INMÓTICA SOCIAL PARA LA MEJORA DE LA EFICIENCIA ENERGÉTICA EN EDIFICIOS PÚBLICOS: LA ESCUELA POLITÉCNICA EN EL PROYECTO EFIPUBLIC

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SOCIAL INMÓTIC TO IMPROVE ENERGY EFFICIENCY IN PUBLIC BUILDINGS: SCHOOL OF TECHNOLOGY IN EFIPUBLIC PROJECT

Abstract

Energy efficiency is an essential aspect for sustainable growth and a way of strengthening security of energy supply. The inefficiency in the use of public buildings must be solved with an added problem: the bill of consumption is not paid directly by the users who are not aware of the expense. Likewise it has not been given the opportunity to the users to make decisions. Information Technologies (ICTs), Social Technologies (TS) and Construction Technologies (TC) are the basis of the Efipublic project, which proposes the improvement of the School of Technology building (UNEX), along with another administrative public building. The Project begins in 2017, and will run for 3 years, it develops after an infrastructure project (Smartpolitech 2013-2016) that provided sensorization and monitoring to the building: energy consumption, comfort, air quality or presence. The approach in Efipublic Project is the energy efficiency improvement, through the sensorization data study obtained in real time. The success of the project is related to communication with the user, and their participation in possible improvements through accessible, persuasive, and participatory information to detect problems and propose solutions.

Key words: *Energy efficiency; energy consumption; smart building; thermal behaviour;*

Resumen

La eficiencia energética es un aspecto esencial para un crecimiento sostenible y una forma de reforzar la seguridad del abastecimiento energético. La ineficiencia en el uso de los edificios públicos debe ser resuelta con una problemática añadida: la factura de consumo no es abonada directamente por el usuarios que no es conscientes del gasto, y al que, tampoco se le ha dado la oportunidad de tomar decisiones. Las Tecnologías de Información (TICs), las Tecnologías Sociales (TS), y las Tecnologías de la Construcción (TC) son la base del proyecto Efipublic, que plantea la mejora del edificio de la Escuela Politécnica (UNEX), junto con otro edificio público de uso administrativo. El Proyecto se inicia en 2017, y se desarrollará durante 3 años; surge tras un proyecto de infraestructuras (Smartpolitech 2013-2016) que dotó al edificio de sensores de consumo energético, confort, calidad del aire y presencia. Ahora en el Proyecto Efipublic el planteamiento es la mejora de su eficiencia energética, a través del estudio de los datos de esta sensorización obtenida en tiempo real. El éxito del proyecto está relacionado con la comunicación con el usuario, y con su participación en las posibles mejoras mediante información accesible, persuasiva, y participativa para detectar problemas y proponer soluciones.

Palabras clave: Eficiencia energética, consumo energético, edificio inteligente, comportamiento térmica

1. INTRODUCTION

In many occasions improvement in energy efficiency of public buildings is difficult to undertake. It depends on many factors that go from the buildings antiquity and obsolescence to the insufficient investments executed by the Administrations in maintenance or improvements. In addition, a critical factor is the necessary participation of the users in the improvement process to achieve the desired goals.

The importance of buildings energy consumption prompted European directive 2002/91/EC (The European Parliament and the Council, 2002) and its subsequent revision and improvement in 2010/31/EU (The European Parliament and the Council, 2010). In Spain these directives were partially implemented through Royal Decree 235/2013 that approves the basic procedure for the buildings energy efficiency certification (Fomento, 2013). These regulations refer to the residential sector and also to the tertiary sector, including public buildings. In 2015, unit electricity consumption per employee in Spanish tertiary sector has reached 5,305 kWh, a great part corresponds to the energy supply That value is higher than the EU28 average and all the near countries, except Portugal (Fig. 1) (Instituto para la Diversificación y ahorro de la Energía. Ministerio de energía turismo y agenda digital. Gobierno de España, 2015).

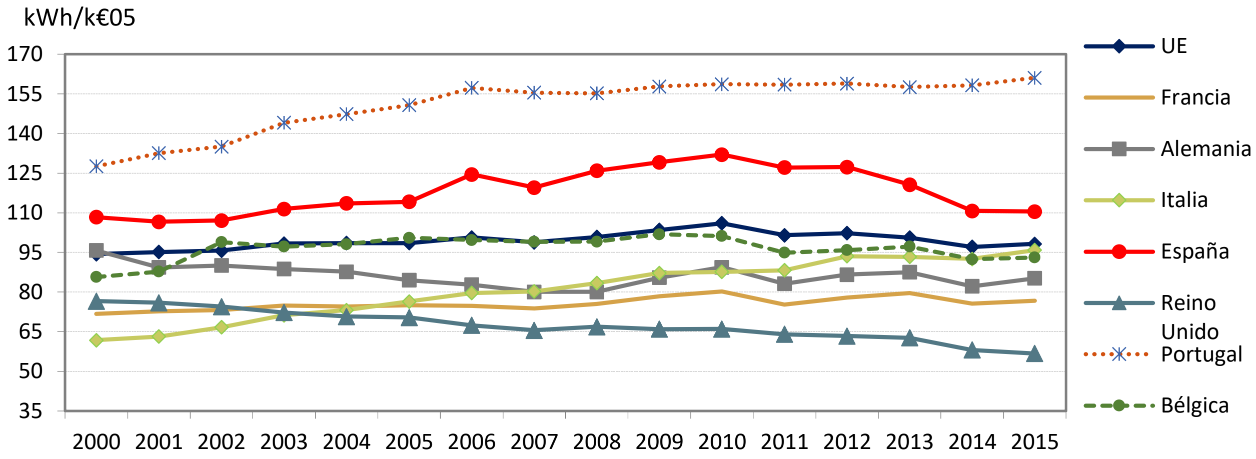

Fig. 1: Electricity intensity in tertiary sector (Instituto para la Diversificación y ahorro de la Energía. Ministerio de energía turismo y agenda digital. Gobierno de España, 2015)

Spanish Government stated that tertiary sector "has a very significant saving potential..., despite having fewer buildings than the residential sector (with a smaller surface area), it is supposed 35% building energy consumption in the country” (Fomento, 2014), (Fomento, 2017).

On the other hand, the contribution of buildings energy consumption in relation to total consumption is not reflected in available information (The European Parliament and the Council, 2010). In this way smart buildings arise from this need, they are designed by incorporating information and communication technologies in real time and in the automation and interrelation of their systems Providing the existing buildings with these resources facilitates timely analysis, efficient energy plans, and improvement indoor environment for the future (Agarwal Y., Balaji B., Gupta R., Lyles J., Wei M., 2010), (Sciurpi, Carletti, Cellai, & Pierangioli, 2015), (Varas-Muriel, Fort, Martínez-Garrido, Zornoza-Indart, & López-Arce, 2014), (Hong, Koo, Kim, Lee, & Jeong, 2015), (Bonacina, Baggio, Cappelletti, & Stevan, 2015).

Among these it can be highlight the Energy Tic project, as an interesting precedent at European level applied to social housing, 1700 homes in France and Spain provide users with intuitive solutions, easily understandable. The project affords user monitoring and adapting their consumption needs (European, 2014). Likewise TABULA project carry out in different typologies of single-family housing but extending to the tertiary sector (Commission, 2016), (Dascalaki, Droutsa, Balaras, & Kontoyiannidis, 2011).

Furthermore theses projects are awareness instruments among users, whose behaviour depends on a very significant percentage of potential savings. According to the 7th FP project "Smart Campus. Building-User Learning Interaction for Energy Efficiency ": between the 20% of expected energy savings, 75% will be due to transformations in user behaviour (“Proyecto SMART CAMPUS. Building-User Learning Interaction for Energy Efficiency,” 2012). In order to face a process as sensitive as the behaviour change in the users habits it is necessary to analyze previously the current behaviour of the individuals; and how to get them to change it to a collective benefit (Schiffman, L; Lazar, 2010), and to identify and involve them with the smart development and management of their workspace (Ojeda, J.F. y Delgado, 2006).

For these reasons, it is necessary to carry out studies that analyze buildings data in real time on the one hand, make the users participate in the improvement and on the other hand, keeping in mind on the EU 2020 framework and climate objective (European, 2017) and the framework adopted by EU leaders in October 2014 for 2030: at least 40% cuts in greenhouse gas emissions(from 1990 levels), at least 27% share for renewable energy, at least 27% improvement in energy efficiency .

2. METHODOLOGY

The project described in this paper is named Efipublic, starts in June 2017 and will run for three years. Information Technologies (ICTs), Social Technologies (ST) and Construction Technologies (CT) are the basis of the project. It is being developed using an existing public building, the School of Technology (ST) that belongs to the University of Extremadura at the city of Cáceres in the southwest spanish region of Extremadura. The building was built in 1987 and it comprises 6 different free-standing pavilions. The ST, as an academic environment, presents great complexity since it offers 7 degrees in different areas of engineering, 4 masters, 3 PhD programs and hosts more than 3000 students, 40 classrooms, 40 laboratories of different use and capacity, and 150 offices.

Many deficiencies have been detected in the ST considering its energy efficiency, energy consumption and deficient use. Some of these weaknesses are as follows:

- Inefficient consumption of central heating in cold periods due to the absence of indoor temperature/humidity conditions measurements. There are many periods of time that individual electrical equipment are working in the offices due to the fact that sometimes building systems do not guarantee comfort. These individual equipments consume a lot of energy and many times remain turned on all night long, without the presence of people.
- Different conditions of the spaces require different energy supplies to get the same level of comfort to cope with dissimilar orientations, various floors, variable occupation, etc. Nevertheless energy systems are uniform in all pavilions.

- For the hot season there is no central refrigeration system in the classrooms and in many offices the existing devices are individual. These situation causes discomfort and high levels of energy consumption.
- Poor indoor air quality due to lack of ventilation. The reason for this situation is that, on one hand, there is not a designated person to take on this task and, in the other, there is a fear to lose the existing indoor heat, which contributes to higher concentrations of CO_2.

The necessary equipment for sensing and monitoring ambiental variables has been installed in the ST funded with the SmartPoliTech project: Intelligent Energy Efficiency System for the School of Technology ("Proyecto SmartPolitech," 2016). It was awarded in 2012-2013 with a scientific-technological infrastructure national call of the Ministry of Economy and Competitiveness, Spain Government and developed from 2013 to 2016 with 137,445.21 € budget. This project consisted in the infrastructure installation to make the School of Technology a living laboratory to carry on research and develop smart technologies. More than 150 sensors have been placed that monitor the environmental state including temperature, humidity, and CO_2 related to the user comfort situation; consumption gas boilers, and heat and cooling pumps; consumption water, and human activity from a network of cameras that provide quantitative and qualitative estimates of the people and the activity in which they are involved. At present, the information system has been deployed and data is being received or captured, and stored in the ST servers. A visualization software, Asana, has been installed and time series and further processed variables such as weekly and monthly electric energy consumption are displayed on six large screens situated in pass-through areas, allowing the users to see and know the data obtained from the buildings in real time (Fig.2).

Fig. 2: Proposal of sensorization provision for the Smartpolitech project

The Efipublic project incorporates the state of the art of energy efficiency systems applied to buildings, smart technologies and social participation, but it includes a novel aspect, up to our knowledge, that is a multidisciplinary approach covering three complementary knowledge areas: construction, psychosociology and TIC. The project has been jointly conceived by three different research groups from the University of Extremadura: COMPHAS (Technology in Sustainable Construction Mobility and Heritage) in Natural Resources and Building area, ROBOLAB (Robotics and Artificial Vision) and GIM (Media Engineering) in the ICTs area, and GidEx (Research and Development Educational Extremadura Group) in the social area. In addition, the General Directorate of Architecture and Housing of the Government of Extremadura also participates providing an administration complex formed by several buildings that was recently build and endowed with smart monitoring and control technologies supplied by Siemens.

Furthermore, the Efipublic project is built on real sustainability basis, providing low-cost solutions that will be integrated into the daily maintenance routine of the buildings and enhanced with environmental and social actions. The goal is to avoid the degradation of the habitability conditions of the buildings and to introduce persuasion strategies to the users so they become an active part of the overall project.

While the majority of energy efficiency projects are carried out on new buildings, in this case we set ourselves the challenge of seeking efficiency on an existing building in full use, assuming the impact of the sensorization of actively used spaces during daily activity.

The project is validated in two case studies: an educational building (School of Technology, University of Extremadura), and an administrative building (Departamental Offices, Government of Extremadura) to be easily transferable to other cases. In this paper, the initial results of the project are presented including the study and analysis of data in order to detect the main deficiencies of the buildings, at the School of Technology (Fig 3), and propose initial strategies to overcome them. To study has been carried out with the time series provided by network of sensors registering climate variables, as described before.

Fig. 3: School of Technology, Extremadura University

3. RESULTS

Sensor data have been analyzed according to different conditions in order to discriminate possible lines of action for the improvement of the building, including both refurbishment works, as well as changes in users daily routines and their access to the available resources. The conditions studied depend on the specific geographical orientation, the thermal envelope, the working schedules and the building use and configuration. These data have been displayed in graphs according to different periods of time.

3.1. Discussion of results according to the geographical orientation

The need for adaptation of the School of Technology air conditioning systems to the geographical orientation has been cleared in graphs in Figure 4. It is observed that at 4 pm on February 5, 2017, there is a difference of temperature up to 2°C between classrooms 1 and 3, with orientations west and east respectively, and classroom 5, with a northern orientation. This is because the sun has been radiating either during the morning or the afternoon the first rooms, but not the last one. In addition it can be observed that between offices 1 and 3 with east and west orientation there is a difference of up to 3°C the same day. February 5 was Sunday and the school was empty, so temperatures given had nothing to do with the occupation or use of the building.

3.2. Discussion of results according to the thermal envelope

With the new sensor information system it is possible to know the characteristics of the thermal envelope of the building. Figure 4 shows how the building fluctuates with the outdoor average temperatures: maximum and minimum. In addition it is observed a very little lag of the thermal wave: from 4ºC in the morning to 10ºC in the night in January, extreme month in winter. This data suggests that the building does not have thermal inertia, but that it does have a good insulation. Even then energy efficiency may be improved to guarantee better inner comfort, that it is insufficient in many cases: under 20ºC in working days

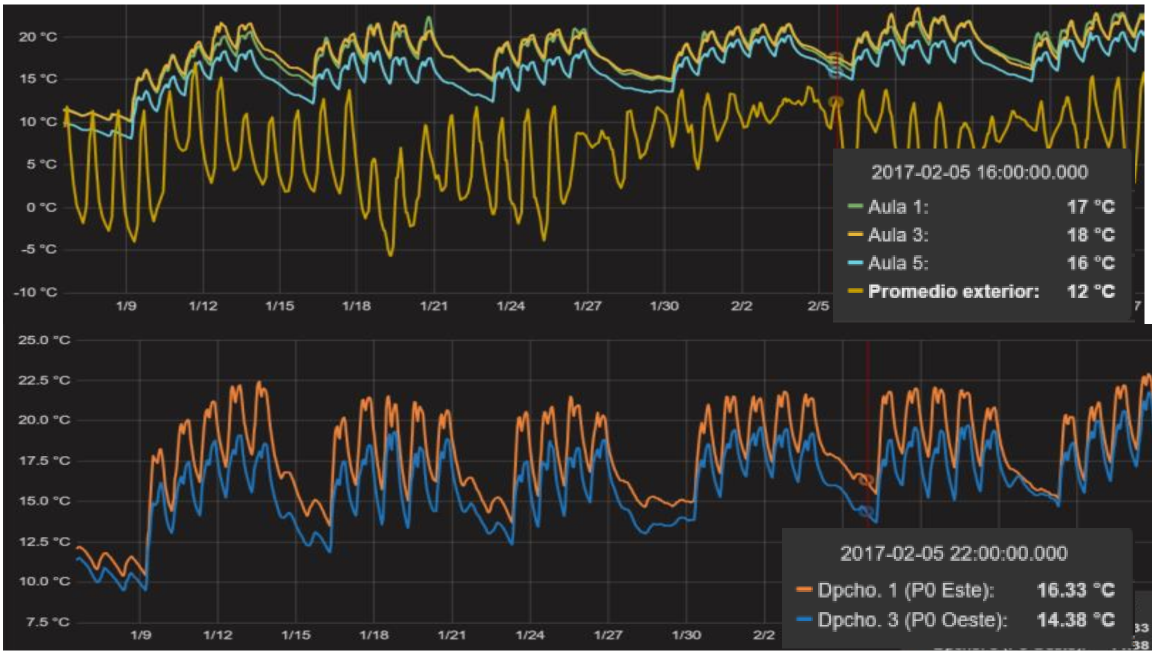

Fig. 4: Graphs of the thermal behaviour in different floors in School of Technology

3.3. Discussion of results according to the heating system on working days

Likewise building sensorization checks energy consumption and heating systems operation. In figure 5 first two charts show the boiler gas consumption, and the different temperatures of water circuits running during the five working days in the week in winter period: February 4 to 20, 2017. It can be observed that consumption is uniform according to the system programming, and all the circuits impulse water to the pavilions of the School of Technology with similar temperatures. This is significant due to there are very different distances of the pipes route from the boiler to each of them. In addition in the second two charts it has been checked, in the same previous period of time, interior temperature of two pavilions with similar occupation and use conditions. In this case temperatures reached similar values during the working time: in midday a maximum temperature of 23 ºC, and in the beginning of the day a minimum of 18 ºC, besides temperature on Mondays is always lower than on Fridays. In addition, the system controls the temperatures of the water returns, and it has been probed is similar in both pavilions.

In that way it can be observed that the heating system works, nevertheless it will be necessary to improve building envelope, or to increase temperatures or hours in the boiler operation to improve thermal comfort. Likewise the start time of the boiler should be programmed so that there are comfort conditions in the classrooms at the beginning of the day, as well as the beginning of the working week (Fig.5).

Fig. 5: Graph of gas consumption in heating system; and graphs of boiler temperatures, and indoor temperatures in different buildings in School of Technology.

3.4. Discussion of results according to the building floors

Depending on the stratification of the air, the temperature varies greatly across the different building floors. Figure 6 shows the thermal situation on January 10th, 2017 at 3:00 p.m. In this case, office 2 on the ground floor shows much lower temperatures, 4°C less than office 1 on the upper floor with the same orientation, west. The same situation reproduces with offices 3 and 4 oriented to the east. A difference of two degrees differentiates the ground floor (colder) from the the upper one. The humidity is maintained in all cases around 50% that prove similar occupation. The graph shows the starting of the building heating system by the second week of January, after Christmas holidays, but even with that energy input, the level of comfort in the building is still low.

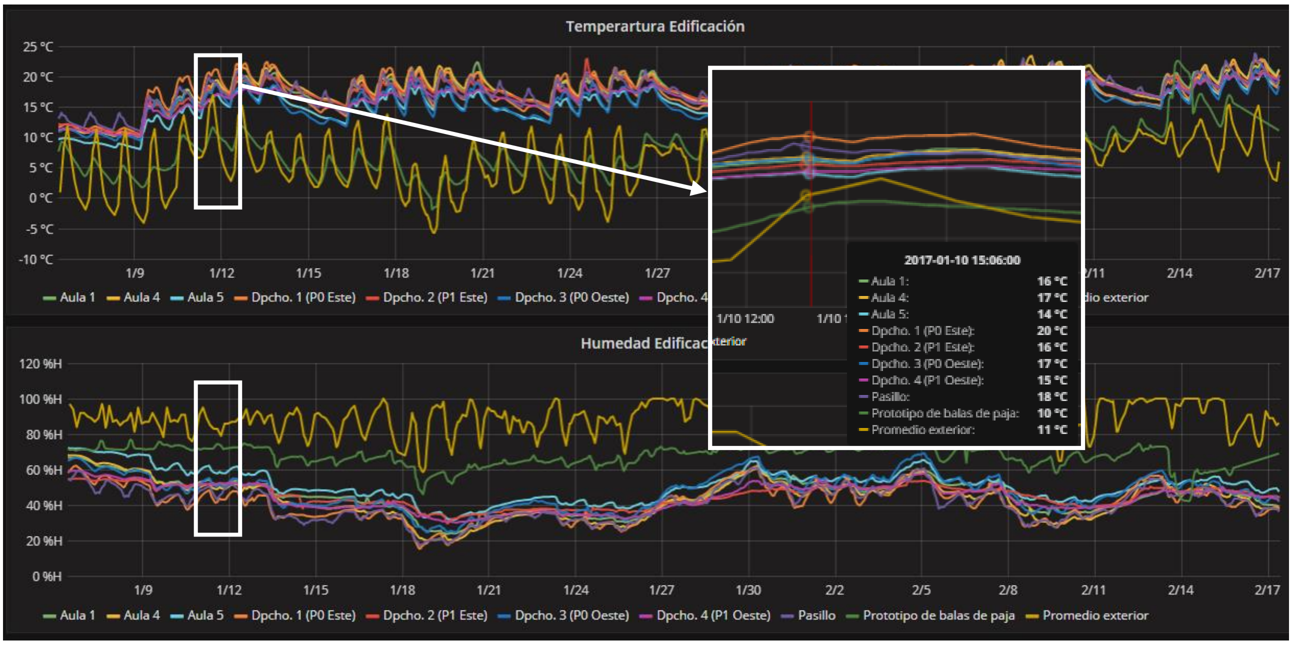

Fig. 6: Graphs of the thermal behaviour in different floors in School of Technology

3.5. Discussion of results according the air quality (ppm CO_2)

By measuring the quality of the air two aspects can be controlled: first, air conditions can be kept at adequate quality levels for the users activity limiting the amount of CO_2 in the classrooms, avoiding a negative effect on the intellectual work being done; and secondly, that the ventilation of the classrooms be effective. In this case and as shown in Figure 7, CO_2 concentrations are unsuitable for activity, exceeding punctually 1800 ppm. It is also observed that the peaks are not maintained in time but fall immediately due to infiltrations that are likely to occur in the building (this statement requires an air infiltration test). With this sensor it is also possible to estimate the real occupation of the classrooms.

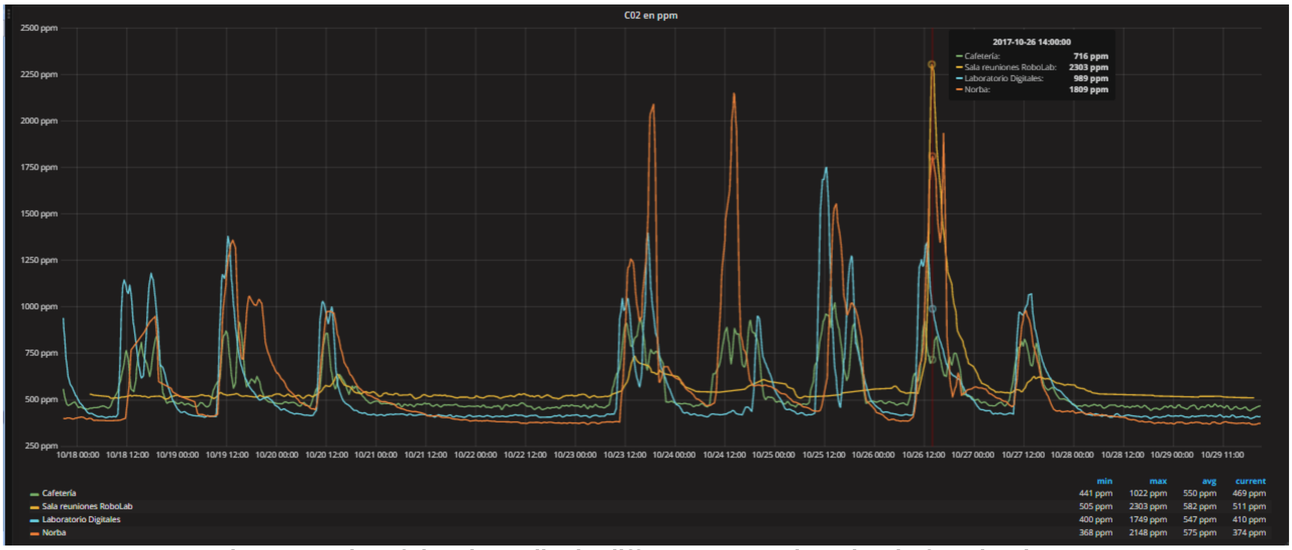

Fig. 7: Graphs of the air quality in different spaces in School of Technology

3.6. Discussion of results about dissuasive information

The data showing monetary cost of daily electricity consumption in each pavilion since the beginning of the day is shown on the large TV screens placed at the School of Technology. This data are presented as a dissuasive, quick and easy to understand option for the users so they can identify their habits with their cost. Also the comparison with other pavilion users should act as an incentive to reduce consumption (Fig. 8). These graphs also help the building managers to focus on the higher expenses zones and where greater savings could be achieved.

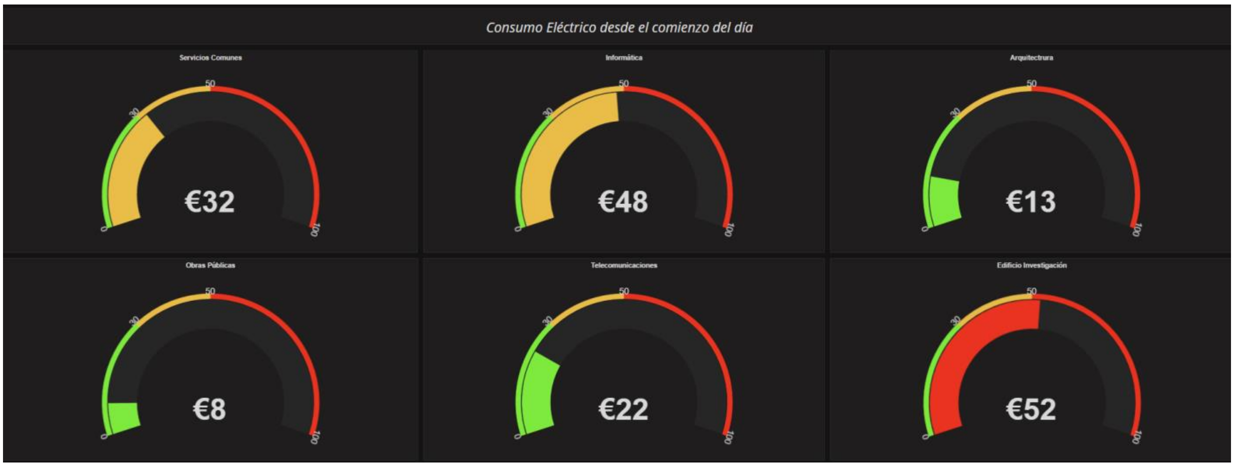

Fig. 8: Graphs of the economic cost of the electric consumption in different buildings in School of Technology

4. CONCLUSIONS

This study is based on the field measurements. It clearly represents more detailed understandings of thermal behavior and energy consumption inside an existing public building. It has been observed that the knowledge of the building operation in real time allows the identification of the building weaknesses and therefore this will allow for improving the most adequate measures.

The actions to improve energy efficiency in public buildings depend on several conditions: in this specific case: on the specific geographical orientation, the thermal envelope, the working schedules or the building use and configuration.

In addition, the low cost of the sensorization and monitoring measures used in this project, and the magnitude of the results obtained indicates that it presents as a recommendable action to improve energy efficiency and comfort.

Likewise, it will be used social awareness and implemented participation strategies shortly. And then it will be studied if the users participation can improve the initial situation. Hence it will be verified the impact on consumption bills.

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