Exploring the possibility of promoting energy conservation behaviors in public buildings within the ENCOURAGE project

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ABSTRACT: Current building energy performance place the sector among the most significant CO_2 emissions sources in Europe. This paper presents a new approach developed under the ENCOURAGE project to optimize energy use in buildings and enable active participation in the future smart grid environment. Within this context, this paper aims at exploring the possiblity of stressing users' involvement to pursue the final objective of increasing energy efficiency and reduce energy costs in public buildings. A comprehensive survey was conducted over 265 UPC urban campus users. Results show that most respondents are largely unaware of how much energy they consume due to their daily activities and that eco-feedback systems could help to reduce their energy consumption. Taking into account that results from the ENCOURAGE project will enable to show individualized real time data, this research concludes that providing campus users with information on actual energy consumption could be a feasible way to increase, even more, the energy savings in the urban campus buildings, supporting the IT-based developments.

1 INTRODUCTION

The European Council of March 2007 emphasized the need to increase energy efficiency in the European Union so as to achieve the objective of reducing by 20% the energy consumption by 2020. According to the Directive 2010/31/EU on the energy performance of buildings, European buildings account for 40% of total energy consumption in the European Union. Taking into account that the sector is expanding, this percentage is bound to increase. Within this context, the need for achieving high energy and greenhouse gas emission savings in the buildings sector has been widely advocated. According to IPCC (2007), buildings offer the largest share of cost-effective opportunities for greenhouse gas emissions mitigation among all the sectors.

According to the Buildings Performance Institute Europe (2010), residential buildings comprise the largest portion of the European building stock (75%) and they are responsible for 68% of the total final energy use in buildings. As stated by IPCC (2007), the energy use of residential buildings highly depends on the behaviour and decisions of occupants and owners. Yu et al. (2011) developed a method to study the influence of occupant behaviour on residential building energy consumption and they found that different occupant behavior, especially those associated with HVAC, can significantly affect indoor climate, which in turn will have an influence on occupant behavior, causing dramatic differences in building energy consumption According to the study carried out by Ouyang & Hokao (2009), if not considering the impact of the changes of other variables, the energy-saving potential by improving occupants' behaviour is 14% in average. This value was found by studying 124 households, half of which were provided with energy-saving education and tips. Moreover and according to Ueno et al. (2006), users reduced 9% of the power consumption over eight households by installing Energy Consumption Information System (ECOIS).

Non-residential buildings account for the remaining 25% of the total stock in Europe, being responsible for 32% of the total final energy use in buildings. The non-residential sector comprises wholesale and retail buildings (28%), offices (23%), educational buildings (17%), hotels and restaurants (11%), hospitals (7%), sport facilities (45) and others (11%) (Buildings Performance Institute Europe 2010). The average specific energy consumption in the non-residential sector is 280 kWh/m^2 (covering all end-uses) which is at least 40% greater than the equivalent value for the residential sector (Buildings Performance Institute Europe 2010). In the non-residential sector, electricity use over the last 20 years has increased by a remarkable 74% (Buildings Performance Institute Europe 2010). Owned by the central government or the municipality, public buildings are generally open to an undetermined amount of people; some of them work inside the building, while others are visitors or clients. Although individual users may change over the time, it can be assumed that user behavior patterns are quite stable and thus, building's energy consumption patterns are dependent on collective user behavior changes. Behaviour of the occupants of public buildings also has a substantial impact on energy use. Although public building users generally do not have a personal financial incentive to act in an energy efficient manner, it has been estimated that between 5% and 20% of the whole consumption is related to consumer behavior and influence (Matthies et al. 2011). Thus, there is a high influence on energy savings based on consumer influence and behaviour. Jain et al. (2012) developed an eco-feedback interface to reduce energy consumption and it was tested on a hall of residence of the campus of Columbia University in New York City. This research proved that both financial and non-financial incentives have a positive effect on the energy reduction. In the same way, Chen et al (2006) found that the interaction with a virtual object also improved the occupants' behaviour in public buildings. In this case, the model was tested in two offices in the Civil Engineering Research Building of National Taiwan University and used a digital aquarium which interacted with the user by adjusting its visual condition towards a 'good' or 'bad' state, based on electricity consumption. Matthies et al. (2011) also carried out an initiative based on the improvement of energy savings in 15 German university buildings. There were two types of implemented measures: (1) information only and (2) techniques that exceed simple information distribution (incentives/rewards and habit focused). The users of the first group of buildings were motivated with posters, mails and staff intervention package, while the second group was also given prompts, commitment, and other motivation activities. After assessing the improvements on energy savings, it was observed that electricity reduced 0.9% for the first group and 7.7 for the second group after 4 months. Long-term effects were only assessed for the second group and it was observed that after 28 months, electricity consumption was reduced 9.5%. Peschiera et al. (2010) also verified that feedback does reduce the consumption. Along the same line, Jain et al. (2012) stated that building users who viewed socially contextualized data of peers in network reduced the most their energy consumption. The influence of users on the energy consumption of public buildings has not only been assessed in universities, but also in hospitals, although to a lesser extent. Sanz-Calcedo et al. (2011) studied the influence of the number of users on energy features of 70 Health Centres in Spain. The results achieved showed that there exists a directly proportional relationship between the number of users in a Health Centre, its floor area and the annual energy consumption of the building. Consequently, by improving user behaviour, energy savings can be achieved.

Taking into account this context, this paper presents a new approach to optimize the energy usage in buildings. This approach, developed under

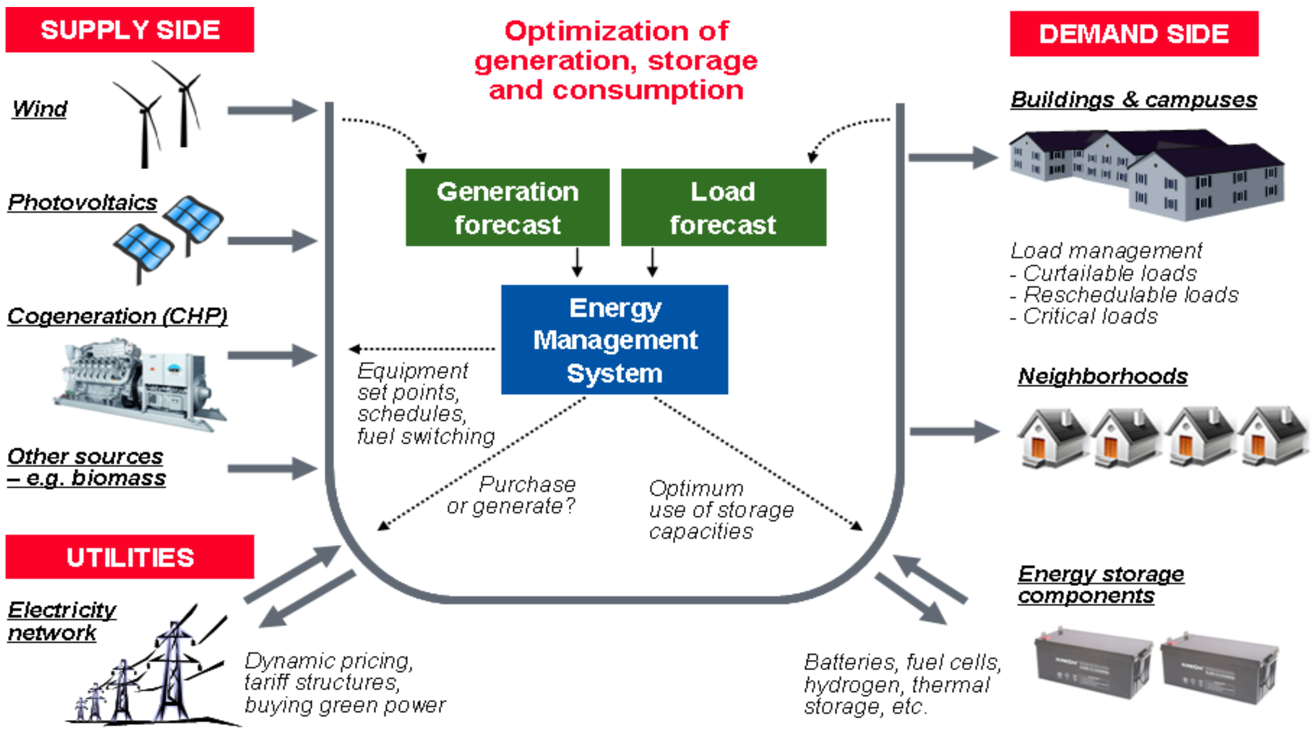

Figure 1. Application domain of the ENCOURAGE project: buildings, campuses, neighbourhoods connected in local microgrids with renewable generation and storage devices. Source: ENCOURAGE project (2012).

the ENCOURAGE project, is based on developing supervisory control strategies, intelligent gateway with embedded logic supporting inter-building exchange and advanced monitoring and diagnostic concepts. Within this context, this paper aims at exploring the possiblity of stressing users' involvement to pursue the final objective of increasing energy efficiency and reduce energy costs in an Urban Campus scenario. Following this introduction, the second section presents the ENCOURAGE project. The third section introduces the urban campus scenario and the questionnaire survey addressed to campus users. Results of the survey are also reported in the third section. The final section discusses the conclusions and the future research issues.

2 THE ENCOURAGE PROJECT

The ENCOURAGE project (Embedded iNtelligent COntrols for bUildings with Renewable generAtion and storaGE) is aimed at developing embedded intelligence and integration technologies that will directly optimize energy use in buildings and enable active participation in the future smart grid environment. Co-funded by the European ARTEMIS programme and the EU Member States, the project involves 11 partners from Spain, Portugal, Italy, Ireland and Denmark. The project duration is 36 months and it was started in June, 2011.

2.1 *ENCOURAGE concept*

Within the ENCOURAGE project, the desired energy savings will be achieved in three complementary ways. Firstly, by developing supervisory control strategies that will be able to coordinate larger subsystems (HVAC, lighting, renewable energy generation, thermal storage, etc) and orchestrate the operation of the numerous devices in such systems. The energy use will be optimized as a trade-off between occupants comfort, energy costs and environmental impact while considering people's habits, weather conditions, characteristics of appliances, local generation and storage capacities and market conditions. Secondly, energy savings will be achieved through an intelligent gateway with embedded logic supporting inter-building energy exchange. This brokerage agent will communicate directly with other buildings and local producers to negotiate possible use of the electricity produced locally in their premises. And thirdly, energy savings will be achieved by developing novel virtual sub-metering technologies and event-based middleware applications that will support advanced monitoring and diagnostics concepts. Systematic performance monitoring will ensure the achieved savings are sustained over long period of

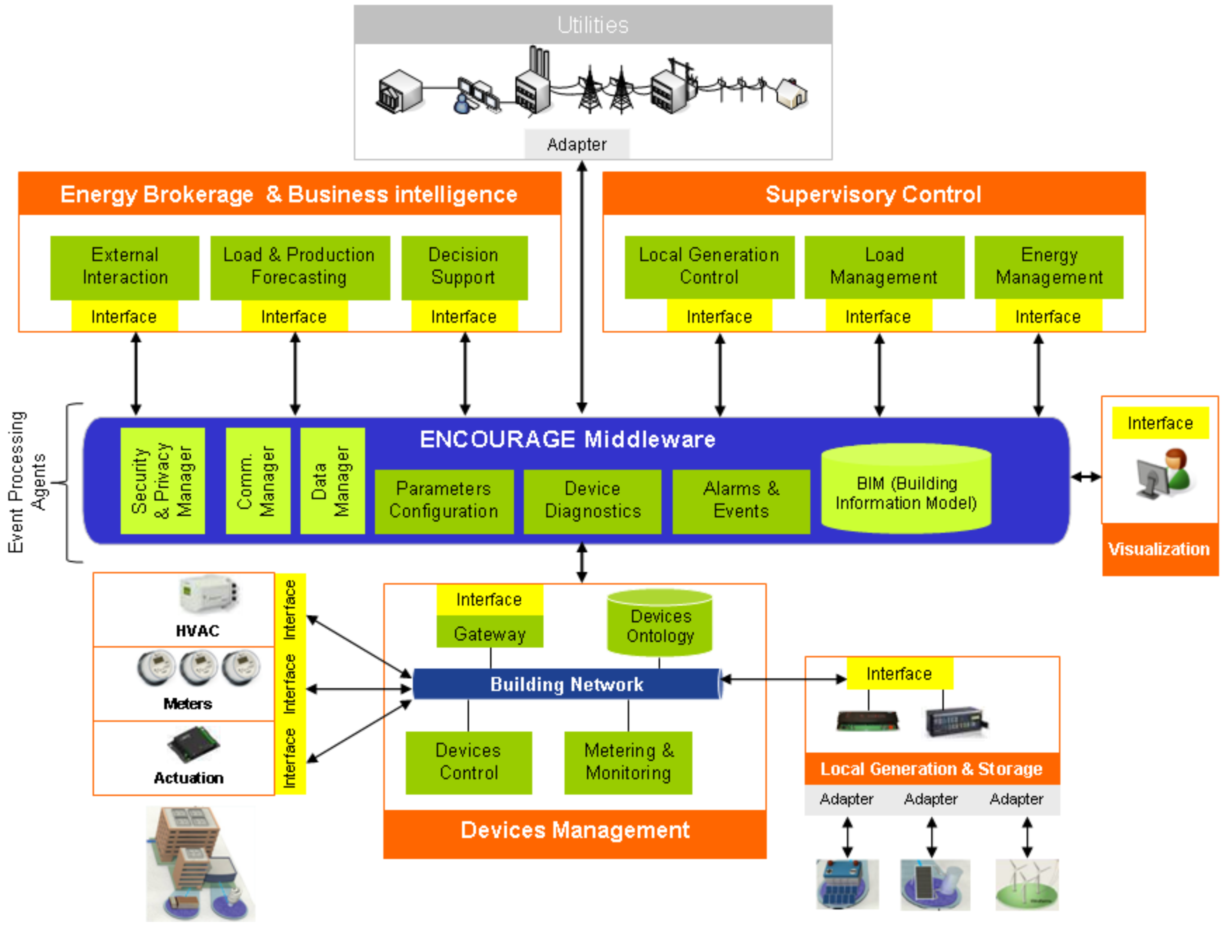

Figure 2. ENCOURAGE architecture. Source: ENCOURAGE project (2012).

time without being degraded by deteriorated performance of both mechanical equipment and the monitoring and control system itself.

ICT-based technologies will enable optimization at different levels:

- Device-level: optimization of individual devices energy consumption supported by continuous monitoring and diagnostics to detect deteriorated performance.
- Building-level: optimization through the coordinated control of local consumption, generation and storage devices.
- District-level (or neighbourhood level): optimization through the ability to perform energy exchange with other participants connected to the electricity grid.

The primary application domains of the ENCOURAGE project are residential buildings and non-residential buildings (figure 1). This is expressed through several demonstrators comprising private homes and campus buildings.

2.2 *ENCOURAGE architecture*

Figure 2 shows a schematic representation of the proposed ENCOURAGE architecture.

- Building Network represents a backbone of the fundamental layer, whose objective is to provide devices management – i.e. access and integration mechanisms for the various heterogeneous devices that either reside inside the building (HVAC equipment, sensors, actuators, meters / sub-meters, etc.) or they are located in the exterior spaces like the local generation and storage equipment.
- Middleware represents an event processing system that takes the data from the building network and processes it as a stream of events. The middleware can be seen as being composed of multiple event processing agents that exchange information between event producers, event consumers, and other agents. This approach will not only handle uncomplicated events but it will also allow for inference of complex events by combining simple ones. The middleware will be able to host various applications, such as the device diagnostics.
- Supervisory Control applications will take advantage of the device integration and data processing capabilities provided by the middleware. They will be receiving meaningful events / data needed for performing the energy optimization, which will be focused either on supply side (local generation control), demand side (load management), or combination of both (energy management).
- Energy Brokerage and Business Intelligence components will provide services that will take advantage of the collected historical data. Based on previous consumption patterns as well as load and generation forecasts it will be possible to make decisions in short-term about the participation in the energy brokerage, or in long-term about possible retrofits, equipment replacements and other capital investment actions.

3 URBAN CAMPUS SCENARIO

3.1 *Description of the scenario*

The urban campus is located in a small urban area at the heart of the Terrassa city (Barcelona). UPC Campus Terrassa has 5400 students and a great number of buildings. For the sake of simplicity, the ENCOURAGE scenario will focus on the Terrassa School of Industrial and Aeronautical Engineering, an academic building with a floor area of 11.600 m^2. The main building has 3 floors mainly devoted to academic uses. Most of the spaces in the ground, the first and the second floors are lecture rooms. The third floor mostly includes computer rooms. The consumption of electricity, water and gas is globally monitored. The heating system is automated and controlled by the central services. The HVAC system is also partially commanded by the central services. In 2011, energy saving measures were implemented at the urban campus. Campus users were informed through mails and posters.

Demonstrator challenges are focused on improving the energy efficiency of this public building by increasing users' awareness. The implementation of the ENCOUAGE system can provide users with context aware information related to their carbon footprint. Information related to the user's location and the time spent in a building will be captured by an automated identification system placed at all the possible entries of the building and/or experimental areas. This information will be sent through the internet wireless network to the ENCOURAGE central server. Information related to the environmental conditions and the energy consumption of the building and/or experimental areas will be also provided by the ENCOURAGE system or measured with different sensors when necessary, and sent to the same server. All this data will be processed and results will be available in a friendly and understandable format in the web interface, easily accessible by the user. This interface will provide information related to the User Carbon Footprint in different formats, to make users aware of their contribution during the day.

3.2 *Survey*

In order to gain a better understanding of the predisposition of campus users to be an active part of the ENCOURAGE system, a survey was administered to 234 students of the Terrassa School of Industrial and Aeronautical Engineering. According to data from the 2008-2009 academic year, 2329 students were enrolled at the School and thus the survey covered 10.1% of students. From a total amount of 240 lecturers working at the Terrassa School of Industrial and Aeronautical Engineering, 19 answered the survey (7.9%). Finally, the questionnaire was also administered to the administrative staff. Within this group, 12 responses out of 23 were gathered (52.2%).

The written questionnaire included 42 questions grouped in six different categories: (1) general information, (2) use of electronic devices, (3) energy habits and environmental awareness, (4) comfort, (5) users' behavior and (6) overall experience. The objectives of the survey were described and the survey form was fully explained to all the participants.

3.3 *Discussion of results*

3.3.1 *General information*

Samples were collected from a total of 265 users of the Terrassa School of Industrial and Aeronautical Engineering. The average age of the surveyed group is almost 26 years (23 years for students, 45 years for lecturers and 40 years for administrative staff). The main gender for students and lecturers is male (with 82.5% and 68.4% respectively) whereas the main gender for the administrative staff is female (66.7%).

Students spend an average of 5.7 hours per day at the School, whereas lecturers spend an average of 7 hours per day. The administrative staff spends, on average, 7.5 hours per day at the School. The three groups spend both morning and afternoon at the School. However, while the usual place for students is lecture rooms, lecturers and administrative staff stay mostly in offices.

In relation to choosing the comfort level, students are the group with less autonomy to choose temperature (only 1 of every 10 thinks that he/she can do it) or ventilation (only 2 out of 10), while lecturers and staff can adjust these levels of comfort. Regarding lecturers, 6 out of 10 can choose the temperature and 4 of every 10, the level of ventilation. For administrative staff, 7 out of 10 can choose both the temperature and the level of ventilation. However, lighting can be chosen in a high percentage by the three groups.

3.3.2 *Use of electronic devices*

Participants were asked for their ability using electronic devices (pc, tablets or smartphones), as well as the uses they give them. The three surveyed groups assert to be comfortable or very comfortable with the use of electronic devices and they use them very often, both for personal use and working purposes. Personal computers are, in number and in hours of use, the most used devices for the three asked groups. Finally, the participants were asked to think about the possibility of reducing the consumption of energy using electronics and informatics. Students, lecturers and administrative staff mainly agreed on this possibility. From 1(total disagree) to 5 (total agree), students chose, in average, 3.73; lecturers, 3.70 and for administrative staff this mean is 4.00.

3.3.3 *Energy habits and environmental awareness*

The majority of students, lecturers and administrative staff completely agreed with being aware of environmental issues. From 1 (total agree) to 5 (total disagree), means were 3.93 for students, 4.42 for lecturers and 4.25 for administrative staff. Moreover, energy saving was found to be a very important issue for them. However, campus users are largely unaware of how much energy they consume due to their daily activities. Regarding to electricity savings, 75% of the administrative staff group totally agreed with the sentence "You try to save electricity". Students and lecturers mainly agreed with it as well. However, from 1 (total disagree) to 5 (total agree), the three collectives chose between 3 and 4 when they were asked for a change of their lifestyle or working habits to make a more efficient use of electricity. Results of the questionnaire also showed that campus users believe that eco-feedback systems can help to reduce the energy consumption.

Questionnaires showed that students are the group less aware of the existing energy saving measures implemented by the campus energy manager, while lecturers and administrative staff declare themselves well informed. To the sentence "You are aware of the university measures to reduce energy consumption", from 1(total disagree) to 5 (total agree), students answered, in average, 2.03, whereas for lecturers the mean was 3.58. Finally, administrative staff chose 4.58 in average.

Concerning the energy efficiency in the university, the three groups are neutral or mainly disagree with the statement that the energy is used efficiently (figure 3). However, in general, students do not have any ideas to mitigate energy wastes, while both lecturers and administrative staff declare to have some of them, such as better management of air cooling systems, implementation of motion sensor switches, use of renewable energies, restriction of the use of air conditioning systems, better use of natural light and turn off computers and printers. In general, winter and summer indoor temperatures are agreed by the three main groups in 20ºC and 25ºC, respectively.

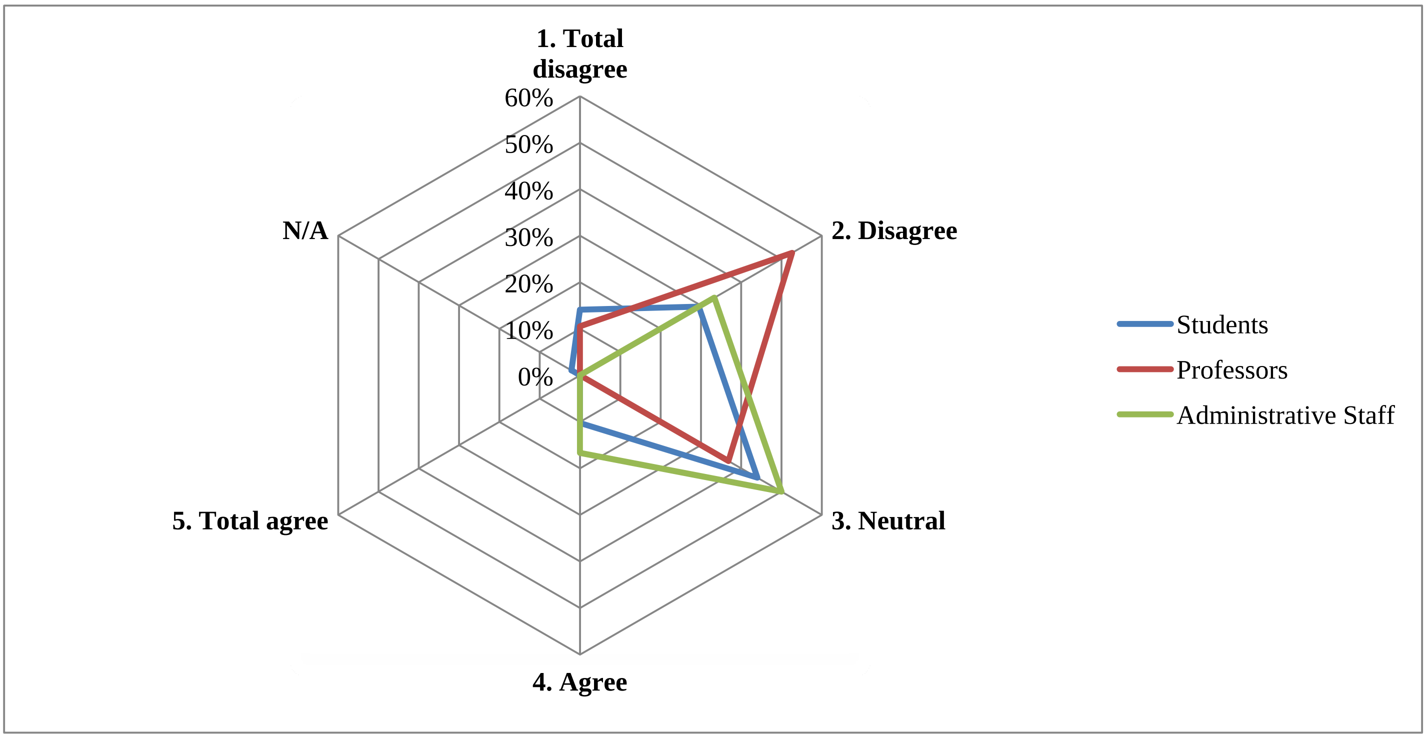

Figure 3. Results to the question:“In your opinion, energy is used efficiently in your university” (1- total disagree / 5- total agree).

3.3.4 *Comfort*

According to the questionnaires, the three main groups (students, lecturers and administrative staff) agreed that the temperature in circulation spaces is between “optimal” and “hot” during summer whereas the temperature is mainly “optimal” during winter. However, the temperature in lecture rooms in summer is, according to the students, mainly too hot. Lecturers and administrative staff spend most of the time in their offices and thus, they can choose its temperature. They think that the temperature in summer is between optimal and too hot. In winter, the temperature in lecture rooms/offices is optimal for the three groups, although it has a slight tendency to be considered “hot”.

Regarding ventilation, students believe that natural ventilation is between “not enough” and “enough” in lecture rooms, while for administrative staff and lecturers, natural ventilation in their workplace is between “enough” and “too much” or “excessive”. For students and administrative staff, air quality at their usual place is mainly between “not enough” and “enough”, while for lecturers it is mainly “enough”.

Finally, concerning the lighting, the three groups considered that it is between “enough” and “too much” in offices, lecture rooms and circulation spaces. Natural light is considered to be “enough” in both offices and lecture rooms.

3.3.5 *Users’ behaviour*

Asking about how often do they override the controls and open windows manually, students answer “sometimes” in average, while lecturers and administrative staff say that they “never” do it. For students, temperature controls are between “almost never” and “sometimes” effective, whereas for lecturers and administrative staff, temperature controls are effective between “sometimes” and “almost always” (figure 4). The three communities recognized that they open the windows when the air quality is not good between “always” and “almost always”. From 1 (never) to 5 (always), students chose 4.26, lecturers chose 3.47 and administrative staff 4.58.

In regard of the temperature, students are the group which “mostly” opens the windows and doors when it is too hot, while lecturers and administrative staff do not do it so frequently.

The three groups mostly assert to switch off the lights when there is nobody in the lecture room or office, but lecturers and administrative staff do it most frequently than students. When there is enough natural light in lecture rooms or offices, most lecturers “always” switch off the light, while students and administrative staff do it between “sometimes” and “always”.

3.3.6 *Overall experience*

In general, lecturers and administrative staff feel “mostly pleasant” in the school, while students feel mostly “neutral”. For the three groups, the main reasons which make them feel unpleasant are “hot temperature”, “lack of ventilation” and the “excess of noise”. For students, the main changes that must be done in order to improve their comfort in the school are the “installation of more effective air cooling systems” and “more decentralized controls”. How-

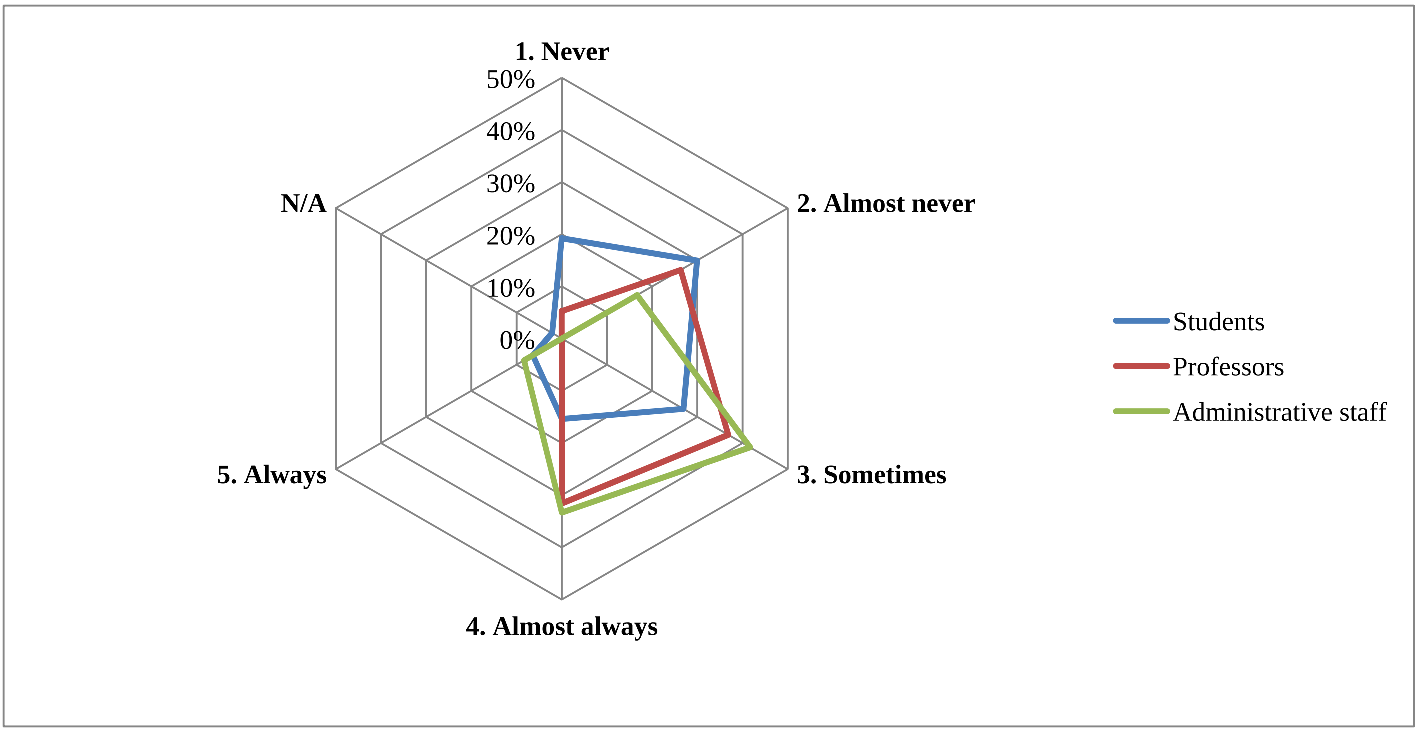

Figure 4. Results to the question: "In your opinion, temperature controls are effective" (1- never / 5- always).

ever, for lecturers, the most important change would be "more interaction with users" and also "more decentralized control". Finally, for administrative staff, these three changes are important. Finally, the participants were asked whether they would like to choose the temperature in lecture rooms through an electronic device (pc, tablet or smartphone). 67% of students and 68% of lecturers would like to be able to do it, while for administrative staff this percentage is lower, with 33% .

4 CONCLUSIONS

Current levels of energy consumption in the urban campus scenario will be diminished by deploying ICT-based technologies developed under the ENCOURAGE project. However, this research has demonstrated that there is energy-saving potential by improving users' behavior through the ENCOURAGE project within the urban campus scenario. A comprehensive survey was conducted over 265 campus users and major findings are as follows:

— Campus users are largely unaware of how much energy they consume due to their daily activities.
— The majority of users are used to electronic devices.
— Campus users believe that eco-feedback systems can help to reduce the consumption of energy.
— Although the majority of users declare themselves to be aware of environmental issues, they appear to be a little bit reluctant when asked for changing their lifestyle or working habits to make a more efficient use of electricity.
— Students are the group less aware of the existing energy saving measures implemented by the energy managers, while lecturers and administrative staff declare themselves well informed.
— Lecturers and administrative staff feel "mostly pleasant" in the school, while students feel mostly "neutral". For the three groups, the main reasons which make them feel unpleasant are "hot temperature" both in winter and in summer and "lack of ventilation". Current centralized temperature controls are seen as inefficient and decentralized controls are claimed as needed changes for a more comfortable environment.
— The majority of users expressed his support for interacting with temperature and ventilation controls through an electronic device (pc, tablet or smartphone).

Energy savings can be maximised by promoting changes of users' behavioral patterns without almost any additional investment. However and based on the survey results, it can be stated that providing generic information on energy saving strategies is not enough to significantly reduce the energy consumption in urban campus buildings, where no financial incentive exist for the users. Information strategies are seen more effective in combination with particularized energy consumption feedback.

Taking into account that results from the ENCOURAGE project will enable to show individualized real time data, providing campus users with information on actual energy consumption could be a way to increase, even more, the energy savings in the urban campus buildings. Decision support technologies and intuitive user interface will help to motivate people to change their behaviour. If users can understand where inefficiencies come from, they can act to mitigate or eliminate them completely. Thus, further research should include developing and implementing an IT-based feedback model for campus users within the ENCOURAGE framework. Taking into account that universities are a socio-physical environment for future decision makers and a place for practical learning, campus users participating in future ENCOURAGE trials will act as multiplicators for promoting a sustainable lifestyle.

ACKNOWLEGEMENTS

The ENCOURAGE project has been funded partly by the European Commission (Artemis Joint Undertaking) and partly by contributions from respective national research programs. The authors also wish to acknowledge ESVALL Projet S.A. for their support and funding and all the project partners for their contributions to the research presented in this paper.

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