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Modelling of Energy and Water Supplies in Hotels in Lanzarote and Fuerteventura with and Without Desalination Plant (SWROP)

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Abstract

Objectives: This article presents a comparative study of energy and water consumption in four-star hotels in the Canary Islands (Spain), specifically on the islands of Fuerteventura and Lanzarote, with and without desalination sea water reverse osmosis plants (SWROP), of order to define a pattern of consumption based on the average occupancy rates of different establishments. **Methods/Statistical Analysis:** The method used for regression calculations of the data obtained has been, initially the data collection and filtration, perform the mean arithmetic of the data according to the intervals calculated, perform calculations and generate the correlation graphs of the different models, change the occupancy rates to a percentage and use all the values for the total calculation as if it were a single hotel, calculate the final model of energy and water consumption for establishments, and create a valid algorithm using the calculated regression models. **Findings:** We demonstrate the validity of the potential and polynomial models of regression used to calculate the approximate values for consumption of water, electricity and energy, valid for most of the hotels with an average occupancy rate of between 40% and 120%, which are typically the average occupancy rates for hotels in the Canary Islands during various months of the year. Through a calculated and demonstrated system of analysis, approximate simulations of consumption can be performed for hotels with the same or similar characteristics and modelling of reduced energy consumption can be performed by simulating occupancy values to test the level of reduction. **Application/Improvements:** The article concludes with the functions for the approximate calculations of energy consumption, electricity and water per guest, per day for hotels with similar characteristics to those in the study.

Keywords: Energy, Efficiency, Hotels, Modelling, nZEB, SWROP, Water

1. Introduction

At a global level, two-thirds of emissions come from energy consumption, the tourism sector-being a major consumer of energy-contributing 5% due to the inefficiency of energy consumption that occurs in that sector. The tourist accommodation sector represents more than 20% of emissions from tourism and energy consumption from tourism overall[1] is equivalent to 1% of global emissions. For this reason, hotel buildings, which operate in geographical areas with a high concentration of tourism and intensive seasonal use, pose a major challenge to the sustainability of tourist destinations.

The European Union has set a goal of reducing energy consumption, as well as CO_2 emissions, by 20% by 2020 in comparison to 1990 levels, stipulating that 20% of total energy consumption must come from renewable sources and giving much importance has been placed on energy efficiency through the publication of several directives on it, as the directive directive 2010/31/EU [2] on energy efficiency in buildings, investigated their application in buildings in one study[3] and directive 2012/27/EU[4] on

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energy efficiency, which also highlights the importance of promoting energy efficiency in buildings, setting a time to achieve Zero Energy Buildings (ZEB) or near to Zero (nZEB), this being an obligation in new constructions for the year 2018 general government and by 2020 the other buildings, which has been studied their application in Lithuania[5].

The archipelago of the Canary Islands, belonging to Spain and located in the Atlantic Ocean near the coast of southern Morocco and the Sahara, north Africa, between coordinates 27º37' and 29º25' north latitude and 13º20' and 18º10' west longitude, with a total area of 7447 km^2 and an oceanic subtropical climate, has stable year-round temperatures mitigated by the sea in winter and in summer by trade winds. Currently the tourism sector in the Canary Islands represents 31% of the archipelago's GDP and generates 36% of employment on the islands[6], it being the main engine of the economy. It is the main engine of the economy and its labour mobility as demonstrated in the study of[7] on the labour market in the Canary Islands. At this location, there are 626 hotels that offer more than 244,000 hotel beds[8]. Annually, around 13,000,000 tourists visit and produce more than 100 million overnight stays in hotels on the islands. Energy consumption for hotels in the tourism sector accounts for 15% of total electricity consumption[9] and 11% of water consumption[10], with respect to the overall consumption of the islands. Taking into account the importance of tourism for the Canary Islands, the search for models of energy consumption and water sustainability is essential and valid for implementing energy efficiency strategies in hotels, which has become an essential aspect of European strategy for sustainable growth in 2020, and one of the most profitable ways to strengthen the security of energy supplies, as well as reduce emissions of greenhouse gases and other pollutants. It is very important to know the distribution of energy consumption in hotels so that it can be shown where improvements can and should be made in order to make reductions. Distribution varies according to geographical area and category of hotel, as can be seen by studies conducted in several countries, for example: in Britain, where the typical distribution is 47% on heating and 20% in Domestic Hot Water (DHW)[11]; in Greece, where the typical distribution is 35% on heating, 15% on refrigeration, and 22% on DHW[12]; hotels in the Balearic Islands is between 22 % for DHW , cooling 14% heating and 21%[13]; and the Canary Islands, where, due to its climatic characteristics, climatization is reserved mainly for air conditioning, with consumption at 31%,and, in second place, DHW at 22% [14]. Tourist associations, along with several universities, have conducted various studies on the consumption of hotels. The International Tourism Partnership (ITP), in conjunction with Cornell University, has published the results of the study "Cornell Hotel Sustainability Benchmarking" (CHSB)[15] to provide points of reference to hotels regarding energy and water consumption, and worldwide carbon footprint references for different types of establishments in various countries. The World Tourism Organization (UNWTO) has launched the project "Hotel Energy Solution", creating the E-Toolkit[16], a tool that allows small and medium-sized European companies in the hotel accommodation sector to make a comparative assessment of energy consumption, efficiency and carbon footprint, with similar companies on the continent. The Spanish Confederation of Hotels and Tourist Accommodation (CEHAT) and the Hotel Technological Institute (ITH) conducted an investigation of hotel consumption using the bench hotel mark tool, which generated a comparative report with hotels with similar characteristics, comparing energy and water consumption with hotels in Madrid[17] and the Canary Islands[18], but without creating a reproducible model for other hotels. All these studies give typical values, but have not generated reproducible models using occupancy as an indicator, which is paramount in actual tourist establishments.

Other research has been carried out by the scientific community, such as that performed in 2009[19] whereby a study of 29 energy intense hotels was conducted in Singapore, checking their linear correlation with various parameters of different hotels, such as the average monthly occupancy rate and average temperature. The average consumption of the hotels stood at 427 kWh/m^2/year. Heterogeneous samples of hotels concluded with the need to group the data into more homogeneous hotels for utility models in simulating energy consumption. In 2012[20], performed a comprehensive study on the basis of 200 hotels in four categories, checking the levels of energy consumption based on the category of hotels, among other factors. Energy consumption was between 280 and 143 kWh/m^2/year and average consumption per occupied room was between 26,7 and 9,4 kWh/room/nigth with 84% of the energy consumed being electricity. In 2012[21], conducted a study on the classification of hotels in Greece for their energy consumption, according to the climatic zone and type of hotel, in which they took into account the size of the hotels but not their occupancy rates. The study in 2007[22]-roughly 184 hotels from the Hilton and Scandic chain in Europe - created a model of energy and water consumption in these hotels, taking into account multiple variables and modelling them by linearization of annual consumption. When basing a study on heterogeneous hotels, values are very generic and hardly usable for modelling all hotels, since there are large variations between them. In the study in 2011[23], to model water consumption in Acapulco, he found that the logarithmic model was the most appropriate for consumption of this type. In 2014[24], investigated the modelling of water consumption in hotels through regression models in order to obtain a hyperbolic model of water consumption in hotels of the type investigated here. In investigations[25] on the impact of tourism by type of accommodation, it means data for different countries and a global estimate is obtained per bed per night use 36 kWh/bed/night, with consumption water through very uneven, with values between 100 to 2000 l/bed/night so cannot generate reliable means of water consumption per customer per day.

Data published by the major chains should also be taken into account, since they provide general data on energy and water consumption in their hotels, motivated by environmental certifications and their corporate environmental responsibility policies, which can be useful for checking the average consumption of different establishments comparatively, albeit without any model of consumption or grouping of hotels with similar characteristics. Examples of annual data published include the NH hotel chain, which gives indicators for occupied rooms of 300 l/day/room and energy consumption of 51.43 kWh/day/room[26], or the Riu hotel chain, with shows an average consumption per guest of 371 l/day/guest and electricity of 15.31 kWh/day/guest[27].

For this research, we focused on hotels in the Canary Islands, specifically on 4-star hotels, both with and without desalination plants to provide their own water, on the islands of Fuerteventura and Lanzarote. These two destinations have an average of 2.3 and 2 million tourists a year and 18.7 and 16.5 million overnight stays respectively. The reason that the study focuses on 4-star hotels, is that they represent more than 55% of the hotels in the Canary Islands and more than 70% of the rooms[8], with which it is possible to realize an approximation of the consumption of most of the hotels on the islands.

2. Experimental

The data obtained from the corporate departments of the hotels from this study of total energy, water and electricity consumption, and number of guests staying a night (=overnight stays), was reviewed alongside the technicians responsible for each establishment, filtering out erroneous data - due mainly to failure to collect it or other chance events outside of normal operations (e.g., water leaks, renovations of facilities, breakage, etc.). With this list of definitive data, already filtered and reviewed, the calculation was performed for the histogram of the resulting data, generating the characteristic points grouped by frequency ranges. To calculate optimal ranges, the Sturges' formula[28] was used, which gives us the number of intervals depending on the amount of data obtained.

The next step was to perform the grouped distributions by intervals calculated, and once the values were grouped, the arithmetic mean of the data was performed in order to obtain the different characteristic points of consumption and perform the correlation calculations. The values are ordered by daily guest occupancy rates, which gives us a more accurate correlation than classic systems of monthly or annual consumption, because in this way, errors due to the different number of days in a month - which would provide an error of 6% in February and 3% in the months containing 31 days – are annulled, obtaining a distribution of values more tightly adjusted to their real values. With the data obtained from hotels, the calculations for total energy, electricity and water costs per guest per night were performed.

To test what kind of correlation resembled the models of consumption the most, correlation calculations were performed for linear, exponential, logarithmic, and polynomial of the second degree and potential models, testing their coefficient of determination and calculating their modelling function.

- Linear Regression whose shape fits: $y = ax + b$
- Exponential Regression whose shape fits: $y = ae^{bX}$
- Logarithmic regression whose shape fits: $y = a \ln x + b$
- Second order polynomial regression whose shape fits: $y = a + bx + cx^2$
- Power Regression whose shape fits: $y = ax^b$

The calculation of the values to find the function of the line of different value matrices was performed by the method of least squares[29]. With the lines generated, calculation of the correlation between the values can be performed, which indicates the degree of dependence between two variables, so we used the correlation coefficient of Karl Pearson[30]. To interpret the correlation coefficient of Karl Pearson, it must be taken into account that its value ranges between 1 and -1. Values closer to 1 imply a perfect positive linear relationship and -1 a perfect negative relationship. Values closer to 0 indicate a lower linear relationship[31].

To test the correlation between the data, the coefficient of determination R^2 was used to interpret the proportion or percentage of variation in the dependent variable, which is explained by the variation in the independent variable, i.e., the percentage of values that fit with the shape of the graph[32]. The functions calculated generate the various energy and water consumption graphs to test their shape and to generate a valid energy model.

This same methodology was used to calculate the correlations of all hotels for different total water, electricity and energy consumption levels. With data from all the establishments, and due to the different maximum capacities of each hotel, guests had to be averaged as a percentage of occupancy, which was necessary to make the relative comparison of the average daily occupancy rate and work with the data from all hotels as if they were a single establishment in order to generate the corresponding function for hotels of similar characteristics.

Figure 1 exhibits schematically the workflow that was followed to perform the correlation calculations, where a summary of the steps taken can be seen as follows: 1. Data collection and filtration, 2. Perform the mean arithmetic of the data according to the intervals calculated, 3. Perform calculations and generate the correlation graphs of the different models, 4. Change the occupancy rates to a percentage and use all the values for the total calculation as if it were a single hotel, 5. Calculate the final model of energy and water consumption for establishments, and 6. Conclusions.

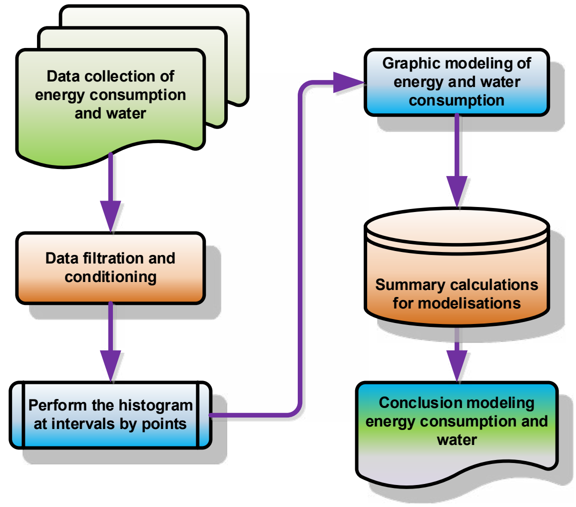

Figure 1. Diagram of the workflow for the research work. Source: Original.

To carry out the study of consumption in hotels, we chose several characteristic hotels in the Canary Islands, located on the eastern islands of Fuerteventura and Lanzarote, which have a peculiarity that distinguishes them from other hotels on other islands: their 100% reliance on desalinated water, due to the absence of hydrological resources for water distribution for general consumption on these islands. The hotels studied differ according to the way they supply water for human consumption, which is by producing water through a desalination Sea Water Reverse Osmosis Plants (SWROP) either located on the premises and belonging to the hotel or through a public water supply from a municipal plant located externally.

In the search for hotels with homogeneous characteristics, facilities were chosen that were less than 30 years old, had a 4-star rating, and fitted into the category 'holiday establishment', which implies a type of tourism where more of the hotel is enjoyed, such as the continual use of restaurants and swimming pools for the duration of the stay. All establishments have swimming pools and air conditioning, not counting heating. The gardens of the hotels are irrigated with desalinated or reclaimed water, which is motivated by the possibility of having

Table 1. Details of facilities and characteristics of hotels studied

DATES		HPE	HT	ESA	ECA	HTI	MSL
GENERAL	Location	Fuerteventura	Fuerteventura	Fuerteventura	Fuerteventura	Lanzarote	Lanzarote
	Construction date	2.000	2.004	2.003	2.007	1.997	1.988
	Land area	30.000	34.879	27.163	34.670	38.622	26.163
	Constructed area	25.912	31.132	22.710	28.307	34.112	24.507
	Rooms	333	354	266	346	329	343
	Beds	678	710	532	692	658	718
	Garden area	8.000	11.000	6.000	14.000	8.000	5.000
	Water source	SWROP	SWROP	Public supply	Public supply	SWROP	SWROP
	Irrigation source	SWROP	SWROP	Recycled	Recycled	SWROP	SWROP
POOLS	Nº Freshwater	2	1	2	1	8	1
	Area m^2	572	240	702	589	1.160	1.084
	Volume m^3	765	266	891	706	1.135	1.727
	Nº Climatized pool	1	3	1	2	2	2
	Heating system	Electricity	AC Recovery	Electricity	Electricity	Electricity	Solar panels
	kW heating	38	378	100	135	25	95
	Area m^2	86	232	331	439	85	120
	Volume m^3	130	240	298	487	95	110
Hot Water DHW	Combustible	LPG Propane	LPG Propane	Diesel oil	Diesel oil	LPG Propane + Diesel oil	Diesel oil
	kW heating	537	650	800	1.000	272+200	450
Renewable energy	Biomass heating kW					270	
	Nº Solar panels					168	92
	Solar panels m^2					340	795
Air Conditioner	HVAC System	1	2	2	2	1	1
	kW Total HVAC chillers	344	828	792	804	485	450
Desalination SWROP	kW Power (feed + plant)	65	65			52	120
	Production m3/hour	12	12			11	18
Years of date		2010-2013	2010-2015	2007-2012	2007-2012	2010-2015	2010-2015

their own treatment plant or external supply of reclaimed or desalinated water, since not all establishments have the possibility of irrigating with reclaimed water. The modelling calculations were performed regardless of the irrigation methods used in each hotel.

The hotels studied do not have the facilities to generate their own electricity, either for their own consumption or for sale, except for replacement generators in case of power failure from the grid, nor do they have their own cogeneration equipment. All electricity comes through an external supply network, being, in all cases, medium voltage with transformers located within the hotel facilities. Other fuels and power generation systems used by hotels, for which data are available are: LPG propane, diesel, biomass pellets and thermal solar panels.

Consumption data for the hotels was obtained between 2007 and 2015, depending on the facilities, with minimum values per hotel of 4 years and maximum of 6 years. During the years of study, diesel boilers have been replaced with biomass boilers, producing similar yields and allowing equivalent calculations to be performed by transferring all combustibles to the same unit of energy, i.e., kWh.

2.1 Data Analysis

Table 1 shows the general data of the establishments studied, with their main characteristics and facilities being presented. The low use of renewable energy can be observed, present only in a few establishments for the heating of water for human consumption (DHW), as well as the lack of heating facilities. Due to the data protection of the hotels, we refer to each hotel with a code.

In considering a study of hotels with similar capacities and facilities, all feature gardens, swimming pools and have air conditioning in all rooms and public areas (restaurants, bars and lounges). The need be able to generate their own supply of water through desalination SWROP is also verified where there is an absence in the public supply, as is the case in some areas of the islands in this study, so it is necessary that hotels have their own desalination plants SWROP. With the main data from the hotels, a comparison was performed to check the average values of the facilities listed in Table 2. In this comparison of different facilities, the homogeneity of establishments can be checked.

Hotels in the Canary Islands, mainly those in the eastern islands of Fuerteventura and Lanzarote, have the peculiarity that they do not need heating in winter. The average winter temperatures do not require the use or installation of heating systems, which reduces the average consumption during the winter months, air conditioning not being required in most establishments either. The average temperature of the coldest months of December, January and February is close to 18°C, with a minimum average of 16°C and a maximum of 20°C[33], making heating and air conditioning unnecessary.

2.2 Consumption Water Performance

To perform the calculations of water consumption, the peculiarity of these establishments must be taken into account, counting two extra types of consumption that are independent of hotel occupancy and operations. These consumptions are the replacement of swimming pool water and the irrigation of gardens, which have been studied independently.

Consumption from irrigation has not been taken into account in the calculations of the total water consumption of the hotels, since irrigation water can be of two types: purified water which has specific rules[34] for its implementation, which was studied and compared with other European countries in 2015[35] and water for human consumption[36], both of which are incompatible with each other. Irrigation costs in respect to total water consumption can be seen in Table 3, reaching an average expenditure at 12% of total water consumption. Given the total surface area of the gardens, irrigation consumption is calculated as m2 of garden, with an average of 2.67 l/m2 and a standard deviation of 0.6 l/m2.

Table 2. Main indicators of the hotels studied

INDICATORS	HPE	HT	ESA	ECA	HTI	MSL	Average	Typical deviation
m^2Construction / rooms	78	88	85	82	104	71	85	11
m^2Gardens / rooms	24	31	23	40	24	15	26	9
% Gardens / land area	27%	32%	22%	40%	21%	19%	27%	8%
m^2 Pools / rooms	2,0	1,5	3,9	3,0	3,8	3,5	2,9	1,0
m^3 Pools / rooms	2,7	1,6	4,5	3,4	3,7	5,4	3,5	1,3
kW Heating water / rooms	1,6	1,8	3,0	2,9	1,4	1,3	2,0	0,7
kW AC / rooms	1,0	2,3	3,0	2,3	1,5	1,3	1,9	0,7

Table 3. Total consumption, percentages and garden surface area for irrigation water

TYPE	HPE	HT	ESA	ECA	HTI	MSL	Total / Average
Total water consumption	453.535	468.617	423.494	397.289	424.167	467.479	2.634.581
Irrigation water consumption	46.286	79.232	25.480	77.285	38.263	37.388	303.934
% Consumption irrigation	10%	17%	6%	19%	9%	8%	12%
m^2garden	8.000	11.000	6.000	14.000	8.000	5.000	52.000
Average daily consumption	21	36	10	42	17	11	139
L/m^2daily	2,64	3,29	1,70	3,03	2,18	2,26	2,67

To perform a simplified approximation of the consumption of irrigation, taking into account only the air temperature and not considering go their factors, such as the type of flora, the similarity of the gardens, or the rainfall of the islands, annual accumulated average being the lowest in both the Canary Islands and Spain at 100 l/m^2 year[37]. With the average data of the percentage of consumption for irrigation in respect to the maximum value of the monthly irrigation values of the hotels shown in Table 4, a linear regression to test their dependence on the temperature was performed, proving that its coefficient of determination is very high and hence their dependence very strong, as shown in Figure 2.

Given that the annual average for daily consumption is 2.67 l/m2, corresponding to 80% of the value of irrigation, the maximum value, 100%, corresponds to 3.34 l/m2, which is the maximum value of daily irrigation. With the function calculated by linear regression, the function for calculating monthly consumption in litres for irrigation according to the surface area of the garden can be generated.

$$W_{irr} = \left(3,34(0,0371t - 0,0152)A_g\right)d$$

Where "A_g" is the area of garden in m^2, "d" is the number of days of the month of calculation and "t" the average monthly temperature in °C in the area where the hotel is situated on the islands.

With the consumption of water in swimming pools, which is another determinant factor in the cost of water, there are several variables involved in the daily renewal necessary to maintain the level of the swimming pools, which can be enumerated with the following factors: evaporation, leakage in the pool itself and the circuit, washing of filters, etc. Table 5 shows consumption data for hotel swimming pools, differentiating between the cold and heated pools. The importance of pool maintenance, which amounts to 13% of the water consumption of a hotel, can be checked, without taking into account maintenance of hot tubs, which are affected by the rules of legionella[38] and which mark the minimum amount of water maintenance of this type. It has been studied for this type of thermal pools[39]. Daily consumption of water for swimming pool maintenance, generically speaking, takes a daily value of 2.42%, with a standard deviation of 0.5%, which is considered sufficient to perform an approximate calculation for the water consumption of swimming pools, according to volume.

As hotel swimming pools use fresh water, this expense for modelling calculations of total water consumption has to be taken into account. In order to calculate approximations of monthly swimming pool water consumption in m3, taking into account the volume, the following function can be used to simulate an approximation of consumption:

$$Wp_m = \left(0,0242V_{Tp}\right)d$$

Where "V_{TP}" is the total volume of cold-water swimming pools, heated pools and Spas in m^3, "d" is the number of days of the month of the calculation.

Table 4. Average air temperature and percentage of monthly irrigation water consumption

UNIT	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dic	Average
Tº	17,9	17,9	18,9	20,2	21,7	23,2	24,8	25,5	24,9	23,8	21,3	19,1	17,9
% irrigation	63%	69%	72%	83%	78%	92%	94%	100%	93%	80%	78%	70%	80%

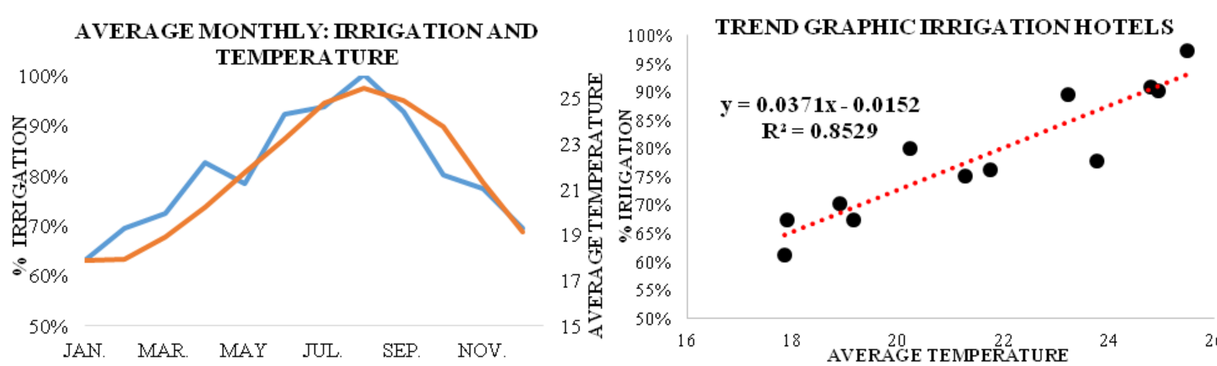

Figure 2. Average consumption of irrigation water and representation of the linear regression function. Source: Original.

Table 5. Water consumption in recreational and climatized pools

TYPE		HPE	HT	ESA	ECA	HTI	MSL	TOTAL
Total Year	Total water consumption	453.535	468.617	423.494	397.289	424.167	467.479	2.634.581
	Consumption water pools	53.929	26.342	49.930	66.824	40.976	113.899	351.900
	% consumption pool	12%	6%	12%	17%	10%	24%	13%
Cold pool	Volume water pool m^3	765	266	891	706	1.135	1.727	5.490
	Average daily consumption	21	4	17	16	18	48	123
	% average daily consumption	2,76%	1,51%	1,91%	2,22%	1,55%	2,78%	2,25%
Climatized pool	Volume water pool m^3	130	298	298	487	79	110	1.402
	Average daily consumption	3	7	7	19	2	6	43
	% average daily consumption	1,96%	2,47%	2,35%	3,85%	2,18%	5,44%	3,09%
Total	Volume water pool m^3	895	564	1.189	1.193	1.214	1.837	6.892
	Average daily consumption	24	11	24	34	19	54	167
	% average daily consumption	2,64%	2,01%	2,02%	2,89%	1,59%	2,94%	2,42%

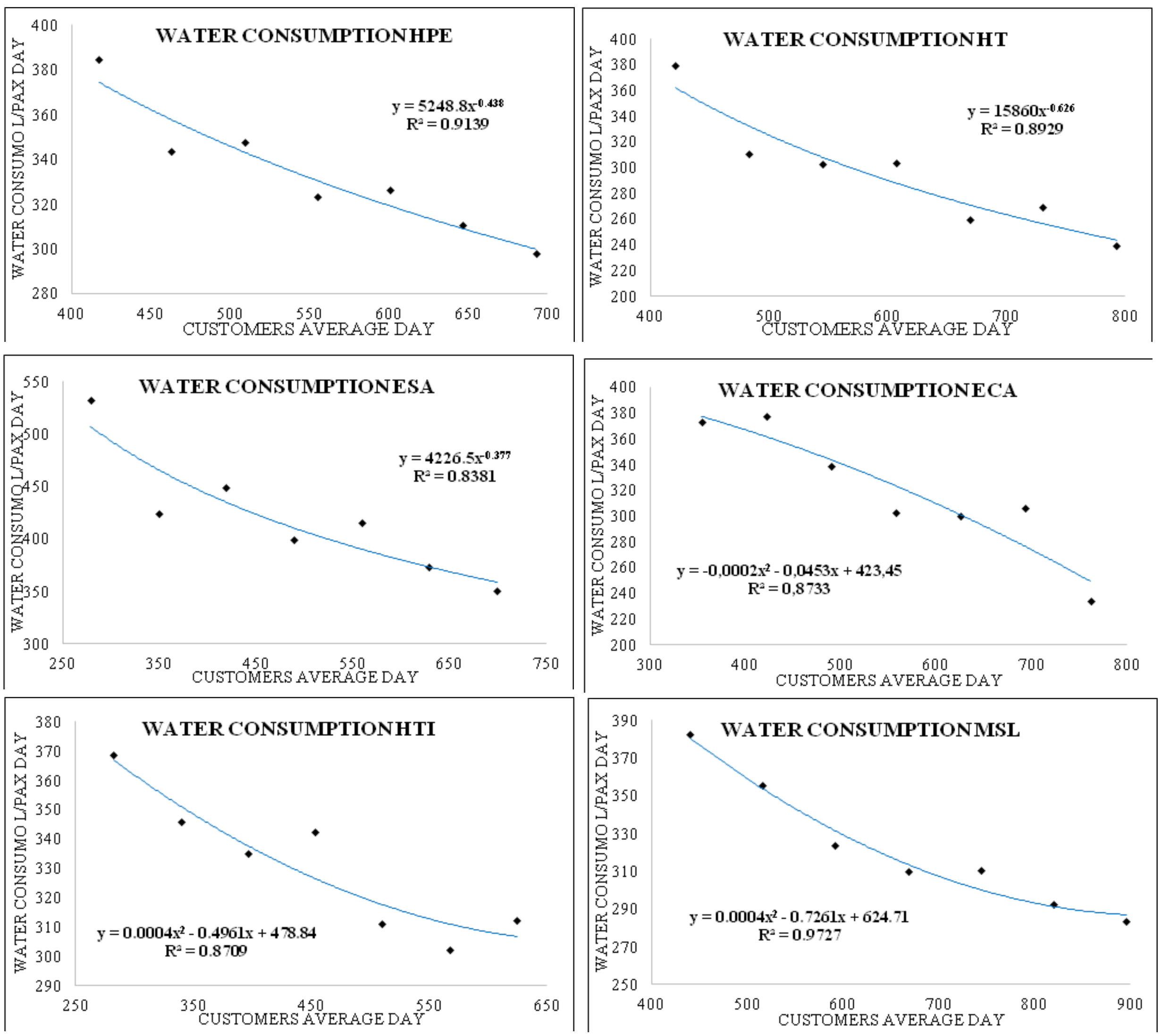

Figure 3. Characteristic function with the greatest correlation index for each hotel for different regression models for water consumption, without considering irrigation. Source: Original.

2.2.1 Water Consumption in Hotels without Irrigation

Having established the average consumption from swimming pools and irrigation, the correlation calculations of different levels of water consumption of hotels-recalling that the consumption of irrigation has not been taken into account, but the consumption of pools has-were performed. The following graphs show the different average points calculated for each hotel, according to the daily occupancy rate and daily average water consumption in litres per guest. In Figure 3 each hotel represents the characteristic function with a greater correlation index and a greater determination coefficient R^2 for different regression models.

Table 6 summarizes the calculation values of the functions of the investigated regression models, where the different values of the coefficient of determination can be checked, with the potential and polynomial correlation which best fit the graph. The increased potential of consumption is due to the declining number of guests. Since the minimum consumption of some facilities is independent of the number of guests, we consider the minimum fixed consumption to be maintained.

2.3 Electricity Consumption

Electricity in hotels is the main source of energy used in them, since most of the equipment and facilities work with this type of energy. Electricity consumption represents about 70% of the total energy consumption of hotels. In the hotels in this study, all electric power is supplied externally, not counting the establishments with any active generation or cogeneration system, so their external dependence is total. This external dependence clashes with the possibility of obtaining buildings with ZEB or nZEB, so it is necessary to model their consumption and check their behaviour according to occupancy rates, seeking alternatives to this external dependence through self-supply of electricity with different types of power generation systems based on renewable energy.

For comparison of electricity consumption, the use of water from the public supply or from the hotel's own desalination Sea Water Reverse Osmosis Plants (SWROP)

Table 6. Summary of functions and coefficient of determination of the different types of correlation for water consumption

CORRELATION TYPE		HPE	HT	ESA
WATER CUSTOMERS	Linear	y=-0,2687x + 483	y=-0,3148x + 486	y=-0,3466x + 590
	Linear R^2	0,8842	0,8496	0,7869
	Exponential	$y = 517{,}53e^{-8E-04x}$	$y = 552{,}06e^{-0{,}001x}$	$y = 619{,}13e^{-8E-04x}$
	Exponential R^2	0,9002	0,8758	0,8161
	Logarithmic	y = -147,9ln(x) + 1265,9	y = -188,7ln(x) + 1499,5	y = -163,3ln(x) + 1424,2
	Logarithmic R^2	0,9034	0,8784	0,8245
	Polynomial	$y = 0{,}0006x^2 - 0{,}8871x + 649{,}43$	$y = 0{,}0006x^2 - 1{,}0462x + 698{,}32$	$y = 0{,}0006x^2 - 0{,}8853x + 710{,}89$
	Polynomial R^2	0,9083	0,8854	0,8162
	Potential	$y = 5248{,}8x^{-0{,}438}$	$y = 15860x^{-0{,}626}$	$y = 4226{,}5x^{-0{,}377}$
	Potential R^2	0,9139	0,8929	0,8381
CORRELATION TYPE		ECA	HTI	MSL
WATER CUSTOMERS	Linear	y=-0,3142x + 494	y=-0,1759x + 411	y=-0,2056x + 460
	Linear R^2	0,8662	0,8380	0,9158
	Exponential	$y = 556{,}66e^{-0{,}001x}$	$y = 419{,}72e^{-5E-04x}$	$y = 487{,}92e^{-6E-04x}$
	Exponential R^2	0,8390	0,8377	0,9338
	Logarithmic	y = -165,4ln(x) + 1359,9	y = -77,36ln(x) + 801,65	y = -135,2ln(x) + 1198,2
	Logarithmic R^2	0,8403	0,8637	0,9554
	Polynomial	$y = -0{,}0002x^2 - 0{,}0453x + 423{,}45$	$y = 0{,}0004x^2 - 0{,}4961x + 478{,}84$	$y = 0{,}0004x^2 - 0{,}7261x + 624{,}71$
	Polynomial R^2	0,8733	0,8709	0,9727
	Potential	$y = 8995{,}3x^{-0{,}533}$	$y = 1352{,}2x^{-0{,}232}$	$y = 4582{,}4x^{-0{,}41}$
	Potential R^2	0,8013	0,8591	0,9653

has to be taken into account, which represent between 10% and 15% of hotels' total consumption. This can be seen in Table 7 of values from 2013, where the average energy consumption from desalinations about 4.77 kWh/m^3, taking into account the SWROP and pumping brackish or saltwater from a catch pit.

To perform the calculations for modelling the consumption of electricity, the consumption of SWROP are not considered, as there are hotels without desalination plants. The following graphs Figure 4 shows the different average points for electricity consumption calculated for each hotel according to the average daily occupancy rates

Table 7. Consumption of electrical energy for desalination in hotels, 2013

TYPE (2013)	HPE	HT	HTI	MSL	TOTAL
ELECTRICITY	2.830.578	4.025.026	3.045.352	2.822.006	12.722.962
DESALINATION	357.115	391.600	292.212	420.801	1.461.729
% Desalination	13%	10%	10%	15%	11%
Desalinated water	68.676	78.320	76.898	82.510	306.404
Consumption kWh/m3	5,20	5,00	3,80	5,10	4,77

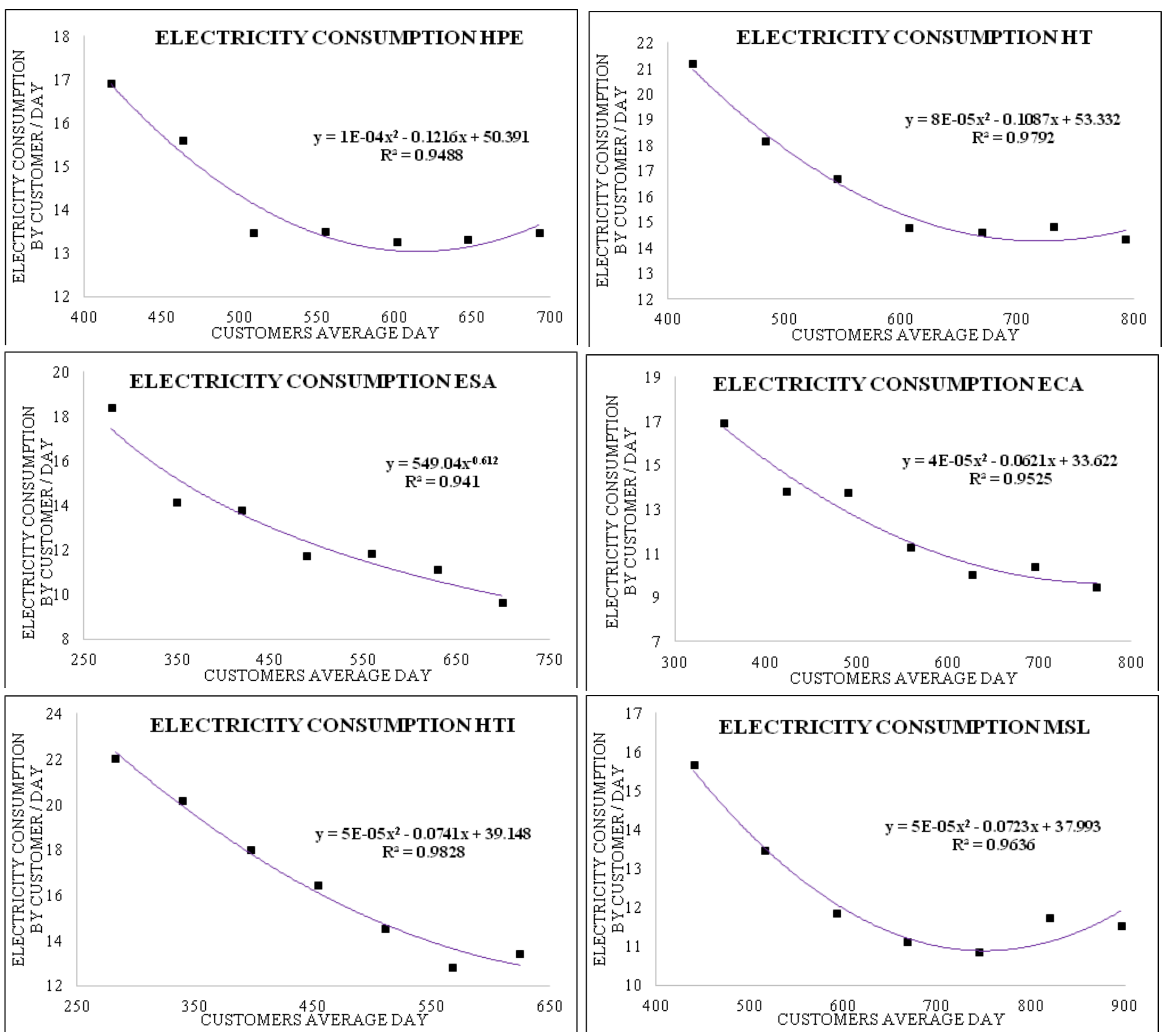

Figure 4. Characteristic function with the greatest correlation index for each hotel for different regression models for electricity consumption, without considering the desalination plant. Source: Original.

and the average daily electrical energy consumption in kWh per guest. They represent in all the graphs the line of tendency according to the correlation function with greater determination coefficient R^2.

Table 8 summarizes the calculations performed to obtain the functions of the regression models of consumption of electricity per customer per day, checking the different values of the coefficient of determination, which indicate the degree of correlation between data. The high correlation of the values of occupancy and consumption of electricity is tested, the polynomial correlation being the one which best fits in almost all cases, except in the case of ESA hotels.

2.4 Energy Performance

Hotels currently use multiple primary energy sources to meet their energy needs. To make comparisons, it is necessary to transfer such energy sources to a common unit of reference, in this case kWh, according to the values of energy conversion given in Table 9 provided by the IDAE[40-46].

The main types of energy used in hotels are:

- Electricity: generic use in all facilities. Between 60 and 75% of energy.
- LPG: kitchens, DHW heating and acclimatization of pools. Between 10 and 30% of energy.
- Diesel: DHW heating and acclimatization of pools. Between 10 and 30% of energy.

Table 8. Summary of functions and coefficient of determination of the different types of correlation for energy consumption

TYPE		HPE	HT	ESA
ELECTRICITY CUSTOMERS	Linear	y=-0,0117x + 21	y=-0,0169x + 27	y=-0,0174x + 21
	Linear R^2	0,6536	0,7952	0,8605
	Exponential	$y = 21{,}941e^{-8E-04x}$	$y = 29{,}509e^{-1E-03x}$	$y = 24{,}094e^{-0{,}001x}$
	Exponential R^2	0,6578	0,8195	0,9083
	Logarithmic	y = -6,692ln(x) + 56,414	y = -10,36ln(x) + 82,512	y = -8,278ln(x) + 63,854
	Logarithmic R^2	0,7167	0,8607	0,9169
	Polynomial	$y = 1E-04x^2 - 0{,}1216x + 50{,}391$	$y = 8E-05x^2 - 0{,}1087x + 53{,}332$	$y = 4E-05x^2 - 0{,}0562x + 30{,}182$
	Polynomial R^2	0,9488	0,9792	0,9260
	Potential	$y = 240{,}9x^{-0{,}449}$	$y = 760{,}9x^{-0{,}603}$	$y = 549{,}04x^{-0{,}612}$
	Potential R^2	0,7202	0,8802	0,9410
TYPE		ECA	HTI	MSL
ELECTRICITY CUSTOMERS	Linear	y=-0,0172x + 22	y=-0,0275x + 29	y=-0,0079x + 18
	Linear R^2	0,8859	0,9505	0,5869
	Exponential	$y = 25{,}85e^{-0{,}001x}$	$y = 34{,}496e^{-0{,}002x}$	$y = 18{,}283e^{-6E-04x}$
	Exponential R^2	0,9126	0,9555	0,5861
	Logarithmic	y = -9,445ln(x) + 71,674	y = -12,07ln(x) + 90,206	y = -5,493ln(x) + 47,902
	Logarithmic R^2	0,9293	0,9748	0,6821
	Polynomial	$y = 4E-05x^2 - 0{,}0621x + 33{,}622$	$y = 5E-05x^2 - 0{,}0741x + 39{,}148$	$y = 5E-05x^2 - 0{,}0723x + 37{,}993$
	Polynomial R^2	0,9525	0,9828	0,9636
	Potential	$y = 1320{,}6x^{-0{,}747}$	$y = 1235{,}8x^{-0{,}71}$	$y = 182{,}49x^{-0{,}417}$
	Potential R^2	0,9418	0,9657	0,6803

Table 9. Factors of conversion for combustible fuel energy in kWh. Source: IDAE

COMBUSTIBLE TYPE	ENERGY CONVERSION FACTORS	
DIESEL OIL	10,28	KWh/L
LPG PROPANE	12,75	kWh/kg
Wood Pellets (humidity<15%)	5,01	kWh/kg
Pellets generally	4,57	kWh/kg

Table 10. Summary of energy consumption from hotels in study from 2011

ENERGY TYPE	HPE	HT	ESA	ECA	HTI	MSL	TOTAL
ELECTRICITY	3.596.447	3.855.650	2.394.797	2.372.912	2.978.048	3.021.838	18.219.692
% Electricity	72%	68%	70%	63%	62%	67%	67%
LPG PROPANE	1.372.410	1.801.014	194.081	272.582	906.895	307.224	4.854.206
% LPG propane	28%	32%	6%	7%	19%	7%	18%
DIESEL OIL			822.400	1.099.960	544.316	441.989	2.908.664
% Diesel oil	0%	0%	24%	29%	11%	10%	11%
THERMAL SOLAR					350.842	739.200	1.090.042
% Thermal solar	0%	0%	0%	0%	7%	16%	4%
TOTAL ENERGY	4.968.857	5.656.664	3.411.278	3.745.454	4.780.100	4.510.250	27.072.603

- Biomass: DHW heating and acclimatization of pools. Usually replacing LPG or diesel oil boilers in the same proportion, representing between 10 and 30% of energy.
- Thermal Solar: DHW heating and acclimatization of pools. Between 5 and 20% of energy.

Table 10 lists the different types of energy consumption in 2011, where the importance of electricity consumption can be seen. Renewable energy does not yet represent a significant percentage of consumption. From 2014, HTI diesel cats switched to biomass, which means an increase to 15% of renewable energy, this value being too low to obtain ZEB or nZEB buildings.

Figure 5 can be used to check the distribution of energy consumption in percentages by energy type for the year 2011, highlighting the importance of electricity consumption in hotels, where it represents 67% of total consumption, and the low importance of renewable energies in that year, representing only 4% from thermal solar energy.

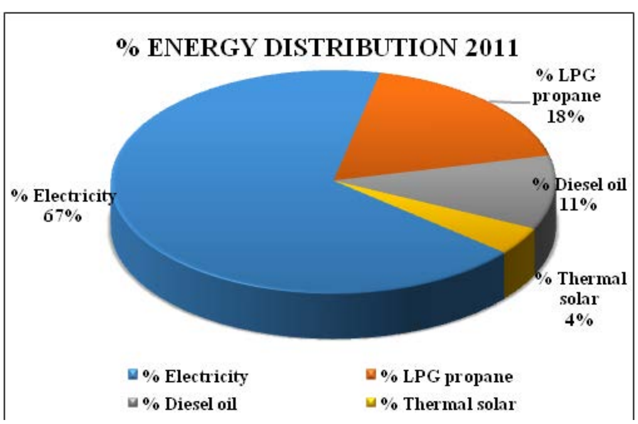

Figure 5. Distribution of energy consumption in hotels study 2011. Source: Original.

In the calculations of the modelling of energy consumption, the consumption of desalination plants is not taken into account. Figure 6 shows the average points of energy consumption calculated for each hotel according to the average daily occupancy rates and the average daily consumption of energy per guest in kWh. The line of tendency is represented in all the graphs, according to the correlation function with the greatest determination coefficient R^2.

Table 11 summarizes the calculations performed to obtain the functions of regression models of total energy consumption per customer per day, checking the different values of the coefficient of determination, which indicates the degree of correlation between the data. The high correlation values of occupancy and energy consumption is tested, the polynomial correlation being that which best fits consumption, except in the case of ESA, where it is the potential, and HTI, where it is the exponential.

2.5 Study Mathematical Model

Since the hotels in this study have different maximum capacities, the same number of clients translates to different percentages of occupancy. This requires changing the ratios of consumption per guest to consumption by percentage of occupancy, since, in this way, we can compare the occupancy rates of different hotels in balance with the conditions of occupancy. With the amount of data from all the hotels, it was found that the occupancy intervals used and on which we have data, cover occupancy values of between 45% and 120%. Once we divided by intervals and filtered them, we performed the correlation calculations for the calculated mean values.

With the calculations performed, Figure 9 was generated, representing the midpoints for consumption of

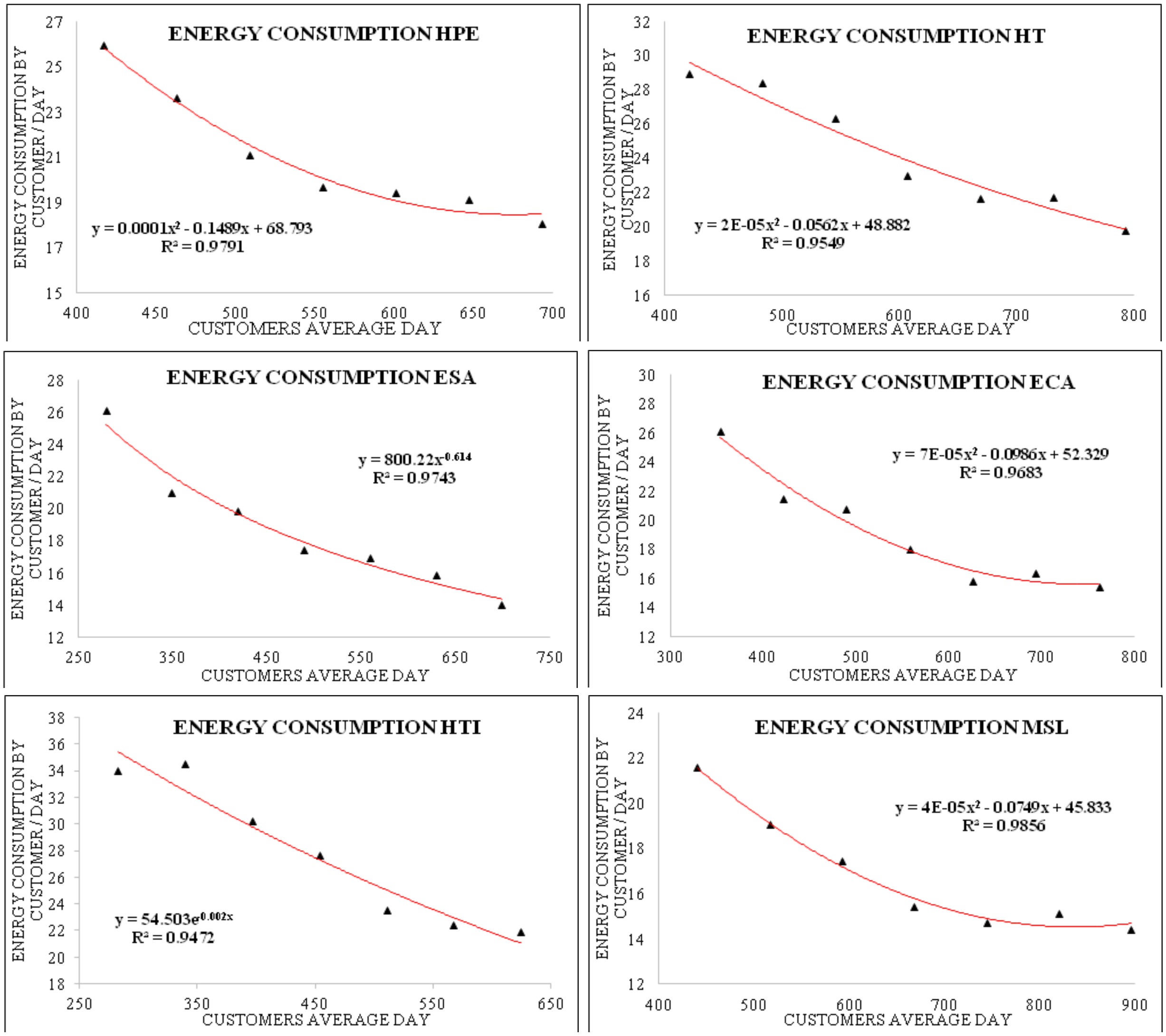

Figure 6. Characteristic function with the greatest correlation index for each hotel for the different regression models for total energy consumption, without considering desalination plants. Source: Original.

water, electricity and energy for all the hotels combined. The line of tendency is represented in all the graphs, according to the correlation function with the greatest determination coefficient R^2.

Table 12 shows the calculations performed to obtain the functions for the regression models of water, electricity and energy are summarized. A strong correlation was found between the consumption of water and energy, which fits almost perfectly with the potential function. The best fit for consumption of electricity is a type of polynomial function, although the potential function also has a high degree of correlation.

After verifying the strong correlation between the systems of polynomial regression in electricity and potential in water and total energy, the suitability of these functions can be confirmed, comparing the actual values of the averages for the hotels with values of the functions generated by the regression models. All the regression models have been compared on the same graph, calculating the values of the functions from an occupancy rate of 1% to 140%, which is shown in Figure 7. It can also be seen how the values of the regression functions have been paired for values of between 40% to 120% occupancy, for which, among these values - which are where the average occupancy rates for the hotels are usually found - the mean values of supplies with any of the functions can be approximated, although taking into account that the optimum fit has to use the potential or

Table 11. Summary of functions and coefficient of determination of the different types of correlation for total energy consumption. Source: Original.

TYPE		HPE	HT	ESA
ENERGY CUSTOMERS	Linear	y=-0,0267x + 36	y=-0,0262x + 40	y=-0,0252x + 31
	Linear R^2	0,8834	0,9452	0,9073
	Exponential	$y = 41{,}405e^{-0{,}001x}$	$y = 46{,}225e^{-0{,}001x}$	$y = 35{,}024e^{-0{,}001x}$
	Exponential R^2	0,9072	0,9514	0,9488
	Logarithmic	y = -14,84ln(x) + 114,53	y = -15,49ln(x) + 123,22	y = -11,9ln(x) + 91,935
	Logarithmic R^2	0,9226	0,9523	0,9566
	Polynomial	$y = 0{,}0001x^2 - 0{,}1489x + 68{,}793$	$y = 2E\text{-}05x^2 - 0{,}0562x + 48{,}882$	$y = 5E\text{-}05x^2 - 0{,}0748x + 42{,}206$
	Polynomial R^2	0,9721	0,9549	0,9615
	Potential	$y = 1571{,}9x^{-0{,}686}$	$y = 1386x^{-0{,}635}$	$y = 800{,}22x^{-0{,}614}$
	Potential R^2	0,9408	0,9511	0,9743
TYPE		ECA	HTI	MSL
ENERGY CUSTOMERS	Linear	y=-0,0247x + 33	y=-0,0421x + 47	y=-0,0151x + 27
	Linear R^2	0,8807	0,9405	0,8549
	Exponential	$y = 37{,}91e^{-0{,}001x}$	$y = 54{,}503e^{-0{,}002x}$	$y = 29{,}695e^{-9E\text{-}04x}$
	Exponential R^2	0,9085	0,9472	0,8758
	Logarithmic	y = -13,61ln(x) + 104,75	y = -18,17ln(x) + 138,32	y = -10,04ln(x) + 81,849
	Logarithmic R^2	0,9323	0,9354	0,9153
	Polynomial	$y = 7E\text{-}05x^2 - 0{,}0986x + 52{,}329$	$y = 3E\text{-}05x^2 - 0{,}0672x + 52{,}174$	$y = 4E\text{-}05x^2 - 0{,}0749x + 45{,}833$
	Polynomial R^2	0,9683	0,9442	0,9856
	Potential	$y = 1402{,}2x^{-0{,}685}$	$y = 1464{,}7x^{-0{,}655}$	$y = 683{,}88x^{-0{,}574}$
	Potential R^2	0,9472	0,9326	0,9286

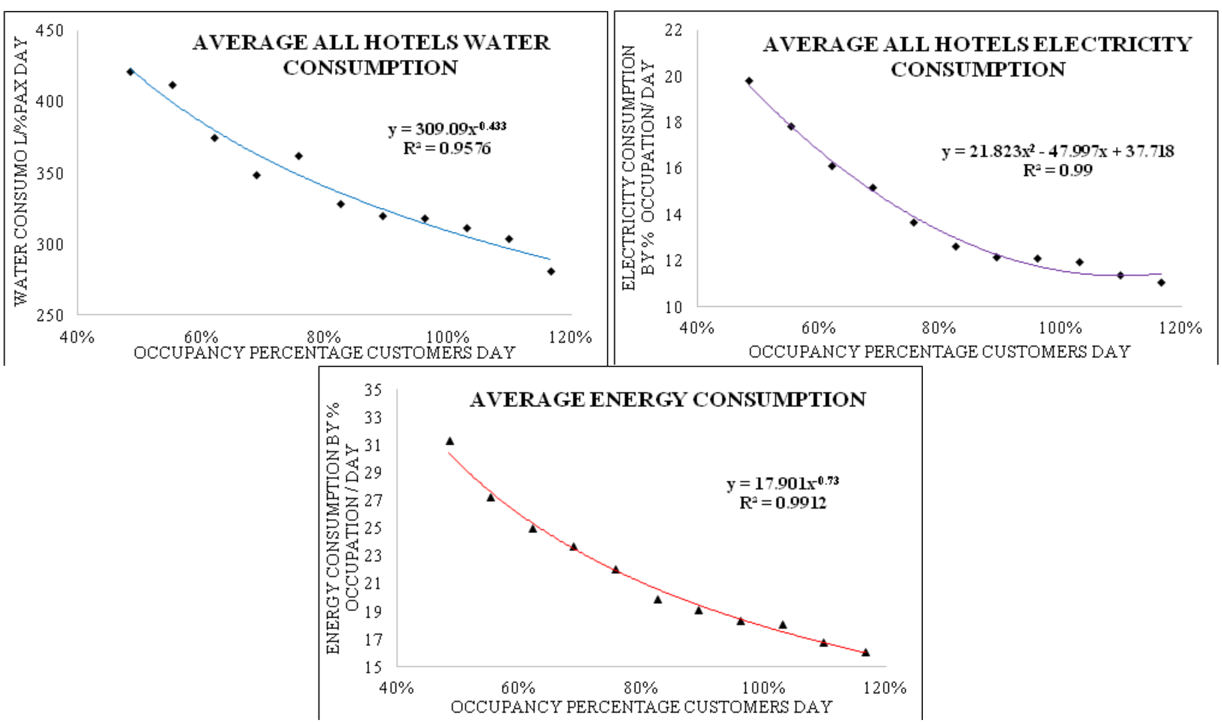

Figure 7. Characteristic function with the greatest correlation index for the consumption of water, electricity and energy of all hotels. Source: Original.

Table 12. Summary of functions and coefficient of determination of the different types of correlation for consumption of water, electricity and energy. Source: Original.

TYPE	DATA FOR ALL HOTELS		
	WATER CUSTOMERS	ELECTRICITY CUSTOMERS	ENERGY CUSTOMERS
Linear	y = -190,38x + 500,91	y = -11,988x + 23,879	y = -20,312x + 38,362
Linear R^2	0,9247	0,8838	0,9257
Exponential	$536{,}13e^{-0{,}547x}$	$y = 27{,}163e^{-0{,}826x}$	$y = 45{,}157e^{-0{,}919x}$
Exponential R^2	0,9412	0,9212	0,9647
Logarithmic	y = -151,6ln(x) + 309,16	y = -9,732ln(x) + 11,762	y = -16,33ln(x) + 17,868
Logarithmic R^2	0,9542	0,9476	0,9733
Polynomial	$y = 180{,}19x^2 - 487{,}69x + 615{,}18$	$y = 21{,}823x^2 - 47{,}997x + 37{,}718$	$y = 27{,}706x^2 - 66{,}027x + 55{,}931$
Polynomial R^2	0,9547	0,9900	0,9882
Potential	$y = 309{,}09x^{-0{,}433}$	$y = 11{,}803x^{-0{,}664}$	$y = 17{,}901x^{-0{,}73}$
Potential R^2	0,9576	0,9700	0,9912

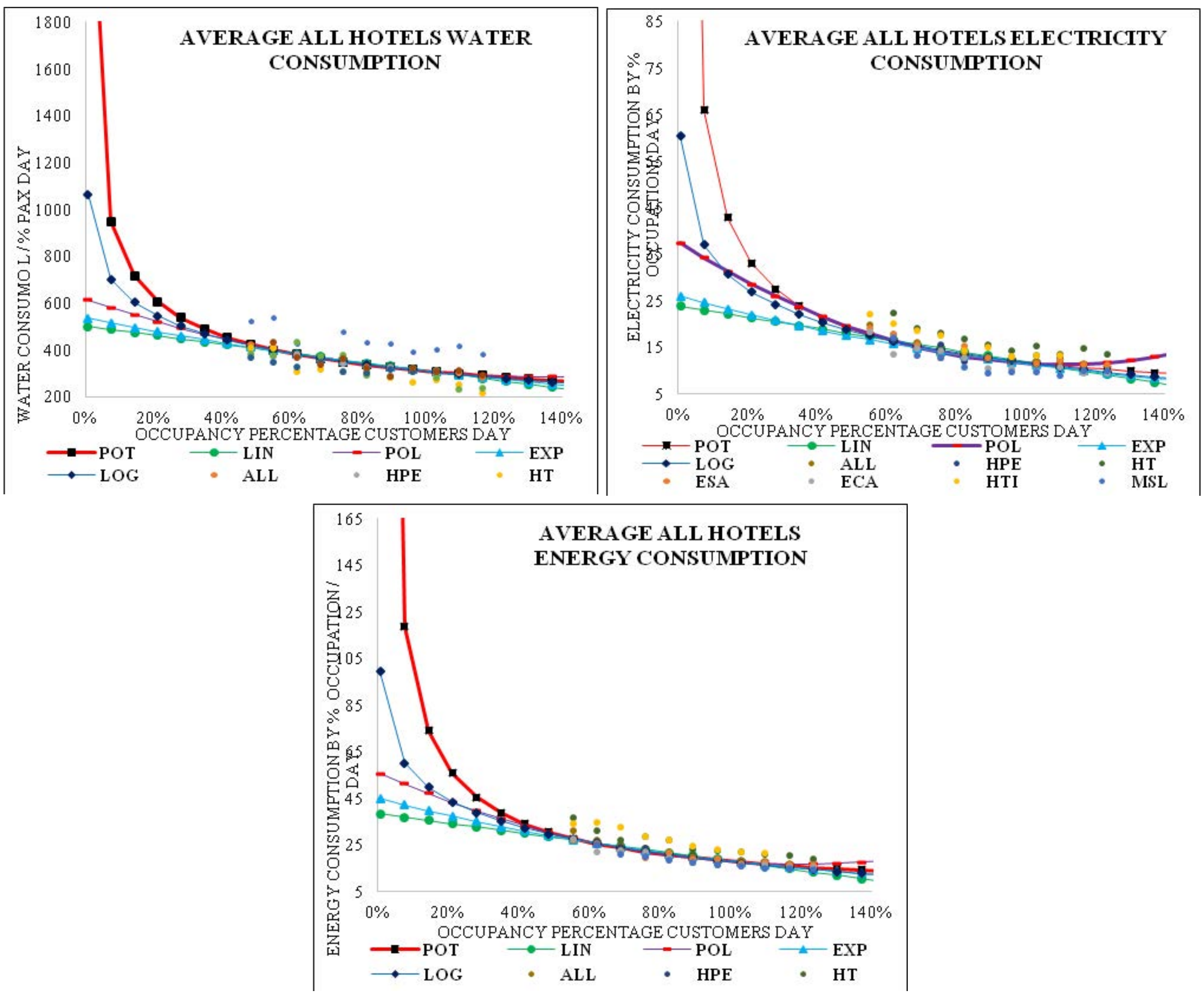

Figure 8. Representation of regression functions between 1 and 140% occupancy with respect to the midpoints of water, electricity and energy consumption of the different hotels.

polynomial function.

3. Results and Discussion

It was found that the values of the midpoints for the levels of consumption of the hotels approximately fit the values of the calculated functions. The next step was to check that the calculated mean values for all hotels fit with the generated function in order to demonstrate the validity of the models calculated for the average occupancy values, which range in a generic sense between 30% and 130%. Figure 9 represents functions of water, electricity and energy appear.

In reviewing the representation of the functions, it was found that the average data fits the graphs generated, so the potential function can be used for the approximation of the values of water and energy consumption, and the polynomial for electricity consumption for a group of four-star hotels with similar characteristics such as those studied here.

The functions that bring us the values of monthly consumption, taking into account the average daily occupancy, air temperature for water consumption for irrigation and desalinated water production for specific consumption, are summarized as follows:

- Water

Consumption without irrigation:

$$W_{TT} = (309,09x^{-0,433})d$$

Consumption with irrigation:

$$W_{TTirr} = \left((309,09x^{-0,433}) + \left(3,34A_g(0,0371t - 0,0152)\right)\right)d$$

- Electricity

Consumption without irrigation:

$$El_{TT} = (21,832x^2 - 47,997x + 37,718)d$$

Consumption desalination SWROP without irrigation:

$$El_{TTdw} = \left((21,832x^2 - 47,997x + 37,718) + (W_{TT}C_{dw})\right)d$$

Consumption desalination SWROP with irrigation:

$$El_{TTdwirr} = \left((21,832x^2 - 47,997x + 37,718) + (W_{TTirr}C_{dw})\right)d$$

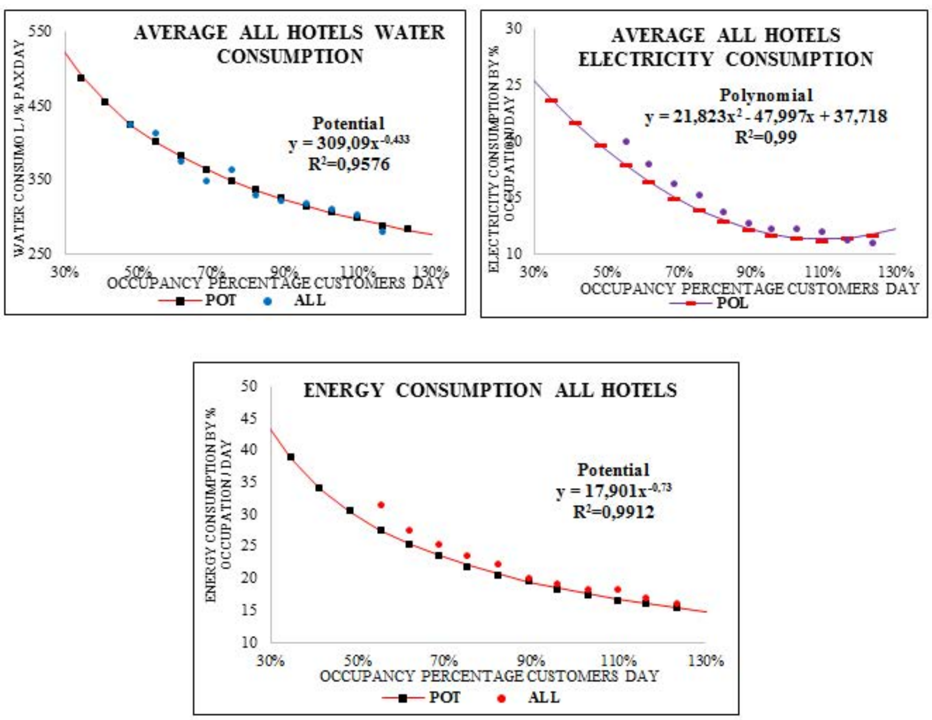

Figure 9. Representation of regression functions between 30 and 130% occupancy with respect to the midpoints of the average consumption of water, electricity and energy calculated for all hotels.

- Energy:

Consumption without irrigation:

$$E_{TT} = (17,901x^{-0,73})d$$

Consumption desalination SWROP without irrigation:

$$E_{TTdw} = \left((17,901x^{-0,73}) + (W_{TT}C_{dw})\right)d$$

Consumption desalination SWROP with irrigation:

$$E_{TTdwirr} = \left((17,901x^{-0,73}) + (W_{TTirr}C_{dw})\right)d$$

Where “x” is the percentage of average occupancy, “C_{dw}” is the specific consumption of the plant in kWh/m^3 of water generated, “A_g” is the surface area of gardens, “d” is the number of days of calculation and “t” the average temperature in the area where the hotel is located on the islands.

The main reasons for the increase in specific consumption, even with decreasing occupancy, are related to the need for facilities to be in place and consuming energy or water at the hotel, with or without guests, since the sectorization of equipment or systems cannot be carried out in most of the hotels studied, implying that the minimum consumption is always due to the ongoing maintenance of facilities.

4. Conclusions

Using the method described, a model of the typical consumption of water, electricity, and energy for a hotel in a determined segment, which may be reproduced for any other hotel in the sector, was obtained, thus making it possible to check and compare consumption. With the application of statistical functions and correlation, optimum consumption models can be generated for a group of homogeneous hotels, taking into account that the more data obtained, the more reliable will be the generated models. The basic procedure followed and demonstrated leaves the field open to more complex and precise research, applicable to any type of supply for hotels.

With the different correlation models studied, it has been found that, in most cases, the potential or polynomial models is applicable, with very little difference between the correlation coefficients. The calculated values, from which we can consider similar approximations for both models, are between 40 and 120% occupancy, being that lower or higher occupancy rates have very large differences from which no equivalent can be made.

The peculiarity of hotels with a desalination seawater reverse osmosis plants SWROP where energy consumption is directly related to water consumption and influence the type of irrigation used - is studied. This proves the need to improve the efficiency of the desalination plants SWROP in reducing water consumption and irrigation in order to achieve a proportional energy reduction in the hotels.

The use of renewable energy is highly unrepresented in the hotels from the study. This can and should be improved, mainly through using renewable energy sources for domestic hot water (DHW), which represents 22% of energy consumption in hotels. In this way, external energy dependence could be reduced.

This study leaves open the way to further investigation into the importance of hotel occupancy rates, with the carbon footprint generated by energy consumption being due to the activity of tourist accommodation, as well as the importance of water desalination in hotels in the Canary Islands, which is a determinant factor in the consumption of energy.

By comparing the different methods and systems for energy efficiency and developing the method studied, improvements can be simulated for application in facilities in order to compare the most optimal and effective models to be adopted, verifying this as hotels get closer to energy independence and achieving the objective of becoming ZEB or nZEB hotels.

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