ASSESSING CLIMATE CHANGE IMPACT IN HOSPITALITY SECTOR. SIMPLIFIED APPROACH USING BUILDING RESOURCES CONSUMPTION SIGNATURE

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Abstract

Climate impact assessments and the development of adaptation strategies requires the study of vulnerabilities and risk to climate variables. The energy and water consumption demand in hotel usually change with occupancy rate and climate. In this article a simplified methodology is presented and applied to identify the climate change impact in hospitality sector using the building energy and water signature. This methodology is applied to sixteen hotels (nine in Lisbon and seven in Algarve) with four and five stars rating. The results show that is expect an increase in water and electricity consumption (manly due to the increase in cooling) and a decrease in gas consumption (for heating). The hotels in Algarve are more vulnerable than Lisbon hotels.

Keywords: climate change, energy, water, hotel, tourism.

1 INTRODUCTION

Hotels are one of building types that consumes more energy and water per person and are vulnerable to climate change because in the occurrence of extreme events (heat waves, water stress) same failures could compromise the hotel services (comfort) and increase energy cost or compromise the landscape and amenities due to water use restriction (UNEP)

Climate impact assessments and the development of adaptation strategies require the study of vulnerabilities and the knowledge about critical climatic variables, namely the availability of high-resolution climate change scenarios. As part of the global CORDEX framework, the EURO-CORDEX provides regional climate projections for Europe at 50 km (EUR-44) and 12.5 km (EUR-11) resolution [5].

To study the risk and vulnerability of hotels to climate change regarding resources consumption (energy and water), in previous studies building energy modelling simulation (BEMS) technique were used to study the increase in energy and water consumption ([12], outros). In general the climate change impact in building is performed studying the transformation of energy and water demand of the building for future climate scenarios [12]. But, hotels are complex buildings and quite different from each other and simplified BEMS usually neglect some important hotel features and projected estimates didn't match hotel sector understanding and expectations.

Taking account all uncertainties, the use of building signature could be helpful to assess in a more clear way the impact of CC in the hospitality sector and using a broad sample. Statistical analysis of the global energy consumption obtained from bills shows that the energy consumption may be predicted within 90% confidence interval only with the outdoor temperature [9], [13] and [8]. The use of regression method was also used by designers to target building design parameters in early design that drive energy performance [10].

2 METHODOLOGY

The proposed methodology to assess the climate change impact in the hospitality sector, regarding comfort and rational use of resources, is proposed to be supported by the estimate of the change in the energy and water demand of the buildings for climate projection. In this simplified approach, it's proposed to use the energy and water signature of the building, using the last three years' monthly data for energy and water consumption, observed weather data and services provided (guest per night and covers).

This methodology is in line with building energy consumption calculations with quasi steady state linear models such as defined in standard ISO 13790:2008 [7]. The building energy and water signature is derived using a multiple linear regression (eq 1 and 2). This type of model assumes that the energy and water consumption is linear related with number of guest, covers and outside weather. In the first two cases this could be true (Pinto, 2015), but usually the building energy demand is not linearly related with outside weather, due to dynamic heat flux phenomena, building thermal inertia, changes in the air flow rate, etc. Despite this limitation for short period analysis, regression analysis is helpful when using longer periods, when some of this phenomena are averaged. For instance, using monthly data, the influence of any phenomenon having dynamics faster than 1 month is neglected, but better correlation are obtained than using short time intervals (10 minutes, 1 hour), due to the influence of random, non-measured disturbances like occupancy, ventilation rates and solar gains that do not follow a normal (Gaussian) distribution (Ghiaus, 2006). In figures 1 to 3 are presented the relation between electricity consumption (EkWh) and independent variables such as outdoor temperatures, occupancy (PAX) cover, etc. The same is done in figures 2 and 3, for gas consumption and water consumption. Those figures, and the study of data from other hotels with Akaike Information Criterion (AIC) show that:

- Occupancy and meal are correlated and in this study it will be used de occupancy do assess the influence of occupancy.
- The influence of climate on building resource consumption is related with average outdoor temperature and we could disregard Heating Degree (GDaq) days and Cooling degrees day (GDarr) that are related with average outdoor temperature.
- Water consumption is strongly related with occupancy and in other hotels with precipitation.
- It's noted that occupancy is also related with outdoor average temperature.

With the previous information, to find the hotels energy and water signatures it was used the linear models presented in eq 3, 4 and 5. This type of energy and water signatures are fit if they present R^2 not smaller than 0.75 and if the independent variable has p-value not greater than 5%.

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_p X_p + \varepsilon \quad (1)$$

$$\hat{Y} = \beta_0 + \beta_1 \hat{X}_1 + \beta_2 \hat{X}_2 + \ldots + \beta_p \hat{X}_p \quad (2)$$

$$E(kWh) = a_e + b_e.T + c_e.G \quad (3)$$

$$G(kWh) = a_g + b_g.T + c_g.G \quad (4)$$

$$W(m^3) = a_w + b_w.T + c_w.G + d_w.P \quad (5)$$

where: G, guest/day; T, average monthly outdoor temperature, P, average monthly precipitation a_i, b_i and c_i are the regression coefficients.

3 METEOROLOGICAL DATA AND CLIMATE CHANGE

Precipitation and temperature observations used in the present work were obtained from the IPMA (Portuguese Institute for the Sea and Atmosphere) observation network. The consist in daily accumulated precipitation and mean, maximum and minimum daily temperatures, measured in five locations, three in the Lisbon area and two in the Algarve, during three years from January 2012 to December 2014.

Data used to evaluate the impacts of climate change was obtained from the EURO-CORDEX initiative (http://www.euro-cordex.net/). EURO-CORDEX is an international climate downscaling initiative that aims to provide high-resolution climate scenarios for Europe (Kotlarski, et al., 2014). The regional simulations were downscaled from the new CMIP5 global climate projections [3] and the new representative concentration pathways (RCPs) [2], [4]. Only one ensemble member was used, the one produced by the ICHEC, forced with global climate simulation produced within the EC-EARTH consortium. Daily precipitation and mean daily temperature were extracted from the EUR-11 (12.5 km) resolution domain, for two locations, one in the Lisbon area and another in the Algarve (Vilamoura). Climate projection corresponding to two emission scenarios, RCP4.5 and RCP8.5 were used.

Three sets of climate data, of twenty years each, were obtained for each scenario. The first represents the beginning of the 21st century (2011-2030), the second the mid 21st century (2031-2050) and the third, the end of this century (2081-2100), figure 1 and table. Heating degree days and cooling degree days were computed on base 20ºC and 22ºC.

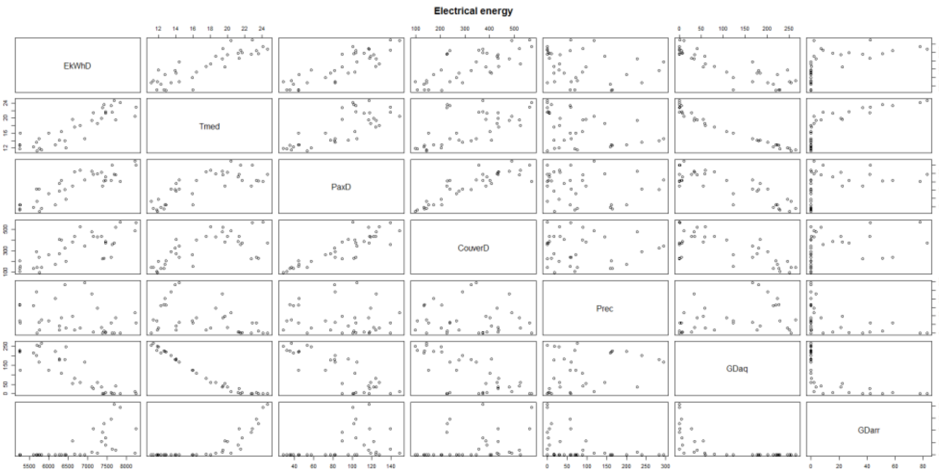

Fig. 1 – Electrical energy consumption and independent variables for one hotel.

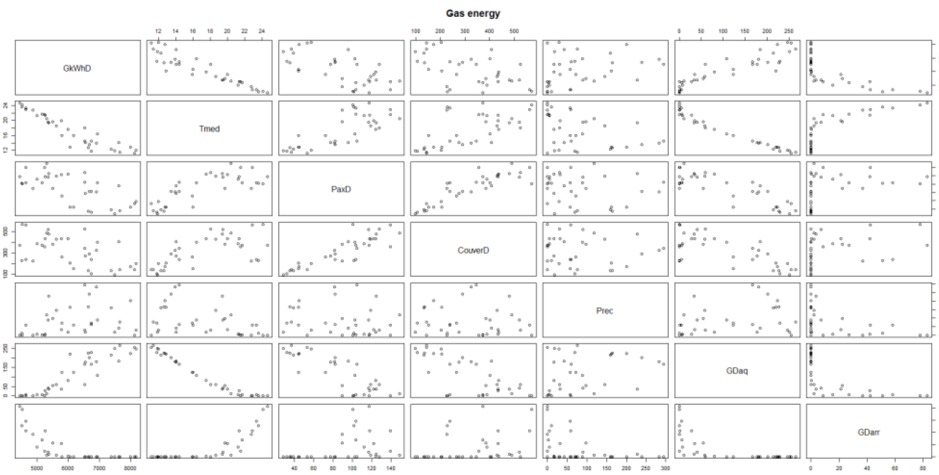

Fig. 2 – Gas consumption and independent variables for one hotel.

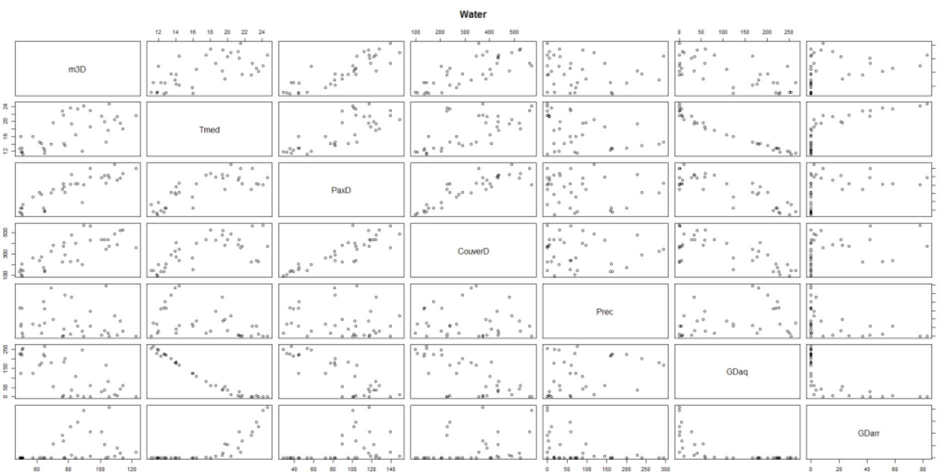

Fig. 3 – Water consumption and independent variables for one hotel.

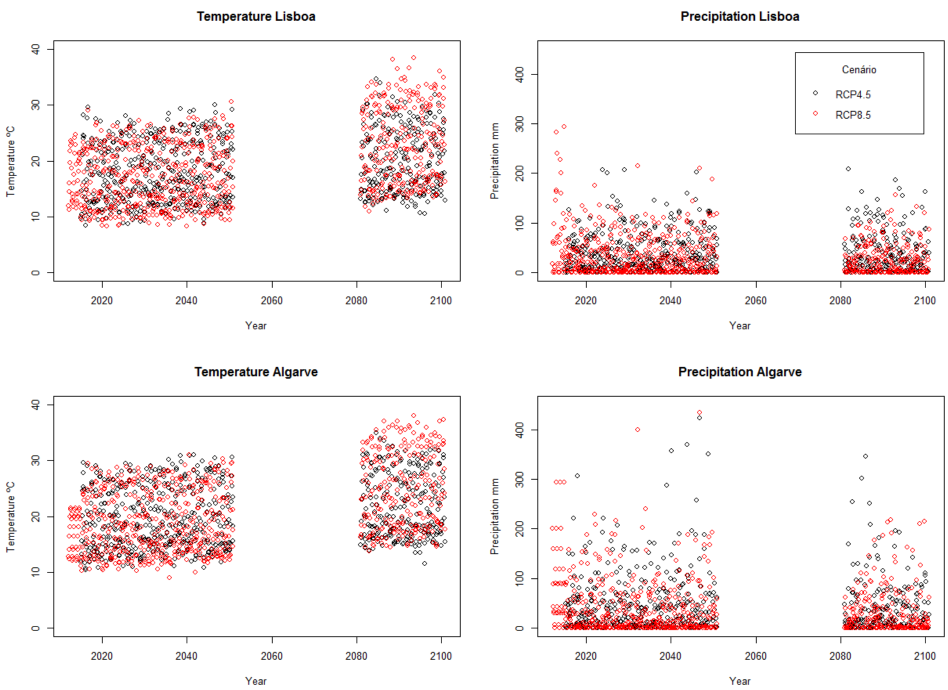

Fig. 4 – Meteorological data and climate change.

Table 1 – Meteorological data and climate change.

Label	Temperature				Precipitation			
	Lisboa	Algarve	Lisboa	Algarve	Lisboa	Algarve	Lisboa	Algarve
	RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5
Min	8.4	8.2	10.4	9.0	0	0	0	0
1st Quartile	13.8	13.8	15.5	15.2	2	1	1	0
Median	17.8	18.2	19.4	19.7	20	17	16	14
Mean	18.7	19.1	20.4	20.7	36	43	32	37
3rd Quartile	23.3	23.6	25.3	25.6	57	57	48	53
Max	34.6	38.5	35.0	38.0	294	424	294	435

4 CASE STUDIES

To assess the climate change in hospitality sector the previous methodology was applied to sixteen hotel, nine hotel in Lisbon and seven in Algarve. The main characteristics of studied hotels and main results are shown in Table 2. All the hotel belong to four or five star category. For both Lisbon and Algarve hotels a 25 kWh/gn (σ=13) electrical energy consumption is estimated. Larger water consumption are detected in Algarve (average 700 l/gn vs 440 l/gn) hotels and more gas consumption in Lisbon hotels (average 23 vs 17 kWh/gn). The majority of this hotels has satisfactory energy efficiency levels. Regarding the presented results, all the hotel are sensitive to climate change. For the period 2030 to 2050, the foreseen climate change impact on building is relatively small compared with prediction for the period 2080 to 2010, were the obtained results with scenario RCP 8.5 are also different from scenarios RCP 4.5.

In the period 2020 to 2030, the most sensitivity aspect is the increase in water and electricity consumption of Algarve hotels. In the period 2080-2100, the expected increase in electricity and water continues to be important in Algarve (28% for energy and 50% for water) but also in Lisbon (14% for energy and 9% for water). With this scenario a decline in gas consumption mainly for heating is also predicted.

Table 2 – Climate change impact in hotels.

Hotel n.º	Place	Nº beds:	N.º rooms	Average ocupancy annual	E eletricity (kWh/PAX)	E gas (kWh/PAX)	Water (l/pax)	Scenario RCP 8.5						Scenario RCP 4.5					
								E CC (2030 a 2050)	E CC (2080 a 2100)	G CC (2030 a 2050)	G CC (2080 a 2100)	W CC (2030 a 2050)	W CC (2080 a 2100)	E CC (2030 a 2050)	E CC (2080 a 2100)	G CC (2030 a 2050)	G CC (2080 a 2100)	W CC (2030 a 2050)	W CC (2080 a 2100)
1	Lisboa	380	180	<50%	49	46	609	0%	10%	-1%	-26%	1%	0%	2%	5%	-5%	-13%	0%	0%
2	Lisboa	252	126	<50%	29	13	511	0%	6%	0%	-29%	3%	44%	1%	3%	-5%	-15%	9%	21%
3	Lisboa	249	198	<50%	15	10	348	0%	16%	-1%	-32%	2%	34%	3%	8%	-6%	-16%	7%	16%
4	Lisboa	48	26	<50%	27	25	396	0%	10%	-1%	-26%	2%	1%	2%	5%	-5%	-13%	1%	0%
5	Lisboa	274	137	<50%	30	17	283	1%	16%	0%	-19%	2%	0%	3%	7%	-3%	-9%	1%	0%
6	Lisboa	56	28	<50%	36	65	1,079	0%	17%	-2%	-65%	1%	0%	3%	8%	-12%	-33%	1%	0%
7	Lisboa	140	70	50% a 70%	12	7	133	0%	17%	0%	0%	0%	0%	3%	8%	0%	0%	0%	0%
8	Lisboa	528	301	50% a 70%	22	1	421	0%	12%	0%	-3%	0%	0%	2%	6%	-1%	-2%	0%	0%
9	Lisboa	518	259	50% a 70%	8	19	162	1%	24%	-1%	-29%	0%	0%	4%	12%	-5%	-14%	0%	0%
10	Algarve	514	257	<50%	13	13	424	4%	29%	-15%	-97%	14%	86%	8%	16%	-30%	-57%	24%	47%
11	Algarve	624	312	<50%	27	21	715	6%	40%	8%	54%	15%	69%	12%	22%	16%	30%	22%	40%
12	Algarve	462	231	<50%	30	22	1,188	2%	10%	-22%	-150%	3%	12%	3%	5%	-47%	-92%	4%	7%
13	Algarve	128	55	<50%	17	19	618	2%	15%	-2%	-14%	6%	25%	4%	8%	-4%	-8%	8%	15%
14	Algarve	378	231	<50%	49	20	878	3%	22%	-3%	-23%	20%	119%	6%	12%	-7%	-13%	33%	64%
15	Algarve	508	182	<50%	23	20	497	9%	57%	-10%	-70%	12%	61%	16%	31%	-21%	-41%	18%	34%
16	Algarve	382	114	<50%	15	5	609	3%	23%	-11%	-74%	10%	56%	7%	13%	-23%	-43%	16%	31%

5 CONCLUSIONS

In this article is presented a simplified approach to draw building signatures for energy and water consumption. For sixteen studied hotels, it was found that relevant independent variable are outdoor temperature, occupancy and precipitation.

With scenarios RPC 4.5 and RCP 8.5 and with the building resources consumption signatures it was forecasted the impact of climate change in the electricity, gas and water resources consumption. For electricity it's forecast an increase in consumption in the order of 10% to 28% (2030-2100), mainly due to the increase in the demand of air condition systems and refrigeration systems. From this model, it's also expect an increase in water consumption of this buildings, maybe for gardens and pools. Besides those increase, it's also expected a decrease in the energy consumption in heating systems, specifically in the gas consumption. The changes are essentially observed in the period 2080-2010, but in the period 2030-2050, some change are also expected, mainly in Algarve hotels, the most vulnerable zone of the two places studied.

This results are in line with other international studies, that predicts an increase in energy consumption of this order of magnitude [11], and show the importance of the development of adaptation plans in the hospitality sector to decrease cooling load demands, water use and also dependency from fossil fuels to cut costs and the impact of energy prices volatility.

This simplified methodology, supported by average monthly data is suitable to assess the impact of climate change at a time lapse of one month. To study the impact of climate variability a smaller time scale is needed, for instance one day and even an hour is required and this aspects will be studied in the framework of AdaPT project.

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