Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 78 (2015) 2178 – 2183

Energy Procedia

6th International Building Physics Conference, IBPC 2015

Improving energy efficiency and cost reduction in airports: contributions from a wireless network web-based monitoring solution

Luísa Dias Pereira[a]*, Gustavo Botte[b], Miguel Soares[b], Manuel Gameiro da Silva[a]

[a]*ADAI, LAETA, Department of Mechanical Engineering, University of Coimbra, 3030-789 Coimbra, Portugal*
[b]*WSBP Electronics, Lda, 3030-199 Coimbra, Portugal*

Abstract

In the present case study – an airport located at the southern region of Portugal with an increasing number of passengers (more than 5.7 million passengers) - a web-based monitoring system was installed, collecting, displaying and registering the information generated by a wireless network of sensors. The monitoring of indoor environmental quality parameters, along with billed energy data control and outdoor weather conditions observation, permitted a continuous tuning of the HVAC systems set-points. Through the comparison of a six month period in two consecutive monitored years, during the cooling season, energy savings up to 13.4% in the HVAC system were achieved.

Keywords: Airport, IEQ, web-based monitoring, energy efficiency, cost reduction.

1. Introduction

Airports represent a key role in transportation of people and goods, and in regional, national, and international commerce and tourism. As stated in [1], yearly energy costs represent typically 10% to 15% of the total operating budget, for which energy efficiency (EE) is identified as a significant mean of achieving running costs reduced. Additionally, as part of the tertiary sector, airports cannot be left outside the indoor environmental quality (IEQ) and EE of buildings banner of the EU, stimulated by the EPBD [2] and following recast [3], that besides efficient

* Corresponding author. Tel.: +0-000-000-0000 ; fax: +0-000-000-0000 .
E-mail address: luisa.pereira@uc.pt

doi:10.1016/j.egypro.2015.11.313

localized energy production systems, stimulates intelligent control and management of energy demand in buildings [4]. The installation of smart monitoring and control networks is also justified by the aim of EE, dependent on having a deep knowledge of the behavior of the different energy vectors in buildings [5].

In the present paper, a web-based monitoring solution, collecting, displaying, registering and processing the information generated by a wireless network of sensors installed in an airport located at the southern region of Portugal - with an increasing number of passengers, more than 5.7 million passengers - is presented. This building management system (BMS) tool – complementing the previous one installed in 1989 at the airport - has been previously presented in [5], [6] and can be found on the web [7]. Herein, IEQ parameters such as air temperature, relative humidity and CO_2 concentration levels were monitored. The ongoing analysis of the data collection data gave very meaningful information about the metabolism of the building and the installed HVAC systems.

The monitoring campaign herein presented considered a six month period in two consecutive years (April - September, 2013 and 2014) - a 12 month data analysis of hourly records was studied in total. This monitoring period corresponds to the pre-cooling (spring time) and cooling season (summer). The airport is daily open to the public, varying its daily occupancy period - nevertheless a baseline non-occupancy period was determined from midnight to 05:00 am (non-flight period and reduced occupancy of the airport).

2. Method and object of study

The airport herein presented is located in the southern region of Portugal. It opened in 1965, it was later expanded and refurbished in 2000 (giving the building its actual shape and size), and besides its relatively small dimension (implantation area of about 42.690 m²) it is presently the main touristic airport of the country [8]. It serves both Algarve (the Portuguese tourist region par excellence) as well as the Spanish region of Huelva, having registered an increasing number of passengers in the last few years (receiving more than 5.7 million passengers) [8].

The terminal's outer walls are mainly glass curtain walls with steel frames, brick walls and glass blocks walls. On the south side there are double layered glass walls with an air layer in between, which total 28 mm of thickness. On the rooftop there are metal panels with isothermal finishing. In terms of HVAC systems, there are two thermal plants responsible for climate control of the open spaces and offices, and one single heat pump for climate control of the retail stores at Faro Airport passenger terminal building. Moreover, climate control on open spaces is granted through 2 pipes air handling units (AHU). Offices and restaurants are served by 4 pipes fan coils and AHU. The 2 pipes system supplies cool or hot water, depending on the time of the year.

As the loads of any building vary from place to place and from time to time, the long term performance of indoor environment of a building is done by evaluating the indoor environment of typical rooms representing different zones in the building [9]. Presently, eleven IEQ monitoring stations are installed in the airport in different areas (e.g. one at the departures, one check-in area, one gate, arrivals, security control, duty free, arrivals, baggage claim) and an outdoor weather station. In the present paper, due to space limitations, only four stations are analyzed.

The measurements of air temperature, relative humidity, and CO_2 concentrations were obtained though the installation of a wireless monitoring system in the airport building, which proved to be extremely important in terms of the IEQ analysis and energy consumption reduction.

2.1. The monitoring system

The flexible solution developed by WSBP is based on a distributed network of sensors with wireless communication. The central unit of the network is a router-like machine that serves as a hub for the information that is received from the various transmission nodes. The information collected through the router is sent to a database residing on a server and can be provided to customers or accessed through a web application. The application software, named Janus, was developed for data processing and for providing direct access to the information via Internet, including a Dashboard module (displaying real-time information at different aggregation data levels) and a Space Investigator module (broadcasting information directly to the area of the airport being monitored), as presented in Fig. 1.

a) **b)**

Fig. 1. Janus graphical interface modules. (a) Dashboard and (b) Space Investigator.

3. Results and data analysis

From the eleven IEQ monitoring stations installed at the airport, four were selected: one in the check-in area (IAQ 3), one at the security control (IAQ5), one in the duty-free area (IAQ 6) and one at a boarding gate (IAQ 9). The IEQ monitoring results are next presented.

3.1. IAQ and CO_2 concentration values

"Air quality of building can be evaluated in buildings where people are the main pollution source by measuring the average CO_2 concentration in the building, when building is fully occupied" [9], since carbon dioxide in the indoor air results mostly from the human metabolism. The continuous monitoring of the CO_2 concentration is generally a faithful indicator of the human occupancy and of the ventilation effectiveness. The threshold limits specified by the current national legislation for CO_2 in the indoor air are 2250 mg/m3 (1250 ppm), average concentration value during the occupancy period (5:00-24:00, in the present case)

In terms of CO_2 concentrations during the various occupancy periods the average values varied between 546 – 844ppm in the four IAQ stations in both years. In terms of the national regulation [10], this parameter reference value in fulfilled in more than 98% of the time (≤1250 ppm), what expresses an extraordinary result in terms of IAQ. Moreover the maximum recorded CO_2 values where only in a few circumstances above the reference values.

Table 1. Summarizing table of the CO_2 concentration average values during occupancy periods (April 1st – September 30th)

Year \ IAQ Station	IAQ 3	IAQ 5	IAQ 6	IAQ 9
2013	574	700	767	832
2014	546	651	819	844

Deepening this analysis, based upon the EN15251 [9], where the CO_2 concentration evaluation can be expressed in concentration above the outdoor CO_2 concentration, it was verified that in all the four spaces, during a significant percentage of the occupied time, the values fall into the optimum category that is normally used for "recommended for spaces occupied by very sensitive and fragile persons with special requirements". Theoretically the airport should fit between categories II and III (new buildings and major renovations; existing buildings). These results, ahead summarized in Fig. 2, revealed that there is significant potential of energy saving through the adjustment of the air flow rates in terms of the occupancy. The obtained results exposed that CO_2 concentration values might be "relaxed" and the airport will probably maintain IAQ levels in a good category in terms of IAQ.

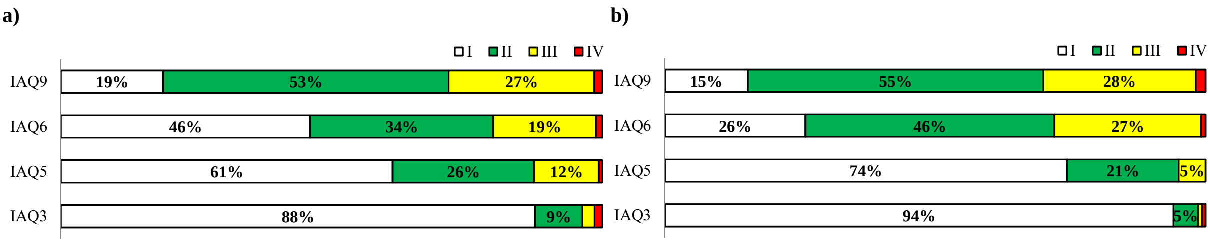

Fig. 2. CO_2 concentration evaluation expressed in percentage of time during occupancy periods in IAQ categories, according with the values of Table B4 in EN15251, expressed in concentration above outdoor concentration (considered 380ppm). (a) 2013 and (b) 2014.

3.2. Thermal environment

"A variety of indoor thermal environments exist within airport terminals, ranging from gate-hold to baggage handling. Maintaining comfortable conditions for occupants with different metabolic rates and clothing levels who are departing to and arriving from different climates or continually entering and exiting the building can be a challenge" [1]. Due to the difficulty exposed, four different areas were selected. The indoor air temperatures (Ta) distribution in both years (from April 1st to September 30th) is presented in Fig. 3. From the results it can be observed that only in a very few occasions Ta was below the lowest references values (≤ 20ºC). Ta above 30ºC was never registered and in IAQ 5, 6 and 9, indoor air temperatures in the interval 28-30ºC were only detected in less than 5% of the occupancy periods. In all the four IAQ stations, from to 2013 to 2014, it was verified a frequency decrease in the interval 28-30ºC, an only IAQ 6 increased the frequency in 2014 in the interval 26-28ºC (curiously decreasing in the interval 20-24ºC).

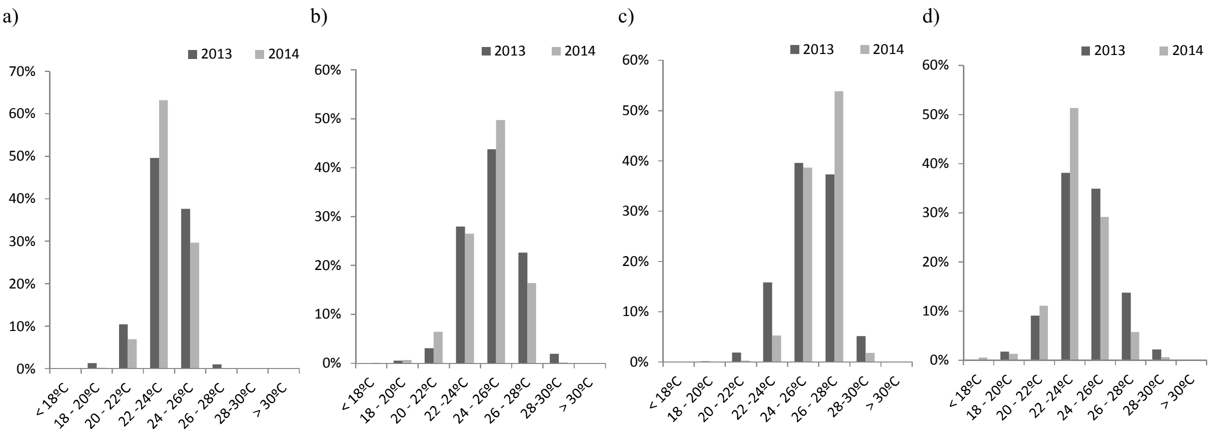

Fig. 3. Air temperature distribution intervals in 2013 and 2014. (a) IAQ 3 – Check-in area; (b) IAQ 5 – Security control; (c) IAQ 6 – Duty free and (d) IAQ 9 – Boarding gate.

Moreover, it was verified: In IAQ 3 in 2013, Ta varied between 22 to 26ºC during 88% of the occupancy periods. In 2014 this interval corresponded to 93%; In IAQ 5 the correspondent percentages to this interval were 72% (2013) and 76% (2014); In IAQ 6, 56% and 44%, respectively; In IAQ 9, 73% and 80% for this temperature interval.

It is noticeable that with the exception of IAQ 6, all the other IAQ stations verified a TA decrease in the highest Ta intervals between 2013 and 2014. It is also worthy reminding that in terms of the external conditions, 2014's spring was much warmer than 2013. This justified, for instance that the peak Ta was achieved both in IAQ 6 and IAQ 9 on April 8th 2014 around 4:00 pm, Ta = 29,3ºC and Ta = 29,0ºC, respectively.

From table 2, next presented it is noticeable that the highest recorded values in each if the IAQ station was higher in 2013 than in 2014 – this is not only a consequence of the outdoor conditions (average monthly mean temperatures are presented in Fig.4) but also reinforces that there has been as effort to keep/improve the passengers' comfort besides energy savings goal.

Table 2. Summarizing table of the recorded values in the four IAQ station during the occupancy periods (April 1st – September 30th)

Year	Statistic Data	IAQ 3	IAQ 5	IAQ 6	IAQ 9
2013	Highest record	26,66	29,21	29,81	29,79
	Lowest record	17,42	18,40	16,00	16,53
	Average	**23,57**	**24,79**	**25,55**	**24,15**
	St. deviation	1,27	1,64	1,64	1,88
2014	Highest record	26,58*	28,43**	29,31***	28,96***
	Lowest record	19,82	18,00	18,40	14,59
	Average	**23,68**	**24,64**	**26,09**	**23,69**
	St. deviation	0,97	1,57	1,12	1,65

Note: value registered at 05:00pm 12/08/2014 – External temperature = 29ºC (daily average temperature = 26ºC)*
*Note**: value registered at 05:00pm 14/06/2014 – External temperature = 28ºC (daily average temperature = 25ºC)*
*Note***: value registered at 04:00pm 08/04/2014 – External temperature = 27ºC (daily average temperature = 20ºC)*

In Fig. 4, the detailed view module of the graphical interface of the air temperature data of the IAQ 6 station is exposed. It is curious that both stations IAQ 6 and IAQ 9 registered the highest Ta on April 8th 2014 (the "abnormal peak" registered on April 9th was not considered; it most probably coincides to somebody touching the sensor – e.g. cleaning – or direct incidence of sunlight). This is the result of an unexpected hotter than average April's week.

a) 

Fig. 4. Detailed view module graphical interface: Air temperature data IAQ 6 (a), 3 – 9 April 2014.

3.3. Energy savings

The permanent O&M trained team along with the integration of the BMS utilities, potentially discover problems within systems almost instantaneously and address immediately to problems as they occur [1]. *"This rapid assessment serves (…) and increase* preventive maintenance to increase the life of the system. Further, because data are constant, energy savings are continuous and ongoing" [1]. Moreover, through the adjustment of reset and set-back temperatures settings — that were often adjusted only over a long time – it was possible to achieve some significant energy savings.

During the two analogue periods under analysis, a decrease on the HVAC systems energy consumption of 13.4% was verified between 2013 and 2014 – in Fig. 5 the HVAC systems monthly energy consumption is plotted along average monthly mean temperatures outdoors. The slightly higher temperatures verified in 2014's spring justify the slightly increase in the energy consumption during this period when facing 2013. This energy consumption reduction was also verified in terms of the energy per passenger indicator (0.84 to 0.70 kWh/passenger). These values are even more significant since there was an intensity increase of 4% in the number of passengers in 2014, during this same period. Admitting that HVAC energy consumption corresponds to 50% of all energy in airports [11], this equals 1.4 kWh/passenger, i.e. 15% of the average energy consumption (9.29 kWh/passenger) in EU airports [4].

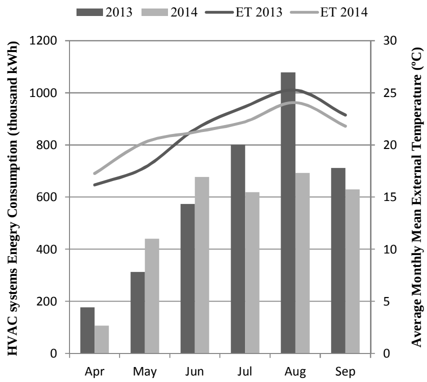

Fig. 5. HVAC systems Electricity Consumption April-September 2013&14 (thousand kWh) plotted together with the external monthly mean temperatures in both periods.

4. Conclusions & outlook

The installation of a complementing BMS tool in the airport, covering, among others, issues related to IEQ, proved to be extremely important at improving the energy efficiency of the HVAC systems. Through the continuous observation of the BMS tool Janus and proper HVAC systems set-point definition, during the cooling season 2014, the airport reduced its energy consumption 13.4% in relation to the equivalent period of the preceding year.

This paper reports EE improvements being implemented at an airport in southern Europe that are low cost by means of BMS tools implementation, followed by EE practices in management and operation towards good airport practices. It potentially targets terminal managers of small airports, staff, consultants, and other stakeholders interested in EE. Moreover, since information can be shared and these energy efficiency measures are scalable, this airport may be used as a reference for bigger airport terminals.

Acknowledgements

The authors are thankful to ANA Aeroportos de Portugal SA, the O&M team of the Faro Airport, and Eng. João Nuno Fernandes and Eng. Duarte Correia, for the provision of the database and care given. Moreover, the first author acknowledges the support of the Portuguese Foundation for Science and Technology under grant SFRH/BD/77105/2011 financed through POPH/FSE program.

References

[1] Transportation Research Board, "ACRP Synthesis 21 | Airport Energy Efficiency and Cost Reduction - A Synthesis of Airport Practice," Washington DC, 2010.
[2] "EPBD, Directive 2002/91/EC of the European Parliament and of the Council of 16 December 2002 on the energy performance of buildings," *Off. J. Eur. Communities*, pp. L1/65–L1/71, 2003.
[3] "EPBD (recast), Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings (recast).," *Off. J. Eur. Union, 2010*, pp. L153/13–153/35, 2010.
[4] A. Costa, L. M. Blanes, C. Donnelly, and M. M. Keane, "Review of EU airport energy interests and priorities with respect to ICT, energy efficiency and enhanced building operation," in *International Conference for Enhanced Building Operations*, 2012.
[5] M. Gameiro da Silva, A. Paulino, M. Bento, M. Góis, G. Botte, R. Valentim, J. Gomes, and R. Fonseca, "A wireless network web-based monitoring solution for indoor environmental quality and energy performance assessment of buildings," in *Clima 2010 REHVA international congress*, 2010.
[6] M. Gameiro, J. J. Costa, A. Gaspar, A. Paulino, M. Bento, and G. Botte, "The influence of wind on the infiltration rates in a web-bases monitored office building," in *Roomvent 2011*, 2011, no. Muy 2006.
[7] We Solve Building Problems © 2012, "WSBP Janus." [Online]. Available: http://www.wsbp.eu/?page_id=16. [Accessed: 01-Jan-2015].
[8] ANA Aeroportos de Portugal S.A., "ANA Faro Airport," 2015. [Online]. Available: http://www.ana.pt/pt-PT/Aeroportos/Algarve/Faro/Paginas/HomeFaro.aspx. [Accessed: 01-Jan-2015].
[9] CEN, "EN 15251:2007 Indoor Environmental Input Parameters for Design and Assessment of Energy Performance of Buildings Addressing Indoor Air Quality, Thermal Environment, Lighting and Acoustics." CEN (European Committee for Standardization), Brussels, 2007.
[10] Portaria n.º 353-A/2013, "Portaria n.º 353-A/2013 (in Portuguese: Regulamento de Desempenho Energético dos Edifícios de Comércio e Serviços (RECS) - Requisitos de Ventilação e Qualidade do Ar Interior)." 2013.
[11] EU Horizon 2020, "CASCADE: reducing energy use by airports." [Online]. Available: https://ec.europa.eu/programmes/horizon2020/en/news/cascade-reducing-energy-use-airports. [Accessed: 10-May-2015].