Barriers to energy efficiency in school buildings Technical and policy issues: a case-study in Portugal

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1. SYNOPSIS

Adequate policy measures are to be taken in order to avoid energy waste and needless environmental impacts of school buildings operation.

2. ABSTRACT

In spite of a variety of regulations, programmes and measures towards increasing energy efficiency in buildings, namely in the EU, an overwhelming number of situations exist where buildings are operated in a way far from efficient. In many cases building design is the first cause of problems, in other cases careless end-use equipment choices are predominant, in a great number there is a total lack of preventive maintenance both of the buildings and equipment. Several barriers to efficient use of energy have been identified in the course of past research projects, ranging from biased policies to the well-known lack of user education.

The paper is motivated by and based on the results of a recent energy survey study, in the context of the SAVE II Programme, directed at school buildings, that included three EU countries. In Portugal, this survey has been conducted according to several pre-defined targets that included also the identification of barriers to the efficient use of energy, from the building design stage to the actual building use. As a background, some considerations are made on aspects of the Portuguese energy policy and on the present role of public administration, to allow the identification of management causes for inefficiency. The paper also provides insight into the main identified problems related with school planning, building design and user behaviour. A census is made of the main barriers to the efficient use of energy and possible ways to circumvent these barriers are identified, both at political and managerial levels, aiming at a realistic transformation of energy / environmental policies.

3. INTRODUCTION

Recently some projects have been carried out in the European Union, which tried to assess how efficiently energy is used in school buildings. One of these projects, completed in December 1999, has been a joint effort of a regional electricity distribution company and a university, both in Austria, a town council in northern Italy and a research institute in Portugal. A survey has been conducted, in the context of the SAVE II Programme, that showed great differences in energy use between Austrian and Northern Italian schools on one side and school buildings in Portugal on the other side. Figures demonstrated what could be (and has actually been) anticipated: heating loads are by far the most important end-use in the first case, while lighting is, on average, the most important energy consuming end-use in Portuguese schools.

In fact, the situations in Austria and Portugal are quite different both from the point of view of global energy consumption and of specific energy needs. Whereas in Austria only 14% of the energy consumed in schools is electricity, this figure raises to 53% in Portugal (lighting alone representing two fifths of this share). In fact, the notoriously different climatic conditions soon led to qualitatively different approaches to energy efficiency improvement within the project, depending on the addressed country. Though the present paper is specifically concerned with energy issues in Portuguese schools, some further figures may help distinguishing the two cases and making clear why each one deserves a separate treatment.

Table 1. Some comparative data between Austrian and Portuguese schools

		kWh/person/year	kWh/ m^2/ year	Energy cost (Euro)/person/year	Energy cost (Euro)/m^2/year
Austria	average	2740	166	130	8,2
	min.	300	40	30	2,3
	max.	18000	500	600	37,5
Portugal	average	296	55	23	0,3
	min.	132	23	13	2,2
	max.	599	155	52	7,1

In fact, the differences are remarkable. If one may say that the highest (worst) numbers of Austrian schools are due to some cases where building quality is neglected, nevertheless it is undeniable that heating needs determine to a great extent most of the energy use in this case. Whereas in Portugal, in spite of the existence of central heating systems where the climate in winter justifies it, these systems are used for a limited number of hours and in much more favourable temperature conditions. Hence, much concern is placed in specific uses of electricity, such as lighting, which correspond to the highest savings potential.

In the Portuguese case, the project assumed the goal of identifying barriers to energy efficient use, besides performing a survey of energy use and identifying energy conservation potential. This orientation has been a consequence of previous studies performed by the same research institute (INESC) in school buildings, where several causes had been gradually identified as possible reasons for energy careless use.

The paper deals mainly with two key-issues: the survey results, in brief, identifying also, on the run, some malfunctions in equipment or procedures, and also a discussion of the barriers that have been identified.

4. THE SURVEY

It is a common practice in the Regional Board of Education of the Centre Region of Portugal, the study target region, to reuse the same building design in different locations whenever it is necessary to build new schools. This fact could not be disregarded in the process of selecting school buildings to be studied within the framework of the project. Several criteria have been used for this selection, which aimed at assuring that, in the sample of buildings chosen, the following conditions could be verified: the same type of building design in different climatic zones, more than one building type in the same area, inclusion of all the possible heating systems available, maximise the students age span.

Seventeen schools have been selected according to these criteria. However, due to the fact that one school, aware of the project objectives, requested to be also included in the sample, eighteen schools have been studied in total.

Data have been collected in two main phases. In the first one, a questionnaire, which has been designed in accordance with all partners in the European project, has been sent to all the schools, which have filled it and sent it back to INESC.

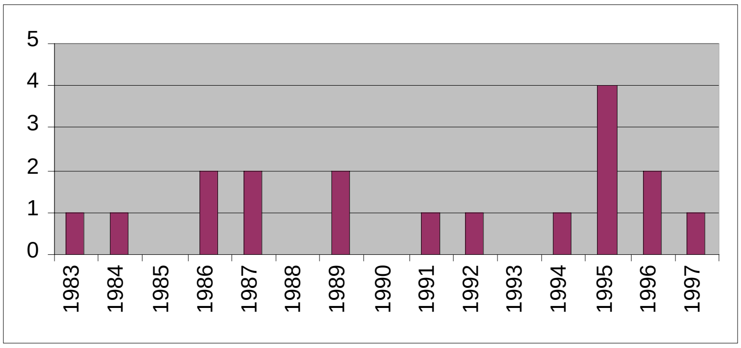
In the second phase every school has been visited, aiming at three main objectives: correct and complete the questionnaire filling which was not totally satisfactory in most of the cases, get local acquaintance with the school building and systems, take note of the occupants' opinions about the building.

General characteristics

Schools in the sample correspond to different pupils' age intervals. EB1,2,3 schools have pupils between 6 and 14 years old. EB2,3 schools, between 10 and 14. EB 2,3+Sec. between 10 and 17. Finally, secondary schools (Sec.) have students between 15 and 17 years of age.

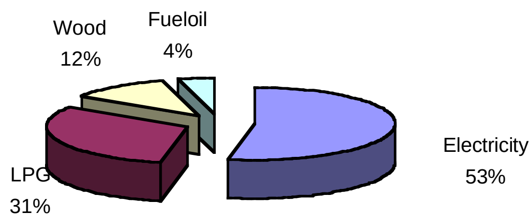
The school buildings have been built between 1983 and 1997, as shown in Figure 1. Different problems related to building age have been found, which nevertheless not always have a direct relation to the construction year.

Figure 1. School building construction dates



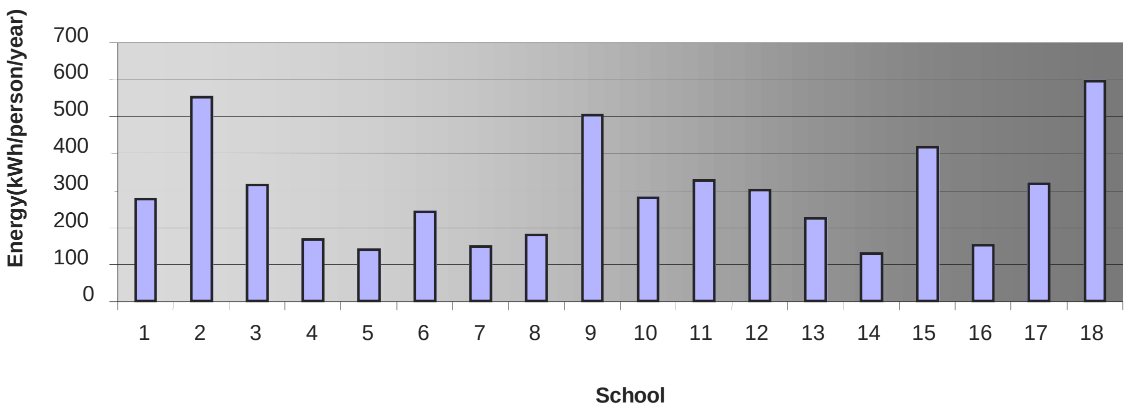
The different energy sources used within the school building sample are shown in Figure 2, where it becomes clear that electricity is the predominant energy source. This is a previously known characteristic of Portuguese schools that the survey has confirmed. It has to do mainly with the fact that average climatic conditions are not so demanding from the point of view of thermal comfort. Nevertheless, there are very different situations along the territory - in some cases occupants are subject to highly uncomfortable conditions.

Figure 2. Use of different energy sources



Energy consumption per person per year in the various buildings is shown below, where the average value is 295,5 kWh.

Figure 3. School buildings annual energy consumption per person



The relatively wide oscillations of this variable are due to several reasons, namely different climatic conditions, different number of students per school, different heating systems (when there is one). In particular, for example, two schools of the same design type, nos. 2 and 3, have very different consumption values, that of no 2 almost doubling that of no. 3. The main reason for this fact is that school no. 3 is located in a zone with a milder climate than school no. 2.

On the other hand, average annual energy consumption per unit area is 54,5 kWh/m2. This is clearly a low value, only possible in a southern European country, which could erroneously lead to the conclusion that energy is very consciously and efficiently managed. The survey results show this is not the case, as will be discussed below.

Location of schools according to climatic zones

Climatic zones in the Portuguese territory are defined in a regulation, which sets targets for the thermal behaviour characteristics of buildings (RCCTE). The country is divided in three winter zones, I_1, I_2 and I_3, and in three Summer Zones, V_1, V_2 and V_3.
The reference values used for winter zones are presented in Table 2.

Table 2. Climatic reference values of winter zones in Portugal

Winter Zones Continental Territory	**Average number of degree-days in the heating season, DD (°C day/year) (*)**	**Average solar energy reaching a vertical surface facing South in the heating season (kWh/m^2 year)**
I_1	400	400
I_2	800	500
I_3	1600 (**)	700

(*)Degree-days based on 15 ºC. The heating season is made up of the periods of the year with an average temperature below 13 ºC.
(**)For altitudes higher than 1000m, this value should be calculated with the expression $DD = H + 800$, where H represents the altitude in metres.

The reference values used for summer zones are presented in Table 3.

Table 3. Climatic reference values of summer zones in Portugal

Summer Zones Continental Territory	**Design external temperature(*) -- Tp (ºC)**	**Daily thermal amplitude -- D(ºC)**
V_1	28	10
V_2	32	13
V_3	35	16

(*) Design external temperature corresponds to the one having an accumulated probability of occurrence of 0,975.

Based on the above-mentioned regulation, the location of the studied school buildings in the corresponding climatic zones, resulted as shown in Table 4.

Table 4. School building distribution through climatic zones

Winter zone	Summer zone	Number of schools
I2	V1	6
I2	V2	6
I2	V3	1
I3	V1	5

As mentioned above, buildings with the same type of design can be found in different climatic zones. This is a common situation in Portugal due to the fact that, for the sake of a conservative management of resources and budget constraints, the same building design is applied to different schools, in different locations and, thus, different climatic conditions. Ten different design types are present in the sample, six of which have more than one occurrence. The following table shows the different climatic zones of each occurrence of each of these repeatedly used designs.

Table 5. Repeated school building designs: occurrences in different climatic zones

Design type	Climatic zones		
A ("Compacto")	I2;V1	I3;V1	
B ("3x3")	I2;V2	I3;V1	I3;V1
C ("Guia")	I2;V1	I2;V2	
D ("Oiã")	I2;V1	I2;V2	
E ("EBI24")	I2,V1	I2,V2	
F ("Cast. Branco")	I2,V1	I2,V3	

It should be noted that window and doorframes are generally made of cast aluminium, normally with single glazing. Only two schools have double-glazing in the North façades.

HVAC systems

About 28% of the schools have no central heating system, in 22% the central heating system is based on electricity (Joule effect) and in the remaining 50% some other energy source is used. Also, in 78% of the cases mobile electric heaters exist and are extensively used.

Only in two of the studied schools there are systems that simultaneously heat water and spaces. The existing boilers are relatively recent - the oldest has been installed in 1986 and the newest in 1998.

Only four schools have some air conditioning system, which, in any case, is only serving limited administrative zones of the buildings.

Due to an effort carried out by the Ministry of Education, Portuguese schools in colder regions have been recently retrofitted with central heating systems, mostly gas-fired (LPG). In some cases, as replacements to electricity-based heating systems, which revealed to be unable to provide comfort, because they had over-conservative design, despite their high operational costs and an appreciable remote environmental impact. Also, in some cases, electric central heating systems had been installed in new buildings only a few years before, which means that this type of system has been chosen until very recently, mainly on a first cost criterion.

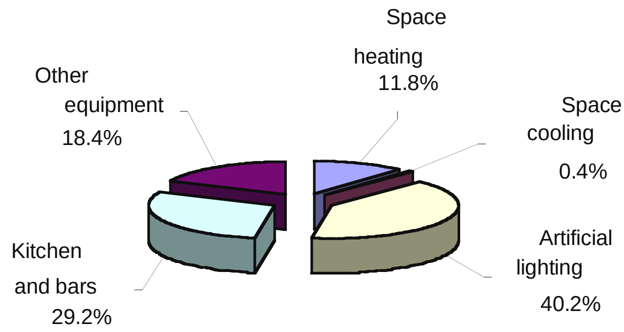
There are still many situations to be solved where thermal comfort in winter is far from acceptable. Hence, it is undeniable that, at present, it will be necessary to raise energy consumption globally in Portuguese schools in order to provide adequate comfort conditions. Notwithstanding this, it is possible to keep this necessary growth at a moderate pace, namely if some measures are adopted: replacement of the existing central electric heating systems (or simply installation where there is none) by other systems using different final energy forms, less costly and with less environmental impact, if possible easily obtainable in the region where each school stands; installation of time switches to control the operating times of the prevailing central electric heating systems; an effective separation of heating circuits in order to allow independent control of each circuit; pre-heating of conditioned spaces; provision of automatic control of heating systems, depending on occupancy by people, on temperature (both external and internal) and on the position (open or closed) of doors and windows.

In the majority of the cases, heating systems controls do not operate, mainly for one of two reasons: either they have failed once and never have been repaired, or they simply never operated (probably the constructor has not been forced to comply with the design).

Lighting

It is worth noting that lighting is the most important electric load in school buildings, as shown in the figure below.

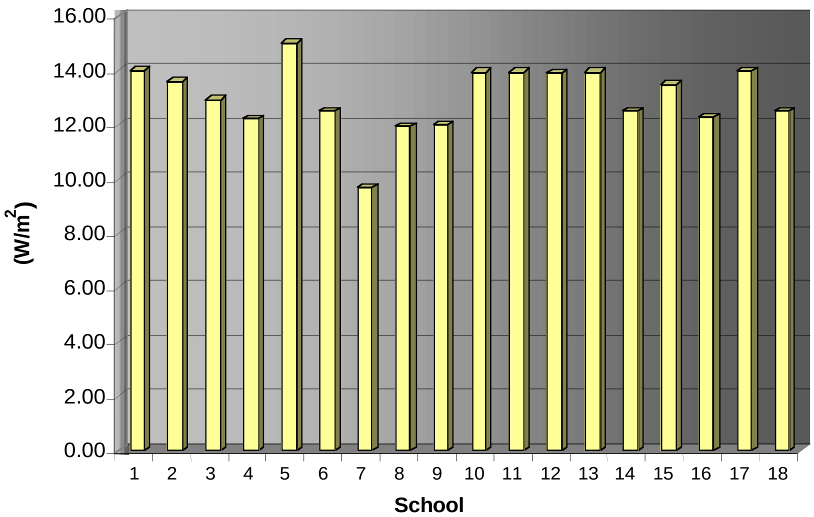
Figure 4. Electricity consumption by end-use relative importance



Interior lighting is almost exclusively achieved through fluorescent lamps and luminaires, be it in classrooms, laboratories, administrative offices or circulation spaces. Incandescent lighting is only used in small and seldom occupied spaces.

The average value of lighting capacity area density (specific capacity, in W/m^2) is $13W/m^2$. As can easily be seen in Figure 5, the lowest value occurs at school no. 7. This is due to the fact that this building has been designed with special concern on energy efficiency, including the extensive use of passive solar technologies, not only for thermal comfort but also for lighting. On top of this, artificial lighting is provided in this building through high efficiency luminaires, including electronic ballasts. This is clear from Figure 5 below, where lighting specific capacities are shown for the studied schools.

Figure 5. Power density in artificial lighting



It is quite clear, after the visits made to all the schools, that luminaire cleaning is not a common practice and lamp replacement occurs on an individual basis, when lamp failures are detected, instead of massive programmed replacements.

Some of the main recommendations of the survey regarding lighting reveal implicitly many of the deficiencies found: use photocells for external lighting control; use sodium lamps for external lighting; periodically clean lamps and fixtures; periodically replace lamps (in groups, according to life derating); use electronic ballasts.

A second group of recommendations came out of the aforementioned survey study, which is directly related to a specific problem found in school buildings. The widely used blackboard model has a high reflectance, which is responsible for unavoidable glare caused by daylight reflection. The pupils are, generally, not able to actually see what is written on a great portion of the blackboard surface. Hence, the usual, spontaneous attitude: shut the blinds available at every window and turn on the lights. This leads to two main consequences: daylight is almost never used and there is an enormous amount of avoidable electricity consumption. In the course of the study, a pilot experiment has been carried out very successfully in one of the schools, not to be described here in detail, which consisted in changing the operating conditions of a certain number of classrooms and in closely monitoring these and a corresponding control group of conventional classrooms. The main changes have been: install translucent curtains on the windows, replace the blackboard luminaires by more efficient ones with more intense and directed light, and install occupancy detectors and luminance detectors associated to a small control unit in each room, allowing manual override, based on a custom design. Measured savings amount to more than 30% in the worst season, between October and January, when the number of daylight hours is small. Hence, the second group of recommendations: use daylight whenever possible; use low reflectance blackboards; use local (at room level) control units for lighting, depending on variables such as occupancy and daylight availability; use differentiated illuminance levels and task lighting. Some behavioural barriers have been identified in the course of monitoring of this pilot experience, which may be useful for future similar initiatives.

5. BEYOND THE TECHNICAL ISSUES

There is a general formulation for sustainability regarding buildings life cycle, which has wide acceptance. In the experience of the authors, who have used it very often, nobody is capable of putting serious objections to it. It says that sustainability may be obtained if four conditions are met: an efficient design (using passive solar technologies), quality assurance in the construction phase, efficient end-use equipment and, last but not the least, intelligent use. The first three, address technology issues and construction management issues, the last one addresses automation and behavioural issues. The conclusion is evident: if the formulation is not arguable, then barriers must exist to prevent it from being widely applied.

During the study, several issues have been addressed, both with different people in the schools and with the Ministry of Education regional authority in the centre region of the country - top-level administration and technical staff. Hence, it has been possible to identify some key issues, some regarding general policy, some others having to do with habits, knowledge and awareness.

One easy identifiable issue is the absence of energy and environment related criteria influencing decisions in general in domains such as taxes, work relations or general economy - and particularly in what concerns school buildings life cycle. This is not different from the general picture in our public administration. It may seem a paradox when one recalls the main EU policy lines of strength and recent recommendations issued by the European Parliament, but inertial thinking, short-term budget constraints and lack of specific legislation are objective factors influencing the course of events.

Lack of specific education in the field of energy efficiency affects not only ordinary consumers but also technical staff in organisations - companies and administration - and also decision-makers, those of whom policies depend. In the case of end-users and designers, most of the time rules of thumb and habits whose origin is often hard to backtrack have an important influence in attitudes and options that affect energy efficiency.

Even when information is passed on to consumers, there are factors that prevent this accrued knowledge to have actual effect: high indirect implementation costs, high level of cost or trouble accessing information relevant for decision or implementation, lack of financial capacity. This is observable in schools as in general.

Besides, there is no provision for self auditing or even self-monitoring in schools, leading also to a total absence of maintenance procedures (not to mention maintenance planning). This is aggravated by the fact that a vast majority of schools do not have any person in charge of operating the various technical systems installed. These facts have a direct consequence in raising unnecessarily the operational costs of buildings and causing a premature equipment ageing and security breaches.

Finally, speaking of management, in view of the framework in which schools are financed and of the stimuli thereof, a crucial pair of questions must be asked, from the point of view of school managers: what is there to gain by energy savings? What is there to lose by not saving energy? In fact, if the budget is determined each year essentially on the basis of the previous year expense level, there is no opportunity for school managers to explore results of savings in other areas that may be relevant to schools. On the other hand, this budget philosophy is blind to waste: energy consumption is simply paid for, stop.

On the basis of the experience acquired in the course of the study, the usual intervention instruments seem to be quite adequate. That is to say, consumer and manager education, dissemination of information on good practice, integration of energy and environmental related issues in the education curricula of students, efficient technology procurement.

There are, however, some useful paths that should be emphasised.

Regulations regarding energy efficiency should be applied to public administration buildings, as the public administration demands private investors to do. If these rules exist there is no sense in not applying them even more strictly to public buildings than to private ones. Moral authority is undermined and the cause of sustainability loses with the present situation.

Moreover, it is evident that there are some areas where energy efficiency regulation is missing, namely in artificial lighting. Limiting power density is a well-known method, which is very effective in constraining building design, even for daylighting improvement.

On top of this, issuing design requirements for each building construction or retrofitting is a powerful means of promoting energy efficiency, if using more stringent rules than those contained in normal regulations. Once imposed to designers, search for compliance induces an automatic effect of energy efficient choices. Design requirements are easily internalised in usual technical procedures at the administration level.

Goal driven plans are possible as long as an adequate policy of budget related stimuli to school management is defined and implemented. Rewards and punishments are not so difficult to design in order to be integrated in budget requirements, provided that energy costs are easily identifiable.

In the structure of the Ministry of Education, either nationally or regionally speaking, there is not any office responsible for the maintenance procedures that should be systematically carried out in Portuguese school buildings. Besides, in no schools whatsoever is there any programme for tackling with maintenance and energy consumption.

Hence, one of the most important conclusions / recommendations of the study may be stated as a need of regional/local structures in charge of regular maintenance and energy management in school buildings, co-ordinated at the level of the Regional Boards of Education.

In a systematised way, a few of the most important recommendations can be stated as: create a specific category in the professional careers in schools dedicated to energy management, providing professional regular skill improvement education to the appointed person; provide schools with personnel capable of correctly operating systems and various kinds of equipment that influence energy consumption and comfort; provide schools with appropriate and detailed documentation on the referred systems and pieces of equipment; install in every school building metering equipment for measuring energy, heat and water consumption, as well as software to assist in management tasks; regularly provide education to users and people in charge, in schools, in order to raise awareness to the economic and environmental benefits of energy efficient use.

6. CONCLUSION

Portuguese schools present low values of specific energy consumption when compared to other countries in the EU. However, this does not mean that energy is efficiently used in general. It actually means that, on one hand, a favourable moderate climate on average, in spite of some extreme climatic conditions in some regions, and on the other hand an average situation of lack of thermal comfort.

An absence of concern with energy efficiency in public administration management and policies has direct consequences in the particular sector of school buildings. From design to operation, only some minor concern can be witnessed in recent years, due only to a shyly growing awareness of the technical staff of the Ministry of Education.

Several political decisions have to be taken in order to raise energy efficiency of this important sector of public buildings, namely at regulatory and management levels. Thence, the most important issue is to circumvent the main barrier of all – the lack of knowledge and awareness of decision-makers at the highest level.

7. ACKNOWLEDGEMENT

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