determine the water consumption of rooms, hot and cold water metres were installed in 2 bedrooms which were representative of the whole. The available data for the period from May 2010 to June 2011 show that average consumption was 124.3 L per person per day, 1/3 as hot water (41.2 L/person) and 2/3 as cold water (83.1 L/person).

The impact of these changes cannot be evaluated by simply comparing consumption for the years before and after they were made. This is because the impact of this technical change is conflated with changes in other factors influencing water consumption, and also because the consumption data are contaminated by the existence of a breakage in the cooling system which was detected and repaired on 5 October 2010 and which had caused a cold water leak of unknown quantity and duration. Therefore, the next section analyses the consumption data in depth.

4. Statistical analysis of the impact of the retrofit on water consumption

4.1. The data

The data used for the statistical analysis correspond to daily observations of the hotel's separate consumption of hot and cold water (in L), obtained from the records kept by the hotel maintenance staff after reading the metres installed for that purpose. The period analysed was from 1 August 2006 to 30 March 2011, a total of T = 1703 days. However, records do not exist for every day, so only aggregate data are available for some periods, especially weekends and public holidays. Consequently, 995 observations were finally available.

In order to avoid the possible confusion of effects when evaluating the impact of the retrofit and the leak on consumption, the following control variables were used: a set of quarterly seasonal effects (distinguishing the 4 seasons of the year); the number of guests staying at the hotel; the number of guests in single and double rooms; the number of equivalent attendees at banquets and similar events (conventions, coffee-breaks and cocktail parties) calculated as $n_{Banquet} + 0.58n_{Convention} + 0.13n_{Coffee-Break} + 0.18n_{Cocktail}$, where n_i is the number of people attending the activity I (I ∈ {Banquet, Convention, Coffee-Break, Cocktail party}) and where the weights were assigned according to the estimates of water consumption per person established by hotel management; and the number of equivalent attendees at meals (breakfasts, lunches and dinners) calculated as $0.57n_{Breakfast} + n_{Lunch} + 0.87n_{Dinner}$.

Finally, after an analysis of multicollinearity between these variables, we decided to use as control variables the "number of guests at the hotel" and the "number of attendees at banquets and similar", as well as a set of quarterly seasonal effects.

Fig. 3 (see Appendix A) shows the evolution of the daily average consumption of hot and cold water and total water. We observe the presence of an approximately constant trend of around 40,000 L total water consumption until mid to late 2007, with a growth trend beginning at that time, reaching a peak of about 65,000 L a day around August-September 2008. This is followed by a falling trend until the end of 2009 and then a levelling out, with large oscillations around the average trend of total consumption around 40,000 L of water, lasting until early October 2010, when the leak was detected and repaired. From that time, total consumption stabilised at around 20,000 L a day. This trend is common across cold water consumption, which has the greater weight in total consumption, and as remarked above, was affected by the leak. Meanwhile, the average consumption of hot water remained more or less constant at around 8500 L. Finally, we observed occasional peaks in consumption due to exceptional events being held on those days.

Fig. 4 (see, also, Appendix A) shows the daily evolution of the average number of guests staying at the hotel, and equivalent attending banquets and similar events. The average number of guests staying at the hotel was 112, although continual oscillations were observed, with a notable local growth trend in July to September 2008 (the dates of the Zaragoza 2008 International Exposition) reaching a maximum of 214. The average number of people attending banquets was 36, although there were occasions where this was much higher, with a maximum of 231 attendees; also, there was a large percentage of days with no events of this kind (around 20%).

4.2. Statistical methodology

The goal is to evaluate the impact of the retrofit on the hotel's water consumption. For this purpose we used three families of dynamic linear regression models where dependent variables are hot, cold or total water consumptions, respectively, and the independent variables are the average number of guests staying at the hotel, equivalent attendees at banquets and similar events and three seasonal dummy variables. To estimate the impact of the retrofit we introduced two dummy variables which indicate the time it was carried out, and its interaction with the corresponding independent variables. The evaluation of these impacts on cold and total water requires the estimation of how much water was lost. For this purpose, we introduced a dummy variable indicating the date of the leak. Given that this date is unknown we include the time $t_{leak\ begin}$ when the leak began as an additional parameter of the model.

The dynamic regression models used are given by the expression:

$$\begin{aligned} Yt = \beta_{cons\tan t} &+ \beta_{summer} I_{summer,t} + \beta_{autumn} I_{autumn,t} + \beta_{winter,t} I_{winter,t} \\ &+ \beta_{guests}(Gueststt - \overline{Guests}) + \beta_{banquests}(Banqt - \overline{Banq}) \\ &+ \beta_{retrofit\_rooms} I_{t_{retrofit\_rooms}, t} \\ &+ \beta_{guests*retrofit\_rooms} I_{t_{retrofit\ rooms}, t} (Gueststt - \overline{Guests}) \\ &+ \beta_{retrofit\ kitchen} I_{t_{retrofit\ kitchen}, t} \\ &+ \beta_{banquests*retrofit_{kitchen}} I_{t_{retrofit\ kitchen}, t} (Banqt - \overline{Banq}) \\ &+ \beta_{leak} I_{t_{leak\_begin}:t_{leak\_end}, t} \ (if\ Y = C_{cold}\ or C_{total}) + \varepsilon_t \quad t = 1, \ldots, T \end{aligned}$$

where $Yt = C_{hot,t}, C_{cold,t}\ or\ C_{total,t}$ depending on whether hot, cold or total water consumption is analysed; $I_{summer,t}, I_{autumn,t}\ and\ I_{winter,t}$ are seasonal dummy variables; $Guests$ and $Banq$ are the average number of guests staying at the hotel ($Guests_t$) and people attending banquets and similar events ($Banq_t$) over the period studied, respectively; $I_{t_{retrofit\_rooms}, t}$ is a dummy variable which takes value 1 if t ≥ 1 June 2009 (time when the retrofit of the bedrooms and public areas was finished) and 0 otherwise; $I_{t_{retrofit\ kitchen}, t}$ is a dummy variable which takes value 1 if t ≥ 1 November 2009 (time when the retrofit of the kitchen was finished) and 0 otherwise; $I_{t_{leak\_begin}:t_{leak\_end}, t}$ is a dummy variable which takes value 1 if t > 5 October 2010 (time when the leak was repaired), −1 if $t < t_{leak\ begin}$ and 0 otherwise; ε_t is the error term, a Gaussian white noise with $\varepsilon_t \sim N(0, \sigma)$.

The models finally used were chosen by a Bayesian variable selection procedure. The parameters of the selected models were estimated using a robust procedure obtained by applying the iterative least square method, and daily and annual predictions drawn up, all taking into account the uncertainty associated with the time the leak began (t_{leak_begin}) and the model selection process. A detailed mathematical description of the selection procedure is available from the authors upon request.

4.3. Results

4.3.1. Selected models and estimated parameters

Table 1 shows the results obtained by applying the process of selection and estimation of the models. The same model was selected for cold water and total water consumption, due to the greater weight of cold water consumption when determining total water consumption (see Fig. 3), eliminating as explanatory variables the interactions of the retrofits in bedrooms and the kitchen with the effects of the number of guests staying and attendees of banquets, respectively. Meanwhile, the model selected for hot water consumption eliminates the interaction of the kitchen retrofit with the number of banquet attendees.

The water leak had a significant effect on cold water consumption: we estimate it increased it by 13,986 L/day. This estimation is significantly higher than that obtained by the selected model for total water consumption, which estimates the increase at 11,818 L. However, this latter figure is less reliable, given that calculation of total consumption includes hot water consumption levels, obscuring the estimation of this impact. However, there is a concordance between both models when situating the time the leak began at the start of 2008 (7 January 2008) with a 95% confidence interval from 10 September 2007 to 15 January 2008. The high degree of asymmetry towards the left in this interval is due to the existence of a 4-month period (September–December 2007) during which water consumption information was available only on a monthly basis, so that the model could not identify dates for these months in more detail.

If we consider the impact of the retrofits, we do see significant effects on consumption of both cold and hot water. The retrofits in bedrooms and public areas (except for those specific to the kitchen) caused a reduction of about 3402 L a day in average cold water consumption, without any significant effect seen on average consumption per guest, which is estimated to remain around 81 L/day. The impact of the retrofit on hot water consumption was a decrease of 2767 L a day, and an additional decrease in consumption per guest of 22 L/day, from 49.5 L/day before the retrofit to 27.5 L/day after it. The main impact of the kitchen retrofit was on daily cold water consumption, which was reduced by 1345 L a day (significant to 85%). The impact of the retrofit was much lower on hot water consumption (232 L a day), although this last value is not statistically significant. In total water consumption, both retrofits had a significant impact, with reductions of 5750 and 2402 L a day due to the retrofits of bedrooms and the kitchen, respectively.

The estimated coefficients of the rest of the covariates included in the models have the expected sign and are mostly significant. Thus increased consumption of hot and cold water per attendee at banquets and similar events is estimated at around 5 and 36 L/day, respectively, both estimations being significant. Regarding the effect of the seasons, and taking water consumption in spring as a reference, we first observe that in average occupancy conditions, the estimated water consumption was 9267 and 27,889 L a day of hot and cold water, respectively, after discounting the effect of the cold water leak (41,875–13,986). In summer there is a reduction of 1560 L a day in hot water consumption and an increase of 3005 L in cold, both effects being significant. In autumn a significant reduction is seen only in the average cold water consumption, of 2689 L a day. Finally, in winter we observe a significant increase in hot water consumption (542 L a day) and a reduction in cold (4475 L a day).

We end by remarking that the fit of the estimated models is good, the multiple correlation coefficients being 0.7373, 0.8562 and 0.9076 for hot, cold and total water consumption, respectively.

4.3.2. Impact of the retrofits on annual water consumption

To assess the overall impact of the retrofits on annual water consumption, we compared the predicted annual water consumption of a reference scenario, without a leak and before the retrofit, to two scenarios, one with a leak (scenario 1) and one after the retrofit (scenario 2). All the cases assumed 112 guests staying at the hotel (the average over the period of the study) and 36 banquet attendees (the average if we include days when there are no events of this type).

For all the scenarios a prediction was made of the daily consumption of hot, cold and total water, using the expected daily consumption of the previously selected models. Annual consumption was obtained by aggregating the daily predictions for the whole year. Thus, for confirmation purposes, total water consumption was also predicted by adding the separately obtained cold and hot water predictions. The results obtained are shown in Table 2. This table shows the predictions obtained for each season and the total annual prediction as well as the percentage increase in consumption for scenarios 1 and 2 compared to the reference scenario.

We observe that the impact of the leak was to increase total consumption by 31.27%, due to the 51.93% increase in cold water, with no impact on hot water, as the leak only affected the cold water system. The impact of the retrofits was to reduce total water consumption by about 21.5%, with a greater impact on hot water (a 33.19% reduction) than on cold (a 17.63% reduction).

5. Financial and economic analysis

The financial analysis assesses the profitability obtained by the hotel carrying out the retrofit, while the economic analysis reflects the net benefit for society as a whole. The first requires the identification and quantification of private costs and benefits, and the second, the social costs and benefits.

The period considered relevant for the analysis is 12 years (2009–2020), as this corresponds to the lifespan attributed by technicians to the new equipment and devices installed, which is the generally recommended criterion (European Commission, 2008).

5.1. The method for calculating the costs and benefits of the retrofit

The investment project carried out in the hotel, as specified in Section 3, consisted of installing a series of water-saving devices in the bedrooms, public areas and kitchen, especially in the taps. According to the technical personnel directing the retrofit, the existing taps had reached the end of their useful life, had become obsolescent, and were due for replacement. This implies that without the project, the taps would have been replaced by equivalents without water saving devices, while the project involved installing taps with equivalent characteristics but with water-saving devices. A more generally applicable case would be that the taps had not reached the end of their useful life, and it was decided to fit them with water-saving devices (if these should prove compatible).

To calculate the project costs, this work will consider both the real case of the hotel (called the particular case) and the general case described above. For the former, only the cost difference between the taps with or without water saving devices will be considered, not including the cost of labour for installing them, as the devices formed part of the new taps. In the general case, the entire cost of the water-saving devices is calculated, plus the cost of labour for installing them in existing taps. In both cases, the retrofit is compatible with maintaining the activity of the hotel, carrying out the work in stages and choosing times of least occupancy, so that costs for stopping or reducing activity do not have to be calculated. Maintenance costs for the new devices are the same as for the older ones, and therefore have not been included.

In the economic analysis, project costs are calculated net of taxes, as they do not represent a net cost for society, but rather an income transfer between different agents forming part of it (De Rus, 2008; European Commission, 2008). This means excluding VAT from the cost of materials and Personal Income Tax from the labour cost. Also, a correction factor was applied to the labour cost to compensate for wage distortions due to labour market imperfections caused by regulations and to macroeconomic imbalance, as shown by the high and persistent unemployment rate or the dualism and segmentation of labour conditions (0.952971, according to Del Bo et al., 2009). Finally, to calculate the total cost, the 5% rate was taken as the opportunity cost of capital, the same as that used for the discount in calculating the financial profitability of the investment (European Commission, 2008).

The benefits deriving from the project come from the reduced costs borne by the hotel as a consequence of lower consumption of water, electricity to pump it and to ensure acceptable water pressure in all parts of the hotel, and natural gas for hot water production, after installing the water-saving devices. The water savings meant electricity savings of 0.3 Kwh/m3 for pumping and natural gas savings of 72 Kwh/m3 for producing hot water, according to the standards estimated by the technical personnel in charge of the hotel retrofit. Also, the economic analysis considers the benefits for society deriving from reduced emissions of pollutants thanks to this lower consumption of electricity and natural gas, as these are positive externalities of the project: 1 Kwh of electricity emits 0.166 kg of CO_2, 0.000217 kg of NO_x and 0.000254 kg of SO_2, according to WWF España (2011); 1 N m3 of natural gas (1 m3 of gas in normal pressure conditions), equivalent to 10.65 Kwh, produces 2.15 kg of CO_2, according to the Oficina Catalana del Canvi Climàtic (2011).

Unlike the investment cost, the benefits deriving from the project are affected by uncertainty, as it is not possible to know exactly the future hotel activity determining water consumption, the evolution of water, electricity and gas prices, or the value of the social cost of CO_2. Therefore these variables have been taken as random in order to run a risk analysis enabling results to be obtained as a probability distribution (De Rus, 2008; European Commission, 2008).

Future water consumption will depend on the level of activity of the hotel, mainly in accommodation and catering. To simplify forecasting, it was assumed that water consumption without the retrofit would follow its historical behaviour according to the data available for 2006–2011, after correcting the effect of the leak. To incorporate risk in the calculation, a thousand simulations were run for each year of life of the project (except the years for which accurate data were available: 2009 and 2010), taking water consumption as a random variable, which in the case of cold water follows a normal distribution of an average 9252.64 m3/year and standard deviation of 1173.22 m3/year, and in the case of hot water, an average 3840.99 m3/year and standard deviation of 901.06 m3/year. Consumption after the retrofit was obtained by applying the percentage reduction of hot and cold water consumption due to the retrofit, according to the estimates above, to the result of the simulations.

The prices of water, electricity, gas and CO_2 in 2010 are shown in Table 3, with taxes for the financial analysis and net of tax for the economic analysis. The price of water is that for the last increasing block tariff applied in the city of Zaragoza for calculating the variable quota for the water supply and sanitation service. The electricity and natural gas prices correspond to the average variable cost borne by the Hotel Reino de Aragón. CO_2 emissions were evaluated according to the price obtained from auctions of emission allowances, according to SENDECO2 (2011), as an approximation of their social cost.

For the 2009 and 2010 calculations the prices for those years were used, while the prices for subsequent years in the life of the project were obtained by applying the real year-on-year increase rate obtained from the behaviour observed in 1999–2010 to the 2010 prices. To incorporate risk in calculating the rates, a thousand simulations were run for each year for which predictions were needed, taking the increase in water, electricity, gas and CO_2 prices as random variables following a normal distribution with the average and standard deviation shown in Table 3.

Also, SO_2 emissions were valued at €6.6/tonne (based on Holland and Watkiss, 2002) and NO_x emissions were transformed into equivalent CO_2 emissions (1 kg of NO_x is equivalent to 296 kg of CO_2), added to the previously estimated CO_2 emissions.

Once the costs and benefits are identified and quantified we can calculate the probability distribution of the net present value (NPV) and thus of the average NPV and its standard deviation, taking into account, as mentioned above, that the useful life of the project is 12 years and that benefits are obtained from the first year. To homogenise and aggregate the values of the annual flows, a 5% discount rate was adopted for the financial analysis and a social discount rate of 3.5% for the economic analysis, following the recommendation of the European Commission for countries not receiving Cohesion Funds. Furthermore, sensitivity analysis was run to observe the variation of the NPV in response to changes in them.

5.2. Results

5.2.1. Financial profitability

The execution costs for the project borne by the hotel are shown in Table 4, taking into account the two cases considered. The total cost of the project in the particular case is €2057, an equivalent annual cost (EAC) of €232/year over its useful life. In the general case, the total cost of the project is €10,987, with an EAC of €1240/year. This shows that when labour costs are included, costs are increased by 534%.

The benefits deriving from the project come from the reduced costs borne by the hotel owner thanks to savings in water, electricity for pumping the water and natural gas for heating it, after the installation of the water-saving devices, and can also be seen in Table 4. They were obtained by multiplying the physical water, electricity and gas units which it is estimated will be saved each year by their predicted unit price. It is shown that the retrofit meant a reduction on costs for the consumption of water, electricity and gas of €88,369, €763 and €57,350 respectively, with a total average reduction of €146,482, considering the entire useful life of the project. This means an average annual reduction of €12,207. The standard deviations obtained indicate that even in the most unfavourable circumstances, according to recent experience, the cost reductions will continue to be positive and substantial, with the reduction for gas consumption being the most sensitive.

The average NPVs of the project and its profitability rate, together with the values of its standard deviation, are presented in Table 5. In the particular case, an average net benefit of €144,425 is obtained, meaning an average profitability rate of 7022%. For the general case, an average NPV of €135,494 is obtained, and an average profitability rate of 1233%. Once again, as is logical, the standard deviations obtained show that even in the most unfavourable circumstances which might be expected, the net benefit and profitability of the project are still positive and substantial. See the probability distribution of the NPV represented in Fig. 5 (the one for the particular case is similar).

The sensitivity analysis (see Table 5) shows that an increase in the discount rate of 1% reduces the NPV by an average of 4.35% in the particular case and an average of 4.62% in the general case. Thus, it is obvious that the profitability of the project is not compromised by changes in the discount rate, within reasonable margins.

5.2.2. Economic benefits

As with the financial analysis, the costs of the project are shown in Table 4, for both the particular and the general case. The total cost of the project in the former is €2809, i.e. an EAC of €291/year over its useful life (€14,126, with an EAC of €1462/year for the general case). This confirms that when labour costs are included, costs are increased by 287%.

The profits obtained also are shown in Table 4, where we can see a reduction in costs of €88,472, €669, €53,949 and €2697 thanks to the savings in water, electricity and gas and the reduction of pollutant emissions, respectively. This means a total saving of € 145,752, considering the entire useful life of the project, and an average annual saving of €12,146. Again, the standard deviations obtained show a very high probability that the cost reductions will be positive and substantial.

Table 5 presents the average NPV values of the project and its profitability rate, together with the values of its standard deviation. For the particular case, an average NPV of €142,943 is obtained, and an average profitability rate for the investment of 5088% (€131,626 and 932% for the general case). The standard deviations and histograms of Fig. 6 (see Appendix A) again indicate that even in the most unfavourable circumstances, the net benefit and profitability of the project would still be positive and substantial (the particular case is similar).

The sensitivity analysis in Table 5 shows that an increase in the discount rate of 1% reduces the NPV by an average of 4.36% in the particular case (4.75% in the general case). Thus the desirability of the project for society would not be compromised by a change in the discount rate.

6. Conclusions

The general aim of this work was to analyse water consumption in hotels, the possibility of reducing that consumption, and the financial and economic profitability of actions taken for this purpose. To do this, we evaluated the case of a hotel in the city of Zaragoza (Spain) which retrofitted its equipment to introduce water-saving technology.

The main contribution of the work is in obtaining results in terms of financial and economic benefits, as most previous studies on this subject analysed only water consumption, and where applicable, the impact of installing water-saving devices. In the area of methodology, notable solutions were found to the difficulties encountered, on one hand, in estimating the impact of the retrofit on water consumption, due to the existence of a leak during the period studied, and on the other, in calculating the monetary benefits of the retrofit, due to the uncertainty of future levels of activity of the hotel and costs associated with water consumption. It is also notable that the water consumption data used had a daily periodicity and reported cold and hot water use separately.

The results of analysing the case show that introducing water-saving devices in the taps of the hotel bedrooms and public areas, together with replacing the taps and dishwashing station in the kitchen, meant a 21.5% reduction in total water consumption (17.6% in cold water and 33.2% in hot). After the retrofit, the average daily water consumption per guest staying at the hotel is estimated to have fallen from 321 to 252 L, 21.4% of which corresponds to hot water, and the rest to cold.

Additionally, other results of this study contribute to improving the state of knowledge of the use of water in the hotel industry. Thus, monitoring two bedrooms showed that the average daily water consumption of guests staying in them is 124.3 L, meaning that half the water consumed by the hotel (50.7%) is used in public or collective areas (reception, cafeteria, restaurant, kitchen, lounges, gymnasium, offices and service areas). Also, modelling water consumption shows a substantial volume of consumption which is fixed, although sensitive to seasonal variation, confirming the existence of scale economies in consumption, as would be expected in services of this type.

The results of the financial and economic analysis show that retrofits to reduce water consumption are extraordinarily profitable, both for the hotel and for society in general. Thus, with an investment costing €14,126 in the least favourable case (and around €2000 in the most favourable), with a useful life of at least 12 years, an average NPV is obtained of around €140,000. Consequently, the profitability rate of the investment ranges from 932% to 7022%, depending basically on whether labour costs are included for installing the water-saving devices in the taps.

The results obtained clearly demonstrate the desirability of installing water-saving devices in hotels, as with a low investment cost and without inconveniencing guests, a significant reduction is achieved in water and power consumption. They provide solid evidence that this type of action can reduce the pressure on water resources and on the environment in the wider sense, while increasing the financial profitability of hotels. In fact, the demonstration of its high financial profitability allows us to conclude that public subsidies are not necessary to encourage the installation of water-saving devices in the hotel sector, although public support does seem to be needed to publicise their advantages. It is also an argument supporting the adoption of regulations in the construction industry to make environmental standards for taps in new buildings (such as homes or offices) mandatory for developers. In general, these results are very encouraging from the point of view of rationalising water use in the context of increasing relative scarcity of this resource.

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Appendix A.

Figures.

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Table 1. Estimation of parameters of the models.

Independent covariates	Dependent variables								
	Hot water consumption			Cold water consumption			Total water consumption		
	Coefficienta	Std	z=coef/std	Coefficienta	Std	z=coef/std	Coefficienta	Std	z=coef/std
Constant	9267.5	223.0	41.55***	41,857.3	525.8	79.61***	51,021.8	495.9	102.90***
Summer	−1560.7	304.6	−5.12***	3005.1	677.6	4.43***	1214.3	637.4	1.91*
Autumn	−25.3	285.6	−0.09	−2689.4	678.6	−3.96***	−3382.1	627.9	−5.39***
Winter	542.5	299.7	1.81*	−4475.6	684.5	−6.54***	−3953.5	655.1	−6.03***
Guests	49.5	3.7	13.33***	80.9	6.7	12.12***	126.2	6.3	20.09***
Banquets	5.0	2.4	2.08**	36.6	5.5	6.70***	36.2	5.1	7.06***
Retrofit_rooms	−2767.1	368.6	−7.51***	−3402.0	857.0	−3.97***	−5749.7	806.5	−7.13***
Guests*retrofit_rooms	−21.8	6.3	−3.49***						
Retrofit_kitchen	−232.4	399.7	−0.58	−1345.2	887.6	−1.52	−2402.1	835.7	−2.87***
Leak				−13,985.8	481.0	−29.07***	−11,818.2	453.4	−26.07***
Leak_begin				07 Jan 08	(10 Sep 07, 15 Jan 08)		07 Jan 08	(01 Jan 08, 22Jan 08)	
Sigma	3980.7			8975.6			8443.1		
R2	0.7373			0.8562			0.9076		

a Values of the coefficient in L/day.

*Significant to 10%

**Significant to 5%

***Significant to 1%

Table 2. Evaluation of the overall impacts of the leak and the retrofit on annual water consumption (in L).

	n days	Hot water	Cold water	Hot+Cold	Total
Reference scenario: without leak and before retrofit					
Spring	91	9693	28,98	38,673	40,629
Summer	92	8177	31,655	39,832	41,624
Autumn	91	9458	25,668	35,126	36,481
Winter	91	8832	21,365	30,196	32,4
Annual total (L/year)	365	3,298,610	9,829,500	13,128,110	13,794,800
Scenario 1: with leak and before retrofit					
Spring	91	9693	42,966	52,658	52,447
Summer	92	8177	45,641	53,818	53,442
Autumn	91	9458	39,654	49,112	48,3
Winter	91	8832	35,351	44,182	44,218
Annual total (L/year)	365	3,298,610	14,934,300	18,232,910	18,108,500
Overall impact of leak (L/year)	365	0	5,104,800	5,104,800	4,313,700
% Increase of consumption over reference scenario		0.00%	51.93%	38.88%	31.27%
Scenario 2: without leak and after retrofit					
Spring	91	6693	24,233	30,926	32,477
Summer	92	5177	26,908	32,085	33,472
Autumn	91	6459	20,921	27,379	28,33
Winter	91	5832	16,618	22,45	24,247

Annual total (L/year)	365	2,203,800	8,096,700	10,300,500	10,819,300
Overall impact of retrofit (L/year)	365	−1,094,810	−1,732,800	−2,827,610	−2,975,500
% Increase of consumption over reference scenario		−33.19%	−17.63%	−21.54%	−21.57%

Table 3. Price of the cost factors associated with water consumption.

	Prices 2010 (€)		Real price increase (%)	
	With taxes	Without taxes	Historial average	Standard deviation
Water (m3)	302.292	279.900	323.402	603.870
Electricity (Kwh)	0.08579	0.06963	295.074	1.100.234
Gas (Kwh)	0.04383	0.03779	859.795	2.227.703
CO2 (Kg)		0.01500	141.233	0.06453

Table 4. Costs and benefits of the water-saving investment (2010 euros).

	Financial analysis		Economic analysis	
	Particular case	General case	Particular case	General case
Cost of the investment				
Washbasin taps (133 units)	719	4815	620	3514
Bidet taps (117 units)	633	4236	545	3092
Showers (121 units)	430	1661	371	1201
Prewash shower heads (2 units)	103	103	69	69
Retrofit of dishwashing station	172	172	131	131
Opportunity cost of capital	–	–	1053	5297
Total costs	2057	10.987	2809	14.126
Equivalent annual cost (EAC)	232	1240	291	1462
Benefits: average present value of the operating costs reduction during the lifetime of the investment[a]				
Due to reduced water consumption	88,369 (9399)		88,472 (9661)	
Due to reduced electricity consumption for pumping water	763 (131)		669 (118)	
Due to reduced gas consumption for heating water	57,35 (24,961)		53,949 (24,105)	
Due to reduced pollutant emissions from power consumption	–		2697 (178)	
Total benefits	147,482 (26,892)		145,752 (26,189)	
Operating costs reduction/Pre-retrofit cost (%)	25.1		25.0	

[a]The benefits for the general case are the same than for the particular one. The standard deviation of each value is presented in brackets.

Table 5. Net benefit and profitability of the water-saving investment.

	Financial analysis[a]		Economic analysis	
	Particular case	General case	Particular case	General case
Net present value (2010 euros)	144425 (26,892)	135494 (26,892)	142943 (26,189)	131626 (26,189)
Profitability (%)	7022 (1307)	1233 (245)	5088 (932)	932 (185)
Sensitivity analysis of the net present value according to the discount rate				
2%	171,253	162,263	155,945	144,628
3%	161,559	152,569	147,093	135,775
3.50%	157,016	148,026	142,943	131,626
4%	152,662	143,672	138,966	127,649
5%	144,425	135,494	131,496	120,178

[a]The average value of each variable is presented without brackets and the standard deviation is in brackets.

Fig. 1. Tap with ecological cartridge and flow limitation aerator.

Fig. 2. Shower with flow limitation disc.

Fig. 3. Daily evolution of average daily consumption of total water, hot water and cold water.

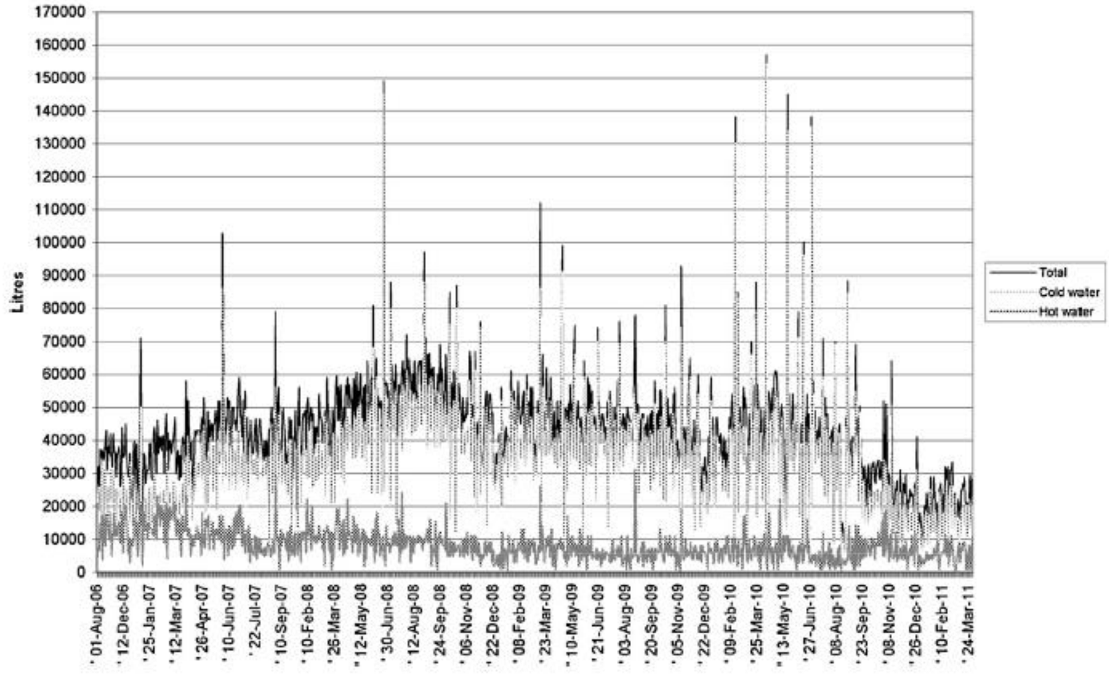

Fig. 4. Daily evolution of the average number of guests staying at the hotel and attendees at a banquet.

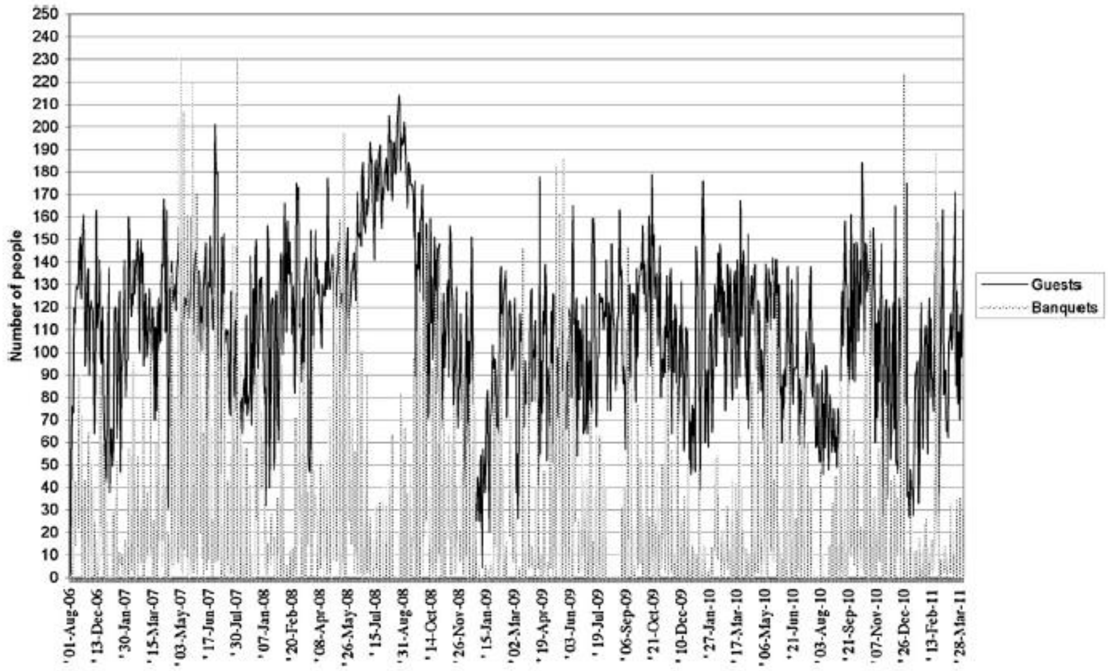

Fig. 5. Distribution function of the financial profitability of the project (general case).

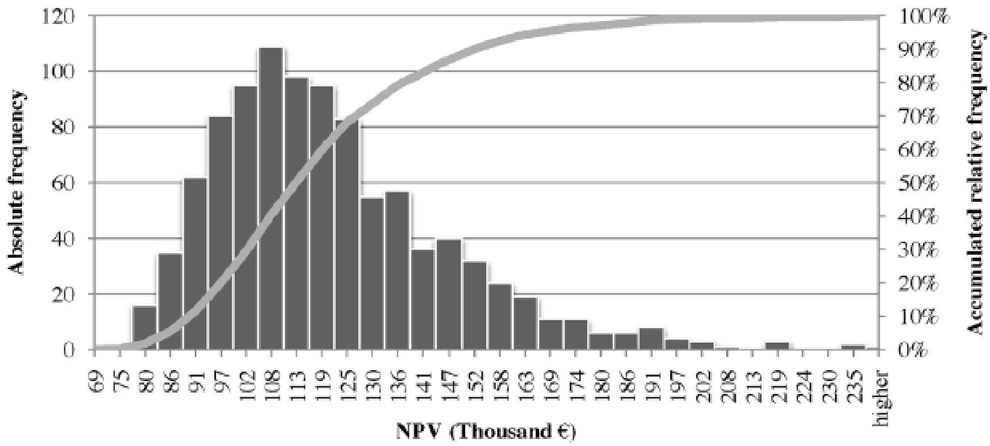

Fig. 6. Distribution function of the economic profitability of the project (general case).