Barriers to efficient use of energy in public higher education buildings – a case study

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Abstract

A pilot-study has been carried out in a sample of higher education public buildings in Portugal, aiming at the identification of several organisational and behavioural barriers to the efficient use of energy. The chosen approach embraced several aspects:

- Concerns of building owners and designers on efficiency, factors influencing designers motivations and decisions, building design performance evaluation;
- Institutional budget definition, legibility of energy items within the budget, accountancy management models, their influence on the stimuli provided to managers and staff regarding efficient use of energy;
- Existence, organisation and procedures used in maintenance of buildings and equipment;
- Behavioural patterns of several categories of building occupants – managers, administrative and technical staff, professors and students – as regards to efficiency of building and equipment use, to externalities of energy consumption, to the use of financial resources devoted to energy consumption.

The pilot-study involved four institutions and required the collection of documentation on buildings design, equipment characteristics, energy consumption, buildings population, types of occupancy and activities, organisational structure and decision instances, funding mechanisms and sources, budget figures. Fieldwork involved a set of personal interviews to some categories of occupants and launching custom questionnaires to the remaining categories. Questionnaire design has been simultaneous with the development of data processing tools, for the sake of usefulness and readability of results.

A wide set of barriers has been identified and classified, as documented in the paper, revealing a complex set of interdependencies, which ultimately require a continued effort for adequately influencing (yet not so complex) political decisions.

Introduction

Portugal depends on 85% of primary energy import for fulfilling its energy needs, which may be split into 67% of oil, 3% of natural gas, 14% of solid fuels and 16% of renewable sources. Buildings account for 23% of final energy consumption and for 55% of electricity consumption (DGE 2002). Portuguese energy policy directed at buildings has evolved at a relatively slow pace during the last decade. At the beginning of the nineties, a regulation was issued aiming at the improvement of the thermal characteristics of buildings, imposing certain constraints to the design through a simplified calculation approach. It has now a noticeable influence in the design practice and in construction, although always accompanied to some extent by the inevitable bureaucratic adaptation of market actors to rules, in such a way as to conveniently bypass them. Later, near the end of the decade, a new regulation was issued, this time aiming at the usage of efficient HVAC systems in big buildings (decree-law nº118/98). Presently, these two decree-laws are in the course of revision, a certification process is being designed and, in general, the adoption of the future European directive on energy efficiency in buildings is being prepared. In fact, except for a very interesting (and creative) regulation on energy efficiency, mainly dedicated to the industrial sector in 1982, the Portuguese energy policy has not since then assumed any other driving attitude. In fact, it has simply adopted, sometimes with a considerable lag, the general guidelines issued by the European Commission (EC).

Efficient use of energy in buildings demands, as it is well known, much more than observing some basic design rules, for the building itself and the systems, and hoping that construction will follow the design orientations. After construction, which must be strictly supervised, efficient use of energy also demands adequate maintenance and informed user behaviour, complemented with a wise degree of automation. Finally, tracking and managing energy consumption should go along with technical maintenance.

There are important barriers that prevent these conditions to be met in most cases. Universities and higher education institutions in general are, in principle, places where it should be easy to find influence of environmental criteria on both planning and everyday decisions towards the use of energy and of other natural resources. This should be expectable predominantly in the case of institutions providing technology-oriented education. The paper tries to identify questions that may be considered barriers to the efficient use of energy in this particular type of institutions. The decision of looking at this universe of buildings has been taken, firstly, because the buildings involved pertain to a specific subsector within the service sector, and this could lead to a better understanding of the characteristics of this subsector. Secondly because, at least to the authors knowledge, there was no previous understanding of how actually aware of the importance of energy efficiency are those people with one of the highest potential for being aware of it.

The questions addressed are of two broad categories. One of them deals with behavioural issues in general, in what concerns attitudes towards energy use. The other deals with technical, legal and organisational issues, in the sense that these normally provide the framework that influences building occupants as regards to energy issues.

The paper identifies the target issues that have been the focus of the underlying study and identifies also the target people involved in the data collection phase. It describes the methodology used and draws conclusions in such a way as to allow the identification of the main barriers to efficient use of energy in the studied buildings and the possible short- and long-term actions apparently adequate to circumvent them. It finally identifies some directions for future developments that seem to be promising.

Defining the buildings in the case-study

In Portugal, the system of public higher education is divided into two subsystems. Universities, accounting for 57,6% of students in the system, make up one of them and Polytechnic Institutes the other, with the remaining 42,4% (INE 2001). Hence, a sample of buildings has been considered, including the same number of buildings in both subsystems. Several constraints have influenced the sample definition, as the scarcity of human resources available and the time limitations imposed by tight schedules for the completion of the fieldwork. The final number of four buildings is compatible with the upfront assumption that the conclusions would not be susceptible of extrapolation. The work should be considered a pilot study whose aim should be to provide enough insight into the main barriers to efficient use of energy in this type of buildings and also to provide knowledge on the problems and difficulties that a deeper study should be prepared to cope with.

The selection of the buildings to be analysed took into account that their dimension and number of students should reflect the reality of the Portuguese public higher education buildings. Furthermore, the chosen buildings are located in the same geographic region. The following institutions have been selected:

- Mathematics Department / Faculty of Science and Technology / University of Coimbra (DM-FCTUC);
- Electrical Engineering and Computers Department / Fac. Sc. and Tech. / Univ. of Coimbra (DEEC-FCTUC);
- Department of Systems and Computer Engineering / Engineering Institute of Coimbra / Polytechnic Institute of Coimbra (DEIS-ISEC/IPC);
- Accounting and Administration Institute / Polytechnic Institute of Coimbra (ISCAC-IPC).

Methodology and Tools

Two types of aspects have been considered in the attempt to identify barriers to efficient use of energy: psychological or behavioural aspects and organisational aspects, as the authors intended to also assess the importance of management models and tools on energy use. Data was collected by means of a set of different questionnaires, customised for several types of building occupants. Some of these have been the basis for conducting personal interviews. However, other tools have been used, both for finding out the main organisational characteristics of each school, and for dealing with technical issues.

Several documents have been collected in all four schools, such as statutes/internal regulations, budget plans, plans of activities, activity reports, official statistical data on the persons attending the establishments, regular office hours. Other aspects having some influence on energy consumption have been directly asked for, when they could not be simply captured by reading the collected documents.

A synthetic audit to energy consumption and to the buildings thermal characteristics has also been accomplished. Hence, electricity bills relating to the year 2001 have been collected, together with building design drawings and other design elements.

Target population

Several categories of building occupants have been considered, in a standard manner, to be used across the whole sample of cases. The definition of these categories was based on the main functions or tasks each agent usually carries out, which has influence on his/her perspective as regards to energy consumption and use. It is obvious that the level of a manager's awareness of the role of energy management determines how he/she decides on certain investments, or chooses to improve maintenance procedures, or keeps track of energy expenditures, etc. Students, for instance, may tend to overlook the impact of leaving lights on in a toilet or, on the contrary, to criticise the eventual negligence of caretakers as regards to energy use. The resulting list of categories is as follows:

- Manager;
- Professors;
- Students;
- Administrative staff (Secretariat, Human Resources Department, etc.);
- Library Staff;
- Auxiliary Personnel (caretakers);
- Energy Manager/ Maintenance Co-ordinator;
- Technical personnel (Electricians, Gardeners, etc.).

Table 1 shows the total population of each school in the sample and Table 2 shows the number of questionnaires collected at each school from each occupant category.

In spite of the noticeable differences among their population figures, approximately the same number of questionnaires has been collected for each category in every school, uniformity of treatment being considered eligible because no general statistical validity was to be assigned to the conclusions. Small differences occur, however, among the numbers of collected questionnaires, due to a set of practical factors, during the field work, that are usually not predictable in detail.

Sample characteristics

TECHNICAL AND ORGANISATIONAL ISSUES

Autonomy and operation

Only one of the schools included in the study (ISCAC) has a thorough independence in what concerns financial management. The other three perform only a part of the administrative tasks in this area and, namely, they are not directly responsible for the actual payment of energy bills. This responsibility is assigned to some hierarchical management level above them, depending on the particular school addressed. This potentially translates into a more permissive attitude towards the consumption of resources in general, although requiring a lighter management structure, which may be attractive from the perspective of economies of scale in management activities (Dispatch of 1997/04/10 [a], Dispatch of 1997/04/10 [b]) (DEEC, 1994) (DEIS, 1999), (Ministerial Dispatch nº 85/95), (FCTUC, 1997).

Table 1. Sample Population by school and by category

	DEIS	ISCAC	DEEC	DM
Students	640	2 729	497	2 113
Teachers	38	101	48	109
Employees	11	36	22	29
Total	689	2 866	567	2 251

Schools integrated in universities usually do not have an additional lecturing shift in the evening and early night, as schools integrated in polytechnic institutes do. This is mainly because there is a significant number of students attending polytechnic institutes that also have a professional activity, which is not so frequently the case in universities. This has some evident implications on energy consumption indicators, on the average usable floor area allocated to each student and on the utilisation of all resources in general.

Buildings data / Thermal behaviour of buildings

Of the four establishments included on the study, only one (DEIS) of them shares its facilities with others (the library serving the whole institute is located in the DEIS building).

In Table 3, the usable floor area and year when operation started at each of the analysed buildings are presented.

Although having different operating conditions, it is quite noticeable that one of the university buildings provides ample space to occupants as compared to the others – the smallest ratio is approximately 5:1 –, which will certainly have influence either on the comfort or on the activities that can be developed in each establishment.

The Portuguese regulation on the thermal characteristics of buildings (RCCTE) was issued in 1991. All the buildings in the sample, except one (DM), are more recent than this date, which would presumably indicate that all of them would comply with the regulation. This regulation defines upper bounds – N_i and N_v – for the nominal values of end-use energy needed per square metre of usable floor area, in both the heating and cooling seasons – N_{ic} and N_{vc} respectively (DGE, 2000). In order to assess how distant the building designs are from these regulatory targets, a thermal behaviour analysis has been conducted on each building, based on design documentation. Table 3 contains the essential results.

Table 2. Number of questionnaires collected at each school

Occupant category	Interview	DEIS	ISCAC	DEEC	DM
Manager	Yes	1	1	1	1
Energy Manager/ Maintenance co-ordinator	Yes	1	n.a.	1	n.a.
Professors	No	5	4	5	4
Students	No	98	90	84	86
Administrative staff	No	5	4	4	5
Library staff	No	2	3	2	2
Auxiliary Personnel	No	2	3	2	2
Technical personnel	No	2	2	2	2
Total		**116**	**106**	**101**	**102**

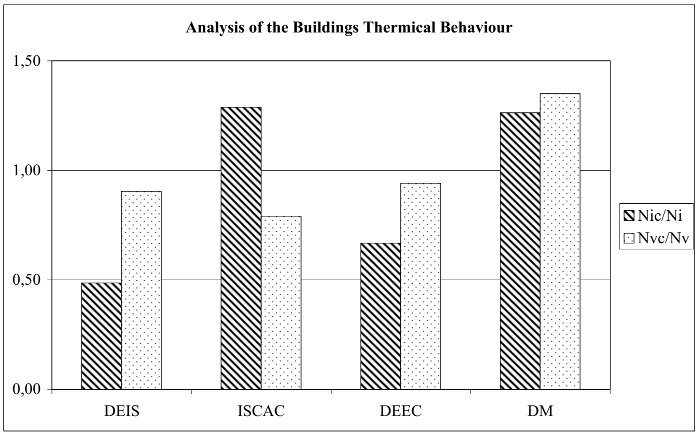


Figure 1. *Buildings thermal analyses. The more recent buildings should comply with the regulatory upper bound of 1 to the represented ratios.*

Table 3. Age and usable floor areas of studied buildings.

	DEIS	ISCAC	DEEC	DM
Operation started in	2000	1995	1996	1969
Usable floor area (m2)	1 800 [2936]	6 041	12 458	8 739
m^2/user	3,2 [4,26]	2,1	22	3,9

Table 4. Results of the analyses of the buildings thermal behaviour.

	N_{ic} (kWh/m^2.year)	N_i (kWh/m^2.year)	N_{ic}/N_i	N_{vc} (kWh/m^2.year)	N_v (kWh/m^2.year)	N_{vc}/N_v	Compliant w/ regulation
DEIS	68,1	140,3	0,49	25,4	28,1	0,90	Yes
ISCAC	76,5	59,4	1,29	7,9	10	0,79	No
DEEC	54,1	81,1	0,67	11,2	11,9	0,95	Yes
DM	76,4	60,5	1,26	13,9	10,3	1,35	No

Table 5. Main electricity consumption and contractual characteristics of the analysed buildings.

	DEIS/ISEC*	ISCAC	DEEC	DM
Tariff Options	MT	MT	MT	BTE-LU
Installed Power (kVA)	440	315	630	
Contractual Power (kW)	325	200	315	166,5
Maximum Power Demand (kW)	325	112,5	180	163,5
Power Factor	0,98	0,99	1	0,94

* In the case of DEIS, power values correspond to those of ISEC, as there are no individual figures for Departments.

Table 6. Active energy consumption values (year 2001).

	DEIS	ISCAC	DEEC	DM
Full Hours consumption (kWh)	118 052	172 698	265 620	207 897
Peak Hours consumption (kWh)	57 481	145 175	153 051	105 111
Valley Hours consumption (kWh)	46 691	71 762	97 276	72 405
Total Energy consumption (kWh)	222 225	398 635	515 947	385 413

In Figure 1, the ratios N_{ic}/N_i and N_{vc}/N_v are graphically represented, where it is easily recognisable that the upper regulatory limit of 1 is violated in two of the buildings for at least one of the seasons.

If in one of the cases (DM) this situation can be considered acceptable, since both the design and the construction preceded the coming in force of the regulation, the other situation is very surprising because its construction is rather recent and, consequently, subsequent to the publication of RCCTE.

Electric Energy Consumption

Energy consumption analysis has been focused at electricity, since the consumption of other forms of energy, when present, is residual.

Electricity bills have been collected, corresponding to the year 2001. However, the case of DEIS had to be dealt with in a different fashion since, as the building has no independent contract with the utility, there are no bills available. Hence, data has been collected on site, by means of a data logger dedicated to energy audits. The data has then been processed according to the contractual options of ISEC, in whose *campus* DEIS is located. Table 5 summarises the results obtained.

With the exception of the DM, the other three buildings have their own Medium Voltage/Low Voltage (MV/LV) transformer, to enable the connection to the electric network at MV level and, hence, to benefit of more convenient contractual supply conditions. As it shows, the electricity consumption of the DM's building suggests there is an opportunity for cost savings if a power transformer may be used for the supply. Also, DEEC electrical installation is clearly over-dimensioned as regards to its actual power demand. As frequently happens, the building design has been influenced by too generous tolerance criteria when defining coincidence factors, leading to higher transformer losses and an unnecessarily higher initial investment. The high power factor of all buildings denotes a positive concern with some avoidable costs, as those of reactive energy. Table 6 and Figure 2 present electric energy consumption values of the four buildings.

In Figure 2, where data from Table 6 has been plotted, it becomes evident that, although the four schools have different working schedules, energy consumption distributions through the three conventional tariff periods are very similar (EDP, 2001). This is mainly due to the fact that, despite the schedule differences, the working periods still occur mainly during peak and full hours. Also, the high relative importance of energy consumption during valley hours denotes the fact that some equipment is frequently left on during the night.

More detailed considerations concerning consumption patterns would need a careful analysis of load diagrams, that have not been collected because that was not an objective of the study.

Some energy consumption indicators have been obtained, as shown in Table 7.

The table shows that engineering schools have, as it could be expected, the highest specific energy consumption values, namely due to the equipment needed for lecturing, mainly in laboratories. Annual utilisation of maximum power demand provides a good indication on the importance of consumption peaks – the smaller they are, the greater are the peak amplitudes and the smaller their duration. Similarly, utilisation of installed power is a good indicator of the adequacy of installed power to the consumption characteristics of an installation – the smaller the value, the higher is installed power, usually much higher than it could be to provide the same energy service level. DEEC is a clear example of this, where one of the two existent power transformers is redundant and corresponds to an unused resource, an unrecoverable investment.

Budget issues

Financial management activities and framework play an important role in the efficiency of energy use in the targeted type of buildings. Three main aspects should be referred.

Firstly, the importance that is given by managers to the virtuous periodic control of expenditure – if this is not done, the capacity to detect abnormalities in resource use, including energy, is absent or very poor.

Secondly, the visibility of the use of energy resources – the official accounting system of the public administration classifies costs into specific categories which do not allow, in the Portuguese case, a clear identification of expenditure with energy resources, as it is mixed together with other types of costs in the same category. Hence, the so-called virtuous periodic budget control is not of much help if other types of separate records on expenditures do not exist (Ferreira, 1995).

Lastly, the framework within which institutions must be managed, determine whether it is possible to use savings for some other strategic purpose – if this is not the case, as it happens in the majority of the analysed establishments, there is no stimulus for energy savings, as the corresponding budget parcel will simply be suppressed when defining next year's budget. Additionally, in three of the four studied cases, managers do not even have to worry about energy or water expenditures, because some central structure (faculty or institute) takes care of the corresponding payments. This absence of local responsibility for the local consumption has a crucial influence in the attitude of management regarding the use of resources and corresponds to an evident organisational barrier.

Data has been collected in the four establishments, corresponding to fiscal year 2001. This helped identifying not only the structure of the classification system for costs and revenues. Together with personal contacts with the staff involved in accounting systems operation, it also allowed drawing the above conclusions on organisational barriers.

For the sake of illustrating the relative importance of electric energy expenditures, they have been compared with the budget part reserved for investment. Figure 3 depicts the resets obtained. In the case of the Mathematics Department, the total amount should justify a particular attention to energy expenditure.

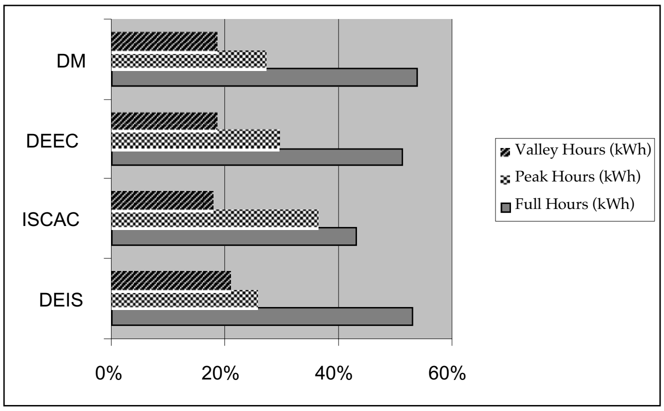


Figure 2. *Electricity consumption distribution through tariff periods.*

APPROACH TO DATA PROCESSING WITH SOME EXAMPLES OF QUANTIFIED RESULTS

The aim of the study being the identification of barriers, characterising each school individually has not been a concern. As a matter of fact, though it is possible to do so, because data is organisable also for that purpose, in general terms it is the opinions and behaviour of the whole set of sampled people in each category that should be assessed.

As the study has been considered a pilot experiment that should precede some possible similar action covering a much higher number of schools, tools for processing a high number of data have been prepared, for the sake of generality. In some cases it has produced too detailed reports because of the comparatively small number of data, but the option seemed appropriate at the time and, in general, revealed to be quite adequate even for the actual sample dimension.

The well-known assertion that "if you can not use the answer then do not ask the question" has been used permanently to obtain a fully usable set of data from the answers gathered during the field work. The practical way to achieve this has been to design the procedures for data analyses and treatment simultaneously with the questionnaire design.

Additionally to the general requirements for data processing that resulted from the above mentioned criteria, when all the data had already been processed according to the previously defined specifications, some cross-analyses of the answers to the questionnaires were done, covering the various categories of building occupants. This was accom-

Table 7. Energy efficiency indicators

	DEIS	ISCAC	DEEC	DM
Specific Energy Consumption (kWh/m^2.year)	75,7	64,5	41,4	43,0
[Specific Consumption / Average Value] (Average Value = 59,3 kWh/m^2.year) (DGE,1994)*	1,28	1,1	0,70	0,72
Specific Energy Consumption per User (kWh/user.year)	322	139	910	171
Annual Utilisation of Maximum Power Demand (Total Energy/ Maximum Power Demand) (hours)	2 890	3 543	2 866	2 357
Annual Utilisation of Installed Power (Total E./Inst. Power) (hours)	2 134	1 265	819	

* Indicated average values have been found in the sole study carried out in Portugal for assessing energy use in buildings of the service sector, which included the Higher Education sub-sector. It has been financed by Directorate General for Energy in 1994, and it considered a sample of 9 institutions in the sub-sector (DGE, 1994).

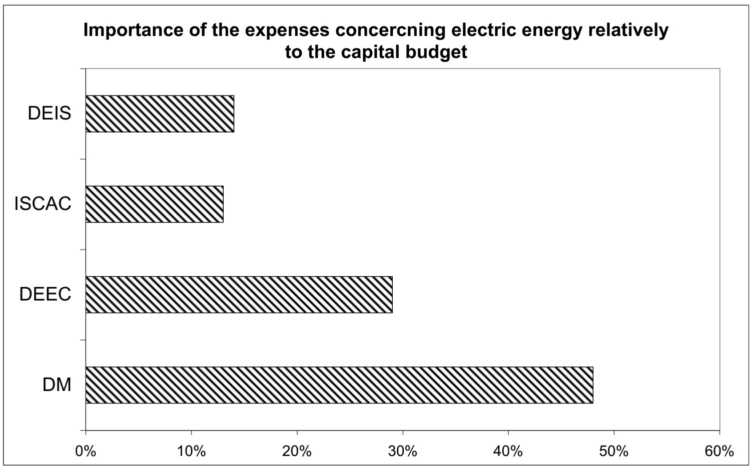
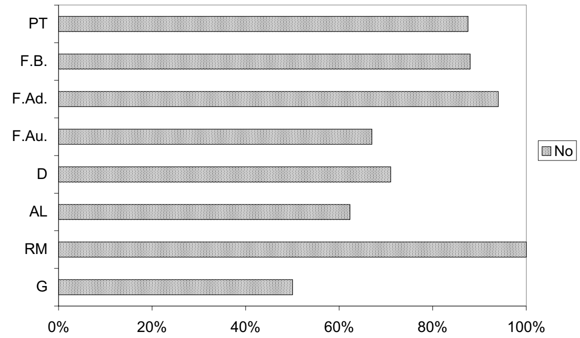


Figure 3. *Electricity expenditure in 2001, as a percentage of the budget allocated to investment*



[G] – Manager; [RM] – Technical manager; [AL] – Students; [D] – Professors; [F.Au] – Auxiliary Staff; [F.AD] – Administrative Staff; [F.B] – Library Staff; [P.T] – Technical personnel

Figure 4. *Percentage of negative replies, per occupant category within the studied buildings, to the question on the existence of a general awareness of the need to use energy efficiently*

plished by combining answers to different questions given by different actors that, however, revealed a potential for revealing aspects that would otherwise remain hidden. Some examples of the conclusions of this particular exercise are given below.

One of them has to do with the classification that each agent assigns his/her own institution, as seen in Table 8. The answers to most of the questions in the questionnaire were coded in a scale of 1 to 4, in this case meaning from bad to good.

Thermal comfort is, on average, the less satisfactory parameter according to occupants' opinion. This can be related to the fact that buildings actually do not have a high thermal quality standard. Namely, there are two of them that do not comply with the moderately demanding rules of the legislation (RCCTE). This regulation, assessing average characteristics only, does not take into account possible asymmetries within buildings. At least in one of the compliant cases there are noticeably different comfort conditions between spaces confining different façades in each of the extreme seasons.

An interesting contradiction has been detected between the notion that people have of their own individual consciousness of the importance of rational use of resources and the collective consciousness they claim to perceive in others. As a matter of fact, almost everyone considers him-/herself aware of the need to use energy efficiently but, when answering to a question on the awareness of others within his/her institution, the results are as depicted in Figure 4. This may well denote a new kind of barrier, which could be the result of a certain persistency effect of the effort of dissemination of energy efficiency practice, and of the moral discomfort it may cause, as it tends to put a psychological burden on the natural negligence of people.

However, there is a strong receptivity to the interest and importance of education and training in the field of efficient use of energy, as the results depicted in Figure 5 clearly show.

These two results taken together seem to indicate that there is not only a good potential for training actions, to deliver information that seems to be lacking, but also that this may be a way of providing people the practical tools to overcome the psychological need to hedge, through insincerity, against the threat of social condemnation.

Main identified barriers

The content of the set of questionnaires, one for each occupant category, is not within the scope of this paper. In the following, the main conclusions drawn from document analyses and from the questionnaires are presented, using a classification presented below. Questionable as any other, the authors decided to use the proposed classification for being able to distinguish subjective causes and causes attributable to factors that are external to people using the buildings. Two categories are used: the first one puts together barriers of political, economical and organisational nature; the sec-

Table 8. In a scale of 1 to 4, the average classification that the various categories of occupants give to the buildings, according to four criteria

	G	RM	AL	D	F.Au	F.Ad	F. B	P.T	Total
Lighting	3,8	3,0	2,9	3,0	2,8	3,4	2,9	2,9	3,1
Thermal comfort	2,8	2,5	2,4	2,5	2,8	3,2	2,6	2,3	2,6
Ventilation / Air quality	3,8	3,0	2,7	3,0	2,9	3,3	2,6	2,6	3,0
Acoustics	3,8	3,0	2,8	2,7	2,7	3,3	2,9	2,4	3,0
Total Average Values	**3,6**	**2,9**	**2,7**	**2,8**	**2,8**	**3,3**	**2,8**	**2,6**	

[G] – Manager; [RM] – Technical manager; [AL] – Students; [D] – Professors; [F.Au] – Auxiliary Staff; [F.AD] – Administrative Staff; [F.B] – Library Staff; [P.T] – Technical personnel. The scale ranges from 1 (bad) to 4 (good).

ond refers to what the authors decided to designate psychological barriers.

Besides, the building occupants have also been grouped, for the sake of identifying barriers, giving place to the following categories of barriers: those pertaining to causes that may be considered as preceding the buildings operation; barriers attributable to people in management; barriers connected to people in charge of technical management tasks; barriers relating to the rest of the building occupant categories. Managers and technical staff play (or should play) a central role in promoting efficient use of resources. Hence its separate consideration in the following conclusions.

Each identified barrier is signalled in the text with an alphanumeric symbolic reference inside brackets, for an inclusive synthesis at the end of the paper.

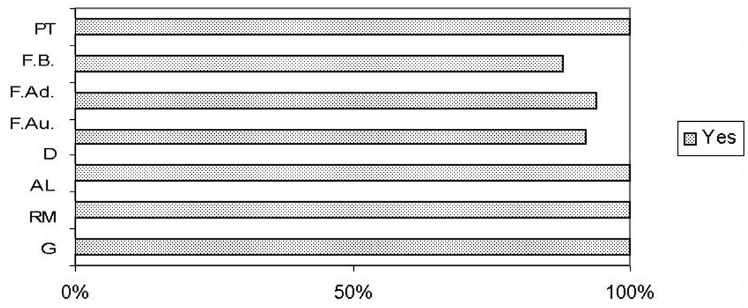


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Figure 5. *Percentage of positive replies, per occupant category within the studied buildings, to the question on the importance of education and training on the efficient use of energy*

BARRIERS PRECEDING THE BUILDINGS OPERATION

Diversity of building design options is quite evident. If this is inevitable, due to the fact that a different architect designed each building and, eventually, due to different types of requirements – engineering schools have different requirements from those of Mathematics or Management – the absence of common concerns on passive efficiency of buildings is also quite notorious. The existence of general regulations for buildings is not enough when it comes to the design of educational buildings, as the particular functional characteristics of these buildings should be the source of also particular requirements informing their design. Opportunities for an efficient behaviour of buildings are irrevocably lost each time a building is designed without the need for compliance with rules that should inform public contracting in this domain. Hence, regulatory omissions are the first barrier in the row (**m1**).

However, regulatory omissions assume a more important meaning in the case of public buildings, as the public administration is not submitted to the same rules as private investors. In fact, local authorities are not required to issue construction licences (which happens in the case of a private initiative, with mandatory verification of legal thermal characteristics of the building) for central public administration buildings (**m2**) (decree-law nº177/2001). Hence, even the smooth regulations in force have no efficacy in these cases, which makes the observation of good practice in building design a matter of consciousness of the designers, with the predictable – and observed in the answers to the questionnaires – consequences on comfort and/or on energy consumption in HVAC services.

Over capacity is frequently found in technical installations, either electrical or mechanical, a good example being the case of the power transformers feeding some of the buildings' electrical installations. This is a case where classifying barriers may reveal difficult or controversial. The way the designer faces his own work, if leading to this type of result, may be seen as a psychological barrier (**m3**). However, the absence of regulation for avoiding this specific careless design may be classified as a political barrier (**m4**) by omission and, finally, the business as usual approach, allegedly funded on practical experience, may be classified as a technical barrier. Alternatively, this last perspective may as well be classified of cultural nature, in the sense that it is characteristic of a certain collective way of looking at rules of thumb as if they meant the safe way of doing things – why change something that never went wrong or, in other words, why improve efficiency when people are, above all, concerned with reliable operation? A possible additional barrier, though it had no practical evidence in the project, may be caused by the way that fees to be paid to designers are calculated, usually as a proportion of the estimate of the building or system value, when completed. This may invite designers to pull up the costs of adopted solutions, over-dimensioning being one possibility (**m5**). However, this is not likely to happen when competition is strong and designers have to lower prices in order to be chosen for the job. If a regulatory approach is to be used, it must decouple fees from total capacity or cost of implementation.

There is a big difference in the attitudes of managers of the studied schools towards rational use of resources, depending on the way they perceive financial responsibility. In fact, if the budget is not fully managed by the school itself (**m6**), the stimuli for economic efficiency are out of focus. Either the manager does not see some costs and will not tend to influence the use of the corresponding resources in an efficient way, or the benefits of efficiency have no repercussion on future budget values. The fact that only one manager out of four knew the approximate value of the building's energy bill is a good illustration of this. Moreover, the lack of readability of energy expenditure in budget organisation and control (**m7**) represents an added difficulty to effective management.

LOCAL MANAGERS

In general, the way managers carry out their job has important repercussions in the attitude of all the other building users.

There may be lack of motivation of the managers, in what concerns the present budgetary policy. As a matter of fact, some managers mentioned the fact of only deciding on a small part of the total budget, as the reason leading them to a short-term based management, solely aiming at the satisfaction of immediate needs of their institutions. Hence, manager's indifference (**g_1**) arises as a psychological barrier even if caused by a political/organisational obstacle. It may be said that managing a global budget would be twice as beneficial to the manager's performance and, most likely, to an eventual rationalisation of energy consumption.

An additional contribution to the managers' eventual lack of motivation may be, in some cases, their election process (**g_2**). Most of the times, personal characteristics and, mainly, the training in management of such or such candidate are not adequately taken into account. Usually, the chosen person is not elected because he/she actually wants to be the manager, or because he/she has particularly adequate characteristics that fit him/her to the job. Under these circumstances, the person that is elected may well face the task as an institutional obligation for which he/she feels no motivation and is not willing to invest much of his effort or personal engagement. This obstacle is a result of the organisational nature of this kind of institutions and of the terms in which the electoral processes are specified, lacking some stimuli, constraints and standards that would help avoiding these problems.

Also related to this aspect, there are obstacles caused by the managers' specific preparation or training in management and resulting also of the length of the period they remain in charge of management. Most of the interviewed managers declared not to have a specific education or training for the job, as they actually are professors. In spite of this, they also considered to be skilled enough for it, which reveals a biased perspective on the management function and demands. This may be seen as a psychological barrier, i.e., the way managers put in perspective their function (**g_3**). In most cases, there is also a high rate of change of the persons in charge of management (**g_4**), which may be considered as an organisational barrier. In fact, the lack of specific training is not even, in these cases, compensated by the experimental knowledge that a longer period in management would in any case provide. This obstacle is seen as a difficulty to a more profound maturity of the management practice, namely when the performance of this task is the only source of information available. Stimuli or obligation to attend training actions would, in the context of the identified organisational characteristics, help reducing the impact of these barriers.

A striking feature that has been noticed during the study is the (only apparent?) lack of importance that managers tend to give to environmental consequences of a less efficient use of resources (**g_5**), when compared to the purely economic impacts. In what concerns energy use, the authors consider this is actually not a truism. In fact, it is undeniable that managers must carefully consider all aspects of resource use from an economic point of view. However, the persons here under consideration manage public higher education institutions, where the absence of internalisation of environmental costs in energy prices should not be an obstacle to a broader perspective on energy resource use. It should actually give place to a higher level of concern than expected elsewhere.

A comparative analysis of the perspectives on comfort conditions leads to the identification of a curious additional psychological obstacle to an efficient use of energy. As a matter of fact, managers consistently identify a higher level of satisfaction with comfort conditions than the remaining building users (**g_6**). This can act as an inhibition factor when some decisions must be taken in order to improve comfort and foster efficiency.

Lastly, an important organisational barrier consists on the absence of a professional structure for facilities management (**g_7**). In two of the studied schools there is a person designated to take care of maintenance and technical management of the building. However, as will be seen below, even in these two cases the results so far are very incipient.

TECHNICAL MANAGERS

The conclusions drawn under this category include, besides the person in charge of the technical aspects of building management and maintenance, the employees under his supervision, currently designated technical personnel.

Technical managers have been found in only two of the four studied cases. One of the flaws easily found during the study is either a lack of a clear specification of the areas where a technical manager must act and, hence, an almost blind recruitment of the person, or a recruitment that has been totally decoupled from the previously (and carefully) designed specifications (**f_1**), namely because other circumstantial factors have influenced the process. In this latter case, a logical consequence is the lack of motivation (**f_2**) of the person for the job he is expected to perform.

None of the two technical managers, when faced with some of the questions raised in the questionnaire, showed to have an idea even of the order of magnitude of the building energy consumption, not to mention load diagrams. They also had no idea on any eventual energy audit that could have been made to the building in the past (in one of the cases an extensive audit had actually taken place, carried out by internal effort and means). Even if these technical managers may have some positive role in other building maintenance aspects, it is certain that they show very little sensibility on energy related topics, namely on energy efficiency (**f3**). This lack of sensibility to energy aspects is common to the technical personnel. In fact, none of the questioned persons could identify the approximate energy consumption even of the equipment they usually operate.

Maintenance management has two main characteristics in the studied buildings. Firstly, it is strictly of corrective nature, solving problems and not preventively avoiding them through planned action. Secondly, there are no procedures whatsoever to keep record of maintenance activity in general, not to mention the complete absence of a systematic set of tools for maintenance management. This situation corresponds to a completely out-of-date, amateur-like philosophy applied to maintenance activities (**f_4**). It should be noted, to emphasise lack of motivation, that the described situation is common to both cases, despite the fact that, in one of them, a maintenance plan existed prior to the technical manager recruitment, created on purpose for providing an organised framework for his activity. Probably, adequate training would be beneficial to this type of situation. Undeniable is the fact that this situation is clearly in contradiction with the needs of an effective management of energy use (DGE, 1996) (DGE, 1997), (Pinto, 1994).

Apathy of the technical personnel (**f_5**) may also be pointed out as one of the barriers. A very small number of persons in this category have made some suggestions for improving comfort or end-use equipment conditions of use, in spite of

Table 9. Barriers according to classification types

	Barriers	Nature	
		Psychological	Political, Economical, Organisational
Precedent to the buildings operation	m_1		X
	m_2		X
	m_3	X	
	m_4		X
	m_5		X
	m_6		X
	m_7		X
Local managers	g_1	X	
	g_2		X
	g_3	X	
	g_4		X
	g_5	X	
	g_6	X	
	g_7		X
Technical managers and personnel	f_1		X
	f_2	X	
	f_3	X	
	f_4		X
	f_5	X	
Other occupant categories	u_1	X	
	u_2	X	
	u_3		X
	u_4		X

the fact that lighting and HVAC are the main targets of the negative references of building users. Technical personnel are supposed to act proactively in the detection and correction of installation and equipment malfunctions.

OTHER CATEGORIES OF BUILDING OCCUPANTS

As a general statement, it may be said that occupants' behaviour is much influenced by the initiatives and omissions of managers and technical personnel.

A high number of respondents to the questionnaires has identified a generalised lack of concern on energy consumption (**u_1**), as (answers refer it) equipment is often found operating without any apparent necessity. Answers also allowed the identification of the classic ignorance, by building occupants, of energy consumption costs (Mudyn and Rysak, 1997) (Golove,1994) (CE, 2000) (Martins, 2000). Users who do not pay directly for the use they give to equipment are naturally not expected to be aware of the energy costs of such use. Furthermore, to a certain extent there is also a disregard of public resources by individuals. In general, there are no visible stimuli or even plain information aiming at a higher conscience level of occupants on the importance of efficiency, in what may well be identified as a predominantly *let go* attitude of managers and technical staff (**u_2**). In fact, not even this category of occupants has made proposals or suggestions on possible modifications of equipment use for improving efficiency.

There is also no standardised and well-publicised procedure for collecting users' suggestions or malfunctions reports (u_3), which is an organisational barrier. Answers to the questionnaires reveal that people face difficulties when attempting to make suggestions or to report some kind of misuse or malfunction, due to the absence of a previously known practical way of doing it. Therefore, people often give up or use a way which is not effective.

Administrative and other non-technical personnel have often referred that no instructions or information has ever been given to them for a correct use of certain devices (**u_4**), which reveals a less effective action of the technical staff.

BARRIERS IN BRIEF

In Table 9, an attempt is made to present a classification synthesis of the barriers that have been identified in the course of the study. Barriers are denoted by the symbolic references that have been assigned to them in the text. The predominance of psychological and organisational barriers, almost with equivalent importance, confirms the need to assess both behavioural aspects and aspects having to do with management methods and organisation.

The authors feel that this project has been useful for a possible extension of this type of analysis to a broader set of buildings in the higher education sector. It has provided an insight into some obstacles to efficient energy use, sometimes confirming suspicions, sometimes revealing unsuspected aspects of reality, as for example the different perceptions of energy efficiency and comfort shown by managers and the remaining occupants, or the lack of motivation of facilities managers for their jobs, or even the importance that energy efficiency has already assumed as a social issue, almost of ethical nature, contrasting with the practical influence it actually has in people's behaviour. There are some prospects of further application of the methodology and there is now a firmer ground for launching initiatives by public authorities, at various levels, aiming at a situation of true positive influence by example (provided by public higher education institutions) on building users behaviour.

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